

The PC's video display is a very complex system. First, there is not a single common device as exists for the parallel and serial ports, or even a few devices (like the keyboard systems found on PCs). No, there are literally dozens of different display adapter cards available for the PC. Furthermore, each adapter typically supports several different display modes. Given the large number of display modes and uses for the display adapters, it would be very easy to write a book as large as this one on the PC's display adapters alone¹ However, this is not that text. This book would hardly be complete without at least mentioning the PC's video display, but there are not enough pages remaining in this book to do justice to the subject. Therefore, this chapter will discuss the 80 x 25 *text display mode* that nearly all display adapters support.

23.1 Memory Mapped Video

Most peripheral devices on the PC use *I/O mapped* input/output. A program communicates with I/O mapped devices using the 80x86 `in`, `out`, `ins`, and `outs` instructions, accessing devices in the PC's I/O address space. While the video controller chips that appear on PC video display adapters also map registers to the PC's I/O space, these cards also employ a second form of I/O addressing: *memory mapped I/O* input/output. In particular, the 80 x 25 text display is nothing more than a two dimensional array of words with each word in the array corresponding a character on the screen. This array appears just above the 640K point in the PC's memory address space. If you store data into this array using standard memory addressing instruction (e.g., `mov`), you will affect the characters appearing on the display.

There are actually two different arrays you need to worry about. Monochrome system (remember those?) locate their text display starting at location B000:0000 in memory. Color systems locate their text displays at location B800:0000 in memory. These locations are the base addresses of a column major order array declared as follows:

```
Display: array [0..79, 0..24] of word;
```

If you prefer to work with row major ordered arrays, no problem, the video display is equal to the following array definition:

```
Display: array [0..24, 0..79] of word;
```

Note that location (0,0) is the upper left hand corner and location (79,24) is the lower right hand corner of the display (the values in parentheses are the x and y coordinates, with the x/horizontal coordinate appearing first).

The L.O. byte of each word contains the PC/ASCII code for the character you want to display (see Appendix A for a listing of the PC/ASCII character set). The H.O. byte of each word is the *attribute byte*. We will return to the attribute byte in the next section.

The display page consumes slightly less than 4 Kilobytes in the memory map. The color display adapters actually provide 32K for text displays and let you select one of eight different displays. Each such display begins on a 4K boundary, at address B800:0, B800:1000, B800:2000, B800:3000, ..., B800:7000. Note that most modern color display adapters actually provide memory from address A000:0 through B000:FFFF (and more), but the text display only uses the 32K from B800:0..B800:7FFF. In this chapter, we will only concern ourselves with the first color display page at address B800:0. However, everything discussed in this chapter applies to the other display pages as well.

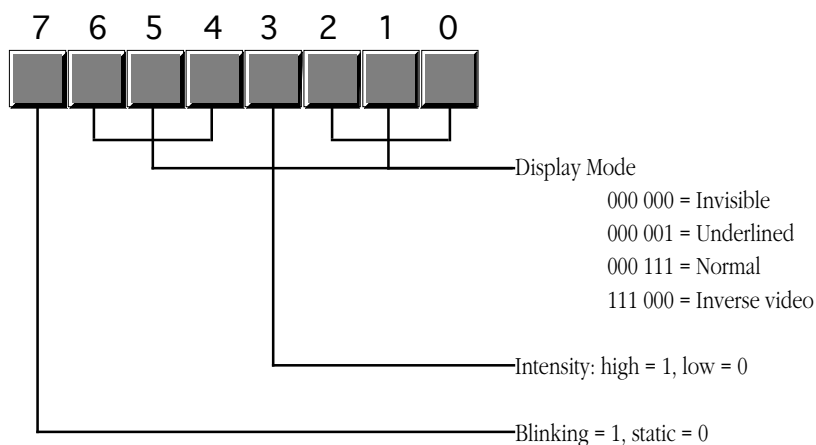
The monochrome adapter provides only a single display page. Indeed, the earliest monochrome display adapters included only 4K on-board memory (contrast this with modern high density color display adapters that have up to four megabytes of on-board memory!).

