Chapter 29

Saving Screens and Other VGA Mysteries

Chapter 29

Useful Nuggets from the VGA Zen File

There are a number of VGA graphics topics that aren't quite involved enough to warrant their own chapters, yet still cause a fair amount of programmer headscratching—and thus deserve treatment somewhere in this book. This is the place, and during the course of this chapter we'll touch on saving and restoring 16-color EGA and VGA screens, the 16-out-of-64 colors issue, and techniques involved in reading and writing VGA control registers.

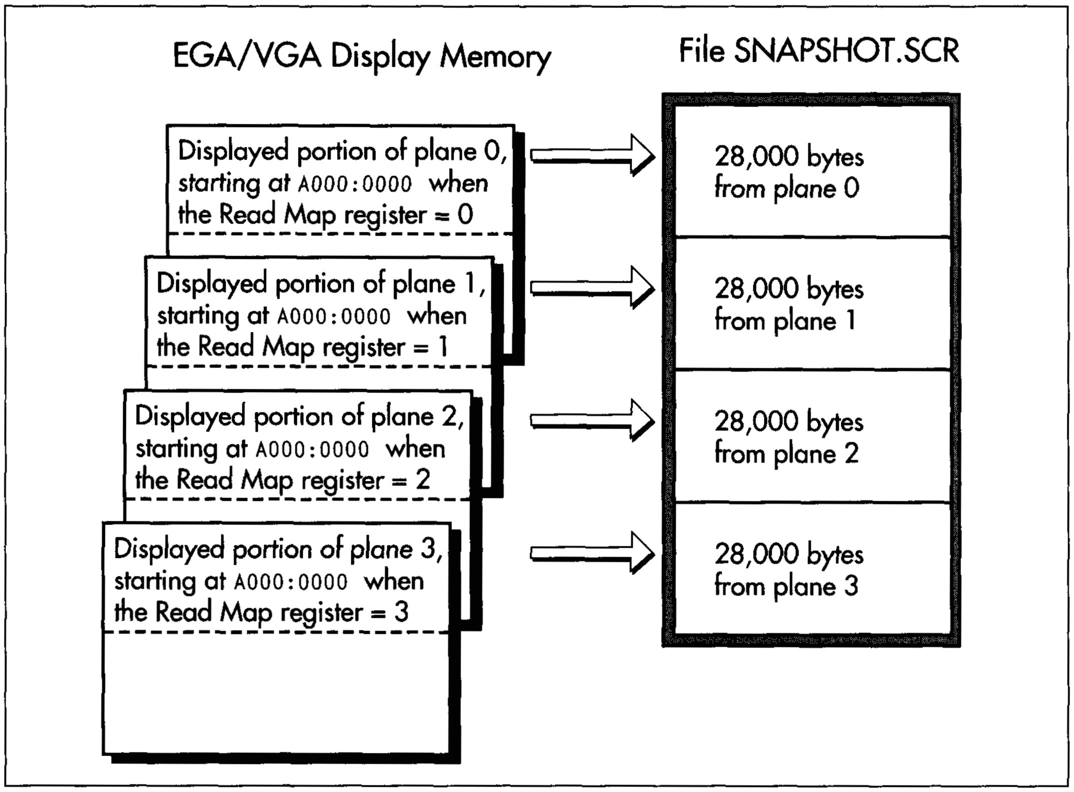
That's a lot of ground to cover, so let's get started!

Saving and Restoring EGA and VGA Screens

The memory architectures of EGAs and VGAs are similar enough to treat both together in this regard. The basic principle for saving EGA and VGA 16-color graphics screens is astonishingly simple: Write each plane to disk separately. Let's take a look at how this works in the EGA's hi-res mode 10H, which provides 16 colors at 640×350.

All we need do is enable reads from plane 0 and write the 28,000 bytes of plane 0 that are displayed in mode 10H to disk, then enable reads from plane 1 and write the displayed portion of that plane to disk, and so on for planes 2 and 3. The result is a file that's 112,000 (28,000 * 4) bytes long, with the planes stored as four distinct 28,000-byte blocks, as shown in Figure 29.1.

The program shown later on in Listing 29.1 does just what I've described here, putting the screen into mode 10H, putting up some bit-mapped text so there is something



EGA/VGA Display Memory
File SNAPSHOT.SCR
Displayed portion of plane 0, starting at A000:0000 when the Read Map register = 0
Displayed portion of plane 1, starting at A000:0000 when the Read Map register = 1
Displayed portion of plane 2, starting at A000:0000 when the Read Map register = 2
Displayed portion of plane 3, starting at A000:0000 when the Read Map register = 3
28,000 bytes from plane 0
28,000 bytes from plane 1
28,000 bytes from plane 2
28,000 bytes from plane 3

Saving EGA/VGA display memory.
Figure 29.1

to save, and creating the 112K file SNAPSHOT.SCR, which contains the visible portion of the mode 10H frame buffer.

The only part of Listing 29.1 that's even remotely tricky is the use of the Read Map register (Graphics Controller register 4) to make each of the four planes of display memory readable in turn. The same code is used to write 28,000 bytes of display memory to disk four times, and 28,000 bytes of memory starting at A000:0000 are written to disk each time; however, a different plane is read each time, thanks to the changing setting of the Read Map register. (If this is unclear, refer back to Figure 29.1; you may also want to reread Chapter 28 to brush up on the operation of the Read Map register in particular and reading EGA and VGA memory in general.)

