



*Personal Computer
Hardware Reference
Library*

IBM Color/Graphics Monitor Adapter

6361509

Contents

Description	1
Controller	5
Mode Set Register	5
Display Buffer	5
Character Generator	5
Timing Generator	6
Composite Color Generator	6
Alphanumeric Mode	6
Graphics Modes	9
Basic Operations	12
Programming Considerations	15
Programming the Mode Control and Status Register	15
Programming the 6845 CRT Controller	15
Color-Select Register	18
Mode-Control Register	19
Mode-Control Register Summary	20
Status Register	20
Sequence of Events for Changing Modes	21
Memory Requirements	22
Specifications	23
Logic Diagrams	27
Index	Index-1

Description

The IBM Color/Graphics Monitor Adapter is designed to attach to the IBM Color Display, to a variety of television-frequency monitors, or to home television sets (user-supplied RF modulator is required for home television sets). The adapter is capable of operating in black-and-white or color. It provides three video interfaces: a composite-video port, a direct-drive port, and a connection interface for driving a user-supplied RF modulator. A light pen interface is also provided.

The adapter has two basic modes of operation: alphanumeric (A/N) and all-points-addressable (APA) graphics. Additional modes are available within the A/N or APA graphics modes. In the A/N mode, the display can be operated in either a 40-column by 25-row mode for a low-resolution monitor or home television, or in an 80-column by 25-row mode for high-resolution monitors. In both modes, characters are defined in an 8-wide by 8-high character box and are 7-wide by 7-high, double dotted characters with one descender. Both uppercase and lowercase characters are supported in all modes.

The character attributes of reverse video, blinking, and highlighting are available in the black-and-white mode. In the color mode, 16 foreground and 8 background colors are available for each character. In addition, blinking on a per-character basis is available.

The monitor adapter contains 16K bytes of storage. As an example, a 40-column by 25-row display screen uses 1000 bytes to store character information and 1000 bytes to store attribute/color information. This means that up to eight screens can be stored in the adapter memory. Similarly, in an 80-wide by 25-row mode, four display screens can be stored in the adapter memory. The entire 16K bytes of storage in the display adapter are directly accessible by the processor, which allows maximum program flexibility in managing the screen.

In A/N color modes, it is also possible to select the color of the screen's border. One of 16 colors can be selected.

In the APA graphics mode, there are two resolutions available: a medium-resolution color graphics mode (320 PELs by 200 rows) and a high-resolution black-and-white graphics mode (640 PELs by 200 rows). In the medium-resolution mode, each picture element (PEL) may have one of four colors. The background color (Color 0) may be any of the 16 possible colors. The remaining three colors come from one of the two program-selectable palettes. One palette contains green/red/brown; the other contains cyan/magenta/white.

The high-resolution mode is available only in black-and-white because the entire 16K bytes of storage in the adapter is used to define the on or off state of the PELs.

The adapter operates in noninterlace mode at either 7 or 14 MHz, depending on the mode of the operation selected.

In the A/N mode, characters are formed from a ROS character generator. The character generator contains dot patterns for 256 different characters. The character set contains the following major groupings of characters.

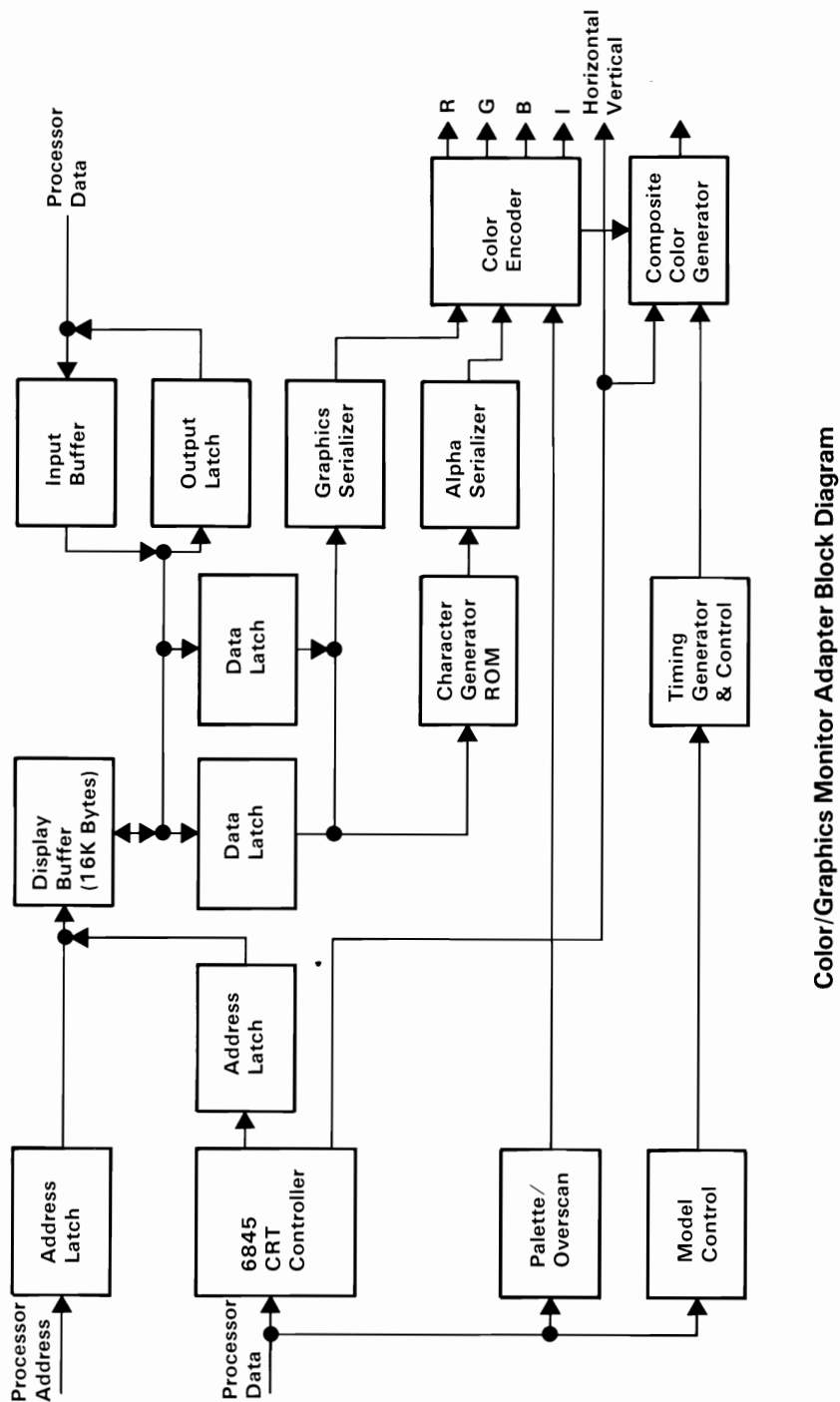
- 16 special characters for game support
- 15 characters for word-processing editing support
- 96 characters for the standard ASCII graphics set
- 48 characters for foreign-language support
- 48 characters for business block-graphics support (for the drawing of charts, boxes, and tables using single and double lines)
- 16 selected Greek characters
- 15 selected scientific-notation characters