1. In fact, several such books exist. See the bibliography.

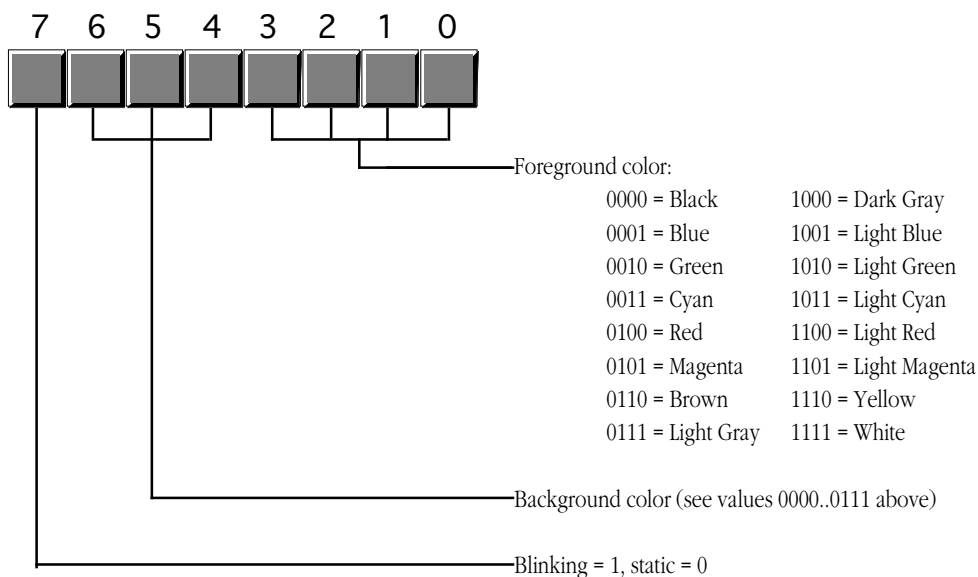
You can address the memory on the video display like ordinary RAM. You could even store program variables, or even code, in this memory. However, it is never a good idea to do this. First of all, any time you write to the display screen, you will wipe out any variables stored in the active display memory. Even if you store such code or variables in an inactive display page (e.g., pages one through seven on a color display adapter), using this memory in this manner is not a good idea because access to the display adapter is very slow. Main memory runs two to ten times faster (depending on the machine).

23.2 The Video Attribute Byte

The video attribute associated with each character on the screen controls underlining, intensity, and blinking video on monochrome adapters. It controls blinking and character foreground/background colors on color displays. The following diagrams provide the possible attribute values:



Monochrome Display Adapter Attribute Byte Format



Color Display Adapter Attribute Byte Format

To get reverse video on the color display, simply swap the foreground and background colors. Note that a foreground color of zero with a background color of seven produces black characters on a white background, the standard reverse video colors and the same attribute values you'd use on the monochrome display adapter.

You need to be careful when choosing foreground and background colors for text on a color display adapters. Some combinations are impossible to read (e.g., white characters on a white background). Other colors go together so poorly the text will be extremely difficult to read, if not impossible (how about light green letters on a green background?). You must choose your colors with care!

Blinking characters are great for drawing attention to some important text on the screen (like a warning). However, it is easy to overdo blinking text on the screen. You should never have more than one word or phrase blinking on the screen at one time. Furthermore, you should never leave blinking characters on the screen for any length of time. After a few seconds, replace blinking characters with normal characters to avoid annoying the user of your software.

Keep in mind, you can easily change the attributes of various characters on the screen without affecting the actual text. Remember, the attribute bytes appear at odd addresses in the memory space for the video display. You can easily go in and change these bytes while leaving the character code data alone.