Of course, we'll want the ability to restore what we've saved, and Listing 29.2 does this. Listing 29.2 reverses the action of Listing 29.1, selecting mode 10H and then loading 28,000 bytes from SNAPSHOT.SCR into each plane of display memory. The Map Mask register (Sequence Controller register 2) is used to select the plane to be written to. If your computer is slow enough, you can see the colors of the text change as each plane is loaded when Listing 29.2 runs. Note that Listing 29.2 does not itself draw any text, but rather simply loads the bit map saved by Listing 29.1 back into the mode 10H frame buffer.

LISTING 29.1 L29-1.ASM

```
; Program to put up a mode 10h EGA graphics screen, then save it
; to the file SNAPSHOT.SCR.
;
VGA_SEGMENT             equ   0a000h
GC_INDEX                equ   3ceh              ;Graphics Controller Index register
READ_MAP                equ   4                 ;Read Map register index in GC
DISPLAYED_SCREEN_SIZE   equ (640/8)*350         ;# of displayed bytes per plane in a
                                                ; hi-res graphics screen
;
stack       segment para stack 'STACK'
                  db            512 dup (?)
stack       ends
;
Data        segment    word 'DATA'
SampleText        db   'This is bit-mapped text, drawn in hi-res '
                  db   'EGA graphics mode 10h.', 0dh, 0ah, 0ah
                  db   'Saving the screen (including this text)...'
                  db   0dh, 0ah, '$'
Filename          db   'SNAPSHOT.SCR',0       ;name of file we're saving to
ErrMsg1           db   '*** Couldn''t open SNAPSHOT.SCR ***',0dh,0ah,'$'
ErrMsg2           db   '*** Error writing to SNAPSHOT.SCR ***',0dh,0ah,'$'
WaitKeyMsg        db   0dh, 0ah, 'Done. Press any key to end...',0dh,0ah,'$'
Handle            dw   ?                      ;handle of file we're saving to
Plane             db   ?                      ;plane being read
Data  ends
;
Code           segment
               assume  cs:Code, ds:Data
Start          proc    near
               mov     ax,Data
               mov     ds,ax
;
; Go to hi-res graphics mode.
;
               mov     ax,10h         ;AH = 0 means mode set, AL = 10h selects
                                      ; hi-res graphics mode
               int     10h            ;BIOS video interrupt
;
; Put up some text, so the screen isn't empty.
;
               mov     ah,9           ;DOS print string function
               mov     dx,offset SampleText
               int     21h
;
; Delete SNAPSHOT.SCR if it exists.
;
               mov     ah,41h         ;DOS unlink file function
               mov     dx,offset Filename
               int     21h
;
; Create the file SNAPSHOT.SCR.
;
               mov     ah,3ch         ;DOS create file function
```

```
                mov     dx,offset Filename
                sub     cx,cx           ;make it a normal file
                int     21h
                mov     [Handle],ax ;save the handle
                jnc     SaveTheScreen ;we're ready to save if no error
                mov     ah,9            ;DOS print string function
                mov     dx,offset ErrMsg1
                int     21h             ;notify of the error
                jmp     short Done      ;and done
;
; Loop through the 4 planes, making each readable in turn and
; writing it to disk. Note that all 4 planes are readable at
; A000:0000; the Read Map register selects which plane is readable
; at any one time.
;
SaveTheScreen:
                mov     [Plane],0       ;start with plane 0
SaveLoop:
                mov     dx,GC_INDEX
                mov     al,READ_MAP ;set GC Index to Read Map register
                out     dx,al
                inc     dx
                mov     al,[Plane]      ;get the # of the plane we want
                                        ; to save
                out     dx,al           ;set to read from the desired plane
                mov     ah,40h          ;DOS write to file function
                mov     bx,[Handle]
                mov     cx,DISPLAYED_SCREEN_SIZE ;# of bytes to save
                sub     dx,dx           ;write all displayed bytes at A000:0000
                push    ds
                mov     si,VGA_SEGMENT
                mov     ds,si
                int     21h             ;write the displayed portion of this plane
                pop     ds
                cmp     ax,DISPLAYED_SCREEN_SIZE ;did all bytes get written?
                jz         SaveLoopBottom
                mov     ah,9            ;DOS print string function
                mov     dx,offset ErrMsg2
                int     21h             ;notify about the error
                jmp     short DoClose ;and done
SaveLoopBottom:
                mov     al,[Plane]
                inc     ax              ;point to the next plane
                mov     [Plane],al
                cmp     al,3            ;have we done all planes?
                jbe     SaveLoop        ;no, so do the next plane
;
; Close SNAPSHOT.SCR.
;
DoClose:
                mov     ah,3eh          ;DOS close file function
                mov     bx,[Handle]
                int     21h
;
; Wait for a keypress.
;
                mov     ah,9            ;DOS print string function
                mov     dx,offset WaitKeyMsg
                int     21h             ;prompt
                mov     ah,8            ;DOS input without echo function
```

```
              int     21h
;
; Restore text mode.
;
              mov     ax,3
              int     10h
;
; Done.
;
Done:
              mov     ah,4ch      ;DOS terminate function
              int     21h
Start         endp
Code          ends
              end     Start
```

