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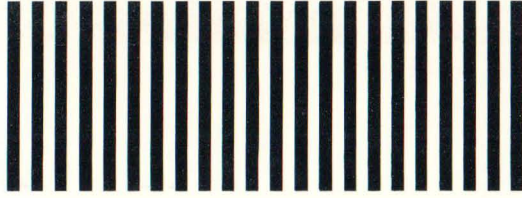
Hercules

Graphics
Card

Owner's Manual



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1 Getting Started

What is the Hercules Graphics Card?

The Hercules Graphics Card is a high resolution graphics card for the IBM PC monochrome display. It replaces the IBM monochrome display/printer adapter and is compatible with its software. The Graphics Card uses the same style high resolution monochrome character set and comes with a parallel printer interface.

The Hercules Graphics Card offers two graphics pages each with a resolution of 720h x 348v. Software supplied with the Graphics Card allows the use of the BASIC graphics commands. A variety of graphics applications software compatible with the Hercules Card is available from other vendors.

Inventory Checklist

Verify that you have received the following items:

- 1 Graphics Card
- 1 owner's manual
- 1 HBASIC diskette

Please fill out the user registration card and return it to us. You will receive our newsletter and important product information for Graphics Cards users. If you did not receive a user registration card, then send us a postcard with your name, address, Graphics Card serial number (which is stamped on the product), and the name of your dealer.

We strongly urge you to read this manual before you attempt to install or operate the Hercules Graphics Card. (You may skip Chapter 2.) If you encounter any problems when using the Graphics Card, consult Appendix 1 before contacting your dealer or us.

Edition 2.0

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1 Getting Started

How to Install the Graphics Card

- A Follow these steps to install the Graphics Card:
- 1 Remove the system unit cover following the instructions in IBM's documentation or consult your dealer if necessary.
 - 2 Make sure that the IBM Monochrome Display/Printer Adapter or any other video board that uses the same screen buffer memory map is not in one of the expansion slots.
 - 3 Locate an empty expansion slot and ensure that there will be enough clearance under the Graphics Card once it is installed. (We recommend slot 2 in the PC and slot 1 in the XT.)
 - 4 Remove the metal plate on the back panel of the system unit opposite the slot you have chosen for the Graphics Card.
 - 5 Firmly insert the Graphics Card into the slot.
 - 6 Replace the bracket screw to secure the card.
 - 7 Set the switch settings on the motherboard for the Monochrome Display or more than one monitor. (Do not count the 64K screen buffer on the Graphics Card when setting the switches for system memory.)
 - 8 Make sure that there is no other card in the system with the same parallel printer port identity LPT1:.
 - 9 If your system is not an IBM PC, consult the manual and contact the factory in case of any difficulties.
 - 10 Run the Diagnostics program.

Important: If you have a Hercules Graphics Card with the model number GB100 stamped on the board, refer to Appendix 4 before running the Diagnostics program.

1 Getting Started

The Graphics Card's "Software Switch"

The Hercules Graphics Card model number GB 101 comes equipped with a "software switch." The purpose of this switch is to allow you to manipulate the Graphics Card with software to select one of three operating configurations.

Pay special attention to the information in this section on setting the "software switch." This is something that needs to be done EACH TIME THE COMPUTER POWERS UP if you want to access either one or both "pages" of graphics screen buffer memory. If you forget to set the card into half or full mode, and you attempt to run any graphics software, your system will probably crash. If this happens, do a "soft boot" (CTRL-ALT-DEL) or power up again.

The DIAG configuration is the state which the card is automatically in after power up. In this configuration, the graphics capabilities are masked, and the Graphics Card emulates an IBM monochrome board for text only. No graphics software may be run while in this mode.

The HALF configuration makes the first graphics page located at B0000-B7FFF accessible to graphics software. The second graphics page located at B8000-BFFFF is suppressed allowing the presence of other video cards provided that their screen buffer does not occupy any portion of the first graphics page. (This configuration allows the presence of an IBM Color Card in the system at the same time as the Hercules Graphics Card.)

The FULL configuration makes the first and second graphics pages accessible to graphics software.

- A Follow these steps to select one of the three configurations:

- 1 To select the DIAG configuration, type

A> HGC DIAG [ENTER]

with the HBASIC diskette in drive A.

