H-80-0483

Graphic8™

COMPUTER GRAPHICS DISPLAY SYSTEM

SERIES 8200

TECHNICAL DESCRIPTION

NOVEMBER 1980

Information Products Division
Federal Systems Group
SANDERS DANIEL WEBSTER HIGHWAY, SOUTH–NASHUA, NEW HAMPSHIRE 03061

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WARNING

This equipment generates, uses, and can radiate radio frequency energy, and if not installed and used in accordance with the instructions manual, may cause interference to radio communications. As temporarily permitted by regulation, it has not been tested for compliance with the limits for Class A computing devices pursuant to Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference. Operation of this equipment in a residential area is likely to cause interference, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

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SECTION 1

GRAPHIC 8 SYSTEM DESCRIPTION

1.1 INTRODUCTION

The Sanders Associates, Inc. GRAPHIC 8™ is a high-performance, intelligent computer graphics terminal system incorporating refreshed raster display technology. The Graphic 8 combines sophisticated display processing techniques, developed by Sanders in the popular GRAPHIC 7™ refreshed stroke graphics product line, with new CRT raster graphics features. It is designed to interface a host computer and to support operator CRT display monitor stations configured with interactive devices, such as keyboards, trackballs, forcesticks, and data tablets. Also, it can produce permanent hard copy records of displayed data.

The GRAPHIC 8 system utilizes many of the key features of the GRAPHIC 7 system. For instance, the GRAPHIC 8 can use any of the existing GRAPHIC 7 high-speed, parallel host computer interfaces or the RS-232C port. Existing GRAPHIC 7 software, including the Sanders' FORTRAN Support Package (FSP), may be used with the GRAPHIC 8. And both systems use a common display processor instruction set.

The 8200 series GRAPHIC 8 features a dynamic display update via a double refresh buffer memory technique. From one up to four CRT display monitors are supported by the 8200 series configurations. Resolutions of 512 x 512, 640 x 480, 1024 x 768 (interlaced) or 1024 x 1024 (interlaced) are available. Both color and monochrome versions are offered with up to 8 bits per pixel to provide as many as 256 simultaneous colors or monochrome intensities (or 128 plus blink).

The GRAPHIC 8 display processor is a general purpose digital computer with a set of over 400 instructions that controls a variety of functions, which reduce the loading on the host computer. In combination with the host computer, the GRAPHIC 8 system permits the user to display digital data in a visual format on the CRT display monitor and to interact with the displayed image by means of keyboards, forcesticks, trackballs, and data tablets. Its high performance and intelligence make it well suited to a variety of applications, such as, CAD/CAM, simulation and training, command and control, cartography, and many others.

The basic GRAPHIC 8 system consists of a terminal controller and a monitor. The basic system can be expanded to include a wide variety of options and enhancements.

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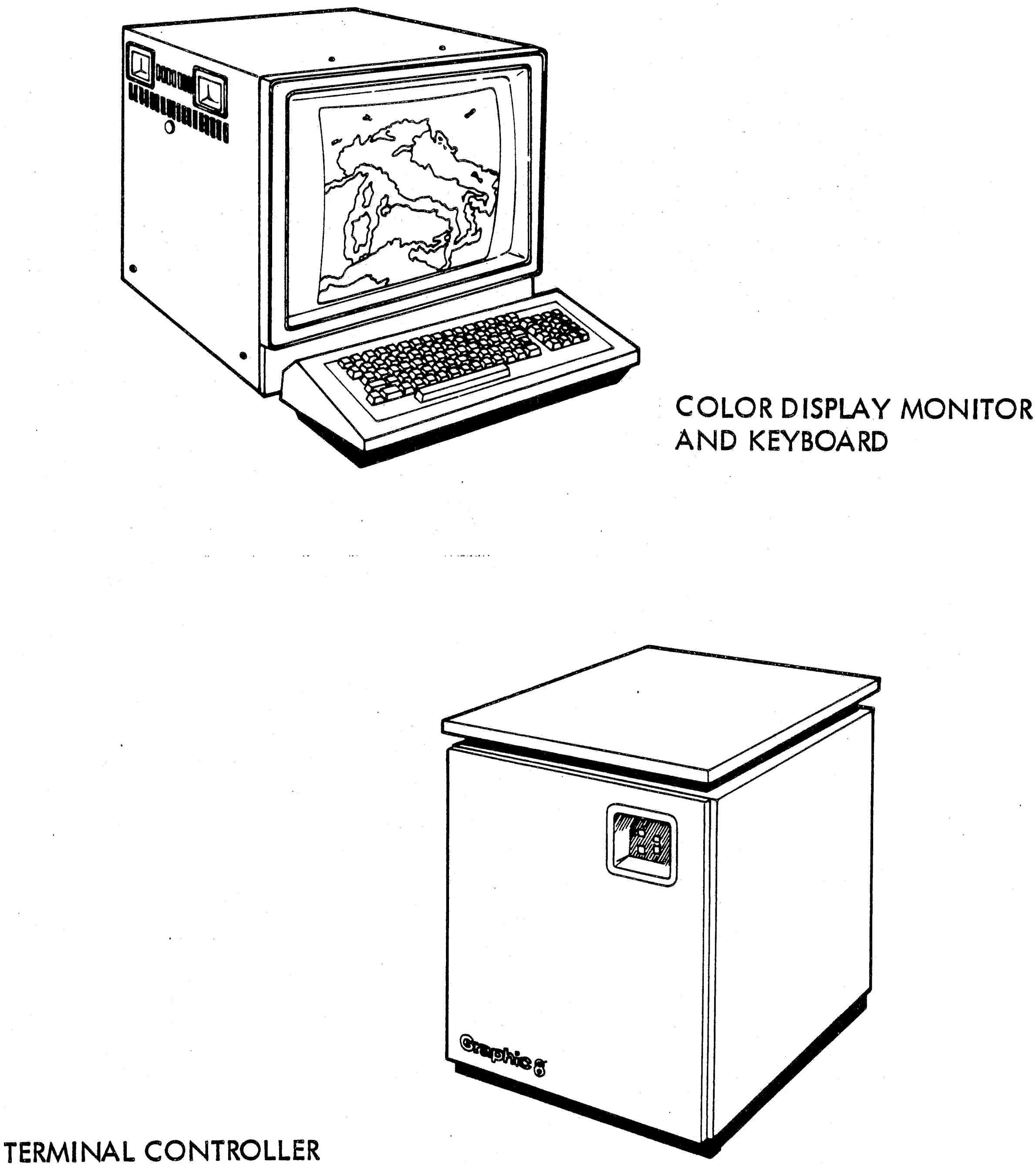
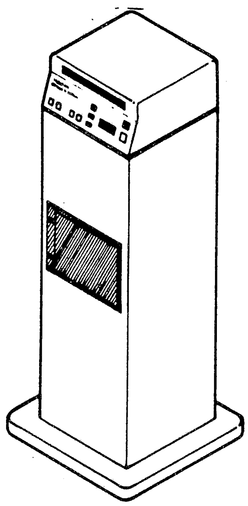


Figure 1-1. GRAPHIC 8 System Components

DESCRIPTION

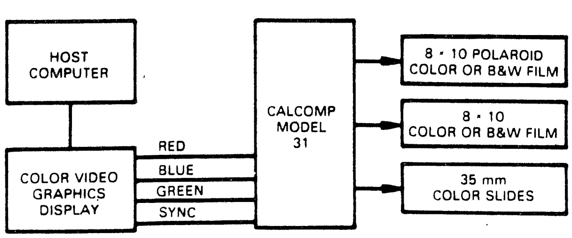
The CalComp Model 31 is a stand-alone recording system for making 8 × 10 inch color or black and white prints and 35 mm color slides of any data presented on its self-contained, high resolution raster scan CRT. With Polaroid Type 808 Polarcolor 2 Land film, the Model 31 makes color prints instantly available.



FEATURES

- Exceptional image resolution with accurate rendition of color hue, saturation and lightness
- High throughput (at least thirty 8 × 10 prints or over one hundred 35 mm slides per hour)
- For use with all raster scan computer graphics and digital image processing applications
- Microprocessor controlled to assure consistent exposure, reliable operation
- Separation mode for automatic three-color separation exposures
- Switchable raster blending for high color saturation prints
- Fully automated 35 mm slide capability with remote control (optional)

SYSTEMS INTERCONNECT



SPECIFICATIONS AND CHARACTERISTICS

Video Monitor:
Nominal resolution of 1400 lines center screen at 100 cd/m² (30 fL) on flat-face CRT.
Pixel position error is<0.5% within a 9 cm circle, <1% at corners.

Speed of Operation:
8" by 10" Polaroid—less than 60 seconds per exposure
8" by 10" Transparency—less than 40 seconds per exposure
35 mm—6 seconds per exposure

Film Type:
8" × 10" (20.32 cm × 25.40 cm)—color or black and white. Must be loadable in cassette format.
With optional auxiliary camera, 35 mm sprocket feed film—color only, in cartridge.

Film Speed:
15 DIN (ASA25) to 24 DIN (ASA200)

Physical Specifications:

Width	38.7 cm (15.25 in.)
Depth	38.7 cm (15.25 in.)
Height	113.2 cm (44.75 in.)
Base	50.4 cm × 50.4 cm (20 in. × 20 in.)
Weight	40 kg (88 lbs.)

Power Requirements: (all units single phase, line to neutral):

Standard	120 VAC ± 10%, 50/60 Hz, 0.8 amps, 110 watts (max)
Optional	100 VAC ± 10%, 50/60 Hz, 1.0 amps, 220 or 240 VAC ± 10%, 50/60 Hz, 0.5 amps

Video Input:
Separate Red, Green, Blue, and Sync video signals of 0.35 to 2.0 peak to peak voltage required.
Standard—Handles horizontal line rate of 500 to 650.
Optional-High Line— Handles horizontal line rate of 800 to 1100 at 60 Hz or 1300 at 50 Hz.

Operating Environment:
Temperature—20°C ± 10°C
Relative Humidity—15% to 90% non-condensing
Altitude—Sea level to 4500 meters
Operating Noise—Negligible

Cables:
Power: 3 meter power cord.
Interface: Four 74 Ohm, RG-59 coaxial cables of 3 meters each. BNC Plug on each end will mate to BNC Bulkhead Receptacle.

Figure 1-2. CalComp Model 31 Color Graphics System Specifications

SECTION 2

OPERATING MODES

2.1 GENERAL

The GRAPHIC 8 system can be operated in either the local or the system mode. In the local mode, the GRAPHIC 8 operates as a stand-alone system; in the system mode, the GRAPHIC 8 operates on-line to the host computer. Initialization in either mode causes built-in diagnostic routines to be performed automatically.

2.2 LOCAL MODE

After primary power has been applied to the GRAPHIC 8, the system may be initialized in the local mode by pressing the LOCAL pushbutton switch on the front of the terminal controller. Pressing this switch causes a verification test pattern to be displayed on each of the associated display monitors, causes the built-in diagnostic routines to be performed, and enables local mode commands to be executed. The following paragraphs discuss these operations as they relate to software.

2.2.1 VERIFICATION TEST PATTERN AND DIAGNOSTICS. Figure 2-1 is the verification test pattern that is displayed on each display monitor when the GRAPHIC 8 is initialized in the local mode. This pattern remains displayed until terminated by the proper command (paragraph 2.2.2) or until a period of 45 minutes has elapsed since an operation affecting the pattern was last performed.

Components of the verification test pattern that are primarily associated with software and the operation of peripheral devices are identified in figure 2-1. When the system is first initialized in the local mode, "XX" appears in the small box in the lower right portion of the pattern. The "XX" indicates that the code appearing in the same box contains the results of the built-in diagnostic routines that were automatically performed. The diagnostic code is a three-digit octal representation of an eight-bit binary code that indicates the results of each diagnostic routine. Bits in the binary code are assigned as follows:

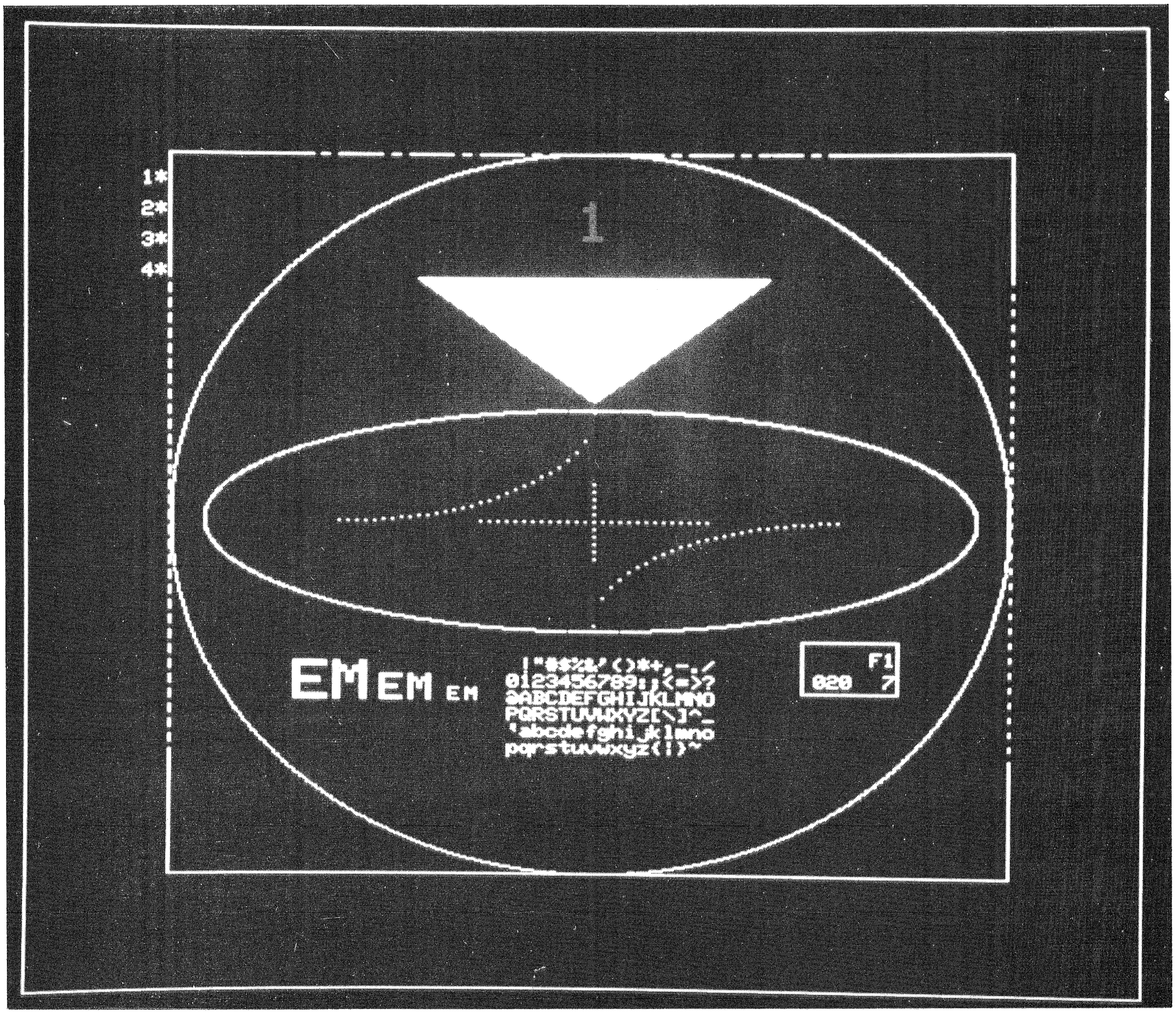
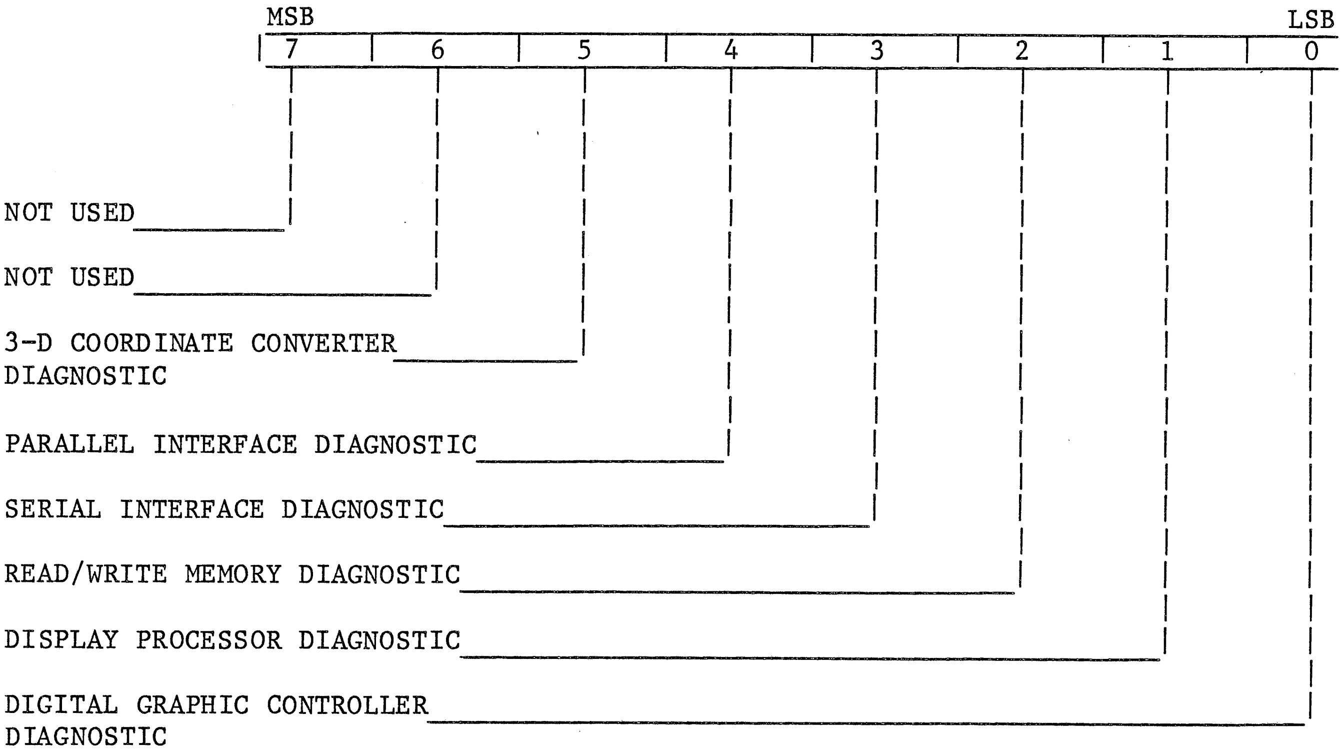


Figure 2-1. Verification Test Pattern



A checksum calculation routine performed whenever the GRAPHIC 8 is initialized in the local mode is a checksum calculation based on all GCP stored in read only memory. The result is deposited in memory location - 500 (octal). Location 500 can also be examined as described in paragraph 2.2.2.1.

When a diagnostic routine detects a malfunction, the corresponding bit in the error code is set to a 1; if no malfunction is detected, the bit is set to a 0. The octal code displayed in the verification test pattern then indicates the results of all the diagnostic tests. For example, 000 indicates all tests passed, 002 indicates the display processor diagnostic test failed, 030 indicates the serial and the parallel interface diagnostic tests failed, and 077 indicates that all diagnostic tests failed.

As soon as any input is received by the terminal controller via a serial interface port, the "XX" in the small box is replaced by a code that indicates the port to which the input device is connected. Codes associated with each serial interface port are shown in table 2-1.

When the serial interface port designation is displayed in the small box, the three digit octal code in the box indicates the code last transmitted to the terminal controller. Additionally, if the code represents a displayable character, the character appears in the upper left corner of the box. If the code does not represent a displayable character, the upper left corner of the box is blank. In systems using SI (shift in) and SO (shift out) codes to identify characters in an extended set, the SI character is displayed over the left hand digit of the code and the SO character is displayed over the right hand digit.

Table 2-1. Serial Interface Port Codes

CODE	SERIAL INTERFACE PORT	DEVICE	ASSOCIATED CONNECTOR
TT	TTY	Console teletypewriter	J2 on ROM and Status card
F1	3	Function keyboard 1	J5 on multiport serial interface card #1
F2	7	Function keyboard 2	J5 on multiport serial interface card #2
F3	2	Function keyboard 3	J4 on multiport serial interface card #1
F4	9	Function keyboard 4	J3 on multiport serial interface card #3
S1	1	Serial host	J2 on multiport serial interface card #1
PED Indicators			
1*	4	PED #1	J6 on card #1
2*	8	PED #2	J6 on card #2
3*	6	PED #3	J4 on card #2
4*	10	PED #4	J4 on card #3

Trackball (or forcestick) indicators appear in the upper left corner of the verification test pattern. The "1*" indicator is associated with the device normally connected to serial interface port 4 (J6 on multiport serial interface card no. 1) while the "2*" is associated with the device normally connected to serial interface port 8 (J6 on multiport serial interface card no. 2). These indicators n* displayed on the test pattern are only those that are included in the system configuration (Display Processor II switch settings) regardless of whether the trackball or forcestick is physically connected to the system. If a trackball or forcestick is connected to port 4 or 8, it can be manipulated to move its associated indicator about the screen of the CRT as desired. (See paragraph 2.2.1.2 for data tablet.)

The 1-digit numeral in the upper center of the verification test pattern indicates the monitor (1-4).

A filled polygon positioned beneath the blinking monitor number will display the default colors/gray levels. The number of colors/gray levels is a function of the configuration and can be 8, 16, 128, or 256.

2.2.1.1 Hardcopy Generation. A hardcopy of the terminal verification pattern can be generated by pressing function key F0 to freeze the pattern and then the hardcopy initiate button located on the hardcopy unit.

2.2.1.2 Data Tablet Testing. The data tablet can be tested by pressing function key F1. This causes the n* trackball/forcestick indicators to change to n#. The 1# and 2# symbols indicate that all messages received via ports 4 and 8 are in data tablet format. (Data tablet messages consist of 10 character messages, whereas the trackball and forcestick generate 2-character messages.) When the data tablet pen switch is pressed and the pen is moved along the active area of the data table surface, the appropriate cursor symbol (1# or 2#) moves at a rate proportional to the movement of the pen. The 1# symbol is associated with the data tablet connected to port 4 and the 2# symbol is associated with the data tablet connected to port 8.