The color/graphics monitor function is on a single adapter. The direct-drive and composite-video ports are right-angle mounted connectors on the adapter, and extend through the rear panel of

the system unit. The direct-drive video port is a 9-pin, D-shell, female connector. The composite-video port is a standard female phono jack.

The display adapter uses a Motorola 6845 CRT Controller device. This adapter is highly programmable with respect to raster and character parameters. Therefore, many additional modes are possible with programming of the adapter.

On the following page is a block diagram of the Color/Graphics Monitor Adapter.



Color/Graphics Monitor Adapter Block Diagram

Controller

The controller is a Motorola 6845 Cathode Ray Tube (CRT) Controller. It provides the necessary interface to drive the raster-scan CRT.

Mode Set Register

The mode set register is a general-purpose, programmable, I/O register. It has I/O ports that may be individually programmed. Its function in this adapter is to provide mode selection and color selection in the medium-resolution color-graphics mode.

Display Buffer

The display buffer resides in the processor-address space, starting at address hex B8000. It provides 16 bytes of dynamic read/write memory. A dual-ported implementation allows the processor and the graphics control unit access to this buffer. The processor and the control unit have equal access to this buffer during all modes of operation, except in the high-resolution alphanumeric mode. In this mode, only the processor should have access to this buffer during the horizontal-retrace intervals. While the processor may write to the required buffer at any time, a small amount of display interference will result if this does not occur during the horizontal-retrace intervals.

Character Generator

A ROS character generator is used with 8K bytes of storage that cannot be read from or written to under program control. This is a general-purpose ROS character generator with three character fonts. Two character fonts are used on the Color/Graphics Monitor Adapter: a 7-high by 7-wide double-dot font and a 7-high by 5-wide single-dot font. The font is selected by a jumper (P3). The single-dot font is selected by inserting the jumper; the double-dot font is selected by removing the jumper.

Timing Generator

This generator produces the timing signals used by the 6845 CRT Controller and by the dynamic memory. It also solves the processor/graphic controller contentions for access to the display buffer.

Composite Color Generator

This generator produces base-band-video color information.

Alphanumeric Mode

Every display character position in the alphanumeric mode is defined by two bytes in the regen buffer (a part of the monitor adapter), not the system memory. Both the Color/Graphics Monitor Adapter and the Monochrome Display and Printer Adapter use the following 2-byte character-attribute format.

Display-Character Code Byte								Attribute Byte							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0

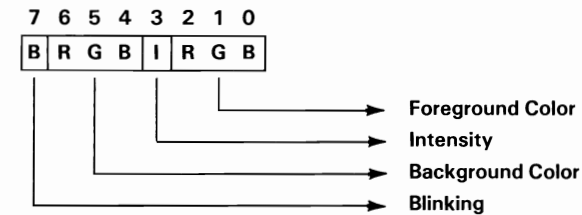
The following table shows the functions of the attribute byte.

Attribute Function	Attribute Byte							
	7	6	5	4	3	2	1	0
	B	R	G	B	I	R	G	B
	FG	Background			Foreground			
Normal	B	0	0	0	I	1	1	1
Reverse Video	B	1	1	1	I	0	0	0
Nondisplay (Black)	B	0	0	0	I	0	0	0
Nondisplay (White)	B	1	1	1	I	1	1	1

I = Highlighted Foreground (Character)

B = Blinking Foreground (Character)

The definitions of the attribute byte are in the following table.



In the alphanumeric mode, the display can be operated in either a low-resolution mode or a high-resolution mode.

The low-resolution alphanumeric mode has the following features:

- Supports home color televisions or low-resolution monitors.
- Displays up to 25 rows of 40 characters each.
- Has a ROS character generator that contains dot patterns for a maximum of 256 different characters.
- Requires 2,000 bytes of read/write memory (on the adapter).
- Has an 8-high by 8-wide character box.
- Has two jumper-controlled character fonts available: a 7-high by 5-wide single-dot character font with one descender, and a 7-high by 7-wide double-dotted character font with one descender.
- Has one character attribute for each character.

The high-resolution alphanumeric mode has the following features:

- Supports the IBM Color Display or other color monitor with direct-drive capability.
- Supports a black-and-white composite-video monitor.
- Displays up to 25 rows of 80 characters each.

- Has a ROS display generator that contains dot patterns for a maximum of 256 characters.
- Requires 4,000 bytes of read/write memory (on the adapter).
- Has an 8-high by 8-wide character box.
- Has two jumper-controlled character fonts available: a 7-high by 5-wide single-dot character font with one descender, and a 7-high by 7-wide double-dot character font with one descender.
- Has one character attribute for each character.

The Color/Graphics Monitor Adapter will change foreground and background colors according to the color value selected in the attribute byte. The following figure shows the color values for the various red, green, blue, and intensity bit settings.

R	G	B	I	Color
0	0	0	0	Black
0	0	1	0	Blue
0	1	0	0	Green
0	1	1	0	Cyan
1	0	0	0	Red
1	0	1	0	Magenta
1	1	0	0	Brown
1	1	1	0	White
0	0	0	1	Gray
0	0	1	1	Light Blue
0	1	0	1	Light Green
0	1	1	1	Light Cyan
1	0	0	1	Light Red
1	0	1	1	Light Magenta
1	1	0	1	Yellow
1	1	1	1	White (High Intensity)

Note: Not all Monitors recognize the intensity (I) bit.