LISTING 29.2 L29-2.ASM

```
; Program to restore a mode 10h EGA graphics screen from
; the file SNAPSHOT.SCR.
;
VGA_SEGMENT                 equu  0a000h
SC_INDEX                    equ   3c4h           ;Sequence Controller Index register
MAP_MASK                    equ   2              ;Map Mask register index in SC
DISPLAYED_SCREEN_SIZE       equ (640/8)*350      ;# of displayed bytes per plane in a
                                                 ; hi-res graphics screen
;
stack       segment para stack 'STACK'
                  db              512 dup (?)
stack       ends
;
Data        segment    word 'DATA'
Filename          db        'SNAPSHOT.SCR',0            ;name of file we're restoring from
ErrMsg1           db        '*** Couldn''t open SNAPSHOT.SCR ***',0dh,0ah,'$'
ErrMsg2           db        '*** Error reading from SNAPSHOT.SCR ***',0dh,0ah,'$'
WaitKeyMsg        db        0dh, 0ah, 'Done. Press any key to end...',0dh,0ah,'$'
Handle            dw        ?                           ;handle of file we're restoring from
Plane             db        ?                           ;plane being written
Data        ends
;
Code          segment
              assume  cs:Code, ds:Data
Start         proc    near
              mov     ax,Data
              mov     ds,ax
;
; Go to hi-res graphics mode.
;
              mov     ax,10h                  ;AH = 0 means mode set, AL = 10h selects
                                              ; hi-res graphics mode
              int     10h                     ;BIOS video interrupt
;
; Open SNAPSHOT.SCR.
;
              mov     ah,3dh                  ;DOS open file function
              mov     dx,offset Filename
              sub     al,al                   ;open for reading
              int     21h
              mov     [Handle],ax             ;save the handle
              jnc     RestoreTheScreen        ;we're ready to restore if no error
              mov     ah,9                    ;DOS print string function
              mov     dx,offset ErrMsg1
              int     21h                   ;notify of the error
              jmp     short Done  ;and done
;
; Loop through the 4 planes, making each writable in turn and
; reading it from disk. Note that all 4 planes are writable at
; A000:0000; the Map Mask register selects which planes are readable
; at any one time. We only make one plane readable at a time.
;
RestoreTheScreen:
              mov     [Plane],0                  ;start with plane 0
RestoreLoop:
              mov     dx,SC_INDEX
              mov     al,MAP_MASK                ;set SC Index to Map Mask register
              out     dx,al
              inc     dx
              mov     cl,[Plane]                 ;get the # of the plane we want
                                                 ; to restore
              mov     al,1
              shl     al,cl                      ;set the bit enabling writes to
                                                 ; only the one desired plane
              out     dx,al                      ;set to read from desired plane
              mov     ah,3fh                     ;DOS read from file function
              mov     bx,[Handle]
              mov     cx,DISPLAYED_SCREEN_SIZE   ;# of bytes to read
              sub     dx,dx                      ;start loading bytes at A000:0000
              push    ds
              mov     si,VGA_SEGMENT
              mov     ds,si
              int     21h                        ;read the displayed portion of this plane
              pop     ds
              jc      ReadError
              cmp     ax,DISPLAYED_SCREEN_SIZE   ;did all bytes get read?
              jz      RestoreLoopBottom
ReadError:
              mov     ah,9                       ;DOS print string function
              mov     dx,offset ErrMsg2
              int     21h                        ;notify about the error
              jmp     short DoClose              ;and done
RestoreLoopBottom:
              mov     al,[Plane]
              inc     ax                         ;point to the next plane
              mov     [Plane],al
              cmp     al,3                       ;have we done all planes?
              jbe     RestoreLoop                ;no, so do the next plane
;
; Close SNAPSHOT.SCR.
;
DoClose:
              mov     ah,3eh                     ;DOS close file function
              mov     bx,[Handle]
              int     21h
;
; Wait for a keypress.
;
              mov     ah,8                       ;DOS input without echo function
              int     21h
;
; Restore text mode.
;
```

```
            mov     ax,3
            int     10h
;
; Done.
;
Done:
            mov     ah,4ch                  ;DOS terminate function
            int     21h
Start       endp
Code        ends
            end     Start
```

If you compare Listings 29.1 and 29.2, you will see that the Map Mask register setting used to load a given plane does not match the Read Map register setting used to read that plane. This is so because while only one plane can ever be read at a time, anywhere from zero to four planes can be written to at once; consequently, Read Map register settings are plane selections from 0 to 3, while Map Mask register settings are plane *masks* from 0 to 15, where a bit 0 setting of 1 enables writes to plane 0, a bit 1 setting of 1 enables writes to plane 1, and so on. Again, Chapter 28 provides a detailed explanation of the differences between the Read Map and Map Mask registers.

Screen saving and restoring is pretty simple, eh? There are a few caveats, of course, but nothing serious. First, the adapter's registers must be programmed properly in order for screen saving and restoring to work. For screen saving, you must be in read mode 0; if you're in color compare mode, there's no telling what bit pattern you'll save, but it certainly won't be the desired screen image. For screen restoring, you must be in write mode 0, with the Bit Mask register set to 0FFH and Data Rotate register set to 0 (no data rotation and the logical function set to pass the data through unchanged).

tip *While these requirements are no problem if you're simply calling a subroutine in order to save an image from your program, they pose a considerable problem if you're designing a hot-key operated TSR that can capture a screen image at any time. With the EGA specifically, there's never any way to tell what state the registers are currently in, since the registers aren't readable. (More on this issue later in this chapter.) As a result, any TSR that sets the Bit Mask to 0FFH, the Data Rotate register to 0, and so on runs the risk of interfering with the drawing code of the program that's already running.*

What's the solution? Frankly, the solution is to get VGA-specific. A TSR designed for the VGA can simply read out and save the state of the registers of interest, program those registers as needed, save the screen image, and restore the original settings. From a programmer's perspective, readable registers are certainly near the top of the list of things to like about the VGA! The remaining installed base of EGAs is steadily dwindling, and you may be able to ignore it as a market today, as you couldn't even a year or two ago.

