AA–AE36A–TV

Rainbow™

Color/Graphics Option Programmer's Reference Guide

digital equipment corporation

First Printing, June 1984

The postage-prepaid READER'S COMMENTS form on the last page of this document requests the user's critical evaluation to assist us in preparing future documentation.

Printed in U.S.A.

Contents

PART IV — Appendixes

Figures

Tables

Preface

The Intended Audience

The *Rainbow Color/Graphics Option Programmer's Reference Guide* is written for the experienced systems programmer who will be programming applications that display graphics on Rainbow video monitors. It is further assumed that the system programmer has had both graphics and 8088 programming experience.

The information contained in this document is not unique to any operating system; however, it is specific to the 8088 hardware and 8088-based software.

Organization of the manual

The *Rainbow Color/Graphics Option Programmer's Reference Guide* is subdivided into four parts containing fifteen chapters and three appendixes as follows:

- PART I — OPERATING PRINCIPLES contains the following four chapters:
  - Chapter 1 provides an overview of the Graphics Option including information on the hardware, logical interface to the CPU, general functionality, color and monochrome ranges, and model dependencies.
  - Chapter 2 describes the monitor configurations supported by the Graphics Option.

- Chapter 3 discusses the logic of data generation, bitmap addressing, and the GDC's handling of the screen display.
- Chapter 4 describes the software components of the Graphics Option such as the control registers, maps, and buffer areas accessible under program control.

- PART II — PROGRAMMING GUIDELINES contains the following eight chapters:
  - Chapter 5 discusses programming the Graphics Option for initialization and control operations.
  - Chapter 6 discusses programming the Graphics Option for setting up bitmap write operations.
  - Chapter 7 discusses programming the Graphics Option for area write operations.
  - Chapter 8 discusses programming the Graphics Option for vector write operations.
  - Chapter 9 discusses programming the Graphics Option for text write operations.
  - Chapter 10 discusses programming the Graphics Option for read operations.
  - Chapter 11 discusses programming the Graphics Option for scroll operations.
  - Chapter 12 contains programming notes and timing considerations.
- PART III — REFERENCE MATERIAL contains the following three chapters:
  - Chapter 13 provides descriptions and contents of the Graphics Option's registers, buffers, masks, and maps.
  - Chapter 14 provides descriptions and contents of the GDC's status register and FIFO buffer.
  - Chapter 15 provides a description of each supported GDC command arranged in alphabetic sequence within functional grouping.
- PART IV — APPENDIXES contain the following three appendixes:
  - Appendix A contains the Graphics Option's Specification Summary.
  - Appendix B is a fold-out sheet containing a block diagram of the Graphics Option.
  - Appendix C lists DIGITAL's International Help Line phone numbers.

Suggestions for the Reader

For more information about the Graphics Display Controller refer to the following:

- *uPD7220 GDC Design Manual*—NEC Electronics U.S.A. Inc.
- *uPD7220 GDC Design Specification*—NEC Electronics U.S.A. Inc.

For a comprehensive tutorial/reference manual on computer graphics, consider ***Fundamentals of Interactive Computer Graphics*** by J. D. Foley and A. Van Dam published by Addison-Wesley Publishing Company, 1982.

Terminology

ALU/PS	Arithmetic Logical Unit and Plane Select (register)
Bitmap	Video display memory
GDC	Graphics Display Controller
Motherboard	A term used to refer to the main circuit board where the processors and main memory are located — hardware options, such as the Graphics Option, plug into and communicate with the motherboard
Nibble	A term commonly used to refer to a half byte (4 bits)
Pixel	Picture element when referring to video display output
Resolution	A measure of the sharpness of a graphics image — usually given as the number of addressable picture elements for some unit of length (pixels per inch)
RGB	Red, green, blue — the acronym for the primary additive colors used in color monitor displays
RGO	Rainbow Graphics Option
RMW	Read/Modify/Write, the action taken when accessing the bitmap during a write or read cycle
VSS	Video Subsystem

Part I

Operating Principles

Contents

PART I

1

Overview

Hardware Components

The Graphics Option is a user-installable module that adds graphics and color display capabilities to the Rainbow system. The graphics module is based on a NEC uPD7220 Graphics Display Controller (GDC) and an 8 × 64K dynamic RAM video memory that is also referred to as the bitmap.

The Graphics Option is supported, with minor differences, on Rainbow systems with either the model A or model B motherboard. The differences involve the number of colors and monochrome intensities that can be simultaneously displayed and the number of colors and monochrome intensities that are available to be displayed (see Table 1). Chapter 5 includes a programming example of how you can determine which model of the motherboard is present in your system.

Table 1. Colors and Monochrome Intensities — Displayed/Available

		MED. RESOLUTION		HIGH RESOLUTION	
CONFIG.	MODEL	COLOR	MONO.	COLOR	MONO.
MONOCHROME MONITOR ONLY	100-A	N/A	4/4	N/A	4/4
	100-B	N/A	16/16	N/A	4/16
COLOR MONITOR ONLY	100-A	16/1024	N/A	4/1024	N/A
	100-B	16/4096	N/A	4/4096	N/A
DUAL MONITORS	100-A	16/4096	4/4	4/4096	4/4
	100-B	16/4096	16/16	4/4096	4/16

LJ-0212

The GDC, in addition to performing the housekeeping chores for the video display, can also:

- Draw lines at any angle
- Draw arcs of specified radii and length
- Fill rectangular areas
- Transfer character bit-patterns from font tables in main memory to the bitmap

Video Memory (Bitmap)

The CPUs on the motherboard have no direct access to the bitmap memory. All writes are performed by the external graphics option hardware to bitmap addresses generated by the GDC.

The bitmap is composed of eight 64K dynamic RAMs. This gives the bitmap a total of 8 × 64K of display memory. In high resolution mode, this memory is configured as two planes, each 8 × 32K. In medium resolution mode, this memory is configured as four planes, each 8 × 16K. However, as far as the GDC is concerned, there is only one plane. All plane interaction is transparent to the GDC.

Although the bitmap is made up of 8 × 64K bits, the GDC sees only 16K of word addresses in high resolution mode (2 planes × 16 bits × 16K words). Similarly, the GDC sees only 8K of word addresses in medium resolution mode (4 planes × 16 bits × 8K words). Bitmap address zero is displayed at the upper left corner of the monitor screen.

Additional Hardware

The option module also contains additional hardware that enhances the performance and versatility of the GDC. This additional hardware includes:

- A 16 × 8-bit Write Buffer used to store byte-aligned or word-aligned characters for high performance text writing or for fast block data moves from main memory to the bitmap
- An 8-bit Pattern Register and a 4-bit Pattern Multiplier for improved vector writing performance
- Address offset hardware (256 × 8-bit Scroll Map) for full and split-screen vertical scrolling
- ALU/PS register to handle bitplane selection and the write functions of Replace, Complement, and Overlay
- A 16 × 16-bit Color Map to provide easy manipulation of pixel color and monochrome intensities
- Readback hardware for reading a selected bitmap memory plane into main memory

Resolution Modes

The Graphics Option operates in either of two resolution modes:

- Medium Resolution Mode
- High Resolution Mode

Medium Resolution Mode

Medium resolution mode displays 384 pixels horizontally by 240 pixels vertically by four bitmap memory planes deep. This resolution mode allows up to 16 colors to be simultaneously displayed on a color monitor. Up to sixteen monochrome shades can be displayed simultaneously on a monochrome monitor.

High Resolution Mode

High resolution mode displays 800 pixels horizontally by 240 pixels vertically by two bitmap memory planes deep. This mode allows up to four colors to be simultaneously displayed on a color monitor. Up to four monochrome shades can be simultaneously displayed on a monochrome monitor.

Operational Modes

The Graphics Option supports the following modes of operations:

- WORD MODE to write 16-bit words to selected planes of the bitmap memory for character and image generation
- VECTOR MODE to write pixel data to bitmap addresses provided by the GDC
- SCROLL MODE for full- and split-screen vertical scrolling and full-screen horizontal scrolling
- READBACK MODE to read 16-bit words from a selected plane of bitmap memory for special applications, hardcopy generation or diagnostic purposes

2

Monitor Configurations

In the Rainbow system with the Graphics Option installed, there are three possible monitor configurations: Monochrome only, Color only, and Dual (color and monochrome). In all three configurations, the selection of the option's monochrome output or the motherboard VT102 video output is controlled by bit two of the system maintenance port (port 0Ah). A 0 in bit 2 selects the motherboard VT102 video output while a 1 in bit 2 selects the option's monochrome output.

Monochrome Monitor Only

As shown in Figure 1, the monochrome monitor can display either graphics option data or motherboard data depending on the setting of bit 2 of port 0Ah. Writing an 87h to port 0Ah selects the Graphics Option data. Writing an 83h to port 0Ah selects the motherboard VT102 data. The red, green and blue data areas in the Color Map should be loaded with all F's to reduce any unnecessary radio frequency emissions.

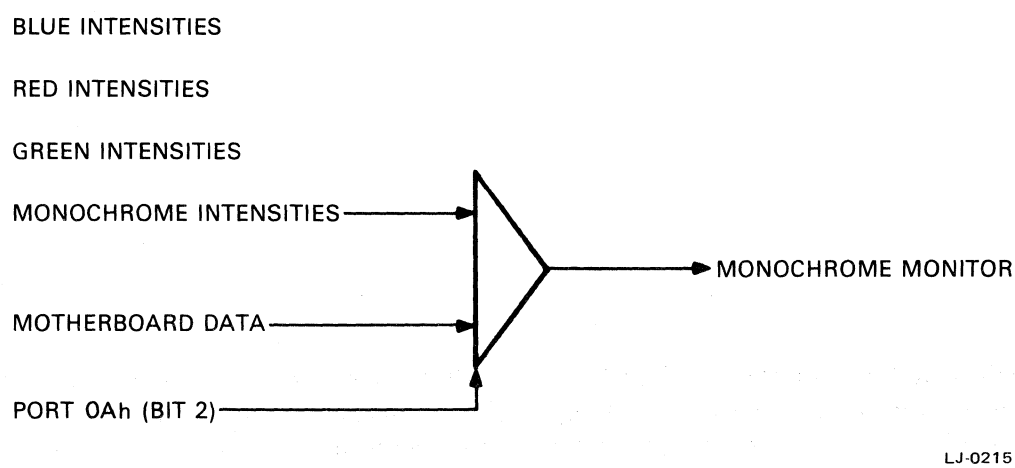


Figure 1. Monochrome Monitor Only System

Color Monitor Only

When the system is configured with only a color monitor, as in Figure 2, the green gun does double duty. It either displays the green component of the graphics output or it displays the monochrome output of the motherboard VT102 video subsystem. Because the green gun takes monochrome intensities, all green intensities must be programmed into the monochrome data area of the Color Map. The green data area of the Color Map should be loaded with all F's to reduce any unnecessary radio frequency emissions.

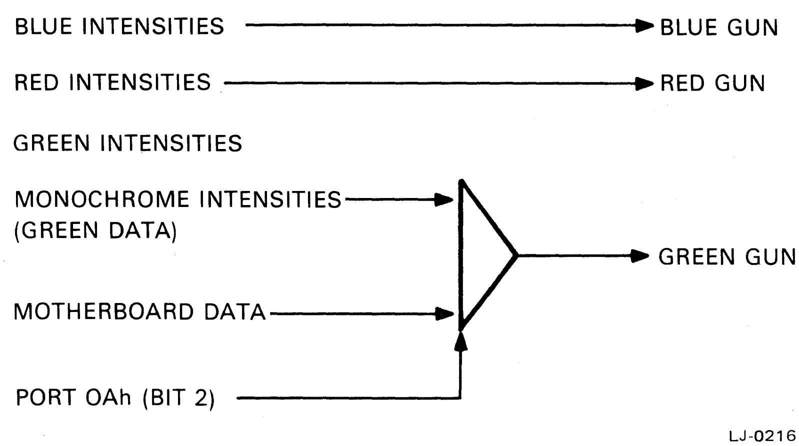


Figure 2. Color Monitor Only System

When motherboard VT102 data is being sent to the green gun, the red and blue output must be turned off at the Graphics Option itself. If not, the red and blue guns will continue to receive data from the option and this output will overlay the motherboard VT102 data and will also be out of synchronization. Bit 7 of the Mode Register is the graphics option output enable bit. If this bit is a 1 red and blue outputs are enabled. If this bit is a 0 red and blue outputs are disabled.

As in the monochrome only configuration, bit 2 of port 0Ah controls the selection of either the graphics option data or the motherboard VT102 data. Writing an 87h to port 0Ah enables the option data. Writing an 83h to port 0Ah selects the motherboard VT102 data.

Dual Monitors

In the configuration shown in Figure 3, both a color monitor and a monochrome monitor are available to the system. Motherboard VT102 video data can be displayed on the monochrome system while color graphics are being displayed on the color monitor. If the need should arise to display graphics on the monochrome monitor, the monochrome intensity output can be directed to the monochrome monitor by writing an 87h to port 0Ah. Writing an 83h to port 0Ah will restore motherboard VT102 video output to the monochrome monitor.

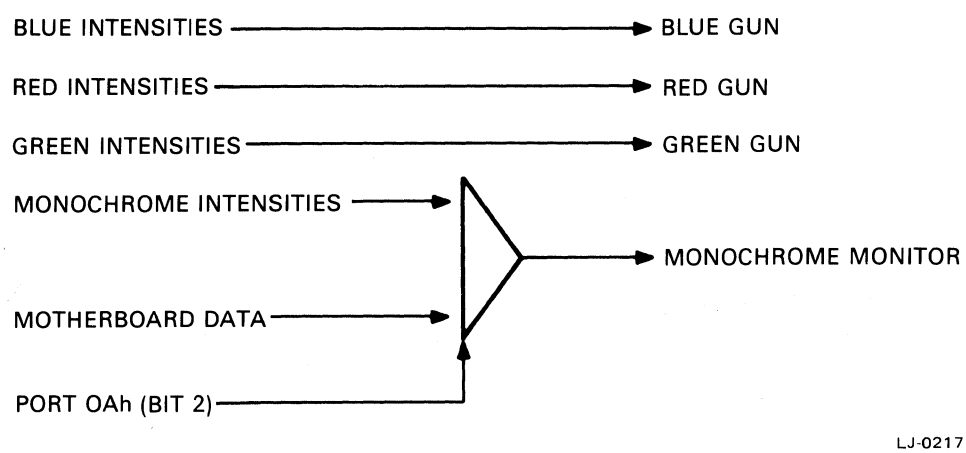


Figure 3. Dual Monitor System

When displaying graphics on the monochrome monitor, the only difference other than the the lack of color is the range of intensities that can be simultaneously displayed on systems with model A motherboards.

Systems with model A motherboards can display only four monochrome intensities at any one time. Even though sixteen entries can be selected when operating in medium resolution mode, only the two low-order bits of the monochrome output are active. This limits the display to only four unique intensities at most. On systems with the model B motherboard, all sixteen monochrome intensities can be displayed.

3

Graphics Option Logic

General

The Graphics Display Controller (GDC) can operate either on one bit at a time or on an entire 16-bit word at a time. It is, however, limited to one address space and therefore can only write into one plane at a time. The Graphics Option is designed in such a manner that while the GDC is doing single pixel operations on just one video plane, the external hardware can be doing 16-bit word operations on up to four planes of video memory.

Write operations are multi-dimensioned. They have width, depth, length and time.

- Width refers to the number of pixels involved in the write operation.
- Depth refers to the number of planes involved in the write operation.
- Length refers to the number of read/modify/write cycles the GDC is programmed to perform.
- Time refers to when the write operation occurs in relation to the normal housekeeping operations the GDC has to perform in order to keep the monitor image stable and coherent.

Data Logic

The Graphics Option can write in two modes: word mode (16 bits at a time) and vector mode (one pixel at a time).

In word mode, the data patterns to be written into the bitmap are based on bit patterns loaded into the Write Buffer, Write Mask, and the Foreground/Background Register, along with the type of write operation programmed into the ALU/PS Register.

In vector mode, the data patterns to be written to the bitmap are based on bit patterns loaded into the Pattern Register, the Pattern Multiplier, the Foreground/Background Register, and the type of write operation programmed into the ALU/PS Register.

In either case, the data will be stored in the bitmap at a location determined by the addressing logic.

Address Logic

The addressing logic of the Graphics Option is responsible for coming up with the plane, the line within the plane, the word within the line, and even the pixel within the word under some conditions.

The display memory on the Graphics Option is one-dimensional. The GDC scans this linear memory to generate the two dimensional display on the CRT. The video display is organized similarly to the fourth quadrant of the Cartesian plane with the origin in the upper left corner. Row addresses (y coordinates of pixels) start at zero and increase downwards while column addresses (x coordinates of pixels) start at zero and increase to the right (see Figure 4). Pixel data is stored in display memory by column within row.

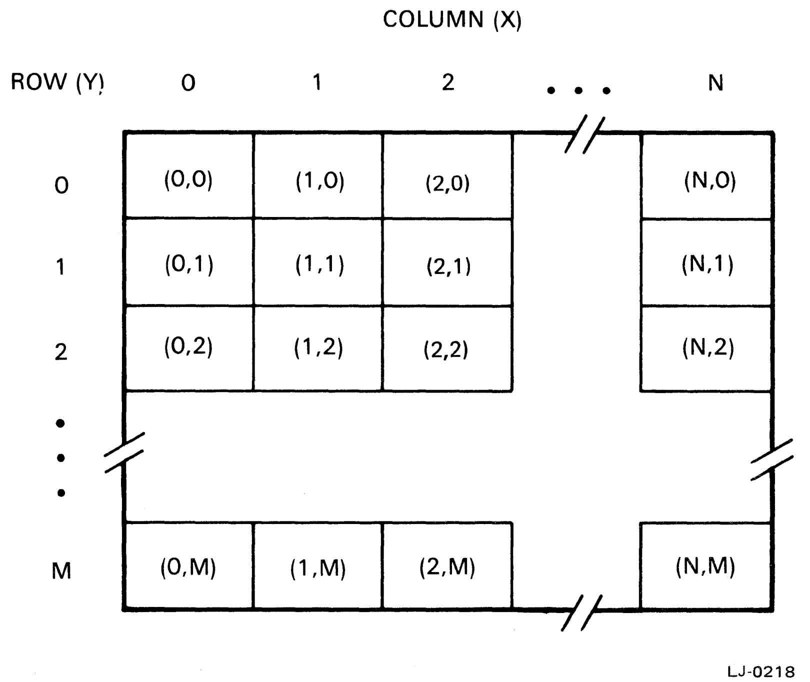
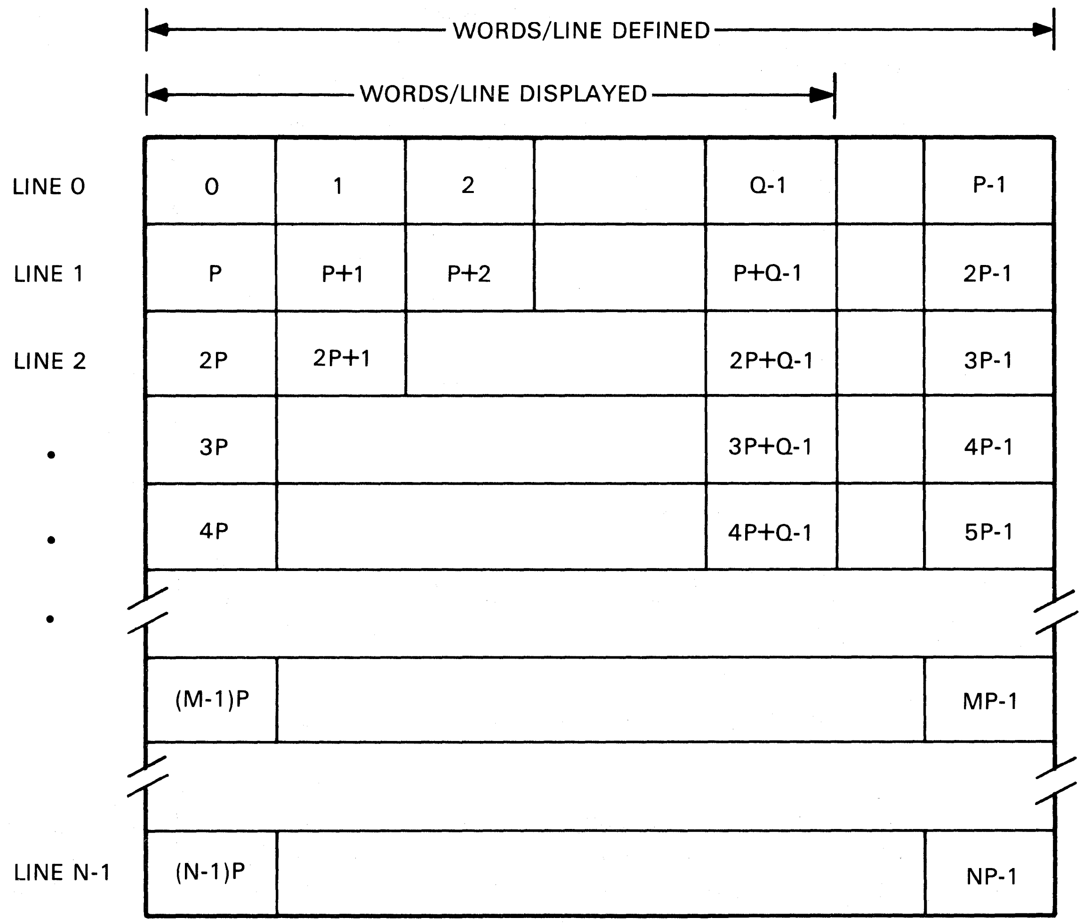


Figure 4. Rows and Columns in Display Memory

The GDC accesses the display memory as a number of 16-bit words where each bit represents a pixel. The number of words defined as well as the number of words displayed on each line is dependent on the resolution. The relationship between words and display lines is shown in Figure 5.



WHERE:

P = WORDS/LINE DEFINED	– 32 IN MEDIUM RESOLUTION. – 64 IN HIGH RESOLUTION.
Q = WORDS/LINE DISPLAYED	– 24 IN MEDIUM RESOLUTION – 50 IN HIGH RESOLUTION
N = NO. OF LINES DEFINED	– 256
M = NO. OF LINES DISPLAYED	– 240

LJ-0219

Figure 5. Relationship of Display Memory to Address Logic

In order to address specific pixels, the GDC requires the word address and the pixel location within that word. The conversion of pixel coordinates to addresses in display memory is accomplished by the following formulas:

```
Given the pixel coordinates (x,y):

Word Address of pixel = (words/line defined * y) + integer(x/16)
Pixel Address within word  = remainder(x/16) * 16
```

Because the Graphics Option is a multi-plane device, a way is provided to selectively enable and disable the reading and writing of the individual planes. This function is performed by the ALU/PS and Mode registers. More than one plane at a time can be enabled for a write operation; however, only one plane can be enabled for a read operation at any one time.

The entire address generated by the GDC does not go directly to the bitmap. The low-order six bits address a word within a line in the bitmap and do go directly to the bitmap. The high-order eight bits address the line within the plane and these bits are used as address inputs to a Scroll Map. The Scroll Map acts as a translator such that the bitmap location can be selectively shifted in units of 64 words. In high resolution mode, 64 words equate to one scan line; in medium resolution mode, they equate to two scan lines. This allows the displayed vertical location of an image to be moved in 64-word increments without actually rewriting it to the bitmap. Programs using this feature can provide full and split screen vertical scrolling. The Scroll Map is used in all bitmap access operations: writing, reading, and refreshing.

If an application requires addressing individual pixels within a word, the two 8-bit Write Mask Registers can be used to provide a 16-bit mask that will write-enable selected pixels. Alternately, a single pixel vector write operation can be used.

There is a difference between the number of words/line defined and the number of words/line displayed. In medium resolution, each scan line is 32 words long but only 24 words are displayed (24 words * 16 bits/word = 384 pixels). The eight words not displayed are unusable. Defining the length of the scan line as 24 words would be a more efficient use of memory but it would take longer to refresh the memory. Because display memory is organized as a 256 by 256 array, it takes 256 bytes of scan to refresh the entire 64K byte memory. Defining the scan line length as 32 words long enables the entire memory to be refreshed in four line scan periods. Defining the scan line length as 24 words long would require five line scans plus 16 bytes.

Similarly, in high resolution, each scan line is 64 words long but only 50 words are displayed. With a 64 word scan line length, it takes two line scan periods to refresh the entire 64K byte memory. If the scan line length were 50 words, it would take two lines plus 56 bytes to refresh the memory.

Another advantage to defining scan line length as 32 or 64 words is that cursor locating can be accomplished by a series of shift instructions which are considerably faster than multiplying.

Display Logic

The display logic of the Graphics Option will be discussed as it applies to both the bitmap and the screen.

Bitmap Logic

Data in the bitmap does not go directly to the monitor. Instead, the bitmap data is used as an address into a Color Map. The output of this Color Map, which has been preloaded with color and monochrome intensity values, is the data that is sent to the monitor.

In medium resolution mode there are four planes to the bitmap; each plane providing an address bit to the Color Map. Four bits can address sixteen unique locations at most. This gives a maximum of 16 addressable Color Map entries. Each Color Map entry is 16 bits wide. Four of the bits are used to drive the color monitor's red gun, four go to the green gun, four go to the blue gun, and four drive the output to the monochrome monitor. In systems with the Model 100-A motherboard, only the two low-order bits of the monochrome output are used. Therefore, although there are 16 possible monochrome selections in the Color Map, the number of unique intensities that can be sent to the monochrome monitor is four.

In high resolution mode there are two planes to the bitmap; each plane providing an address bit to the Color Map. Two bits can address four entries in the Color Map at most. Again, each Color Map entry is sixteen bits wide with 12 bits of information used for color and four used for monochrome shades. In systems with the Model 100-A motherboard, only the two low-order bits of the monochrome output are used. This limits the number of unique monochrome intensities to four.

Although the Color Map is 16 bits wide, the color intensity values are loaded one byte at a time. First, the 16 pairs of values representing the red and green intensities are loaded into bits 0 through 7 of the map. Then, the 16 pairs of values representing the blue and monochrome intensities are loaded into bits 8 through 15 of the map.

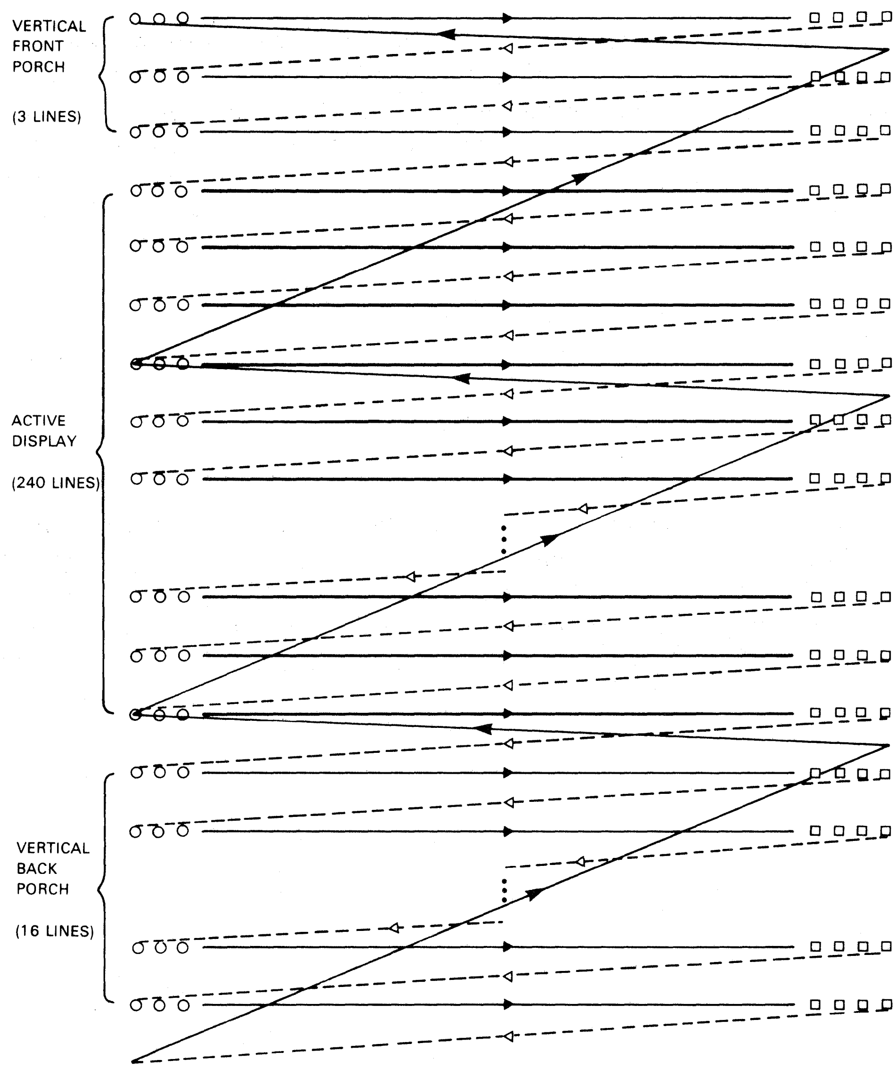
Screen Logic

The image displayed on the screen is generated by an electron beam performing a series of horizontal line scans from left to right. At the end of each horizontal scan line, a horizontal retrace takes place at which time the electron beam reverses its horizontal direction. During this horizontal retrace, the electron beam is also being moved down to the beginning of the next scan line. When the last line has completed its horizontal retrace, a vertical retrace takes place at which time the electron beam's vertical movement is reversed and the beam is positioned at the beginning of the first scan line.

The GDC writes to the bitmap only during the screen's horizontal and vertical retrace periods. During active screen time, the GDC is taking information out of the bitmap and presenting it to the video screen hardware. For example, if the GDC is drawing a vector to the bitmap, it will stop writing during active screen time and resume writing the vector at the next horizontal or vertical retrace.

In addition to the active screen time and the horizontal and vertical retrace times, there are several other screen control parameters that precede and follow the active horizontal scans and active lines. These are the Vertical Front and Back Porches and the Horizontal Front and Back Porches. The relationship between the screen control parameters is shown in Figure 6. Taking all the parameters into account, the proportion of active screen time to bitmap writing time is approximately four to one.

GDC VIDEO CONTROL PARAMETERS



		HIGH RESOLUTION	MEDIUM RESOLUTION
O O O	HORIZONTAL FRONT PORCH (WORDS)	3	2
□ □ □	HORIZONTAL BACK PORCH (WORDS)	4	3
◁- - -	HORIZONTAL RETRACE (WORDS)	5	2
━━▶━━	HORIZONTAL ACTIVE (WORDS)	50	24
──▶──	HORIZONTAL INACTIVE (VERTICAL FRONT & BACK PORCHES)		
────	VERTICAL RETRACE (LINES)	3	3

LJ-0220

Figure 6. GDC Screen Control Parameters

GDC Command Logic

Commands are passed to the GDC command processor from the Rainbow system by writing command bytes to port 57h and parameter bytes to port 56h. Data written to these two ports is stored in the GDC's FIFO buffer, a 16 x 9-bit area that is used to both read from and write to the GDC. The FIFO buffer operates in half-duplex mode — passing data in both directions, one direction at a time. The direction of data flow at any one time is controlled by GDC commands.

When commands are stored in the FIFO buffer, a flag bit is associated with each data byte depending on whether the data byte was written to the command address (57h) or the parameter address (56h). A flag bit of 1 denotes a command byte; a flag bit of 0 denotes a parameter byte. The command processor tests this flag bit as it interprets the contents of the FIFO buffer.

The receipt of a command byte by the command processor signifies the end of the previous command and any associated parameters. If the command is one that requires a response from the GDC such as RDAT, the FIFO buffer is automatically placed into read mode and the buffer direction is reversed. The specified data from the bitmap is loaded into the FIFO buffer and can be accessed by the system using read operations to port 57h. Any commands or parameters in the FIFO buffer that follow the read command are lost when the FIFO buffer's direction is reversed.

When the FIFO buffer is in read mode, any command byte written to port 57h will immediately terminate the read operation and reverse the buffer direction to write mode. Any data that has not been read by the Rainbow system from the FIFO buffer will be lost.

4

Graphics Option Components

I/O Ports

The CPUs on the Rainbow system's motherboard use a number of 8-bit I/O ports to exchange information with the various subsystems and options. The I/O ports assigned to the Graphics Option are ports 50h through 57h. They are used to generate and display graphic images, inquire status, and read the contents of video memory (bitmap). The function of each of the Graphics Option's I/O ports is as follows:

Port	Function
50h	Graphics option software reset. Any write to this port also resynchronizes the read/modify/write memory cycles of the Graphics Option to those of the GDC.
51h	Data written to this port is loaded into the area selected by the previous write to port 53h.
52h	Data written to this port is loaded into the Write Buffer.
53h	Data written to this port provides address selection for indirect addressing (see Indirect Register).
54h	Data written to this port is loaded into the low-order byte of the Write Mask.
55h	Data written to this port is loaded into the high-order byte of the Write Mask.
56h	Data written to this port is loaded into the GDC's FIFO Buffer and flagged as a parameter. Data read from this port reflects the GDC status.
57h	Data written to this port is loaded into the GDC's FIFO Buffer and flagged as a command. Data read from this port reflects information extracted from the bitmap.