Alternatively, while in BASICA (not HBASIC), type

OUT &H3BF,0
SYSTEM

Note *On power up, the Graphics Card will be in the DIAG configuration. Remember that it is necessary to be in the DIAG configuration before attempting to run the Diagnostic Program. However, this is probably the only occasion you'll want to be in this mode.*

1 Getting Started

- 2 To select the HALF configuration, type

A> HGC HALF [ENTER]

Alternatively, while in BASICA (not HBASIC), type

OUT &H3BF,1
SYSTEM

Note *It is necessary to be in the HALF configuration if you have an IBM Color Graphics Adapter in your system and you wish to run graphics software utilizing the first graphics page. (1-2-3 and AutoCad require the FULL configuration.)*

- 3 To select the FULL configuration, type

A> HGC FULL [ENTER]

Alternatively, while in BASICA (not HBASIC), type

OUT &H3BF,3
SYSTEM

Note *It is necessary to be in FULL configuration before running most graphics software, including Lotus 1-2-3 and HBASIC. You may consider this to be the normal operating configuration of the Graphics Card.*

The file on the HBASIC diskette called HGC.EXE is the file that is accessed when you issue the configuration command (e.g. HGC FULL). We recommend that you copy this file onto a system diskette that you power up with.

DOS allows you to create a special batch file (AUTOEXEC.BAT) which is executed automatically when the system boots or reboots. You may find that it is best to include the configuration command (HGC FULL) in such an AUTOEXEC.BAT file on your system diskette. (Make sure that HGC.EXE is also on this diskette.)

Before setting the "software switch," confirm that the program you wish to run is compatible with the Hercules Graphics Card.

1 Getting Started

HBASIC

HBASIC allows you to use BASICA's graphics commands with the Hercules Graphics Card. (The BASIC commands that do not require the IBM Color Card will work without HBASIC on the Hercules Graphics Card.)

A To use HBASIC, follow these steps:

- 1 Put the HBASIC diskette in drive B. (We suggest that you write-protect your HBASIC diskette.)
- 2 Type DIR B: [ENTER]. Verify that these files are on your HBASIC diskette:

HGC.EXE
FIXDIAG.EXE
HBASIC.EXE
HBASIC1.EXE
PATTERN.BAS
FONT.COM
- 3 Copy the files on the HBASIC diskette onto your diskette or hard disk. To do this, with the HBASIC diskette in drive B and your diskette or hard disk in the default drive other than drive B, type

COPY B:*.* [ENTER]
- 4 To run HBASIC, make sure that BASICA.COM from the IBM DOS diskette is also in the default drive, and make sure that you have configured the Hercules card into its full mode. Then type

HBASIC [ENTER] (for DOS 2.0 or 2.1)
or
HBASIC1 [ENTER] (for DOS 1.1)

You can run HBASIC and HBASIC1 from any drive provided BASICA.COM is in the default drive.
- 5 You should now see the BASIC copyright statement and the BASIC prompt, "OK". We suggest that you run PATTERN.BAS when you are in HBASIC to verify that HBASIC is operating properly.

1 Getting Started

- 6 *For advanced users:* HBASIC version 2.1 supports the extended character set (character codes 128 to 255) provided that the font has been loaded prior to the execution of HBASIC. To load the font, type

A> FONT [ENTER]

While in HBASIC, you can key in these extended characters by holding down the [ALT] key while keying in the decimal value of the code on the numeric keypad. In an HBASIC program, you can invoke these characters by using the CHR\$() function. For example, PRINT CHR\$(133) will invoke "à".

B HBASIC FEATURES

- 1 HBASIC will not accept the following statements:
- COLOR
 - SCREEN 0
 - SCREEN 1
 - WIDTH 40
- 2 HBASIC uses a character size of 9 dots wide by 14 dots tall. BASICA uses a character size of 8 × 8 dots. Be aware of this difference when converting screen positions from rows and columns to x,y coordinates.
- 3 When you embed color specifications in a BASIC statement, they will be interpreted modulo 2. This means that if your color specification is 2 in a CIRCLE statement, then the circle will be drawn black. For example:
- CIRCLE(360,174),100,2,,2/3
- 4 The range of values of the screen coordinates are 0-719 horizontal from left to right, and 0-347 vertical from top to bottom.
- 5 The monochrome display has an aspect ratio of 2/3. Embed this in a CIRCLE statement to draw a round circle (see step 3.) Also, to draw a square, make the vertical lines 2/3 as long as the horizontal lines.

