GA-76-165 (REV 5)

Graphic 7™

COMPUTER GRAPHICS DISPLAY SYSTEM

TECHNICAL DESCRIPTION

Information Products Division
Federal Systems Group
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Sanders Associates, Inc., reserves the right to modify the products described in this manual and to make corrections or alterations to this manual at any time without notice.

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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 7 SYSTEM DESCRIPTION

Sanders' GRAPHIC 7® is an intelligent interactive graphic terminal that comes ready to use. The display image is created by refreshed CRT stroke writing for the maximum in brightness, clarity, and rapid response. It is initialized by a single button push, and features stand-alone built-in test with convenient operator confidence checks. Figure 1-1 shows representative GRAPHIC 7 configurations.

The GRAPHIC 7 contains two high-performance microprocessors to handle the separate tasks of imaging and interaction. A read-only memory in the controller stores the graphic control program (GCP+) that handles communications between the terminal and the host computer, controls the data entry devices, and manages the display image refresh.

The easy adaptability and all-around high performance of the GRAPHIC 7 make it ideally suited for such applications as:

- Computer-aided design and manufacturing
- Simulation and training
- Resource and information management
- Command and control
- Air traffic control
- Data reduction
- Interactive mapping

A major characteristic of the GRAPHIC 7 is its easy compatibility with most computers through its standard serial and parallel interfaces. Freedom in the selection of the host computer is aided by the terminal firmware (GCP+) and built-in test routines that otherwise would require software support in the host. The terminal intelligence and the interfaces give the terminal user the option of locating interactive displays remotely from the host computer.

The GRAPHIC 7 minimizes the host computer software effort in several ways:

1. The device and refresh image handling routines that are committed to firmware in the terminal controller represent a first level of operational software support that would have been necessary in the host computer in display systems of previous generations.

® GRAPHIC 7 is a trademark of Sanders Associates, Inc.

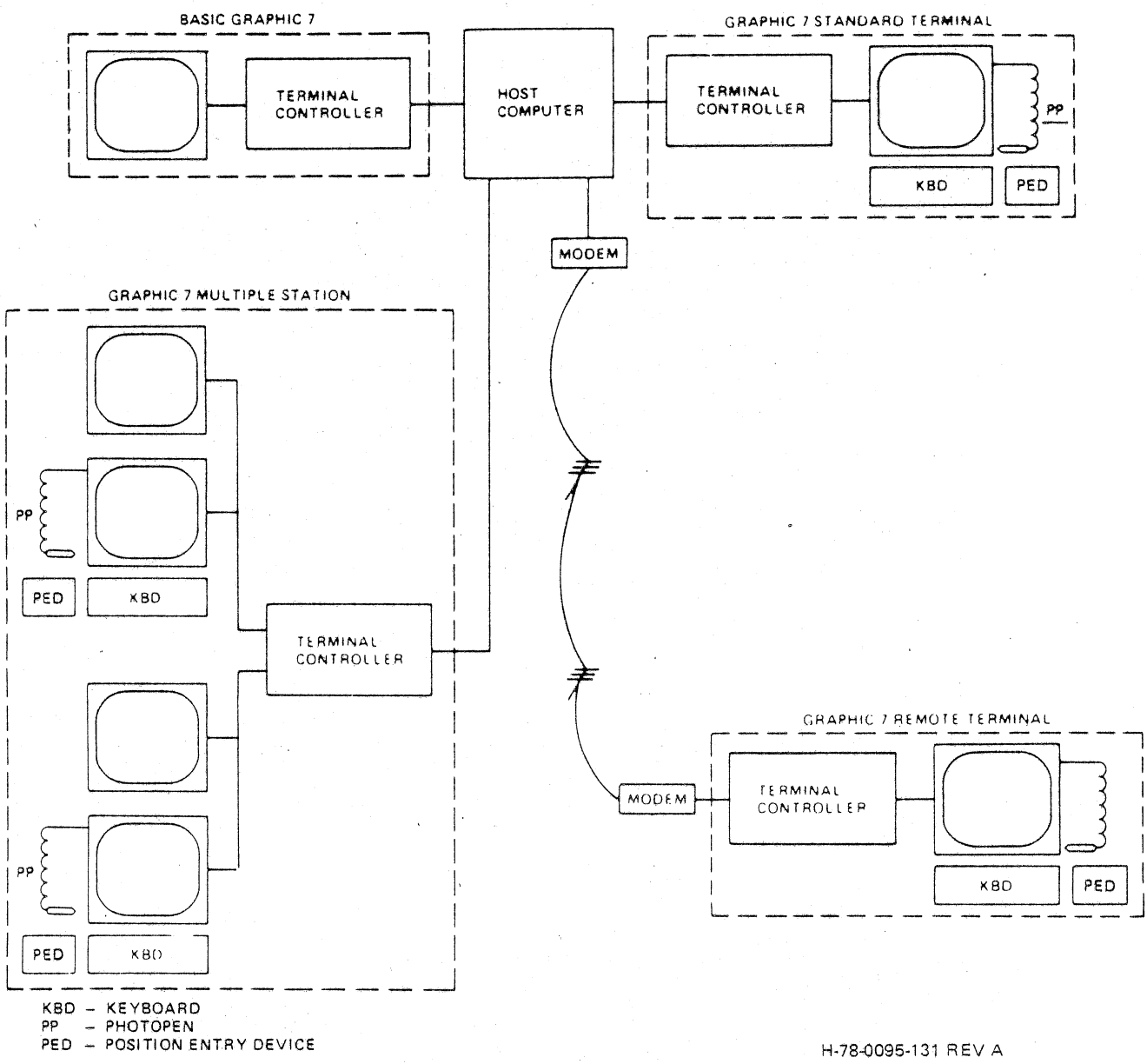

Figure 1-1. GRAPHIC 7 System Configurations

2. The terminal command structure is designed for compatibility with the communications routines of the host computer operating system.