Indirect Register

The Graphics Option uses indirect addressing to enable it to address more registers and storage areas on the option module than there are address lines (ports) to accommodate them. Indirect addressing involves writing to two ports. A write to port 53h loads the Indirect Register with a bit array in which each bit selects one of eight areas.

The Indirect Register bits and the corresponding areas are as follows:

Bit	**Area Selected**
0	Write Buffer (*)
1	Pattern Multiplier
2	Pattern Register
3	Foreground/Background Register
4	ALU/PS Register
5	Color Map (*)
6	Mode Register
7	Scroll Map (*)
(*)	Also clears the associated index counter

After selecting an area by writing to port 53h, you access and load data into most selected areas by writing to port 51h. For the Write Buffer however, you need both a write of anything to port 51h to access the buffer and clear the counter and then a write to port 52h to load the data.

Write Buffer

A 16 $\times$ 8-bit Write Buffer provides the data for the bitmap when the Graphics Option is in Word Mode. You can use the buffer to transfer blocks of data from the system's memory to the bitmap. The data can be full screen images of the bitmap or bit-pattern representations of font characters that have been stored in motherboard memory. The buffer has an associated index counter that is cleared when the Write Buffer is selected.

Although the CPU accesses the Write Buffer as sixteen 8-bit bytes, the GDC accesses the buffer as eight 16-bit words. (See Figure 7.) A 16-bit Write Mask gives the GDC control over individual bits of a word.

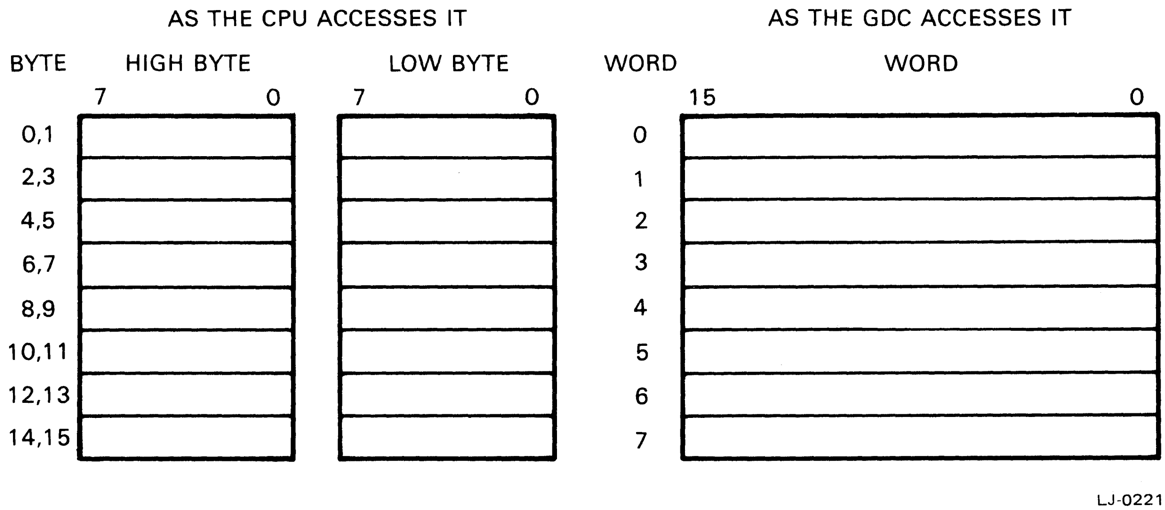


Figure 7. Write Buffer as Accessed by the CPU and the GDC

The output of the Write Buffer is the inverse of its input. If a word is written into the buffer as FFB6h, it will be read out of the buffer as 0049h. To have the same data written out to the bitmap as was received from the CPU requires an added inversion step. You can exclusive or (XOR) the CPU data with FFh to pre-invert the data before going through the Write Buffer. Alternately, you can write zeros into the Foreground Register and ones into the Background Register to re-invert the data after it leaves the Write Buffer and before it is written to the bitmap. Use one method or the other, not both.

In order to load data into the Write Buffer, you first write an FEh to port 53h and any value to port 51h. This not only selects the Write Buffer but also sets the Write Buffer Index Counter to zero. The data is then loaded into the buffer by writing it to port 52h in high-byte low-byte order. If more than 16 bytes are written to the buffer the first 16 bytes will be overwritten.

If you load the buffer with less than 16 bytes (or other than a multiple of 16 bytes for some reason or other) the GDC will find an index value other than zero in the counter. Starting at a location other than zero alters the data intended for the bitmap. Therefore, before the GDC is given the command to write to the bitmap, you must again clear the Write Buffer Index Counter so that the GDC will start accessing the data at word zero.

Write Mask Registers

When the Graphics Option is in Word Mode, bitmap operations are carried out in units of 16-bit words. A 16-bit Write Mask controls the writing of individual bits within a word. A zero in a bit position of the mask allows writing to the corresponding position of the word. A one in a bit position of the mask disables writing to the corresponding position of the word.

While the GDC accesses the mask as a 16-bit word, the CPU accesses the mask as two of the Graphic Option's I/O ports. The high-order Write Mask Register is loaded with a write to port 55h and corresponds to bits 15 through 8 of the Write Mask. The low-order Write Mask Register is loaded with a write to port 54h and corresponds to bits 7 through 0 of the Write Mask. (See Figure 8.)

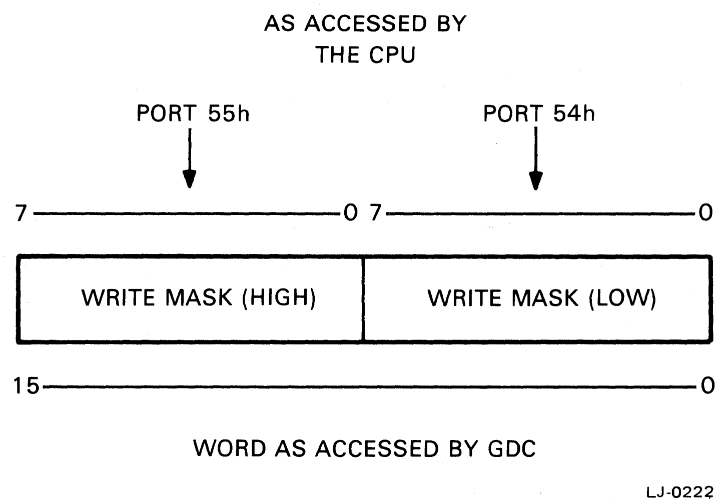


Figure 8. Write Mask Registers

Pattern Generator

When the Graphics Option is in Vector Mode, the Pattern Generator provides the data to be written to the bitmap. The Pattern Generator is composed of a Pattern Register and a Pattern Multiplier.

The Pattern Register is an 8-bit recirculating shift register that is first selected by writing FBh to port 53h and then loaded by writing an 8-bit data pattern to port 51h.

The Pattern Multiplier is a 4-bit register that is first selected by writing FDh to port 53h and then loaded by writing a value of 0-Fh to port 51h.

> **NOTE**
> You must load the Pattern Multiplier before loading the Pattern Register.

Figure 9 shows the logic of the Pattern Generator. Data destined for the bitmap originates from the low-order bit of the Pattern Register. That same bit continues to be the output until the Pattern Register is shifted. When the most significant bit of the Pattern Register has completed its output cycle, the next bit to shift out will be the least significant bit again.

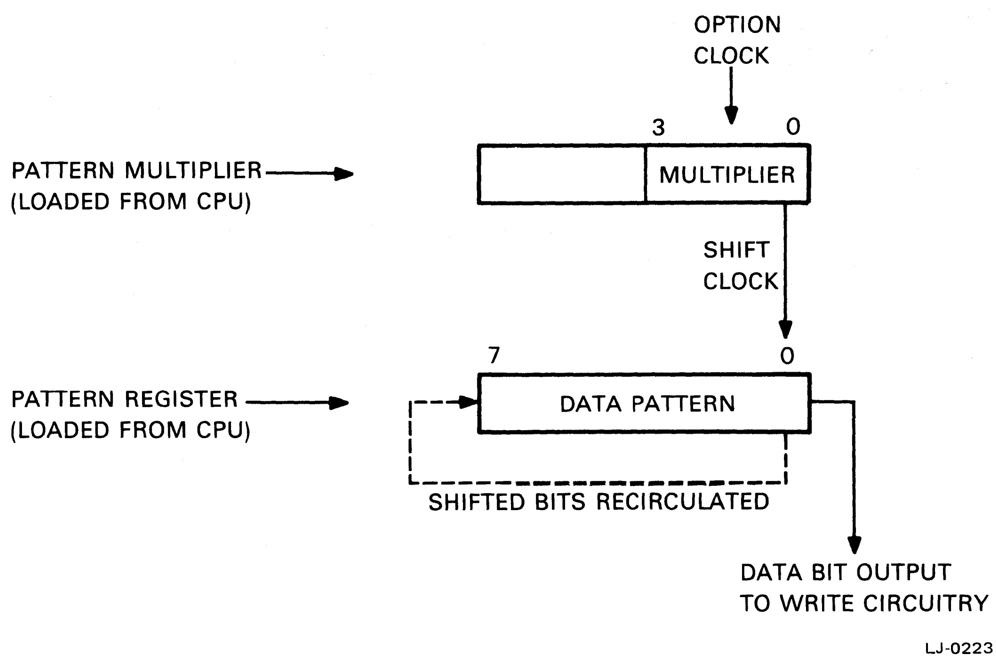


Figure 9. Pattern Generator

The shift frequency is the write frequency from the option clock divided by 16 minus the value in the Pattern Multiplier. For example, if the value in the Pattern Multiplier is 12, the shift frequency divisor would be 16 minus 12 or four. The shift frequency would be one fourth of the write frequency and therefore each bit in the Pattern Register would be replicated in the output stream four times. A multiplier of 15 would take 16 – 15 or one write cycle for each Pattern Register bit shifted out. A multiplier of five would take 16 – 5 or 11 write cycles for each bit in the Pattern Register.

NOTE
Do not change the contents of the Pattern Multiplier or the Pattern Register before the GDC has completed all pending vector mode write operations. If you do, the vector pattern that is in the process of being displayed will take on the new characteristics of the Pattern Generator.

Foreground/Background Register

The Foreground/Background Register is an eight-bit write-only register. The high-order nibble is the Foreground Register; the low-order nibble is the Background Register. Each of the four bitmap planes has a Foreground/Background bit-pair associated with it (see Figure 10). The bit settings in the Foreground/Background Register, along with the mode specified in the ALU/PS Register, determine the data that is eventually received by the bitmap. For example; if the mode is REPLACE, an incoming data bit of 0 is replaced by the corresponding bit in the Background Register. If the incoming data bit is a 1, the bit would be replaced by the corresponding bit in the Foreground Register.

Each bitmap plane has its own individual Foreground/Background bit pair. Therefore, it is possible for two enabled planes to use the same incoming data pattern and end up with different bitmap patterns.

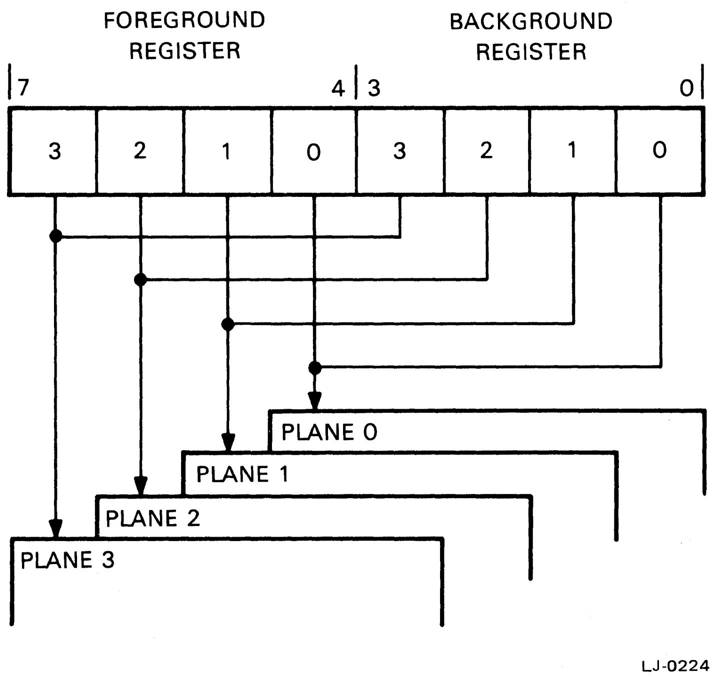


Figure 10. Foreground/Background Register

NOTE

Do not change the contents of the Foreground/Background Register before the GDC has completed all pending write operations. If you do, the information that is in the process of being displayed will take on the new values of the Foreground/Background Register.

ALU/PS Register

The ALU/PS Register has two functions.

Bits 0 through 3 of the ALU/PS Register are used to inhibit writes to one or more of the bitmap planes. If you could not inhibit writes to the bitmap planes, each write operation would affect all available planes. When a plane select bit is set to 1, writes to that plane will be inhibited. When a plane select bit is set to 0, writes to that plane will be allowed.

NOTE
During a readback mode operation, all plane select bits should be set to ones to prevent accidental changes to the bitmap data.

Bits 4 and 5 of the ALU/PS Register define an arithmetic logic unit function. The three logic functions supported by the option are REPLACE, COMPLEMENT, and OVERLAY. These functions operate on the incoming data from the Write Buffer or the Pattern Generator as modified by the Foreground/Background Register as well as the current data in the bitmap and generate the new data to be placed into the bitmap.

When the logic unit is operating in REPLACE mode, the current data in the bitmap is replaced by the Foreground/Background data selected as follows:

- An incoming data bit 0 selects the Background data.
- An incoming data bit 1 selects the Foreground data.

When the logic unit is operating in COMPLEMENT mode, the current data in the bitmap is modified as follows:

- An incoming data bit 0 results in no change.
- An incoming data bit 1 results in the current data being exclusively or'ed (XOR) with the appropriate Foreground bit. If the Foreground bit is 0, the current data is unchanged. If the Foreground bit is 1, the current data is complemented by binary inversion. In effect, the Foreground Register acts as a plane select register for the complement operation.

When the logic unit is operating in OVERLAY mode, the current data in the bitmap is modified as follows:

- An incoming data bit 0 results in no change.
- An incoming data bit 1 results in the current data being replaced by the appropriate Foreground bit.

NOTE
Do not change the contents of the ALU/PS Register before the GDC has completed all pending write operations. If you do, the information that is in the process of being displayed will take on the new characteristics of the ALU/PS Register.

Color Map

The Color Map is a 16 $\times$ 16-bit RAM area where each of the 16 entries is composed of four 4-bit values representing color intensities. These values represent, from high order to low order, the monochrome, blue, red, and green outputs to the video monitor. Intensity values are specified in inverse logic. At one extreme, a value of zero represents maximum intensity (100% output) for a particular color or monochrome shade. At the other extreme, a value of 0Fh represents minimum intensity (zero output).

Bitmap data is not directly displayed on the monitor, each bitmap plane contributes one bit to an index into the Color Map. The output of the Color Map is the data that is passed to the monitor. Four bitmap planes (medium resolution) provide four bits to form an index allowing up to 16 intensities of color or monochrome to be simultaneously displayed on the monitor. Two bitmap planes (high resolution) provide two bits to form an index allowing only four intensities of color or monochrome to be simultaneously displayed on the monitor.

In Figure 11, a medium resolution configuration, the bitmap data for the display point x,y is 0110b. This value, when applied as an index into the Color Map, selects the seventh entry out of a possible sixteen. Each Color Map entry is sixteen bits wide. Four of the bits are used to drive the color monitor's red gun, four go to the green gun, four go to the blue gun, and four drive the output to the monochrome monitor. The twelve bits going to the color monitor support a color palette of 4096 colors; the four bits to the monochrome monitor support 16 shades. (In systems with the Model 100-A motherboard, only the two low-order bits of the monochrome output are active. This limits the monochrome output to four unique intensities.)

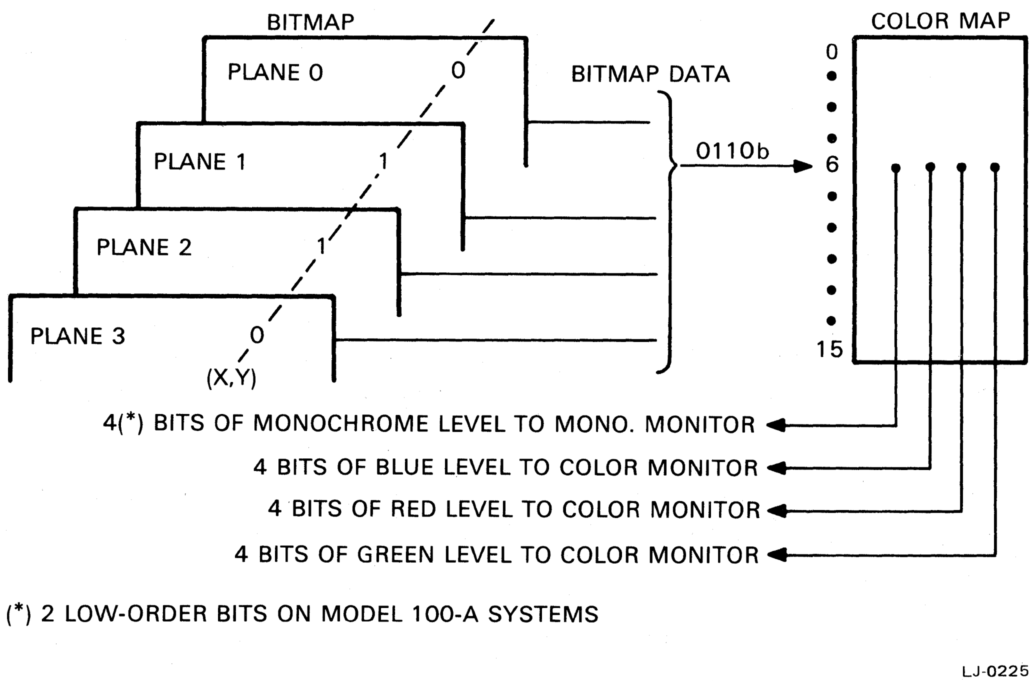


Figure 11. Bitmap/Color Map Interaction (medium resolution)

In Figure 12, a high resolution configuration, the bitmap data for point (x,y) is 10b. This value, when applied as an index into the Color Map, selects the third entry out of a possible four. Again, each Color Map entry is sixteen bits wide; 12 bits of information are used for color and four are used for monochrome. (In systems with the Model 100-A motherboard, only the two low-order bits of the monochrome output are active. This limits the monochrome output to four unique intensities.)

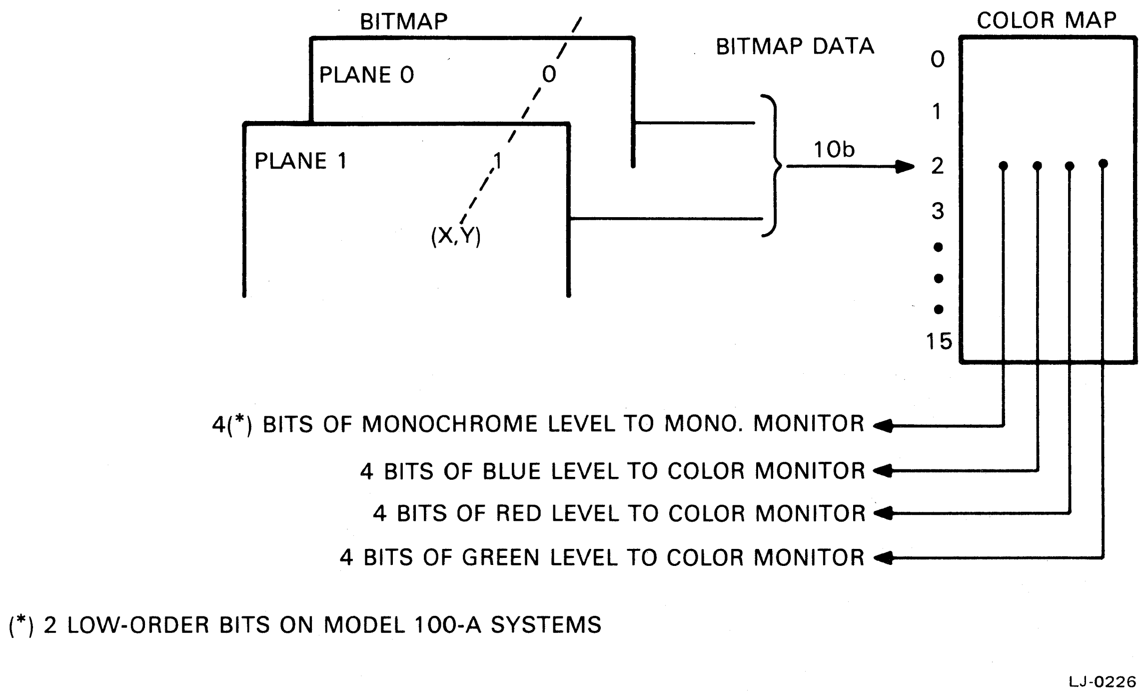


Figure 12. Bitmap/Color Map Interaction (high resolution)

Loading the Color Map

The Graphics Option accesses the Color Map as sixteen 16-bit words. However, the CPU accesses the Color Map as 32 eight-bit bytes. The 32 bytes of intensity values are loaded into the Color Map one entire column of 16 bytes at a time. The red and green values are always loaded first, then the monochrome and blue values. (See Figure 13.)

	2ND 16 BYTES LOADED BY THE CPU		1ST 16 BYTES LOADED BY THE CPU			
	7 4	3 0	7 4	3 0		
ADDRESS VALUE	MONO. DATA	BLUE DATA	RED DATA	GREEN DATA	COLOR DISPLAYED	MONOCHROME DISPLAYED
0	15	15	15	15	BLACK	BLACK
1	14	15	0	15	RED	• • •
2	13	15	15	0	GREEN	GRAY SHADES
3	12	0	15	15	BLUE	
4	11	0	0	15	MAGENTA	
5	10	0	15	0	CYAN	
6	9	15	0	0	YELLOW	
• • • •					• • • •	• • •
15	0	0	0	0	WHITE	WHITE

LJ-0227

Figure 13. Sample Color Map With Loading Sequence

Writing the value DFh to port 53h selects the Color Map and also clears the Color Map Index Counter to zero. To load data into the Color Map requires writing to port 51h. Each write to port 51h will cause whatever is on the motherboard data bus to be loaded into the current Color Map location. After each write, the Color Map Index Counter is incremented by one. If 33 writes are made to the Color Map, the first Color Map location will be overwritten.

NOTE
Do not change the contents of the Color Map before the GDC has completed all pending write operations. If you do, the information that is in the process of being displayed will take on the new Color Map characteristics.

Video Drive Voltages

The output of the Color Map, as shown in Figures 11 and 12, consists of four 4-bit values that represent the red, green, blue, and monochrome intensities to be displayed on some applicable monitor. These four intensity values are the input to four digital-to-analog converters. (Refer to the block diagram in Appendix B.) The output of these converters are the video drive voltages that are applied to pins 9 through 12 of the J3 Video Output Jack.

The output of the digital-to-analog converters for the red, green, and blue intensities is not dependent on the model of the system motherboard. The digital-to-analog converter for the monochrome intensities, however, produces different output depending on whether the motherboard is a model A or a model B. On systems with a model A motherboard, only the two low-order bits of the intensity value are active. This provides a limited range of only four output voltages for the monochrome signal. On a color monitor only configuration, where the green output is derived from the monochrome portion of the Color Map, the same limited range applies. On systems with a model B motherboard, all four bits of the intensity value are active. This provides the full range of 16 output voltages for the red, green, blue, and monochrome signals. The conversion of Color Map intensity values to video drive voltages for each of these ranges are shown in Table 2.

The perceived intensity of a display is not linearly related to the video drive voltages. A given difference in drive voltage at the high end of the range is not as noticeable as the same difference occurring at the low end of the range.

Table 2. Intensity Values vs Video Drive Voltages

INTENSITY VALUES		VIDEO DRIVE VOLTAGES (NORMALIZED)	
HEX	BINARY	LIMITED RANGE	FULL RANGE
0	0000	1.09	1.00
1	0001	0.79	0.85
2	0010	0.71	0.79
3	0011	0.09	0.73
4	0100	1.09	0.67
5	0101	0.79	0.61
6	0110	0.71	0.55
7	0111	0.09	0.49
8	1000	1.09	0.43
9	1001	0.79	0.38
A	1010	0.71	0.31
B	1011	0.09	0.26
C	1100	1.09	0.21
D	1101	0.79	0.12
E	1110	0.71	0.07
F	1111	0.09	0.00

LIMITED RANGE: MODEL A — ALL MONOCHROME OUTPUT
— GREEN OUTPUT ON COLOR MONITOR ONLY SYSTEM

FULL RANGE: MODEL A — RED/BLUE OUTPUT ON COLOR MONITOR ONLY SYSTEM
— RED/GREEN/BLUE OUTPUT ON DUAL MONITOR SYSTEM
MODEL B — RED/BLUE/GREEN/MONOCHROME OUTPUT ON ALL SYSTEMS

LJ-0259

Mode Register

The Mode Register is an 8-bit multi-purpose register that is loaded by first selecting it with a write of BFh to port 53h and then writing a data byte to port 51h. The bits in the Mode Register have the following functions:

- Bit 0 determines the resolution mode:

  0 = medium resolution mode (384 pixels across)
  1 = high resolution mode (800 pixels across)

- Bit 1 determines the write mode:

  0 = word mode, 16 bits/RMW cycle, data from Write Buffer
  1 = vector mode, 1 bit/RMW cycle, data from Pattern Generator

- Bits 3 and 2 select a bitmap plane for readback mode operation:

  00 = plane 0
  01 = plane 1
  10 = plane 2
  11 = plane 3

- Bit 4 determines the option's mode of operation:

  0 = read mode, bits 3 and 2 determine readback plane
  1 = write mode, writes to the bitmap allowed but not mandatory

- Bit 5 controls writing to the Scroll Map:

  0 = writing is enabled (after selection by the Indirect Register)
  1 = writing is disabled

- Bit 6 controls the interrupts to the CPU generated by the Graphics Option every time the GDC issues a vertical sync pulse:

  0 = interrupts are disabled, any pending interrupts are cleared
  1 = interrupts are enabled

- Bit 7 controls the video data output from the option:

  0 = output is disabled, other option operations still take place
  1 = output is enabled

NOTE
Do not change the contents of the Mode Register before the GDC has completed all pending write operations. If you do, the functions controlled by the Mode Register will take on the new characteristics and the results may be indeterminate.

Scroll Map

The Scroll Map is a 256 × 8-bit recirculating ring buffer that is used to offset scan line addresses in the bitmap in order to provide full and split-screen vertical scrolling. The entire address as generated by the GDC does not go directly to the bitmap. Only the low-order six bits of the GDC address go directly to the bitmap. They represent one of the 64 word addresses that are the equivalent of one scan line in high resolution mode or two scan lines in medium resolution mode. The eight high-order bits of the GDC address represent a line address and are used as an index into the 256-byte Scroll Map. The eight bits at the selected location then become the new eight high-order bits of the address that the bitmap sees. (See Figure 14.) By manipulating the contents of the Scroll Map, you can perform quick dynamic relocations of the bitmap data in 64-word blocks.

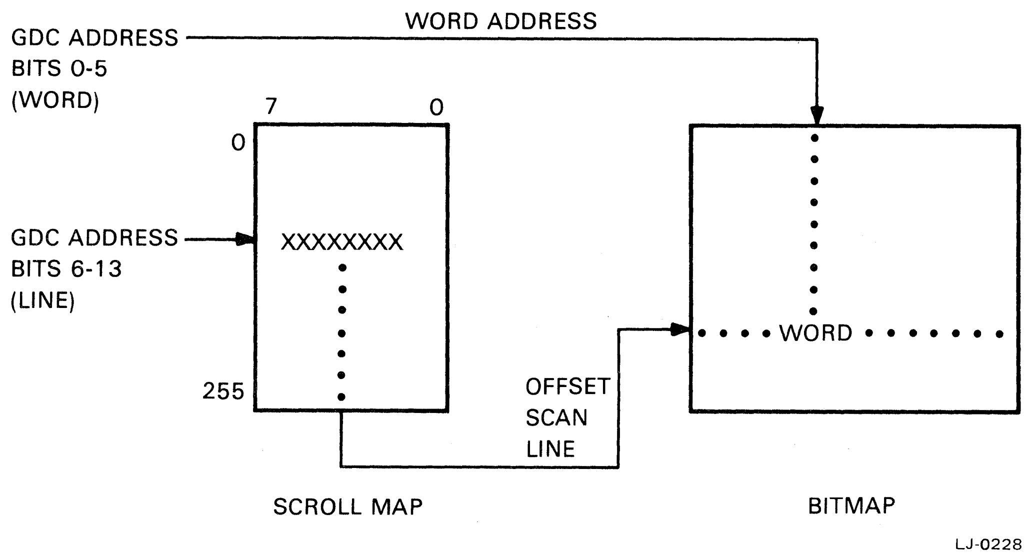


Figure 14. Scroll Map Operation

Loading the Scroll Map

Start loading the offset addresses into the Scroll Map at the beginning of a vertical retrace. First set bit 5 of the Mode Register to zero to enable the Scroll Map for writing. Write a 7Fh to port 53h to select the Scroll Map and clear the Scroll Map Index Counter to zero. Then do a series of writes to port 51h with the offset values to be stored in the Scroll Map. Loading always begins at location zero of the Scroll Map. With each write, the Scroll Map Index Counter is automatically incremented until the write operations terminate. If there are more than 256 writes, the index counter loops back to Scroll Map location zero. This also means that if line 255 requires a change, lines 0-254 will have to be rewritten first.

All 256 scroll map entries should be defined even if all 256 addresses are not displayed. This is to avoid mapping undesirable data onto the screen. After the last write operation, bit 5 of the Mode Register should be set to one to disable further writing to the Scroll Map.

The time spent to load the Scroll Map should be kept as short as possible. During loading, the GDC's address lines no longer have a path to the bitmap and therefore memory refresh is not taking place. Delaying memory refresh can result in lost data.

While it is possible to read out of the Scroll Map, time constraints preclude doing both a read and a rewrite during the same vertical retrace period. If necessary, a shadow image of the Scroll Map can be kept in some area in memory. The shadow image can be updated at any time and then transferred into the Scroll Map during a vertical retrace.

Part II

Programming Guidelines

Contents

PART II

5

Initialization and Control

The examples in this chapter cover the initialization of the Graphics Display Controller (GDC) and the Graphics Option, the control of the graphics output, and the management of the option's color palette.

Test for Option Present

Before starting any application, you should ensure that the Graphics Option has been installed on the Rainbow system. Attempting to use the Graphics Option when it is not installed can result in a system reset that can in turn result in the loss of application data. The following code will test for the option's presence.

Example of Option Test

```
;*********************************************************************
;                                                                    *
;       p r o c e d u r e   o p t i o n _ p r e s e n t _ t e s t    *
;                                                                    *
;       purpose:        test if Graphics Option is present.          *
;       entry:          none.                                        *
;       exit:           dl = 1          option present.              *
;                       dl = 0          option not present.          *
;       register usage: ax,dx                                        *
;*********************************************************************
```

```
cseg    segment byte    public  'codesg'
        public  option_present_test
        assume  cs:cseg,ds:nothing,es:nothing,ss:nothing
option_present_test     proc    near
        mov     dl,1            ;set dl for option present
        in      al,8            ;input from port 8
        test    al,04h          ;test bit 2 to see if option present
        jz      opt1            ;if option is present, exit
        xor     dl,dl           ;else, set dl for option not present
opt1:   ret
option_present_test     endp
cseg    ends
        end
```

Test for Motherboard Version

When you initially load or subsequently modify the Color Map, it is necessary to know what version of the motherboard is installed in the Rainbow system. The code to determine this is operating system dependent. The examples in the following sections are written for CP/M, MS-DOS, and Concurrent CP/M.