NOTE

Successively pressing function key F1 causes the terminal verification pattern to switch from processing data tablet messages to trackball/forcestick messages and vice versa.

2.2.2 LOCAL MODE COMMANDS. After the GRAPHIC 8 has been initialized in the local mode the verification test pattern is no longer required, display of the pattern may be terminated by pressing the RETURN key on the keyboard. The pattern then disappears and the letters "BO M" are displayed on the center of the CRT screen as an indication that the system is in the local monitor mode. At this point, the operator can perform any of several operations that permit him to monitor or debug a program, transfer control, or communicate with the host computer.

NOTE

Commands are executed when the RETURN key on the keyboard is pressed.

The following paragraphs discuss commands that can be executed when the system is in the local monitor mode. A summary of the commands is given in table 2-2.

2.2.2.1 Memory Commands. The content of a memory location is displayed by typing the octal address (typing of leading zeros is not required) followed by a slash (/). As soon as the slash is typed, the content of the memory location is displayed immediately to the right of the address. Successive memory locations can then be examined simply by pressing the slash key. Each time the slash key is pressed, the memory address is incremented by two and its content displayed immediately to the right of the slash.

Table 2-2. Local Mode Command Summary

KEYBOARD ENTRY	OPERATION
RETURN	Executes local mode command or returns system to local monitor level.
nnnnnn/	Displays contents of memory address nnnnnn (octal).
/	Increments memory address counter by two and displays address contents.
∧ or ↑	Decrements memory address counter by two and displays address contents.
Bn	Select different memory bank. (B0 0-32K; B1 32-64K; B2 64-96K; B3 96-128K; and B4 16-32K RAM).
S	Transfers GRAPHIC 8 to system mode operation.
T RETURN	Transfers to the verification test pattern.
L RETURN	Loads memory from paper tape reader.
nnnnL RETURN	Loads selected option from expansion module.
U RETURN	Unload all options.
O RETURN	Display status of all options loaded.
Q	Decrements contents of display processor Q register by two and displays result. Used with diagnostics to indicate address at which display processor halted.
nnnnnnD RETURN	Directs graphic controller to display refresh file beginning at address nnnnnnn (octal).
nnnnnnG RETURN	Transfers control of display processor to program beginning at memory address nnnnn (octal).
Y RETURN	Calls teletypewriter emulation program. After entering emulation program, function key F0 clears CRT screen. Function key F1 selects full or half duplex operation; receipt of octal code 035 from the host computer or pressing function key F13 transfers GRAPHIC 8 to system operating mode.
RUB OUT	Deletes last octal entry from keyboard.

After the slash key has been used to examine the content of a memory location, the up arrow (↑ or ∧) key may be used in a similar manner to examine preceding memory locations. Each time the up arrow key is pressed, the memory address is decremented by two and its content displayed immediately to the right of the slash.

The content of a memory location may be changed after it has been examined by typing the new data (typing of leading zeros is not required) before pressing the slash or up arrow key. The new data is displayed to the right of the old data and is automatically substituted when the slash or up arrow key is pressed.

Memory locations in other banks can be examined or changed via the bank (B) select command. Typing B0, B1, B2, B3, or B4 causes the memory bank selection to be changed to bank 0, bank 1, bank 2, bank 3, or bank 4 respectively. Below is a table representing the associated virtual and physical addresses for each bank.

Bank Number	Virtual Address	Physical Address	Pages
0*	000000-177777	000000-177777	00-07
1	000000-177777	200000-377777	10-17
2	000000-177777	400000-577777	20-27
3	000000-177777	600000-777777	30-37
4*	000000-177777	100000-177777	04-07

NOTE

*Addresses in the range of 140000-177777 (pages 4, 5, 6, and 7) for bank 0 correspond to ROM and I/O device registers. Addresses in the range of 140000-177777 for bank 4 correspond to RAM.

Return to the monitor level is accomplished by pressing the RETURN key. When this key is pressed, any specified memory content change is completed and the system returns to monitor level as indicated by letters "Bn M" displayed at the center of the CRT screen.

2.2.2.2 Displaying a Refresh File. When the system is in the local monitor mode, the contents of a refresh file may be displayed by typing the starting address of the file (in octal notation) followed by a "D" and then pressing the RETURN key. This command instructs the graphic controller to display the entire refresh file that begins at the specified address. Display of the refresh file continues until the RETURN key is pressed again, at which time the system returns to the local monitor level. This command is subject to the bank argument presently displayed.

2.2.2.3 Transfer of Program Control. Program control may be transferred from local monitor level to any desired address location in bank 0 by typing the address location in octal notation followed by a "G" and then pressing the RETURN key. The display processor then executes instructions beginning with the instruction at the specified address. Any further operations depend on the program to which control is transferred.

2.2.2.4 Transfer to System Mode. To transfer to the system mode of operation from monitor level, type "S". This command has the same effect as pressing the SYSTEM switch on the terminal controller (paragraph 2.3). After transferring to the system mode, operation in the local mode can be reestablished only by a message from the host computer or by pressing the LOCAL switch on the terminal controller.

2.2.2.5 Teletypewriter Emulation. For purposes of communicating with a host computer, the GRAPHIC 8 can be made to emulate the functions of a teletypewriter. In this mode, the keyboard operates like the keyboard of a teletypewriter and the display monitor serves as the printout device. Scrolling of data on the display monitor is handled on a half-page basis. That is, when the CRT screen is full, the top half of the data is deleted from the display and the bottom half of the data moves up to take its place.

If a parallel interface card is installed in the terminal controller, the Graphic Control Program assumes that communications with the host computer are to be handled over the parallel interface. In this case, teletypewriter emulation signals are transmitted in parallel using only the low order byte (bits 0-7) of the 16-bit interface. If a parallel interface card is not installed, a standard 8-bit serial interface via serial interface port 1 is assumed. In either case, bit 7 is always equal to zero.

The emulation program is entered from the monitor level by typing the letter "Y" followed by RETURN. Full-duplex of half-duplex emulation may then be selected by pressing function key F1 which changes the selection each time it is pressed. The type of emulation selected is indicated by the "TTY F" (full duplex) or "TTY H" (half duplex) that is displayed at the top of the screen at all times during emulation. Switching between full and half duplex operation may be accomplished at any time during emulation by pressing function key F1. Pressing function key F0 during teletypewriter emulation causes the screen to be cleared.

Exit from the teletypewriter emulation program occurs when octal code 035 (ASCII control character GS Group Separator) is received from the host computer. This code, which can also be generated by pressing function key F13, immediately causes the GRAPHIC 8 to transfer to the system mode of operation. Return to the local monitor level can be achieved only by a command from the host computer or by pressing the LOCAL pushbutton switch on the terminal controller.

2.2.2.6 Additional Local Mode Commands. Additional commands that can be used when the GRAPHIC 8 is in the local mode at the monitor level are the L, U, O, T, Q, and RUB OUT commands. The L command enables the memory to be loaded from a paper tape reader connected to the terminal controller. After the tape has been placed in the reader, loading is initiated by typing the letter "L" followed by RETURN.

NOTE

> A paper tape reader may be connected to multiport serial interface card ports 1, 2, or 3 or to the serial interface port on the ROM and status logic card.

The L command can also be used to load in options from the expansion module. The option command format is as follows:

nnnnL RETURN

where nnnn is the option number. Valid option numbers are in the ranges of 1 to 3777 and 4001 to 7777.

NOTE

The optional expansion module can store a variety of option types.

The U command is used to unload all options. Typing "U" followed by RETURN will cause all options to be unloaded.

The O command is used to detect the presence and status of all loaded options. Typing O followed by RETURN causes the display of the first option loaded. Successively pressing the RETURN key causes the display of all other options loaded. The option status is displayed in the following format.

nnnn ss   Where nnnn is the option number and ss is the option status

The option status code is as follows:

00	Detected but unloaded
01	Unloaded, checksum error (local)
11	Unloaded, checksum error (system)
02	Unloaded, checksum OK, hardware not present (local)
12	Unloaded, checksum OK, hardware not present (system)
03	Unloaded, checksum OK, self test = no go (local)
13	Unloaded, checksum OK, self test = no go (system)
04	Loaded, checksum OK, self test = go (local)
14	Loaded, checksum OK, self test = go (system)

The T command is used to recall the verification test pattern when the system is at the local monitor level. This command is executed by typing the letter "T" followed by RETURN. The effect is the same as pressing the LOCAL switch on the terminal controller. Pressing RETURN a second time causes the system to return to the monitor level.

Table 2-3. Standard Transfer Table

ADDRESS (OCTAL)	INFORMATION OR ROUTINE	REMARKS
157700	GCP date (year and month)	High order byte indicates month in octal form. Low order byte indicates last two digits of year in octal form (e.g., 003115 indicates June 1977).
157702	GCP date (day)	Day of month is indicated in octal form.
157704	GCP release number	Release number is indicated in octal form.
157706	Number of GCP field changes	Number of field changes is indicated by the number of bits set to 1 (e.g., 000007 indicates three field changes).
157710	ZERO	Maintenance routine. Graphic controller sets X and Y positions at zero (center of screen) and then halts.
157720	PLUS	Maintenance routine. Graphic controller sets X and Y positions at maximum on-screen positions (upper and right corner) and then halts.
157730	MINUS	Maintenance routine. Graphic controller sets X and Y positions at minimum on-screen positions (lower left corner) and then halts.
157740	LOADER	Enables a file to be loaded into read/write memory from various input devices.
157750	MONITOR MODE	Enables local mode commands to be executed.
157760	SYSTEM MODE	Enables system mode.
157770	TEST PATTERN	Transfers to verification test pattern.

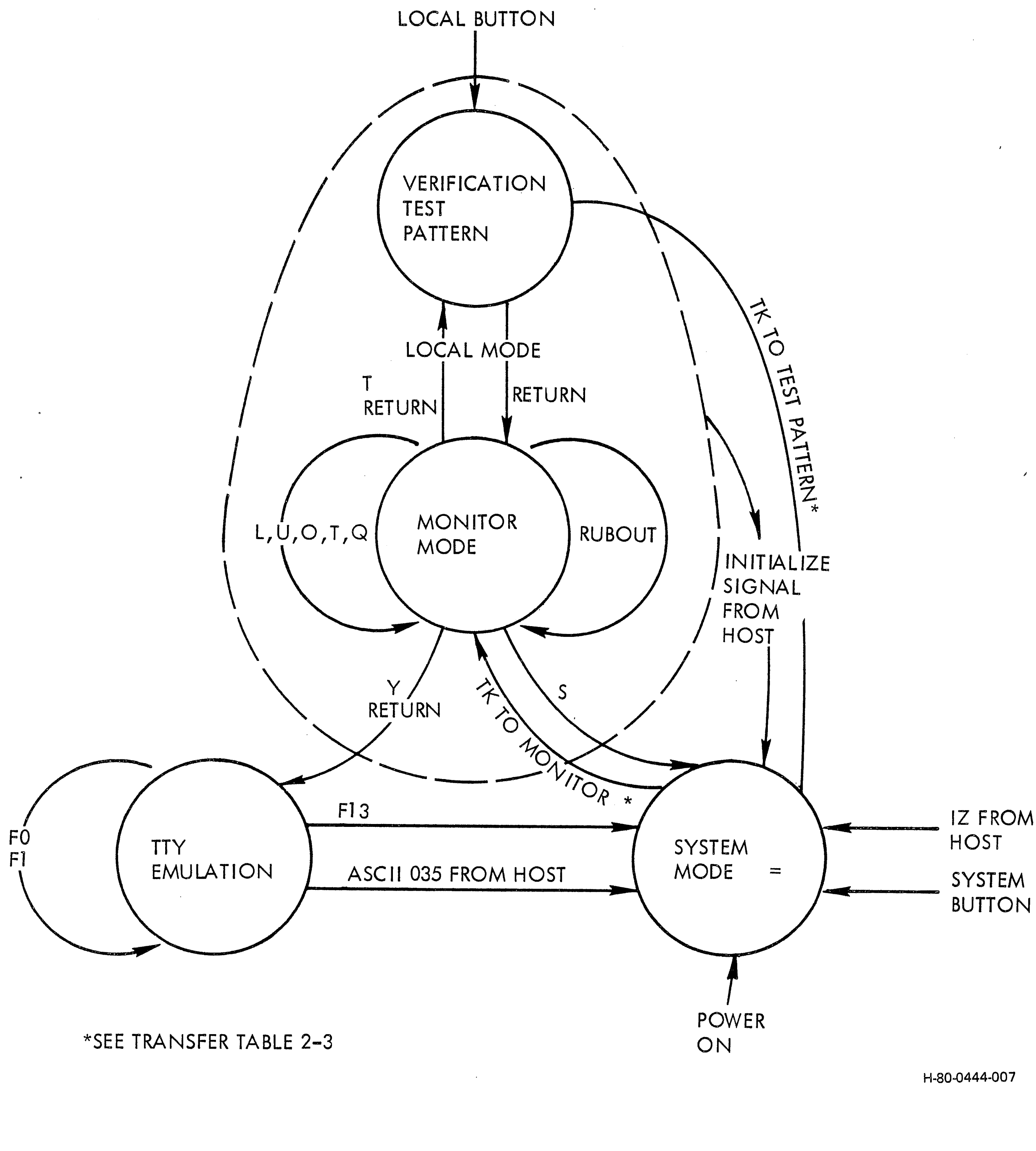


Figure 2-2. Summary of GRAPHIC 8 Operating Modes

SECTION 3

DISPLAY SYSTEM SOFTWARE/FIRMWARE

3.1 SYSTEM SOFTWARE/FIRMWARE CONSIDERATIONS

GRAPHIC 8, with the standard interactive graphic functions in read-only memory (ROM), can be treated entirely as a hardware device by the system programmer. This frees the programmer from having to generate software for a display processor in addition to the software for his central processor.

The system mode initialization includes a test of the display processor, memory, graphic controller, and pixel memories. In addition, a static test of the interface is performed. The go/no-go results of these tests are automatically transmitted to the host in the error condition format (XX).

After the system mode go/no-go verification test, the GRAPHIC 8 is ready to accept messages from the host computer. Any keyboards associated with the GRAPHIC 8 are initialized to allow keyboard inputs without any special action by the host. The Graphic Control Program (GCP) located in ROM handles all internal display interrupts and operator inputs. GCP performs all routine housekeeping required for these events and presents a "simple" message to the host computer containing all the information necessary to make operational decisions. The host may preset the GRAPHIC 8 to transmit only certain types of events and to disallow all others.

GCP handles the trackball manipulation without requiring host intervention. Trackball movements by the operator are detected and are either transmitted to the host computer or used to update the position of a predefined trackball symbol on the display. The way in which GCP processes the trackball and the trackball symbol are controlled by the host application program by special commands.

GCP also has the capability of inserting A/N keyboard data directly into refresh, allowing the operator to enter a message and edit it without host intervention. The operator edits the message by typing the DELETE key which deletes the last character he entered. When the message is complete, the operator then pushes the RETURN key. GCP then informs the host computer that a message is ready. The application program controls how A/N keys will be handled by the GCP by transmitting a special command.

The serial interface version of GRAPHIC 8 is designed such that only standard ASCII characters need be transmitted between the graphic terminal and the host computer. Any binary number may be encoded in the ASCII set. This was done to enable the use of standard communication software in the host computer. Since only the ASCII characters A-Z and 0-9 are required, the data can be transparent to the operating system and the usual communication or teletype software in the host is applicable.

The elimination of the detailed device handling and the use of standard ASCII characters are both in keeping with the GRAPHIC 8 goal of minimizing the host computer software impact. This can be especially important for a host that is running with a general operating system.

The application programmer has access to all display registers, display parameters and the organization of the display image. This detailed control means that the host computer is required to generate the image instruction codes as well as control the organization of the total image. Since most computers now have macro assembler capability, display macros can be used to quickly add the display instruction capability to the host computer assembler.*

The user has the ability to write application subroutines and independent programs that are run in the GRAPHIC 8. There are over 400 general purpose instructions available to the user in the display processor. The instructions include: load, store, add, subtract, compare, complement, rotate, shift, conditional branches, jump, subroutine calls, trap, and interrupt. Eight general registers, eight addressing modes, and a stack are also available to the user. A program can be "down-loaded" from the host to the GRAPHIC 8, and control passed from the normal GRAPHIC 8 logic to the user's program. This enables the user to tailor the GRAPHIC 8 logic to his particular application.

GCP has three linkages to read-write memory, which enables the user to perform additional tasks in the terminal for his particular application. These linkages exist in the reserved read-write area (0-512) and may be modified by the host computer to call a subroutine downloaded from the host. The first linkage allows for non-standard or non-GCP messages to be sent from the host computer and processed by the downloaded software. The second linkage is in the executive loop of GCP and is for applications that require action independent of a host message or operator actions. The third is for operator actions, i.e., keyboard and PED, to be processed locally rather than a message transmitted to the host.

3.2 COMMUNICATION AND RESPONSES

The fundamental GRAPHIC 8 messages are:

a. Host-to-Terminal

- Initialize (Initializes the Terminal)
- Memory Update (Transfer Display Data to the Terminal)
- Start Picture (Display the Image)
- Halt Picture (Blank the Display Image)

*Extended macro assemblers with the display macros already exist for some computers. Other methods of generating display codes include host-resident graphic support packages or data statements. The GRAPHIC 8 has available as an option a remote-based FORTRAN support package (FSP).

b. Terminal-to-Host

- Keyboard (Key Code Transferred to the Host)
- Function Key (Function Code Transferred to Host)

With these messages, which represent a nucleus of standard GRAPHIC 8 functions, the user achieves an interactive graphic capability. These messages provide a means to display a graphic image, and allow (a) the image to be rapidly transformed and (b) system identification of particular items within the image in response to operator actions.

For the user who desires more extensive control of the display, there are additional commands and responses that provide access to all display registers, functions and configurations that exist in GRAPHIC 8. These commands are available in the basic terminal controller, ready to be used when they are needed. The additional commands and responses include the provision to allow the operator to generate a scratchpad message entirely at the display without requiring that each key strike be separately sent to the host. When completed, the message is read by the host. Refer to Sanders Manual H-80-0444 Programmer's Reference Manual.

Either of two basic interfaces may be used to link the GRAPHIC 8 to the host computer. One of these is a serial interface compatible with the standard communication ports of most computers. The other is a generalized 16-bit parallel interface. The parallel interface provides for direct binary image communication between the host computer and GRAPHIC 8. The serial interface uses standard ASCII characters for all operation codes and data. The serial message formatting is a direct transform of the messages for the parallel interface.

3.2.1 MEMORY MAP. The memory addresses for the GRAPHIC 8 are byte-oriented. However, the starting address for a Start Picture (SP) command must be on an even word address and, for normal operations, all memory updates and dumps use an even number as the first address. The GRAPHIC 8 basic memory map is shown in figure 3-1.

3.2.2 SERIAL COMMUNICATION. The serial version of GRAPHIC 8 communicates with the host computer using character-oriented messages. The messages are formatted entirely with standard ASCII characters, A-Z and 0-9, for both command codes and data. The purpose of this formatting is easy compatibility with host computer operating systems and major communication protocols.

In the GRAPHIC 8, the message characters are transmitted and received via a serial, asynchronous, 8-bit interface adapter. For each of these interfaces, the format algorithm described in this section applies. The serial interface protocol is a direct transform of the 16-bit parallel formats already described. Therefore, only the general structure is described here.

For the standard character-oriented interfaces of the GRAPHIC 8, the basic message structure is as follows:

- Command Code - Two characters at the beginning of the message that identify the message type. Command characters are always in the ASCII code range from G to Z.

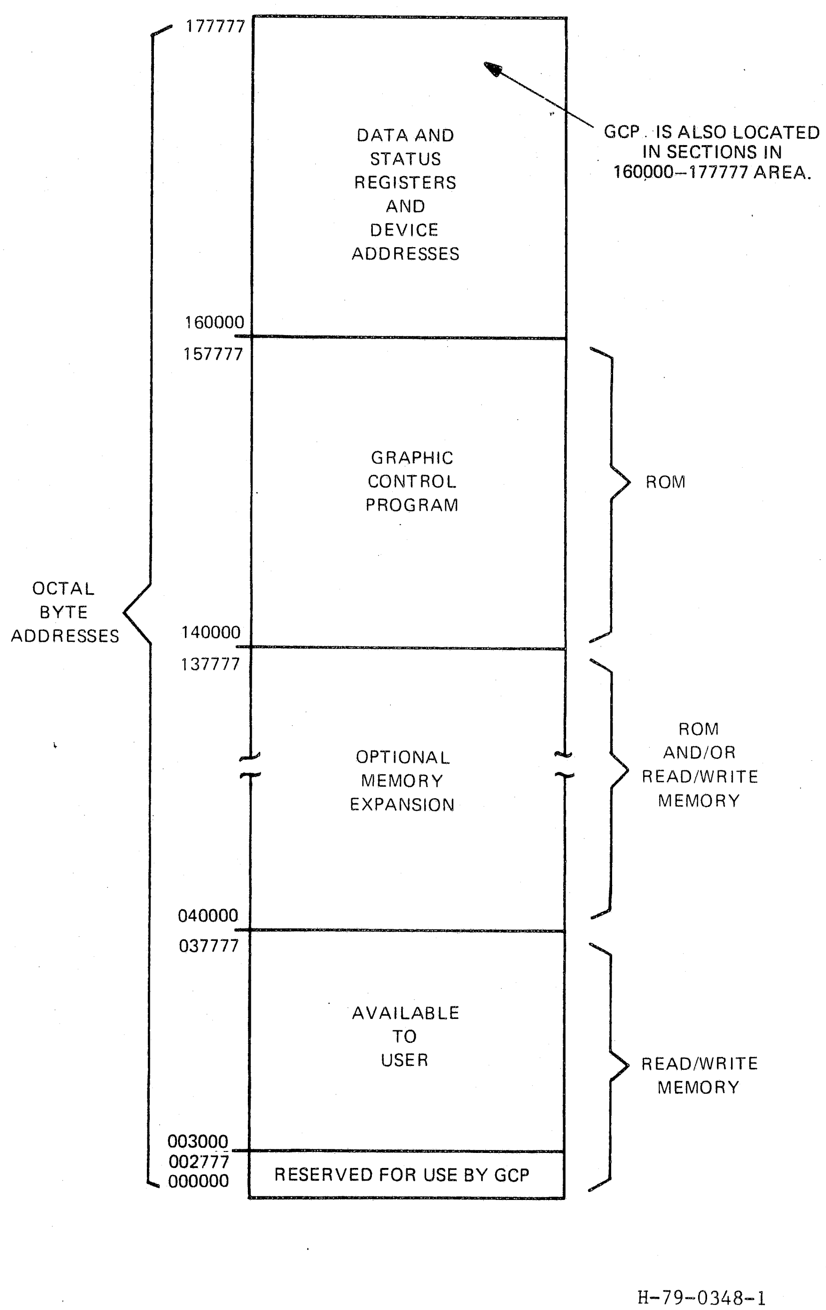


Figure 3-1. GRAPHIC 8 Memory Address Map

- Arguments - These specify register numbers, register data, starting address, interrupt mask, data for display, etc. Argument characters are always in the ASCII code range from 0-9 and A-F to signify a 4-bit (hexadecimal) number. Thus, four data characters are used to transmit a 16-bit binary word. The number of arguments in a given message depends upon the message type.