1 Getting Started

- 6 HBASIC interprets slower than BASICA, so timing loops will take longer to run.
- 7 Many people find it helpful to know the sequence of steps HBASIC goes through. After you type HBASIC (or HBASIC1 if you are using DOS 1.1) the HBASIC program will load BASICA.COM from the default drive, make some changes to the graphics routines in BASICA, set the screen mode to SCREEN 2 (also known as hi-res mode), and then enter the modified BASICA.
- As HBASIC runs in hi-res mode, do not use SCREEN 0 or SCREEN 1 statements. They will put you back in either text or lo-res mode, which HBASIC is not designed to run in.
- 8 To edit BASIC programs written for the IBM color card:
- a Change SCREEN 0 and SCREEN 1 statements to SCREEN 2
 - b Eliminate the COLOR statements
 - c Change all WIDTH 40 statements to WIDTH 80
 - d Change the aspect ratios to 2/3
 - e Change the x/y coordinates to compensate for the larger monochrome screen.

Configuring the Graphics Card

The Graphics Card uses 64K of the 128K IBM set aside as the PC's video buffer. This 64K buffer is divided into two approximately 32K buffers for each of the two graphics pages.

The printer connected to the Graphics Card will serve as the system's primary printing device (i.e. as LPT1: in DOS terminology). Any parallel port printer or plotter can be used with the Graphics Card, although the operation of those printers will vary with their control codes.

A Display Buffer

Page 0 = B0000-B7FFF (32K bytes)
 Page 1 = B8000-BFFFF (32K bytes)

B Input/Output Ports*

- (Out) 03B4 = 6845 Index Register
- (In/Out) 03B5 = 6845 Data Register
- (Out) 03B8 = Display Mode Ctrl Port
- (Out) 03B9 = Set Lt Pen Flip Flop
- (In) 03BA = Display Status Port
- (Out) 03BB = Reset Lt Pen Flip Flop
- (In/Out) 03BC = Printer Data Port
- (In) 03BD = Printer Status Port
- (In/Out) 03BE = Printer Control Port
- (Out)** 03BF = Configuration Switch

*Non DMA only

**Model number GB101 has Page 1 masked off until the Configuration Switch (03BF) is properly set by software. See section entitled "Programming" for details.

C Interrupt Requests

IRQ7 This interrupt is generated when the printer acknowledges data. It is normally masked off until enabled via the Printer Control Port (03BE).

D Logical Devices Identities

Display = CON: (Monochrome Display)
 Printer = LPT1:

Programming

The Graphics Card is a powerful tool. Exercise caution when programming it until you are familiar with its features. It is possible to damage the monitor with improper programming. Pay particular attention to the warning in the sections entitled "Display Mode Control Port" and "Configuration Switch."

A Interfacing the Graphics Card

1 Display Interface

Interface to the monochrome display is done via the following input/output ports which are discussed in detail below:

- 03B4 6845 Index Register
- 03B5 6845 Data Register
- 03B8 Display Mode Control Port
- 03BA Display Status Port

a 6845 Index and Data Registers (03B4/03B5)

The 6845 controls the frequencies for the monochrome display and the width and height of the screen. There are 16 parameters that govern the display. They are loaded into the 6845 one by one via a single input/output port. Another output port is used to specify which parameter will be loaded next. These two ports are said to be interfacing with the 6845 Data and Index Registers respectively.

Description of Parameters

Index	Data
0	Total characters per row including SYNC less 1.
1	Number of visible characters per row.
2	Position of the first character during SYNC, less 1.
3	Number of characters during SYNC per row, less 1.
4	Number of rows less 1, including the row during vertical retrace.
5	Number of scans (row fractions) in addition to total number of rows. (See index #4 above.)

- 6 Number of visible rows.
- 7 Row number to begin the retrace, less 1.
(This will always last 16 scans.)
- 8 Always output 2. (Consult 6845 data sheet.)
- 9 Number of scans per row, less 1.
- 10 First scan where the cursor will overlay a character.
- 11 Last scan where the cursor will overlay a character.
- 12 Always output 0. (Consult 6845 data sheet.)
- 13 Always output 0. (Consult 6845 data sheet.)
- 14 Offset of the cursor position in the display buffer (H).
- 15 Offset of the cursor position in the display buffer (L).
- 16 Offset into the buffer when lightpen tripped (H).
- 17 Offset into the buffer when lightpen tripped (L).