Example of Version Test for CP/M System

```
;*********************************************************************
;                                                                    *
;       p r o c e d u r e   t e s t _ b o a r d _ v e r s i o n      *
;                                                                    *
;       purpose:        Test motherboard version                     *
;       restriction:    This routine will work under cp/m only.      *
;       entry:          none.                                        *
;       exit:           flag :=         0 = 'A' motherboard          *
;                                       1 = 'B' motherboard          *
;       register usage: ax,bx,cx,dx,di,si,es                         *
;*********************************************************************
```

```
;
        dseg
flag    db      000h
buffer  rs      14                  ;reserve 14 bytes
        cseg
test_board_version:
        push    bp
        mov     ax,ds               ;clear buffer, just to be sure
        mov     es,ax               ;point es:di at it
        mov     di,0
        mov     cx,14               ;14 bytes to clear
        xor     al,al               ;clear clearing byte
opt1:   mov     buffer[di],al       ;do the clear
        inc     di
        loop    opt1                ;loop till done
        mov     ax,ds               ;point bp:dx at buffer for
        mov     bp,ax               ; int 40 call
        mov     dx,offset buffer
        mov     di,1ah              ;set opcode for call to get hw #
        int     40
        mov     si,0
        mov     cx,8                ;set count for possible return ASCII
opt2:   cmp     buffer[si],0
        jne     opt3                ;got something back, have rainbow 'B'
        inc     si
        loop    opt2                ;loop till done
        mov     flag,0              ;no ASCII, set rainbow 'A' type
        jmp     opt4
opt3:   mov     flag,1              ;got ASCII, set rainbow 'B' type
opt4:   pop     bp
        ret
```

Example of Version Test for MS-DOS System

```
;*********************************************************************
;                                                                    *
;       p r o c e d u r e   t e s t _ b o a r d _ v e r s i o n      *
;                                                                    *
;       purpose:        test motherboard version                     *
;       restriction:    this routine will work under MS-DOS only     *
;       entry:          none                                         *
;       exit:           flag :=         0 = 'A' motherboard          *
;                                       1 = 'B' motherboard          *
;       register usage: ax,bx,cx,dx,di,si                            *
;*********************************************************************
```

```
;
cseg    segment byte    public  'codesg'
        public  test_board_version
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
;
test_board_version      proc    near
        push    bp                      ;save bp
        mov     di,0                    ;clear buffer to be sure
        mov     cx,14                   ;14 bytes to clear
        xor     al,al                   ;clear clearing byte
tb1:    mov     byte ptr buffer[di],al  ;do the clear
        inc     di
        loop    tb1                     ;loop till done
        mov     ax,ds                   ;point bp:dx at buffer for
        mov     bp,ax                   ; int 18h call
        mov     dx,offset buffer
        mov     di,1ah          ;set opcode for call to get hw #
        int     18h             ;int 40 remapped to 18h under MS-DOS
        mov     si,0
        mov     cx,8            ;set count for possible return ASCII
tb2:    cmp     byte ptr buffer[si],0
        jne     tb3             ;got something back, have rainbow 'B'
        inc     si
        loop    tb2
        mov     flag,0          ;no ASCII, set rainbow 'A' type
        jmp     tb4
tb3:    mov     flag,1          ;got ASCII, set rainbow B type
tb4:    pop     bp              ;recover bp
        ret
test_board_version      endp
cseg    ends
dseg    segment byte    public  'datasg'
        public  flag
flag    db      0
buffer  db      14      dup (?)
dseg    ends
        end
```

Example of Version Test for Concurrent CP/M System

```
;*****************************************************************
;                                                               *
;       p r o c e d u r e    t e s t _ b o a r d _ v e r s i o n  *
;                                                               *
;       purpose:        test motherboard version                *
;       restriction:    this routine for Concurrent CP/M only   *
;       entry:          none                                    *
;       exit:           flag :=         0 = 'A' motherboard     *
;                                       1 = 'B' motherboard     *
;       register usage: ax,bx,cx,dx,si                          *
;*****************************************************************
;
test_board_version:
        mov     control_b+2,ds
        mov     di,offset biosd
        mov     bx,3
        mov     [di+bx],ds
        mov     dx,offset biosd         ;setup for function 50 call
        mov     cl,32h
        int     0e0h                    ;function 50
        mov     flag,0                  ;set flag for rainbow 'A'
        mov     bx,6                    ;offset to array_14
        mov     si,offset array_14
        mov     al,'0'
        cmp     [si+bx],al              ;'0', could be a rainbow 'A'
        jne     found_b                 ;no, must be rainbow 'B'
        inc     bx                      ;next number...
        mov     al,'1'                  ;can be either 1...
        cmp     [si+bx],al
        je      test_board_exit
        mov     al,'2'                  ;or 2 ...
        cmp     [si+bx],al
        je      test_board_exit
        mov     al,'3'                  ;or 3 if its a rainbow 'A'
        cmp     [si+bx],al
        je      test_board_exit
```

```
found_b:
        mov     flag,1                    ;its a rainbow 'B'
test_board_exit:
        ret
        dseg
biosd           db      80h
                dw      offset control_b
                dw      0
control_b       dw      4
                dw      0
                dw      offset array_14
array_14        rs      14
flag            db      0
        end
```

Initialize the Graphics Option

Initializing the Graphics Option can be separated into the following three major steps:

- Reset the GDC to the desired display environment.
- Initialize the rest of the GDC's operating parameters.
- Initialize the Graphic Option's registers, buffers, and maps.

Reset the GDC

To reset the GDC, give the RESET command with the appropriate parameters followed by commands and parameters to set the initial environment. The RESET command is given by writing a zero byte to port 57h. The reset command parameters are written to port 56h.

The GDC Reset Command parameters are the following:

Parameter	Value	Meaning
1	12h	The GDC is in graphics mode Video display is noninterlaced No refresh cycles by the GDC Drawing permitted only during retrace
2	16h 30h	For medium resolution For high resolution The number of active words per line, less two. There are 24 (18h) active words per line in medium resolution mode and 50 (32h) words per line in high resolution mode.

Parameter	Value	Meaning
3	61h 64h	For medium resolution For high resolution The low-order five bits are the horizontal sync width in words less one (medium res. HS=2, high res. HS=5). The high-order three bits are the low-order three bits of the vertical sync width in lines (VS=3).
4	04h 08h	For medium resolution For high resolution The low-order two bits are the high-order two bits of the vertical sync width in lines. The high-order six bits are the horizontal front porch width in words less one (medium res. HFP=2, high res. HFP=3).
5	02h 03h	For medium resolution For high resolution Horizontal back porch width in words less one (medium res. HBP=3, high res. HBP=4).
6	03h	Vertical front porch width in lines (VFP=3).
7	F0h	Number of active lines per video field (single field, 240 line display).
8	40h	The low-order two bits are the high-order two bits of the number of active lines per video field. The high-order six bits are the vertical back porch width in lines (VBP=16).

Initialize the GDC

Now that the GDC has been reset and the video display has been defined, you can issue the rest of the initialization commands and associated parameters by writing to ports 57h and 56h respectively.

Start the GDC by issuing the START command (6Bh).

ZOOM must be defined; however, since there is no hardware support for the Zoom feature, program a zoom magnification factor of one by issuing the ZOOM command (46h) with a parameter byte of 00.

Issue the WDAT command (22h) to define the type of Read/Modify/Write operations as word transfers - low byte, then high byte. No parameters are needed at this time because the GDC is not being asked to do a write operation; it is only being told how to relate to the memory.

Issue the PITCH command (47h) with a parameter byte of 20h for medium resolution or 40h for high resolution to tell the GDC that each scan line begins 32 words after the previous one for medium resolution and 64 words after the previous one for high resolution. Note, however, that only 24 or 50 words are displayed on each screen line. The undisplayed words left unscanned are unusable.

The GDC can simultaneously display up to four windows. The PRAM command defines the window display starting address in words and its length in lines. The Graphics Option uses only one display window with a starting address of 0000 and a length of 256 lines. To set this up, issue the PRAM command (70h) with four parameter bytes of 00,00,F0,0F.

Another function of the GDC's parameter RAM is to hold soft character fonts and line patterns to be drawn into the bitmap. The Graphics Option, rather than using the PRAM for this purpose, uses the external Character RAM and Pattern Generator. For the external hardware to work properly, the PRAM command bytes 9 and 10 must be loaded with all ones. Issue the PRAM command (78h) with two parameter bytes of FF,FF.

Issue the CCHAR command (4Bh) with three parameter bytes of 00,00,00, to define the cursor characteristics as being a non-displayed point, one line high.

Issue the VSYNC command (6Fh) to make the GDC operate in master sync mode.

Issue the SYNC command (0Fh) to start the video refresh action.

The GDC is now initialized.

Initialize the Graphics Option

First you must synchronize the Graphics Option with the GDC's write cycles. Reset the Mode Register by writing anything to port 50h and then load the Mode Register.

Next, load the Scroll Map. Wait for the start of a vertical retrace, enable Scroll Map addressing, select the Scroll Map, and load it with data.

Initialize the Color Map with default data kept in a shadow area. The Color Map is a write-only area and using a shadow area makes the changing of the color palette more convenient.

Set the Pattern Generator to all ones in the Pattern Register and all ones in the Pattern Multiplier.

Set the Foreground/Background Register to all ones in the foreground and all zeros in the background.

Set the ALU/PS Register to enable all four planes and put the option in REPLACE mode.

Finally, clear the screen by setting the entire bitmap to zeros.

Example of Initializing the Graphics Option

The following example is a routine that will initialize the Graphics Option including the GDC. This initialization procedure leaves the bitmap cleared to zeros and enabled for writing but with graphics output turned off. Use the procedure in the next section to turn the graphics output on. Updating of the bitmap is independent of whether the graphics output is on or off.

```
;*********************************************************************
;                                                                    *
;       p r o c e d u r e    i n i t _ o p t i o n                   *
;                                                                    *
;       purpose:        initialize the graphics option               *
;                                                                    *
;       entry:          dx = 1     medium resolution                 *
;                       dx = 2     high resolution                   *
;       exit:           all shadow bytes initialized                 *
;       register usage: none, all registers are saved                *
;*********************************************************************
cseg    segment byte    public  'codesg'
extrn   alups:near,pattern_register:near,pattern_mult:near,fgbg:near
        public  init_option
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
init_option     proc    near
        push    ax              ;save the registers
        push    bx
        push    cx
        push    dx
        push    di
        push    si
        cld                     ;make sure that stos incs.
;
;First we have to find out what the interrupt vector is for the
;graphics option.  If this is a Model 100-A, interrupt vector
;22h is the graphics interrupt.  If this is a Model 100-B, the
;interrupt vector is relocated up to A2.  If EE00:0F44h and
;04<>0, we have the relocated vectors of a Model 100-B and need
;to OR the msb of our vector.
;
        mov     ax,ds
        mov     word ptr cs:segment_save,ax
        push    es              ;save valid es
        mov     bx,0ee00h       ;test if vectors are relocated
        mov     es,bx
        mov     ax,88h                  ;100-A int. vector base addr
        test    es:byte ptr 0f44h,4     ;relocated vectors?
        jz      g0                      ;jump if yes
        mov     ax,288h                 ;100-B int. vector base addr
```

```
g0:     mov     word ptr g_int_vec,ax
        pop     es
        cmp     dx,1                ;medium resolution?
        jz      mid_res             ;jump if yes
        jmp     hi_res              ;else is high resolution
mid_res:
        mov     al,00               ;medium resolution reset command
        out     57h,al
        mov     gbmod,030h          ;mode = med res, text, no readback
        call    mode                ;turn off graphics output
        mov     al,12h              ;p1. refresh, draw enabled during
        out     056h,al             ;retrace
        mov     al,16h              ;p2. 24 words/line minus 2
        out     056h,al             ;384/16 pixels/word=24 words/line
        mov     al,61h              ;p3. 3 bits vs/5 bits hs width - 1
        out     056h,al             ;vs=3, hs=2
        mov     al,04               ;p4. 6 bits hfp-1, 2 bits vs high
        out     056h,al             ;byte, 2 words hfp, no vs high byte
        mov     al,02               ;p5. hbp-1, 3 words hbp
        out     056h,al
        mov     al,03               ;p6. vertical front porch, 3 lines
        out     056h,al
        mov     al,0f0h             ;p7. active lines displayed
        out     056h,al
        mov     al,40h              ;p8. 6 bits vbp/2 bits lines/field
        out     056h,al             ;high byte, vbp=16 lines
        mov     al,047h             ;pitch command, med res, straight up
        out     057h,al
        mov     al,32               ;med res memory width for vert. pitch
        out     056h,al
        mov     word ptr nmritl,3fffh
        mov     word ptr xmax,383        ;384 pixels across in med res
        mov     byte ptr num_planes,4    ;4 planes in med res
        mov     byte ptr shifts_per_line,5 ;rotates for 32 wds/line
        mov     byte ptr words_per_line,32 ;words in a line
        jmp     common_init
```

```
hi_res: mov     al,00               ;high resolution reset command
        out     57h,al
        mov     gbmod,031h          ;mode = high res, text, no readback
        call    mode                ;disable graphics output
        mov     al,12h              ;p1. refresh, draw enabled during
        out     056h,al             ;retrace
        mov     al,30h              ;p2. 50 words/line - 2
        out     056h,al
        mov     al,64h              ;p3. hsync w-1=4(low 5 bits), vsync
        out     056h,al             ;w=3(upper three bits)
        mov     al,08               ;p4. hor fp w-1=2(upper 2 bits),
        out     056h,al             ;vsync high byte = 0
        mov     al,03               ;p5. hbp-1. 3 words hbp
        out     056h,al
        mov     al,03               ;p6. vertical front porch, 3 lines
        out     056h,al
        mov     al,0f0h             ;p7. active lines displayed
        out     056h,al
        mov     al,40h              ;p8. 6 bits vbp/2 bits lines per field
        out     056h,al             ;high byte. vbp=16 lines
        mov     al,047h             ;pitch command, high res, straight up
        out     057h,al
        mov     al,64               ;high res pitch is 64 words/line
        out     056h,al
        mov     word ptr nmritl,7fffh
        mov     word ptr xmax,799        ;800 pixels across
        mov     byte ptr num_planes,2    ;2 planes in high res
        mov     byte ptr shifts_per_line,6 ;shifts for 64 wds/line
        mov     byte ptr words_per_line,64 ;number of words/line
common_init:
        mov     al,00               ;setup start window display for memory
        mov     startl,al           ;location 00
        mov     starth,al
        mov     al,06bh             ;start command
        out     057h,al             ;start the video signals going
        mov     al,046h             ;zoom command
        out     057h,al
        mov     al,0                ;magnification assumed to be 0
        out     056h,al
        mov     al,22h              ;setup R/M/W memory cycles for
        out     57h,al              ;figure drawing
```

```
;
;Initialize PRAM command. Start window at the address in startl,
;starth.  Set the window length for 256 lines. Fill PRAM parameters
;8 and 9 with all ones so GDC can do graphics draw commands without
;altering the data we want drawn.
;
        mov     al,070h            ;issue the pram command, setup
        out     057h,al            ;GDC display
        mov     al,startl          ;p1. display window starting address
        out     056h,al            ;low byte
        mov     al,starth          ;p2. display window starting address
        out     056h,al            ;high byte
        mov     al,0ffh            ;p3. make window 256 lines
        out     056h,al
        mov     al,0fh             ;p4. high nibble display line on
        out     056h,al            ;right, the rest = 0
        mov     al,078h            ;issue pram command pointing to p8
        out     057h,al
        mov     al,0ffh            ;fill pram with ones pattern
        out     056h,al
        out     056h,al
        mov     al,04bh            ;issue the cchar command
        out     057h,al
        xor     al,al              ;initialize cchar parameter bytes
        mov     cchp1,al           ;graphics cursor is one line, not
        out     056h,al            ;displayed, non-blinking
        mov     cchp2,al
        out     056h,al
        mov     cchp3,al
        out     056h,al
        mov     al,06fh            ;vsync command
        out     057h,al
        out     050h,al            ;reset the graphics board
        mov     al,0bfh
        out     53h,al
        mov     al,byte ptr gbmod  ;enable, then disable interrupts
        or      al,40h                ;to flush the interrupt hardware
        out     51h,al                ;latches
        mov     cx,4920               ;wait for a vert sync to happen
```

```
g1:     loop    g1
        mov     al,0bfh                 ;disable the interrupts
        out     53h,al
        mov     al,byte ptr gbmod
        out     51h,al
        call    assert_colormap         ;load colormap
        call    inscrl                  ;initialize scroll map
        mov     bl,1                    ;set pattern multiplier to 16-bl
        call    pattern_mult            ;see example "pattern_mult"
        mov     bl,0ffh                 ;set pattern data of all bits set
        call    pattern_register        ;see example "pattern_register"
        mov     bl,0f0h                 ;enable all foreground registers
        call    fgbg                    ;see example "fgbg"
        mov     bl,0                    ;enable planes 0-3, REPLACE logic
        call    alups                   ;see example "alups"
        mov     di,offset p1            ;fill the p table with ff's.
        mov     al,0ffh
        mov     cx,16
        rep     stosb
        mov     al,0                    ;enable all gb mask writes.
        mov     gbmskl,al
        mov     gbmskh,al
        mov     al,0ffh                 ;set GDC mask bits
        mov     gdcml,al
        mov     gdcmh,al
        mov     word ptr curl0,0        ;set cursor to top screen left
        mov     ax,word ptr gbmskl      ;fetch and issue the graphics
        out     54h,al                  ;option text mask
        mov     al,ah
        out     55h,al
        call    setram                  ;then set ram to p1 thru p16 data
        mov     word ptr ymax,239
        mov     al,0dh
        out     57h,al                  ;enable the display
        pop     si                      ;recover the registers
        pop     di
        pop     dx
        pop     cx
        pop     bx
        pop     ax
        ret
init_option     endp
```

```
;

;*****************************************************************
;*                                                               *
;*      g r a p h i c s   s u b r o u t i n e s                  *
;*                                                               *
;*****************************************************************
;
gsubs   proc near
public  setram,assert_colormap,gdc_not_busy,imode,color_int,scrol_int
public  cxy2cp,mode
;
;*****************************************************************
;                                                                *
;       s u b r o u t i n e   a s s e r t _ c o l o r m a p      *
;                                                                *
;       colormap is located at clmpda which is defined in        *
;       procedure "change_colormap"                              *
;                                                                *
;       entry:          clmpda = colormap to be loaded           *
;       exit:           none                                     *
;       register usage: ax,bx                                    *
;*****************************************************************
;
assert_colormap:
        cld
        call    gdc_not_busy    ;make sure nothing's happening
;
;The graphics interrupt vector "giv" is going to be either 22h or
;A2h depending on whether this is a Model 100-A or a Model 100-B
;with relocated vectors. Read the old vector, save it, then
;overwrite it with the new vector.
;
        push    es
        xor     ax,ax
        mov     es,ax
        mov     bx,word ptr g_int_vec   ;fetch address of "giv"
        cli                             ;temp. disable interrupts
        mov     ax,es:[bx]              ;read the old offset
        mov     word ptr old_int_off,ax
        mov     ax,es:[bx+2]            ;read the old segment
        mov     word ptr old_int_seg,ax
        mov     word ptr es:[bx],offset color_int ;load new offset
        mov     ax,cs
        mov     es:[bx+2],ax            ;load new int segment
        sti                             ;re-enable interrupts
        pop     es
        mov     byte ptr int_done,0     ;clear interrupt flag
        or      byte ptr gbmod,40h      ;enable graphics interrupt
        call    mode
```

```
ac1:    test    byte ptr int_done,0ffh  ;has interrupt routine run?
        jz      ac1
        push    es                      ;restore interrupt vectors
        xor     ax,ax
        mov     es,ax
        mov     bx,word ptr g_int_vec   ;fetch graphics vector offset
        cli
        mov     ax,word ptr old_int_off ;restore old interrupt vector
        mov     es:[bx],ax
        mov     ax,word ptr old_int_seg
        mov     es:[bx+2],ax
        sti
        pop     es
        cld                             ;make lods inc si
        ret
color_int:
        push    es
        push    ds
        push    si
        push    cx
        push    ax
        mov     ax,word ptr cs:segment_save ;can't depend on es or ds
        mov     ds,ax                       ;reload segment registers
        mov     es,ax
        cld
        and     byte ptr gbmod,0bfh     ;disable graphics interrupts
        call    mode
        mov     si,offset clmpda        ;fetch color source
        mov     al,0dfh                 ;get the color map's attention
        out     053h,al
        mov     cx,32           ;32 color map entries
ci1:    lodsb                   ;fetch current color map data
        out     051h,al         ;load color map
        loop    ci1             ;loop until all color map data loaded
        mov     byte ptr int_done,0ffh  ;set "interrupt done" flag
        pop     ax
        pop     cx
        pop     si
        pop     ds
        pop     es
        iret
```

```
;
;*******************************************************************
;                                                                 *
;       s u b r o u t i n e    c x y 2 c p                        *
;                                                                 *
;       CXY2CP takes the xinit and yinit numbers, converts them to *
;       an absolute memory location and puts that location into   *
;       curl0,1,2.  yinit is multiplied by the number of words per *
;       line.  The lower 4 bits of xinit are shifted to the left   *
;       four places and put into curl2. xinit is shifted right four *
;       places to get rid of pixel information and then added to   *
;       yinit times words per line.  This result becomes curl0,    *
;       curl1.                                                    *
;                                                                 *
;       entry:          xinit = x pixel location                  *
;                       yinit = y pixel location                  *
;       exit:           curl0,1,2                                 *
;       register usage: ax,bx,cx,dx                               *
;*******************************************************************
;
cxy2cp: mov     cl,byte ptr shifts_per_line
        mov     ax,yinit        ;compute yinit times words/line
        shl     ax,cl           ;ax has yinit times words/line
        mov     bx,xinit        ;calculate the pixel address
        mov     dx,bx           ;save a copy of xinit
        mov     cl,4            ;shift xinit 4 places to the left
        shl     bl,cl           ;bl has pixel within word address
        mov     curl2,bl        ;pixel within word address
        mov     cl,4            ;shift xinit 4 places to right
        shr     dx,cl           ;to get xinit words
        add     ax,dx
        mov     word ptr curl0,ax   ;word address
        ret
;*******************************************************************
;                                                                 *
;       s u b r o u t i n e    g d c _ n o t _ b u s y            *
;                                                                 *
;       gdc_not_busy will put a harmless command into the GDC and  *
;       wait for the command to be read out of the command FIFO.   *
;       This means that the GDC is not busy doing a write or read  *
;       operation.                                                *
;                                                                 *
;       entry:          none                                      *
;       exit:           none                                      *
;       register usage: ax                                        *
;*******************************************************************
```

```
;
gdc_not_busy:
        push    cx              ;use cx as a time-out loop counter
        in      al,056h         ;first check if the FIFO is full
        test    al,2
        jz      gnb2            ;jump if not
        mov     cx,8000h        ;wait for FIFO not full or reasonable
gnb0:   in      al,056h         ;time, whichever happens first
        test    al,2            ;has a slot opened up yet?
        jz      gnb2            ;jump if yes
        loop    gnb0            ;if loop count exceeded, go on anyway
gnb2:   mov     al,0dh          ;issue a screen-on command to GDC
        out     057h,al
        in      al,056h         ;did that last command fill it?
        test    al,2
        jz      gnb4            ;jump if not
        mov     cx,8000h
gnb3:   in      al,056h         ;read status register
        test    al,2            ;test FIFO full bit
        jnz     gnb4            ;jump if FIFO not full
        loop    gnb3            ;loop until FIFO not full or give up
gnb4:   mov     ax,40dh         ;issue another screen-on,
        out     057h,al         ;wait for FIFO empty
        mov     cx,8000h
gnb5:   in      al,056h         ;read the GDC status
        test    ah,al           ;FIFO empty bit set?
        jnz     gnb6            ;jump if not.
        loop    gnb5
gnb6:   pop     cx
        ret
;*********************************************************************
;                                                                   *
;       s u b r o u t i n e    i m o d e                            *
;                                                                   *
;       issue Mode command with the parameters from register gbmod  *
;                                                                   *
;       entry:          gbmod                                       *
;       exit:           none                                        *
;       register usage: ax                                          *
;*********************************************************************
;
imode:  call    gdc_not_busy
        mov     al,0bfh         ;address the mode register through
        out     53h,al          ;the indirect register
        mov     al,gbmod
        out     51h,al          ;load the mode register
        ret
```

```
mode:   mov     al,0bfh         ;address the mode register through
        out     53h,al          ;the indirect register
        mov     al,gbmod
        out     51h,al          ;load the mode register
        ret
;******************************************************************
;                                                                 *
;       s u b r o u t i n e   i n s c r l                         *
;                                                                 *
;       initialize the scroll map                                 *
;                                                                 *
;       entry:          none                                      *
;       exit:           none                                      *
;       register usage: ax,bx,cx,dx,di,si                         *
;******************************************************************
;
inscrl: cld
        mov     cx,256          ;initialize all 256 locations of the
        xor     al,al           ;shadow area to desired values
        mov     di,offset scrltb
insc0:  stosb
        inc     al
        loop    insc0
;
;The graphics interrupt vector is going to be either 22h or A2h
;depending on whether this is a Model 100-A or a Model 100-B with
;relocated vectors.  Read the old vector, save it, and overwrite it
;with the new vector.  Before we call the interrupt, we need to
;make sure that the GDC is not writing something out to the bitmap.
;
ascrol: call    gdc_not_busy            ;check if GDC id busy
        push    es
        xor     ax,ax
        mov     es,ax
        mov     bx,word ptr g_int_vec
        cli                             ;temporarily disable interrupts
        mov     ax,es:[bx]              ;read the old offset
        mov     word ptr old_int_off,ax
        mov     ax,es:[bx+2]            ;read the old segment
        mov     word ptr old_int_seg,ax
        mov     word ptr es:[bx],offset scrol_int ;load new offset
        mov     ax,cs
        mov     es:[bx+2],ax            ;load new interrupt segment
        sti                             ;re-enable interrupts
        pop     es
        mov     byte ptr int_done,0     ;clear interrupt flag
        or      byte ptr gbmod,40h      ;enable graphics interrupt
        call    mode
```

```
as1:    test    byte ptr int_done,0ffh ;has interrupt routine run?
        jz      as1
        push    es                      ;restore the interrupt vectors
        xor     ax,ax
        mov     es,ax
        mov     bx,word ptr g_int_vec ;fetch graphics vector offset
        cli
        mov     ax,word ptr old_int_off ;restore old interrupt vector
        mov     es:[bx],ax
        mov     ax,word ptr old_int_seg
        mov     es:[bx+2],ax
        sti
        pop     es
        ret
;
;Scrollmap loading during interrupt routine.
;Fetch the current mode byte and enable scroll map addressing.
;
scrol_int:
        push    es
        push    ds
        push    si
        push    dx
        push    cx
        push    ax
        cld
        mov     ax,word ptr cs:segment_save ;can't depend on ds
        mov     ds,ax                       ;reload it
        mov     es,ax
        and     byte ptr gbmod,0bfh   ;disable graphics interrupts
        mov     al,gbmod          ;prepare to access scroll map
        mov     gtemp1,al         ;first save current gbmod
        and     gbmod,0dfh        ;enable writing to scroll map
        call    mode              ;do it
        mov     al,07fh           ;select scroll map and reset scroll
        out     53h,al            ;map address counter
        mov     dl,51h            ;output port destination
        xor     dh,dh
        mov     si,offset scrltb  ;first line's high byte address=0
        mov     cx,16             ;256 lines to write to
        test    byte ptr gbmod,1  ;high resolution?
        jnz     ins1              ;jump if yes
        shr     cx,1             ;only 128 lines if medium resolution
```

```
ins1:   lodsw                       ;fetch two scrollmap locations
        out     dx,al               ;assert the even byte
        mov     al,ah
        out     dx,al               ;assert the odd byte
        lodsw                       ;fetch two scrollmap locations
        out     dx,al               ;assert the even byte
        mov     al,ah
        out     dx,al               ;assert the odd byte
        lodsw                       ;fetch two scrollmap locations
        out     dx,al               ;assert the even byte
        mov     al,ah
        out     dx,al               ;assert the odd byte
        lodsw                       ;fetch two scrollmap locations
        out     dx,al               ;assert the even byte
        mov     al,ah
        out     dx,al               ;assert the odd byte
        lodsw                       ;fetch two scrollmap locations
        out     dx,al               ;assert the even byte
        mov     al,ah
        out     dx,al               ;assert the odd byte
        lodsw                       ;fetch two scrollmap locations
        out     dx,al               ;assert the even byte
        mov     al,ah
        out     dx,al               ;assert the odd byte
        lodsw                       ;fetch two scrollmap locations
        out     dx,al               ;assert the even byte
        mov     al,ah
        out     dx,al               ;assert the odd byte
        lodsw                       ;fetch two scrollmap locations
        out     dx,al               ;assert the even byte
        mov     al,ah
        out     dx,al               ;assert the odd byte
        loop    ins1
        mov     al,gtemp1           ;restore previous mode register
        mov     gbmod,al
        call    mode
        mov     byte ptr int_done,0ffh  ;set interrupt-done flag
        pop     ax
        pop     cx
        pop     dx
        pop     si
        pop     ds
        pop     es
        iret                        ;return from interrupt
```

```
;*******************************************************************
;                                                                  *
;       s u b r o u t i n e    s e t r a m                         *
;                                                                  *
;       set video ram to a value stored in the p table             *
;                                                                  *
;       entry:          16 byte p1 table                           *
;       exit:           none                                       *
;       register usage: ax,bx,cx,dx,di,si                          *
;*******************************************************************
;
setram: mov     byte ptr twdir,2  ;set write direction to the right
        call    gdc_not_busy      ;make sure that the GDC isn't busy
        mov     al,0feh           ;select the write buffer
        out     053h,al
        out     051h,al         ;reset the write buffer counter
        mov     si,offset p1    ;initialize si to start of data
        mov     cx,10h          ;load 16 chars into write buffer
setr1:  lodsb                   ;fetch byte to go to write buffer
        out     52h,al
        loop    setr1
        mov     al,0feh         ;select the write buffer
        out     053h,al
        out     051h,al         ;reset the write buffer counter
        mov     al,049h         ;issue GDC cursor location command
        out     57h,al
        mov     al,byte ptr curl0 ;fetch word location low byte
        out     56h,al            ;load parameter
        mov     al,byte ptr curl1 ;fetch word location high byte
        out     56h,al            ;load parameter
        mov     al,4ah            ;set the GDC mask to all F's
        out     57h,al
        mov     al,0ffh
        out     56h,al
        out     56h,al
        mov     al,04ch           ;issue figs command
        out     57h,al
        mov     al,byte ptr twdir ;direction to write.
        out     56h,al
        mov     al,nmritl         ;number of GDC writes, low byte
        out     56h,al
        mov     al,nmrith         ;number of GDC writes, high byte
        out     56h,al
        mov     al,22h            ;wdat command
        out     57h,al
        mov     al,0ffh       ;p1 and p2 are dummy parameters
        out     56h,al        ;the GDC requires them for internal
        out     56h,al        ;purposes - no effect on the outside
        ret
```

```
segment_save     dw      0          ;ds save area for interrupts
gsubs   endp
        cseg    ends
dseg    segment byte    public  'datasg'
extrn   clmpda:byte
public  xmax,ymax,alu,d,d1,d2,dc
public  curl0,curl1,curl2,dir,fg,gbmskl,gbmskh,gbmod,gdcml,gdcmh
public  nmredl,nmredh,nmritl,nmrith,p1,prdata,prmult,scrltb,startl
public  gtemp3,gtemp4,starth,gtemp,gtemp1,gtemp2,twdir,xinit,xfinal
public  yinit,yfinal,ascrol,num_planes,shifts_per_line
public  words_per_line,g_int_vec
;
;variables to be remembered about the graphics board states
;
alu     db      0          ;current ALU state
cchp1   db      0          ;cursor/character
cchp2   db      0          ;    size definition
cchp3   db      0          ;        parameter bytes
curl0   db      0          ;cursor          - low byte
curl1   db      0          ;  location      - middle byte
curl2   db      0          ;    storage     - high bits & dot address
dc      dw      0          ;figs command dc parameter
d       dw      0          ;figs command d parameter
d2      dw      0          ;figs command d2 parameter
d1      dw      0          ;figs command d1 parameter
dir     db      0          ;figs direction.
fg      db      0          ;current foreground register
gbmskl  db      0          ;graphics board mask register - low byte
gbmskh  db      0          ;                             - high byte
gbmod   db      0          ;graphics board mode register
gdcml   db      0          ;GDC mask register bits - low byte
gdcmh   db      0          ;                       - high byte
```

```
g_int_vec        dw      0   ;graphics option's interrupt vector
gtemp   dw      0            ;temporary storage
gtemp1  db      0            ;temporary storage
gtemp2  db      0            ;temporary storage
gtemp3  db      0            ;temporary storage
gtemp4  db      0            ;temporary storage
int_done         db      0   ;interrupt-done state
nmredl  db      0          ;number of read operations - low byte
nmredh  db      0          ;                          - high byte
nmritl  db      0          ;number of GDC writes - low byte
nmrith  db      0          ;                     - high byte
num_planes       db      0 ;number of planes in current resolution
old_int_seg      dw      0 ;old interrupt segment
old_int_off      dw      0 ;old interrupt offset
p1      db      16 dup (?) ;shadow write buffer & GDC parameters
prdata  db      0          ;pattern register data
prmult  db      0          ;pattern register multiplier factor
scrltb  db      100h dup (?) ;scroll map shadow area
si_temp dw      0
startl  db      0          ;register for start address of display
starth  db      0
twdir   db      0          ;direction for text mode write operation
shifts_per_line db       0 ;shift factor for one line of words
words_per_line  db       0 ;words/scan line for current resolution
xinit   dw      0          ;x initial position
yinit   dw      0          ;y initial position
xfinal  dw      0          ;x final position
yfinal  dw      0          ;y final position
xmax    dw      0
ymax    dw      0
dseg            ends
        end
```

Controlling Graphics Output

There will be occasions when you will want to control the graphics output to the monitors. The procedure varies according to the monitor configuration. The following two examples illustrate how graphics output can be turned on and off in a single monitor system. The same procedures can be used to turn graphics output on and off in a dual monitor system. However, in a dual monitor configuration, you may want to display graphics output only on the color monitor and continue to display VT102 VSS text output on the monochrome monitor. This can be accomplished by loading an 83h into 0Ah instead of an 87h.