- End Character - An ASCII Carriage Return code that marks the end of the message.

The parallel interface to serial interface transformation is shown in figure 3-2.

The serial messages as illustrated by the example in figure 3-2 constitute the basic GRAPHIC 8 protocol to be used either exactly as shown for the local installation, or as data blocks within an existing operating system or communication network protocol. GRAPHIC 8 interface hardware and ROM control program are modular to allow the terminal to be smoothly adapted to a particular message protocol.

3.3 GRAPHIC SUPPORT SOFTWARE

The FORTRAN Support Package is an easy-to-use software package which allows anyone familiar with FORTRAN to manipulate pictures ón the Monitor screen and respond to operator inputs. FSP processing is distributed between the host computer and the terminal. This provides flexibility allowing the support package to be used with almost any host processor.

FSP is a powerful tool for an application programmer. It allows him to concentrate on his task and the relation between that task and the display images. He communicates with FSP in user coordinates via FORTRAN subroutine calls, rather than display coordinates, freeing him from any concern with detailed display instructions. FSP provides the following graphic functions: text, vectors, points, circles, ellipses, cursor, scaling, windowing, scissoring, clipping, rotation, and smoothing. The package responds to operator devices such as keyboards, trackballs, forcesticks, and data tablets.

After initializing, the user defines the boundaries of his display screen in user coordinates. Then, he simply calls the desired draw and move operations in these same user coordinates; either absolute or relative to the previous position. The graphical data need not be entirely on-screen because the FSP handles the necessary windowing and clipping to display all of the data that is within the defined boundaries. Lines of text may also be called and displayed at the desired position.

The user may assign each functional group of moves, draws, and test to a separate page. This is the key to the dynamics afforded by FSP. It is further possible to selectively modify data within a page.

The following FORTRAN-callable subroutines will be available to the application program in the host computer. Refer to Sanders Manual H-80-0021 for a detailed description.

PARALLEL INTERFACE SEQUENCE

		MSB			LSB
COMMAND WORD	GI	ASCII G CODE		ASCII I CODE	
ARGUMENT 1 – STARTING ADDRESS (EXAMPLE)		0 0 0 1	0 1 1 1	1 1 0 0	0 0 0 0
ARGUMENT 2 – END ADDRESS (EXAMPLE)		0 0 0 1	1 0 0 0	0 0 1 1	1 1 1 0

SERIAL INTERFACE CHARACTER SEQUENCE

COMMAND CODE	ASCII G CODE
	ASCII I CODE
ARGUMENT 1 (EXAMPLE)	ASCII 1 CODE
	ASCII 7 CODE
	ASCII C CODE
	ASCII 0 CODE
ARGUMENT 2 (EXAMPLE)	ASCII 1 CODE
	ASCII 8 CODE
	ASCII 3 CODE
	ASCII E CODE
END-OF-MESSAGE	CARRIAGE RETURN CODE

H-80-0483-006

Figure 3-2. GRAPHIC 8 Parallel Interface/Serial Interface Transform

Setup Routines

1. INIT
2. LAYOUT
3. SCALE
4. ENBBOX
5. DSABOX
6. ENBERR
7. DSAERR
8. THEEND

Status Routines

1. TPARM
2. LMARGN
3. STATUS
4. LAMPON
5. LAMPOF
6. COLORI
7. GRAYI

Image Generation Routines

1. MOVE
2. DRAW
3. TEXT
4. NEWLIN
5. CIRCLE
6. ELIPSE
7. XYPLOT
8. HTPLOT
9. VTPLOT
10. FILL
11. SCOLOR
12. SGRAY

Page Management Routines

1. ADDREF
2. UPDATE
3. ERASEP
4. PICTUR
5. GETMRK
6. MOVEIM
7. COPYIM

Event Routine

1. EVENT

PERIPHERAL DEVICE ROUTINES

Alphanumeric/Function Keyboard Routines

1. ENBPAD
2. DSAPAD
3. GETTXT
4. GETKEY

Trackball/Forcestick/Data Tablet Routines

1. ENAPED
2. DSAPED
3. ENACUR
4. DSACUR

Packed Vector Routines

1. ENBPMD
2. PDRAW
3. PMOVE
4. DSAPMD

Two Dimensional Scale, Rotate & Translate Routines

1. CC2DBL
2. MOV2D
3. DRAW2D
4. T2D2D
5. MTRX2D
6. V2DBOX

Three Dimensional Scale, Rotate & Translate Routines

1. INIT3D
2. SCAL3D
3. CCBLK
4. MOVE3D
5. DRAW3D
6. T3D2D
7. MTRX3D
8. VIEWPT
9. VIEWBX

Image Control Routines

1. CLIP
2. SMOOTH
3. SPLIT

PERIPHERAL DEVICE ROUTINES (Cont)

Data Transfer Routines

1. REFDAT
2. REQIM
3. GETIM
4. MOVDAT
5. GETERR

GRAPHIC 8 Instruction Timing

SANDERS' GRAPHIC 8

Vector Write Times

A. Vertical Line

1. Overhead	2.7 usec (per vector)
2. Time/pixel	900 nsec

B. Horizontal Line

1. Overhead	4.5 usec
2. Time/pixel	*600 nsec

C. 45° Line

1. Overhead	6.6 usec (max.)
2. Time/pixel	1.2 usec

D. All Others

1. Overhead	15.9 usec (max.)
2. Time/pixel	1.5 usec

Character Write Times (Small Size)

A. Overhead

1. CHAR instruction	4.5 usec
2. TXT instruction	8.4 usec

B.	"L" Character (15 pixels)	37.2 usec (5 x 7)	46.2 usec (7 x 9)
	"E" Character (24 pixels)	38.7 usec (5 x 7)	52.2 usec (7 x 9)

Data Move

Assume a 642 block of pixels:

Configuration:

1. 8 bits/pixel	22.1 msec
2. 4 bits/pixel	21.5 msec

Fill

*600 ns/pixel

*These values are average values. True values can vary anywhere from 100 ns/pixel to 1.0 usec/pixel depending on length and position of vector.

SECTION 4

EQUIPMENT DESCRIPTION

4.1 DISPLAY CONTROLLER

The display controller is the controlling unit in the GRAPHIC 8 system. The controller contains the necessary control modules, arithmetic units, registers, and logic to:

- Control specific applications programs
- Interface with large, general-purpose computers
- Build and store display files for CRT screen refresh
- Perform display file update for dynamic and interactive display images
- Interface with data entry devices (e.g., keyboard, trackballs, etc.)

The primary functional modules in the display controller are: display processor, read/write memory, ROM and status, serial interface (option), and parallel interface (option), large read/write memory (option), device and memory expansion (option), 2-D/3-D coordinate converter (option), and floating point converter (option).

4.1.1 DISPLAY PROCESSOR. The display processor is a microprocessor with master control of the GRAPHIC 8 system. This control includes system initialization, interface handling, local data editing, and control of generating simple display pictures locally. The display processor performs arithmetic and logic operations and instruction decoding. The processor contains multiple high-speed general-purpose registers which can be used as accumulators, pointers, index registers, or autoindexing pointers in autoincrement or autodecrement modes. The processor is programmable with basic capabilities under ROM Control. The control includes all communications with the host computer.

4.1.2 READ/WRITE MEMORY. The basic controller read/write memory consists of 16,381 16-bit words of MOS memory. The memory is of modular design expandable to 131,072 16-bit words, with addressing contained on each printed circuit card for word or byte control. The entire memory system may be used by the controller for normal arithmetic, I/O and logic functions, or display refresh.

4.1.3 READ-ONLY MEMORY AND STATUS MODULE. The ROM and status module contains the read-only memory (ROM) for the macro-control of the display processor and the display status and interrupt logic. In addition, one serial interface port featuring teletype or RS-232C levels is provided. This I/O port is used primarily for diagnostic checkout in conjunction with a teletypewriter. The ROM, a 4K control memory, handles initialization, communications between host and display system, display refresh, and self-test.

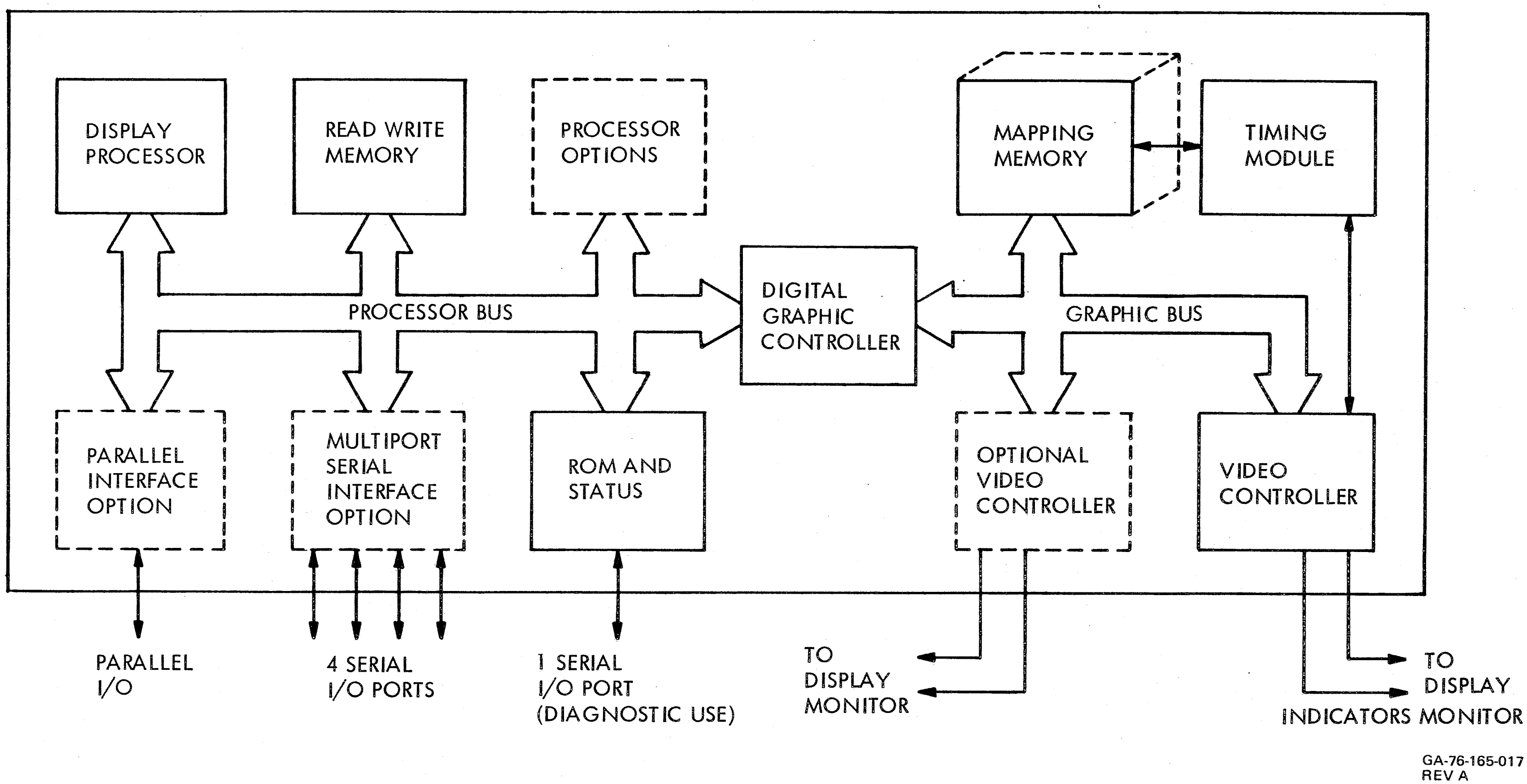


Figure 4-1. GRAPHIC 8 Terminal Controller Functional Modules

4.1.4 MULTIPORT SERIAL INTERFACE. The multiport serial interface module contains four serial asynchronous interface ports. Three of these ports use RS-232C or TTL voltage levels with standard transmission rates up to 9600 baud. The fourth port can be operated as a full RS-232C asynchronous interface at transmission rates up to 9600 baud. Optional data rates greater than 9600 baud are also available. The serial interface is compatible with the standard communication and terminal interfaces supplied by most manufacturers of minicomputers and mainframes.

The GRAPHIC 8 system software will support a maximum of three multiport serial interface modules. The individual device addresses of each of the modules is selected by setting DIP switches on each of the multiport serial interface circuit cards. Installing three multiport serial interface cards will allow up to eight data entry devices to communicate with the terminal controller.

The serial interface uses character-oriented messages to communicate with the host computer. The formats of those messages are described in Section 3.

4.1.4.1 Standard Asynchronous Interface. The basic GRAPHIC 8 asynchronous interface has one start bit, eight data bits and either one or two stop bits (one stop bit is normally supplied). The interface is fully compliant with RS-232C signal levels, electrical characteristics and pin assignments. TTL voltage levels may be specified in lieu of the RS-232C voltage levels. The interface will operate in either full or half duplex mode.

Computer manufacturers, almost unanimously, offer RS-232C standard communication modules that are compatible with the GRAPHIC 8. These modules often consist of a single printed circuit board that may be plugged into an available slot in the computer chassis. For local terminal installations, the standard data set connector of the communication module cable may be plugged directly into the null modem connector of the GRAPHIC 8 terminal controller.

4.1.4.2 High-Speed Serial Interface. For local operation, a high-speed option for both the synchronous and asynchronous serial interface is available which allows host/GRAPHIC 8 communication at burst rates up to 50 kilobaud. This interface is identical with the 9600-baud interface with respect to bit discipline, message protocol and signal levels.

4.1.4.3 Remote Interfacing. The basic, asynchronous interface is capable of operating with standard modems and data sets. The interface is RS-232C compatible and includes a 25-foot cable with a standard data set connector. It contains the control lines necessary to operate the modems in a switched line mode. The local mode control sequence in each interface allows the GRAPHIC 8 to be directly connected to a basic data set operating in a dedicated line mode. The control sequence can be modified to meet the requirements of a particular data set and system.

The asynchronous interface can be optionally preset for the control sequence patterns of particular data sets including Bell modems 103, 202 and 113. Any standard communication baud rate from 110 to 9600 may be specified.

The basic message protocol of GRAPHIC 8 (see Section 3) is compatible with major communication protocols using eight bit characters with ASCII codes. The GRAPHIC 8 protocol can be directly incorporated as the text field in an existing system message protocol. To enhance this capability, all GRAPHIC 8 commands and data words are contained within the ASCII set of letters and numerals with the exceptions of the Carriage Return code to terminate the basic message (or text field in a message protocol).

4.1.5 PARALLEL INTERFACE TO THE HOST COMPUTER. The parallel interface card is an option intended for installations where the GRAPHIC 8 is located in proximity to the host computer. It allows high-speed host/GRAPHIC 8 communications with handshaking and can be operated in a DMA mode. If a parallel interface card is installed in the terminal controller, GCP assumes that it is connected to the host computer. Therefore, if serial communication with the host computer is desired, a parallel interface card cannot be connected to the processor bus. The parallel interface is specially designed to interface with a particular host computer. Sixteen-bit and 32-bit models are available.

NOTE

Normally, if a parallel interface port is used, a single parallel interface card (for the host computer) is installed in the terminal controller.

Typical parallel interface signals are shown in figure 4-2. All of the signals are TTL voltage levels and are high-true unless otherwise specified. With the exception of the Output Data Received signal and the Input Data Ready signal, all of the signals are levels that, when activated, remain in the active state until the proper response is received. The two exceptions named are normally 400 nanosecond pulses.

4.1.6 LARGE READ/WRITE MEMORY. A large read/write memory card is capable of storing $65,536_{10}$ (64K) sixteen-bit words or 128K separately addressable eight-bit bytes. A maximum of two large read/write memory cards can be installed in the GRAPHIC 8 system, for a total of 128K sixteen-bit words of memory. (The large read/write memory card is also available in 16K and 32K word sizes.)

Each large read/write memory card has its own local oscillator, memory controller, refresh controller, and memory mapping logic. However, though the large read/write memory cards connect to and are controlled by the processor bus, they can never assume control of that bus. Instead, any circuit card capable of acting as bus master can read data from or write data into a specific location on the large read/write memory cards by seizing control of the bus and asserting or clearing the appropriate address, data, and control lines.

The large read/write memory card is divided into 4K "pages". Each page is a 4K word storage area: page 0 = addresses through 4K-1; page 1 = addresses 4K through 8K-1; etc. The 64K memory card has 16 such pages, the 32K memory card has eight such pages, and the 16K memory card has four such pages.

Table 4-1 lists the octal-value page numbers and the corresponding octal-value addresses for each page of the maximum memory configuration (32 pages). Note that page 0 is dedicated and cannot be used for general purpose applications. Page 0 contains all the vector trap addresses and certain other reserved functions. Pages 6 and 7 are a special case. The addresses associated with page 6 are also the addresses associated with the GCP stored in ROM on the ROM and status card. Similarly, the addresses associated with page 7 are also the device addresses associated with the particular devices connected to the processor bus. Typical

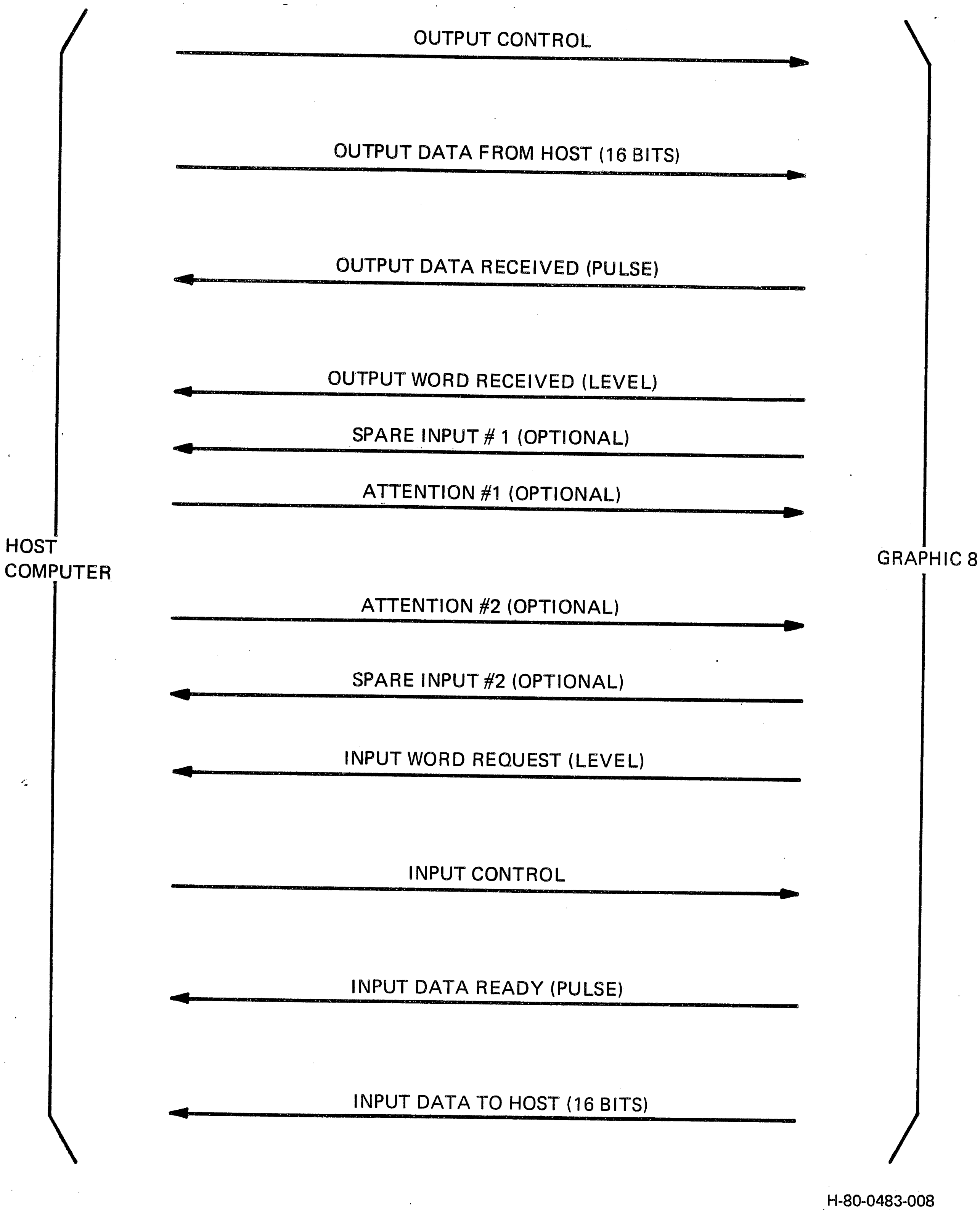


Figure 4-2. Parallel Interface Signals (Typical)

Table 4-1. Correspondence Between Octal Page Numbers and Their Associated Addresses

OCTAL PAGE #		EFFECTIVE ADDRESSES
	MEMORY CARD 1	
0	RESERVED	000000:017776
1	MAP AREA 1	020000:037776
2	MAP AREA 2	040000:057776
3	MAP AREA 3	060000:077776
4		100000:117776
5		120000:137776
6	GCP (ROM)	140000:157776
7	DEVICE ADDRESSES	160000:177776
10		200000:217776
11		220000:237776
12		240000:257776
13		260000:277776
14		300000:317776
15		320000:337776
16		340000:357776
17		360000:377776
	MEMORY CARD 2	
20		400000:417776
21		420000:437776
22		440000:457776
23		460000:477776
24		500000:517776
25		520000:537776
26		540000:557776
27		560000:577776
30		600000:617776
31		620000:637776
32		640000:657776
33		660000:677776
34		700000:717776
35		720000:737776
36		740000:757776
37		760000:777776

devices that have access to the large read/write memory include the display processor, the digital graphic controller, and the parallel interface. However, through a special mapping technique, the display processor is the only device that can access pages 6 and 7. All other devices address the memory directly. A special paging feature (pages 1, 2, and 3) allows the display processor to access pages 6 and 7.