Graphics Modes

The Color/Graphics Monitor Adapter has three graphics modes: low-resolution, medium-resolution, and high-resolution color graphics. However, only medium- and high-resolution graphics are supported in ROM. The following figure shows these modes.

Mode	Horizontal (PELs)	Vertical (Rows)	Number of Colors Available (Includes Background Color)
Low Resolution	160	100	16 (Includes black-and-white)
Medium Resolution	320	200	4 Colors Total 1 of 16 for Background and 1 of Green, Red, or Brown or 1 of Cyan, Magenta, or White
High Resolution	640	200	Black-and-white only

Low-Resolution Color/Graphics Mode

The low-resolution mode supports home televisions or color monitors. This mode, not supported in ROM, has the following features:

- Contains a maximum of 160 PELs by 100 rows, with each PEL being 2-high by 2-wide.
- Specifies 1 of 16 colors for each PEL by the I, R, G, and B bits.
- Requires 16,000 bytes of read/write memory on the adapter.
- Uses memory-mapped graphics.

Medium-Resolution Color/Graphics Mode

The medium-resolution mode supports home televisions or color monitors. It has the following features:

- Contains a maximum of 320 PELs by 200 rows, with each PEL being 1-high by 1-wide.

- Preselects 1 of 4 colors for each PEL.
- Requires 16,000 bytes of read/write memory on the adapter.
- Uses memory-mapped graphics.
- Formats 4 PELs per byte in the following manner:

7	6	5	4	3	2	1	0
C1	C0	C1	C0	C1	C0	C1	C0
First Display PEL		Second Display PEL		Third Display PEL		Fourth Display PEL	

- Organizes graphics storage into two banks of 8,000 bytes, using the following format:

Memory Address (in hex)	Function
B8000	Even Scans (0,2,4,...198) 8,000 bytes
B9F3F	Not Used
BA000	Odd Scans (1,3,5...199) 8,000 Bytes
BBF3F	Not Used
BBFFF	

Address hex B8000 contains the PEL instruction for the upper-left corner of the display area.

- Color selection is determined by the following logic:

C1	C0	Function
0	0	Dot takes on the color of 1 of 16 preselected background colors
0	1	Selects first color of preselected Color Set 1 or Color Set 2
1	0	Selects second color of preselected Color Set 1 or Color Set 2
1	1	Selects third color of preselected Color Set 1 or Color Set 2

C1 and C0 select 4 of 16 preselected colors. This color selection (palette) is preloaded in an I/O port.

The two color sets are:

Color Set 1	Color Set 2
Color 1 is Green	Color 1 is Cyan
Color 2 is Red	Color 2 is Magenta
Color 3 is Brown	Color 3 is White

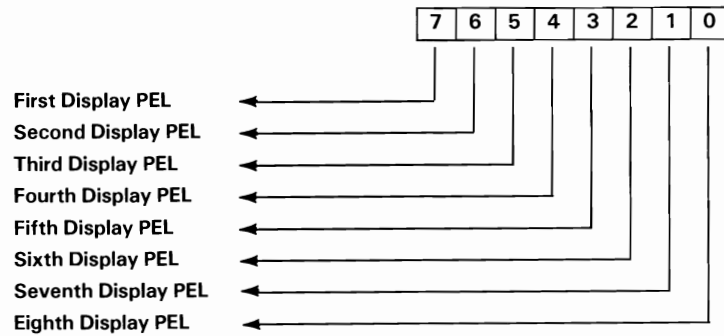
The background colors are the same basic 8 colors defined for low-resolution graphics, plus 8 alternate intensities defined by the intensity bit, for a total of 16 colors, including black and white.

High-Resolution Black-and-White Graphics Mode

The high-resolution mode supports color monitors. This mode has the following features:

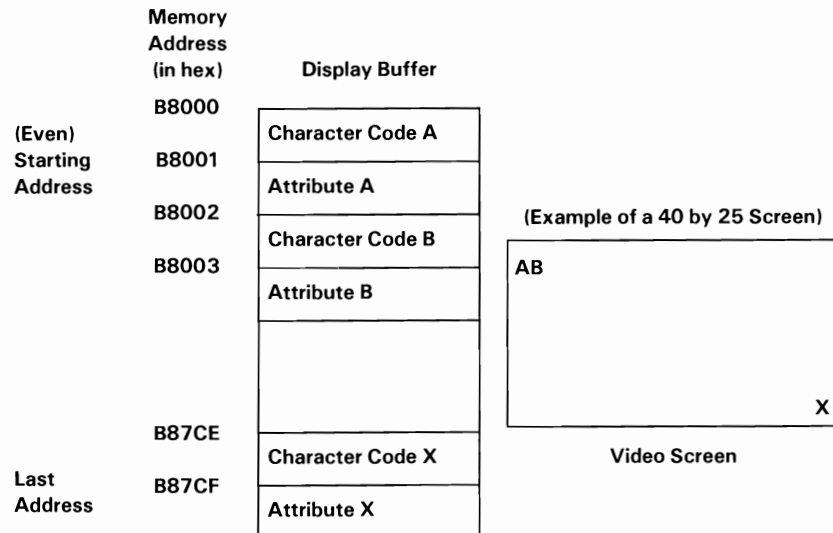
- Contains a maximum of 640 PELs by 200 rows, with each PEL being 1-high by 1-wide.
- Supports black-and-white only.
- Requires 16,000 bytes of read/write memory on the adapter.
- Addressing and mapping procedures are the same as medium-resolution color/graphics, but the data format is different. In this mode, each bit in memory is mapped to a PEL on the screen.

- Formats 8 PELs per byte in the following manner:



Basic Operations

In the alphanumeric mode, the adapter fetches character and attribute information from its display buffer. The starting address of the display buffer is programmable through the CRT controller, but it must be an even address. The character codes and attributes are then displayed according to their relative positions in the buffer. The following addresses will produce an "AB" in the upper-left corner of a 40 by 25 screen and an "X" in the lower-right corner.