Example of Enabling a Single Monitor

```
;*******************************************************************
;                                                                  *
;       p r o c e d u r e   g r a p h i c s _ o n                  *
;                                                                  *
;       purpose:         enable graphics output on single          *
;                        color monitor                             *
;                                                                  *
;       entry:           gbmod contains mode register shadow byte  *
;       exit:            none                                      *
;       register usage:  ax                                        *
;*******************************************************************
;
dseg    segment byte    public  'datasg'
extrn   gbmod:byte      ;defined in procedure 'init_option'
dseg    ends
cseg    segment byte    public  'codesg'
extrn   imode:near      ;defined in procedure 'init_option'
        public  graphics_on
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
;
graphics_on     proc    near
        mov     al,87h
        out     0ah,al          ;enable graphics on monochrome line
        or      byte ptr gbmod,080h  ;enable graphics output in gbmod
        call    imode           ;assert new mode register
        ret                     ;
graphics_on     endp
cseg    ends
        end
```

Example of Disabling a Single Monitor

```
;*******************************************************************
;                                                                  *
;       p r o c e d u r e   g r a p h i c s _ o f f                *
;                                                                  *
;       purpose:        disable graphics output to single          *
;                       (color) monitor                            *
;                                                                  *
;       entry:          gbmod contains mode register shadow byte   *
;       exit:           none                                       *
;       register usage: ax                                         *
;*******************************************************************
;
dseg    segment byte    public  'datasg'
extrn   gbmod:byte      ;defined in procedure 'init_option'
dseg    ends
cseg    segment byte    public  'codesg'
extrn   imode:near      ;defined in procedure 'init_option'
        public  graphics_off
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
;
graphics_off    proc    near
        and     byte ptr gbmod,07fh ;disable graphics output in gbmod
        call    imode           ;assert new mode register
        mov     al,83h
        out     0ah,al          ;turn off graphics on monochrome line
        ret
graphics_off    endp
cseg    ends
        end
```

Modifying and Loading the Color Map

For an application to modify the Color Map, it must first select the Color Map by way of the Indirect Register (write DFh to port 53h). This will also clear the Color Map Index Counter to zero so loading always starts at the beginning of the map.

Loading the Color Map is done during vertical retrace so there will be no interference with the normal refreshing of the bitmap. To ensure that there is sufficient time to load the Color Map, you must catch the beginning of a vertical retrace. First, check for vertical retrace going inactive (bit 5 of the GDC Status Register = 0). Then, look for the vertical retrace to start again (bit 5 of the GDC Status Register = 1).

To modify only an entry or two, the use of a shadow color map is suggested. Changes can first be made anywhere in the shadow map and then the entire shadow map can be loaded into the Color Map. The next section is an example of modifying a shadow color map and then loading the data from the shadow map into the Color Map.

Example of Modifying and Loading Color Data in a Shadow Map

```
;*******************************************************************
;                                                                  *
;               p r o c e d u r e   c h a n g e__c o l o r m a p   *
;                                                                  *
;  purpose:     change a color in the colormap                     *
;  entry:       ax = new color (0 = highest intensity)             *
;                              (F = lowest intensity)              *
;                         al = high nibble = red data              *
;                              low nibble  = green data            *
;                         ah = high nibble = gray data             *
;                              low nibble  = blue data             *
;               bx = palette entry number                          *
;                                                                  *
;  exit:                  none                                     *
;  register usage:        ax,bx,si                                 *
;*******************************************************************
;
cseg    segment byte    public  'codesg'
        extrn   assert_colormap:near ;defined in 'init_option'
        public  change_colormap
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
;
change_colormap proc    near
        mov     si,offset clmpda  ;colormap shadow
        mov     [si+bx],al        ;store the red and green data
        add     bx,16             ;increment to gray and blue data
        mov     [si+bx],ah        ;store the gray and blue data
        call    assert_colormap   ;defined in 'init_option'
change_colormap endp
cseg    ends
dseg    segment byte    public  'datasg'
public  clmpda
```

```
;Colormaps:
;---------
;Information in the Color Map is stored as 16 bytes of red and
;green data followed by 16 bytes of monochrome and blue data.
;For each color entry, a 0 specifies full intensity and 0fh
;specifies zero intensity.
;A sample set of color map entries for a Model 100-B system with
;a monochrome monitor in medium resolution (16 shades) would look
;as follows in the shadow area labelled CLMPDA:
;                no red or green data

;clmpda                  db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;                        db     0ffh
;
;                monochrome data, no blue data
;
;                        db     0ffh        ;black
;                        db     00fh        ;white
;                        db     01fh        ;       .
;                        db     02fh        ;       .
;                        db     03fh        ;light monochrome
;                        db     04fh        ;       .
;                        db     05fh        ;       .
;                        db     06fh        ;       .
;                        db     07fh        ;medium monochrome
;                        db     08fh        ;       .
;                        db     09fh        ;       .
;                        db     0afh        ;       .
;                        db     0bfh        ;dark monochrome
;                        db     0cfh        ;       .
;                        db     0dfh        ;       .
;                        db     0efh        ;       .
;
;
```

```
;
;On a Model 100-A system, only the lower two bits of the monochrome
;nibble are significant.  This allows only four monochrome shades
;as opposed to 16 shades on the Model 100-B system in medium
;resolution mode.  The following sample set of data applies to both
;the Model 100-A monochrome-only system in either medium or high
;resolution mode, as well as the Model 100-B monochrome-only system
;in high resolution mode.
;
;
;                ;no red or green data
;
;clmpda                 db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;                       db     0ffh
;
;                ;monochrome data, no blue data
;
;                       db     0ffh        ;black
;                       db     00fh        ;white
;                       db     05fh        ;light monochrome
;                       db     0afh        ;dark monochrome
;                       db     0ffh        ;black
;                       db     0ffh        ;black
;                       db     0ffh        ;black
;                       db     0ffh        ;black
;                       db     0ffh        ;black
;                       db     0ffh        ;black
;                       db     0ffh        ;black
;                       db     0ffh        ;black
;                       db     0ffh        ;black
;                       db     0ffh        ;black
;                       db     0ffh        ;black
;                       db     0ffh        ;black
;
```

```
;
;In a dual monitor configuration, with a Model 100-B system in
;medium resolution mode, all four components of each color entry
;are present: red, green, blue and monochrome.  A sample set of
;color data would be as follows:
;
;                       ;red and green data
;
;clmpda                    db     0ffh       ;black
;                          db     000h       ;white
;                          db     0f0h       ;cyan
;                          db     00fh       ;magenta
;                          db     000h       ;yellow
;                          db     00fh       ;red
;                          db     0ffh       ;blue
;                          db     0f0h       ;green
;                          db     0aah       ;dk gray
;                          db     0f8h       ;dk cyan
;                          db     08fh       ;dk magenta
;                          db     088h       ;dk yellow
;                          db     08fh       ;dk red
;                          db     0ffh       ;dk blue
;                          db     0f8h       ;dk green
;                          db     077h       ;gray
;
;                       ;monochrome and blue data
;
;                          db     0ffh       ;black         black
;                          db     000h       ;white         white
;                          db     010h       ;    .         cyan
;                          db     020h       ;    .         magenta
;                          db     03fh       ;light mono.   yellow
;                          db     04fh       ;    .         red
;                          db     050h       ;    .         blue
;                          db     06fh       ;    .         green
;                          db     07ah       ;med. mono.    dk gray
;                          db     0f8h       ;    .         dk cyan
;                          db     098h       ;    .         dk magenta
;                          db     0afh       ;    .         dk yellow
;                          db     0bfh       ;dark mono.    dk red
;                          db     0c8h       ;    .         dk blue
;                          db     0dfh       ;    .         dk green
;                          db     0e7h       ;    .         gray
;
```

```
;
;On a Model 100-A dual monitor configuration, in medium resolution
;mode, all 16 color entries are displayable.  However, only two
;bits of monochrome data are available allowing for only 4
;monochrome shades.
;
;On a Model 100-A dual monitor configuration, in high resolution
;mode, there are four displayable colors and again, four monochrome
;shades.
;
;On a Model 100-B dual monitor configuration, in high resolution
;mode, there also are four displayable colors and four monochrome
;shades.
;
;In a color monitor only system, the green data must be mapped
;to the monochrome output.  For a Model 100-B single color monitor
;system, in medium resolution mode, a sample color map would be as
;shown below:
;
;                               NOTE
;
;           The following sample color map will be
;           assembled with this example.  If this
;           is not appropriate, substitute one of
;           the other samples or generate one that
;           is custom tailored to the application.
;
;
                ;red data, green data mapped to mono.
;
clmpda                  db      0ffh        ;black
                        db      00fh        ;white
                        db      0ffh        ;cyan
                        db      00fh        ;magenta
                        db      00fh        ;yellow
                        db      00fh        ;red
                        db      0ffh        ;blue
                        db      0ffh        ;green
                        db      0afh        ;dk gray
                        db      0ffh        ;dk cyan
                        db      08fh        ;dk magenta
                        db      08fh        ;dk yellow
                        db      08fh        ;dk red
                        db      0ffh        ;dk blue
                        db      0ffh        ;dk green
                        db      07fh        ;gray
;
```

```
                        ;green data, blue data
;
                         db     0ffh       ;black
                         db     000h       ;white
                         db     000h       ;cyan
                         db     0f0h       ;magenta
                         db     00fh       ;yellow
                         db     0ffh       ;red
                         db     0f0h       ;blue
                         db     00fh       ;green
                         db     0aah       ;dk gray
                         db     088h       ;dk cyan
                         db     0f8h       ;dk magenta
                         db     08fh       ;dk yellow
                         db     0ffh       ;dk red
                         db     0f8h       ;dk blue
                         db     08fh       ;dk green
                         db     077h       ;gray
;
;
;For a Model 100-A single color monitor system, in either high or
;medium resolution mode, only the lower two bits of the monochrome
;output are significant.  Therefore, you can only display four
;intensities of green since the green data must be output through
;the monochrome line.  The same applies to a Model 100-B single
;color monitor system in high resolution mode.
;
;
dseg    ends
        end
```

6

Bitmap Write Setup (General)

Loading the ALU/PS Register

The ALU/PS Register data determines which bitmap planes will be written to during a Read/Modify/Write (RMW) cycle and also sets the operation of the logic unit to one of three write modes.

Bits 0 through 3 enable or disable the appropriate planes and bits 4 and 5 set the writing mode to REPLACE, COMPLEMENT, or OVERLAY. Bits 6 and 7 are not used. Bit definitions for the ALU/PS Register are in Part III of this manual.

Write an EFh to port 53h to select the ALU/PS Register and write the data to port 51h.

Example of Loading the ALU/PS Register

```
;*******************************************************************
;                                                                  *
;       p r o c e d u r e    a l u p s                             *
;                                                                  *
;       purpose:        set the ALU/PS register                    *
;                                                                  *
;       entry:          bl = value to set ALU/PS register to       *
;       exit:           update ALU/PS shadow byte                  *
;       register usage: ax,                                        *
;*******************************************************************
```

```
;
dseg    segment byte    public  'datasg'
extrn   alu:byte
dseg    ends
cseg    segment byte    public  'codesg'
        extrn   gdc_not_busy:near
        public  alups
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
;
alups   proc    near
        call    gdc_not_busy    ;defined in procedure 'init_option'
        mov     al,0efh         ;select ALU/PS register
        out     53h,al
        mov     byte ptr alu,bl ;update shadow byte (alu)
        mov     al,bl           ;move new ALU/PS value to al
        out     51h,al          ;load new value into ALU/PS register
        ret
alups   endp
cseg    ends
        end
```

Loading the Foreground/Background Register

The data byte in the Foreground/Background Register determines whether bits are set or cleared in each of the bitmap planes during a bitmap write (RMW) operation. Bit definitions for the Foreground/Background Register are in Part III of this manual.

Write an F7h to port 53h to select the Foreground/Background Register and write the data byte to port 51h.

Example of Loading the Foreground/Background Register

```
;*******************************************************************
;                                                                  *
;       p r o c e d u r e    f g b g                               *
;                                                                  *
;       purpose:        set the foreground / background register   *
;                                                                  *
;       entry:          bl = value to set fgbg register to         *
;       exit:           update fgbg shadow byte                    *
;       register usage: ax                                         *
;*******************************************************************
```

```
;
dseg    segment byte    public  'datasg'
extrn   fg:byte
dseg    ends
cseg    segment byte    public  'codesg'
        extrn   gdc_not_busy:near
        public  fgbg
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
;
fgbg    proc    near
        call    gdc_not_busy     ;defined in 'init_option'
        mov     al,0f7h          ;select the foreground/background
        out     53h,al           ;  register
        mov     byte ptr fg,bl   ;update shadow byte with new value
        mov     al,bl
        out     51h,al           ;load new value into fgbg register
        ret
fgbg    endp
cseg    ends
        end
```

7

Area Write Operations

This chapter contains examples that illustrate displaying 64K bytes of memory, and clearing a rectangular area of the screen to a given color.

Display Data from Memory

In the following example, video data in a 64K byte area of memory is loaded into the bitmap in order to display it on the monitor. The last byte of the memory area specifies the resolution to be used. A value of zero means use medium resolution mode. A value other than zero means use high resolution mode. In medium resolution mode, the 64K bytes are written to four planes in the bitmap; in high resolution mode, the 64K bytes are written to two planes.

Example of Displaying Data from Memory

```
;*********************************************************************
;                                                                    *
;       p r o c e d u r e    r i t v i d                             *
;                                                                    *
;       purpose:        restore a graphics screen save in a 64k      *
;                       segment of main memory by the procedure      *
;                       ritvid.                                      *
;                                                                    *
;*********************************************************************
```

```
;
        dseg    segment byte    public 'datasg'
extrn   gbmod:byte,gtemp:word,num_planes:byte,cur10:byte,gtemp1:byte
dseg ends
vidseg  segment byte    public  'vseg'
extrn   viddata:byte
vidseg  ends
        cseg    segment byte    public 'codesg'
extrn   init_option:near,fgbg:near,gdc_not_busy:near,alups:near
extrn   imode:near
        public  ritvid
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
;
ritvid  proc    near
;
;The video data is in vidseg. The last byte in vidseg is the
;resolution flag.  If flag is=0 the option is in medium resolution
;mode; otherwise it is in high resolution mode.  Initialize the
;option to that resolution.
;
        mov     ax,es
        mov     word ptr cs:segment_save,ax     ;save es
        call    gdc_not_busy    ;wait till GDC is free
        mov     ax,vidseg       ;set es to point to video buffer
        mov     es,ax
        mov     si,0ffffh       ;fetch the resolution flag from
        mov     al,es:[si]      ;  the last byte of vidbuf
        test    al,0ffh         ;is it high resolution?
        jnz     rt1             ;jump if yes.
        mov     dx,1
        jmp     rt2
rt1:    mov     dx,2
rt2:    mov     ax,word ptr cs:segment_save
        mov     es,ax           ;restore old es
        call    init_option     ;assert the new resolution.
;
;init-option leaves us in text mode with fg=f0 and alups=0.
;
        and     byte ptr gbmod,0fdh
        or      byte ptr gbmod,010h
        call    imode           ;make sure we're in text mode
        mov     bl,0fh          ;put 1's into bg and 0's into fg
        call    fgbg            ;because write buffer inverts data
        test    byte ptr gbmod,1    ;high resolution?
        jnz     rt3                 ;jump if yes.
        mov     word ptr gtemp,1024 ;8 wrd-writes/plane (med res)
        jmp     rt4
rt3:    mov     word ptr gtemp,2048 ;8 wrd-writes/plane (high res)
```

```
rt4:    mov     di,0                    ;start at beginning of vidbuf.
        mov     ax,vidseg               ;set es to point to video buffer
        mov     es,ax
        mov     cl,byte ptr num_planes  ;fetch number of planes
        xor     ch,ch                   ;  to be written
;
;Enable a plane to be written.
;
rt5:    mov     word ptr gtemp1,cx      ;save plane writing counter
        mov     bl,byte ptr num_planes  ;select plane to write enable
        sub     bl,cl                   ;this is plane to write enable
        mov     cl,bl
        mov     bl,0feh       ;put a 0 in that plane's select position
        rol     bl,cl
        and     bl,0fh                  ;keep in REPLACE mode
        call    alups                   ;assert the new ALU/PS
;
;Fill that plane with data, 8 words at a time, from vidseg.
;
        mov     word ptr curl0,0        ;start write at top left
        mov     cx,word ptr gtemp       ;number of 8 word writes
rt6:    push    cx                      ;  to fill plane
        call    gdc_not_busy            ;wait until GDC has finished
        mov     al,0feh                 ;  previous write
        out     53h,al
        out     51h,al
        mov     cx,16                   ;fetch 16 bytes
rt7:    mov     al,es:[di]              ;fill ptable with data
        inc     di                      ;  to be written
        out     52h,al
        loop    rt7
        mov     al,49h                  ;assert the position to
        out     57h,al                  ;  start the write
        mov     ax,word ptr curl0
        out     56h,al
        mov     al,ah
        out     56h,al
        mov     al,04ah                 ;init the mask to 0ffffh
        out     57h,al
        mov     al,0ffh
        out     56h,al
        out     56h,al
        xor     al,al
        out     54h,al
        out     55h,al
        mov     al,4ch
        out     57h,al                  ;now start the write
        mov     al,2                    ;direction is down
```

```
        out     56h,al
        mov     al,7                    ;do 8 writes
        out     56h,al
        xor     al,al
        out     56h,al
        mov     al,22h                  ;start the write
        out     57h,al
        mov     al,0ffh
        out     56h,al
        out     56h,al
        add     word ptr curl0,08       ;next location to be written
        pop     cx
        loop    rt6                     ;loop to complete this plane
        mov     cx,word ptr gtemp1      ;keep looping until all
        loop    rt5                     ;  planes are written
        mov     ax,word ptr cs:segment_save
        mov     es,ax
        ret
ritvid  endp
segment_save    dw      0
cseg    ends
        end
```

Set a Rectangular Area to a Color

The example that follows illustrates how to set a rectangular area of the screen to some specified color. Input data consists of the coordinates of the upper left and lower right corners of the area (in pixels) plus the color specification (a 4-bit index value). The special case of setting the entire screen to a specified color is included in the example as a subroutine that calls the general routine.

Example of Setting a Rectangular Area to a Color

```
;*********************************************************************
;                                                                    *
;   p r o c e d u r e    s e t _ a l l _ s c r e e n                *
;                                                                    *
;   purpose:            set entire screen to a user defined color    *
;                                                                    *
;   entry:              di is the color to clear the screen to       *
;   exit:               fgbg and alups shadow bytes updated          *
;   register usage:     ax,bx,cx,dx,si,di                            *
;*********************************************************************
;
cseg    segment byte    public  'codesg'
extrn   fgbg:near,gdc_not_busy:near,imode:near,alups:near
        public  set_all_screen,set_rectangle
        assume  cs:cseg,ds:dseg,es:nothing,ss:nothing
```

```
;
set_all_screen  proc    near
        mov     word ptr xstart,0    ;start at the top left corner
        mov     word ptr ystart,0
        mov     ax,word ptr xmax
        mov     word ptr xstop,ax    ;fetch the bottom right corner
        mov     ax,word ptr ymax
        mov     word ptr ystop,ax    ;coordinates.
        jmp     set_rectangle
set_all_screen  endp
;
;*******************************************************************
;                                                                  *
;   p r o c e d u r e    s e t _ r e c t a n g l e                 *
;                                                                  *
;   purpose:    set a user defined screen rectangle to a           *
;               user defined color                                 *
;                                                                  *
;   entry:      xstart has the start x in pixels                   *
;               ystart has the start y in scan lines               *
;               xstop has the stop x in pixels                     *
;               ystop has the stop y in scan lines                 *
;               di is the color to clear the screen to             *
;   exit:                                                          *
;   register usage:    ax,bx,cx,dx,di,si,xstart is altered         *
;*******************************************************************
;
set_rectangle           proc    near
;
;No validity checks are being made on start and stop coordinates.
;
;     xstart must be <= xstop
;     ystart must be <= ystop
;
;Assert the new screen color to both nibbles of the the foreground/
;background register.  Put the option into REPLACE mode with all
;planes enabled and in write-enabled word mode.
;
        mov     bx,di       ;di has the color; only low nibble valid
        mov     bh,bl       ;combine color number into both fg and bg
        mov     cl,4        ;shift the color up to the high nibble
        shl     bh,cl
        or      bl,bh       ;combine high nibble with old low nibble
        call    fgbg        ;assert new value to fgbg register
        xor     bl,bl       ;set up REPLACE mode, all planes
        call    alups       ;assert new value to ALU/PS register
        and     byte ptr gbmod,0fdh     ;set up text mode
        or      byte ptr gbmod,10h      ;set up write enable mode
        call    imode       ;assert new value to mode register
```

```
;
;Do the rectangle write.
;
;Do the write one column at a time.  Since the GDC is a word device,
;we have to take into account that we might have our write window
;start on a pixel that isn't on a word boundary.  The graphics
;options write mask must be set accordingly.  Do a write buffer
;write to all of the rectangle as defined by start,stop.  Calculate
;the first curl0.  Calculate the number of scans per column to be
;written.
;
        mov     ax,word ptr xstart  ;turn pixel address into
        mov     cl,4                ;  word address
        shr     ax,cl
        mov     dx,word ptr ystart  ;turn scan start to words/line*y
        mov     cl,byte ptr shifts_per_line ;number of shifts
        shl     dx,cl
        add     dx,ax               ;combine x and y word addresses
        mov     word ptr curl0,dx   ;first curl0.
        mov     ax,word ptr ystop   ;subtract start from stop.
        sub     ax,word ptr ystart
        mov     word ptr nmritl,ax
;
;Program the text mask.
;
;There are four possible write conditions-
;
;       a - partially write disabled to left
;       b - completely write enabled
;       c - partially disabled to the right
;       d - partially disabled to both left and right
;
;The portion to be write disabled to the left will be the current
;xstart pixel information.  As we write a column, we update the
;current xstart location.  Only the first xstart will have a left
;hand portion write disabled.  Only the last will have a right
;hand portion disabled.  If the first is also the last, a portion
;of both sides will be disabled.
;

cls1:   mov     bx,0ffffh     ;calculate the current write mask
        mov     cx,word ptr xstart
        and     cx,0fh        ;eliminate all but pixel information
        shr     bx,cl         ;shift in a 0 for each left pixel
                              ;  to be disabled
```

```
;
;Write buffer write is done by columns.  Take the current xstart
;and use it as the column to be written to.  When the word address
;of xstart is greater than the word address of xstop, we are
;finished.  There is a case where the current word address of
;xstop is equal to the current word address xstart.  In that
;case we have to be concerned about write disabling the bits to
;the right.  When xstop becomes less than xstart then we are done.
;
        mov     ax,word ptr xstart  ;test if word xstop is equal
        and     ax,0fff0h           ;  to word xstart
        mov     cx,word ptr xstop
        and     cx,0fff0h
        cmp     ax,cx               ;below?
        jb      cls3                ;jump if yes
        je      cls2                ;jump if equal - do last write
        jmp     exit                ;all done - exit
;
;We need to set up the right hand write disable.  This is also the
;last write.  bx has the left hand write enable mask in it.
;Preserve and combine with the right hand mask which will be
;(f-stop pixel address) bits on the right.
;
cls2:   mov     cx,word ptr xstop   ;strip pixel info out of xstop
        and     cx,0fh
        inc     cx                  ;make endpoint inclusive of write
        mov     ax,0ffffh           ;shift the disable mask
        shr     ax,cl               ;wherever there is a one, we
        xor     ax,0ffffh           ;want to enable writes
        and     bx,ax               ;combine right and left masks
;
;bx currently has the mask bytes in it.  Where we have a one, we
;want to make a zero so that particular bit will be write enabled.
;
cls3:   xor     bx,0ffffh           ;invert to get zeros for ones
;
;Assert the new write mask.  Make sure that the GDC is not busy
;before we change the mask.
;
cls4:   call    gdc_not_busy        ;check that the GDC isn't busy
        mov     al,bh               ;assert the upper write mask
        out     55h,al
        mov     al,bl               ;assert the lower write mask
        out     54h,al
;
;Position the GDC at the top of the column to be written.  This
;address was calculated earlier and the word need only be fetched
;and applied.  The number of scans to be written has already been
;calculated.
```

```
;
        mov     al,49h              ;assert the GDC cursor address
        out     57h,al
        mov     ax,word ptr curl0   ;assert word address low byte
        out     56h,al
        mov     al,dh               ;assert word address high byte
        out     56h,al
;
;Start the write operation.  Textmask, alups, gbmod and fgbg are
;already set up.  GDC is positioned.
;
        mov     al,4ch          ;assert figs to GDC
        out     57h,al
        xor     al,al           ;direction is down
        out     56h,al
        mov     ax,word ptr nmritl
        out     56h,al          ;assert number of write
        mov     al,ah           ;  operations to perform
        out     56h,al
        mov     al,22h          ;assert wdat
        out     57h,al
        mov     al,0ffh
        out     56h,al
        out     56h,al
;
;Update the starting x coordinate for the start of the next
;column write.  Strip off the pixel information and then add 16
;pixels to it to get the next word address.
;
        and     word ptr xstart,0fff0h    ;strip off pixel info
        add     word ptr xstart,16        ;address the next word
        inc     word ptr curl0
        jmp     cls1            ;check for another column to clear
exit:   ret
set_rectangle   endp
cseg            ends
dseg    segment byte    public  'datasg'
extrn   curl0:word,gbmod:byte,xmax:word,ymax:word
extrn   shifts_per_line:byte
public  xstart,xstop,ystart,ystop
xstart  dw      0
xstop   dw      0
ystart  dw      0
ystop   dw      0
nmritl  dw      0
dseg            ends
                end
```

8

Vector Write Operations

The examples in this chapter illustrate some basic vector write operations. They cover setting up the Pattern Generator and drawing a single pixel, a line, and a circle.

Setting Up the Pattern Generator

When operating in Vector Mode, all incoming data originates from the Pattern Generator. The Pattern Generator is composed of a Pattern Register and a Pattern Multiplier. The Pattern Register supplies the bit pattern to be written. The Pattern Multiplier determines how many times each bit is sent to the bitmap write circuitry before being recirculated.

> **NOTE**
> The Pattern Multiplier must be loaded before loading the Pattern Register.

Example of Loading the Pattern Register

The Pattern Register is an 8-bit register that is loaded with a bit pattern. This bit pattern, modified by a repeat factor stored in the Pattern Multiplier, is the data sent to the bitmap write circuitry when the option is in Vector Mode.

```
;*******************************************************************
;                                                                  *
;       p r o c e d u r e   p a t t e r n _ r e g i s t e r        *
;                                                                  *
;       purpose:         set the pattern register                  *
;                                                                  *
;       entry:           bl = pattern data                         *
;       exit:            update pattern register shadow byte       *
;       register usage: ax                                         *
;       caution:         you must set the pattern multiplier before *
;                        setting the pattern register              *
;*******************************************************************
;
;The pattern register contains a 16-bit pixel pattern that is written
;to the bitmap when the Graphics Option is in Vector Mode.
;
;Sample register values and corresponding patterns are:
;
;    register value        pattern output
;
;        0ffh                 11111111
;        0aah                 10101010
;        0f0h                 11110000
;        0cdh                 11001101
;
;The above assumes that the Pattern Multiplier has been set to
;multiply the pattern by 1.  If the Pattern Multiplier had been set
;to multiply the pattern by 3, the above examples, when output to
;the bitmap would look as follows:
;
;    register value        pattern output
;
;        0ffh          111111111111111111111111
;        0aah          111000111000111000111000
;        0f0h          111111111111000000000000
;        0cdh          111111000000111111000111
;
dseg    segment byte    public  'datasg'
extrn   prdata:byte
dseg    ends
cseg    segment byte    public  'codesg'
        extrn   gdc_not_busy:near
        public  pattern_register
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
```

```
;
pattern_register        proc    near
        call    gdc_not_busy    ;defined in 'init_option'
        mov     al,0fbh         ;select the pattern register
        out     53h,al
        mov     byte ptr prdata,bl ;update shadow byte
        mov     al,bl
        out     51h,al          ;load the pattern register
        ret
pattern_register        endp
cseg    ends
        end
```

Example of Loading the Pattern Multiplier

The Graphics Option expects to find a value in the Pattern Multiplier such that sixteen minus that value is the number of times each bit in the Pattern Register is repeated. In the following example, you supply the actual repeat factor and the coding converts it to the correct value for the Graphics Option.

```
;*********************************************************************
;                                                                   *
;       p r o c e d u r e   p a t t e r n _ m u l t                 *
;                                                                   *
;       purpose:        set the pattern multiplier                  *
;                                                                   *
;       entry:          bl = value to multiply pattern by (1 - 16)  *
;       exit:           updated pattern multiplier shadow byte      *
;       register usage: ax,bx                                       *
;       caution:        you must set the pattern multiplier before  *
;                       setting the pattern register                *
;                                                                   *
;*********************************************************************
;
dseg    segment byte    public  'datasg'
extrn   prmult:byte
dseg    ends
cseg    segment byte    public  'codesg'
        extrn   gdc_not_busy:near       ;defined in 'init_option'
        public  pattern_mult
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
```

```
;
pattern_mult    proc    near
        call    gdc_not_busy     ;defined in 'init_option'
        mov     byte ptr prmult,bl ;update multiplier shadow byte
        dec     bl               ;make bl zero relative
        not     bl               ;invert it - remember that pattern
                                 ;register is multiplied by 16 minus
                                 ;the multiplier value
        mov     al,0fdh          ;select the pattern multiplier
        out     53h,al
        mov     al,bl            ;load the pattern multiplier
        out     51h,al
        ret
pattern_mult    endp
cseg    ends
        end
```

Display a Pixel

The following example displays a single pixel at a location specified by a given set of x and y coordinates. Coordinate position 0,0 is in the upper left corner of the screen. The x and y values are in pixels and are positive and zero-based. Valid values are:

```
x = 0 - 799 for high resolution
    0 - 383 for medium resolution

y = 0 - 239 for high or medium resolution
```

Also, in the following example, it is assumed that the Mode, ALU/PS, and Foreground/Background registers have already been set up for a vector write operation.

Example of Displaying a Single Pixel

```
;*********************************************************************
;                                                                    *
;       p r o c e d u r e    p i x e l                               *
;                                                                    *
;       purpose:        draw a pixel                                 *
;                                                                    *
;       entry:          xinit = x location                           *
;                       yinit = y location                           *
;                       valid x values   = 0-799 high resolution     *
;                                        = 0-383 medium resolution   *
;                       valid y values   = 0-239 med. or high res.   *
;                                                                    *
;*********************************************************************
```

```
;
;Do a vector draw of one pixel at coordinates in xinit,yinit.  Assume
;that the Graphics Option is already set up in terms of Mode Register,
;Foreground/Background Register, and ALU/PS Register.
;
dseg    segment byte    public  'datasg'
extrn   gbmod:byte,curl0:byte,curl1:byte,curl2:byte,xinit:word
extrn   yinit:word
dseg    ends
cseg    segment byte    public  'codesg'
        extrn   cxy2cp:near,gdc_not_busy:near
        public  pixel
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
;
pixel   proc    near
        call    gdc_not_busy
        call    cxy2cp          ;convert x,y to a cursor position
        mov     al,49h          ;send out the cursor command byte
        out     57h,al
        mov     ax,word ptr curl0 ;assert cursor location low byte
        out     56h,al
        mov     al,ah           ;assert cursor location high byte
        out     56h,al
        mov     al,byte ptr curl2 ;assert cursor pixel location
        out     56h,al
        mov     al,4ch          ;assert the figs command
        out     57h,al
        mov     al,02h          ;line direction - to the right
        out     56h,al
        mov     al,6ch          ;tell GDC to draw pixel when ready
        out     57h,al
        ret
pixel   endp
cseg    ends
        end
```

Display a Vector

The example in this section will draw a line between two points specified by x and y coordinates given in pixels. The valid ranges for these coordinates are the same as specified for the previous example. Again it is assumed that the Mode, ALU/PS, and Foreground/Background registers have already been set up for a vector write operation. In addition, the Pattern Generator has been set up for the type of line to be drawn between the two points.