- Note
- i *The monochrome display requires a scan to be approximately 54 microseconds.*
 - ii *The total number of rows and scans must be adjusted to allow enough time for the screen to be updated 50 times per second.*
 - iii *The local oscillator on the Graphics Card will generate a time base of 0.5625 microseconds per character in text mode and 1 microsecond per character in bit-mapped mode.*
 - iv *In bit-mapped mode, one character is 16 dots wide and 4 scans tall. In text mode, it is 9 dots wide and 14 scans tall.*
 - v *See Appendix 3 for typical parameter values.*

b Display Mode Control Port (03B8)

This output port sets the mode of operation for the Graphics Card.

- | Bit | Options |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0 | Not used |
| 1 | 0 = text mode (Power on default.)
1 = graphics mode
(Note: The 6845 must be reprogrammed each time this bit changes value.) |
| 2 | Not used |
| 3 | 0 = blank the screen (Power on default.)
1 = activates the screen
(This bit is useful when changing modes. By keeping the screen blank for a period of time, the change from text to graphics modes can be done without any screen bounce.) |
| 4 | Not used |
| 5 | 0 = turn off the text blinker (Power on default.)
1 = turn on the text blinker
(This blinker has no effect on the cursor. Every character whose attribute indicates blinking, will now blink.) |
| 6 | Not used |
| 7 | 0 = Page 0 (Power on default. Start display at B0000.)
1 = Page 1 (Start display at B8000. This bit selects the active display buffer on the Graphics Card.) |

- Note
- Be particularly careful when changing between text and graphics modes. You must simultaneously:*
- program the Display Mode Control Port bit 1, and*
 - program the 6845 with the proper parameters.*

When you switch between text and graphics modes, your monitor is subject to some

undefined horizontal and vertical frequencies. For this reason we suggest that you do not use high level languages to control the Display Mode Control Port bit 1. (This does not include memory access which can be done in any language.) See Appendix 3 for a listing of the correct way to change modes.

c Display Status Port (03BA)

This input port is used to sense the real time status of the monochrome display.

Bit	Conditions
0	0 = normal character 1 = SYNC (Screen is temporarily blanked.)
1	Not used
2	Not used
3	0 = dots off 1 = dots on (This bit can be used as a software checkpoint to verify that the monochrome display is receiving an active video signal.)
4	Not used
5	Not used
6	Not used
7	0 = vertical retrace (Screen is temporarily blanked.) 1 = active display. (This information is useful when software wants to make sure that the screen is blanked.)

2 The printer interface uses the following input/output ports:

03BC Printer Data Port
03BD Printer Status Port
03BE Printer Control Port

a Printer Data Port (03BC)

An output to this port will latch the value from the data bus to the printer. The actual pin conditions are returned when input. This feature is used to verify the integrity of the data path.

b Printer Status Port (03BD)

This is an input port only.

Bit	Conditions
0	Not used
1	Not used
2	Not used
3	0 = printer error 1 = normal operation
4	0 = printer not attentive 1 = printer is listening
5	0 = normal operation 1 = out of paper
6	0 = accepting data 1 = ready for more
7	0 = printer is busy, not selected or in error 1 = normal operation

c Printer Control Port (03BE)

This is an input/output port.

Bit	Actions
0	0 = strobe the printer to accept data at the data latch 1 = release the strobe (Power on default.)
1	0 = auto line feed 1 = remote line feed control (Power on default.)
2	0 = initialize the printer (Power on default.) 1 = release the printer for normal operation
3	0 = deselect the printer 1 = select the printer (Power on default.)
4	0 = mask off IRQ7 (Power on default.) 1 = enable IRQ7 when the printer is ready for data
5	Not used
6	Not used
7	Not used

d Configuration Switch (03BF)

This port accesses the software switch that allows one of three configurations of the Graphics Card's memory map and protects against the accidental setting of graphics mode.

Bit	Option
0	0 = (power on default) prevents the setting of graphics mode (bit 1 of Display Mode Control Port) 1 = allows the setting of graphics mode bit (bit 1 of Display Mode Control Port)
1	0 = (power on default) mask Page 1 (B8000-BFFFF) out of the memory map and prevent the setting of page bit (bit 7 of Display Mode Control Port) 1 = bring Page 1 (B8000-BFFFF) into the memory map and allow the setting of page bit (bit 7 of Display Mode Control Port)

B How the Dots Are Generated: Text

In text mode, the display buffer is used to store the character codes and the attribute codes for displayed characters. The offset of the storage is:

$$B0000-B0FFF \text{ (4K bytes)}$$

The text display is 80 characters wide and 25 lines long. All the characters are stored contiguously using up 160 bytes per line. For each character, one byte is used for the character code and one for the attribute.