3. The built-in test and stand-alone confidence checks of the GRAPHIC 7 eliminate those concerns from the host computer software effort.

4. An optional FORTRAN support package (FSP) lets the host programmer communicate with the terminal using FORTRAN-callable subroutines. Features of FSP include distributed processing, refresh paging, data scaling, image scissoring, selective updating, and data smoothing.

The basic GRAPHIC 7 system consists of a terminal controller, a CRT display, and optional input devices such as a keyboard, PHOTOPEN®, trackball, forcestick, and data tablet. Optional output devices such as hardcopy units are also available. Figure 1-2 shows some of these system elements.

The basic terminal controller contains (in addition to its control ROM) a random access memory, ranging in size from 16K words by 16 bits to 128K words by 16 bits. The RAM is available for both refresh storage and enhanced terminal intelligence. The two microprocessors in the terminal controller access the RAM via a high speed bus.

The standard display indicators are a 21-inch rectangular CRT with a nominal display area of 12 by 12 inches or a 23-inch round CRT with a nominal display area of 20 inches diameter. These displays produce high brightness, high contrast images of excellent quality at the fastest GRAPHIC 7 writing rates. While the standard output device is a refreshed CRT display indicator, optional output devices such as storage scopes, microfilm recorders, hardcopy devices, etc., may be used to display or record graphic data. Both displays are available in monochrome or four color, with a variety of phosphors.

DATA LOAD CAPABILITY

The GRAPHIC 7 data is displayed at the normal refresh rate of 60 Hz (16.7 millisecond refresh period). This rate allows the use of a high speed phosphor featuring precise line width and high character quality. Large volumes of data may be displayed using a longer persistence phosphor and refreshing at 40 or 30 Hz (25 and 33 millisecond refresh rates, respectively). Typical times for moving the beam, drawing vectors, and drawing characters are as follows:

- A full-screen blanked move takes 25 microseconds
- A full-screen vector draw takes 40 microseconds
- A typical character requires approximately 7 microseconds

Figure 1-3 shows the GRAPHIC 7 data load as a mix of characters and vectors at three refresh rates.

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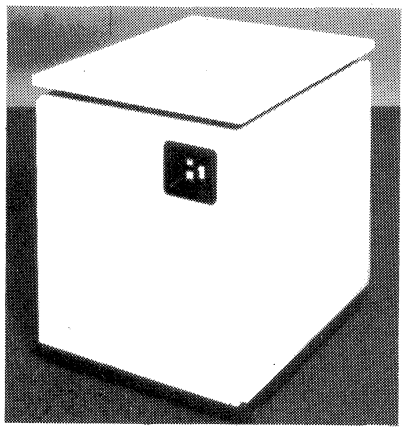
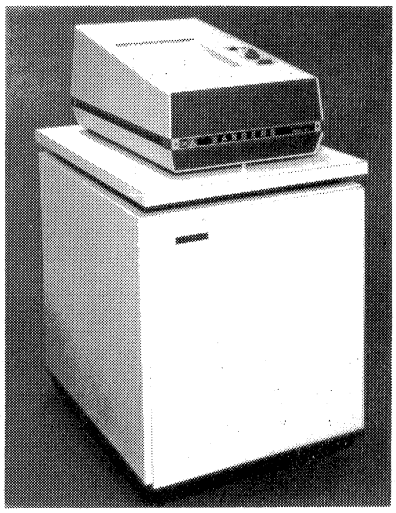
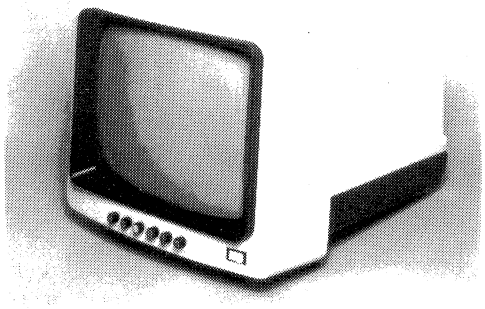


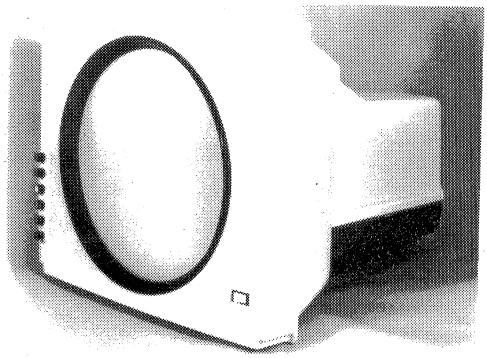
Terminal Controller



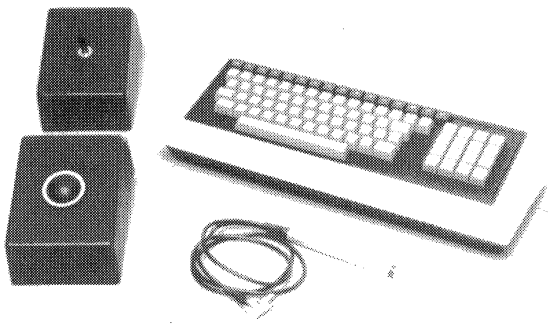
Hardcopy Unit



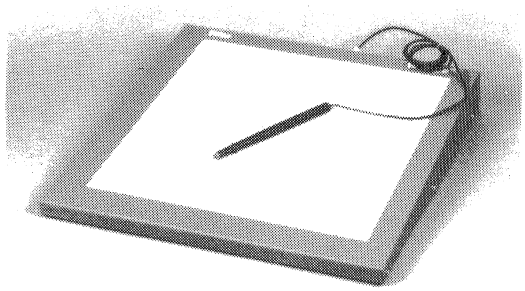
21-inch Display



23-inch Display



Position Entry Devices



Data Tablet

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Figure 1-2. GRAPHIC 7 System Components