Example of Displaying a Vector

```
;*****************************************************************
;                                                                *
;       p r o c e d u r e    v e c t o r                         *
;                                                                *
;       purpose:        draw a vector                            *
;                                                                *
;       entry:          xinit = starting x location              *
;                       yinit = starting y location              *
;                       xfinal= ending x location                *
;                       yfinal= ending y location                *
;                       valid x values = 0 - 799 high resolution    *
;                                        0 - 383 medium resolution  *
;                       valid y values = 0 - 239 high or med. res.  *
;       exit:                                                    *
;       register usage: ax                                       *
;*****************************************************************
;
dseg    segment byte    public  'datasg'
extrn   curl0:byte,curl1:byte,curl2:byte,dc:word,d:word,d2:word
extrn   d1:word,dir:byte,xinit:word,yinit:word,xfinal:word
extrn   yfinal:word,gbmod:byte,p1:byte
dseg    ends
cseg    segment byte    public  'codesg'
extrn   gdc_not_busy:near,cxy2cp:near
        public  vector
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
vector  proc    near
;
;Draw a vector.
;Assume the start and stop coordinates to be in xinit, yinit,
;xfinal, and yfinal.  The Foreground/Background, ALU/PS, Mode,
;and Pattern Registers as well as the GDC PRAM bytes and all other
;incidental requirements such as "gdc_not_busy" have been taken
;care of already.  This routine positions the cursor, computes the
;draw direction, dc, d, d2, d1 and then implements the actual figs
;and figd commands.
;
        call    gdc_not_busy
        call    cxy2cp  ;convert starting x,y to a cursor position
        mov     al,49h      ;set cursor location from curl0,1,2
        out     57h,al      ;issue the GDC cursor location command
        mov     al,curl0    ;fetch word - low address
        out     56h,al
        mov     al,curl1    ;fetch word - middle address
        out     56h,al
```

```
        mov     al,curl2    ;dot address (top 4 bits)/high address
        out     56h,al
        mov     ax,word ptr xinit  ;start and stop points the same?
        cmp     ax,word ptr xfinal ;jump if not
        jnz     v1
        mov     ax,word ptr yinit  ;might be - check the y's
        cmp     ax,word ptr yfinal
        jnz     v1                 ;jump if not
        mov     al,04ch ;write single pixel - current vector write
        out     057h,al ;can't handle a one pixel write
        mov     al,2
        out     056h,al
        mov     al,06ch
        out     057h,al
        ret
v1:     mov     bx,yfinal    ;compute delta y
        sub     bx,yinit     ;delta y negative now?
        jns     quad34       ;jump if not (must be quad 3 or 4)
quad12: neg     bx           ;delta y is negative, make absolute
        mov     ax,xfinal    ;compute delta x
        sub     ax,xinit     ;delta x negative?
        js      quad2        ;jump if yes
quad1:  cmp     ax,bx        ;octant 2?
        jbe     oct3         ;jump if not
oct2:   mov     p1,02        ;direction of write
        jmp     vxind ;abs(deltax)>abs(deltay), independent axis=x-axis
oct3:   mov     p1,03        ;direction of write
        jmp     vyind ;abs(deltax)=<abs(deltay), independent axis=y-axis
quad2:  neg     ax           ;delta x is negative, make absolute
        cmp     ax,bx        ;octant 4?
        jae     oct5         ;jump if not
oct4:   mov     p1,04        ;direction of write
        jmp     vyind ;abs(deltax)=<abs(deltay), independent axis=y-axis
oct5:   mov     p1,05        ;direction of write
        jmp     vxind ;abs(deltax)>abs(deltay), independent axis=x-axis
quad34: mov     ax,xfinal    ;compute delta x
        sub     ax,xinit
        jns     quad4        ;jump if delta x is positive
quad3:  neg     ax           ;make delta x absolute instead of negative
        cmp     ax,bx        ;octant 6?
        jbe     oct7         ;jump if not
oct6:   mov     p1,06        ;direction of write
        jmp     vxind ;abs(deltax)>abs(deltay), independent axis=x-axis
oct7:   mov     p1,07        ;direction of write
        jmp     vyind ;abs(deltax)<=abs(deltay), independent axis=y-axis
```

```
quad4:  cmp     ax,bx       ;octant 0?
        jae     oct1        ;jump if not
oct0:   mov     p1,0        ;direction of write
        jmp     vyind ;abs(deltax)<abs(deltay), independent axis=y-axis
oct1:   mov     p1,01       ;direction of write
        jmp     vxind ;abs(deltax)=>(deltay), independent axis=x-axis
vyind:  xchg    ax,bx       ;put independent axis in ax, dependent in bx
vxind:  and     ax,03fffh   ;limit to 14 bits
        mov     dc,ax       ;dc=abs(delta x)
        push    bx          ;save abs(delta y)
        shl     bx,1
        sub     bx,ax
        and     bx,03fffh   ;limit to 14 bits
        mov     d,bx        ;d=2*abs(delta y)-abs(delta x)
        pop     bx          ;restore (abs(delta y)
        push    bx          ;save abs(delta y)
        sub     bx,ax
        shl     bx,1
        and     bx,03fffh   ;limit to 14 bits
        mov     d2,bx       ;d2=2*(abs(delta y)-abs(delta x))
        pop     bx
        shl     bx,1
        dec     bx
        and     bx,03fffh   ;limit to 14 bits
        mov     d1,bx       ;d1=2*abs(delta y)-1
vdo:    mov     al,04ch     ;issue the figs command
        out     57h,al
        mov     al,08       ;construct p1 of figs command
        or      al,p1
        out     56h,al      ;issue a parameter byte
        mov     si,offset dc
        mov     cx,08       ;issue the 8 bytes of dc,d,d2,d1
vdo1:   lodsb               ;fetch byte
        out     56h,al      ;issue to the GDC
        loop    vdo1        ;loop until all 8 done
        mov     al,06ch     ;start the drawing process in motion
        out     57h,al      ;by issuing figd
        ret
vector  endp
cseg    ends
        end
```

Display a Circle

The example in this section will display a circle, given the radius and the coordinates of the center in pixels. The code is valid only if the option is in medium resolution mode. If this code is executed in high resolution mode, the aspect ratio would cause the output to be generated as an ellipse. As in the previous examples, the option is assumed to have been set up for a vector write operation with the appropriate type of line programmed into the Pattern Generator.

Example of Drawing a Circle

```
;*********************************************************************
;                                                                    *
;       p r o c e d u r e    c i r c l e                             *
;                                                                    *
;       purpose:        draw a circle in medium resolution mode      *
;                                                                    *
;       entry:          xinit = circle center x coordinate (0-799)   *
;                       yinit = circle center y coordinate (0-239)   *
;                       radius = radius of the circle in pixels      *
;                                                                    *
;       caution:        This routine will only work in medium        *
;                       resolution mode.  Due to the aspect ratio    *
;                       of high resolution mode, circles appear      *
;                       as ellipses.                                 *
;                                                                    *
;*********************************************************************
;
;Draw an circle.
;This routine positions the cursor, computes the draw direction, dc,
;d, d2, d1 and implements the actual figs and figd commands.
;The Mode Register has been set up for graphics operations, the write
;mode and planes select is set up in the ALU/PS Register, the
;Foreground/Background Register is loaded with the desired foreground
;and background colors and the Pattern Multiplier/Pattern Register is
;loaded.  In graphics mode, all incoming data comes from the Pattern
;Register.  We have to make sure that the GDC's PRAM 8 and 9 are all
;ones so that it will try to write all ones to the bitmap.  The
;external hardware intervene and put the pattern register's data
;into the bitmap.
```

```
;
extrn   gbmod:byte,curl0:byte,curl1:byte,curl2:byte,xinit:word
extrn   yinit:word,dir:byte,shifts_per_line:byte
dseg    segment byte    public  'datasg'
        public  radius,xad,yad
dc      dw      0
d       dw      0
d2      dw      0
d1      dw      0
dm      dw      0
xad     dw      0
yad     dw      0
radius  dw      0
dseg    ends
cseg    segment byte    public  'codesg'
        extrn   gdc_not_busy:near
        public  circle
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
;
circle  proc    near
        call    gdc_not_busy
        mov     al,78h
        out     57h,al                  ;set pram bytes 8 and 9
        mov     al,0ffh
        out     56h,al
        out     56h,al

        mov     word ptr d1,-1          ;set figs d1 parameter
        mov     word ptr dm,0           ;set figs d2 parameter
        mov     bx,word ptr radius      ;get radius
        mov     ax,0b505h               ;get 1/1.41
        inc     bx
        mul     bx
        mov     word ptr dc,dx          ;set figs dc parameter
        dec     bx
        mov     word ptr d,bx           ;set figs d parameter
        shl     bx,1
        mov     word ptr d2,bx          ;set figs d2 parameter

        mov     ax,word ptr xinit       ;get center x
        mov     word ptr xad,ax         ;save it
        mov     ax,word ptr yinit       ;get center y
        sub     ax,word ptr radius      ;subtract radius
        mov     word ptr yad,ax         ;save it
        call    acvt                    ;position cursor
        mov     byte ptr dir,01h        ;arc 1
        call    avdo                    ;draw it
        call    acvt                    ;position cursor
        mov     byte ptr dir,06h        ;arc 6
        call    avdo                    ;draw it
```

```
        mov     ax,word ptr xinit    ;get center x
        mov     word ptr xad,ax      ;save it
        mov     ax,word ptr yinit    ;get center y
        add     ax,word ptr radius   ;add in radius
        mov     word ptr yad,ax      ;save it
        call    acvt                 ;position cursor
        mov     byte ptr dir,02h     ;arc 2
        call    avdo                 ;draw it
        call    acvt                 ;position cursor
        mov     byte ptr dir,05h     ;arc 5
        call    avdo                 ;draw it

        mov     ax,word ptr xinit    ;get center x
        sub     ax,word ptr radius   ;subtract radius
        mov     word ptr xad,ax      ;save it
        mov     ax,word ptr yinit    ;get center y
        mov     word ptr yad,ax      ;save it
        call    acvt                 ;position cursor
        mov     byte ptr dir,03h     ;arc 3
        call    avdo                 ;draw it
        call    acvt                 ;position cursor
        mov     byte ptr dir,00h     ;arc 0
        call    avdo                 ;draw it

        mov     ax,word ptr xinit    ;get center x
        add     ax,word ptr radius   ;add in the radius
        mov     word ptr xad,ax      ;save it
        mov     ax,word ptr yinit    ;get center y
        mov     word ptr yad, ax     ;save it
        call    acvt                 ;position cursor
        mov     byte ptr dir,07h     ;arc 7
        call    avdo                 ;draw it
        call    acvt                 ;position cursor
        mov     byte ptr dir,04h     ;arc 4
        call    avdo                 ;draw it
        ret
;
;Convert the starting x,y coordinate pair into a cursor position
;word value.
```

```
;
acvt:
        mov     cl,byte ptr shifts_per_line ;set up for 32/16-bit
        xor     dx,dx           ;math - clear upper 16 bit
        mov     ax,word ptr yad
        shl     ax,cl
        mov     bx,ax           ;save lines * word/line
        mov     ax,word ptr xad ;compute number of words on last line
        mov     cx,16           ;16 bits/word
        div     cx          ;ax has number of extra words to add in
        add     ax,bx       ;dx has the <16 dot address left over
        mov     curl0,al    ;this is the new cursor memory address
        mov     curl1,ah
        mov     cl,04       ;dot address is high nibble of byte
        shl     dl,cl
        mov     curl2,dl
        mov     al,49h      ;set cursor location to curl0,1,2
        out     57h,al      ;issue the GDC cursor location command
        mov     al,curl0    ;fetch word - low address
        out     56h,al
        mov     al,curl1    ;fetch word - middle address
        out     56h,al
        mov     al,curl2    ;dot address (top 4 bits)/high address
        out     56h,al
        ret
avdo:   call    gdc_not_busy
        mov     al,4ch          ;issue the figs command
        out     57h,al
        mov     al,020h         ;construct p1 of figs command
        or      al,byte ptr dir
        out     56h,al          ;issue a parameter byte
        mov     si,offset dc
        mov     cx,10           ;issue the 10 bytes of dc,d,d2,d1
avdo1:  mov     al,[si]         ;fetch byte
        out     56h,al          ;issue to the GDC
        inc     si              ;point to next in list
        loop    avdo1           ;loop until all 10 done
        mov     al,6ch          ;start drawing process in motion
        out     57h,al          ;by issuing figd
        ret
circle  endp
cseg    ends
        end
```

9

Text Write Operations

In this chapter the examples illustrate coding for writing byte-aligned 8 $\times$ 10 characters, determining type and position of the cursor, and writing bit-aligned vector (stroked) characters.

Write a Byte-Aligned Character

This example uses a character matrix that is eight pixels wide and ten scan lines high. The characters are written in high resolution mode and are aligned on byte boundaries. The inputs are the column and row numbers that locate the character, the code for the character, and the color attribute.

Example of Writing a Byte-Aligned Character

```
;*******************************************************************
;                                                                  *
;       p r o c e d u r e     g t e x t                            *
;                                                                  *
;       purpose:        write 8 pixels wide x 10 scan lines        *
;                       graphics text in high resolution           *
;                                                                  *
;       entry:          ax is the column location of the character *
;                       bx is the row location of the character    *
;                       dl is the character                        *
;                       dh is the fgbg                             *
;*******************************************************************
;
dseg    segment byte    public  'datasg'
```

```
extrn   curl0:byte,curl2:byte,gbmod:byte,fg:byte
;
;This table has the addresses of the individual text font characters.
;Particular textab addresses are found by taking the offset of the
;textab, adding in the ASCII offset of the character to be printed
;and loading the resulting word. This word is the address of the
;start of the character's text font.
;
gbmskl  db      0
gbmskh  db      0
textab  dw      0
        dw      10
        dw      20
        dw      30
        dw      40
        dw      50
        dw      60
        dw      70
        dw      80
        dw      90
        dw      100
        dw      110
        dw      120
        dw      130
        dw      140
        dw      150
        dw      160
        dw      170
        dw      180
        dw      190
        dw      200
        dw      210
        dw      220
        dw      230
        dw      240
        dw      250
        dw      260
        dw      270
        dw      280
        dw      290
        dw      300
        dw      310
        dw      320
        dw      330
        dw      340
        dw      350
        dw      360
        dw      370
```

```
dw      380
dw      390
dw      400
dw      410
dw      420
dw      430
dw      440
dw      450
dw      460
dw      470
dw      480
dw      490
dw      500
dw      510
dw      520
dw      530
dw      540
dw      550
dw      560
dw      570
dw      580
dw      590
dw      600
dw      610
dw      620
dw      630
dw      640
dw      650
dw      660
dw      670
dw      680
dw      690
dw      700
dw      710
dw      720
dw      730
dw      740
dw      750
dw      760
dw      770
dw      780
dw      790
dw      800
dw      810
dw      820
dw      830
dw      840
dw      850
```

```
        dw      860
        dw      870
        dw      880
        dw      890
        dw      900
        dw      910
        dw      920
        dw      930
        dw      940
;
;text font
;
space   db      11111111b
        db      0ffh
        db      0ffh
        db      0ffh
        db      0ffh
        db      0ffh
        db      0ffh
        db      0ffh
        db      0ffh
        db      11111111b

exclam  db      11111111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11111111b
        db      11100111b
        db      11111111b
        db      11111111b

quote   db      11111111b
        db      0d7h
        db      0d7h
        db      0d7h
        db      0ffh
        db      0ffh
        db      0ffh
        db      0ffh
        db      0ffh
        db      11111111b
```

```
num     db      11111111b
        db      11010111b
        db      11010111b
        db      00000001b
        db      11010111b
        db      00000001b
        db      11010111b
        db      11010111b
        db      11111111b
        db      11111111b

dollar  db      11111111b
        db      11101111b
        db      10000001b
        db      01101111b
        db      10000011b
        db      11101101b
        db      00000011b
        db      11101111b
        db      11111111b
        db      11111111b

percent db      11111111b
        db      00111101b
        db      00111011b
        db      11110111b
        db      11101111b
        db      11011111b
        db      10111001b
        db      01111001b
        db      11111111b
        db      11111111b

amp     db      11111111b
        db      10000111b
        db      01111011b
        db      10110111b
        db      11001111b
        db      10110101b
        db      01111011b
        db      10000100b
        db      11111111b
        db      11111111b
```

```
apos    db      11111111b
        db      11100111b
        db      11101111b
        db      11011111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b

lefpar  db      11111111b
        db      11110011b
        db      11100111b
        db      11001111b
        db      11001111b
        db      11001111b
        db      11100111b
        db      11110011b
        db      11111111b
        db      11111111b

ritpar  db      11111111b
        db      11001111b
        db      11100111b
        db      11110011b
        db      11110011b
        db      11110011b
        db      11100111b
        db      11001111b
        db      11111111b
        db      11111111b

aster   db      11111111b
        db      11111111b
        db      10111011b
        db      11010111b
        db      00000001b
        db      11010111b
        db      10111011b
        db      11111111b
        db      11111111b
        db      11111111b
```

```
plus    db      11111111b
        db      11111111b
        db      11101111b
        db      11101111b
        db      00000001b
        db      11101111b
        db      11101111b
        db      11111111b
        db      11111111b
        db      11111111b

comma   db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11100111b
        db      11100111b
        db      11001111b
        db      11111111b

minus   db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      00000001b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b

period  db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11100111b
        db      11100111b
        db      11111111b
        db      11111111b
```

```
slash   db      11111111b
        db      11111101b
        db      11111001b
        db      11110011b
        db      11100111b
        db      11001111b
        db      10011111b
        db      00111111b
        db      11111111b
        db      11111111b

zero    db      11111111b
        db      11000101b
        db      10010001b
        db      10010001b
        db      10001001b
        db      10001001b
        db      10011001b
        db      10100011b
        db      11111111b
        db      11111111b

one     db      11111111b
        db      11100111b
        db      11000111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      10000001b
        db      11111111b
        db      11111111b

two     db      11111111b
        db      11000011b
        db      10011001b
        db      11111001b
        db      11100011b
        db      11001111b
        db      10011111b
        db      10000001b
        db      11111111b
        db      11111111b
```

```
three   db      11111111b
        db      10000001b
        db      11110011b
        db      11100111b
        db      11000011b
        db      11111001b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b

four    db      11111111b
        db      11110001b
        db      11100001b
        db      11001001b
        db      10011001b
        db      10000001b
        db      11111001b
        db      11111001b
        db      11111111b
        db      11111111b

five    db      11111111b
        db      10000001b
        db      10011111b
        db      10000011b
        db      11111001b
        db      11111001b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b

six     db      11111111b
        db      11000011b
        db      10011001b
        db      10011111b
        db      10000011b
        db      10001001b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b
```

```
seven   db      11111111b
        db      10000001b
        db      11111001b
        db      11110011b
        db      11100111b
        db      11001111b
        db      10011111b
        db      10011111b
        db      11111111b
        db      11111111b

eight   db      11111111b
        db      11000011b
        db      10011001b
        db      10011001b
        db      11000011b
        db      10011001b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b

nine    db      11111111b
        db      11000011b
        db      10011001b
        db      10010001b
        db      11000001b
        db      11111001b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b

colon   db      11111111b
        db      11111111b
        db      11111111b
        db      11100111b
        db      11100111b
        db      11111111b
        db      11100111b
        db      11100111b
        db      11111111b
        db      11111111b
```

```
scolon  db      11111111b
        db      11111111b
        db      11111111b
        db      11100111b
        db      11100111b
        db      11111111b
        db      11100111b
        db      11100111b
        db      11001111b
        db      11111111b

lesst   db      11111111b
        db      11111001b
        db      11110011b
        db      11001111b
        db      10011111b
        db      11001111b
        db      11110011b
        db      11111001b
        db      11111111b
        db      11111111b

equal   db      11111111b
        db      11111111b
        db      11111111b
        db      10000001b
        db      11111111b
        db      10000001b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b

greatr  db      11111111b
        db      10011111b
        db      11001111b
        db      11110011b
        db      11111001b
        db      11110011b
        db      11001111b
        db      10011111b
        db      11111111b
        db      11111111b
```

```
ques    db      11111111b
        db      11000011b
        db      10011001b
        db      11111001b
        db      11110011b
        db      11100111b
        db      11111111b
        db      11100111b
        db      11111111b
        db      11111111b

at      db      11111111b
        db      11000011b
        db      10011001b
        db      10011001b
        db      10010001b
        db      10010011b
        db      10011111b
        db      11000001b
        db      11111111b
        db      11111111b

capa    db      11111111b
        db      11100111b
        db      11000011b
        db      10011001b
        db      10011001b
        db      10000001b
        db      10011001b
        db      10011001b
        db      11111111b
        db      11111111b

capb    db      11111111b
        db      10000011b
        db      10011001b
        db      10011001b
        db      10000011b
        db      10011001b
        db      10011001b
        db      10000011b
        db      11111111b
        db      11111111b
```

```
capc    db      11111111b
        db      11000011b
        db      10011001b
        db      10011111b
        db      10011111b
        db      10011111b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b

capd    db      11111111b
        db      10000011b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10000011b
        db      11111111b
        db      11111111b

cape    db      11111111b
        db      10000001b
        db      10011111b
        db      10011111b
        db      10000011b
        db      10011111b
        db      10011111b
        db      10000001b
        db      11111111b
        db      11111111b

capf    db      11111111b
        db      10000001b
        db      10011101b
        db      10011111b
        db      10000111b
        db      10011111b
        db      10011111b
        db      10011111b
        db      11111111b
        db      11111111b
```

```
capg    db      11111111b
        db      11000011b
        db      10011001b
        db      10011001b
        db      10011111b
        db      10010001b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b

caph    db      11111111b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10000001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      11111111b
        db      11111111b

capi    db      11111111b
        db      11000011b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11000011b
        db      11111111b
        db      11111111b

capj    db      11111111b
        db      11100001b
        db      11110011b
        db      11110011b
        db      11110011b
        db      11110011b
        db      10010011b
        db      11000111b
        db      11111111b
        db      11111111b
```

```
capk    db      11111111b
        db      10011001b
        db      10010011b
        db      10000111b
        db      10001111b
        db      10000111b
        db      10010011b
        db      10011001b
        db      11111111b
        db      11111111b

capl    db      11111111b
        db      10000111b
        db      11001111b
        db      11001111b
        db      11001111b
        db      11001111b
        db      11001101b
        db      10000001b
        db      11111111b
        db      11111111b

capm    db      11111111b
        db      00111001b
        db      00010001b
        db      00101001b
        db      00101001b
        db      00111001b
        db      00111001b
        db      00111001b
        db      11111111b
        db      11111111b

capn    db      11111111b
        db      10011001b
        db      10001001b
        db      10001001b
        db      10000001b
        db      10010001b
        db      10010001b
        db      10011001b
        db      11111111b
        db      11111111b
```

```
capo    db      11111111b
        db      11000011b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b
capp    db      11111111b
        db      10000011b
        db      10011001b
        db      10011001b
        db      10000011b
        db      10011111b
        db      10011111b
        db      10011111b
        db      11111111b
        db      11111111b

capq    db      11111111b
        db      11000011b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10010001b
        db      10011001b
        db      11000001b
        db      11111100b
        db      11111111b

capr    db      11111111b
        db      10000011b
        db      10011001b
        db      10011001b
        db      10000011b
        db      10000111b
        db      10010011b
        db      10011001b
        db      11111111b
        db      11111111b
```

```
caps    db      11111111b
        db      11000011b
        db      10011001b
        db      10011111b
        db      11000111b
        db      11110001b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b

capt    db      11111111b
        db      10000001b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11111111b
        db      11111111b

capu    db      11111111b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b

capv    db      11111111b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      11000011b
        db      11100111b
        db      11111111b
        db      11111111b
```

```
capw    db      11111111b
        db      00111001b
        db      00111001b
        db      00111001b
        db      00111001b
        db      00101001b
        db      00000001b
        db      00111001b
        db      11111111b
        db      11111111b

capx    db      11111111b
        db      10011001b
        db      10011001b
        db      11000011b
        db      11100111b
        db      11000011b
        db      10011001b
        db      10011001b
        db      11111111b
        db      11111111b


capy    db      11111111b
        db      10011001b
        db      10011001b
        db      11000011b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11000011b
        db      11111111b
        db      11111111b

capz    db      11111111b
        db      10000001b
        db      11111001b
        db      11110011b
        db      11100111b
        db      11001111b
        db      10011101b
        db      10000001b
        db      11111111b
        db      11111111b
```

```
lbrak   db      11111111b
        db      10000011b
        db      10011111b
        db      10011111b
        db      10011111b
        db      10011111b
        db      10011111b
        db      10000011b
        db      11111111b
        db      11111111b

bslash  db      11111111b
        db      10111111b
        db      10011111b
        db      11001111b
        db      11100111b
        db      11110011b
        db      11111001b
        db      11111101b
        db      11111111b
        db      11111111b

rbrak   db      11111111b
        db      10000011b
        db      11110011b
        db      11110011b
        db      11110011b
        db      11110011b
        db      11110011b
        db      10000011b
        db      11111111b
        db      11111111b
caret   db      11111111b
        db      11101111b
        db      11010111b
        db      10111011b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
```

```
underl  db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      00000000b

lsquot  db      11111111b
        db      11100111b
        db      11100111b
        db      11110111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b

lita    db      11111111b
        db      11111111b
        db      11111111b
        db      10000011b
        db      11111001b
        db      11000001b
        db      10011001b
        db      11000001b
        db      11111111b
        db      11111111b

litb    db      11111111b
        db      10011111b
        db      10011111b
        db      10000011b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10000011b
        db      11111111b
        db      11111111b
```

```
litc    db      11111111b
        db      11111111b
        db      11111111b
        db      11000011b
        db      10011001b
        db      10011111b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b

litd    db      11111111b
        db      11111001b
        db      11111001b
        db      11000001b
        db      10010001b
        db      10011001b
        db      10010001b
        db      11000001b
        db      11111111b
        db      11111111b

lite    db      11111111b
        db      11111111b
        db      11111111b
        db      11000011b
        db      10011001b
        db      10000011b
        db      10011111b
        db      11000011b
        db      11111111b
        db      11111111b

litf    db      11111111b
        db      11100011b
        db      11001001b
        db      11001111b
        db      10000011b
        db      11001111b
        db      11001111b
        db      11001111b
        db      11111111b
        db      11111111b
```

```
litg    db      11111111b
        db      11111111b
        db      11111001b
        db      11000001b
        db      10010011b
        db      10010011b
        db      11000011b
        db      11110011b
        db      10010011b
        db      11000111b

lith    db      11111111b
        db      10011111b
        db      10011111b
        db      10000011b
        db      10001001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      11111111b
        db      11111111b

liti    db      11111111b
        db      11111111b
        db      11100111b
        db      11111111b
        db      11000111b
        db      11100111b
        db      11100111b
        db      10000001b
        db      11111111b
        db      11111111b

litj    db      11111111b
        db      11111111b
        db      11110011b
        db      11111111b
        db      11110011b
        db      11110011b
        db      11110011b
        db      11110011b
        db      10010011b
        db      11000111b
```

```
litk    db      11111111b
        db      10011111b
        db      10011111b
        db      10010011b
        db      10000111b
        db      10000111b
        db      10010011b
        db      10011001b
        db      11111111b
        db      11111111b

litl    db      11111111b
        db      11000111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11000011b
        db      11111111b
        db      11111111b

litm    db      11111111b
        db      11111111b
        db      11111111b
        db      10010011b
        db      00101001b
        db      00101001b
        db      00101001b
        db      00111001b
        db      11111111b
        db      11111111b

litn    db      11111111b
        db      11111111b
        db      11111111b
        db      10100011b
        db      10001001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      11111111b
        db      11111111b
```

```
lito    db      11111111b
        db      11111111b
        db      11111111b
        db      11000011b
        db      10011001b
        db      10011001b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b

litp    db      11111111b
        db      11111111b
        db      11111111b
        db      10100011b
        db      10001001b
        db      10011001b
        db      10001001b
        db      10000011b
        db      10011111b
        db      10011111b

litq    db      11111111b
        db      11111111b
        db      11111111b
        db      11000101b
        db      10010001b
        db      10011001b
        db      10010001b
        db      11000001b
        db      11111001b
        db      11111001b

litr    db      11111111b
        db      11111111b
        db      11111111b
        db      10100011b
        db      10011001b
        db      10011111b
        db      10011111b
        db      10011111b
        db      11111111b
        db      11111111b
```

```
lits    db      11111111b
        db      11111111b
        db      11111111b
        db      11000001b
        db      10011111b
        db      11000011b
        db      11111001b
        db      10000011b
        db      11111111b
        db      11111111b

litt    db      11111111b
        db      11111111b
        db      11001111b
        db      10000011b
        db      11001111b
        db      11001111b
        db      11001001b
        db      11100011b
        db      11111111b
        db      11111111b

litu    db      11111111b
        db      11111111b
        db      11111111b
        db      10011001b
        db      10011001b
        db      10011001b
        db      10011001b
        db      11000011b
        db      11111111b
        db      11111111b

litv    db      11111111b
        db      11111111b
        db      11111111b
        db      10011001b
        db      10011001b
        db      10011001b
        db      11011011b
        db      11100111b
        db      11111111b
        db      11111111b
```

```
litw    db      11111111b
        db      11111111b
        db      11111111b
        db      00111001b
        db      00111001b
        db      00101001b
        db      10101011b
        db      10010011b
        db      11111111b
        db      11111111b

litx    db      11111111b
        db      11111111b
        db      11111111b
        db      10011001b
        db      11000011b
        db      11100111b
        db      11000011b
        db      10011001b
        db      11111111b
        db      11111111b

lity    db      11111111b
        db      11111111b
        db      11111111b
        db      10011001b
        db      10011001b
        db      10011001b
        db      11100001b
        db      11111001b
        db      10011001b
        db      11000011b

litz    db      11111111b
        db      11111111b
        db      11111111b
        db      10000001b
        db      11110011b
        db      11100111b
        db      11001111b
        db      10000001b
        db      11111111b
        db      11111111b
```

```
lsbrak  db      11111111b
        db      11110001b
        db      11100111b
        db      11001111b
        db      10011111b
        db      11001111b
        db      11001111b
        db      11100011b
        db      11111111b
        db      11111111b

vertl   db      11111111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11100111b
        db      11111111b
rsbrak  db      11111111b
        db      10001111b
        db      11100111b
        db      11110011b
        db      11111001b
        db      11110011b
        db      11100111b
        db      10001111b
        db      11111111b
        db      11111111b

tilde   db      11111111b
        db      10011111b
        db      01100101b
        db      11110011b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
        db      11111111b
dseg            ends
cseg    segment byte    public  'codesg'
        public  gtext
extrn   mode:near,gdc_not_busy:near
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
gtext           proc    near
```

```
;
;We are going to assume that the character is byte-aligned. Anything
;else will be ignored with the char being written out to the integer
;of the byte address.
;
;Special conditions: if dl=0ffh - don't print anything.
;
;1)Make sure that the Graphics Option doesn't have any pending
;operations to be completed.
;2)Turn the x,y coordinates passed in ax,bx into a cursor word
;address to be saved and then asserted to the GDC.
;3)If the current foreground/background colors are not those
;desired, assert the desired colors to the Foreground/Background
;Register.
;4)Determine in which half of the word the character is to be
;written to and then enable that portion of the write.
;5)Check to see if the character we are being requested to print is
;legal. Anything under 20h is considered to be unprintable and so we
;just exit. We also consider 0ffh to be unprintable since the Rainbow
;uses this code as a delete marker.
;6)Turn the character's code into a word offset. Use this offset to
;find an address in a table. This table is a table of near addresses
;that define the starting address of the ten bytes that is the
;particular character's font. Fetch the first two bytes and assert to
;the screen. We have to assert write buffer counter reset because we
;are only using two of the words in the write buffer, not all 8.
;Each byte is loaded into both the left and right byte of a write
;buffer word. The GDC is programmed to perform the two-scan-line
;write and we wait for the write to finish. The next 8 scan lines
;of the character font are loaded into both the left and right bytes
;of the write buffer and these eight lines are then written to the
;screen.
;
        push    ax
        call    gdc_not_busy
        pop     ax
;
;Ax = the column number of the character. Bx is the row number.
;In high resolution, each bx is = 640 words
;Cursor position = (ax/2)+10*(bx*scan line width in words)
;
        mov     di,ax    ;save the x so that we can check it later
        shr     ax,1     ;turn column position into a word address
        mov     cx,6     ;high resolution is 64 words per line
        shl     bx,cl    ;bx*scan line length
        mov     si,bx    ;save a copy of scan times count
        mov     cl,3     ;to get bx*10 first multiply bx by 8
        shl     bx,cl    ;then
        add     bx,si    ;add in the 2*bx*scan line length
```

```
        add     bx,si    ;this gives 10*bx*scan line length
        add     bx,ax    ;combine x and y into a word address
        mov     word ptr curl0,bx ;position to write the word at
;
;Assert the colors attributes of the character to fgbg. Dh has the
;foreground and background attributes in it.
;
        cmp     dh,byte ptr fg      ;is the fgbg color the one we want?
        jz      cont                ;jump if yes
        mov     al,0f7h
        out     53h,al
        mov     byte ptr fg,dh
        mov     al,dh
        out     51h,al
;
;Assert the graphics board's text mask. The GDC does 16-bit writes
;in text mode but our characters are only 8 bits wide. We must enable
;half of the write and disable the other half. If the x was odd then
;enable the right half. If the x was even then enable the left half.
;
cont:   test    di,1              ;is this a first byte?
        jnz     odd               ;jump if not
        mov     word ptr gbmskl,00ffh
        jmp     com
odd:    mov     word ptr gbmskl,0ff00h
com:    call    stgbm             ;assert the graphics board mask
;
;Only the characters below 127h are defined - the others are legal
;but not in the font table. After checking for a legal character
;fetch the address entry (character number - 20h) in the table.
;This is the address of the first byte of the character's font.
;
        cmp     dl,1fh            ;unprintable character?
        ja      cont0             ;jump if not
        jmp     exit              ;don't print illegal character
cont0:  cmp     dl,0ffh           ;is this a delete marker?
        jnz     cont1             ;jump if not
        jmp     exit              ;exit if yes
cont1:  sub     dl,20h            ;table starts with a space
        xor     dh,dh             ; at 0
        mov     bx,dx             ;access table & index off bx
        shl     bx,1              ;byte to word address offset
        mov     si,textab[bx]
;
;Textab has the relative offsets of each character in it. All we have
;to do is add the start of the font table to the relative offset of
;the particular character.
```

```
;
        add     si,offset space ;combine table offset with
                                ;character  offset
;
;Transfer the font from the font table into the write buffer.
;Write the first two scans, then do the last 8.
;
        cld                     ;make sure lodsb incs si.
        mov     al,0feh         ;reset the write buffer counter
        out     53h,al
        out     51h,al
        lodsw                   ;fetch both bytes.
        out     52h,al          ;put the byte into both 1 and 2
        out     52h,al          ;write buffer bytes
        mov     al,ah
        out     52h,al          ;put the byte into both 1 and 2
        out     52h,al          ;write buffer bytes
        mov     al,0feh         ;reset the write buffer counter
        out     53h,al
        out     51h,al
;
;Check to see if already in text mode.
;
        test    byte ptr gbmod,2
        jz      textm                   ;jump if in text mode else
        and     byte ptr gbmod,0fdh     ;assert text mode
        call    mode
textm:  mov     al,49h          ;assert the cursor command
        out     57h,al
        mov     ax,word ptr curl0
        out     56h,al
        mov     al,ah
        out     56h,al
        mov     al,4ah          ;assert the mask command
        out     57h,al
        mov     al,0ffh
        out     56h,al
        out     56h,al
        mov     al,4ch          ;assert the figs command
        out     57h,al
        xor     al,al           ;assert the down direction to write
        out     56h,al
        mov     al,1            ;do it 2 write cycles
        out     56h,al
        xor     al,al
        out     56h,al
```

```
        mov     al,22h          ;assert the wdat command
        out     57h,al
        mov     al,0ffh
        out     56h,al
        out     56h,al
;
;Wait for the first two scans to be written.
;
        mov     ax,422h         ;make sure the GDC isn't drawing
        out     57h,al          ;write a wdat to the GDC
here1:  in      al,56h          ;read the status register
        test    ah,al           ;did the wdat get executed?
        jz      here1           ;jump if not
;
;si is still pointing to the next scan line to be fetched. Get the
;next two scan lines and then tell the GDC to write them. No new
;cursor, GDC mask, graphics mask or mode commands need be issued.
;
        mov     cx,8            ;eight scan lines
ldcr:   lodsb                   ;fetch the byte
        out     52h,al          ;put the byte into both 1 and 2
        out     52h,al          ;write buffer bytes
        loop    ldcr
        mov     al,4ch          ;assert the figs command
        out     57h,al
        xor     al,al           ;assert the down direction to write
        out     56h,al
        mov     ax,7            ;do 8 write cycles
        out     56h,al
        mov     al,ah
        out     56h,al
        mov     al,22h          ;assert the wdat command
        out     57h,al
        mov     al,0ffh
        out     56h,al
        out     56h,al
exit:   ret
stgbm:  mov     ax,word ptr gbmskl
        out     54h,al
        mov     al,ah
        out     55h,al
        ret
gtext   endp
cseg    ends
        end
```

Define and Position the Cursor

There are two routines in the following example. One sets the cursor type to no cursor, block, underscore, or block and underscore. It then sets up the current cursor location and calls the second routine. The second routine accepts new coordinates for the cursor and moves the cursor to the new location.