If you are going to write a hi-res VGA version of the screen capture program, be sure to account for the increased size of the VGA's mode 12H bit map. The mode 12H (640×480) screen uses 37.5K per plane of display memory, so for mode 12H the displayed screen size equate in Listings 29.1 and 29.2 should be changed to:

```
DISPLAYED_SCREEN_SIZE  equ   (640/8)*480
```

Similarly, if you're capturing a graphics screen that starts at an offset other than 0 in the segment at A000H, you must change the memory offset used by the disk functions to match. You can, if you so desire, read the start offset of the display memory providing the information shown on the screen from the Start Address registers (CRT Controller registers 0CH and 0DH); these registers are readable even on an EGA.

Finally, be aware that the screen capture and restore programs in Listings 29.1 and 29.2 are only appropriate for EGA/VGA modes 0DH, 0EH, 0FH, 010H, and 012H, since they assume a four- plane configuration of EGA/VGA memory. In all text modes and in CGA graphics modes, and in VGA modes 11H and 13H as well, display memory can simply be written to disk and read back as a linear block of memory, just like a normal array.

While Listings 29.1 and 29.2 are written in assembly, the principles they illustrate apply equally well to high-level languages. In fact, there's no need for any assembly at all when saving an EGA/VGA screen, as long as the high-level language you're using can perform direct port I/O to set up the adapter and can read and write display memory directly.

One tip if you're saving and restoring the screen from a high-level language on an EGA, though: After you've completed the save or restore operation, be sure to put any registers that you've changed back to their default settings. Some high-level languages (and the BIOS as well) assume that various registers are left in a certain state, so on the EGA it's safest to leave the registers in their most likely state. On the VGA, of course, you can just read the registers out before you change them, then put them back the way you found them when you're done.

16 Colors out of 64

How does one produce the 64 colors from which the 16 colors displayed by the EGA can be chosen? The answer is simple enough: There's a BIOS function that lets you select the mapping of the 16 possible pixel values to the 64 possible colors. Let's lay out a bit of background before proceeding, however.

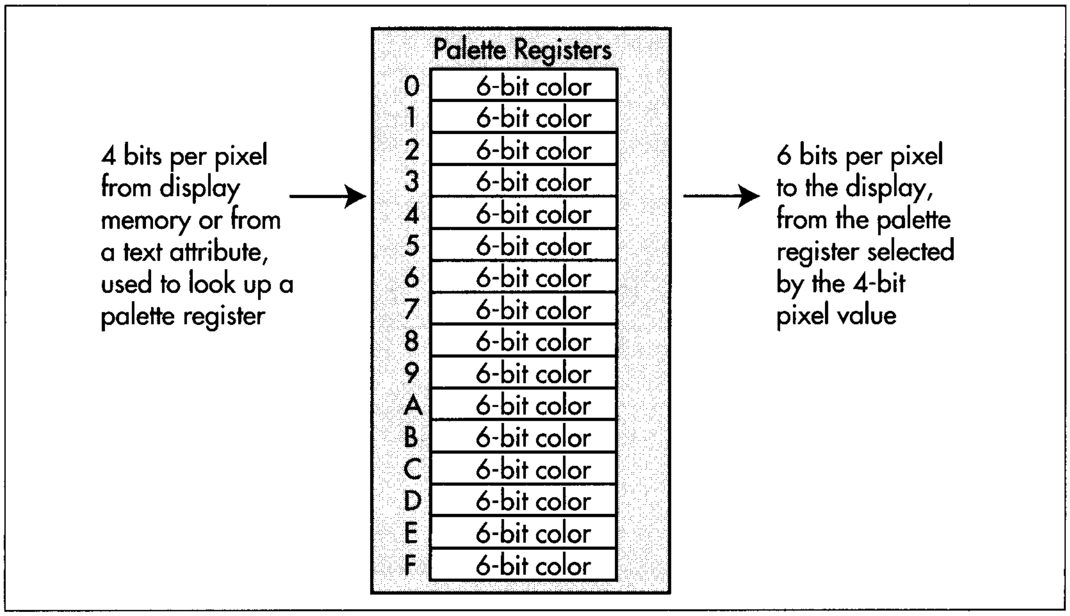
The EGA sends pixel information to the monitor on 6 pins. This means that there are 2 to the 6th, or 64 possible colors that an EGA can generate. However, for compatibility with pre-EGA monitors, in 200-scan-line modes Enhanced Color Display-compatible monitors ignore two of the signals. As a result, in CGA-compatible modes (modes 4, 5, 6, and the 200-scan-line versions of modes 0, 1, 2, and 3) you can select from only 16 colors (although the colors can still be remapped, as described below). If you're not hooked up to a monitor capable of displaying 350 scan lines (such as the old

IBM Color Display), you can never select from more than 16 colors, since those monitors only accept four input signals. For now, we'll assume we're in one of the 350-scan line color modes, a group which includes mode 10H and the 350-scan-line versions of modes 0, 1, 2, and 3.

Each pixel comes out of memory (or, in text mode, out of the attribute-handling portion of the EGA) as a 4-bit value, denoting 1 of 16 possible colors. In graphics modes, the 4-bit pixel value is made up of one bit from each plane, with 8 pixels' worth of data stored at any given byte address in display memory. Normally, we think of the 4-bit value of a pixel as being that pixel's color, so a pixel value of 0 is black, a pixel value of 1 is blue, and so on, as if that's a built-in feature of the EGA.

Actually, though, the correspondence of pixel values to color is absolutely arbitrary, depending solely on how the color-mapping portion of the EGA containing the palette registers is programmed. If you cared to have color 0 be bright red and color 1 be black, that could easily be arranged, as could a mapping in which all 16 colors were yellow. What's more, these mappings affect text-mode characters as readily as they do graphics-mode pixels, so you could map text attribute 0 to white and text attribute 15 to black to produce a black on white display, if you wished.