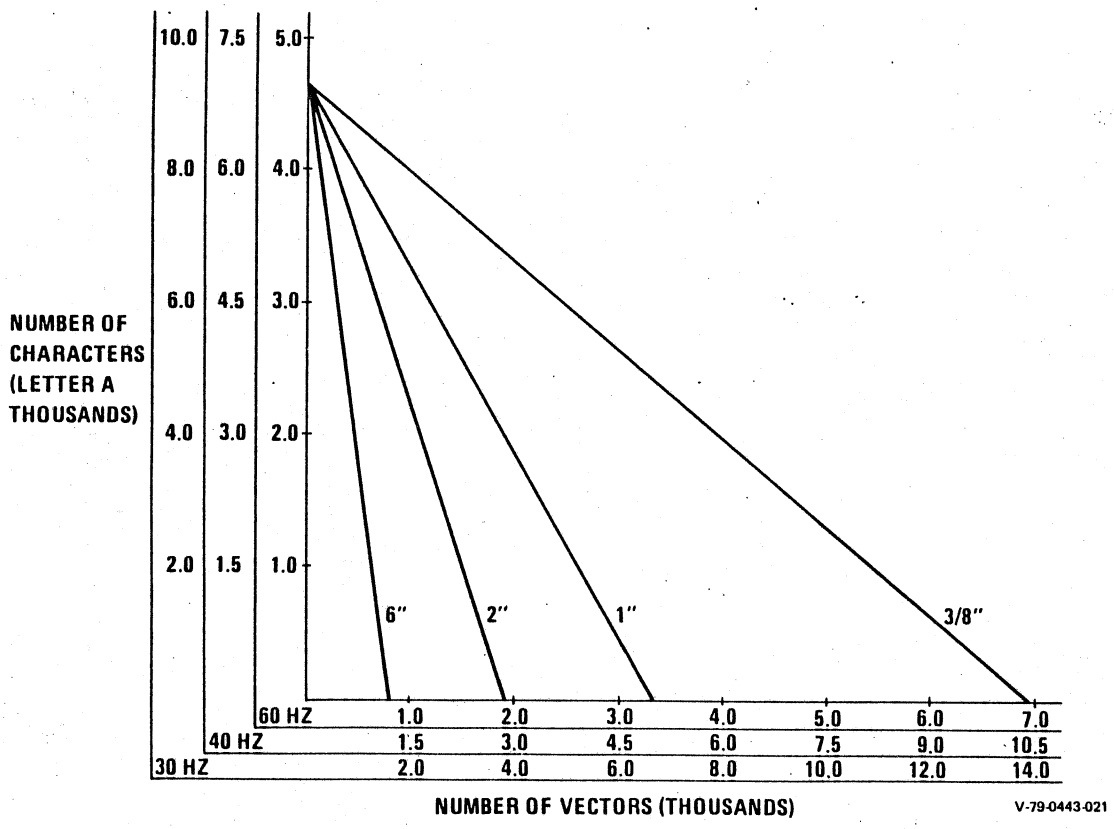
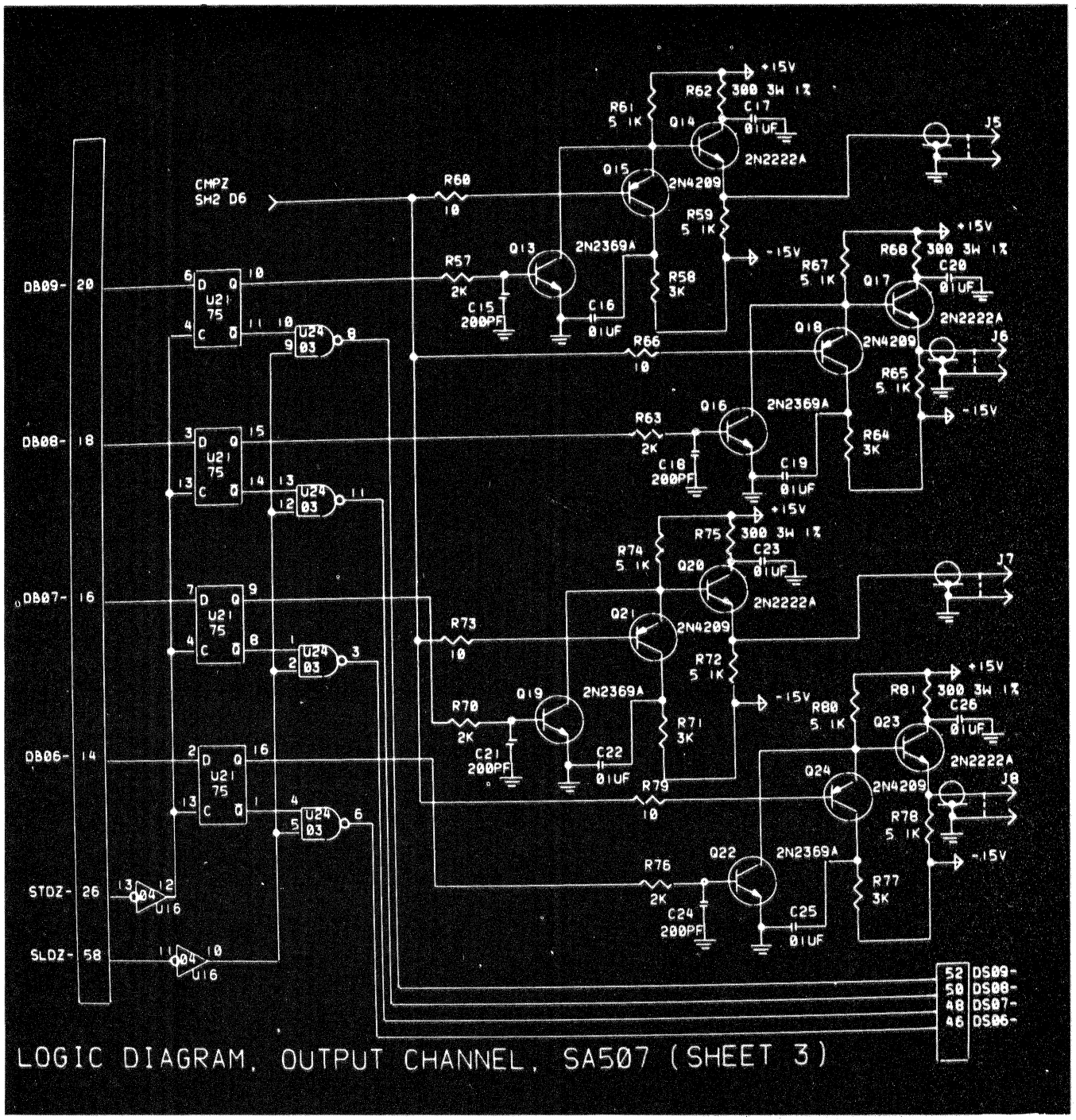