23.3 Programming the Text Display

You might ask why anyone would want to bother working directly with the memory mapped display on the PC. After all, DOS, BIOS, and the UCR Standard Library provide *much* more convenient ways to display text on the screen. Handling new lines (carriage return and line feed) at the end of each line or, worse yet, scrolling the screen when the display is full, is a lot of work. Work that is taken care of for you automatically by the aforementioned routines. Work you have to do yourself if you access screen memory directly. So why bother?

There are two reasons: performance and flexibility. The BIOS video display routines² are *dreadfully* slow. You can easily get a 10 to 100 times performance boost by writing directly to screen memory. For a typical computer science class project, this may not be important, especially if you're running on a fast machine like a 150 MHz Pentium. On the other hand, if you are developing a program that displays and removes several windows or pop-up menus on the screen, the BIOS routines won't cut it.

Although the BIOS int 10h functions provide a large set of video I/O routines, there will be lots of functions you might want to have that the BIOS just doesn't provide. In such cases, going directly to screen memory is one way to solve the problem.

Another difficulty with BIOS routine is that they are not reentrant. You cannot call a BIOS display function from an interrupt service routine, nor can you freely call BIOS from concurrently executing processes. However, by writing your own video service routines, you can easily create a window for each concurrent thread you application is executing. Then each thread can call your routines to display its output independent of the other threads executing on the system.

The AMAZE.ASM program (see "Processes, Coroutines, and Concurrency" on page 1065) is a good example of a program that directly access the text display by directly storing data into the video display's memory mapped display array. This program access display memory directly because it is more convenient to do so (the screen's display array maps quite nicely to the internal maze array). Simple video games like a space invaders game or a "remove the bricks" game also map nicely to a memory mapped video display.

The following program provides an excellent example of an application that needs to access video memory directly. This program is a *screen capture* TSR. When you press the left shift key and then the right shift key, this program copies the current screen contents to an internal buffer. When you press the

2. The Standard Library calls DOS and DOS calls BIOS for all display I/O, hence they all become BIOS calls at one level or another.

right shift key followed by the left shift key, this program copies its internal buffer to the display screen. Originally, this program was written to capture CodeView screens for the lab manual accompanying this text. There are commercial screen capture programs (e.g., Hijak) that would normally do the job, but are incompatible with CodeView. This short TSR allows one to capture screens in CodeView, quit CodeView, put the CodeView screen back onto the display, and the use a program like Hijak to capture the output.

```

; GRABSCRN.ASM
;
; A short TSR to capture the current display screen and display it later.
;
; Note that this code does not patch into int 2Fh (multiplex interrupt)
; nor can you remove this code from memory except by rebooting.
; If you want to be able to do these two things (as well as check for
; a previous installation), see the chapter on resident programs. Such
; code was omitted from this program because of length constraints.
;
;
; cseg and EndResident must occur before the standard library segments!

cseg          segment      para public 'code'
OldInt9       dword        ?
ScreenSave    byte         4096 dup (?)
cseg          ends

; Marker segment, to find the end of the resident section.

EndResident   segment      para public 'Resident'
EndResident   ends

               .xlist
               include     stdlib.a
               includelib  stdlib.lib
               .list

RShiftScan    equ          36h
LShiftScan    equ          2ah

; Bits for the shift/modifier keys

RShfBit       equ          1
LShfBit       equ          2

KbdFlags      equ          <byte ptr ds:[17h]>

byp           equ          <byte ptr>

; Screen segment address. This value is for color displays only.
; Change to B000h if you want to use this program on a mono display.

ScreenSeg     equ          0B800h

cseg          segment      para public 'code'
               assume     ds:nothing

; MyInt9-     INT 9 ISR. This routine reads the keyboard port to see
;             if a shift key scan code just came along. If the right
;             shift bit is set in KbdFlags the a left shift key scan
;             code comes along, we want to copy the data from our
;             internal buffer to the screen's memory. If the left shift
;             bit is set and a right shift key scan code comes along,
;             we want to copy the screen memory into our local array.
;             In any case (including none of the above), we always transfer
;             control to the original INT 9 handler.

MyInt9        proc          far
               push       ds
               push       ax