Pages 1, 2, and 3 are also used to map from locations 4K through 16K-1 to locations above 32K-1. Since the display processor is a 16-bit device, it normally has direct access to only 8 pages (32K words) of memory. However, the paging feature allows the display processor to indirectly access 18-bit addresses. Three page registers on the large read/write memory card are preloaded with five-bit values. When the display processor addresses a page register, the five bits stored in that register become the most significant bits of the extended address, thus allowing the processor to map to 32 pages (128K words).

The large read/write memory card allows the following operations to be performed:

- Load five bits of data into the page registers.
- Read a 16-bit word from memory.
- Write a 16-bit word into memory.
- Read eight least significant bits from memory.
- Write eight least significant bits into memory.
- Read eight most significant bits from memory onto the least significant bit lines of the processor data bus.
- Write eight least significant bits from the processor data bus into eight most significant bit locations in memory.

When none of these operations is being performed, the large read/write memory card runs through a program of continuously refreshing itself.

4.1.7 EXPANSION MODULE. The expansion module is an optional circuit card that accommodates memory features associated with equipment options. The terminal controller can accept two expansion module cards. Each expansion module consists of two parts: (1) a circuit card assembly that plugs into the terminal controller card cage; and (2) the programmed GCP software options, stored in erasable programmed read-only memories (EPROM's), that are placed on the circuit card. The software routines stored on the expansion module can be loaded into RAM memory by the terminal controller's GCP, relieving the host computer of that task.

Each group of two EPROM's on the expansion module represents a 2048 by 16-bit option group. This is the smallest grouping in which options are supplied. An option group is installed on plug-in sockets on the circuit card. Unused option group locations on the circuit card are usually left bare.

The expansion module connects to and is controlled by the GRAPHIC 8 processor bus; however, it can never assume control of that bus. Memory data read out of the expansion module is placed on the bus data lines when the display processor seizes control of the bus and addresses the expansion module. The expansion module has two modes of addressing: device and memory. The device mode is used by the GCP to load options into RAM memory. The memory mode is used to provide direct read out of memory to the user.

In the device mode, the expansion module is accessed through only one address and all memory locations are read out consecutively. In the memory mode, the expansion module responds to memory requests on the processor bus. The particular addressing mode used is selected by setting a DIP switch on the expansion module circuit card.

4.1.8 2-D/3-D COORDINATE CONVERTER. The 2-D/3-D coordinate converter option allows the GRAPHIC 8 to display independent dynamic manipulation of objects in apparent space. Among the functions provided by the coordinate converter are:

- Translation.
- Scaling.
- Rotation.
- Windowing.
- Independent display coordinate mapping.
- Perspective.
- Zooming with perspective.

The perspective feature is especially useful for realistic viewing of an object. Utilizing perspective, the location of the viewer is defined relative to the image space, and all lines and objects within the image space are then viewed at the proper perspective for that location. The view may also be completely orthographic if the viewer does not wish to use the perspective feature.

Objects can be defined with a 64K (X), 64K (Y), by 32K (Z) image space and presented on any portion of the screen, up to 1K by 1K. Translations can be made within the limits of the image space, and the scaling range is 64 to 1. Rotation can be provided about any axis.

3-D windowing, in conjunction with independent screen coordinate mapping, allows the presentation of any data within a software-definable X, Y, Z image space to be presented on the full screen or any portion of the screen. Zooming is accommodated by scaling and changing the user's apparent perspective viewpoint.

Alphanumeric data can be moved about on the screen with vector-defined data, but without scaling and rotation.

The coordinate converter provides for both homogeneous and non-homogeneous matrix operation. Transformations of 2-D images can also be accomplished, including translation, rotation, scaling, and windowing.

The basic approach used is pre-refresh digital. The coordinate converter is a 16-bit microprocessor that can interrupt the display processor and perform read/write operations on the GRAPHIC 8 memory. Microprocessor operation is controlled by a control ROM; its data input comes from the GRAPHIC 8 processor data bus. An address decoder recognizes when the coordinate converter is being addressed and generates the CCADD (coordinate converter addresses) signal. The decoder also decodes the address into a form recognizable by the ROM sequencer logic.

The coordinate converter operates on 3-D instructions in an image file and converts these to 2-D instructions in a refresh file that is accessed by the digital graphic controller. The conversions do not alter the image files, and different transformations on the same image occupying the same image space may be displayed simultaneously on the monitor. Point transformation times are typically better than 50 microseconds (maximum).

The image file or unconverted program is loaded into the GRAPHIC 8 read/write memory by a Memory Update or Selective Update host-to-terminal message.

The expanded graphic control program (GCP) includes the following GRAPHIC 8-to-host interrupt messages relating to the coordinate converter:

- Halt interrupt.
- Illegal instruction interrupt.
- Data anomaly interrupt.
- Refresh limit exceeded interrupt.

The coordinate converter also generates its own set of move, load, and draw commands in refresh code in response to similar input commands. In addition, the coordinate converter interprets special control instructions, such as Call Subroutine, Return, Jump, or Halt, which are imbedded in an object description in the image file. Further, regular refresh instructions can be imbedded in an object description; these instructions, which are already in a format recognizable by the GRAPHIC 8 digital graphic controller card, simply pass through the coordinate converter without modification and are stored in the appropriate address in refresh memory.

4.1.9 FLOATING-POINT CONVERTER. The floating point converter option transforms incoming floating-point binary numbers into displayable numbers. The displayable numbers may be in any of sixteen formats selected by the host computer. The bidirectional converter also converts the displayed numbers into floating-point binary for transmission back to the host.

The floating-point converter saves the host computer time and storage resources by performing these conversions within the graphic terminal. It allows data to be transmitted to and from the host in its most compact form and frees the host programmer from the conversion programming task.

The floating-point converter can perform more than 500 conversions per second, which allows it to be used in high data rate applications, resulting in significant off-loading of the host computer.

The floating-point converter consists of a processor card, a special purpose program in ROM (or RAM), and a portion of RAM reserved exclusively for the input/output conversion process. The floating-point converter is essentially a modified display processor: interrupt capability has been deleted and extended instructions, which improve the execution speed of binary-to-decimal and decimal-to-binary conversion, have been added.

4.2 DISPLAY GENERATOR

The display generator (DG) (figure 4-1) maps the digital control and data signals into mapping memory to drive the display indicators. To perform this function, the DG interfaces with the display controller and display indicator(s) and provides:

- Instruction interpretation
- Vector generation
- Character and symbol generation
- CRT raster timing
- Display indicator selection and signal input

All instructions and data required for the graphic display are stored in the refresh file (or display file) of the display controller memory. The graphic controller fetches the total contents of the refresh file word by word, interprets these words and writes the appropriate pixels in the mapping memory. For each instruction, the DG converts the digital data into pixel addresses and writes the appropriate pixels into mapping memory at the locations specified.

The basic DG consists of:

- Graphic Controller
- Mapping Memory
- Video Controller
- Timing Module

4.2.1 DIGITAL GRAPHIC CONTROLLER. The Digital Controller Module (DGC) is a 16-bit microprocessor implemented with 2903 4-bit microprocessor slices. This microprocessor retrieves display instructions from the refresh memory, interprets these commands, and extracts and distributes data contained in each. The controller then initiates the actions specified by the instruction.

The DGC maintains the program address, controls the read/write memory and mapping memory, and performs the branching specified by nongraphic commands. The DGC also determines the operations specified by an instruction, calculates the relative data when required, loads data into the appropriate registers, and initiates execution of the instruction.

The DGC calculates pixel addresses for vector, character, conic and point plot generation and loads these into the mapping memory. The DGC also controls the clearing of displayed data in the mapping memory.

Line texturing of vectors is controlled by the DGC. The DGC generates 7 x 9 or 5 x 7 line characters (depending on the system resolution) from data contained in the ROM's. The characters can be positioned on screen to any random pixel. The character set can be rotated 90 degrees for writing in the margins.

The DGC also updates the video control registers (start of frame pointers, etc.) on the video controller.

4.2.2 MAPPING MEMORY MODULE. The mapping (or pixel) memory consists of identical memory boards combined and configured to give the desired resolution and options.

Multiple channels on the same memory board must be scrolled together since memory addressing may be unique only at the board level. This presents no problem if multiple channels on the same board are common (bits in the same pixel) to one display monitor. If it is desired to independently scroll up to two displays while leaving all other displays unaffected, then separate memory boards must be used to drive each interactive display. In addition, all other displays (non-interactive) must have their own memory board (or set of boards if configuration dictates).

The dual memory allows updating of one memory while the other is refreshing the display(s). The two memories then swap roles. This allows memory updating without display refresh contention.

The memory board may be read by the DGC or by the video controller or written into from the DGC by pixel (1-8 bits). With these configurations requiring more than one memory board, pixel data up to 8 bits in length is read or written simultaneously.

The memory board is configured as 16K words of 64 bits. A 64-bit readout is performed for display refresh and the 64-bit register is serially shifted out to the video controller. With more than one channel utilized on the memory board, the 64-bit register may be utilized as two 32-bit registers driving two channels, four 16-bit registers driving up to four channels or eight 8-bit registers driving up to eight channels.

High-speed erase of memory or fill of memory with a particular pattern is implemented as a 64-bit parallel write operation on each memory board at maximum pixel writing rate.

Memory refresh is implemented on the memory board with refresh cycles occurring during horizontal and vertical retrace.

4.2.3 VIDEO CONTROLLER MODULE. The video controller obtains data from the mapping memory and formats this for presentation to the display monitor(s). Outputs are compatible with EIA standard RS-343-A. Composite video or separate video and sync signals are provided for both RGB color or monochrome outputs.

External video may be summed on the board for background mapping, etc.

A 256-word by 8-bit RAM video look-up table is provided on the video controller board. Loading of the look-up table allows pseudo color or intensity level transformations, allocation of particular bits for blinking, foreground or background data, etc.

The video controller contains the cursor registers, start of frame registers, split screen registers, and contains the logic for controlling the scrolling function.

The video controller controls the refresh of the dynamic RAM devices used on the mapping memory boards. The video controller generates the RAM refresh request to the memory boards.

The video controller board can handle up to 8 memory channels. In addition, the video controller can be set up to accommodate a number of different display monitor configurations. This is handled by providing for digital-to-analog converter (DAC) alternatives on the video controller board.

Each interactive monitor must have its own video controller. Each video controller is equipped with one set of cursor registers, start of frame registers, split screen registers, and logic for scrolling functions.

4.2.4 TIMING MODULE. The timing module generates all display timing. Switch-selectable options on the board allow for different resolutions and for interlaced or non-interlaced display refresh.

Monitor synchronization signals are generated on the timing module board. An external sync signal is accepted to allow synchronization to an outside source. In addition, an output sync signal is provided to allow synchronization of an outside device to the internally generated signals.

4.2.5 CHARACTER GENERATION. Character generation on the GRAPHIC 8 is performed by the DGC. The basic system has a standard set of 96 characters, with six additional groups available as options. Typical characters, consisting of upper case, lower case and alphanumerics, are shown in figure 4-3. Table 4-2 lists the code assigned to each character. The basic 96 character set is located in columns 2 through 7 of the table. Columns 0 and 1 are reserved for control codes which are not displayable: NULL, SHIFT-OUT, SHIFT-IN, SET MARGIN, LINE FEED, and CARRIAGE RETURN. When the DGC receives any code in column 0 or 1, no character is displayed and any tabular move associated with that character position is inhibited. When only that function is desired, the NULL code is normally used. When the other assigned control codes are used, the NULL function is included along with the code function.

The SHIFT-OUT code provides access to the 96 optional, customer-defined special characters. When the graphic controller receives this code, it interprets the codes differently than the symbols listed in table 4-2. When the special symbol option is included, the codes in columns 2 through 7 are available for those special symbols in the SHIFT-OUT mode. SHIFT-IN causes the character generator to return to the normal mode. The special symbols are supplied as separate options of 32 characters each.

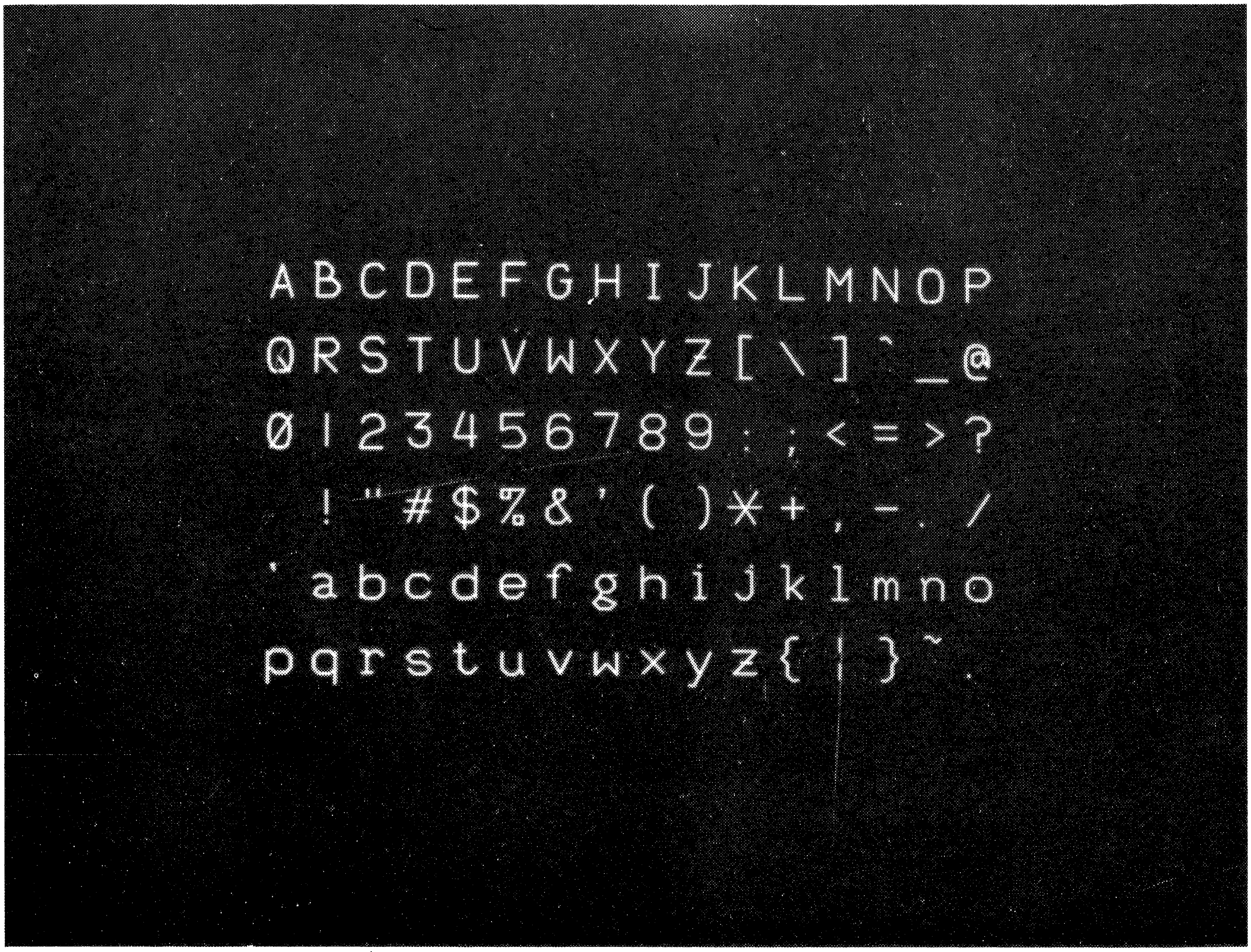


Figure 4-3. Basic Character Set

Table 4-2. Character Generator Code Assignment

BITS b4	b3	b2	b1	COL → / row ↓	0 (b7 b6 b5 = 0 0 0)	1 (0 0 1)	2 (0 1 0)	3 (0 1 1)	4 (1 0 0)	5 (1 0 1)	6 (1 1 0)	7 (1 1 1)
0	0	0	0	0	NUL		SP	0	@	P	`	p
0	0	0	1	1			!	1	A	Q	a	q
0	0	1	0	2	SET MARGIN		”	2	B	R	b	r
0	0	1	1	3			#	3	C	S	c	s
0	1	0	0	4			$	4	D	T	d	t
0	1	0	1	5			%	5	E	U	e	u
0	1	1	0	6			&	6	F	V	f	v
0	1	1	1	7			’	7	G	W	g	w
1	0	0	0	8			(	8	H	X	h	x
1	0	0	1	9			)	9	I	Y	i	y
1	0	1	0	10	LINE FEED		*	:	J	Z	j	z
1	0	1	1	11			+	;	K	[	k	{
1	1	0	0	12			,	<	L	\	l	¦
1	1	0	1	13	CARRIAGE RETURN		–	=	M	]	m	}
1	1	1	0	14	SHIFT OUT		.	>	N	^	n	~
1	1	1	1	15	SHIFT IN		/	?	O	–	o	

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If desired, the optional special symbols may replace the standard characters located in columns 6 and 7. This method allows the symbols to be displayed without the use of SHIFT-OUT and SHIFT-IN.

Under program control, the graphic controller can generate characters at three different sizes in a 5 x 7 or 7 x 9 pixel font. These characters may also be rotated 90 degrees counterclockwise for writing in the margins.

For displayed tabular data, the horizontal spacing between characters is determined by the value in the text increment register (DTI). The vertical spacing between text strings is determined by the value in the line increment register (DLI). Both of these parameters are under software control.

4.2.6 CONIC GENERATION. The DGC generates circles and ellipses. The lengths of the semimajor and semiminor axes are independently programmable from zero to half screen. The center of a conic is located at any point addressable by the graphic controller. Ellipses may be drawn with any combination of 90-degree are segments displayable under program control.

4.3 EQUIPMENT CABINET

The equipment cabinet (figure 4-4) is available as a user option. The equipment cabinet is a four-wheeled, semi-portable equipment rack. The equipment cabinet has doors on both front and rear. The front door is hinged on the right side, and the rear door is hinged on the left side. Both doors are held shut by magnetic latches. A cut out in the bottom rear of the cabinet provides an entryway for power and signal cables.

In a typical GRAPHIC 8 installation, the equipment cabinet is used to house the terminal`controller, a power panel assembly, and a system interconnect panel assembly.

4.3.1 TERMINAL CONTROLLER. The terminal controller is installed in the upper half of the equipment cabinet. The terminal controller typically comprises a 17-slot card cage, a power supply, and two blower fans. A control panel covers the front of the unit; a protective cover is mounted on the back. The terminal controller controls and indicators are accessible through a cutout in the front door of the equipment. The terminal controller may be mounted in a standard 19-inch equipment rack if the equipment cabinet has not been selected as a user option.

The GRAPHIC 8 circuit card modules are inserted into the card cage from the front of the terminal controller, and plug into a wire-wrapped backplane. The location of each circuit card in the GRAPHIC 8 terminal controller card cage is shown in figure 4-5.

4.3.2 POWER PANEL ASSEMBLY. The power panel assembly is accessible from the front of the equipment cabinet, and is installed in the lower half of the cabinet. The power panel assembly consists of a circuit breaker in the prime power lines, a programmable power transformer, a line filter assembly, a 15-pin connector for voltage configuration, and a duplex 110 Vac power outlet. The power panel can operate from 100 Vac, 120 Vac, 220 Vac, or 240 Vac. An alternative power panel assembly can operate from 110 Vac.