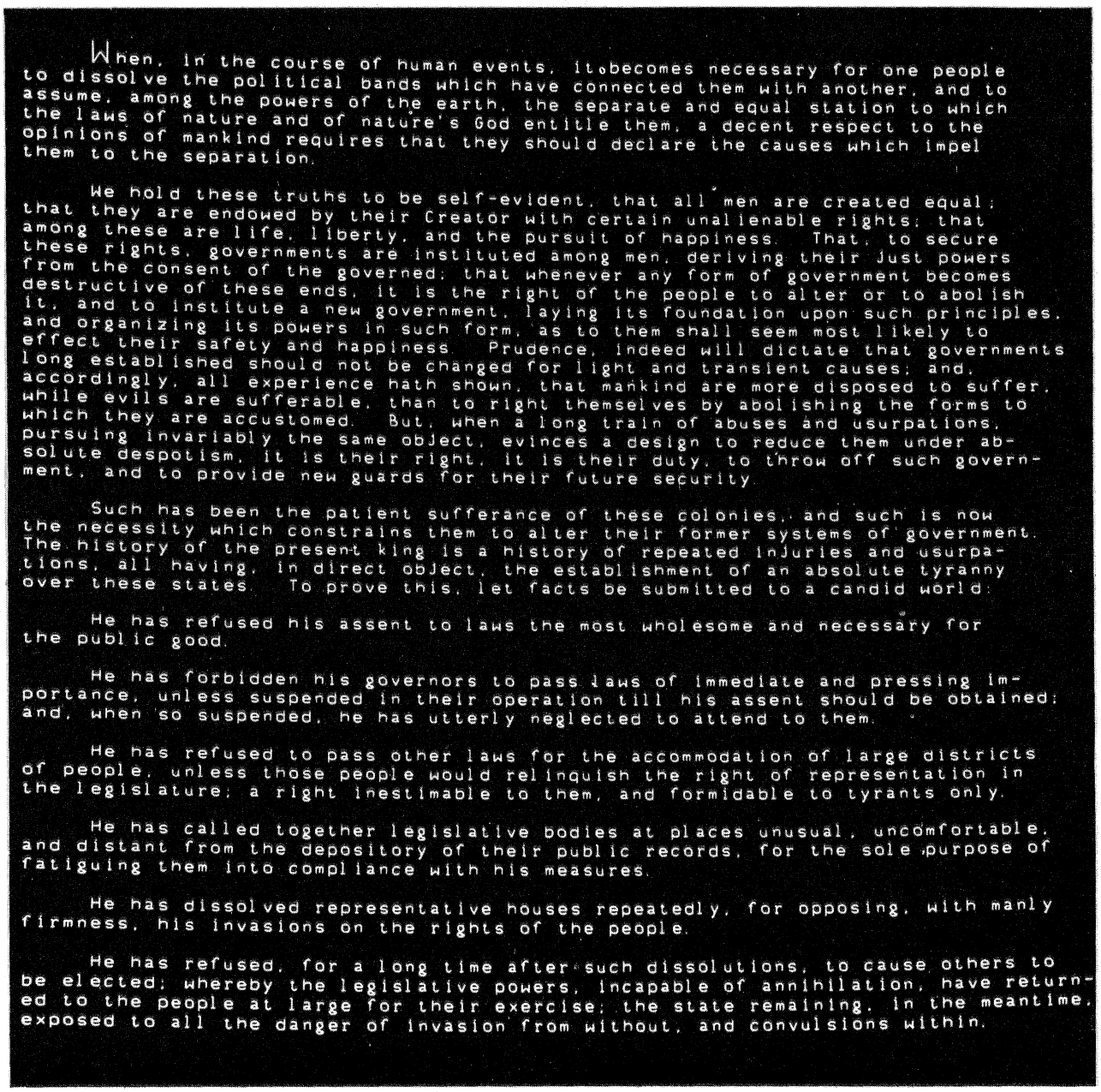
Figure 1-3. GRAPHIC 7 Data Mix

Figures 1-4 through 1-7 show some display images and the total drawing time required to produce them using a standard GRAPHIC 7. For reference, figure 1-5 contains approximately 3500 characters, while figure 1-6 contains approximately 500 vectors for a total length of 2600 inches.