```

```

        mov     ax, 40h
        mov     ds, ax

        in      al, 60h           ;Read the keyboard port.
        cmp    al, RShiftScan    ;Right shift just go down?
        je     DoRight
        cmp    al, LShiftScan    ;How about the left shift?
        jne    QuitMyInt9

; If this is the left scan code, see if the right shift key is already
; down.

        test   KbdFlags, RShfBit
        je     QuitMyInt9       ;Branch if no

; Okay, right shift was down and we just saw left shift, copy our local
; data back to screen memory:

        pushf
        push   es
        push   cx
        push   di
        push   si
        mov    cx, 2048
        mov    si, cs
        mov    ds, si
        lea   si, ScreenSave
        mov    di, ScreenSeg
        mov    es, di
        xor    di, di
        jmp   DoMove

; Okay, we just saw the right shift key scan code, see if the left shift
; key is already down. If so, save the current screen data to our local
; array.

DoRight:  test   KbdFlags, LShfBit
        je     QuitMyInt9

        pushf
        push   es
        push   cx
        push   di
        push   si
        mov    cx, 2048
        mov    ax, cs
        mov    es, ax
        lea   di, ScreenSave
        mov    si, ScreenSeg
        mov    ds, si
        xor    si, si

DoMove:   cld
        rep   movsw
        pop   si
        pop   di
        pop   cx
        pop   es
        popf

QuitMyInt9:  pop   ax
            pop   ds
            jmp   OldInt9

MyInt9    endp

Main      proc
        assume ds:cseg

        mov    ax, cseg
        mov    ds, ax

        print

```

```

        byte    "Screen capture TSR",cr,lf
        byte    "Pressing left shift, then right shift, captures "
        byte    "the current screen.",cr,lf
        byte    "Pressing right shift, then left shift, displays "
        byte    "the last captured screen.",cr,lf
        byte    0

; Patch into the INT 9 interrupt vector. Note that the
; statements above have made cseg the current data segment,
; so we can store the old INT 9 value directly into
; the OldInt9 variable.

        cli                    ;Turn off interrupts!
        mov     ax, 0
        mov     es, ax
        mov     ax, es:[9*4]
        mov     word ptr OldInt9, ax
        mov     ax, es:[9*4 + 2]
        mov     word ptr OldInt9+2, ax
        mov     es:[9*4], offset MyInt9
        mov     es:[9*4+2], cs
        sti                    ;Okay, ints back on.

; We're hooked up, the only thing that remains is to terminate and
; stay resident.

        print
        byte    "Installed.",cr,lf,0

        mov     ah, 62h        ;Get this program's PSP
        int     21h           ; value.

        mov     dx, EndResident ;Compute size of program.
        sub     dx, bx
        mov     ax, 3100h     ;DOS TSR command.
        int     21h

Main
cseg    endp
        ends

sseg    segment    para stack 'stack'
stk     db         1024 dup ("stack ")
sseg    ends

zzzzzzseg    segment    para public 'zzzzzz'
LastBytes   db         16 dup (?)
zzzzzzseg    ends
end        Main

```

23.4 Summary

The PC's video system uses a memory mapped array for the screen data. This is an 80 x 25 column major organized array of words. Each word in the array corresponds to a single character on the screen. This array begins at location B000:0 for monochrome displays and B800:0 for color displays. For additional information, see:

- "Memory Mapped Video" on page 1247

The L.O. byte is the PC/ASCII character code for that particular screen position, the H.O. byte contains the attributes for that character. The attribute selects blinking, intensity, and background/foreground colors (on a color display). For more information on the attribute byte, see:

- "The Video Attribute Byte" on page 1248

There are a few reasons why you would want to bother accessing display memory directly. Speed and flexibility are the two primary reasons people go directly to screen memory. You can create your own

screen functions that the BIOS doesn't support and do it one or two orders of magnitude faster than the BIOS by writing directly to screen memory. To find out about this, and to see a simple example, check out

- “Programming the Text Display” on page 1249