Each of the 16 palette registers stores the mapping of one of the 16 possible 4-bit pixel values from memory to one of 64 possible 6-bit pixel values to be sent to the monitor as video data, as shown in Figure 29.2. A 4-bit pixel value of 0 causes the 6-bit value

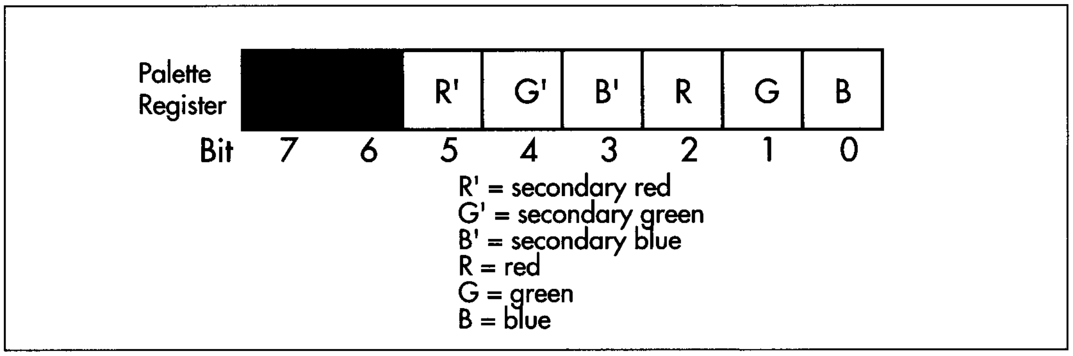


Color translation via the palette registers.
Figure 29.2

stored in palette register 0 to be sent to the display as the color of that pixel, a pixel value of 1 causes the contents of palette register 1 to be sent to the display, and so on. Since there are only four input bits, it stands to reason that only 16 colors are available at any one time; since there are six output bits, however, those 16 colors can be mapped to any of 64 colors. The mapping for each of the 16 pixel values is controlled by the lower six bits of the corresponding palette register, as shown in Figure 29.3. Secondary red, green, and blue are less-intense versions of red, green, and blue, although their exact effects vary from monitor to monitor. The best way to figure out what the 64 colors look like on your monitor is to see them, and that's just what the program in Listing 29.3, which we'll discuss shortly, lets you do.

How does one go about setting the palette registers? Well, it's certainly possible to set the palette registers directly by addressing them at registers 0 through 0FH of the Attribute Controller. However, setting the palette registers is a bit tricky—bit 5 of the Attribute Controller Index register must be 0 while the palette registers are written to, and glitches can occur if the updating doesn't take place during the blanking interval—and besides, it turns out that there's no need at all to go straight to the hardware on this one. Conveniently, the EGA BIOS provides us with video function 10H, which supports setting either any one palette register or all 16 palette registers (and the overscan register as well) with a single video interrupt.

Video function 10H is invoked by performing an **INT** 10H with AH set to 10H. If AL is 0 (subfunction 0), then BL contains the number of the palette register to set, and BH contains the value to set that register to. If AL is 1 (subfunction 1), then BH contains the value to set the overscan (border) color to. Finally, if AL is 2 (subfunction 2), then ES:DX points to a 17-byte array containing the values to set palette registers 0-15 and the overscan register to. (For completeness, although it's unrelated to the palette registers, there is one more subfunction of video function 10H. If AL = 3



Bit organization within a palette register.
Figure 29.3

(subfunction 3), bit 0 of BL is set to 1 to cause bit 7 of text attributes to select blinking, or set to 0 to cause bit 7 of text attributes to select high-intensity reverse video.)

Listing 29.3 uses video function 10H, subfunction 2 to step through all 64 possible colors. This is accomplished by putting up 16 color bars, one for each of the 16 possible 4-bit pixel values, then changing the mapping provided by the palette registers to select a different group of 16 colors from the set of 64 each time a key is pressed. Initially, colors 0-15 are displayed, then 1-16, then 2-17, and so on up to color 3FH wrapping around to colors 0-14, and finally back to colors 0-15. (By the way, at mode set time the 16 palette registers are not set to colors 0-15, but rather to 0H, 1H, 2H, 3H, 4H, 5H, 14H, 7H, 38H, 39H, 3AH, 3BH, 3CH, 3DH, 3EH, and 3FH, respectively. Bits 6, 5, and 4—secondary red, green, and blue—are all set to 1 in palette registers 8-15 in order to produce high-intensity colors. Palette register 6 is set to 14H to produce brown, rather than the yellow that the expected value of 6H would produce.)

When you run Listing 29.3, you'll see that the whole screen changes color as each new color set is selected. This occurs because most of the pixels on the screen have a value of 0, selecting the background color stored in palette register 0, and we're reprogramming palette register 0 right along with the other 15 palette registers.

It's important to understand that in Listing 29.3 the contents of display memory are never changed after initialization. The only change is the mapping from the 4-bit pixel data coming out of display memory to the 6-bit data going to the monitor. For this reason, it's technically inaccurate to speak of bits in display memory as representing colors; more accurately, they represent attributes in the range 0-15, which are mapped to colors 0-3FH by the palette registers.