The processor and the display control unit have equal access to the display buffer during all of the operating modes, except the high-resolution alphanumeric mode. During this mode, the processor gains access to the display buffer during the vertical retrace time. If it does not, the display will be affected with random patterns as the microprocessor is using the display buffer. In the alphanumeric mode, the characters are displayed from a pre-stored ROM character generator that contains the dot patterns for all of the displayable characters.

In the graphics mode, the displayed dots and colors, up to 16K bytes, are fetched from the display buffer.

Programming Considerations

Programming the Mode Control and Status Register

The following I/O devices are defined on the Color/Graphics Monitor Adapter.

Hex Address	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0	Function of Register
3D8	1	1	1	1	0	1	1	0	0	0	Mode Control Register (D0)
3D9	1	1	1	1	0	1	1	0	0	1	Color Select Register (D0)
3DA	1	1	1	1	0	1	1	0	1	0	Status Register (D1)
3DB	1	1	1	1	0	1	1	0	1	1	Clear Light Pen Latch
3DC	1	1	1	1	0	1	1	1	0	0	Preset Light Pen Latch
3D4	1	1	1	1	0	1	0	Z	Z	0	6845 Index Register
3D5	1	1	1	1	0	1	0	Z	Z	1	6845 Data Register
Z = don't care condition											

Programming the 6845 CRT Controller

The controller has 19 internal accessible registers, which are used to define and control a raster-scan CRT display. One of these registers, the index register, is used as a pointer to the other 18 registers. It is a write-only register, which is loaded from the processor by executing an 'out' instruction to I/O address hex 3D4. The five least-significant bits of the I/O bus are loaded into the index register.

In order to load any of the other 18 registers, the index register is first loaded with the necessary pointer, then the data register is

loaded with the information to be placed in the selected register. The data register is loaded from the processor by executing an 'out' instruction to I/O address hex 3D5.

The table on the next page defines the values that must be loaded into the 6845 CRT Controller registers to control the different modes of operation supported by the attachment.

Address Register	Register Number	Register Type	Units	I/O	40 by 25 Alpha-numeric	80 by 25 Alpha-numeric	Graphic Modes
0	R0	Horizontal Total	Character	Write Only	38	71	38
1	R1	Horizontal Displayed	Character	Write Only	28	50	28
2	R2	Horizontal Sync Position	Character	Write Only	2D	5A	2D
3	R3	Horizontal Sync Width	Character	Write Only	0A	0A	0A
4	R4	Vertical Total	Character Row	Write Only	1F	1F	7F
5	R5	Vertical Total Adjust	Scan Line	Write Only	06	06	06
6	R6	Vertical Displayed	Character Row	Write Only	19	19	64
7	R7	Vertical Sync Position	Character Row	Write Only	1C	1C	70
8	R8	Interlace Mode	-	Write Only	02	02	02
9	R9	Maximum Scan Line Address	Scan Line	Write Only	07	07	01
A	R10	Cursor Start	Scan Line	Write Only	06	06	06
B	R11	Cursor End	Scan Line	Write Only	07	07	07
C	R12	Start Address (H)	-	Write Only	00	00	00
D	R13	Start Address (L)	-	Write Only	00	00	00
E	R14	Cursor Address (H)	-	Read/Write	XX	XX	XX
F	R15	Cursor Address (L)	-	Read/Write	XX	XX	XX
10	R16	Light Pen (H)	-	Read Only	XX	XX	XX
11	R17	Light Pen (L)	-	Read Only	XX	XX	XX
Note: All register values are given in hexadecimal							

6845 Register Description

Color-Select Register

The color-select register is a 6-bit output-only register. Its I/O address is hex 3D9, and it can be written to using a processor 'out' command. The following are the bit definitions for this register.

- Bit 0** Selects blue border color in 40 by 25 alphanumeric mode.
 Selects blue background color (C0-C1) in 320 by 200 graphics mode.
 Selects blue foreground color in 640 by 200 graphics mode.
- Bit 1** Selects green border color in 40 by 25 alphanumeric mode.
 Selects green background color (C0-C1) in 320 by 200 graphics mode.
 Selects green foreground color in 640 by 200 graphics mode.
- Bit 2** Selects red border color in 40 by 25 alphanumeric mode.
 Selects red background color (C0-C1) in 320 by 200 graphics mode.
 Selects red foreground color in 640 by 200 graphics mode.
- Bit 3** Selects intensified border color in 40 by 25 alphanumeric mode.
 Selects intensified background color (C0-C1) in 320 by 200 graphics mode.
 Selects intensified foreground color in 640 by 200 graphics mode.
- Bit 4** Selects alternate, intensified set of colors in the graphics mode.
 Selects background colors in the alphanumeric mode.
- Bit 5** Selects active color set in 320 by 200 graphics mode.

When bit 5 is set to 1, colors are determined as follows:

C1	C0	Set Selected
0	0	Background (Defined by bits 0-3 of port hex 3D9)
0	1	Cyan
1	0	Magenta
1	1	White

When bit 5 is set to 0, colors are determined as follows:

C1	C0	Set Selected
0	0	Background (Defined by bits 0-3 of port hex 3D9)
0	1	Green
1	0	Red
1	1	Brown

Bit 6 Not used

Bit 7 Not used

Mode-Control Register

The mode-control register is a 6-bit output-only register. Its I/O address is hex 3D8, and it can be written to using a processor 'out' command. The following are bit definitions for this register.

- Bit 0** A 1 selects 80 by 25 alphanumeric mode.
 A 0 selects 40 by 25 alphanumeric mode.
- Bit 1** A 1 selects 320 by 200 graphics mode.
 A 0 selects alphanumeric mode.
- Bit 2** A 1 selects black-and-white mode.
 A 0 selects color mode.
- Bit 3** A 1 enables the video signal. The video signal is disabled when changing modes.

Bit 4 A 1 selects the high-resolution (640 by 200) black-and-white graphics mode. One of eight colors can be selected on direct-drive monitors in this mode by using register hex 3D9.

Bit 5 A 1 will change the character background intensity to the blinking attribute function for alphanumeric modes. When the high-order attribute is not selected, 16 background colors or intensified colors are available. This bit is set to 1 to allow the blinking function.