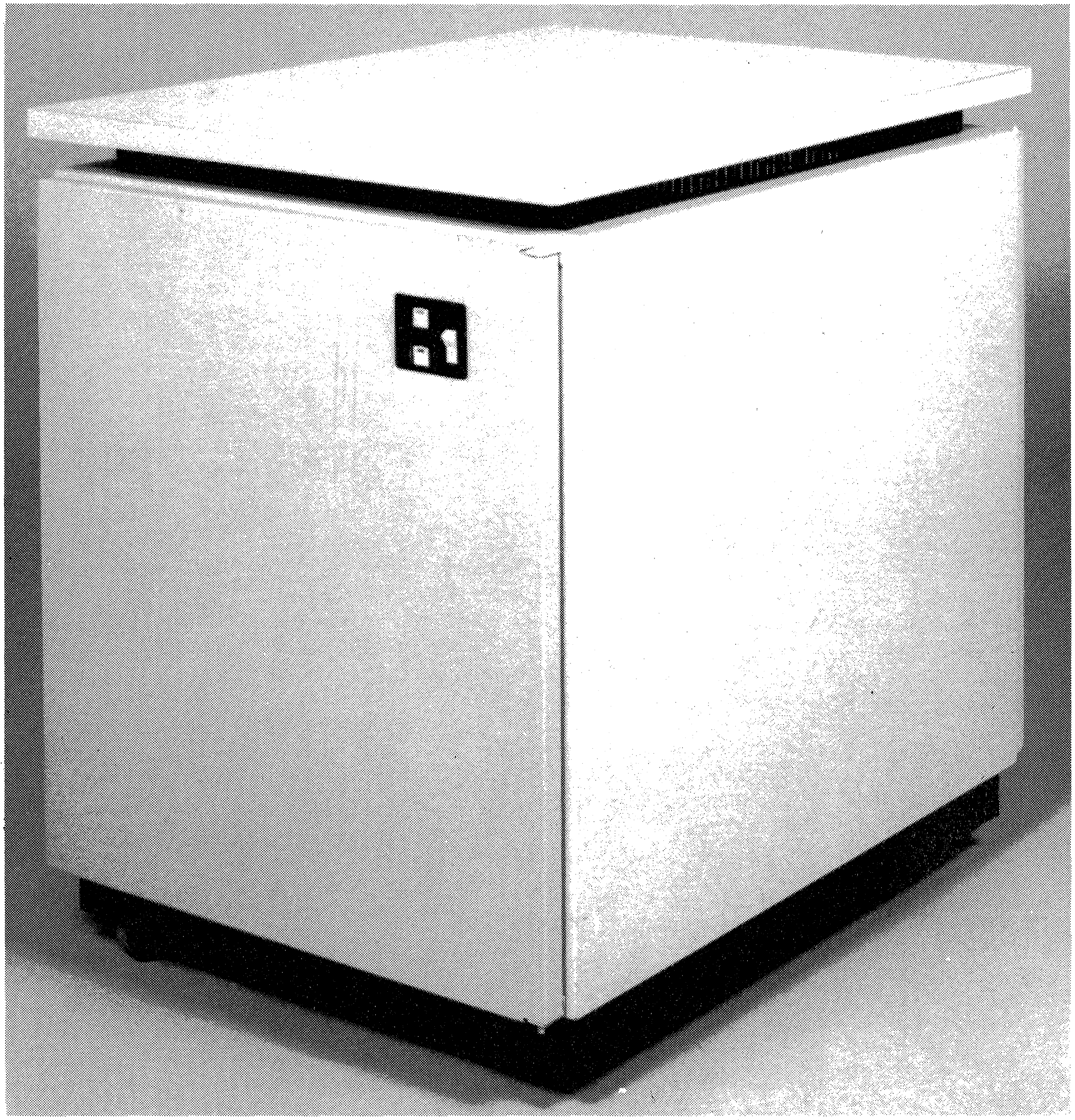


Figure 4-4. Equipment Cabinet

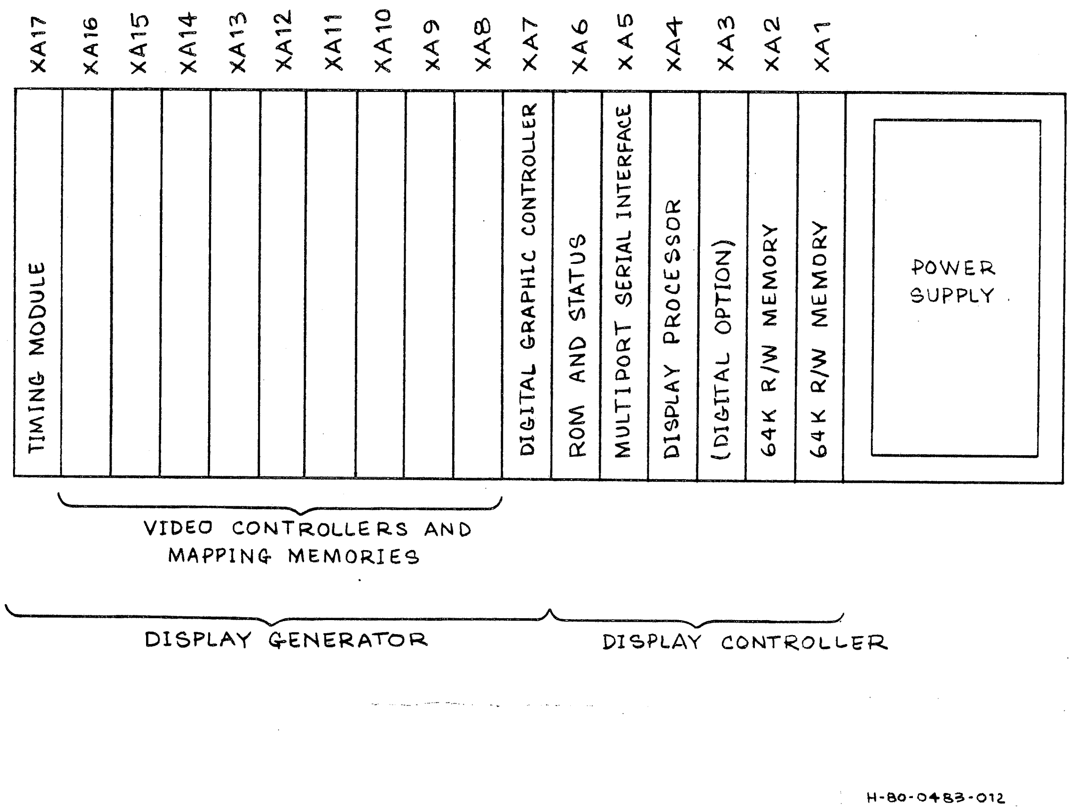


Figure 4-5. GRAPHIC 8 Terminal Controller Card Locations

4.3.3 SYSTEM INTERCONNECT PANEL ASSEMBLY. The system interconnect panel assembly (figure 4-6) is accessible from the rear of the equipment, and is installed in the lower half of the cabinet. The system interconnect panel assembly consists of a panel with cutouts, and a number of cable assemblies with connectors; some of the connectors are secured to the panel at their respective cutouts.

The system interconnect panel assembly provides a means of connecting the terminal controller to the host computer, to the display indicators, and to other peripheral devices (keyboards, PED's, hard copy units, etc.)

4.4 DISPLAY MONITORS

The display monitor (figure 4-7) provides the GRAPHIC 8 system operator with a visual presentation of dynamic as well as static data on the screen of a cathode-ray tube (CRT). Visual displays on the CRT are under control of the display generator portion of the terminal controller.

The GRAPHIC 8 offers the user a choice of CRT monitors to provide the right monitor for the intended application.

Positions on the screen are specified in terms of a matrix containing 2048 coordinates in the X dimension and 2048 coordinates in the Y dimension. Two's complement notation is used to designate the coordinates with location 0,0 being defined as the center of the screen. Of the 2048 by 2048 addressable locations, the displayable area comprises the field of coordinates centered about the middle of the screen.

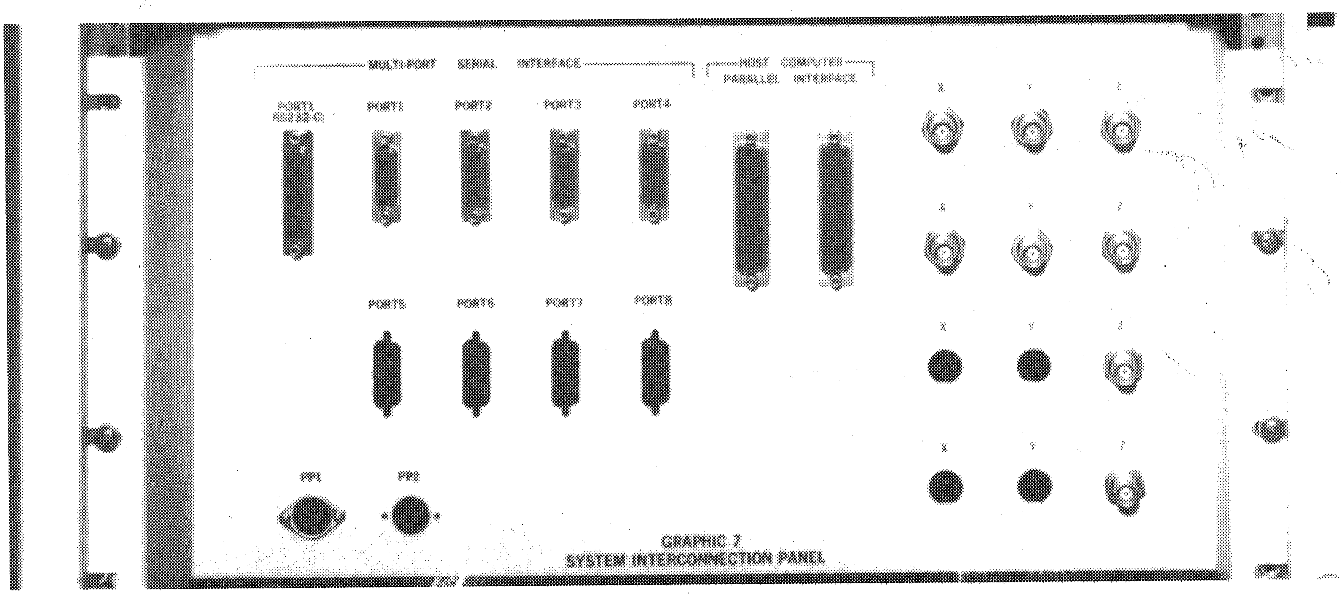


Figure 4-6. System Interconnect Panel Assembly (Typical)

Figure 4-7. Display Monitor

4.5 DATA ENTRY DEVICES

Optional data entry devices are available for the GRAPHIC 8 to give the operator two-way interaction with the display and processing system. The types of devices provided, and their methods of implementation, allow both the operator and the system programmer to achieve high efficiency.

These devices, in general, communicate with the display controller via the serial interface. The standard firmware supports two keyboards, and two position entry devices (trackball, forcestick, or data tablet).

4.5.1 KEYBOARD. The model 5784 keyboard (figure 4-8) includes the main block of 55 ASCII alphanumeric and cursor control keys, and also a matrix of 16 lighted function keys to the right. An additional row of 16 more lighted function keys are positioned at the rear of the alphanumeric keys. The keyboard consists of a matrix of 128 intersections (16 "X" lines crossing 8 "Y" lines). Each X line is activated, one line at a time, by a series of 32 pulses from the timing generator. The Y-line multiplexer advances one count after scanning eight X lines. A complete scan cycle ends after every combination of 16 X lines and 8 Y lines has been scanned.

When you press a key, you are increasing the capacitance between one X line and one Y line (one intersection). The increased capacitance couples the burst of 32 pulses through the Y-line multiplexer to the keystroke detector.

The keystroke detector converts the 32 short pulses to a single pulse that latches the timing signal states into the RAM (random access memory) and PROM's (programmable read-only memories). Each timing signal state is the equivalent of a unique character or control key. The condition is put into the RAM to prevent unwanted repetitions of a keystroke (the X and Y lines scan faster than you would normally press and release a key). The PROM's produce an 8-bit output that is the ASCII equivalent of the key you pressed.

A universal asynchronous receiver-transmitter (UART) converts the eight parallel data bits to a serial string, adds a start bit, and sends the 9-bit serial string to the graphics controller. A separate adjustable clock controls the UART transfer rate (nominally 9600 baud). The output circuits provide the 9-bit serial string at various levels and polarities. The stop bit is implied. There is at least a 2-bit space between consecutive characters.

Communication between keyboard and controller occurs via the multiport serial interface. The path is serial, full duplex and operates at 9600 baud. The interface logic in the display generator is completely transparent to the character codes and data bytes being sent to the display processor. Communication discipline is handled by the GRAPHIC 8 firmware, including character code and data byte recognition.

In the Model 5784 only, the lamp-lighting message from the terminal controller turns on or turns off any of the lamps in the 16 function keys and the 16 matrix keys. The keyboard operator has no control over this function.

The model 5783 keyboard is identical, but the matrix and function keys are not lighted.

Figure 4-8. Model 5784 or 5783 Keyboard

4.5.1.1 Keyboard Send. All function, matrix, and alphanumeric keys work in the same manner; that is, they are momentary action switches, with each transmitting its own unique 8-bit code (figure 4-9 and table 4-3). The codes sent by alphanumeric keys are modified by depressing CTRL (control) or SHIFT (or CAPS LOCK). When CTRL is pressed and an alphanumeric or symbol key is pressed, control codes may be generated as outlined in table 4-4.

4.5.1.2 Keyboard Receive (Model 5784 only). Data to light keys are received by the keyboard from the display controller. The LAMP DATA synchronization code is 224 (octal).

4.5.1.3 Keyboard Indicator Lamp Control. The processor controls the lighting of optional indicators by sending a sync code for LAMP DATA followed by the appropriate bits to light the indicator. LAMP DATA informs the keyboard that bit(s) in the following four bytes specify lamp indicators to be lighted.

The code for LAMP DATA is given in paragraph 4.5.1.2. The bit positions for lighting the keys are given in table 4-5.

4.5.2 TRACKBALL, FORCESTICK AND DATA TABLET. The trackball, forcestick, and data tablet are referred to as position entry devices (PED's). These devices are used to move a cursor and/or data displayed on the display indicator CRT screen, as determined by program control. PED's are connected to the system via ports on the multiport serial interface card(s) in the terminal controller.

The trackball shown in figure 4-10 is a high-resolution optical encoder unit used with the display controller for fast and accurate positioning of the display cursor. Movement initiated by the trackball is proportional to the speed and direction in which the trackball is rolled.

The forcestick shown in figure 4-11 is a miniature, two-axis, pressure-sensitive control used with the display controller that causes cursor movement in the direction of applied force. The speed of the cursor movement initiated by the forcestick is proportional to the amount of force applied.

The data tablet shown in figure 4-12 is a digitizer that uses a system of magnetic coupling between an electronic pen stylus transducer and an active surface to resolve positional coordinates. Movement initiated by the data tablet is proportional to the speed and direction in which the pen stylus is moved along the active surface. The data tablet may also be used to plot individual X,Y coordinate pairs.

4.5.3 MAINTENANCE DATA INPUT DEVICES. A teletypewriter and/or a paper tape reader can be connected to the GRAPHIC 8 to input data for maintenance purposes. The teletypewriter is normally connected to a port on the ROM and status card in the terminal controller, while the paper tape reader is connected to port 1 on a multiport serial interface card. The teletypewriter serves basically as a troubleshooting aid. The paper tape reader is used to load special user or diagnostic programs into the GRAPHIC 8.

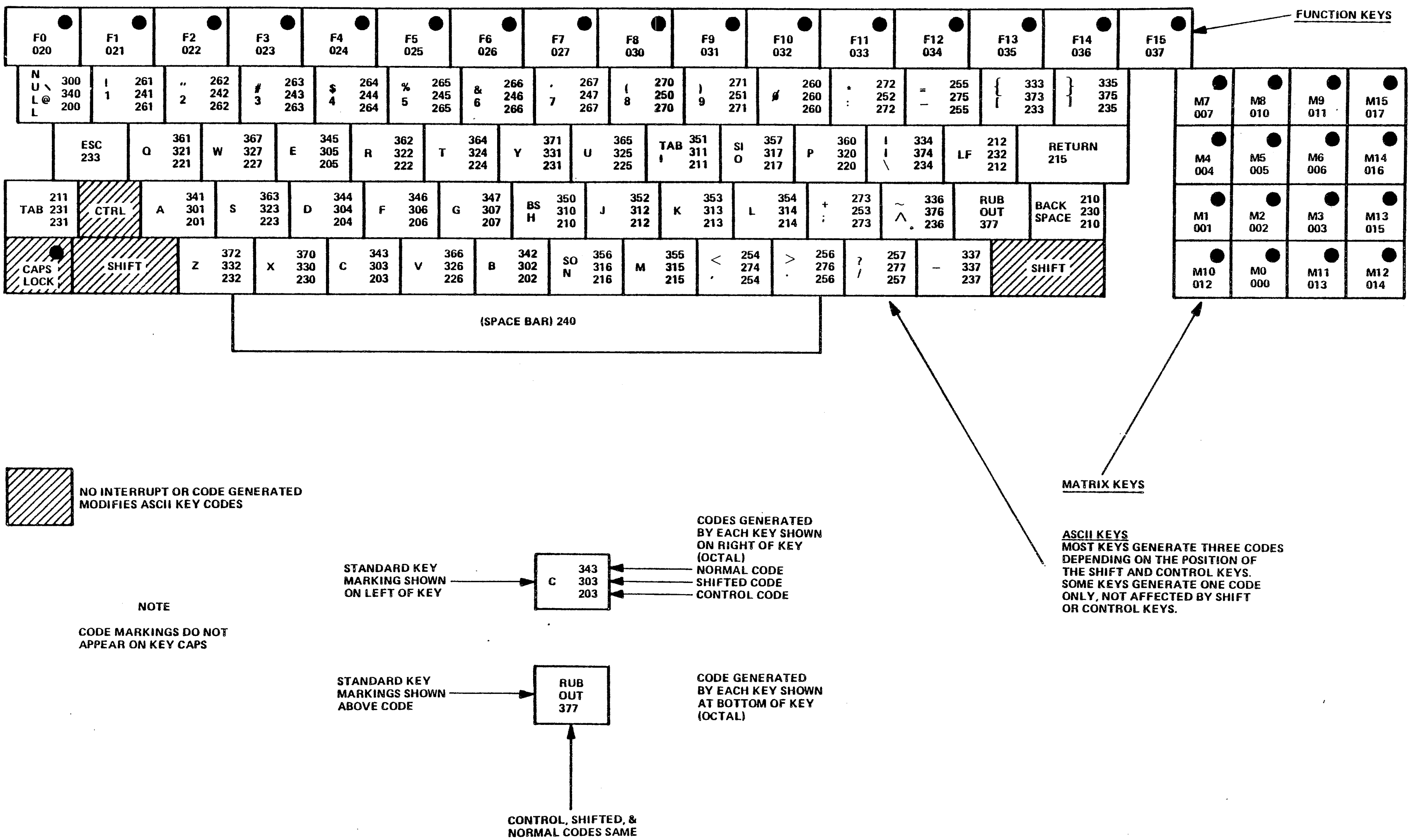


Figure 4-9. Keyboard Layout and Octal Codes

Table 4-3. Keyboard Code Assignments

UNSHIFTED ASCII CHARACTER	UNSHIFED	SHIFTED	CONTROL	SHIFT AND CONTROL
M0	000	000	000	000
M1	001	001	001	001
M2	002	002	002	002
M3	003	003	003	003
M4	004	004	004	004
M5	005	005	005	005
M6	006	006	006	006
M7	007	007	007	007
M8	010	010	010	010
M9	011	011	011	011
M10	012	012	012	012
M11	013	013	013	013
M12	014	014	014	014
M13	015	015	015	015
M14	016	016	016	016
M15	017	017	017	017
F0	020	020	020	020
F1	021	021	021	021
F2	022	022	022	022
F3	023	023	023	023
F4	024	024	024	024
F5	025	025	025	025
F6	026	026	026	026
F7	027	027	027	027
F8	030	030	030	030
F9	031	031	031	031
F10	032	032	032	032
F11	033	033	033	033
F12	034	034	034	034
F13	035	035	035	035
F14	036	036	036	036
F15	037	037	037	037
LF	212	232	232	232
RETURN	215	215	215	215
ESC	233	233	233	233
RUBOUT	377	377	377	377
BACKSPACE	210	230	230	230
SPACE (bar)	240	240	240	240
TAB	211	231	231	231
,	254	274 (<)	254	254
-	255	275 (=)	255	255
.	256	276 (>)	256	256
/	257	277 (?)	257	257

UNSHIFTED ASCII CHARACTER	UNSHIFTED	SHIFTED	P1 only	CONTROL	P2 only	SHIFT AND CONTROL
0	260	260		260		260
1	261	241 (!)		261		261
2	262	242 (")		262		262
3	263	243 (#)		263		263
4	264	244 ($)		264		264
5	265	245 (%)		265		265
6	266	246 (&)		266		266
7	267	247 (')		267		267
8	270	250 (()		270		270
9	271	251 ())		271		271
:	272	252 (*)		272		272
;	273	253 (+)		273		273
	333	373 ({)		233		233
	334	374 (¦)		234		234
	335	375 (})		235		235
	336	376 (~)		236		236
	337	337		237		237
@	300	340 ( )		200		200
A	341 (a)	301		201		201
B	342 (b)	302		202		202
C	343 (c)	303		203		203
D	344 (d)	304		204		204
E	345 (e)	305		205		205
F	346 (f)	306		206		206
G	347 (g)	307		207		207
H	350 (h)	310		210		210
I	351 (i)	311		211		211
J	352 (j)	312		212		212
K	353 (k)	313	233		213	233
L	354 (l)	314	234		214	234
M	355 (m)	315	235		215	235
N	356 (n)	316	236		216	236
O	357 (o)	317	237		217	237
P	360 (p)	320	200		220	200
Q	361 (q)	321		221		221
R	362 (r)	322		222		222
S	363 (s)	323		223		223
T	364 (t)	324		224		224
U	365 (u)	325		225		225
V	366 (v)	326		226		226
W	367 (w)	327		227		227
X	370 (x)	330		230		230
Y	371 (y)	331		231		231
Z	372 (z)	332		232		232

Table 4-4. Alphanumeric Keyboard Control Character Generation

(CTRL key pressed and held down)

Key Label	Control Function	Key Label	Control Function
A	SOH (start of heading)	N	SO (shift out)
B	STX (start of text)	O	SI (shift in)
C	ETX (end of text)	P	DLE (data link escape)
D	EOT (end of transmission)	Q	DC1 (device control 1)
E	ENQ (inquiry)	R	DC2 (device control 2)
F	ACK (acknowledge)	S	DC3 (device control 3)
G	BEL (bell)	T	DC4 (device control 4)
H	BS (backspace)	U	NAK (negative acknowledge)
I	HT (horizontal tab)	V	SYN (synchronous idle)
J	LF (line feed)	W	ETB (end of transmission block)
K	VT (vertical tab)	X	CAN (cancel)
L	FF (form feed)	Y	EM (end of medium)
M	CR (carriage return)	Z	SUB (substitute)

Table 4-5. Model 5784 Keyboard Lamp Data Bit Assignment

BIT	7	6	5	4	3	2	1	0
1st Byte - Function Keys	7	6	5	4	3	2	1	0
2nd Byte - Function Keys	15	14	13	12	11	10	9	8
3rd Byte - Matrix Keys	7	6	5	4	3	2	1	0
4th Byte - Matrix Keys	15	14	13	12	11	10	9	8

4.5.4 OUTPUT DEVICES. The standard output device for the GRAPHIC 8 is the CRT display monitor described in paragraph 4.4. A hard copy unit is available as an optional output device. Using the same signals that go to a standard display indicator, the hard copy unit can produce a duplicate on paper of any static image displayed on the display monitor CRT screen. Operation of the hardcopy unit is controlled manually.