LISTING 29.3 L29-3.ASM

```
; Program to illustrate the color mapping capabilities of the
; EGA's palette registers.
;
VGA_SEGMENT     equ   0a000h
SC_INDEX        equ   3c4h            ;Sequence Controller Index register
MAP_MASK        equ   2               ;Map Mask register index in SC
BAR_HEIGHT      equ   14              ;height of each bar
TOP_BAR         equ   BAR_HEIGHT*6    ;start the bars down a bit to
                                      ; leave room for text
;
stack       segment para stack 'STACK'
                  db              512 dup (?)
stack       ends
;
Data        segment     word 'DATA'
KeyMsg      db          'Press any key to see the next color set. '
            db          'There are 64 color sets in all.'
            db          0dh, 0ah, 0ah, 0ah, 0ah
            db          13 dup (' '), 'Attribute'
            db          38 dup (' '), 'Color$'
;
; Used to label the attributes of the color bars.
;
```

```
AttributeNumbers        label byte
x=          0
            rept        16
if x lt 10
            db          '0', x+'0', 'h', 0ah, 8, 8, 8
else
            db          '0', x+'A'-10, 'h', 0ah, 8, 8, 8
endif
x=          x+1
            endm
            db          '$'
;
; Used to label the colors of the color bars. (Color values are
; filled in on the fly.)
;
ColorNumbers            label byte
            rept        16
            db          '000h', 0ah, 8, 8, 8, 8
            endm
COLOR_ENTRY_LENGTH      equu  ($-ColorNumbers)/16
            db          '$'
;
CurrentColor      db    ?
;
; Space for the array of 16 colors we'll pass to the BIOS, plus
; an overscan setting of black.
;
ColorTable      db      16 dup (?), 0
Data            ends
;
Code            segment
                assume  cs:Code, ds:Data
Start           proc    near
                cld
                mov     ax,Data
                mov     ds,ax
;
; Go to hi-res graphics mode.
;
                mov     ax,10h              ;AH = 0 means mode set, AL = 10h selects
                                            ; hi-res graphics mode
                int     10h                 ;BIOS video interrupt
;
; Put up relevant text.
;
                mov     ah,9                ;DOS print string function
                mov     dx,offset KeyMsg
                int     21h
;
; Put up the color bars, one in each of the 16 possible pixel values
; (which we'll call attributes).
;
                mov     cx,16               ;we'll put up 16 color bars
                sub     al,al               ;start with attribute 0
BarLoop:
                push    ax
                push    cx
                call    BarUp
                pop     cx
                pop     ax
                inc     ax              ;select the next attribute
                loop    BarLoop
;
; Put up the attribute labels.
;
                mov     ah,2            ;video interrupt set cursor position function
                sub     bh,bh           ;page 0
                mov     dh,TOP_BAR/14   ;counting in character rows, match to
                                        ; top of first bar, counting in
                                        ; scan lines
                mov     dl,16           ;just to left of bars
                int     10h
                mov     ah,9            ;DOS print string function
                mov     dx,offset AttributeNumbers
                int     21h
;
; Loop through the color set, one new setting per keypress.
;
                mov     [CurrentColor],0 ;start with color zero
ColorLoop:
;
; Set the palette registers to the current color set, consisting
; of the current color mapped to attribute 0, current color + 1
; mapped to attribute 1, and so on.
;
                mov     al,[CurrentColor]
                mov     bx,offset ColorTable
                mov     cx,16           ;we have 16 colors to set
PaletteSetLoop:
                and     al,3fh          ;limit to 6-bit color values
                mov     [bx],al         ;build the 16-color table used for setting
                inc     bx              ; the palette registers
                inc     ax
                loop    PaletteSetLoop
                mov     ah,10h          ;video interrupt palette function
                mov     al,2            ;subfunction to set all 16 palette registers
                                        ; and overscan at once
                mov     dx,offset ColorTable
                push    ds
                pop     es              ;ES:DX points to the color table
                int     10h             ;invoke the video interrupt to set the palette
;
; Put up the color numbers, so we can see how attributes map
; to color values, and so we can see how each color # looks
; (at least on this particular screen).
;
                call    ColorNumbersUp
;
; Wait for a keypress, so they can see this color set.
;
WaitKey:
                mov     ah,8            ;DOS input without echo function
                int     21h
;
; Advance to the next color set.
;
                mov     al,[CurrentColor]
                inc     ax
                mov     [CurrentColor],al
                cmp     al,64
                jbe     ColorLoop
```

```
;
; Restore text mode.
;
              mov     ax,3
              int     10h
;
; Done.
;
Done:
              mov     ah,4ch           ;DOS terminate function
              int     21h
;
; Puts up a bar consisting of the specified attribute (pixel value),
; at a vertical position corresponding to the attribute.
;
; Input: AL = attribute
;
BarUp         proc    near
              mov     dx,SC_INDEX
              mov     ah,al
              mov     al,MAP_MASK
              out     dx,al
              inc     dx
              mov     al,ah
              out     dx,al            ;set the Map Mask register to produce
                                       ; the desired color
              mov     ah,BAR_HEIGHT
              mul     ah               ;row of top of bar
              add     ax,TOP_BAR       ;start a few lines down to leave room for
                                       ; text
              mov     dx,80            ;rows are 80 bytes long
              mul     dx               ;offset in bytes of start of scan line bar
                                       ; starts on
              add     ax,20            ;offset in bytes of upper left corner of bar
              mov     di,ax
              mov     ax,VGA_SEGMENT
              mov     es,ax            ;ES:DI points to offset of upper left
                                       ; corner of bar
              mov     dx,BAR_HEIGHT
              mov     al,0ffh
BarLineLoop:
              mov     cx,40            ;make the bars 40 wide
              rep     stosb            ;do one scan line of the bar
              add     di,40            ;point to the start of the next scan line
                                       ; of the bar
              dec     dx
              jnz     BarLineLoop
              ret
BarUp         endp
;
; Converts AL to a hex digit in the range 0-F.
;
BinToHexDigit proc    near
              cmp     al,9
              ja              IsHex
              add     al,'0'
              ret
IsHex:
              add     al,'A'-10
              ret
BinToHexDigit endp
```

```
;
; Displays the color values generated by the color bars given the
; current palette register settings off to the right of the color
; bars.
;
ColorNumbersUp proc     near
              mov      ah,2                ;video interrupt set cursor position function
              sub      bh,bh               ;page 0
              mov      dh,TOP_BAR/14       ;counting in character rows, match to
                                           ; top of first bar, counting in
                                           ; scan lines
              mov      dl,20+40+1          ;just to right of bars
              int      10h
              mov      al,[CurrentColor];start with the current color
              mov      bx,offset ColorNumbers+1
                                           ;build color number text string on the fly
              mov      cx,16               ;we've got 16 colors to do
ColorNumberLoop:
              push     ax                  ;save the color #
              and      al,3fh              ;limit to 6-bit color values
              shr      al,1
              shr      al,1
              shr      al,1
              shr      al,1                ;isolate the high nibble of the color #
              call     BinToHexDigit       ;convert the high color # nibble
              mov      [bx],al             ; and put it into the text
              pop      ax                  ;get back the color #
              push     ax                  ;save the color #
              and      al,0fh              ;isolate the low color # nibble
              call     BinToHexDigit       ;convert the low nibble of the
                                           ; color # to ASCII
              mov      [bx+1],al           ; and put it into the text
              add      bx,COLOR_ENTRY_LENGTH        ;point to the next entry
              pop      ax                  ;get back the color #
              inc      ax                  ;next color #
              loop     ColorNumberLoop
              mov      ah,9                ;DOS print string function
              mov      dx,offset ColorNumbers
              int      21h                 ;put up the attribute numbers
              ret
ColorNumbersUp endp
;
Start         endp
Code          ends
              end      Start
```