Mode-Control Register Summary

Bits						
0	1	2	3	4	5	
0	0	1	1	0	1	40 x 25 Alphanumeric Black-and-White
0	0	0	1	0	1	40 x 25 Alphanumeric Color
0	0	0	1	0	1	80 x 25 Alphanumeric Black-and-White
1	0	1	1	0	1	80 x 25 Alphanumeric Color
1	0	0	1	0	1	320 x 200 Black-and-White Graphics
0	1	1	1	0	z	320 x 200 Color Graphics
0	1	0	1	0	z	640 x 200 Black-and-White Graphics
0	1	1	1	1	z	

z = don't care condition

Note: The low-resolution (160 by 100) mode requires special programming and is set up as the 40 by 25 alphanumeric mode.

Status Register

The status register is a 4-bit read-only register. Its I/O address is hex 3DA, and it can be read using the processor 'in' instruction. The following are bit definitions for this register.

Bit 0 A 1 indicates that a regen-buffer memory access can be made without interfering with the display.

Bit 1 A 1 indicates that a positive-going edge from the light pen has set the light pen's trigger. This trigger is reset when power is turned on and may also be cleared by a processor 'out' command to hex address 3DB. No specific data setting is required; the action is address-activated.

Bit 2 The light pen switch is reflected in this bit. The switch is not latched or debounced. A 0 indicates that the switch is on.

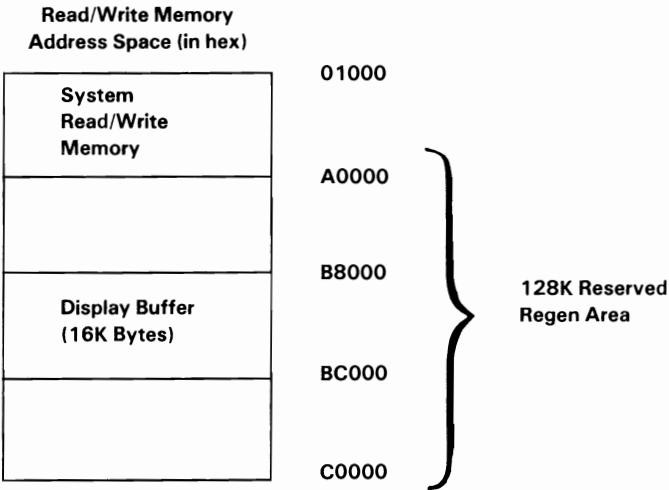
Bit 3 A 1 indicates that the raster is in a vertical retrace mode. Screen-buffer updating can be performed at this time.

Sequence of Events for Changing Modes

- 1 Determine the mode of operation.
- 2 Reset the video-enable bit in the mode-control register.
- 3 Program the 6845 CRT Controller to select the mode.
- 4 Program the mode-control and color-select registers including re-enabling the video.

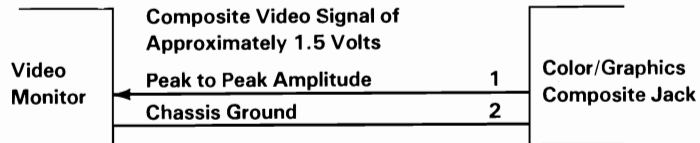
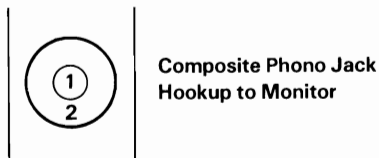
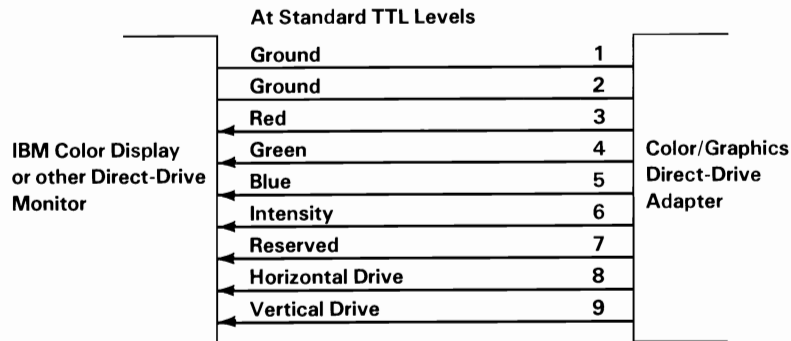
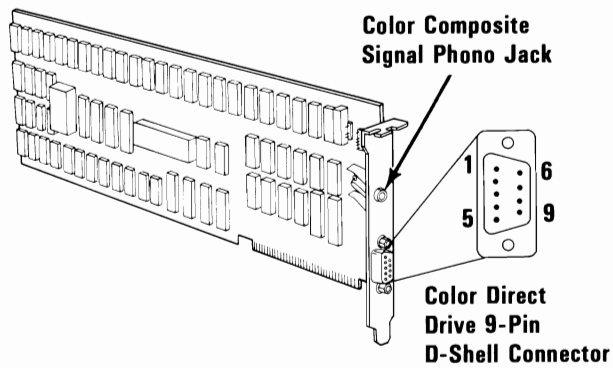
Memory Requirements

The memory used by this adapter is self-contained. It consists of 16K bytes of memory without parity. This memory is used as both a display buffer for alphanumeric data and as a bit map for graphics data. The regen buffer's address starts at hex B8000.

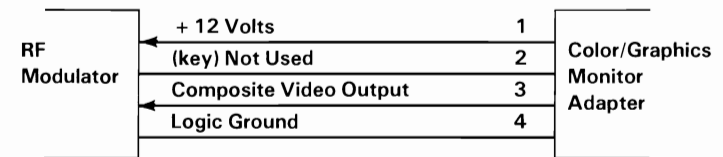
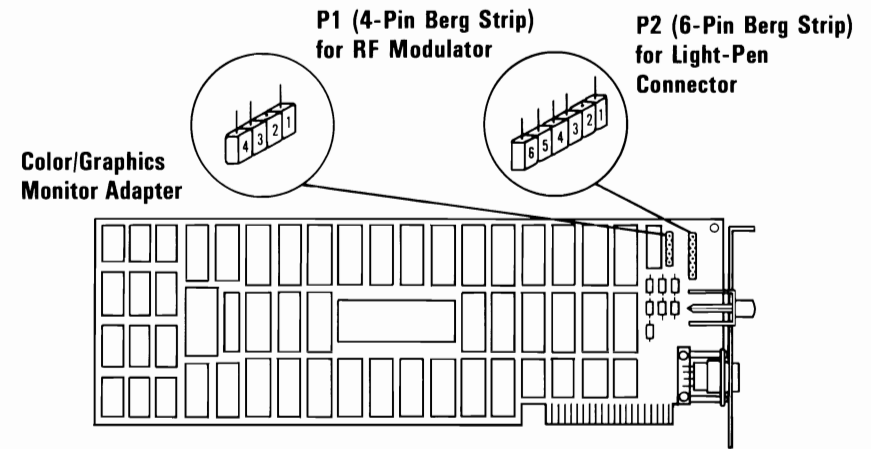