Example of Defining and Positioning the Cursor

```
;*********************************************************************
;                                                                    *
;       p r o c e d u r e       g s e t t y p                        *
;                                                                    *
;       purpose:        assert new cursor type                       *
;       entry:          dl bits determine cursor style               *
;                       (if no bits set, no cursor is displayed)     *
;                          bit 0 = block                             *
;                          bit 1 = undefined                         *
;                          bit 2 = undefined                         *
;                          bit 3 = underscore                        *
;*********************************************************************
;
dseg    segment byte    public  'datasg'
extrn   curl0:byte,curl2:byte,gbmod:byte
block   db      0,0,0,0,0,0,0,0,0,0
cdis    db      0
lastcl  dw      0
        dw      0
ocurs   db      0
newcl   dw      0
        dw      0
ncurs   db      0
unders  db      0ffh,0ffh,0ffh,0ffh,0ffh,0ffh,0ffh,0ffh,0,0ffh
userd   db      0,0,0,0,0,0,0,0,0,0
dseg            ends
;
;Implements the new cursor type to be displayed. The current
;cursor type and location must become the old type and location.
;The new type becomes whatever is in dl.  This routine will fetch
;the previous cursor type out of NCURS and put it into OCURS and
;then put the new cursor type into NCURS.  The previous cursor
;coordinates are fetched and put into ax and bx.  A branch to
;GSETPOS then erases the old cursor and displays the new cursor.
;Cursor type bits are not exclusive of each other.  A cursor can
;be both an underscore and a block.
```

```
;
;  dl= 0 = turns the cursor display off
;      1 = displays the insert cursor (full block)
;      8 = displays the overwrite cursor (underscore)
;      9 = displays a simultaneous underscore and block cursor
;
cseg    segment byte    public  'codesg'
extrn   mode:near
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
        public  gsettyp
;
gsettyp         proc    near
        mov     al,byte ptr ncurs       ;current cursor becomes
        mov     byte ptr ocurs,al       ;  old cursor type
        mov     byte ptr ncurs,dl       ;pick up new cursor type
        mov     ax,word ptr newcl       ;pick up current x and y
        mov     bx,word ptr newcl+2     ;  cursor coordinates
        jmp     pos                     ;branch to assert new cursor
gsettyp endp                            ;  type in old location
;
;*******************************************************************
;                                                                  *
;       p r o c e d u r e       g s e t p o s                      *
;                                                                  *
;       purpose:        assert new cursor position                 *
;       entry:          ax = x location                            *
;                       bx = y location                            *
;                                                                  *
;*******************************************************************
;
                public  gsetpos
gsetpos proc    near

;Display the cursor.  Cursor type was defined by GSETTYP.  The
;cursor type is stored in NCURS.  Fetch the type and address of the
;previous cursor and put it into OCURS and also into lastcl and
;lastcl+2.  If a cursor is currently being displayed, erase it.  If
;there is a new cursor to display, write it (or them) to the screen.
;A cursor may be a block or an underscore or both.
;
;The x and y coordinates of the cursor are converted into an address
;that the GDC can use.  Either the left or the right half of the text
;mask is enabled, depending on whether the x is even or odd. The
;write operation itself takes places in complement mode so that no
;information on the screen is lost or obscured but only inverted in
;value.  In order to ensure that all planes are inverted, a 0f0h is
;loaded into the Foreground/Background Register and all planes are
;write enabled.  The cursor is written to the screen in two separate
;writes because the write buffer is eight, not ten, words long.
```

```
;
;Move current cursor type and location to previous type and location.
;
        mov     cl,byte ptr ncurs       ;move current cursor type
        mov     byte ptr ocurs,cl       ;  into old cursor type
pos:    cld
        mov     cx,word ptr newcl       ;move current cursor
        mov     word ptr lastcl,cx      ;  location into old cursor
        mov     cx,word ptr newcl+2     ;  location
        mov     word ptr lastcl+2,cx
        mov     word ptr newcl,ax       ;save new cursor coordinates
        mov     word ptr newcl+2,bx     ;in new cursor location
;
;Before doing anything to the graphics option we need to make sure
;that the option isn't already in use.  Assert a harmless command
;into the FIFO and wait for the GDC to execute it.
;
        call    not_busy
;
;Set up the graphics option.  Put the Graphics Option in complement
;and text modes with all planes enabled.  Assert fgbg and text mask.
;Calculate the write address and store in curl0,1.
;
        mov     ax,10efh                ;address the ALU/PS
        out     53h,al                  ;  register
        mov     al,ah                   ;set complement mode with
        out     51h,al                  ;  all planes enabled
;
;Assert text mode with read disabled.
;
        mov     al,byte ptr gbmod       ;get mode shadow byte
        and     al,0fdh                 ;set text mode
        or      al,10h                  ;set write enabled mode
        cmp     al,byte ptr gbmod       ;is mode already asserted
        jz      gspos0                  ;  this way? If yes, jump
        mov     byte ptr gbmod,al       ;update the mode register
        call    mode
gspos0: mov     al,0f7h                 ;set Foreground/Background
        out     53h,al                  ;  register to invert data
        mov     al,0f0h
        out     51h,al
;
;Is a cursor currently being displayed?  If cdis<>0, then yes. Any
;current cursor will have to be erased before we display a new one.
;
gsp01:  test    byte ptr cdis,1         ;if no old cursor to erase,
        jz      gspos2                  ;  just display old one
```

```
;
;This part will erase the old cursor.
;
        mov     byte ptr cdis,0         ;set no cursor on screen
        mov     dh,byte ptr lastcl      ;fetch x and y, put into dx,
        mov     dl,byte ptr lastcl+2    ;  and call dx2curl
        call    asmask                  ;assert the mask registers
        call    dx2curl                 ;turn dx into GDC address
        test    byte ptr ocurs,8        ;underline?
        jz      gspos1                  ;jump if not
        mov     si,offset unders        ;erase the underline
        call    discurs                 ;do the write
gspos1: test    byte ptr ocurs,1        ;block?
        jz      gspos2                  ;jump if not
        call    not_busy          ;wait till done erasing underline
        mov     si,offset block         ;erase the block
        call    discurs                 ;do the write
;
;Write the new cursor out to the screen.
;
gspos2: cmp     byte ptr ncurs,0        ;write a new cursor?
        jz      gspos5                  ;jump if not
        mov     dh,byte ptr newcl       ;fetch coordinates of
        mov     dl,byte ptr newcl+2     ;  new cursor
        call    not_busy                ;wait for erase to finish
        call    asmask                  ;assert the mask registers
        call    dx2curl
        test    byte ptr ncurs,8        ;underscore cursor?
        jz      gspos3                  ;jump if not
        mov     si,offset unders        ;set up for underline cursor
        call    discurs                 ;do the write
gspos3: test    byte ptr ncurs,1        ;block cursor?
        jz      gspos4                  ;jump if not
        call    not_busy                ;wait for any write to finish
        mov     si,offset block         ;set up for block cursor
        call    discurs                 ;do the write.
gspos4: or      byte ptr cdis,1         ;set cursor displayed flag
gspos5: call    not_busy
        ret
;
;Enable one byte of the text mask.
;
asmask: mov     ax,00ffh                ;set up the text mask
        test    dh,1                    ;write to the right byte?
        jz      ritc4                   ;jump if yes
        mov     ax,0ff00h
ritc4:  out     55h,al                  ;issue low byte of mask
        mov     al,ah
        out     54h,al                  ;issue high byte of mask
        ret
```

```
;
;Display the cursor.
;
;Assume that the option is already set up in text mode, complement
;write and that the appropriate text mask is already set.  The
;address of the cursor pattern is loaded into the si.
;
discurs:
        mov     al,0feh         ;select the write buffer and clear
        out     53h,al          ;  the write buffer counter
        out     51h,al
        lodsb
        out     52h,al          ;feed the same byte to both halves
        out     52h,al          ;  of the word to be written
        lodsb
        out     52h,al          ;feed the same byte to both halves
        out     52h,al          ;  of the word to be written
        mov     al,0feh         ;select the write buffer and clear
        out     53h,al          ;  the write buffer counter
        out     51h,al
        mov     al,49h          ;assert the position to write
        out     57h,al
        mov     ax,word ptr curl0
        out     56h,al
        mov     al,ah
        out     56h,al
        mov     al,4ah          ;issue the GDC mask command to
        out     57h,al          ;  set all GDC mask bits
        mov     al,0ffh
        out     56h,al
        out     56h,al
        mov     al,4ch          ;program a write of ten scans
        out     57h,al          ;  first do two scans, then eight
        xor     al,al
        out     56h,al
        mov     al,1
        out     56h,al
        xor     al,al
        out     56h,al
        mov     al,22h          ;start the write
        out     57h,al
        mov     al,0ffh
        out     56h,al
        out     56h,al
        call    not_busy        ;wait for first two lines to finish
        mov     cx,8            ;then write the next 8 scans
```

```
ritc6:  lodsb                   ;fetch the cursor shape
        out     52h,al          ;feed the same byte to both halves
        out     52h,al          ;  of the word
        loop    ritc6
        mov     al,4ch          ;program a write of eight scans
        out     57h,al
        xor     al,al
        out     56h,al
        mov     al,7
        out     56h,al
        xor     al,al
        out     56h,al
        mov     al,22h          ;start the write
        out     57h,al
        mov     al,0ffh
        out     56h,al
        out     56h,al
        ret
;
;Turn dh and dl into a word address (dl is the line and  dh
;is the column).  Store the result in word ptr curl0.  Start with
;turning dl (line) into a word address.
;
;       Word address = dl * number of words/line * 10
;
;Turn dh (column) into a word address.
;
;       Word address = dh/2
;
;Combine the two.  This gives the curl0 address to be asserted to
;the GDC.
;
dx2curl:
        mov     al,dh           ;store the column count
        mov     cl,5            ;medium resolution = 32 words/line
        test    byte ptr gbmod,1    ;is it high resolution?
        jz      ritc5           ;jump if not
        inc     cl              ;high resolution = 64 words/line
ritc5:  xor     dh,dh
        shl     dx,cl
        mov     bx,dx           ;multiply dx by ten
        mov     cl,3
        shl     bx,1
        shl     dx,cl
        add     dx,bx           ;this is the row address
        shr     al,1            ;this is the column number
```

```
        xor     ah,ah
        add     dx,ax               ;this is the combined row and
        mov     word ptr curl0,dx   ;column address
        ret
;
;This is a quicker version of GDC_NOT_BUSY.  We don't waste time on
;some of the normal checks and things that GDC_NOT_BUSY does due to
;the need to move as quickly as possible on the cursor erase/write
;routines. This routine does the same sort of things. A harmless
;command is issued to the GDC. If the GDC is in the process of
;performing some other command, the WDAT we just issued
;will stay in the GDC's command FIFO until such time as the GDC can
;get to it. If the FIFO empty bit is set, the GDC executed the
;WDAT command and must be finished with any previous operations
;programmed into it.
;
not_busy:
        mov     ax,422h         ;assert a WDAT
        out     57h,al
busy:   in      al,56h          ;wait for FIFO empty bit
        test    ah,al
        jz      busy
        ret
gsetpos endp
cseg    ends
        end
```

Write a Text String

The example in this section writes a string of ASCII text starting at a specified location and using a specified scale factor. It uses the vector write routine from Chapter 8 to form each character.

Example of Writing a Text String

```
;*********************************************************************
;                                                                    *
;       p r o c e d u r e   v e c t o r _ t e x t                    *
;                                                                    *
;                                                                    *
;       entry:     cx = string length                                *
;                  text = pointer to externally defined array of     *
;                         ASCII characters                           *
;                  scale = character scale                           *
;                  xinit = starting  x location                      *
;                  yinit = starting  y location                      *
;*********************************************************************
```

```
;
cseg    segment byte    public  'codesg'
        extrn   imode:near,pattern_mult:near,pattern_register:near
        extrn   vector:near
        public  vector_text
        assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
;
vector_text     proc    near
        or      byte ptr gbmod,082h
        call    imode                   ;ensure we're in graphics mode
        mov     al,4ah
        out     57h,al
        mov     al,0ffh
        out     56h,al
        out     56h,al                  ;enable GDC mask data write
        xor     al,al                   ;enable all option mask writes
        out     55h,al
        out     54h,al
        mov     bl,1
        call    pattern_mult            ;set pattern multiplier
        mov     bl,0ffh
        call    pattern_register        ;set pattern register
        mov     ax,word ptr xinit           ;get initial x
        mov     word ptr xad,ax             ;save it
        mov     ax,word ptr yinit           ;get initial y
        mov     word ptr yad,ax             ;save it
        mov     si,offset text
do_string:
        lodsb                           ;get character
        push    si
        push    cx
        call    display_character           ;display it
        mov     ax,8
        mov     cl,byte ptr scale           ;move over by cell value
        mul     cx
        add     word ptr xad,ax
        pop     cx
        pop     si
        loop    do_string                   ;loop until done
        ret
display_character:
        cmp     al,07fh                 ;make sure we're in font table
        jbe     char_cont_1             ;continue if we are
        ret
char_cont_1:
        cmp     al,20h                  ;check if we can print character
        ja      char_cont               ;continue if we can
        ret
```

```
char_cont:
        xor     ah,ah                   ;clear high byte
        shl     ax,1                    ;make it a word pointer
        mov     si,ax
        mov     si,font_table[si]              ;point si to font info
get_next_stroke:
        mov     ax,word ptr xad
        mov     word ptr xinit,ax
        mov     ax,word ptr yad
        mov     word ptr yinit,ax
        lodsb                                  ;get stroke info
        cmp     al,endc                        ;end of character ?
        jnz     cont_1                         ;continue if not
        ret
cont_1: mov     bx,ax
        and     ax,0fh                         ;mask to y value
        test    al,08h                         ;negative ?
        jz      ct
        or      ax,0fff0h                      ;sign extend
ct:     mov     cl,byte ptr scale
        xor     ch,ch
        push    cx
        imul    cx                             ;multiply by scale value
        sub     word ptr yinit,ax              ;subtract to y offset
        and     bx,0f0h                        ;mask to x value
        shr     bx,1                           ;shift to four least
        shr     bx,1                           ;  significant bits
        shr     bx,1
        shr     bx,1
        test    bl,08h                         ;negative ?
        jz      ct1
        or      bx,0fff0h                      ;sign extend
ct1:    mov     ax,bx
        pop     cx                             ;recover scale
        imul    cx                             ;multiply by scale value
        add     word ptr xinit,ax              ;add to x offset
```

```
next_stroke:
        mov     ax,word ptr xad         ;set up xy offsets
        mov     word ptr xfinal,ax
        mov     ax,word ptr yad
        mov     word ptr yfinal,ax
        lodsb                           ;get stroke byte
        cmp     al,endc                 ;end of character ?
        jz      display_char_exit       ;yes then leave
        cmp     al,endv                 ;dark vector ?
        jz      get_next_stroke         ;yes, begin again
        mov     bx,ax
        and     ax,0fh                  ;mask to y value
        test    al,08h                  ;negative
        jz      ct2
        or      ax,0fff0h               ;sign extend
ct2:    mov     cl,byte ptr scale       ;get scale information
        xor     ch,ch
        push    cx
        imul    cx                      ;multiply by scale
        sub     word ptr yfinal,ax      ;subtract to y offset
        and     bx,0f0h                 ;mask to x value
        shr     bx,1                    ;shift to four least
        shr     bx,1                    ;  significant bits
        shr     bx,1
        shr     bx,1
        test    bl,08h                  ;negative ?
        jz      ct3
        or      bx,0fff0h               ;sign extend
ct3:    mov     ax,bx
        pop     cx                      ;recover scale
        imul    cx                      ;multiply by scale
        add     word ptr xfinal,ax      ;add to x offset
        push    si                      ;save index to font info
        call    vector                  ;draw stroke
        pop     si                      ;recover font index
        mov     ax,word ptr xfinal      ;end of stroke becomes
        mov     word ptr xinit,ax       ;  beginning of next stroke
        mov     ax,word ptr yfinal
        mov     word ptr yinit,ax
        jmp     next_stroke
display_char_exit:
        ret
vector_text     endp
;
cseg    ends
dseg    segment byte    public  'datasg'
extrn   gbmod:byte,xinit:word,yinit:word,xfinal:word,yfinal:word
extrn   xad:word,yad:word,text:byte
public  scale
```

```
;
;*******************************************************************
;*                                                                 *
;*                    stroke font character set                    *
;*                                                                 *
;*******************************************************************
;
;The following tables contain vertex data for a stroked character
;set.  The x and y coordinate information is represented by 4-bit,
;2s-complement numbers in the range of + or - 7.  The x and y bit
;positions are as follows:
;
;       bit     7 6 5 4 3 2 1 0
;               !     ! !     !
;                \   /   \   /
;                  x       y
;
;End of character is represented by the value x = -8, y = -8.
;The dark vector is represented by x = -8, y = 0.
;
;ASCII characters are mapped into the positive quadrant, with the
;origin at the lower left corner of an upper case character.
;
endc            equ     10001000b       ;end of character
endv            equ     10000000b       ;last vector of polyline
;
font_table      dw      offset  font_00
                dw      offset  font_01
                dw      offset  font_02
                dw      offset  font_03
                dw      offset  font_04
                dw      offset  font_05
                dw      offset  font_06
                dw      offset  font_07
                dw      offset  font_08
                dw      offset  font_09
                dw      offset  font_0a
                dw      offset  font_0b
                dw      offset  font_0c
                dw      offset  font_0d
                dw      offset  font_0e
                dw      offset  font_0f
                dw      offset  font_10
                dw      offset  font_11
                dw      offset  font_12
                dw      offset  font_13
                dw      offset  font_14
                dw      offset  font_15
```

```
        dw      offset  font_16
        dw      offset  font_17
        dw      offset  font_18
        dw      offset  font_19
        dw      offset  font_1a
        dw      offset  font_1b
        dw      offset  font_1c
        dw      offset  font_1d
        dw      offset  font_1e
        dw      offset  font_1f
        dw      offset  font_20     ;space
        dw      offset  font_21     ;!
        dw      offset  font_22
        dw      offset  font_23
        dw      offset  font_24
        dw      offset  font_25
        dw      offset  font_26
        dw      offset  font_27
        dw      offset  font_28
        dw      offset  font_29
        dw      offset  font_2a
        dw      offset  font_2b
        dw      offset  font_2c
        dw      offset  font_2d
        dw      offset  font_2e
        dw      offset  font_2f
        dw      offset  font_30
        dw      offset  font_31
        dw      offset  font_32
        dw      offset  font_33
        dw      offset  font_34
        dw      offset  font_35
        dw      offset  font_36
        dw      offset  font_37
        dw      offset  font_38
        dw      offset  font_39
        dw      offset  font_3a
        dw      offset  font_3b
        dw      offset  font_3c
        dw      offset  font_3d
        dw      offset  font_3e
        dw      offset  font_3f
        dw      offset  font_40
        dw      offset  font_41
        dw      offset  font_42
        dw      offset  font_43
```

```
dw      offset  font_44
dw      offset  font_45
dw      offset  font_46
dw      offset  font_47
dw      offset  font_48
dw      offset  font_49
dw      offset  font_4a
dw      offset  font_4b
dw      offset  font_4c
dw      offset  font_4d
dw      offset  font_4e
dw      offset  font_4f
dw      offset  font_50
dw      offset  font_51
dw      offset  font_52
dw      offset  font_53
dw      offset  font_54
dw      offset  font_55
dw      offset  font_56
dw      offset  font_57
dw      offset  font_58
dw      offset  font_59
dw      offset  font_5a
dw      offset  font_5b
dw      offset  font_5c
dw      offset  font_5d
dw      offset  font_5e
dw      offset  font_5f
dw      offset  font_60
dw      offset  font_61
dw      offset  font_62
dw      offset  font_63
dw      offset  font_64
dw      offset  font_65
dw      offset  font_66
dw      offset  font_67
dw      offset  font_68
dw      offset  font_69
dw      offset  font_6a
dw      offset  font_6b
dw      offset  font_6c
dw      offset  font_6d
dw      offset  font_6e
dw      offset  font_6f
dw      offset  font_70
dw      offset  font_71
dw      offset  font_72
dw      offset  font_73
```

```
                dw      offset  font_74
                dw      offset  font_75
                dw      offset  font_76
                dw      offset  font_77
                dw      offset  font_78
                dw      offset  font_79
                dw      offset  font_7a
                dw      offset  font_7b
                dw      offset  font_7c
                dw      offset  font_7d
                dw      offset  font_7e
                dw      offset  font_7f
;
font_00         db      endc
font_01         db      endc
font_02         db      endc
font_03         db      endc
font_04         db      endc
font_05         db      endc
font_06         db      endc
font_07         db      endc
font_08         db      endc
font_09         db      endc
font_0a         db      endc
font_0b         db      endc
font_0c         db      endc
font_0d         db      endc
font_0e         db      endc
font_0f         db      endc
font_10         db      endc
font_11         db      endc
font_12         db      endc
font_13         db      endc
font_14         db      endc
font_15         db      endc
font_16         db      endc
font_17         db      endc
font_18         db      endc
font_19         db      endc
font_1a         db      endc
font_1b         db      endc
font_1c         db      endc
font_1d         db      endc
font_1e         db      endc
font_1f         db      endc
font_20         db      endc                    ;space
```

```
font_21         db 20h,21h,endv,23h,26h,endc
font_22         db 24h,26h,endv,54h,56h,endc
font_23         db 20h,26h,endv,40h,46h,endv,04h,64h,endv,02h,62h
                db endc
font_24         db 2fh,27h,endv,01h,10h,30h,41h,42h,33h,13h,04h,05h
                db 16h,36h,045h,endc
font_25         db 11h,55h,endv,14h,15h,25h,24h,14h,endv,41h,51h,52h
                db 42h,41h,endc
font_26         db 50h,14h,15h,26h,36h,45h,44h,11h,10h,30h,52h,endc
font_27         db 34h,36h,endc
font_28         db 4eh,11h,14h,47h,endc
font_29         db 0eh,31h,34h,07h,endc
font_2a         db 30h,36h,endv,11h,55h,endv,15h,51h,endv,03h,63h
                db endc
font_2b         db 30h,36h,endv,03h,63h,endc
font_2c         db 11h,20h,2fh,0dh,endc
font_2d         db 03h,63h,endc
font_2e         db 00h,01h,11h,10h,00h,endc
font_2f         db 00h,01h,45h,46h,endc
font_30         db 01h,05h,16h,36h,45h,41h,30h,10h,01h,endc
font_31         db 04h,26h,20h,endv,00h,040h,endc
font_32         db 05h,16h,36h,45h,44h,00h,40h,041h,endc
font_33         db 05h,16h,36h,45h,44h,33h,42h,41h,30h,10h,01h,endv
                db 13h,033h,endc
font_34         db 06h,03h,043h,endv,20h,026h,endc
font_35         db 01h,10h,30h,41h,42h,33h,03h,06h,046h,endc
font_36         db 02h,13h,33h,42h,41h,30h,10h,01h,05h,16h,36h,045h
                db endc
font_37         db 06h,46h,44h,00h,endc
font_38         db 01h,02h,13h,04h,05h,16h,36h,45h,44h,33h,42h,41h
                db 30h,10h,01h,endv,13h,023h,endc
font_39         db 01h,10h,30h,41h,45h,36h,16h,05h,04h,13h,33h,044h
                db endc
font_3a         db 15h,25h,24h,14h,15h,endv,12h,22h,21h,11h,12h
                db endc
font_3b         db 15h,25h,24h,14h,15h,endv,21h,11h,12h,22h,20h,1fh
                db endc
font_3c         db 30h,03h,036h,endc
font_3d         db 02h,042h,endv,04h,044h,endc
font_3e         db 10h,43h,16h,endc
font_3f         db 06h,17h,37h,46h,45h,34h,24h,022h,endv,21h,020h
                db endc
font_40         db 50h,10h,01h,06h,17h,57h,66h,63h,52h,32h,23h,24h
                db 35h,55h,064h,endc
font_41         db 00h,04h,26h,44h,040h,endv,03h,043h,endc
font_42         db 00h,06h,36h,45h,44h,33h,42h,41h,30h,00h,endv
                db 03h,033h,endc
```

```
font_43         db 45h,36h,16h,05h,01h,10h,30h,041h,endc
font_44         db 00h,06h,36h,45h,41h,30h,00h,endc
font_45         db 40h,00h,06h,046h,endv,03h,023h,endc
font_46         db 00h,06h,046h,endv,03h,023h,endc
font_47         db 45h,36h,16h,05h,01h,10h,30h,41h,43h,023h,endc
font_48         db 00h,06h,endv,03h,043h,endv,40h,046h,endc
font_49         db 10h,030h,endv,20h,026h,endv,16h,036h,endc
font_4a         db 01h,10h,30h,41h,046h,endc
font_4b         db 00h,06h,endv,02h,046h,endv,13h,040h,endc
font_4c         db 40h,00h,06h,endc
font_4d         db 00h,06h,24h,46h,040h,endc
font_4e         db 00h,06h,endv,05h,041h,endv,40h,046h,endc
font_4f         db 01h,05h,16h,36h,45h,41h,30h,10h,01h,endc
font_50         db 00h,06h,36h,45h,44h,33h,03h,endc
font_51         db 12h,30h,10h,01h,05h,16h,36h,45h,41h,30h,endc
font_52         db 00h,06h,36h,45h,44h,33h,03h,endv,13h,040h,endc
font_53         db 01h,10h,30h,41h,42h,33h,13h,04h,05h,16h,36h
                db 045h,endc
font_54         db 06h,046h,endv,20h,026h,endc
font_55         db 06h,01h,10h,30h,41h,046h,endc
font_56         db 06h,02h,20h,42h,046h,endc
font_57         db 06h,00h,22h,40h,046h,endc
font_58         db 00h,01h,45h,046h,endv,40h,41h,05h,06h,endc
font_59         db 06h,24h,020h,endv,24h,46h,endc
font_5a         db 06h,46h,45h,01h,00h,40h,endc
font_5b         db 37h,17h,1fh,3fh,endc
font_5c         db 06h,05h,41h,40h,endc
font_5d         db 17h,37h,3fh,2fh,endc
font_5e         db 04h,26h,044h,endc
font_5f         db 0fh,07fh,endc
font_60         db 54h,36h,endc
font_61         db 40h,43h,34h,14h,03h,01h,10h,30h,041h,endc
font_62         db 06h,01h,10h,30h,41h,43h,34h,14h,03h,endc
font_63         db 41h,30h,10h,01h,03h,14h,34h,043h,endc
font_64         db 46h,41h,30h,10h,01h,03h,14h,34h,43h,endc
font_65         db 41h,30h,10h,01h,03h,14h,34h,43h,42h,02h,endc
font_66         db 20h,25h,36h,46h,55h,endv,03h,43h,endc
font_67         db 41h,30h,10h,01h,03h,14h,34h,43h,4fh,3eh,1eh
                db 0fh,endc
```

```
font_68         db 00h,06h,endv,03h,14h,34h,43h,40h,endc
font_69         db 20h,23h,endv,25h,26h,endc
font_6a         db 46h,45h,endv,43h,4fh,3eh,1eh,0fh,endc
font_6b         db 00h,06h,endv,01h,34h,endv,12h,30h,endc
font_6c         db 20h,26h,endc
font_6d         db 00h,04h,endv,03h,14h,23h,34h,43h,40h,endc
font_6e         db 00h,04h,endv,03h,14h,34h,43h,40h,endc
font_6f         db 01h,03h,14h,34h,43h,41h,30h,10h,01h,endc
font_70         db 04h,0eh,endv,01h,10h,30h,41h,43h,34h,14h
                db 03h,endc
font_71         db 41h,30h,10h,01h,03h,14h,34h,43h,endv,44h
                db 4eh,endc
font_72         db 00h,04h,endv,03h,14h,34h,endc
font_73         db 01h,10h,30h,41h,32h,12h,03h,14h,34h
                db 43h,endc
font_74         db 04h,44h,endv,26h,21h,30h,40h,51h,endc
font_75         db 04h,01h,10h,30h,41h,endv,44h,40h,endc
font_76         db 04h,02h,20h,42h,44h,endc
font_77         db 04h,00h,22h,40h,44h,endc
font_78         db 00h,44h,endv,04h,40h,endc
font_79         db 04h,01h,10h,30h,41h,endv,44h,4fh,3eh,1eh
                db 0fh,endc
font_7a         db 04h,44h,00h,40h,endc
font_7b         db 40h,11h,32h,03h,34h,15h,46h,endc
font_7c         db 20h,23h,endv,25h,27h,endc
font_7d         db 00h,31h,12h,43h,14h,35h,06h,endc
font_7e         db 06h,27h,46h,67h,endc
font_7f         db 07,77,endc

scale   db      0
dseg    ends
        end
```

10

Read Operations

The Read Process

Programming a read operation is simpler than programming a write operation. From the Graphics Option's point of view, only the Mode and ALU/PS registers need to be programmed. There is no need to involve the Foreground/Background Register, Text Mask, Write Buffer, or the Pattern Generator. GDC reads are programmed much like text writes except for the action command which in this case is RDAT. When reading data from the bitmap, only one plane can be active at any one time. Therefore, it can take four times as long to read back data as it did to write it in the first place.

Read the Entire Bitmap

In the following example, the entire bitmap, one plane at a time, is read and written into a 64K byte buffer in memory. This example compliments the example of displaying data from memory found in Chapter 7.