Overscan

While we're at it, I'm going to touch on overscan. Overscan is the color of the border of the display, the rectangular area around the edge of the monitor that's outside the region displaying active video data but inside the blanking area. The overscan (or border) color can be programmed to any of the 64 possible colors by either setting Attribute Controller register 11H directly or calling video function 10H, subfunction 1.

On ECD-compatible monitors, however, there's too little scan time to display a proper border when the EGA is in 350-scan-line mode, so overscan should always be 0 (black) unless you're in 200-scan-line mode. Note, though, that a VGA can easily display a border on a VGA-compatible monitor, and VGAs are in fact programmed at mode set for an 8-pixel-wide border in all modes; all you need do is set the overscan color on any VGA to see the border.

A Bonus Blanker

An interesting bonus: The Attribute Controller provides a very convenient way to blank the screen, in the form of the aforementioned bit 5 of the Attribute Controller Index register (at address 3C0H after the Input Status 1 register—3DAH in color, 3BAH in monochrome—has been read and on every other write to 3C0H thereafter). Whenever bit 5 of the AC Index register is 0, video data is cut off, effectively blanking the screen. Setting bit 5 of the AC Index back to 1 restores video data immediately. Listing 29.4 illustrates this simple but effective form of screen blanking.

LISTING 29.4 L29-4.ASM

```
; Program to demonstrate screen blanking via bit 5 of the
; Attribute Controller Index register.
;
AC_INDEX               equ   3c0h             ;Attribute Controller Index register
INPUT_STATUS_1         equ   3dah             ;color-mode address of the Input
                                              ; Status 1 register
;
; Macro to wait for and clear the next keypress.
;
WAIT_KEY macro
              mov      ah,8                ;DOS input without echo function
              int      21h
              endm
;
stack         segment para stack 'STACK'
              db       512 dup (?)
stack         ends
;
Data  segment    word        'DATA'
SampleText       db          'This is bit-mapped text, drawn in hi-res '
                 db          'EGA graphics mode 10h.', 0dh, 0ah, 0ah
                 db          'Press any key to blank the screen, then '
                 db          'any key to unblank it,', 0dh, 0ah
                 db          'then any key to end.$'
Data          ends
;
Code          segment
              assume   cs:Code, ds:Data
Start         proc     near
              mov      ax,Data
              mov      ds,ax
;
; Go to hi-res graphics mode.
;
              mov      ax,10h                 ;AH = 0 means mode set, AL = 10h selects
                                              ; hi-res graphics mode
              int      10h                    ;BIOS video interrupt
```

```
;
; Put up some text, so the screen isn't empty.
;
              mov     ah,9                 ;DOS print string function
              mov     dx,offset SampleText
              int     21h
;
              WAIT_KEY
;
; Blank the screen.
;
              mov     dx,INPUT_STATUS_1
              in      al,dx                ;reset port 3c0h to index (rather than data)
                                           ; mode
              mov     dx,AC_INDEX
              sub     al,al                ;make bit 5 zero...
              out     dx,al                ;...which blanks the screen
;
              WAIT_KEY
;
; Unblank the screen.
;
              mov     dx,INPUT_STATUS_1
              in      al,dx                ;reset port 3c0h to Index (rather than data)
                                           ; mode
              mov     dx,AC_INDEX
              mov     al,20h               ;make bit 5 one...
              out     dx,al                ;...which unblanks the screen
;
              WAIT_KEY
;
; Restore text mode.
;
              mov     ax,2
              int     10h
;
; Done.
;
Done:
              mov     ah,4ch               ;DOS terminate function
              int     21h
Start                 endp
Code                  ends
              end     Start
```

Does that do it for color selection? Yes and no. For the EGA, we've covered the whole of color selection—but not so for the VGA. The VGA can emulate everything we've discussed, but actually performs one 4-bit to 8-bit translation (except in 256-color modes, where all 256 colors are simultaneously available), followed by yet another translation, this one 8-bit to 18-bit. What's more, the VGA has the ability to flip instantly through as many as 16 16-color sets. The VGA's color selection capabilities, which are supported by another set of BIOS functions, can be used to produce stunning color effects, as we'll see when we cover them starting in Chapter 33.