Specifications

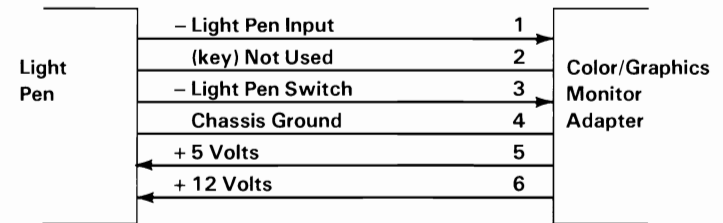
The following pages contain card and connector specifications for the IBM Color/Graphics Monitor Adapter.



Connector Specifications (Part 1 of 2)



RF Modulator Interface

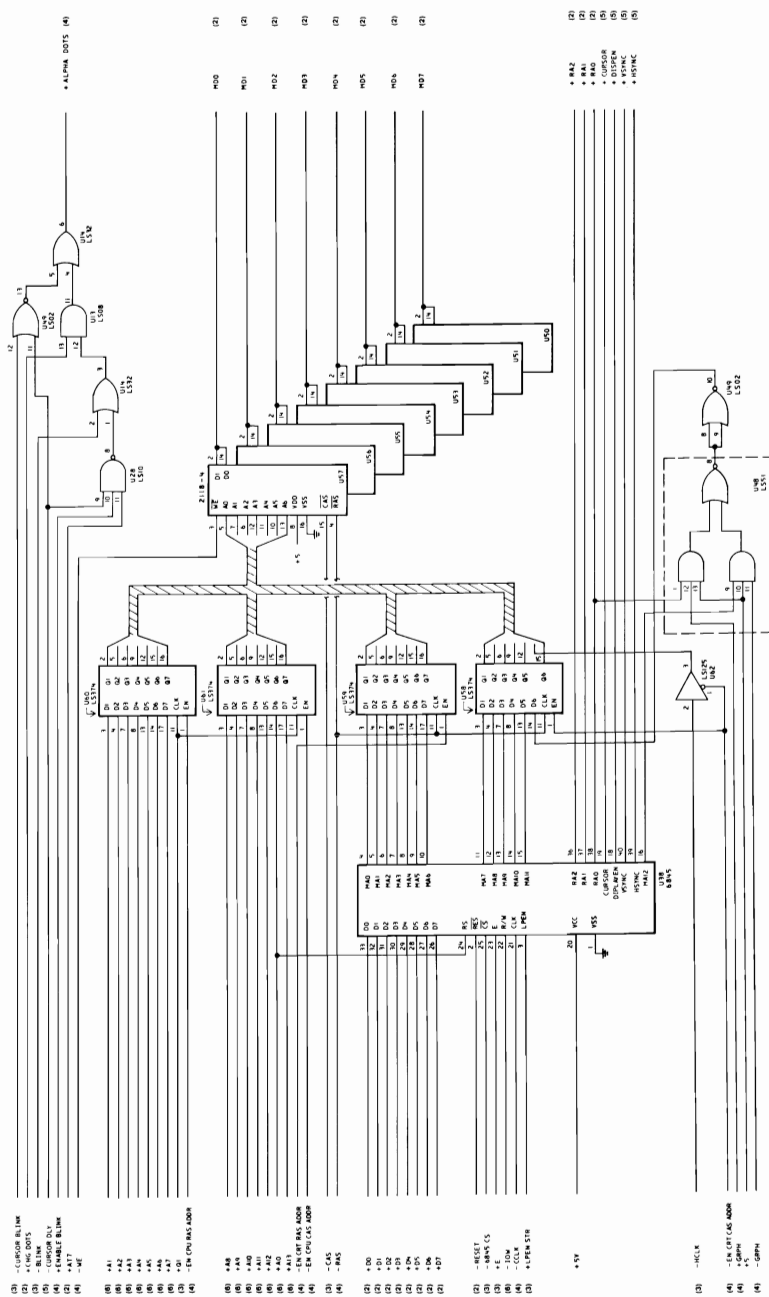