Offset of the character code of a character:

$$= 160 * (\text{LINE} - 1) + 2 * (\text{COLUMN} - 1)$$

Offset of the attribute of a character:

$$= 160 * (\text{LINE} - 1) + 2 * (\text{COLUMN} - 1) + 1$$

where LINE is between 1 and 25
COLUMN is between 1 and 80

The Graphics Card has a hardware character generator which can do 256 different characters specified by the character codes. There is an attribute decoder which can underline, reverse video, blank, bold face, or blink any character. The character generator conforms to the standard IBM PC character font.

The attribute decoder follows these rules:

7	6	5	4	3	2	1	0	Attribute Codes
B	0	0	0	I	0	0	0	Blank
B	0	0	0	I	0	0	1	Underline
B	0	0	0	I	1	1	1	Normal Display
B	1	1	1	I	0	0	0	Reverse Video

where I = 0 for normal body
I = 1 for bold body.

If the blinker is off (i.e. the display mode control port bit 5 = 0) then

B = 0 for normal background
B = 1 for bold background

If the blinker is on (display mode control port bit 5 = 1) then

B = 0 for no blink
B = 1 for blinking

2 For Advanced Users

C How the Dots Are Generated: Graphics

Once the Graphics Card is in the bit-mapped mode, the display buffer can store two pages, or two screens using one bit per dot. These two pages can be alternately displayed.

While a page or screen is being displayed, any alteration to the buffer for that page will be shown on the display. For the page not being displayed, changes to it will be shown only when it is selected.

The page selection is done by using bit 7 of the Display Mode Control Port in the following manner:

0 for Page 0
1 for Page 1

The buffer area is allocated as follows:

Page 0 = B0000-B7FFF
Page 1 = B8000-BFFFF

The offset (into the page) of the byte containing dot (x,y) in each page is:

$$[2000H * (Y \text{ MOD } 4)] + [90 * \text{INTEGER}(Y/4)] + [\text{INTEGER}(X/8)]$$

and the bit in the byte that stores the dot is bit position

$$7 - (X \text{ MOD } 8)$$

where x is between 0 and 719
y is between 0 and 347

EXAMPLE: The offset of (300,250) is

$$\begin{aligned} & [2000H * (250 \text{ MOD } 4)] + [90 * (\text{INTEGER}(250/4))] + \\ & [\text{INTEGER}(300/8)] \\ & = [2000H * (2)] + [90 * (62)] + (37) \\ & = 4000H + 5617 \\ & = 4000H + 15F1H \\ & = 55F1H \end{aligned}$$

and bit position is

$$7 - (300 \text{ MOD } 8) = 7 - (4) = 3.$$

A Appendix 1

Troubleshooting

If you encounter any problems when using the Graphics Card, please review the following:

- A You cannot run graphics software written solely for the IBM Color Graphics Adapter (e.g. Microsoft's Flight Simulator.) Make sure that you have the Hercules version of the graphics program you would like to run (e.g. Version 1A of 1-2-3).
- B Make sure that you do not have an IBM Color Graphics Adapter or Monochrome Display/Printer Adapter in the system at the same time as the Hercules Graphics Card. (This also applies to other graphics cards which use the same screen buffer address as the Graphics Card.)
- C Check these points when using HBASIC:
 - 1 Use the "HBASIC" file with DOS 2.0 or DOS 2.1 and use the "HBASIC1" file with DOS 1.1. (HBASIC does not work with DOS 1.0.)
 - 2 Run HBASIC in SCREEN 2 mode only.
 - 3 Do not use HBASIC version 1.0, 1.1, 2.0 with a disk emulator like JFORMAT.
 - 4 Check your switch settings and make sure that they are set for the monochrome display. (See "How to Install the Graphics Card.")