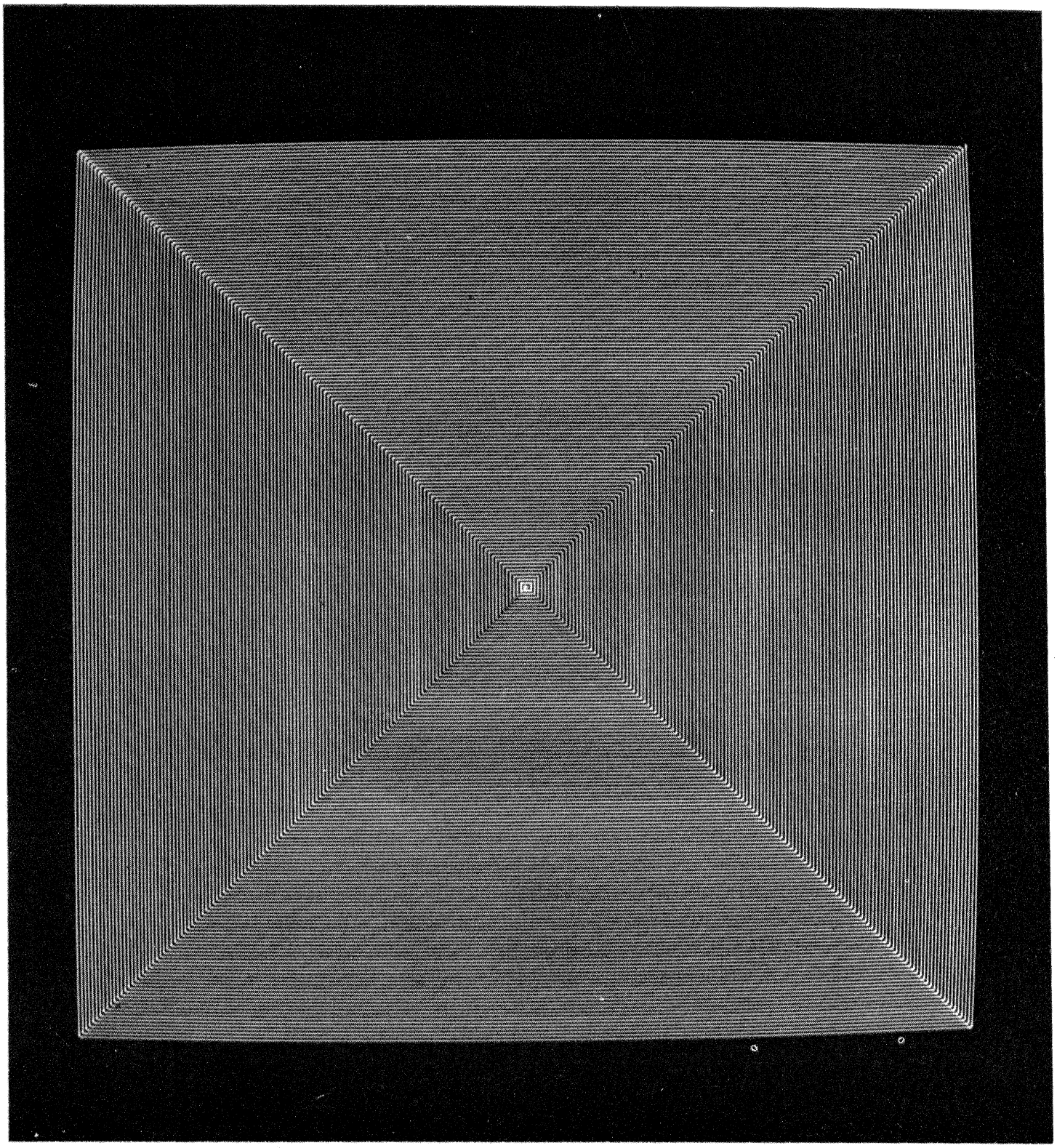
74-542-9

Figure 1-4. Schematic (9.5 ms)



75-021-1

Figure 1-5. (Text (11.5 ms)



74-542-14

Figure 1-6. Vectors (11.0 ms)