Light Pen Interface

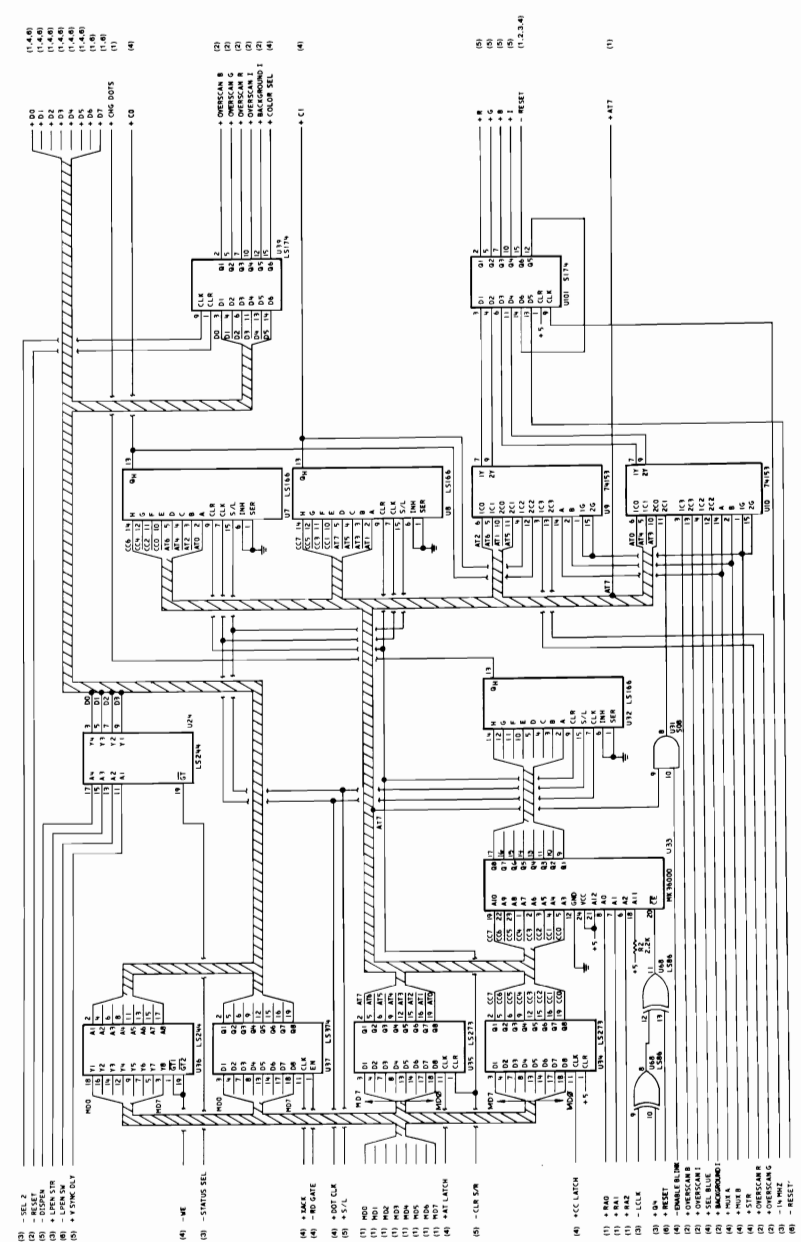
Connector Specifications (Part 2 of 2)

Logic Diagrams

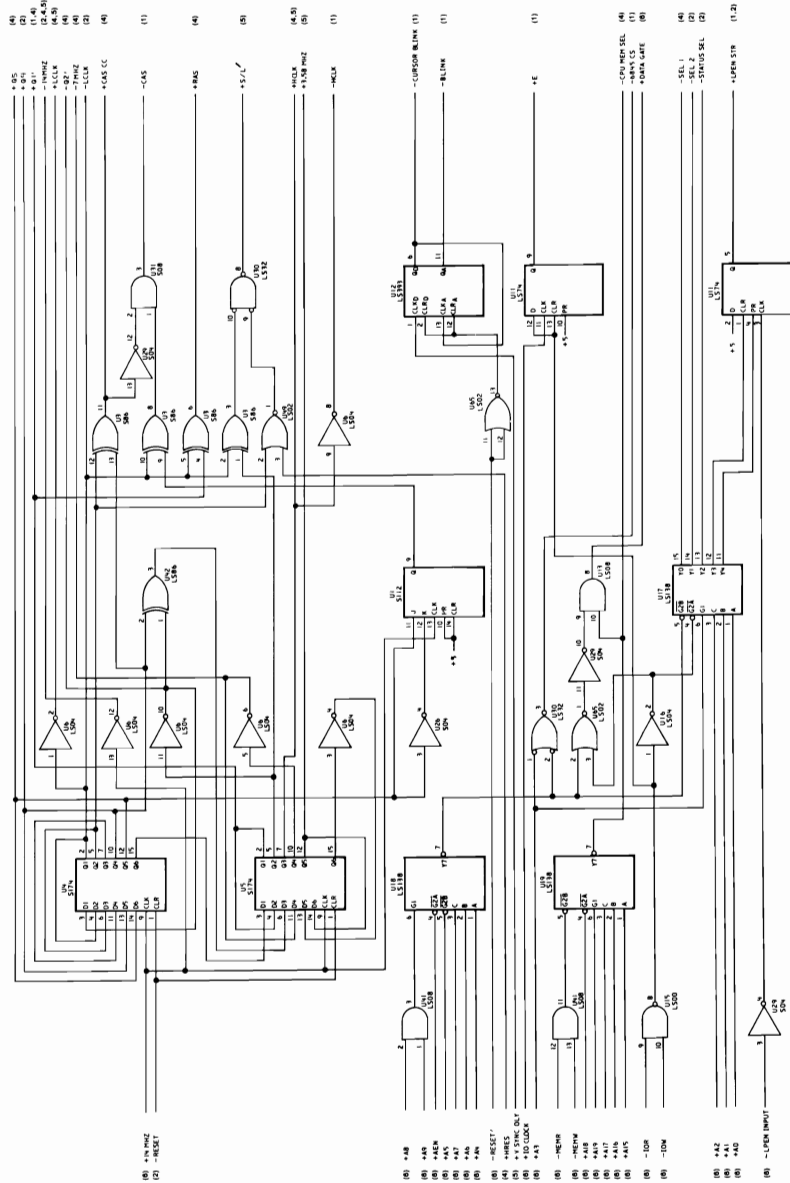
The following pages contain the logic diagrams for the IBM Color/Graphics Monitor Adapter.