Example of Reading the Entire Bitmap

```
;*******************************************************************
;                                                                  *
;       p r o c e d u r e    r e d v i d                           *
;                                                                  *
;       purpose:        this routine will read out all of display  *
;                       memory, one plane at a time, then store    *
;                       that data in a 64k buffer in motherboard   *
;                       memory.                                    *
;       entry:                                                     *
;       exit:                                                      *
;       register usage: ax,cx,di                                   *
;*******************************************************************
;
dseg    segment byte    public 'datasg'
extrn   num_planes:byte,gbmod:byte,nmredl:word,gtemp:word,curl0:word
dseg ends
vidseg  segment byte    public  'vseg'
        public  viddata
viddata db      0ffffh dup (?)
vidseg  ends
cseg segment byte  public 'codesg'
extrn   gdc_not_busy:near,alups:near,fgbg:near,init_option:near
extrn   mode:near
        assume cs:cseg,ds:dseg,es:dseg,ss:nothing
        public  redvid
;
redvid  proc    near
;
;Set up to enable reads.  The Graphics Option has to disable writes
;in the ALU/PS, enable a plane to be read in the Mode Register, and
;program the GDC to perform one plane's worth of reads.
;GDC programming consists of issuing a CURSOR command of 0, a mask
;of FFFFh, a FIGS command with a direction to the right and a read
;of an entire plane, and finally the RDAT command to start the read
;in motion.  Note that the GDC can't read in all 8000h words of a
;high resolution plane but it doesn't matter because not all 8000h
;words of a high resolution plane have useful information in them.
```

```
;
        cld                     ;clear the direction flag
        call    gdc_not_busy    ;make sure the GDC is not busy
        mov     al,0efh
        out     53h,al
        mov     al,0fh          ;disable all writes
        out     51h,al
        mov     ax,3fffh        ;assume high resolution read
        test    byte ptr gbmod,01 ;actually high resolution?
        jnz     rd1             ;jump if yes
        mov     ax,2000h        ;medium resolution no. of reads
rd1:    mov     word ptr nmredl,ax
;
;Blank the screen. This will let the GDC have 100% use of the time
;to read the screen in.
;
        mov     al,0ch          ;blank command
        out     57h,al
;
;Set up to transfer data as it is being read from the screen into
;the VIDSEG data segment.
;
        mov     ax,vidseg       ;set up the es register to point
        mov     es,ax           ;  to the video buffer
        mov     di,0            ;start at beginning of the buffer
        mov     cl,byte ptr num_planes ;init routine sets this byte
        xor     ch,ch           ;num_planes = 2 or 4
rd2:    mov     word ptr gtemp,cx       ;save plane count
        mov     al,0bfh                 ;address the mode register
        out     53h,al
        mov     al,byte ptr num_planes ;figure which plane to enable
        sub     al,cl
        shl     al,1                    ;shift to enable bits over 2
        shl     al,1
        mov     ah,byte ptr gbmod   ;mode byte = no graphics,
        and     ah,0e1h             ;  plane to read, write enable
        or      al,ah               ;combine with plane to read
        out     51h,al              ;assert new mode
        mov     al,49h              ;position the GDC cursor to
        out     57h,al              ;  top left
        xor     al,al
        out     56h,al
        out     56h,al
        mov     al,4ah              ;set all bits in GDC mask
        out     57h,al
        mov     al,0ffh
        out     56h,al
        out     56h,al
```

```
        mov     al,4ch                  ;assert the FIGS command
        out     57h,al
        mov     al,2                    ;direction is to the right
        out     56h,al
        mov     ax,word ptr nmredl      ;number of word reads to do
        out     56h,al
        mov     al,ah
        out     56h,al
        mov     al,0a0h                 ;start the read operation now
        out     57h,al
        mov     cx,word ptr nmredl      ;read in as they are ready.
        shl     cx,1                    ;bytes = 2 * words read
rd4:    in      al,56h                  ;byte ready to be read?
        test    al,1
        jz      rd4                     ;jump if not
        in      al,57h                  ;read the byte
        stosb                           ;store in vidseg
        loop    rd4
;
;We've finished reading all of the information out of that plane.
;If high resolution, increment di by a word because we were one
;word short of the entire 32k high resolution plane.  Recover the
;plane to read count and loop if not done.
;
        test    byte ptr gbmod,1        ;high resolution?
        jz      rd5                     ;jump if not
        stosw           ;dummy stos to keep no. reads=words/plane
rd5:    mov     cx,word ptr gtemp
        loop    rd2                     ;loop if more planes to be read
;
;We're done with the read.
;Restore video refresh and set the high/medium resolution flag byte
;at the end of vidseg so that when it is written back into the video
;we do it in the proper resolution.
;
        mov     al,0dh                  ;unblank the screen
        out     57h,al
        test    byte ptr gbmod,1        ;high res?
        jnz     rd6                     ;jump if yes
        xor     al,al           ;last byte = 0 for medium resolution
        jmp     rd7
rd6:    mov     al,0ffh         ;last byte = ff for high resolution
rd7:    mov     di,0ffffh               ;set the resolution flag
        mov     byte ptr es:[di],al
        mov     ax,dseg
        mov     es,ax                   ;restore es
        ret
redvid  endp
cseg    ends
        end
```

Pixel Write After a Read Operation

After a read operation has completed, the graphics option is temporarily unable to do a pixel write. (Word writes are not affected by preceding read operations.) However, the execution of a word write operation restores the option's ability to do pixel writes. Therefore, whenever you intend to do a pixel write after a read operation, you must first execute a word write. This will ensure that subsequent vectors, arcs, and pixels will be enabled.

The following code sequence will execute a word write operation that will not write anything into the bitmap. The code assumes that the GDC is not busy since it has just completed a read operation. It also assumes that this code is entered after all the required bytes have been read out of the FIFO buffer.

```
;*********************************************************************
;                                                                    *
;   p r o c e d u r e    w r i t e__a f t e r__r e a d               *
;                                                                    *
;   purpose:     Execute a no-op word write after read operation is  *
;                completed.                                          *
;                                                                    *
;*********************************************************************
;
cseg    segment byte    public  'codesg'
extrn   imode:near,alups:near
        public  write_after_read
        assume  cs:cseg,ds:dseg,es:nothing,ss:nothing
;
write_after_read        proc    near
        mov     al,0dh  ;sometimes the GDC will not accept the
        out     57h,al  ;  first command after a read - this command
                        ;  can safely be missed and serves to ensure
                        ;  that the FIFO buffer is cleared and
                        ;  pointing in the right direction
        xor     bl,bl   ;restore write enable replace mode to all
        call    alups   ;  planes in the ALU/PS Register
        mov     al,0ffh ;disable writes to all bits at the
        out     55h,al  ;  option's Mask Registers
        out     54h,al
        or      byte ptr gbmod,10h ;enable writes to Mode Register
        call    imode              ;it is already in word mode
        mov     al,4ch  ;unnecessary to assert cursor or mask since
        out     57h,al  ;  it doesn't matter where you write - the
        xor     al,al   ;  write is completely disabled anyway -
        out     56h,al  ;  just going through the word write
        out     56h,al  ;  operation will enable subsequent pixel
        out     56h,al  ;  writes
```

```
        mov     al,22h
        out     57h,al   ;execute the write operation
        ret
write_after_read         endp
cseg            ends
dseg    segment byte     public  'datasg'
extrn   gbmod:byte
dseg            ends
                end
```

11

Scroll Operations

Vertical Scrolling

The Scroll map controls the location of 64-word blocks of display memory on the video monitor. In medium resolution mode, this is two scan lines. In high resolution mode, this is one scan line. By redefining scan line locations in the Scroll Map, you effectively move 64 words of data into new screen locations.

All Scroll Map operations by the CPU start at location zero and increment by one with each succeeding CPU access. The CPU has no direct control over which Scroll Map location it is reading or writing. All input addresses are generated by an eight-bit index counter which is cleared to zero when the CPU first accesses the Scroll Map through the Indirect Register. There is no random access of a Scroll Map address.

Programming the Scroll Map involves a number of steps. First ensure that the GDC is not currently accessing the Scroll Map and that it won't be for some time (the beginning of a vertical retrace for example). Clearing bit 5 of the Mode Register to zero enables the Scroll Map for writing. Clearing bit 7 of the Indirect Register to zero selects the Scroll Map and clears the Scroll Map Counter to zero. Data can then be entered into the Scroll Map by writing to port 51h. When the programming operation is complete or just before the end of the vertical retrace period (whichever comes first) control of the Scroll Map addressing is returned to the GDC by setting bit 5 of the Mode Register to one.

If, for some reason, programming the Scroll Map requires more than one vertical retrace period, there is a way to break the operation up into two segments. A read of the Scroll Map increments the Scroll Map Index Counter just as though it were a write. You can therefore program the first half, wait for the next vertical retrace, read the first half and then finish the write of the last half.

Example of Vertical Scrolling One Scan Line

```
;*******************************************************************
;                                                                  *
;       p r o c e d u r e   v s c r o l l                          *
;                                                                  *
;       purpose:    move the current entire screen up one scan line *
;                                                                  *
;       entry:                                                     *
;       exit:                                                      *
;       register usage: ax,cx,di,si                                *
;*******************************************************************
;
dseg    segment byte public 'datasg'
extrn   scrltb:byte,gtemp1:byte,startl:byte,gbmod:byte ;see Example 3
dseg    ends
cseg    segment byte public 'codesg'
extrn   ascrol:near     ;defined in Example 3.
assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
public  vscroll
;
vscroll proc    near
;The scrollmap controls which 64 word display memory segment will be
;displayed on a particular screen line.  The scroll map will display
;on the top high resolution scan line the 64-word segment denoted by
;the data loaded into location 0.  If the data is a 0, the first
;64-word segment is accessed.  If the data is a 10, the 11th 64-word
;segment is displayed.  By simply rewriting the order of 64-word
;segments in the scroll map, the order in which they are displayed is
;correspondingly altered.  If the entire screen is to be scrolled up
;one line, the entire scroll map's contents are moved up one location.
;Data at address 1 is moved into address 0, data at address 2 is moved
;into address 1 and so on.  A split screen scroll can be accomplished
;by keeping the stationary part of the screen unchanged in the scroll
;map while loading the appropriate information into the moving window.
;If more than one scroll map location is loaded with the same data,
;the corresponding scan will be displayed multiple times on the screen.
```

```
;
;Note that the information in the bitmap hasn't been changed, only the
;location where the information is displayed on the video monitor has
;been changed.  When the lines that used to be off the bottom of the
;screen scroll up and become visible, they will have in them whatever
;had been written there before.  If a guaranteed clear scan line is
;desirable, the off-screen lines should be cleared with a write before
;the scroll takes place.
;
;In medium resolution, only the first 128 scroll map entries have
;meaning because while each medium resolution scan is 32 words long,
;each scroll map entry controls the location of 64 words of data.  In
;medium resolution, this is the same as two entire scans. The scroll
;map acts as if the most significant bit of the scroll map entries was
;always 0.  Loading an 80h into a location is the same as loading a 0.
;Loading an 81h is the equivalent to writing a 1.  The example shown
;below assumes a high resolution, 256 location, scrollmap.   Had it
;been medium resolution, only the first 128 scans would have been
;moved.  The other 128 scroll map locations still exist but are of no
;practical use to the programmer.  What this means to the applications
;programmer is that in medium resolution, after the scroll map has
;been initialized, the first 128 entries are treated as if they were
;the only scroll map locations in the table.
;
;Save the contents of the first section of the scroll table to be
;overwritten, fetch the data from however many scans away we want to
;scroll by, then move the contents of the table in a circular fashion.
;The last entry to be written is the scan we first saved.  After the
;shadow scroll table has been updated, it can then be asserted by a
;call to the "ascrol" routine in the "init_option" procedure.
;
        mov     si,offset scrltb     ;set the source of the data
        mov     di,si                ;set the destination of the data
        lodsb                        ;fetch the first scan
        mov     byte ptr gtemp1,al   ;  and save it
        mov     cx,255               ;move the other 255 scroll
        rep     movsw                ;  table bytes
        mov     al,byte ptr gtemp1   ;recover the first scan and put
        stosb                        ;  it into scan 256 location
        call    ascrol               ;assert updated scroll table
        ret                          ;  to scroll map
vscroll endp
cseg    ends
        end
```

Horizontal Scrolling

Not only can the video display be scrolled up and down but it can also be scrolled from side to side as well. The GDC can be programmed to start video action at an address other than location 0000. Using the PRAM command to specify the starting address of the display partition as 0002 will effectively shift the screen two words to the left. Since the screen display width is not the same as the number of words displayed on the line there is a section of memory that is unrefreshed. The data that scrolls off the screen leaves the refresh area and it will also be unrefreshed. To have the data rotate or wrap around the screen and be saved requires that data be read from the side about to go off the screen and be written to the side coming on to the screen. If the application is not rotating but simply moving old data out to make room for new information, the old image can be allowed to disappear into the unrefreshed area.

Although the specifications for the dynamic RAMs only guarantee a data persistence of two milliseconds, most of the chips will hold data much longer. Therefore, it is possible to completely rotate video memory off one side and back onto the other. However, applications considering using this characteristic should be aware of the time dependency and plan accordingly.

Example of Horizontal Scrolling One Word

```
;*********************************************************************
;                                                                    *
;       p r o c e d u r e   h s c r o l l                            *
;                                                                    *
;       purpose:        move the current entire screen to right      *
;                       or left a word address.                      *
;                                                                    *
;       entry:          if al = 0< move screen to the left.          *
;                       if al <> 0, move screen to the right.        *
;       exit:                                                        *
;       register usage: ax                                           *
;*********************************************************************
;
;The GDC is programmable (on a word boundary) as to where it starts
;displaying the screen. By incrementing or decrementing that starting
;address word we can redefine the starting address of each scan line
;and thereby give the appearance of horizontal scrolling. Assume that
;this start window display address is stored in the variables: startl
;and starth. Let's further assume that we want to limit scrolling to
;one scan line's worth.  Therefore, in high resolution we can never
;issue a starting address higher than 63; in medium resolution, none
;higher than 31.
```

```
;
dseg    segment byte public 'datasg'
extrn   scrltb:byte,gtemp1:byte,startl:byte,gbmod:byte
dseg    ends
cseg    segment byte public 'codesg'
extrn   gdc_not_busy:near
assume  cs:cseg,ds:dseg,es:dseg,ss:nothing
        public  hscroll
;
hscroll proc    near
        or      al,al                   ;move screen to left?
        jz      hs1                     ;jump if not
        dec     byte ptr startl         ;move screen to right
        jmp     hs2
hs1:    inc     byte ptr startl         ;move screen to left
hs2:    test    byte ptr gbmod,1        ;high res?
        jnz     hs3                     ;jump if yes
        and     byte ptr startl,31      ;limit to 1st medium
        jmp     hs4                     ;  resolution scan
hs3:    and     byte ptr startl,63      ;limit to 1st high
                                        ;  resolution scan
;
;Assert the new startl, starth to the GDC.  Assume that starth is
;always going to be 0 although this is not a necessity. Issue the
;PRAM command and rewrite the starting address of the GDC display
;window 0.
;
hs4:    call    gdc_not_busy        ;make sure the GDC is not busy
        mov     al,70h              ;issue the PRAM command
        out     57h,al
        mov     al,byte ptr startl  ;fetch low byte of the starting
        out     56h,al              ;  address
        xor     al,al               ;assume high byte is always 0
        out     56h,al
        ret
hscroll endp
cseg    ends
        end
```

12

Programming Notes

Shadow Areas

Most of the registers in the Graphics Option control more than one function. In addition, the registers are write-only areas. In order to change selected bits in a register while retaining the settings of the rest, shadow images of these registers should be kept in motherboard memory. The current contents of the registers can be determined from the shadow area, selected bits can be set or reset by ORing or ANDing into the shadow area, and the result can be written over the existing register.

Modifying the Color Map and the Scroll Map is also made easier using a shadow area in motherboard memory. These are relatively large areas and must be loaded during the time that the screen is inactive. It is more efficient to modify a shadow area in motherboard memory and then use a fast move routine to load the shadow area into the Map during some period of screen inactivity such as a vertical retrace.

Bitmap Refresh

The Graphics Option uses the same memory accesses that fill the screen with data to also refresh the memory. This means that if the screen display stops, the dynamic video memory will lose all the data that was being displayed within two milliseconds. In high resolution, it takes two scan lines to refresh the memory (approximately 125 microseconds). In medium resolution, it takes four scan lines to refresh the memory (approximately 250 microseconds). During vertical retrace (1.6 milliseconds) and horizontal retrace (10 microseconds) there is no refreshing of the memory. Under a worst case condition, you can stop the display for no more than two milliseconds minus four medium resolution scans minus vertical retrace or just about 150 microseconds. This is particularly important when programming the Scroll Map.

All write and read operations should take place during retrace time. Failure to limit reads and writes to retrace time will result in interference with the systematic refreshing of the dynamic RAMs as well as not displaying bitmap data during the read and write time. However, the GDC is usually programmed to limit its bitmap accesses to retrace time as part of the initialization process.

Software Reset

Whenever you reset the GDC by issuing the RESET command (a write of zero to port 57h), the Graphics Option must also be reset (a write of any data to port 50h). This is to synchronize the memory operations of the Graphics Option with the read/modify/write operations generated by the GDC. A reset of the Graphics Option by itself does not reset the GDC; they are separate reset operations.

Setting Up Clock Interrupts

With the Graphics Option installed on a Rainbow system, there are two 60 hz clocks available to the programmer—one from the motherboard and one from the Graphics Option. The motherboard clock is primarily used for a number of system purposes. However, you can intercept it providing that any routine that is inserted be kept short and compatible with the interrupt handler. Refer to the "init_option" procedure in Chapter 5 for a coding example of how to insert a new interrupt vector under MS-DOS.

Clock interrupt types and vector addresses differ depending on the model of the motherboard as well as whether the interrupt is for the Graphics Option or for the motherboard. (Refer to Table 3.)

It is important to keep all interrupt handlers short! Failure to do so can cause a system reset when the motherboard's MHFU line goes active. New interrupt handlers should restore any registers that are altered by the routine.

Table 3. Clock Interrupt Parameters

	MOTHERBOARD MODEL	INTERRUPT TYPE	VECTOR ADDRESS
GRAPHICS OPTION	A	22h	88h
	B	A2h	288h
MOTHERBOARD	A	20h	80h
	B	A0h	280h

LJ-0229

Operational Requirements

All data modifications to the bitmap are performed by hardware that is external to the GDC. In this environment, it is a requirement that the GDC be kept in graphics mode and be programmed to write in Replace mode. Also, the internal write data patterns of the GDC must be kept as all ones for the external hardware to function correctly. The external hardware isolates the GDC from the data in the bitmap such that the GDC is not aware of multiple planes or incoming data patterns.

Although it is possible to use the GDC's internal parameter RAM for soft character fonts and graphics characters, it is faster to use the option's Write Buffer. However, to operate in the GDC's native mode, the Write Buffer and Pattern Generator should be loaded with all ones, the Mode Register should be set to graphics mode, and the Foreground/Background Register should be loaded with F0h.

When the Graphics Option is in Word Mode, the GDC's mask register should be filled with all ones. This causes the GDC to go on to the next word after each pixel operation is done. The external hardware in the meantime, has taken care of all sixteen bits on all four planes while the GDC was taking care of only one pixel.

When the option is in Vector Mode, the GDC is also in graphics mode. The GDC's mask register is now set by the third byte of the cursor positioning command (CURS). The GDC will be able to tell the option which pixel to perform the write on but the option sets the mode, data and planes.

Set-Up Mode

When you press the SET-UP key on the keyboard, the system is placed in set-up mode. This, in turn, suspends any non-interrupt driven software and brings up a set-up screen if the monitor is displaying VT102 video output. If, however, the system is displaying graphics output, the fact that the system is in set-up mode will not be apparent to a user except for the lack of any further interaction with the graphics application that has been suspended. The set-up screen will not be displayed.

Users of applications that involve graphics output should be warned of this condition and cautioned not to press the SET-UP key when in graphics output mode. Note also that pressing the SET-UP key a second time will resume the execution of the suspended graphics software.

In either case, whether the set-up screen is displayed or not, set-up mode accepts any and all keyboard data until the SET-UP key is again pressed.

Timing Considerations

It is possible for an application to modify the associated hardware that is external to the GDC (registers, buffers, maps) before the GDC has completed all pending operations. If this should occur, the pending operations would then be influenced by the new values with unwanted results.

Before changing the values in the registers, buffers, and color map, you must ensure that the GDC has completed all pending operations. The "gdc_not_busy" subroutine in the "init_option" procedure in Chapter 5 is one method of checking that the GDC has completed all pending operations.

Part III

Reference Material

Contents

PART III

13

Option Registers, Buffers, and Maps

The Graphics Option uses a number of registers, buffers, and maps to generate graphic images and control the display of these images on a monochrome or color monitor. Detailed discussions of these areas may be found in Chapter 3 of this manual.

I/O Ports

The CPUs on the Rainbow system's motherboard use the following I/O ports to communicate with the Graphics Option:

Port	**Function**
50h	Graphics option software reset and resynchronization.
51h	Data input to area selected through port 53h.
52h	Data input to the Write Buffer.

53h	Area select input to Indirect Register.
54h	Input to low-order byte of Write Mask.
55h	Input to high-order byte of Write Mask.
56h	Parameter input to GDC - Status output from GDC.
57h	Command input to GDC - Data output from GDC.

Indirect Register

The Indirect Register is used to select one of eight areas to be written into.

Load Data: Write data byte to port 53h.

INDIRECT REGISTER

7	6	5	4	3	2	1	0

LJ-0230

where:

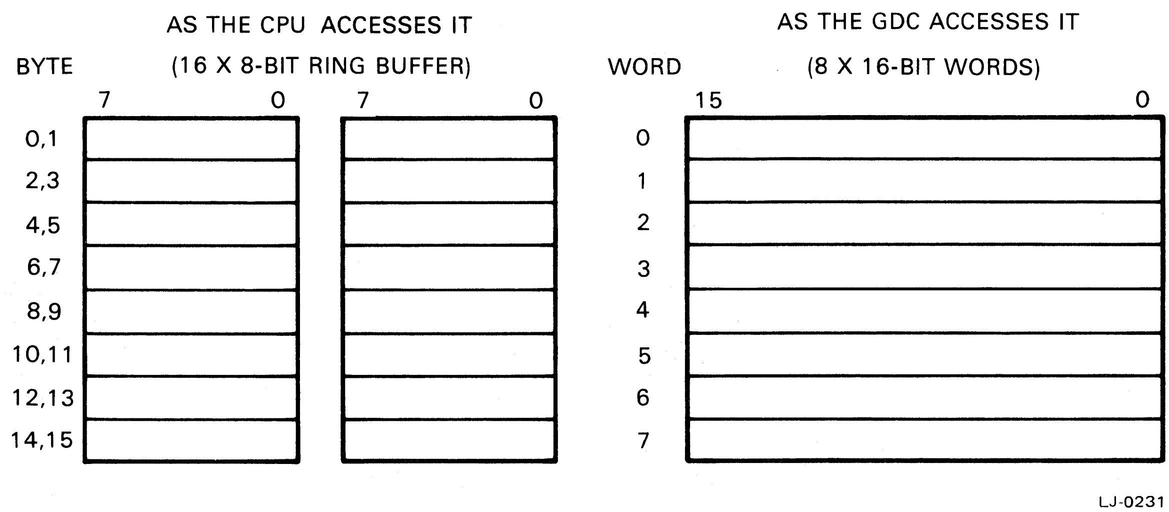
Data Byte	Active Bit	Function
FEh	0	selects the Write Buffer
FDh	1	selects the Pattern Multiplier. (Pattern Multiplier must always be loaded before the Pattern Register)
FBh	2	selects the Pattern Register.
F7h	3	selects the Foreground/Background Register.
EFh	4	selects the ALU/PS Register.
DFh	5	selects the Color Map and resets the Color Map Address Counter to zero.
BFh	6	selects the Graphics Option Mode Register.
7Fh	7	selects the Scroll Map and resets the Scroll Map Address Counter to zero.

NOTE
If more than one bit is set to zero, more than one area will be selected and the results of subsequent write operations will be unpredictable.

Write Buffer

The Write Buffer is the incoming data source when the Graphics Option is in Word Mode.

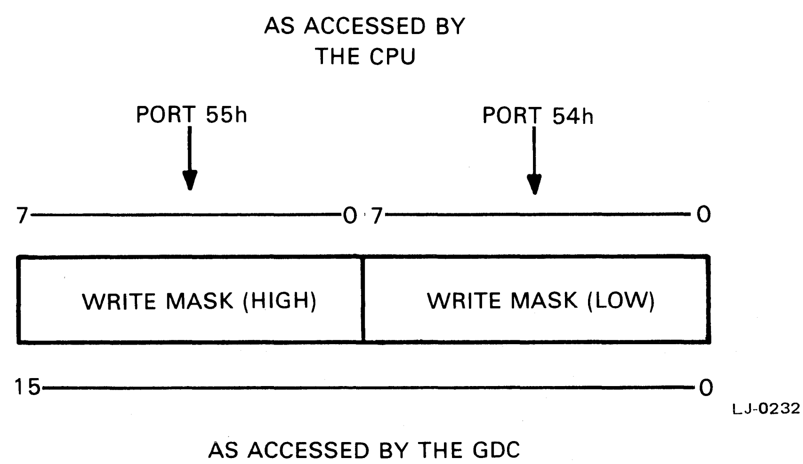
Select Area:	write FEh to port 53h
Clear Counter:	write any value to port 51h
Load Data:	write up to 16 bytes to port 52h



Write Mask Registers

The Write Mask Registers control the writing of individual bits in a bitmap word.

Select Area:	no selection required
Load Data:	write low-order data byte to port 54h write high-order data byte to port 55h



where:

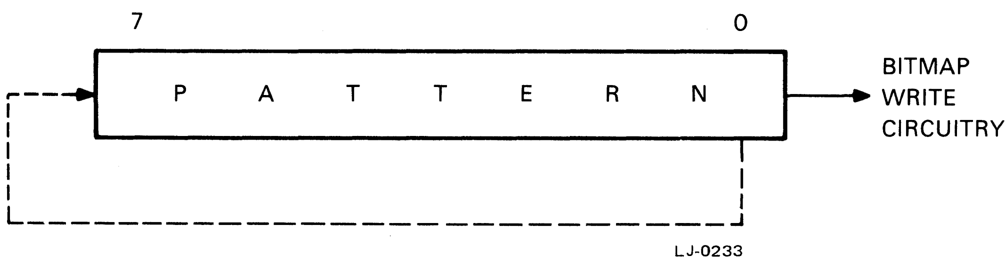
bit = 0	enables a write in the corresponding bit position of the word being displayed.
bit = 1	disables a write in the corresponding bit position of the word being displayed.

Pattern Register

The Pattern Register provides the incoming data when the Graphics Option is in Vector Mode.

Select Area: write FBh to port 53h

Load Data: write data byte to port 51h



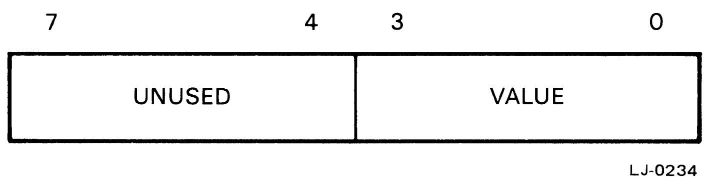
where:

Pattern is the pixel data to be displayed by the option when in Vector Mode.

Pattern Multiplier

The Pattern Multiplier controls the recirculating frequency of the bits in the Pattern Register.

Select Area:	write FDh to port 53h
Load Data:	write data byte to port 51h



where:

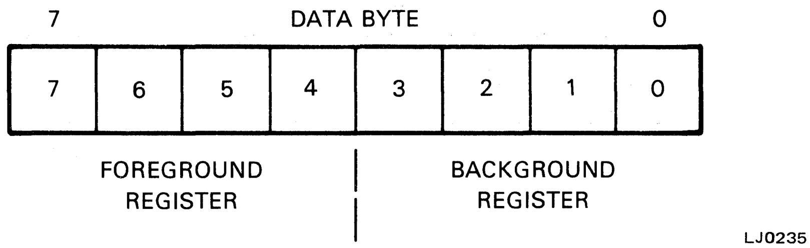
value — is a number in the range of 0 through 15 such that 16 minus this value is the factor that determines when the Pattern Register is shifted.

Foreground/Background Register

The Foreground/Background Register controls the bit/plane input to the bitmap.

Select Area: write F7h to port 53h

Load Data: write data byte to port 51h



where:

Bits

0-3 are the bits written to bitmap planes 0-3 respectively when the option is in REPLACE mode and the incoming data bit is a zero.

If the option is in OVERLAY or COMPLEMENT mode and the incoming data bit is a zero, there is no change to the bitmap value.

4-7 are the bits written to bitmap planes 4-7 respectively when the option is in REPLACE or OVERLAY mode and the incoming data bit is a one.

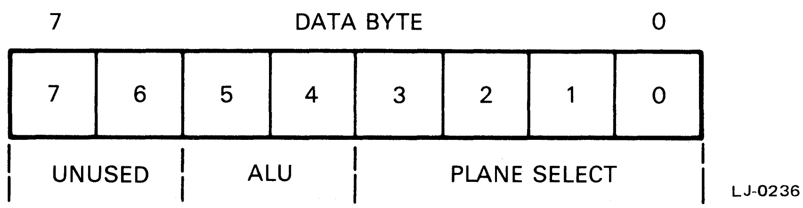
If the option is in COMPLEMENT mode and the incoming data bit is a one, the Foreground bit determines the action. If it is a one, the bitmap value is inverted; if it is a zero, the bitmap value is unchanged.

ALU/PS Register

The ALU/PS Register controls the logic used in writing to the bitmap and the inhibiting of writing to specified planes.

Select Area: write EFh to port 53h

Load Data: write data byte to port 51h



where:

Bit	Value	Function
0	0	enable writes to plane 0
	1	inhibit writes to plane 0
1	0	enable writes to plane
	1	inhibit writes to plane 1
2	0	enable writes to plane 2
	1	inhibit writes to plane 2
3	0	enable writes to plane 3
	1	inhibit writes to plane 3
5,4	00	place option in REPLACE mode
	01	place option in COMPLEMENT mode
	10	place option in OVERLAY mode
	11	Unused
7,6		Unused

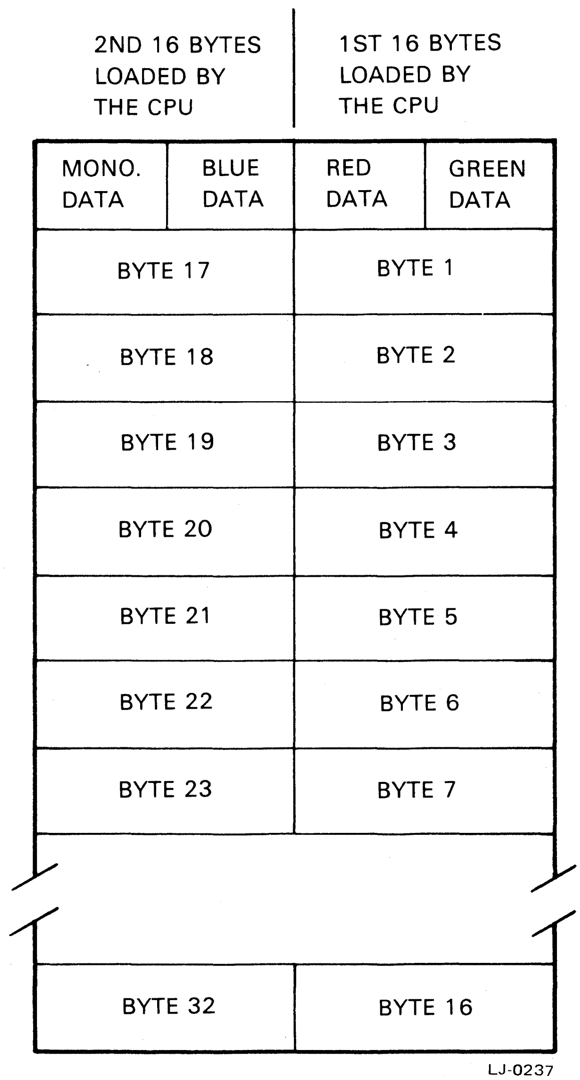
Color Map

The Color Map translates bitmap data into the monochrome and color intensities that are applied to the video monitors.

Select Area: write DFh to port 53h (also clears the index counter)

Coordinate: wait for vertical sync interrupt

Load Data: write 32 bytes to port 51h



Mode Register

The Mode Register controls a number of the Graphics Option's operating characteristics.

Select Area: write BFh to port 53h

Load Data: write data byte to port 51h

7	6	5	4	3	2	1	0

LJ-0238

where:

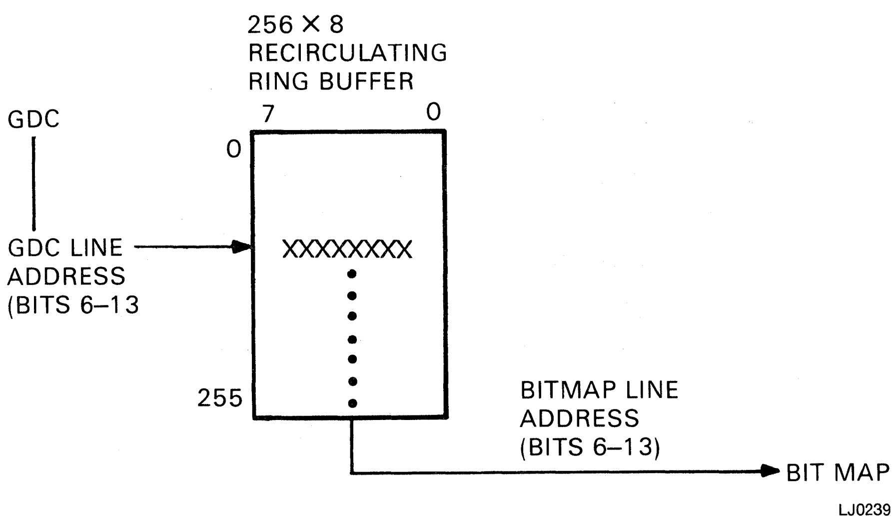
Bit	Value	Function
0	0	place option in medium resolution mode
	1	place option in high resolution mode
1	0	place option into word mode
	1	place option into vector mode
3,2	00	select plane 0 for readback operation
	01	select plane 1 for readback operation
	10	select plane 2 for readback operation
	11	select plane 3 for readback operation
4	0	enable readback operation
	1	enable write operation
5	0	enable writing to the Scroll Map
	1	disable writing to the Scroll Map
6	0	disable vertical sync interrupts to CPU
	1	enable vertical sync interrupts to CPU
7	0	disable video output from Graphics Option
	1	enable video output from Graphics Option

NOTE
The Mode Register must be reloaded following any write to port 50h (software reset).