A Appendix 2

Register Descriptions

Bit #	CRT Control (03B8) (Write Only)	CRT Status (03BA) (Read Only)	Printer Data (03BC) (Read/Write)	Printer Status (03BD) (Read Only)	Printer Control (03BE) (Read/Write)
0	Not used	+ Horizontal Sync	D0	Not used	+ Strobe
1	+ Select Graphic Mode	Reserved	D1	Not used	+ Auto Feed
2	Not used	Reserved	D2	Not used	- Initialize Printer
3	+ Enable Video Output	+ Video Output	D3	- Error	+ Select In
4	Not used	Not used	D4	+ Select Status	+ Enable IRQ7 On - Ack
5	+ Enable Char Blink	Not used	D5	+ Paper Out	Not used
6	Not used	Not used	D6	- Ack	Not used
7	Page #	- VSync	D7	- Busy	Not used

A Appendix 3

Application Notes

Code segments to change modes. (Make sure that the configuration bit is set to your requirements before attempting to change modes.)

```

;      port address
index  equ      03b4h
cntrl  equ      03b8h

;      control codes
scrn_on  equ      8
grph     equ      2
text     equ      20h

xdata segment public 'data'
gtable  db      35h,2dh,2eh,07h
        db      5bh,02h,57h,57h
        db      02h,03h,00h,00h

ttable  db      61h,50h,52h,0fh
        db      19h,06h,19h,19h
        db      02h,0dh,0bh,0ch

xdata ends
xcode segment public 'code'
        assume cs:xcode,ds:xdata
    
```

GRAPHICS MODE—programs the 6845 CRT controller for the 720 × 348 graphics mode. The active page for both writing and display is set to the default value of page 0.

ON ENTRY: no parameters.

```

gmode  proc      near
        push     es
        push     ds

        mov     ax,xdata
        mov     ds,ax

        mov     al,grph
        lea    si,gtable
        mov     bx,0
        mov     cx,4000h
        call   setmd
    
```

A Appendix 3

```

        pop     ds
        pop     es
        ret
gmode  endp

```

TEXT MODE—programs the 6845 and CRT control register to produce text mode.

ON ENTRY: no parameters.

```

tmode  proc      near
        push    es
        push    ds
        mov     ax, xdata
        mov     ds, ax
        mov     al, text
        lea    si, ttable
        mov     bx, 720h
        mov     cx, 2000
        call   setmd
        pop     ds
        pop     es
        ret
tmode  endp
setmd  proc      near
;      sets mode to graphics or text
;      depending on al
;      si = parameter table
;      cx = number of words to be cleared
;      bx = blank value
        push    ds
        push    es
        push    ax
        push    bx
        push    cx
;      change mode but without scrn_on
        mov     dx, cntrl
        out     dx, al

```

A Appendix 3

```

;      initialize the 6845
        mov     ax, ds
        mov     es, ax      ;also point es:si
                           ;to parameter
                           ;table
        mov     dx, index
        mov     cx, 12     ;12 parameters to
                           ;be output
                           ;starting from
                           ;reg.0
parms:  mov     al, ah
        out     dx, al     ;output register
                           ;number
        inc     dx
        lodsb
        out     dx, al     ;output data
        inc     ah         ;next value
        dec     dx
        loop   parms
        pop     cx         ;clear the buffer
        mov     ax, 0b000h
        cld
        mov     es, ax
        xor     di, di
        pop     ax
        rep    stosw
;      scrn_on, page 0
        mov     dx, cntrl
        pop     ax
        add     al, scrn_on
        out     dx, al
        pop     es
        pop     ds
        ret
setmd  endp
xcode ends

```

A Appendix 4

Modifying the Diagnostics Program

If you have a Hercules Graphics Card model number GB 100, do not attempt to run the IBM diagnostic program versions 1.0, 1.01, 1.02 or 1.03 without making the changes described below. (Diagnostics version 2.0 can be run without modification.)

- A** Make a copy of the diagnostics program by formatting a blank diskette and using the DISKCOPY or COPY command described in the DOS manual.
- B** Boot DOS and wait for the A>.
- C** Insert the HBASIC diskette in drive A:.
- D** Insert your copy of the diagnostics diskette in drive B:.
- E** Execute the "FIXDIAG.EXE" program on drive A: by typing
FIXDIAG [ENTER]
- F** To run the diagnostic program, put your modified diagnostic copy in drive A: . Hold down the [ALT], [CTRL] and [DEL] keys simultaneously to reset the system and start the diagnostics program.
- G** Consult your IBM Guide to Operations to step through the diagnostics program.

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