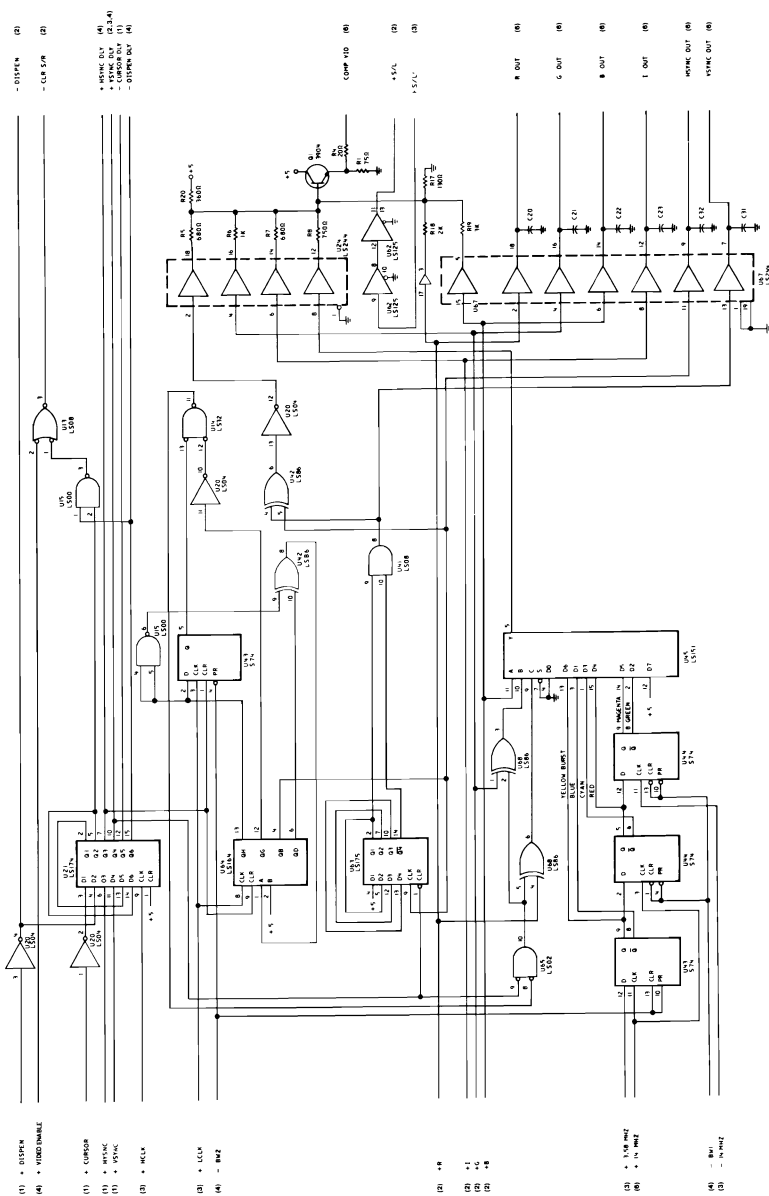


Color/Graphics Monitor Adapter (Sheet 1 of 6)

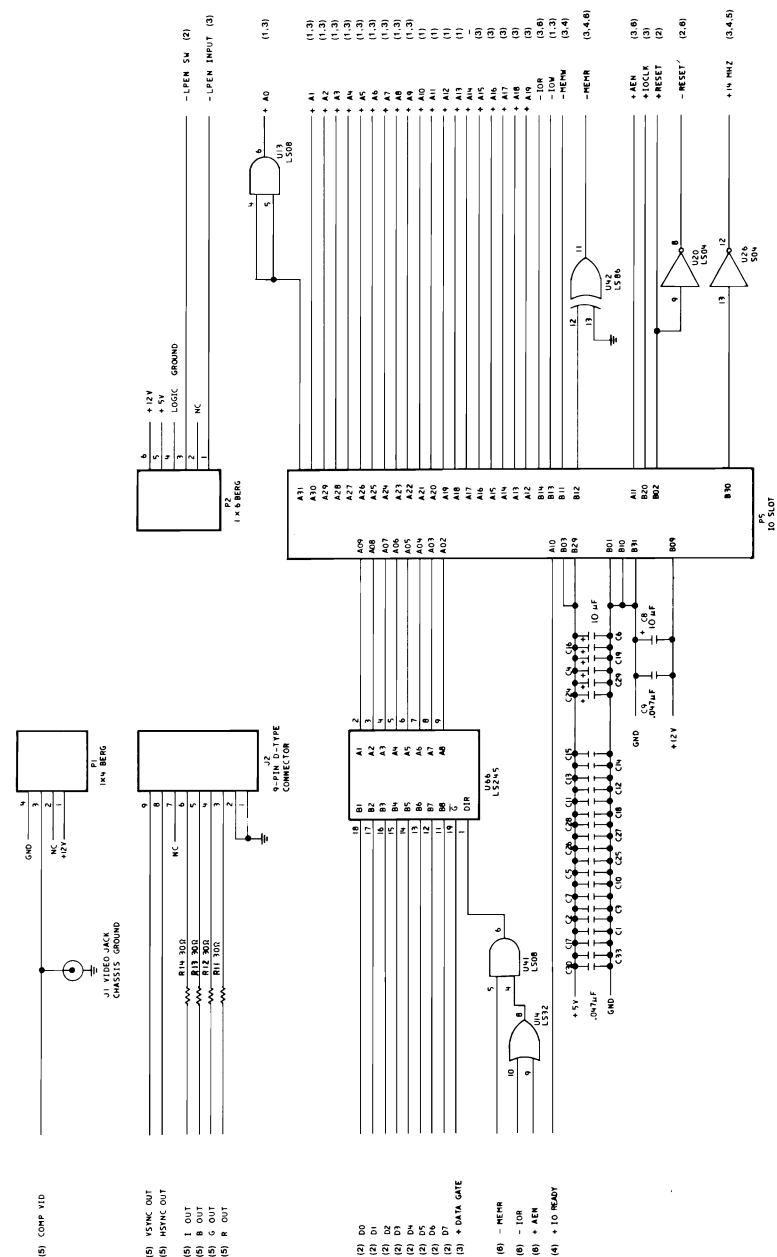


Color/Graphics Monitor Adapter (Sheet 2 of 6)





Color/Graphics Monitor Adapter (Sheet 5 of 6)



Color/Graphics Monitor Adapter (Sheet 6 of 6)

Index

A

alphanumeric mode 6

B

basic operations 12

C

change modes 21
character generator 5
color-select register 18
composite color generator 6
controller 5

D

description 1
display buffer 5

G

graphics modes 9
 high-resolution black-and-white 11
 low-resolution color 9
 medium-resolution color 9

H

high-resolution black-and-white graphics mode 11

L

logic diagrams 27
low-resolution color/graphics mode 9

M

medium-resolution color/graphics mode 9
memory requirements 22
mode set register 5
mode types
 alphanumeric 6
 graphics 9
mode-control register 19
mode-control register summary 20
modes of operation 1

P

programming considerations 15
programming the mode control and status register 15
programming the 6845 crt controller 15

R

registers
 color-select 18
 mode control and status 15
 mode set 5
 mode-control 19
 status 21

S

sequence of events for changing modes 21
specifications 23
status register 21

T

timing generator 6