A hardcopy multiplex switch is also available as an optional device. The multiplex switch is capable of interfacing up to four GRAPHIC 8 units to a single hardcopy unit.

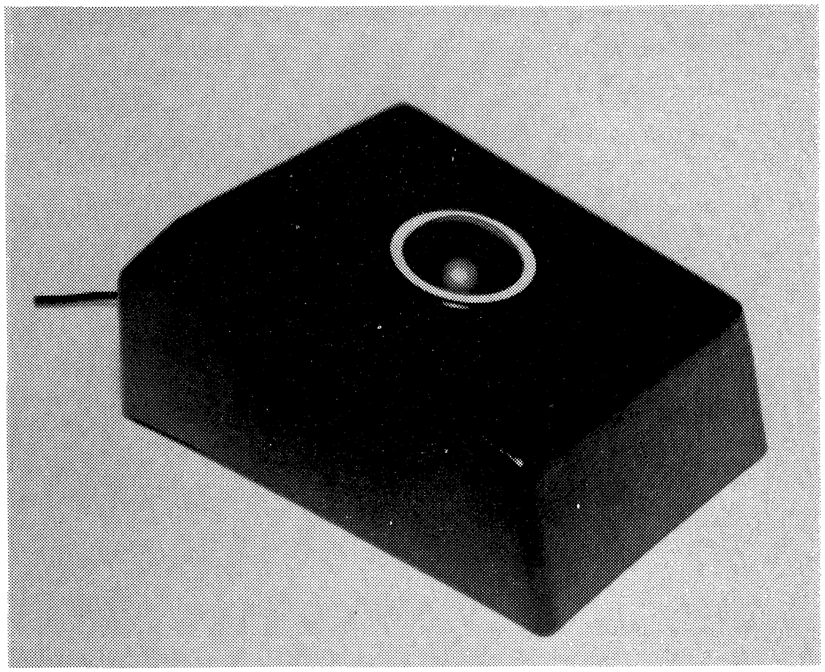


Figure 4-10. Trackball

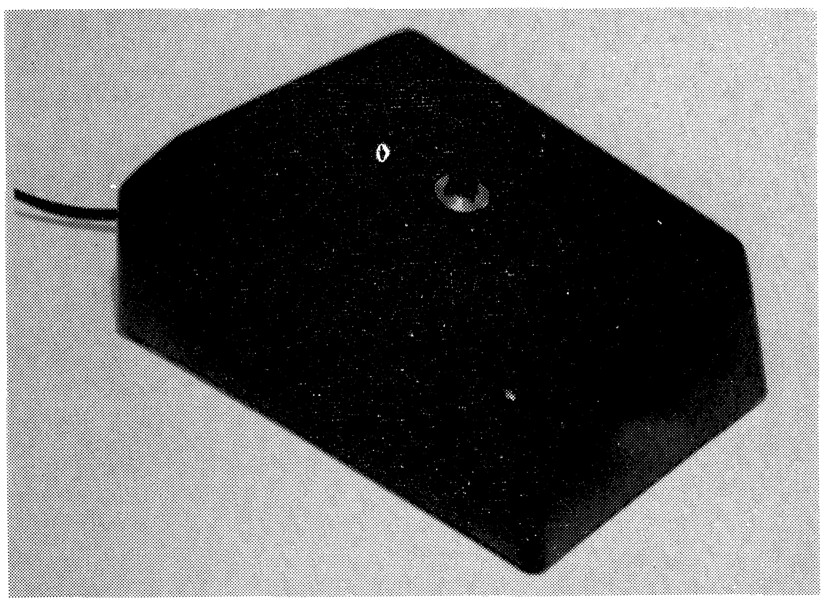


Figure 4-11. Forcestick

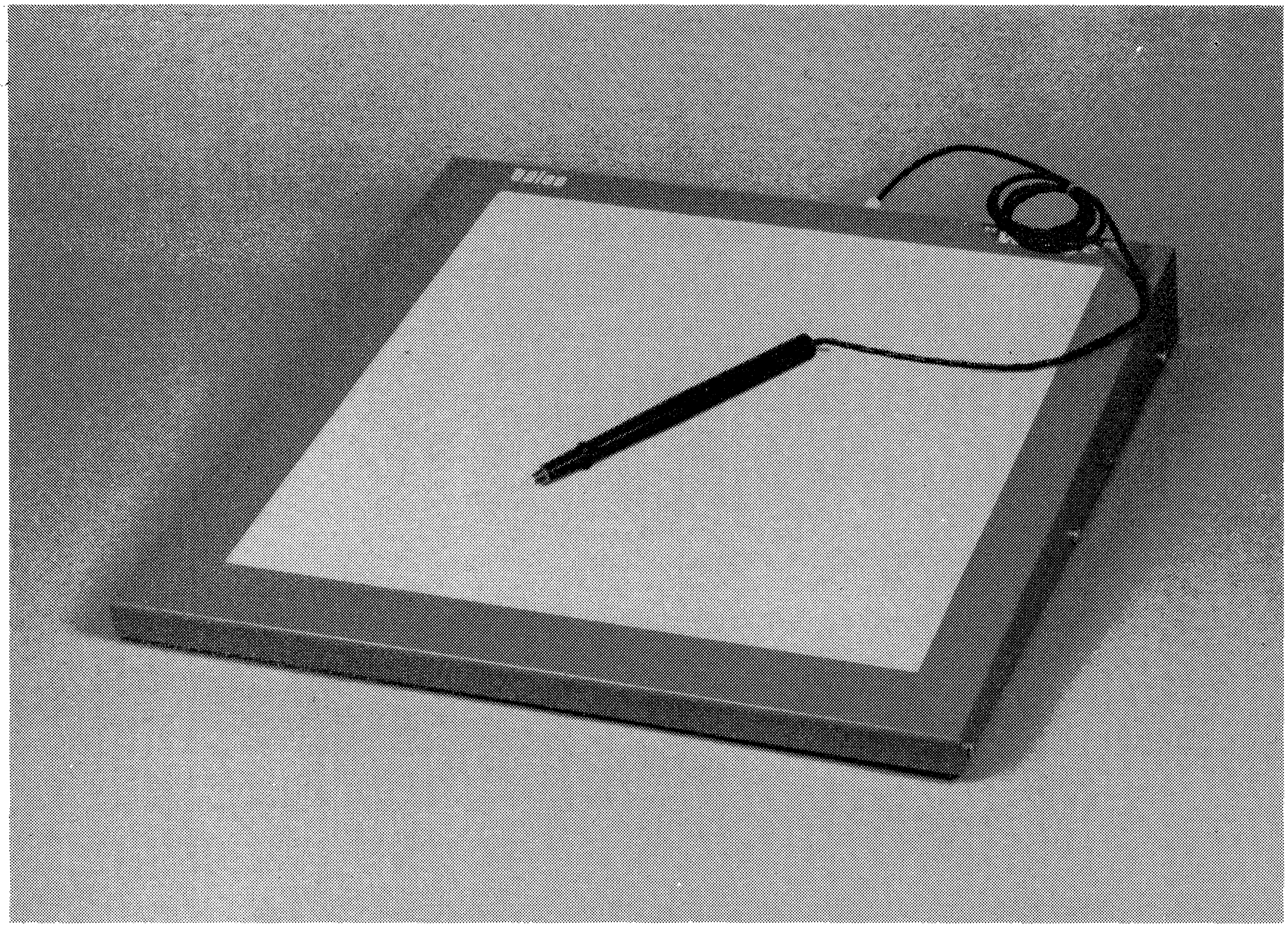


Figure 4-12. Data Tablet

SECTION 5

SYSTEM SUPPORT

5.1 RELIABILITY

5.1.1 PREDICTED MEAN-TIME-BETWEEN-FAILURE. The reliability prediction for the basic GRAPHIC 8 display system was prepared using equipments parts lists which reflect the standard production equipment configuration, assumed average component stress levels, and part failure rates obtained from MIL-HDBK-217C, Notice A*, and Sanders experience with similar operational equipment (see paragraph 5.1.3).

The predicted mean-time-between-failure (MTBF) for the basic GRAPHIC 8 terminal is 2598 hours (see figure 5-1).

5.1.2 BASIS OF PREDICTION. The GRAPHIC 8 reliability prediction, reflects these assumptions:

- Part failures are functionally independent and occur randomly in time.
- Part failure rates remain essentially constant throughout the useful life of the equipment.
- Limited-life components are replaced on a scheduled basis, before exceeding their specified operating life.
- Operating internal ambient temperature is assumed to be 40°C.
- Equipment operating environment corresponds to the fixed group environment of MIL-HDBK-217C.

5.1.3 DISCUSSION OF PART FAILURE RATES. Evaluation of data obtained from Sanders display equipment of this nature can readily exceed the reliability levels predicted in MIL-HDBK-217C. The exceptions to MIL-HDBK-217C include the failure rates for SSI, MSI, and linear microcircuits, which were taken from Sanders' own assessment of plastic, commercial-grade IC's, LSI, memory devices and non-generic part failure rates were determined using results from the vendors' own life test programs.

5.1.4 RELIABILITY ANALYSIS. In developing the reliability prediction, failure of any element constituted unit failure. This is reflected in the dependency diagram for the basic GRAPHIC 8 display system (figure 5-1). The failure rates shown for each element were obtained by summing the failure rates of the element's component parts. Likewise, the failure rate for the entire system was obtained by summing the failure rates of the individual elements in the serial dependency model. The MTBF is the reciprocal of total system failure rate.

*MIL-HDBK-217C, "Reliability Prediction of Electronic Equipment," dated 1 May 1980.

5.2 MAINTAINABILITY

Ease of maintenance was a prime consideration in the design of the GRAPHIC 8. Functional modular packaging techniques are used throughout the equipment. Distinct electrical functions are physically packaged and designed for plug-in installation, where possible. Identical assemblies/subassemblies ensure interchangeability without mechanical or electrical modification. Safety of maintenance personnel was also a prime consideration; i.e., warning labels and safety covers are used to protect from hazardous voltages or temperatures.

5.2.1 MAINTENANCE CONCEPT. The GRAPHIC 8 maintenance concept consists of rapid, unambiguous onsite fault-isolation to the replaceable assembly level and repair by replacement of the faulty assembly. Replaceable assemblies within the display controller and display generator units consist of plug-in printed circuit boards or modular assemblies. Display indicators are replaced as entire units.

Fault localization to the unit level is generally accomplished immediately by inspection of the display presentations. In the few instances where ambiguous failure symptoms are detected, the fault is easily located by observing an oscilloscope presentation of interunit signals. Once localized, the fault is isolated to the replaceable assembly within the display controller or display generator using a combination of built-in and external test equipment. Built-in ROM diagnostic routines provide further localization to a group of boards, while isolation to the single faulty printed circuit board is accomplished using an oscilloscope and extender card to probe test points on individual boards.

Once isolated, most assemblies are replaced by a simple unplug and plug-in operation, while none require more than the removal of a few multiturn screws.

5.3 QUALITY ASSURANCE

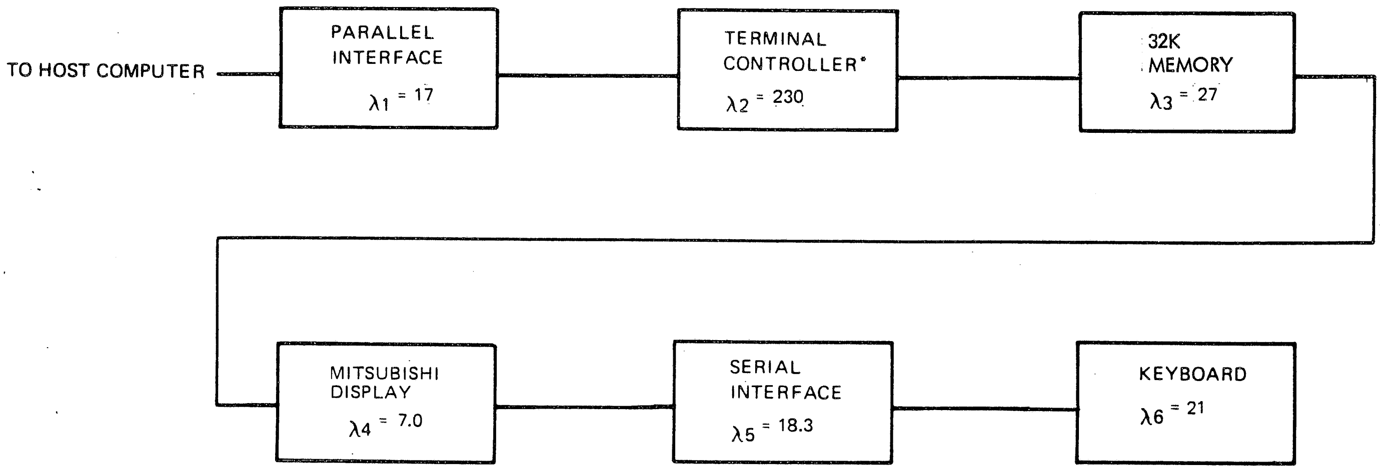
Sanders inspection and quality control system is similar to MIL-Q-9858A with the exception of Government Source Inspection. The system provides for complete assurance of product quality and integrity.

Standard product line inspection is implemented through a Quality Assurance management structure which holds QA control over all phases of product manufacture.

Sanders QA system encompasses all aspects of fabrication, from the control of purchases and raw materials to post-fabrication testing and packaging. Vendors are required to provide data or certification as necessary to ensure acceptable materials. Source or incoming inspection of all procured materials ensures the quality of these items. In-process inspection is performed at all major levels of manufacture with necessary control of special processes. Indication of inspection status is maintained to segregate nonconforming materials which are further controlled through a system of evaluation and disposition. Quality records are maintained for all product lines and analysis is performed for initiation and implementation of corrective action at all levels.

Final inspection and test ensures that all product items conform to applicable drawings and specifications. Inspection and test equipment, controlled through a Corporate activity, ensures product integrity.

All inspection criteria are documented at a level commensurate with Sanders commercial workmanship standards.



$$\lambda_T = T = \sum_{1}^{7} T = 384.9$$

$$MTBF = \frac{1}{\lambda T} = 2598 \text{ HOURS}$$

λ= FAILURE RATE IN FAILURES PER 10^6 HOURS

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Figure 5-1. GRAPHIC 8 Display System Reliability Diagram

SECTION 6

PHYSICAL CHARACTERISTICS

6.1 TERMINAL CONTROLLER

The GRAPHIC 8 terminal controller may be ordered as a rack-mounted configuration, or installed in an optional equipment cabinet (figure 6-1). If the terminal controller and equipment cabinet are ordered at the same time, the terminal controller card cage assembly (figure 6-2) is shipped from the factory installed in the equipment cabinet, and all connections between the terminal controller and the power panel assembly (figure 6-3) and system interconnect panel assembly (figure 6-4) are already made. The rack-mounted terminal controller weighs approximately 55 pounds; the equipment cabinet installation weighs approximately 155 pounds.

6.2 DISPLAY INDICATOR

The Model 8520 color indicator is a high resolution display capable of various configurations up to a 1024 by 1024 interlace. Physical dimensions of the indicator are shown in figures 6-5 and 6-6.

6.3 KEYBOARD

The Model 5784 keyboard is shown in figure 6-7. The keyboard weighs approximately 7 pounds. The Model 5783 keyboard is the same size and weight as the Model 5784 keyboard.

6.4 POSITION ENTRY DEVICES

The Model 5786 trackball is shown in figure 6-8. The trackball weighs approximately 3.5 pounds. The Model 5787 forcestick is shown in figure 6-9. The forcestick case size is identical to the trackball case size; however, the forcestick weighs only 2.5 pounds. The Model 5788 data tablet is shown in figure 6-10. The data tablet weighs approximately 7-1/4 pounds.