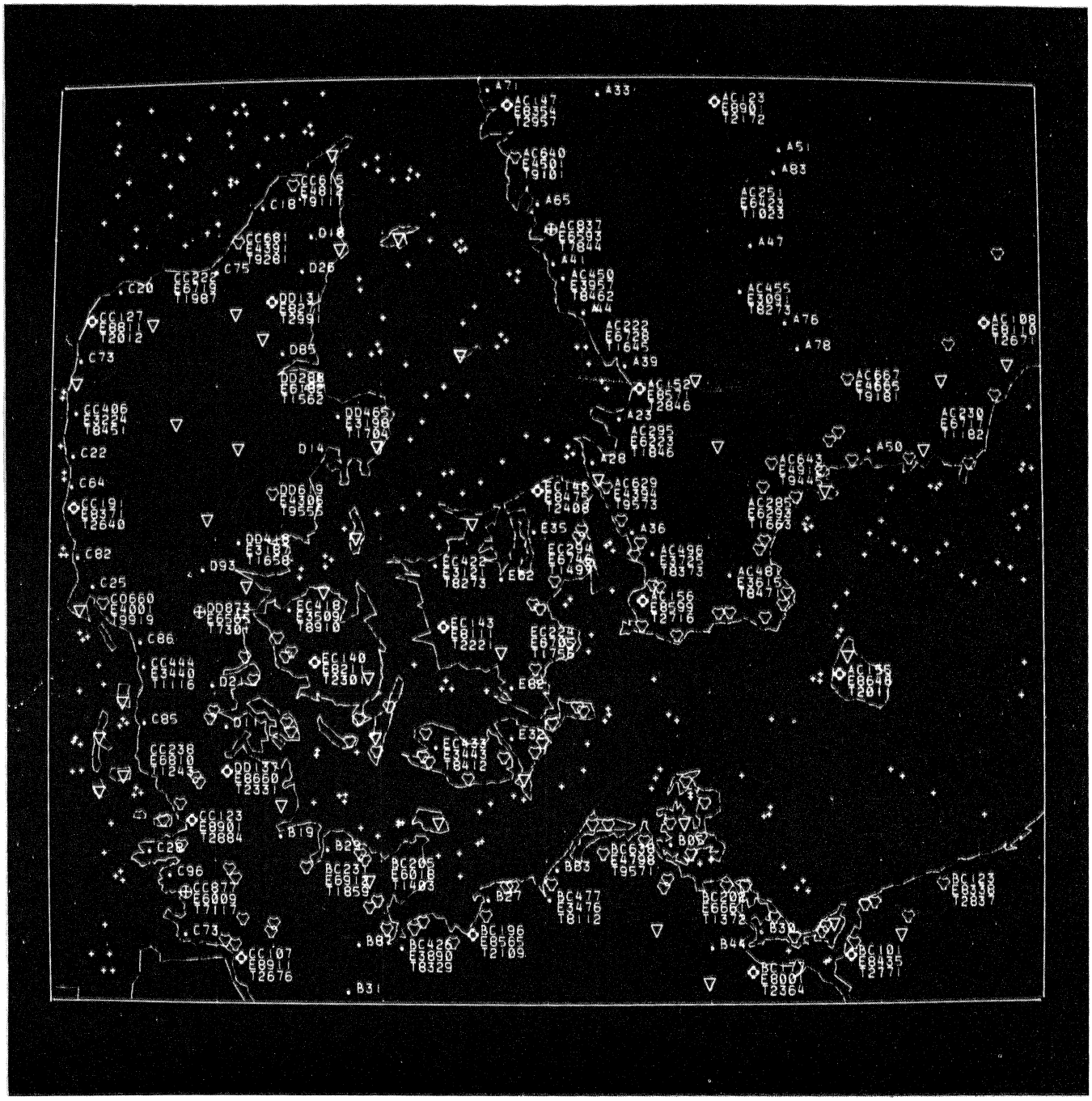


Figure 1-7. Map (15.0 ms)

SECTION 2

OPERATOR PROCEDURES

2.1 GENERAL

The GRAPHIC 7 can be operated in either the local or the system mode. In the local mode, the GRAPHIC 7 operates as a stand-alone system; in the system mode, the GRAPHIC 7 operates on-line to the host computer. Initialization in either mode causes the GRAPHIC 7 to perform its built-in diagnostic routines.

2.2 LOCAL MODE

After the GRAPHIC 7 has been turned on, it may be initialized in the local mode by pressing the LOC (LOCAL) pushbutton on the front of the cabinet (figure 2-1). Pressing this switch causes a verification test pattern to be displayed on each of the associated display indicators, causes the built-in diagnostic routines to be performed, and lets local mode commands be executed.

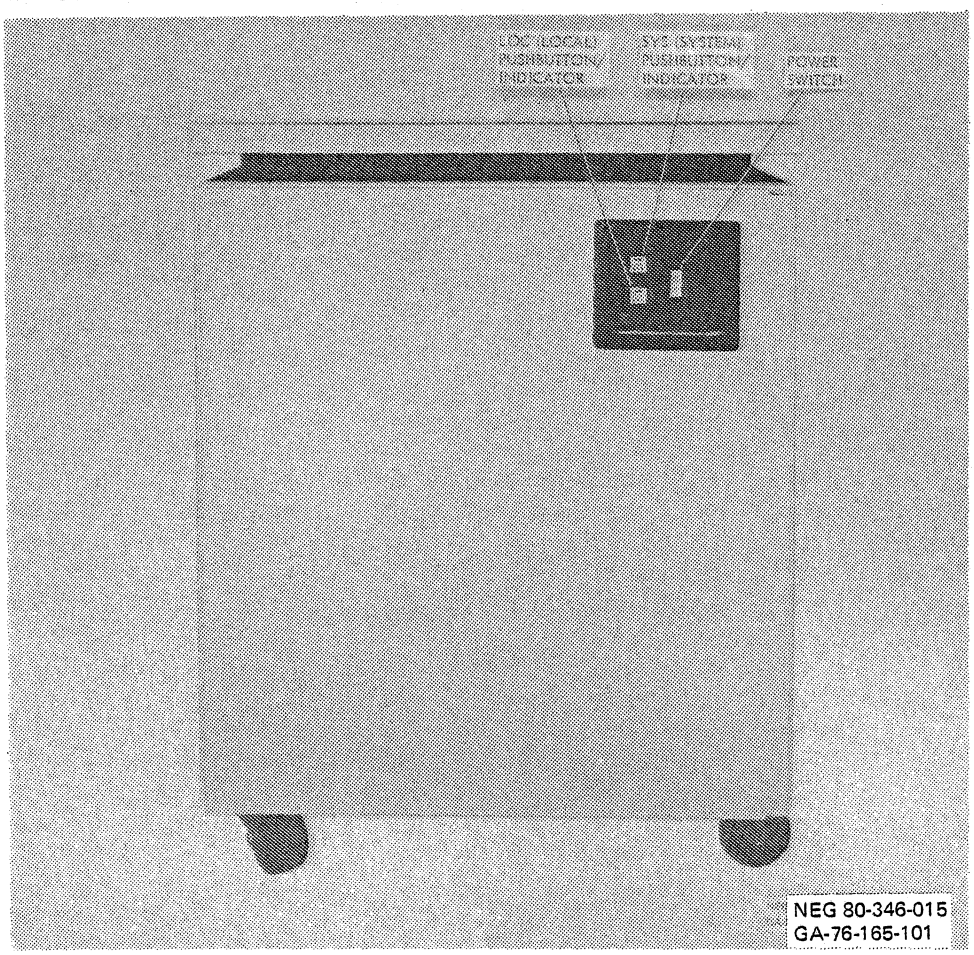
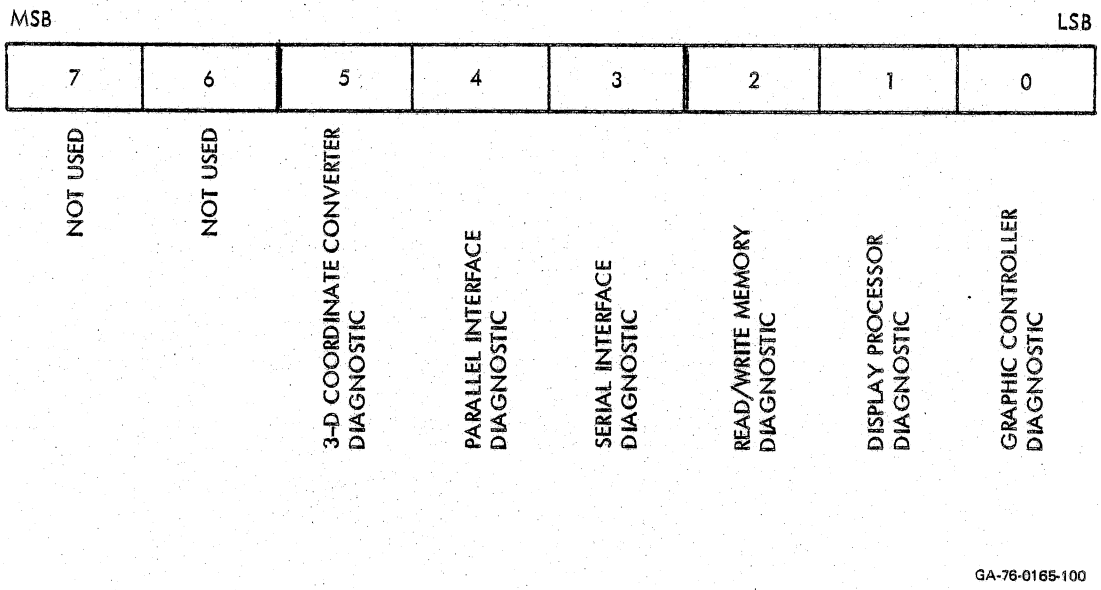