Modifying VGA Registers

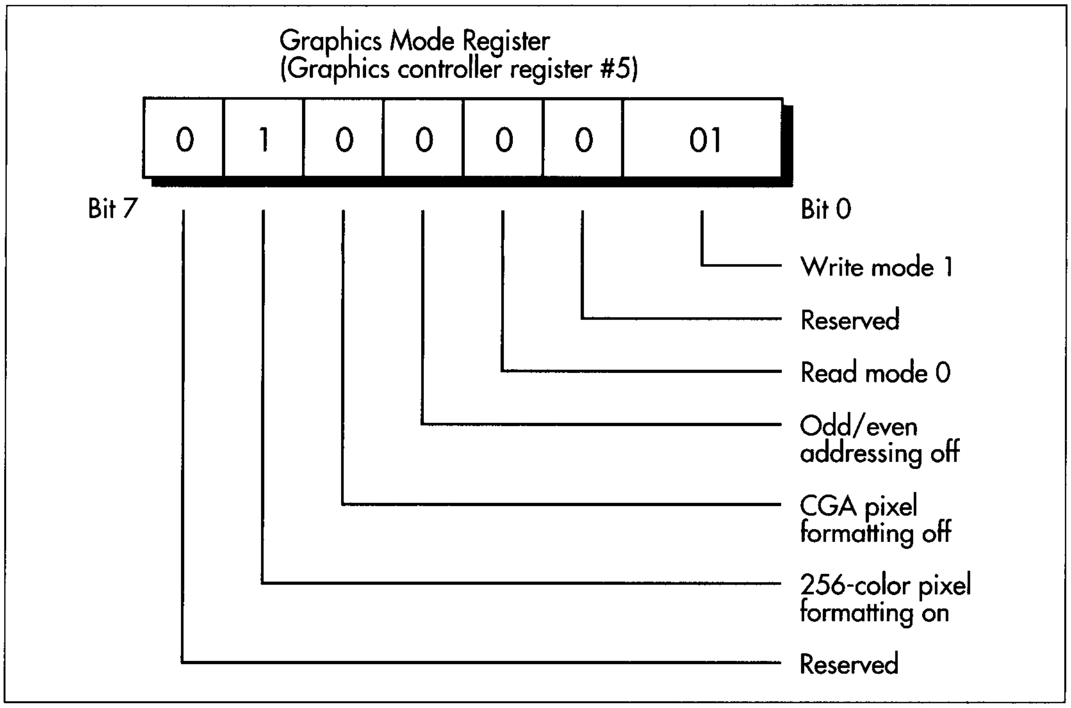
EGA registers are not readable. VGA registers are readable. This revelation will not come as news to most of you, but many programmers still insist on setting entire VGA registers even when they're modifying only selected bits, as if they were programming the EGA. This comes to mind because I recently received a query inquiring why write mode 1 (in which the contents of the latches are copied directly to display memory) didn't work in Mode X. (I'll go into Mode X in detail later in this book.) Actually, write mode 1 does work in Mode X; it didn't work when this particular correspondent enabled it because he did so by writing the value 01H to the Graphics Mode register. As it happens, the write mode field is only one of several fields in that register, as shown in Figure 29.4. In 256-color modes, one of the other fields—bit 6, which enables 256-color pixel formatting—is not 0, and setting it to 0 messes up the screen quite thoroughly.

The correct way to set a field within a VGA register is, of course, to read the register, mask off the desired field, insert the desired setting, and write the result back to the register. In the case of setting the VGA to write mode 1, do this:

```
mov   dx,3ceh               ;Graphics controller index
mov   al,5                  ;Graphics mode reg index
out   dx,al                 ;point GC index to G_MODE
inc   dx                    ;Graphics controller data
in    al,dx                 ;get current mode setting
and   al,not 3              ;mask off write mode field
or    al,1                  ;set write mode field to 1
out   dx,al                 ;set write mode 1
```

This approach is more of a nuisance than simply setting the whole register, but it's safer. It's also slower; for cases where you must set a field repeatedly, it might be worthwhile to read and mask the register once at the start, and save it in a variable, so that the value is readily available in memory and need not be repeatedly read from the port. This approach is especially attractive because **IN**s are much slower than memory accesses on 386 and 486 machines.

Astute readers may wonder why I didn't put a delay sequence, such as **JMP $+2**, between the **IN** and **OUT** involving the same register. There are, after all, guidelines from IBM, specifying that a certain period should be allowed to elapse before a second access to an I/O port is attempted, because not all devices can respond as rapidly as a 286 or faster CPU can access a port. My answer is that while I can't guarantee that a delay isn't needed, I've never found a VGA that required one; I suspect that the delay specification has more to do with motherboard chips such as the timer, the interrupt controller, and the like, and I sure hate to waste the delay time if it's not necessary. However, I've never been able to find anyone with the definitive word on whether delays might ever be needed when accessing VGAs, so if



Graphics mode register fields.
Figure 29.4

you know the gospel truth, or if you know of a VGA/processor combo that does require delays, please let me know by contacting me through the publisher. You'd be doing a favor for a whole generation of graphics programmers who aren't sure whether they're skating on thin ice without those legendary delays.