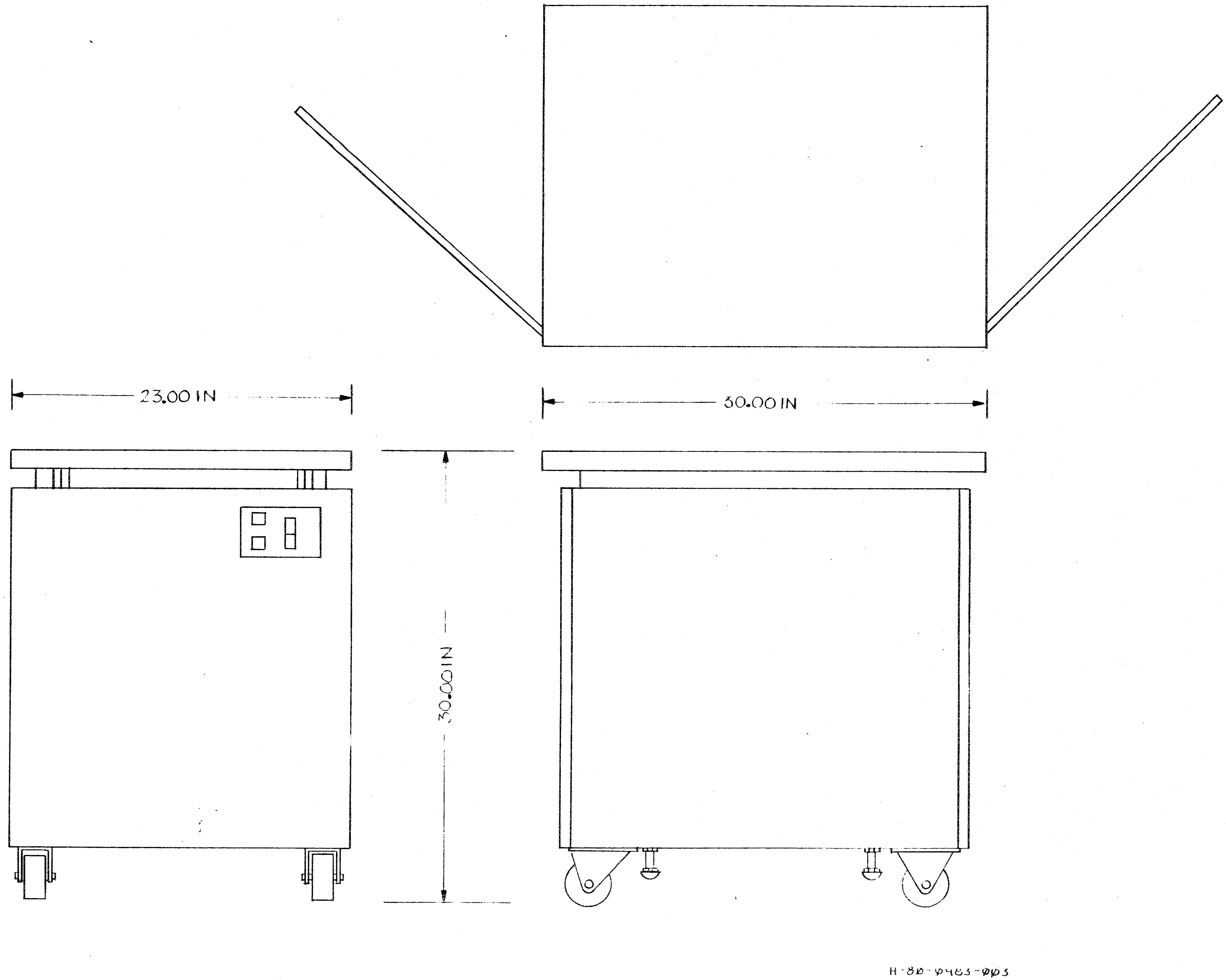

Figure 6-1. Equipment Cabinet

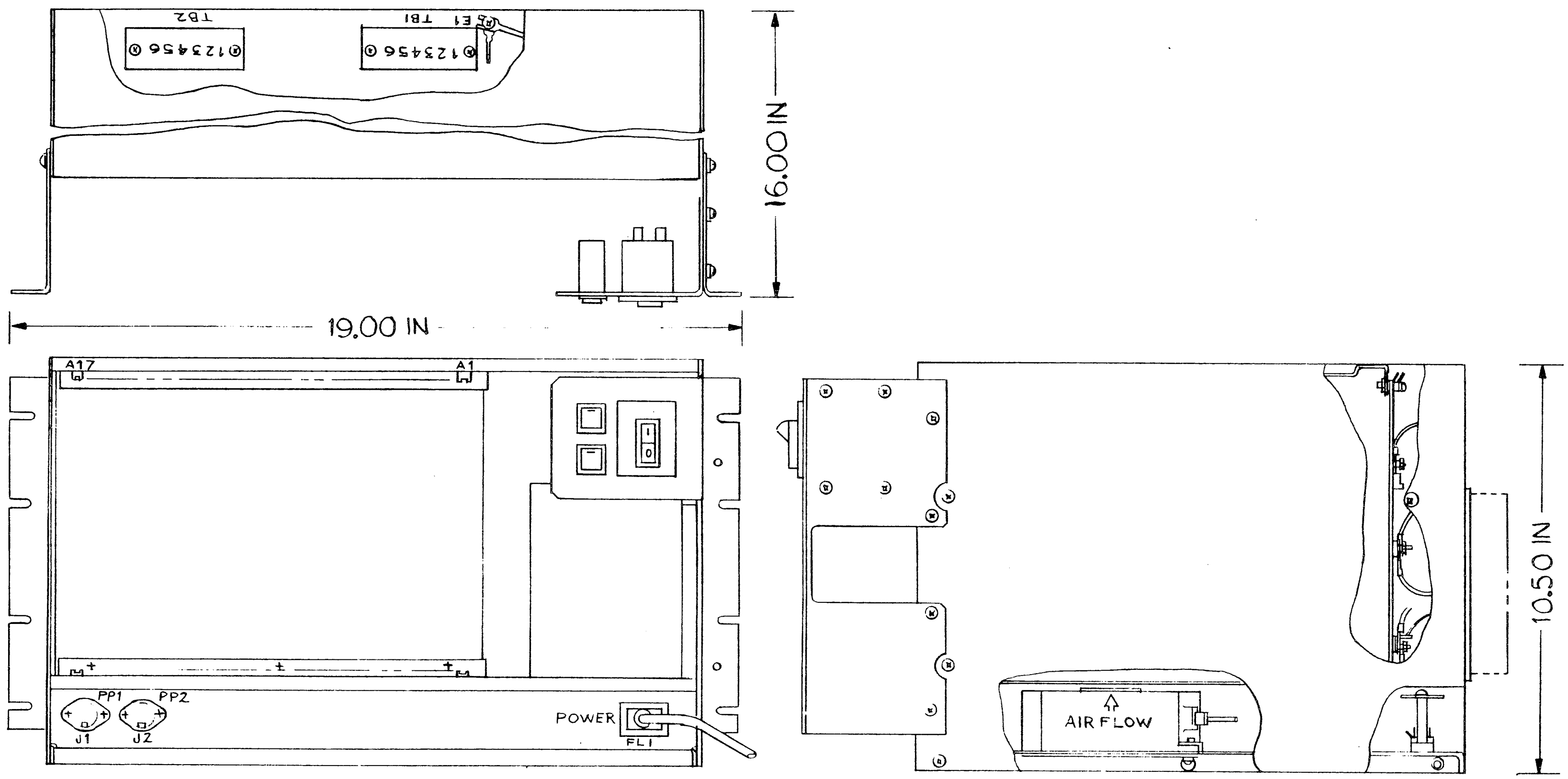

Figure 6-2. Card Cage Assembly

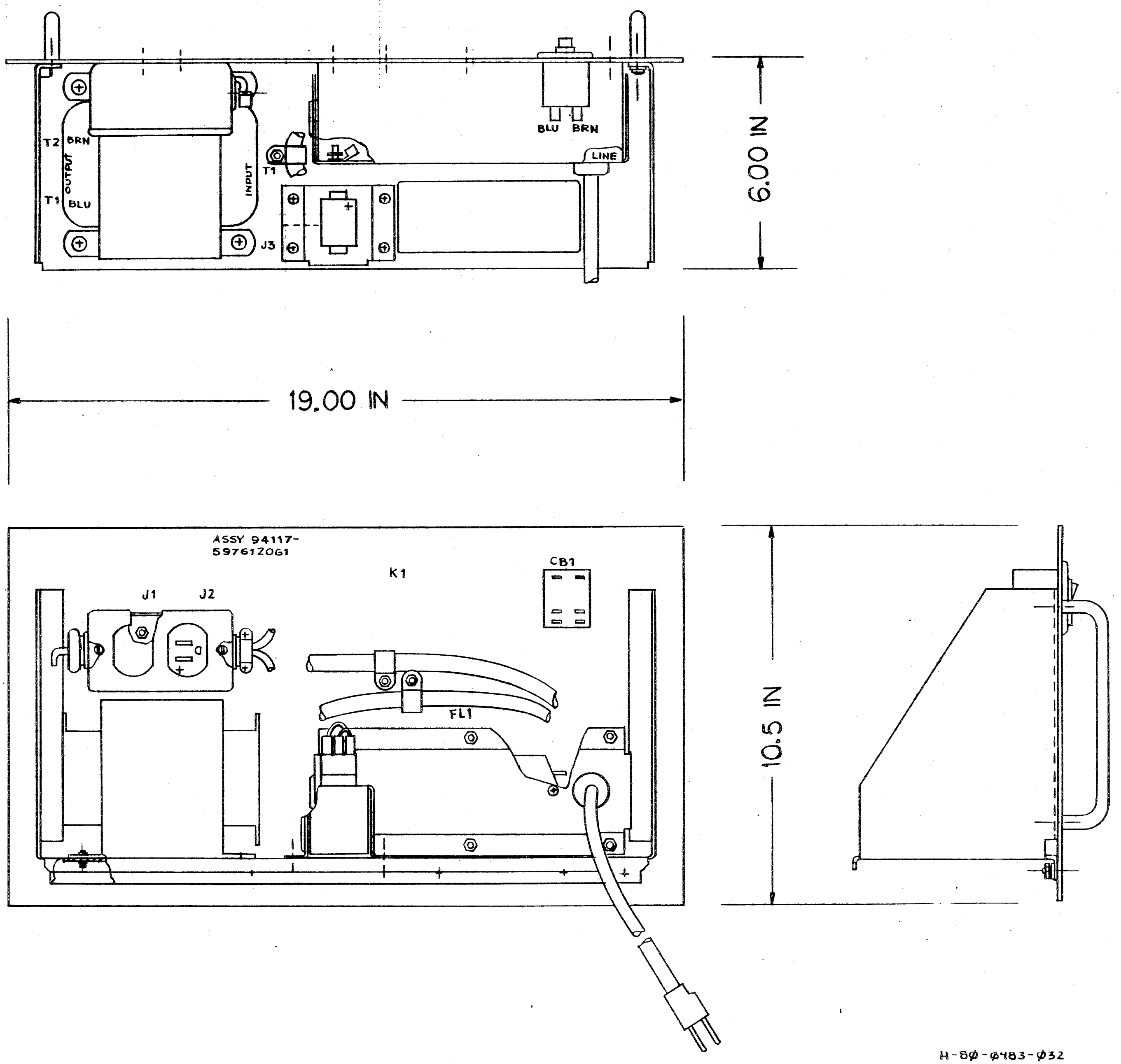

Figure 6-3. Power Panel Assembly

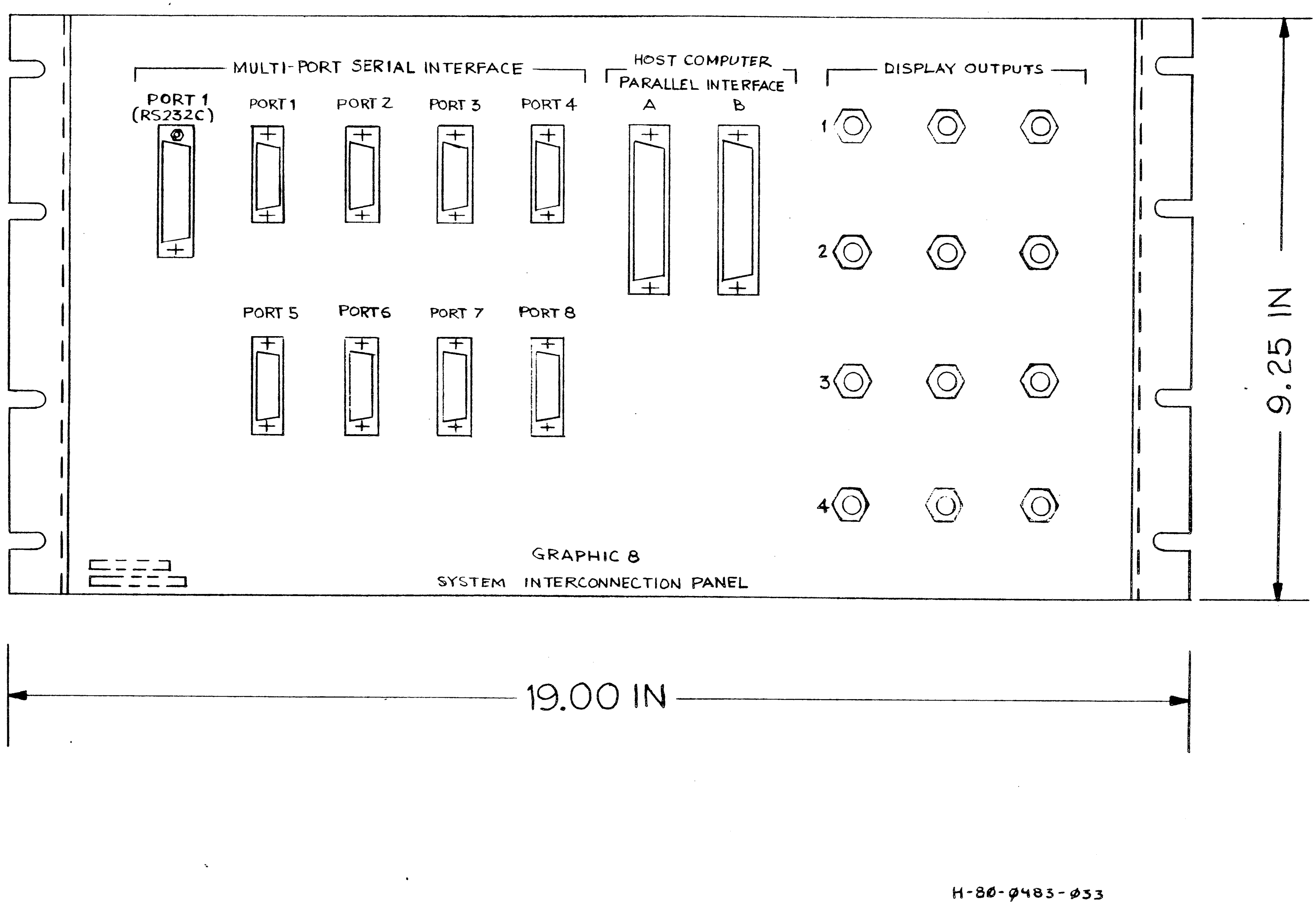

Figure 6-4. System Interconnect Panel Assembly

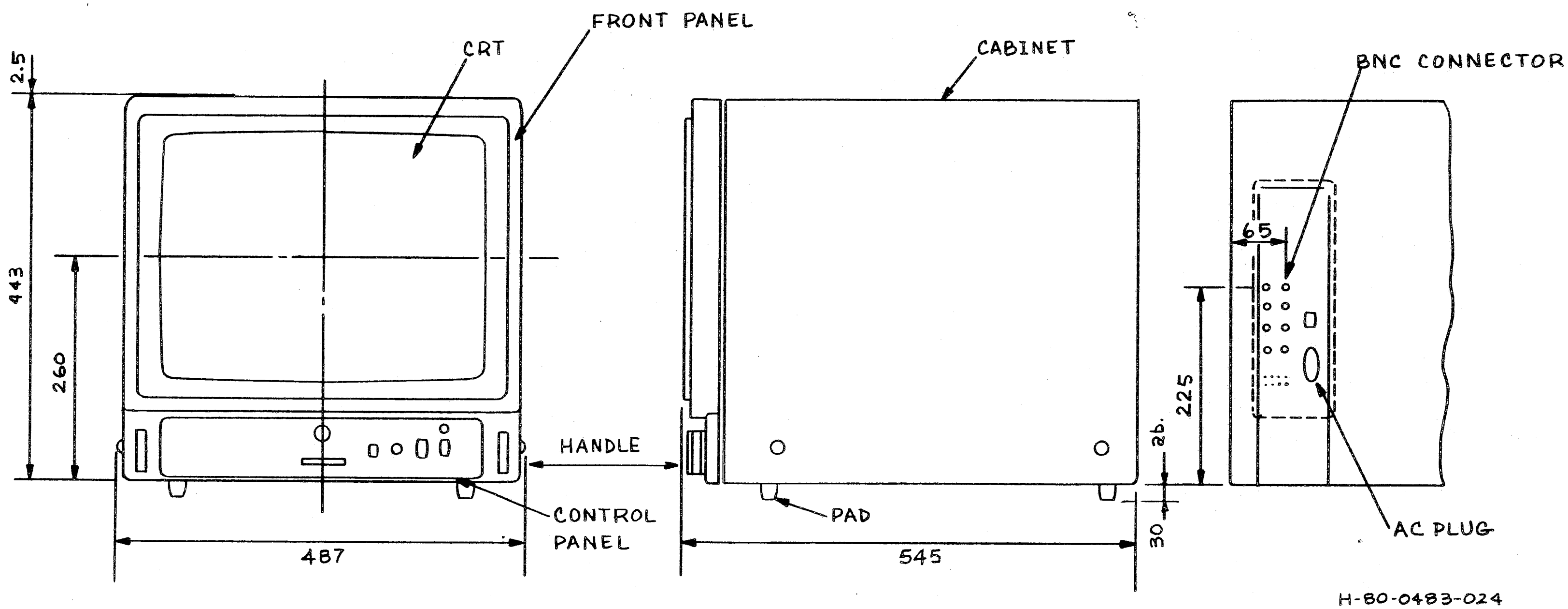

Figure 6-5. Model 8520 Color Monitor, Cabinet Configuration

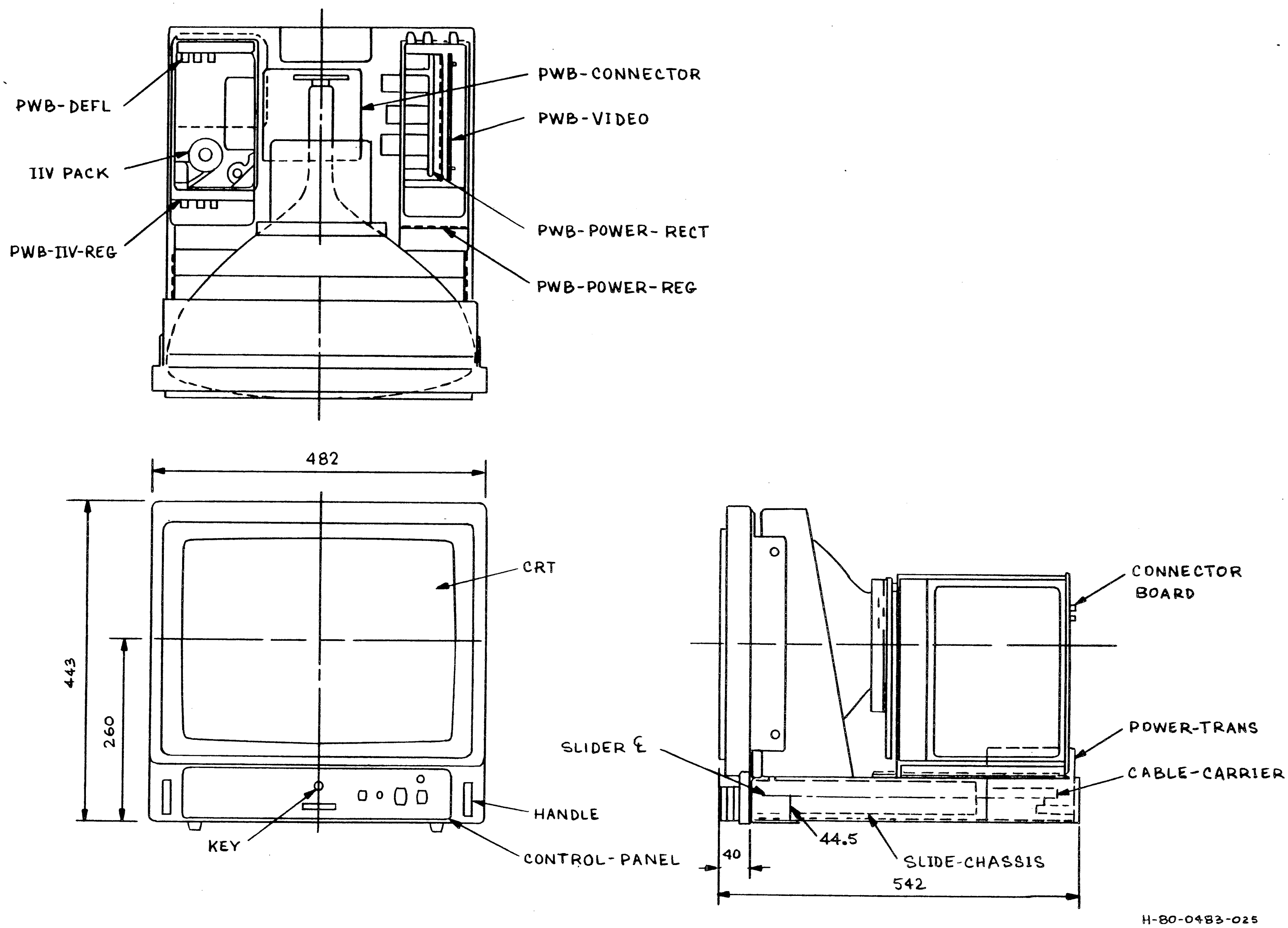

Figure 6-6. Model 8521 Color Monitor, 19-Inch Rack Mount Configuration with Slides

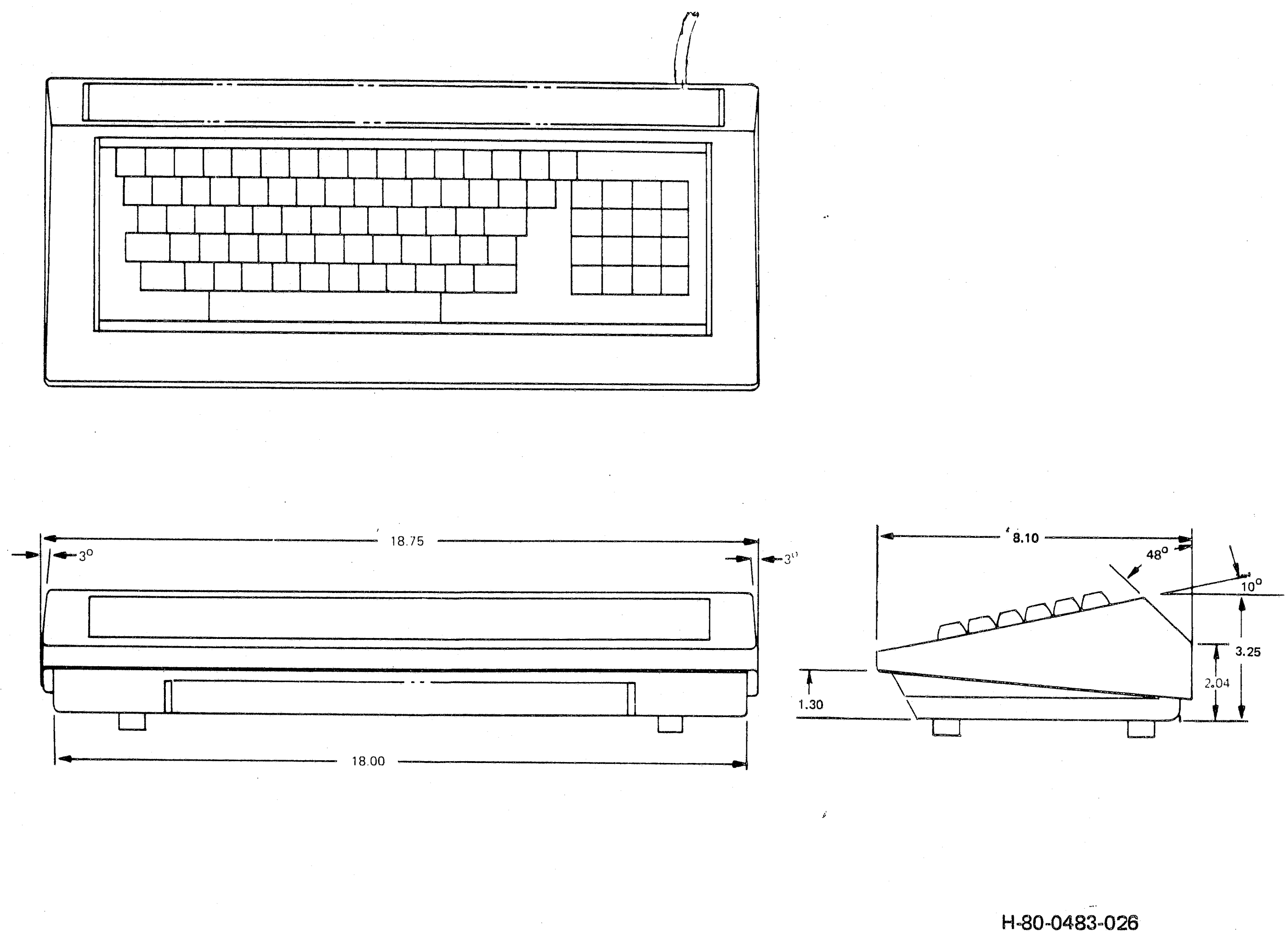

Figure 6-7. Keyboard - Model 5784 or 5783

8. SIGNAL LEVEL DEFINITIONS:

SIGNAL LEVEL	START-STOP SIGNAL	TELEGRAPH NOMENCLATURE	LOGICAL VALUE
-6 VOLTS	STOP	MARK	1
+6 VOLTS	START	SPACE	0

7. SEQUENCE PULSES ARE COUNTED DURING A 25 MSEC PERIOD, NUMBER OF PULSES IN X AND Y ARE TRANSMITTED, COUNTERS ARE RESET TO ZERO.