Figure 2-1. Terminal Controller Controls and Indicators

2.2.1 VERIFICATION TEST PATTERN AND DIAGNOSTICS. Figure 2-2 is typical of the verification test pattern that is displayed on each display indicator when the GRAPHIC 7 is initialized in the local mode. This pattern remains displayed until terminated by the proper command or until a period of approximately 45 minutes has elapsed since an operation affecting the pattern was last performed. (After 45 minutes the display is blanked off, but can be immediately recalled.)

Figure 2-2 identifies those components of the verification test pattern that are primarily associated with software and the operation of peripheral devices. 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 3-digit octal representation of an 8-bit binary code that indicates the results of each diagnostic routine. Bits in the binary code are assigned as follows:



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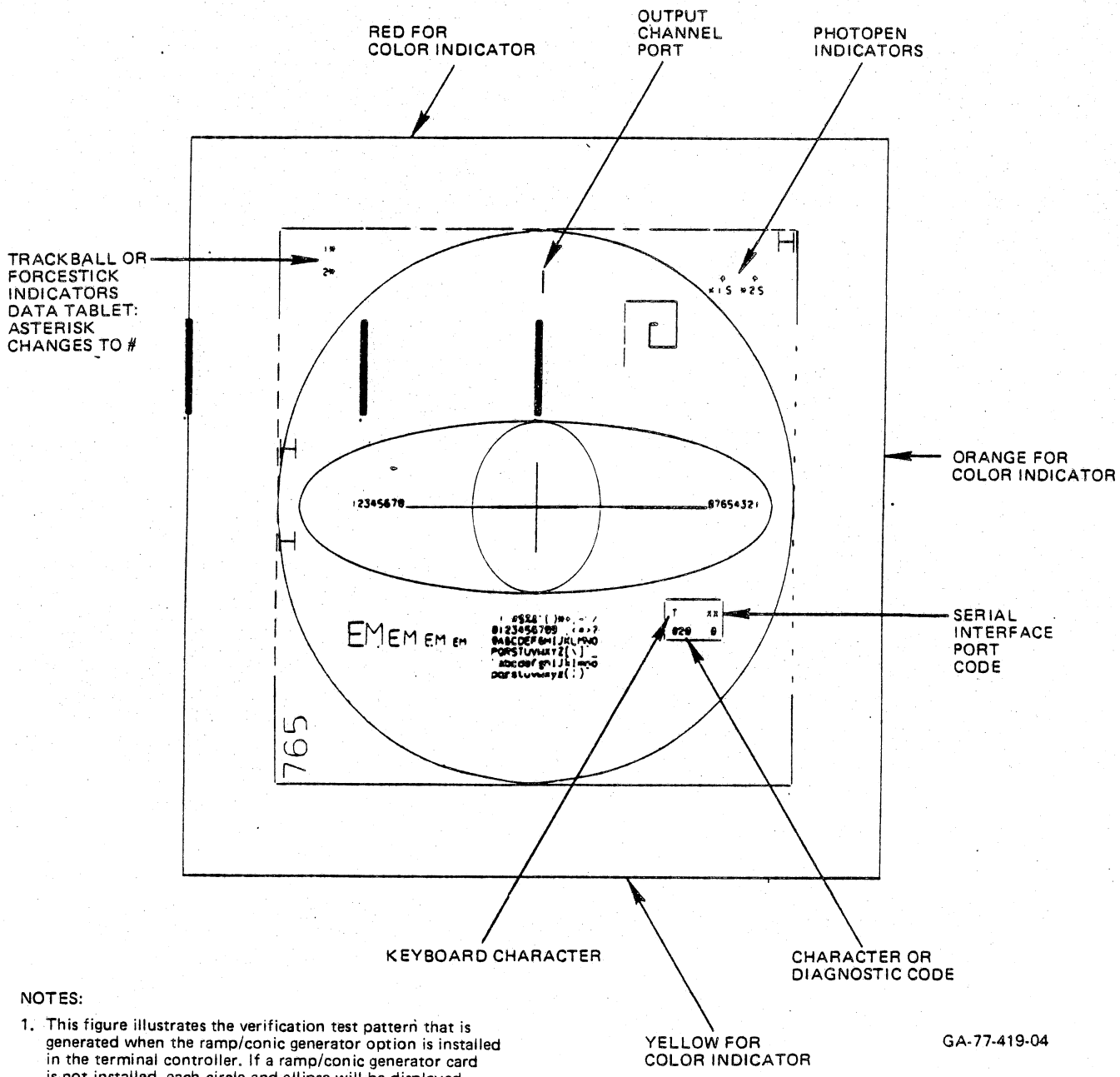
When a diagnostic routine detects a malfunction, the corresponding bit in the error code is set to a 1; if no malfunction is detected, the bit is set to a 0. The octal code displayed in the verification test pattern then indicates the results of all the diagnostic tests. For example, 000 indicates all 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.