Scroll Map

The Scroll Map controls the location of each line displayed on the monitor screen.

Preliminary:	enable Scroll Map writing (Mode Register bit 5 = 0)
Select Area:	write 7Fh to port 53h (also clears the index counter)
Coordinate:	wait for vertical sync interrupt
Load Data:	write 256 bytes to port 51h
Final:	disable Scroll Map writing (Mode Register bit 5 = 1)



where:

GDC Line Address	is the line address as generated by the GDC and used as an index into the Scroll Map.
Bitmap Line Address	is the offset line address found by indexing into the Scroll Map. It becomes the new line address of data going into the bitmap.

14

GDC Registers and Buffers

The GDC has an 8-bit Status Register and a 16 x 9-bit first-in, first-out (FIFO) Buffer that provide the interface to the Graphics Option. The Status Register supplies information on the current activity of the GDC and the status of the FIFO Buffer. The FIFO Buffer contains GDC commands and parameters when the GDC is in write mode. It contains bitmap data when the GDC is in read mode.

Status Register

The GDC's internal status can be interrogated by doing a read from port 56h. The Status Register contents are as follows:

7	6	5	4	3	2	1	0

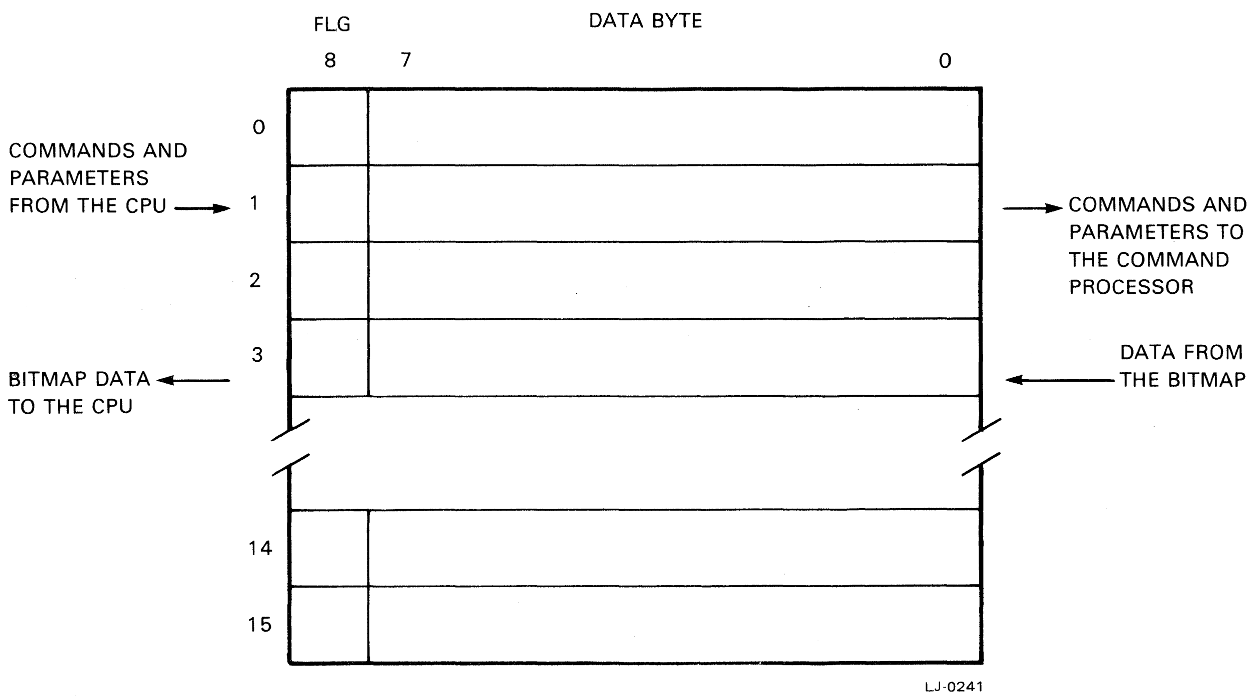
LJ0240

where:

Bit	Status	Explanation
0	DATA READY	When set, data is ready to be read from the FIFO.
1	FIFO FULL	When set, the command/parameter FIFO is full.
2	FIFO EMPTY	When set, the command/parameter FIFO is completely empty.
3	DRAWING IN PROGRESS	When set, the GDC is performing a drawing function. Note, however, that this bit can be cleared before the DRAW command is fully completed. The GDC does not draw continuously and this bit is reset during interrupts to the write operation.
4	DMA EXECUTE	Not used.
5	VERTICAL SYNC ACTIVE	When set, the GDC is doing a vertical sync.
6	HORIZONTAL SYNC ACTIVE	When set, the GDC is doing a horizontal sync.
7	LIGHT PEN DETECTED	Not used.

FIFO Buffer

You can both read from and write to the FIFO Buffer. The direction that the data takes through the buffer is controlled by the Rainbow system using GDC commands. GDC commands and their associated parameters are written to ports 57h and 56h respectively. The GDC stores both in the FIFO Buffer where they are picked up by the GDC command processor. The GDC uses the ninth bit in the FIFO Buffer as a flag bit to allow the command processor to distinguish between commands and parameters. Contents of the bitmap are read from the FIFO using reads from port 57h.



where:

flg	is a flag bit to be interpreted as: 0 – data byte is a parameter 1 – data byte is a command
data byte	is a GDC command or parameter

When you reverse the direction of flow in the FIFO Buffer, any pending data in the FIFO is lost. If a read operation is in progress and a command is written to port 56h, the unread data still in the FIFO is lost. If a write operation is in progress and a read command is processed, any unprocessed commands and parameters in the FIFO Buffer are lost.

15

GDC COMMANDS

Introduction

This chapter contains detailed reference information on the GDC commands and parameters supported by the Graphics Option. The commands are listed in alphabetical order within functional category as follows:

- Video Control Commands

CCHAR	–	Specifies the cursor and character row heights
RESET	–	Resets the GDC to its idle state
SYNC	–	Specifies the video display format
VSYNC	–	Selects Master/Slave video synchronization mode

- Display Control Commands

BCTRL	–	Controls the blanking/unblanking of the display
CURS	–	Sets the position of the cursor in display memory
PITCH	–	Specifies the width of display memory
PRAM	–	Defines the display area parameters
START	–	Ends idle mode and unblanks the display
ZOOM	–	Specifies zoom factor for the graphics display

- Drawing Control Commands

FIGD	–	Draws the figure as specified by FIGS command
FIGS	–	Specifies the drawing controller parameters
GCHRD	–	Draws the graphics character into display memory
MASK	–	Sets the mask register contents
WDAT	–	Writes data words or bytes into display memory

- Data Read Commands

RDAT	–	Reads data words or bytes from display memory

Video Control Commands

CCHAR – Specify Cursor and Character Characteristics

Use the CCHAR command to specify the cursor and character row heights and characteristics.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	1	0	0	1	0	1	1

PARAMETER BYTES

	7	6	5	4	3	2	1	0
P1	DC	0	0	LR				
P2	BR(LO)		SC	CTOP				
P3	CBOT					BR(HI)		

LJ-0242

where:

DC — controls the display of the cursor

0 – do not display cursor
1 – display the cursor

LR — is the number of lines per character row, minus 1

BR — is the blink rate (5 bits)

SC — controls the action of the cursor

0 – blinking cursor
1 – steady cursor

CTOP — is the cursor's top line number in the row

CBOT — is the cursor's bottom line number in the row (CBOT must be less than LR)

RESET – Reset the GDC

Use the RESET command to reset the GDC. This command blanks the display, places the GDC in idle mode, and initializes the FIFO buffer, command processor, and the internal counters. If parameter bytes are present, they are loaded into the sync generator.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0

PARAMETER BYTES

	7	6	5	4	3	2	1	0
P1	0	0	C	F	I	D	G	S
P2	AW							
P3	VS(LO)			HS				
P4	HFP						VS(HI)	
P5	0	0	HBP					
P6	0	0	VFP					
P7	AL(LO)							
P8	VBP						AL(HI)	

LJ-0243

where:

CG	sets the display mode for the GDC 00 – mixed graphics and character mode 01 – graphics mode only 10 – character mode only 11 – invalid
IS	controls the video framing for the GDC 00 – noninterlaced 01 – invalid 10 – interlaced repeat field for character displays 11 – interlaced
D	controls the RAM refresh cycles 0 – no refresh – static RAM 1 – refresh – dynamic RAM
F	controls the drawing time window 0 – drawing during active display time and retrace blanking 1 – drawing only during retrace blanking
AW	active display words per line minus 2; must be an even number
HS	horizontal sync width minus 1
VS	vertical sync width
HFP	horizontal front porch width minus 1
HBP	horizontal back porch width minus 1
VFP	vertical front porch width
AL	active display lines per video field
VBP	vertical back porch width

SYNC – Sync Format Specify

Use the SYNC command to load parameters into the sync generator. The GDC is neither reset nor placed in idle mode.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	0	0	0	1	1	1	DE

LJ-0244

where:

DE controls the display

0 – disables (blanks) the display
1 – enables the display

PARAMETER BYTES

<table>
<tr><th></th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td>P1</td><td>0</td><td>0</td><td>C</td><td>F</td><td>I</td><td>D</td><td>G</td><td>S</td></tr>
<tr><td>P2</td><td colspan="8">AW</td></tr>
<tr><td>P3</td><td colspan="3">VS(LO)</td><td colspan="5">HS</td></tr>
<tr><td>P4</td><td colspan="6">HFP</td><td colspan="2">VS(HI)</td></tr>
<tr><td>P5</td><td>0</td><td>0</td><td colspan="6">HBP</td></tr>
<tr><td>P6</td><td>0</td><td>0</td><td colspan="6">VFP</td></tr>
<tr><td>P7</td><td colspan="8">AL(LO)</td></tr>
<tr><td>P8</td><td colspan="6">VBP</td><td colspan="2">AL(HI)</td></tr>
</table>

LJ-0244

where:

CG	sets the display mode for the GDC 00 – mixed graphics and character mode 01 – graphics mode only 10 – character mode only 11 – invalid
IS	controls the video framing for the GDC 00 – noninterlaced 01 – invalid 10 – interlaced repeat field for character displays 11 – interlaced
D	controls the RAM refresh cycles 0 – no refresh – static RAM 1 – refresh – dynamic RAM
F	controls the drawing time window 0 – drawing during active display time and retrace blanking 1 – drawing only during retrace blanking
AW	active display words per line minus 2; must be an even number
HS	horizontal sync width minus 1
VS	vertical sync width
HFP	horizontal front porch width minus 1
HBP	horizontal back porch width minus 1
VFP	vertical front porch width
AL	active display lines per video field
VBP	vertical back porch width

VSYNC – Vertical Sync Mode

Use the VSYNC command to control the slave/master relationship whenever multiple GDC's are used to contribute to a single image.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	1	1	0	1	1	1	M

LJ-0245

where:

M   sets the synchronization status of the GDC

0 – slave mode (accept external vertical sync pulses)
1 – master mode (generate and output vertical sync pulses)

Display Control Commands

BCTRL – Control Display Blanking

Use the BCTRL command to specify whether the display is blanked or enabled.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	0	0	0	1	1	0	DE

LJ-0246

where:

DE controls the display

0 – disables (blanks) the display
1 – enables the display

CURS – Specify Cursor Position

Use the CURS command to set the position of the cursor in display memory. In character mode the cursor is displayed for the length of the word. In graphics mode the word address specifies the word that contains the starting pixel of the drawing; the dot address specifies the pixel within that word.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	1	0	0	1	0	0	1

PARAMETER BYTES

	7	6	5	4	3	2	1	0	
P1	EAD(LO)								
P2	EAD(MID)								
P3	dAD				0	0	EAD(HI)		← GRAPHICS MODE ONLY

LJ-0213

where:

EAD is the execute word address (18 bits)

dAD is the dot address within the word

PITCH – Specify Horizontal Pitch

Use the PITCH command to set the width of the display memory. The drawing processor uses this value to locate the word directly above or below the current word. It is also used during display to find the start of the next line.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	1	0	0	0	1	1	1

PARAMETER BYTES

	7	6	5	4	3	2	1	0
P1	P							

LJ-0214

where:

P   is the number of word addresses in display memory in the horizontal direction

PRAM – Load the Parameter RAM

Use the PRAM command to load up to 16 bytes of information into the parameter RAM at specified adjacent locations. There is no count of the number of parameter bytes to be loaded; the sensing of the next command byte stops the load operation. Because the Graphics Option requires that the GDC be kept in graphics mode, only parameter bytes one through four, nine, and ten are used.

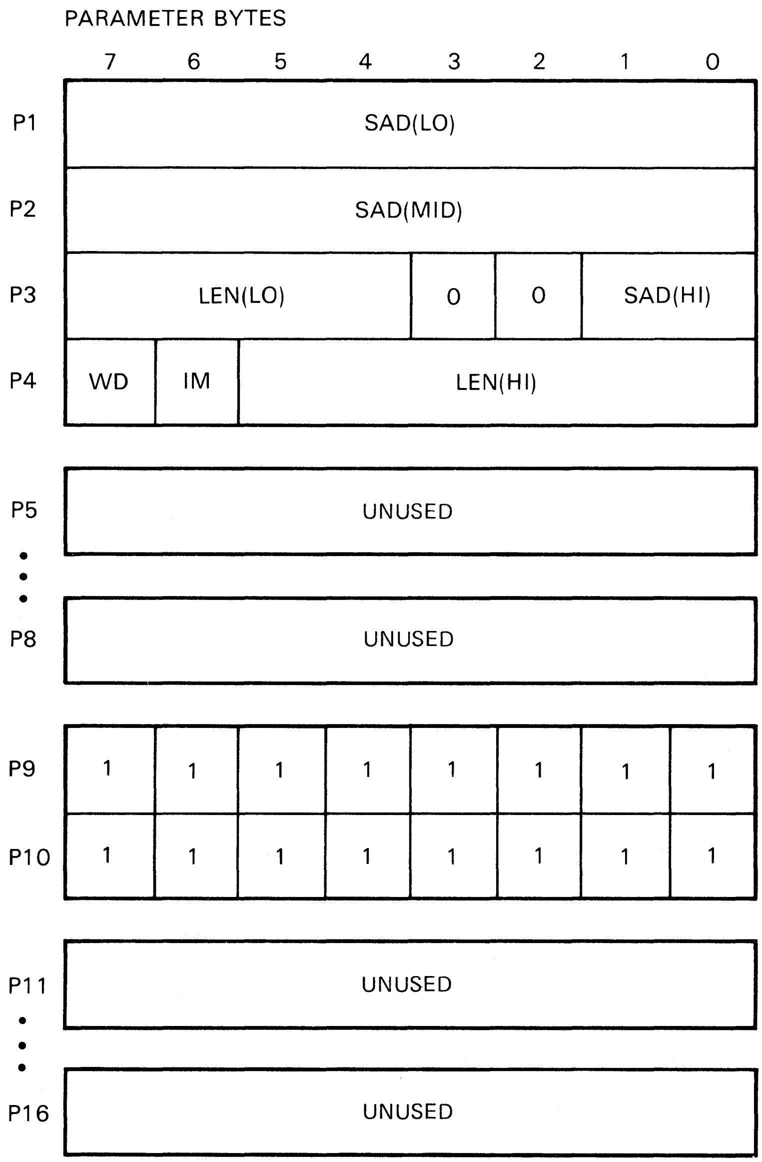
COMMAND BYTE

7	6	5	4	3	2	1	0
0	1	1	1	SA			

LJ-0247

where:

SA is the start address for the load operation (Pn – 1)



LJ-0247

where:

SAD   is the start address of the display area (18 bits)

LEN   is the number of lines in the display area (10 bits)

WD sets the display width

0 – one word per memory cycle (16 bits)
1 – two words per memory cycle (8 bits)

IM sets the current type of display when the GDC is in mixed graphics and character mode

0 – character area
1 – image or graphics area

NOTE
When the GDC is in graphics mode, the IM bit must be a zero.

START – Start Display and End Idle Mode

Use the START command to end idle mode and enable the video display.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	1	1	0	1	0	1	1

LJ-0248

ZOOM – Specify the Zoom Factor

Use the ZOOM command to set up a magnification factor of 1 through 16 (using codes 0 through 15) for the display and for graphics character writing.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	1	0	0	0	1	1	0

PARAMETER BYTES

	7	6	5	4	3	2	1	0
P1	DISP				GCHR			

LJ-0249

where:

DISP — is the zoom factor (minus one) for the display

GCHR — is the zoom factor (minus one) for graphics character writing and area fills

Drawing Control Commands

FIGD – Start Figure Drawing

Use the FIGD command to start drawing the figure specified with the FIGS command. This command causes the GDC to:

- load the parameters from the parameter RAM into the drawing controller, and
- start the drawing process at the pixel pointed to by the cursor: Execute Word Address (EAD) and Dot Address within the word (dAD)

COMMAND BYTE

7	6	5	4	3	2	1	0
0	1	1	0	1	1	0	0

LJ-0250

FIGS – Specify Figure Drawing Parameters

Use the FIGS command to supply the drawing controller with the necessary figure type, direction, and drawing parameters needed to draw figures into display memory.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	1	0	0	1	1	0	0

PARAMETER BYTES

<table>
<tr><th></th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td>P1</td><td>SL</td><td>R</td><td>A</td><td>GC</td><td>L</td><td colspan="3">DIR</td></tr>
<tr><td>P2</td><td colspan="8">DC(LO)</td></tr>
<tr><td>P3</td><td>0</td><td>GD</td><td colspan="6">DC(HI)</td></tr>
<tr><td>P4</td><td colspan="8">D(LO)</td></tr>
<tr><td>P5</td><td>0</td><td>0</td><td colspan="6">D(HI)</td></tr>
<tr><td>P6</td><td colspan="8">D2(LO)</td></tr>
<tr><td>P7</td><td>0</td><td>0</td><td colspan="6">D2(HI)</td></tr>
<tr><td>P8</td><td colspan="8">D1(LO)</td></tr>
<tr><td>P9</td><td>0</td><td>0</td><td colspan="6">D1(HI)</td></tr>
<tr><td>P10</td><td colspan="8">DM(LO)</td></tr>
<tr><td>P11</td><td>0</td><td>0</td><td colspan="6">DM(HI)</td></tr>
</table>

LJ-0251

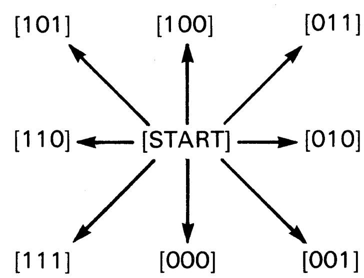
where:

SL	Slanted Graphics Character	Figure Type Select Bits (see valid combinations below)
R	Rectangle	
A	Arc/Circle	
GC	Graphics Character	
L	Line (Vector)	
DIR	is the drawing direction base (see definitions below)	
DC	is the DC drawing parameter (14 bits)	
GD	is the graphic drawing flag used in mixed graphics and character mode	
D	is the D drawing parameter (14 bits)	
D2	is the D2 drawing parameter (14 bits)	
D1	is the D1 drawing parameter (14 bits)	
DM	is the DM drawing parameter (14 bits)	

FIGURE TYPE SELECT BITS (VALID COMBINATIONS)

SL R A GC L	OPERATION
0 0 0 0 0	CHARACTER DISPLAY MODE DRAWING, INDIVIDUAL DOT DRAWING, WDAT, AND RDAT
0 0 0 0 1	STRAIGHT LINE DRAWING
0 0 0 1 0	GRAPHICS CHARACTER DRAWING AND AREA FILL WITH GRAPHICS CHARACTER PATTERN
0 0 1 0 0	ARC AND CIRCLE DRAWING
0 1 0 0 0	RECTANGLE DRAWING
1 0 0 1 0	SLANTED GRAPHICS CHARACTER DRAWING AND SLANTED AREA FILL

DRAWING DIRECTION BASE (DIR)



LJ-0252

GCHRD – Start Graphics Character Draw and Area Fill

Use the GCHRD command to initiate the drawing of the graphics character or area fill pattern that is stored in the Parameter RAM. The drawing is further controlled by the parameters loaded by the FIGS command. Drawing begins at the address in display memory pointed to by the Execute Address (EAD) and Dot Address (dAD) values.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	1	1	0	1	0	0	0

LJ-0253

MASK – Load the Mask Register

Use the MASK command to set the value of the 16-bit Mask Register that controls which bits of a word can be modified during a Read/Modify/Write (RMW) cycle.

COMMAND BYTE

7	6	5	4	3	2	1	0
0	1	0	0	1	0	1	0

PARAMETER BYTES

	7 6 5 4 3 2 1 0
P1	M(LO)
P2	M(HI)

LJ-0254

where:

M is the bit configuration to be loaded into the Mask Register (16 bits). Each bit in the Mask Registercontrols the writing of the corresponding bit in the word being processed as follows:

0 – disable writing
1 – enable writing

WDAT – Write Data Into Display Memory

Use the WDAT command to perform RMW cycles into display memory starting at the location pointed to by the cursor Execute Word Address (EAD). Precede this command with a FIGS command to supply the writing direction (DIR) and the number of transfers (DC).

COMMAND BYTE

7	6	5	4	3	2	1	0
0	0	1	TYPE		0	MOD	

LJ-0255

where:

TYPE is the type of transfer

- 00 – word transfer (first low then high byte)
- 01 – invalid
- 10 – byte transfer (low byte of the word only)
- 11 – byte transfer (high byte of the word only)

MOD is the RMW memory logical operation

- 00 – REPLACE with Pattern
- 01 – COMPLEMENT
- 10 – RESET to Zero
- 11 – SET to One

PARAMETER BYTES

	7	6	5	4	3	2	1	0
P1	WORD(LO) OR BYTE							
P2	WORD(HI)							
•								
•								

LJ-0255

where:

WORD is a 16-bit data value

BYTE is an 8-bit data value

Data Read Commands

RDAT – Read Data From Display Memory

Use the RDAT command to read data from display memory and pass it through the FIFO buffer and microprocessor interface to the host system. Use the CURS command to set the starting address and the FIGS command to supply the direction (DIR) and the number of transfers(DC). The type of transfer is coded in the command itself.

COMMAND BYTE

7	6	5	4	3	2	1	0
1	0	1	TYPE		0	MOD	

LJ-0256

where:

TYPE is the type of transfer

00 – word transfer (first low then high byte)
01 – invalid
10 – byte transfer (low byte of the word only)
11 – byte transfer (high byte of the word only)

MOD is the RMW memory logical operation

00 – REPLACE with Pattern
01 – COMPLEMENT
10 – RESET to Zero
11 – SET to One

NOTE
The MOD field should be set to 00 if no modification to the video buffer is desired.

Part IV

Appendixes

Contents

A

Option Specification Summary

Physical Specifications

The Graphics Option Video Subsystem is a 5.7" × 10.0", high density, four-layer PCB with one 40-pin female connector located on side 1. This connector plugs into a shrouded male connector located on the system module. The option module is also supported by two standoffs.

Environmental Specifications

Temperature

- Operating ambient temperature range is 10 to 40 degrees C.
- Storage temperature is –40 to 70 degrees C.

Humidity

- 10% to 90% non-condensing
- Maximum wet bulb, 28 degrees C.
- Minimum dew point, 2 degrees C.

Altitude

- Derate maximum operating temperature 1 degree per 1,000 feet elevation
- Operating limit: 22.2 in. Hg. (8,000 ft.)
- Storage limit: 8.9 in Hg. (30,000 ft.)

Power Requirements

	Calculated Typical	Calculated Maximum
+5V DC (+/–5%)	3.05 amps	3.36 amps
+12V DC (+/–10%)	180 mA	220 mA

Standards and Regulations

The Graphics Option module complies with the following standards and recommendations:

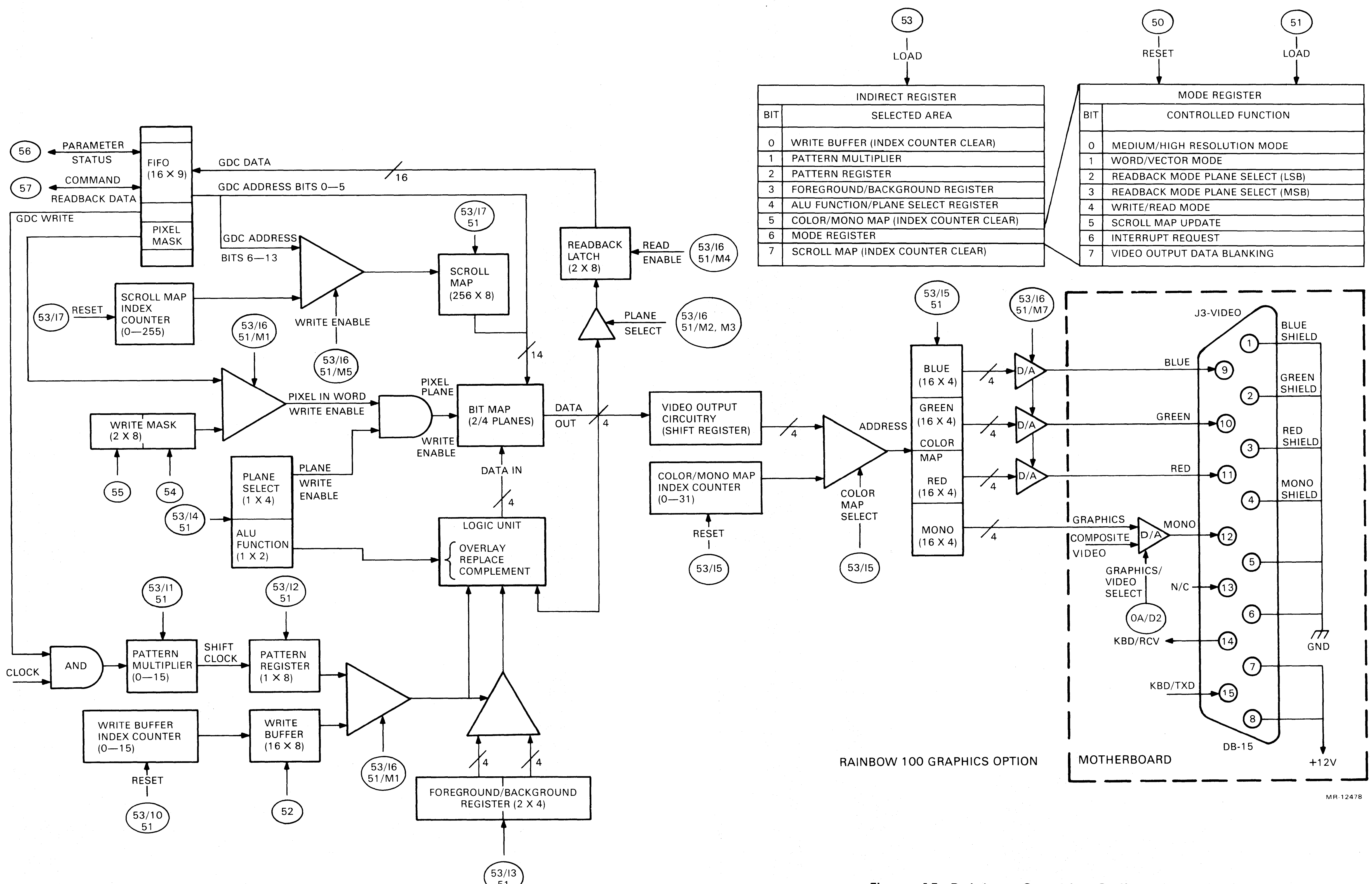
- DEC Standard 119 – Digital Product Safety (covers UL 478, UL 114, CSA 22.2 No. 154, VDE 0806, and IEC 380)
- IEC 485 – Safety of Data Processing Equipment
- EIA RS170 – Electrical Performance Standards – Monochrome Television Studio Facilities
- CCITT Recommendation V.24 – List of Definitions for Interchange Circuit Between Data Terminal Equipment and Data Circuit Terminating Equipment
- CCITT Recommendation V.28 – Electrical Characteristics for Unbalanced Double-Current Interchange Circuits

Part and Kit Numbers

Graphics Option	PC1XX-BA
Hardware:	
Printed Circuit Board	54-15688
Color RGB Cable	BCC17-06
Software and Documentation:	
Rainbow Color/Graphics Option Installation Guide	EK-PCCOL-IN-001
Rainbow Color/Graphics Option Programmer's Reference Guide	AA-AE36A-TV
Rainbow GSX-86 Programmer's Reference Manual	AA-V526A-TV
Rainbow GSX-86 Getting Started	AA-W964A-TV
Rainbow Diagnostic/GSX-86 Diskette	BL-W965A-RV
Rainbow 100 CP/M-86/80 V1.0 Technical Documentation	QV043-GZ
Rainbow 100 MS-DOS V2.01 Technical Documentation	QV025-GZ

B

Rainbow Graphics Option – Block Diagram



INDIRECT REGISTER

BIT	SELECTED AREA
0	WRITE BUFFER (INDEX COUNTER CLEAR)
1	PATTERN MULTIPLIER
2	PATTERN REGISTER
3	FOREGROUND/BACKGROUND REGISTER
4	ALU FUNCTION/PLANE SELECT REGISTER
5	COLOR/MONO MAP (INDEX COUNTER CLEAR)
6	MODE REGISTER
7	SCROLL MAP (INDEX COUNTER CLEAR)

MODE REGISTER

BIT	CONTROLLED FUNCTION
0	MEDIUM/HIGH RESOLUTION MODE
1	WORD/VECTOR MODE
2	READBACK MODE PLANE SELECT (LSB)
3	READBACK MODE PLANE SELECT (MSB)
4	WRITE/READ MODE
5	SCROLL MAP UPDATE
6	INTERRUPT REQUEST
7	VIDEO OUTPUT DATA BLANKING

Figure 15. Rainbow Graphics Option — Block Diagram

C
Getting Help

Help Line Phone Numbers

Country	Phone Number
U.S.A.	(800) DEC-8000
Canada	(800) 267-5251
United Kingdom	(0256) 59 200
Belgium	(02)-24 26 790
West Germany	(089) 95 91 66 44
Italy	(02)-617 53 81 or 617 53 82
Japan	(0424) 64-3302
Denmark	(04)-30 10 05
Spain	(1)-73 34 307
Finland	(90)-42 33 32
Holland	(1820)-31 100
Switzerland	(01)-810 51 21
Sweden	(08)-98 88 35
Norway	(02)-25 64 22
France	(1)-687 31 52
Austria	(222)-67 76 41 extension 444
Australia	
Sydney	(02) 412-5555
All other areas	(008) 226377

Index

A

B

C

D

E

H

I

L

M

S

T

V

W

Z

HOW TO ORDER
ADDITIONAL DOCUMENTATION

If you want to order additional documentation by phone:

And you live in:	**Call:**	**Between the hours of:**
New Hampshire, Alaska or Hawaii	603-884-6660	8:30 AM and 6:00 PM Eastern Time
Continental USA or Puerto Rico	1-800-258-1710	8:30 AM and 6:00PM Eastern Time
Canada (Ottawa-Hull)	613-234-7726	8:00 AM and 5:00 PM Eastern Time
Canada (British Columbia)	1-800-267-6146	8:00 AM and 5:00 PM Eastern Time
Canada (all other)	112-800-267-6146	8:00 AM and 5:00 PM Eastern Time

If you want to order additional documentation by direct mail:

And you live in:	**Write to:**
USA or Puerto Rico	DIGITAL EQUIPMENT CORPORATION ATTN: Peripherals and Supplies Group P.O. Box CS2008 Nashua, NH 03061 NOTE: Prepaid orders from Puerto Rico must be placed with the local DIGITAL subsidiary (Phone 809-754-7575)
Canada	DIGITAL EQUIPMENT OF CANADA LTD. 940 Belfast Road Ottawa, Ontario K1G 4C2 Attn: P&SG Business Manager
Other than USA, Puerto Rico or Canada	DIGITAL EQUIPMENT CORPORATION Peripherals and Supplies Group P&SG Business Manager c/o Digital's local subsidiary or approved distributor

TO ORDER MANUALS WITH EK PART NUMBERS
WRITE OR CALL

P&CS PUBLICATIONS
Circulation Services
10 Forbes Road
NR03/W3
Northboro, Massachusetts 01532
(617)351-4325

Rainbow™
Color/Graphics Option
Programmer's Reference Guide
AA–AE36A–TV

READER'S COMMENTS

Did you find this manual understandable, usable, and well-organized? Please make suggestions for improvement.

Did you find errors in this manual? If so, specify the error and the page number.

Please indicate the type of reader that you most nearly represent.

- ☐ First-time computer user
- ☐ Experienced computer user
- ☐ Application package user
- ☐ Programmer
- ☐ Other (please specify)__________

Name__________

Date__________

Organization__________

Street__________

City__________

State__________

Zip Code
or Country__________

--------Do Not Tear - Fold Here and Tape--------

digital

No Postage
Necessary
if Mailed in the
United States

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 33 MAYNARD MASS.

POSTAGE WILL BE PAID BY ADDRESSEE

SOFTWARE PUBLICATIONS
200 FOREST STREET MRO1-2/L12
MARLBOROUGH, MA 01752

------ Do Not Tear - Fold Here and Tape --------

Cut Along Dotted Line