6. CODES: X AND Y, 2'S COMPLEMENT, BINARY

5. WORD ORGANIZATION:

BIT NO.	X-Y WORD	TEST WORD
1	START	START
2-8	X SIGNAL	TEST SIGNAL
9	X IDENT (=0)	TEST SIGNAL
10-16	STOP	STOP
17	START	STOP
18-24	Y SIGNAL	STOP
25	Y IDENT (=1)	STOP
26-256	STOP	STOP

4. WEIGHT: LESS THAN 3.5 LBS (1.6 KG).

3. POWER REQUIRED:

+5 VDC REGULATED ±1% AT 410 ma
+15 VDC ±.75V AT 25 ma
-15 VDC ∓.75V AT 25 ma

2. SIGNAL TIMING: 9600 ±0.1% BAUD CRYSTAL CONTROLLED, 37.5 Hz (26.67 MSEC) REPETITION RATE.

1. FUNCTION: CONVERTS MANUAL RATE COMMANDS TO AN ASYNCHRONOUS RS232-C COMPATIBLE SIGNAL.

CONNECTOR PIN FUNCTION	
FUNCTION	PIN NO.
SIGNAL OUT	1
-15V	2
--	3
GND	4
TEST IN	5
GND	6
--	7
SPARE	8
GND	9
+15V	10
--	11
--	12
+5V	13
--	14
--	15

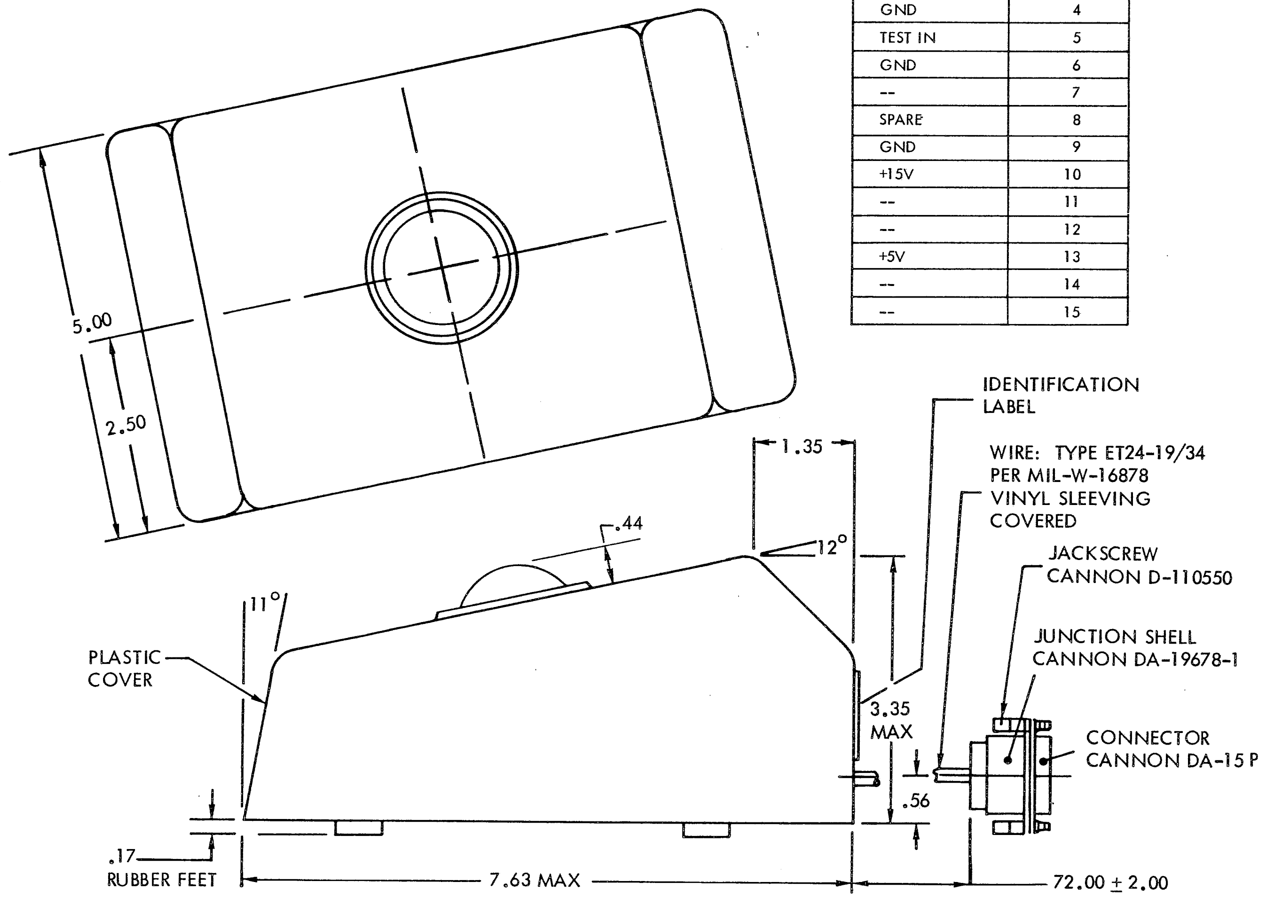

Figure 6-8. Model 5786 Trackball

8. SIGNAL LEVEL DEFINITIONS:

SIGNAL LEVEL	START-STOP SIGNAL	TELEGRAPH NOMENCLATURE	LOGICAL VALUE
-6 VOLTS	STOP	MARK	1
+6 VOLTS	START	SPACE	0

7. SEQUENCE PULSES ARE COUNTED DURING A 25 MSEC PERIOD, NUMBER OF PULSES IN X AND Y ARE TRANSMITTED, COUNTERS ARE RESET TO ZERO.

6. CODES: X AND Y, 2'S COMPLEMENT, BINARY

5. WORD ORGANIZATION:

BIT NO.	X-Y WORD	TEST WORD
1	START	START
2-8	X SIGNAL	TEST SIGNAL
9	X IDENT (=0)	TEST SIGNAL
10-16	STOP	STOP
17	START	STOP
18-24	Y SIGNAL	STOP
25	Y IDENT (=1)	STOP
26-256	STOP	STOP

4. WEIGHT: LESS THAN 2.5 LBS (1.1 KG).

3. POWER REQUIRED:

+5 VDC REGULATED ±1% AT 450 ma
+15 VDC ±.75V AT 20 ma
-15 VDC ∓.75V AT 20 ma

2. SIGNAL TIMING: 9600 ±0.1% BAUD CRYSTAL CONTROLLED, 37.5 Hz (26.67 MSEC) REPETITION RATE.

1. FUNCTION: CONVERTS MANUAL RATE COMMANDS TO AN ASYNCHRONOUS RS232-C COMPATIBLE SIGNAL.

CONNECTOR PIN FUNCTION	
FUNCTION	PIN NO.
SIGNAL OUT	1
-15V	2
--	3
GND	4
TEST IN	5
GND	6
--	7
SPARE	8
GND	9
+15V	10
--	11
--	12
+5V	13
--	14
--	15

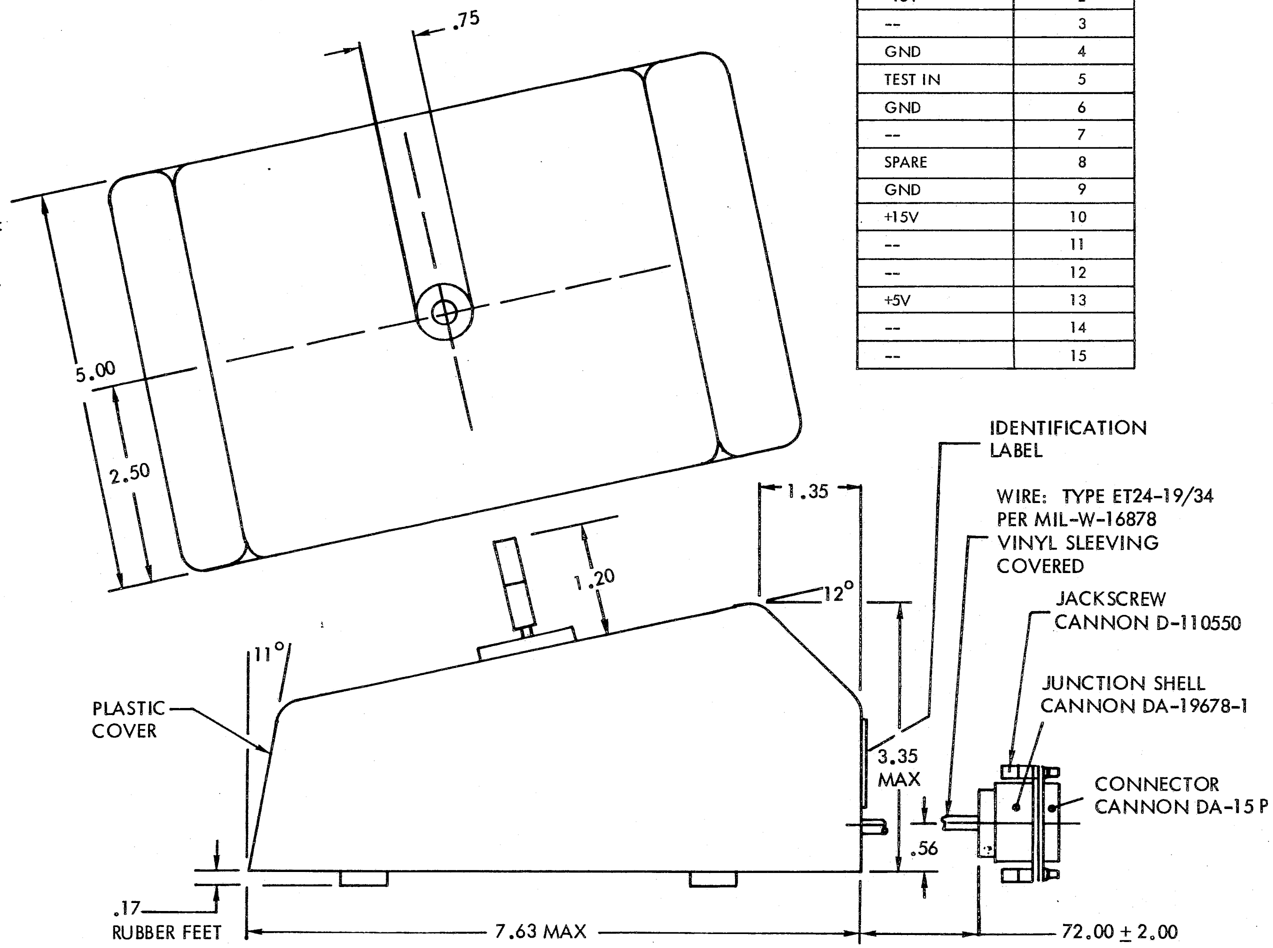

Figure 6-9. Model 5787 Forcestick

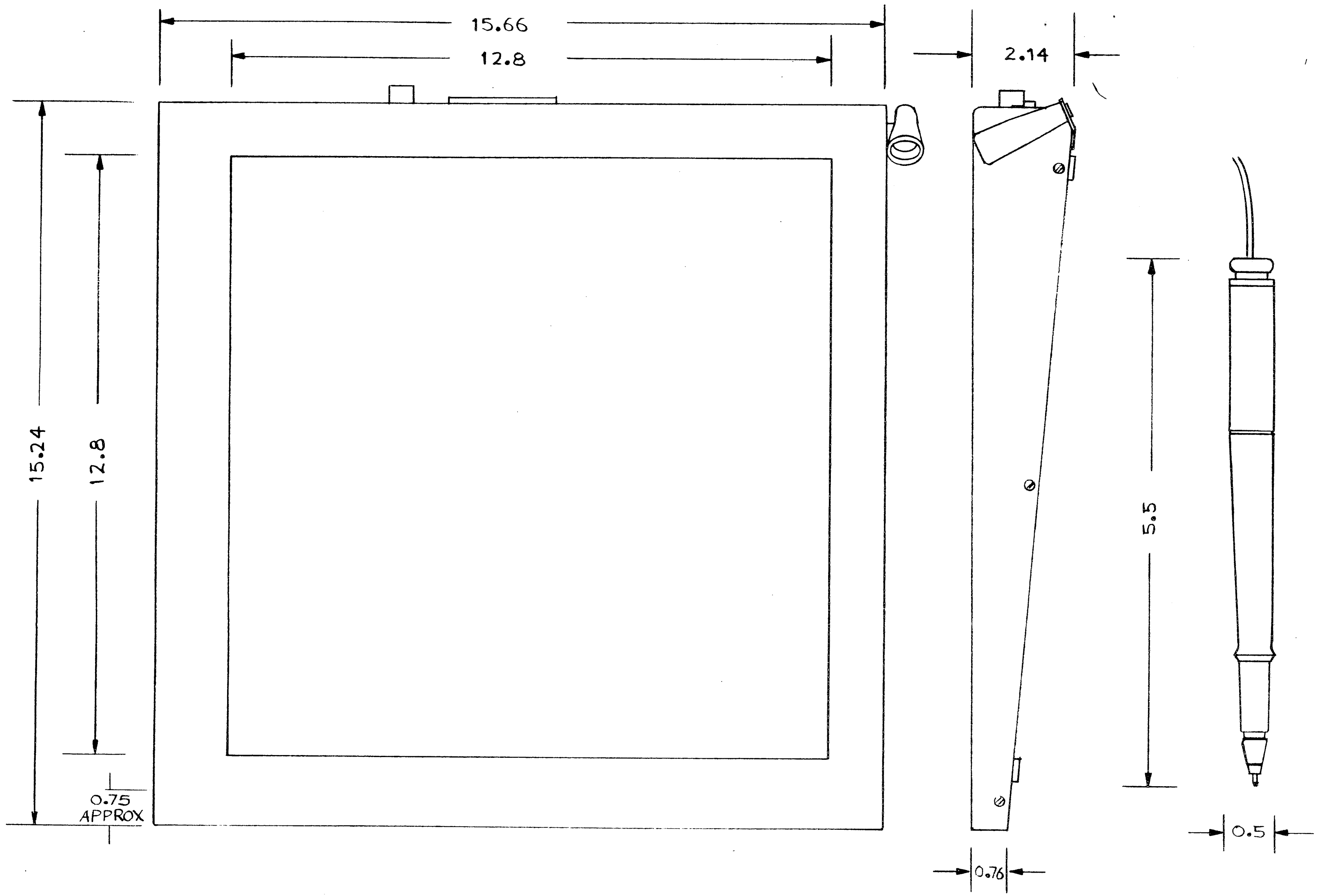

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Figure 6-10. Model 5788 Data Tablet (with Pen Stylus)

SECTION 7

GRAPHIC 8 SPECIFICATIONS

Specifications for the GRAPHIC 8 terminal controller, display indicators and data entry devices are listed in tables 7-1, 7-2, and 7-3, respectively.

Table 7-1. GRAPHIC 8 Terminal Controller (Model 8XXX) Specifications

GENERAL	
Power Source	115 ± 10 vac 47 to 63 Hz
Power	300 Watts
Temperature Storage	0° to 50°C
Temperature Operating	15° to 40°C
Relative Humidity	10 to 90%
Dimensions:	
Rack Mount Configuration	
Height	10.5 in (26.8 cm)
Width	19.0 in (48.2 cm)
Depth	16.0 in (40.6 cm)
Weight	55 lbs (25 kg) including cards
Equipment Cabinet Configuration	
Height	30 in (76.2 cm)
Width	23 in (58.4 cm)
Depth	30 in (76.2 cm)
Weight	155 lbs (70.3 kg) on four casters
DISPLAY PROCESSOR	
General Purpose Microprocessor	Yes
Word Length	16 bits
Byte Mode	8 bits
Instructions	400 plus
Registers	8
Hardware Stacks	Yes
Automatic Priority Interrupt	Yes
Memory	16 bit words
ROM	8192 words
RAM	65,536 words
Expansion RAM to	131,072 words
INTERFACE OPTIONS (DIGITAL)	
Parallel	16 bits 32 bits (optional)
Serial	RS-232C

GRAPHIC CONTROLLER	
Parallel Microprocessor	16 bits
Display Instructions	50 plus
Synchronized Linkage to Display Processor	Yes
Subroutine Stack	Yes
Display Registers	64 plus
Registers (GP)	4
VECTORS/CONICS	
Line Texture	4
Ellipse	any angle
CHARACTERS	
Font Size	5 x 7 7 x 9
Character Set (STD)	96
User Defined (OPT)	96
Rotation	90° CLK
Sizes	3
Tabular Characters	Auto Text Spacing
Positioning	Random
MAPPING MEMORY	
Addressable Locations	2048 x 2048
Bits/Pixel	2,4,8
VIDEO CONTROLLER	
Blink	Yes
Color or Gray Level	256
Screen Splits	3
Cursor	non-destructive
Terminations	75 ohm
Video	Composite
Displays Max	6

Table 7-2. GRAPHIC 8 Display Monitor Specifications

SPECIFICATION		
AC Power Voltage	:	AC100, 110, 120, 220, 240V ±10%, tap selectable
AC Power Frequency	:	50 or 60 Hz
Power Consumption	:	Abt. 280VA
Input Signal		
(a) Termination	:	75 ohm or high impedance, selected by termination switches.
(b) Connectors	:	BNC connectors for all inputs.
(c) Sorts of inputs	:	Red - Video signal
		Green - Video signal or composite video signal
		Blue - Video signal

These three (3) signals are positive white and sync shall be composited in green. Separate sync input shall be applied on sync input in case video signal is without sync.

		Sync - Composite sync, negative going.
(d) Input levels	:	0.3Vp-p - 2.0Vp-p for RGB Inputs 1.0Vp-p - 5Vp-p for sync signal
CRT	:	3 guns, shadow mask burst protection type; inner magnetic shield; electric-magnetic deflection; static focus
Aspect Ratio	:	3 : 4 and 1 : 1 aspect ratio, selected by plug-in position of a connector.
Max. Effective Screen Size	:	394(W) x 195(H) mm
Ambient Temperature	:	Ambient temperature on operation shall be -5°C to +40°C

Package Environment

Equipment can withstand room air temperature of -35°C to +60°C and 50cm free drops encountered during transportation. Also can withstand relative humidity of 0 to 95%.

Table 7-2. GRAPHIC 8 Display Monitor Specifications (Cont)

Video Amplifier

Video amplifier is linear and drives the cathode of the CRT.

Video signals are compatible with the timing requirements of EIA-STD-RS-170.

The peak-to-peak inputs signal amplitude is between 0.35 volts and 2.0 volts.

Composite video signal is composed of apx. 70% video and apx. 30% sync amplitude.

a) Frequency response and pulse response

Frequency Response		$\pm$3 dB or better between 50 Hz to 40 MHz
Pulse Response	Rise Time	Better than 11ns
	Fall Time	Better than 11ns

b) Differential Gain : Better than 5%

c) Black Level Stability

Feedback clamp circuits.

Maintains black level within 1% at any average picture level (APL) of 10% to 90%.

Convergence

Better than 0.5 mm in a centrally located area bounded by a circle. The diameter of this circle is equal to picture height. Elsewhere the deviation is better than 1.0 mm.

Raster Size Regulation

Raster size change caused by change of CRT beam current 0 to 500 uA is less than 1% of raster height.

Linearity and Geometry

Linearity measured and calculated by the following formula is better than 7%.

Formula: $\frac{\text{MAX-MIN}}{\text{MEAN}} \times \frac{1}{2} \times 100\ (\%)$

Raster distortion is better than 2% of raster height.

Table 7-3. GRAPHIC 8 Data Entry Device Specifications

ALPHANUMERIC/FUNCTION KEYBOARD (Model 5784 or 5783)

PARAMETER	CHARACTERISTIC
Alphanumeric keys	55, momentary action, of which 50 are upper and lower case
Matrix keys	16, momentary action
Function keys	16, momentary action
Power	+5V, ±1%, 750 mA max +15V, ±1%, 50 mA max -15V, ±1%, 50 mA max
Output levels	Logic low is 0.0 to +0.45V Logic high is +2.45 to +5.25V
Output signal characteristics	Serial, RS-232 compatible, negative true • Rest = low • Logic 1 = low • Code = 10 bit (one start bit, eight data bits, one stop bit)
Maximum cable length (keyboard to terminal controller)	Model 5783 - 50 feet Model 5784 - 100 feet with external +5V power supply
Operating temperature range	+4°C to +49°C (40°F to 120°F)
Storage temperature range	-40°C to +60°C (-40°F to 140°F)
Humidity	5% to 95%, non-condensing
Storage pressure range	483 mm Hg to 813 mm Hg (19 to 32 inches Hg)
Dimensions	475 mm wide by 206 mm deep by 94 mm high (18.75 by 8.1 by 3.7 inches)
Weight	3.2 kg (7 lbs.)

Table 7-3. GRAPHIC 8 Data Entry Device Specifications (Cont)

	Trackball (Model 5786)	Forcestick (Model 5787)
Electrical Interface (to Terminal Controller)		
Code	256-bit binary words, 9600 baud,	
Signal Levels	asynchronous RS-232C	
Word Repetition Rate	37.5 Hz	
Cursor Movement	300 display elements per revolution of ball	1280 display elements per second maximum
Resolution	Within one display element in 1024 (±0.006 inch on Model 0530 Display Indicator)	
Force to Move Cursor	15 grams (typical)	37 grams, minimum cursor movement 909 grams, maximum cursor movement
Power Requirements	+5V, 410 mA ±15V, 20 mA	+5V, 450 mA ±15V, 20 mA
Operating Temperature	15°C to 40°C (59°F to 104°F)	
Humidity	10% to 90%	
Connector	Cannon DA-15P	
Cable	6 feet supplied, 50 feet maximum length	
Size	Height - 3.3 inches Width - 5.0 inches Depth - 7.5 inches	
Weight	3.0 pounds (1.36 kg)	2.5 pounds (1.14 kg)
Mechanical Action	Friction drive, spring loaded	Spring return to center

Table 7-3. GRAPHIC 8 Data Entry Device Specifications (Cont)

Data Tablet (Model 5788)

Electrical	
Active Surface Area (in.)	11 x 11
Total Surface Area (in.)	12.8 x 12.8
Resolution (lines/in.)	400
Accuracy (in.)	±0.025
Coordinate Refresh Rate (pr/sec)	120 (Standard)
Operating Modes	Point, Run (switch selectable)
Transducer	Pen Stylus
Output Configuration	Serial, TTL, and RS-232C compatible
Output Data Rate	30 coordinate points per second, min.
Data Format	Ten Bytes/Coordinate Pair: 1) Status 2-5) X Data (MSD First) 6-9) Y Data (MSD First) 10) Carriage Return
Byte Format	ASCII
Baud Rate	9600
Additional Control Lines	Clear to Send Remote Point/Run
Nominal Power Requirements	15 Vdc at .15A, ±1% resolution
Operational Temperature Range	15° to 40°C

Table 7-3. GRAPHIC 8 Data Entry Device Specifications (Cont)

Mechanical	
Tablet:	
Weight (lb)	7.25
Enclosure	Steel and Aluminum
Size (in.)	15.66 x 15.24 x (.76 front; 2.14 rear)
Pen Stylus Assembly:	
Length (in.)	5.5
Width (in.)	0.5
Cable (in.)	40

Name: ______________________________

Company: ______________________________

Address: ______________________________

____

Telephone: [   ] ______________________________

Date: ______________________________

Sanders Equipment ______________________________

Part Number ______________________________

Software/Firmware System ______________________________

Version ______________________________

Host computer ______________________________

Host operating system ____________ Version __________

Host-GRAPHIC 8 interface ______________________________

My problem is: hardware ☐ software ☐

firmware ☐ manual ☐

Description of problem (or suggestion for improvement):

Related tech manual number ______________________________

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