An additional routine performed whenever the GRAPHIC 7 is initialized in the local mode is a checksum calculation based on all GCP+ stored in read-only memory. The result, which is deposited in memory 500 (octal), can be examined as described in paragraph 2.2.2.1 and compared with the correct value contained in the GCP+ program listing.

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.



NOTES:

1. This figure illustrates the verification test pattern that is generated when the ramp/conic generator option is installed in the terminal controller. If a ramp/conic generator card is not installed, each circle and ellipse will be displayed as four straight lines. If a 2-D coordinate converter card is installed in the terminal controller, all information contained within the ellipse will be rotated, translated and displayed at the top left of the display.
2. For special models, the character set displayed at the bottom center of the verification test pattern will differ from that shown. Refer to the overall system manual for your particular application for details.

Figure 2-2. Verification Test Pattern

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.

The numeral in the upper center of the verification test pattern indicates the port on the output channel card to which the Z of the display indicator is connected.

Trackball (or forcestick) indicators appear in the upper left corner of the verification test pattern. The 1* indicator is associated with device #1, while the 2* indicator is associated with device #2. These indicators are always displayed on the test pattern, regardless of whether or not a trackball or forcestick is connected to the system. If a trackball or forcestick is connected, 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.)

PHOTOPEN indicators are displayed in the upper right corner of the verification test pattern. Like the trackball/forcestick indicators, the PHOTOPEN indicators appear on the verification test pattern whether or not PHOTOPENs are connected to the system.

If a PHOTOPEN is connected to a monochrome system, its associated indicator responds as the PHOTOPEN senses light from various data items. Whenever an item of data is sensed, the sensed point is intensified and the indicator moves so that the arrow points to the location at which the data item ends. Alphanumeric data is normally stored with two characters per data item. Therefore, the arrow always points to the end of the second character in a pair. If the PHOTOPEN is also pointed at the character, an asterisk is added to the indicator. When the PHOTOPEN is pointed at the first character in a pair or at a non-character data item, the asterisk is removed from the indicator.

The S in each indicator provides an indication of PHOTOPEN switch operation. When the switch is actuated by pressing the PHOTOPEN against the CRT screen, the S is removed from the indicator. Pressing the PHOTOPEN a second time causes the S to reappear on the indicator.

NOTE

The complete character set is displayed at the bottom center of the terminal verification test pattern. In this area, all characters are insensitive to PHOTOPEN strikes.

2.2.1.1 Hardcopy Generation. A hardcopy of the terminal verification test pattern can be made by pressing function key F0 on the keyboard. When this key is pressed, HC appears in the serial interface port code. The HC indicates that a hardcopy

request has been initiated. At the end of the hardcopy cycle, S5 is displayed in the serial interface port code and the number 000 appears in the character or diagnostic code section of the terminal verification test pattern. If the hardcopy request is unsuccessful, the characters HC remain displayed in the serial interface port code.

NOTE

The generation of hardcopies takes approximately 10 seconds. To generate hardcopies remotely with function key F0 requires that a control cable be connected between the multiport serial interface and the hardcopy unit. The X, Y, Z cables must also be connected between the output channel card and the hardcopy unit or hardcopy multiplex switch.

2.2.1.2 Data Tablet Testing. The data tablet can be tested by pressing function key F1. This causes the 1* and 2* trackball/forcestick indicators to change to 1# and 2#. The 1# and 2# symbols indicate that the messages received by the multiport serial interface are in data tablet format. When the data tablet pen switch is pressed and the pen is moved along the active area of the data tablet surface, the appropriate cursor symbol (1# or 2#) moves at a rate proportional to the movement of the pen.

2.2.2 LOCAL MODE COMMANDS. After the GRAPHIC 7 has been initialized in the local mode and 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 in 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. Table 2-1 is a summary of the commands.

Table 2-1. 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 7 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 nnnnnn (octal).
nnnnnnG RETURN	Transfers control of display processor to program beginning at memory address nnnnnn (octal).
Y RETURN P 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 7 to system operating mode. (Y - Serial Entry; P - Parallel Entry)
RUB OUT	Deletes last octal entry from keyboard.

*Only applicable to release 3 and greater.

2.2.2.1 Memory Commands. The content of a memory location is displayed by 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.

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.

Bank Number	Virtual Address	Physical Address	Pages
0 (0-32K)	000000-177777	000000-177777	00-07
1 (32K-64K)	000000-177777	200000-377777	10-17
2 (64K-96K)	000000-177777	400000-577777	20-27
3 (96K-128K)	000000-177777	600000-777777	30-37
4 (16K-32K)	100000-177777	100000-177777	04-07

NOTE

*Addresses in the range of 100000-177777 (pages 4, 5, 6, and 7) for bank 0 correspond to ROM and I/O device registers. Addresses in the range of 100000-177777 for bank 4 correspond to RAM

Return to the monitor level is 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 the 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, 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, 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 from monitor level to system mode of operation, type S and press RETURN key: This command has the same effect as pressing the SYS (SYSTEM) switch on the terminal controller (paragraph 2.3). After transferring to the system mode, operation in the local mode can be reestablished by:

1. A message from the host computer.

2. Pressing the LOC (LOCAL) switch on the terminal controller.

3. Pressing CONTROL and SHIFT and RETURN together at the keyboard.

2.2.2.5 Teletypewriter Emulation. For purposes of communicating with a host computer, the GRAPHIC 7 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 indicator serves the printout device. Scrolling of data on the display indicator 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.

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 7 to transfer to the system mode of operation. Return to the local monitor level can then occur by:

1. A command from the host computer.

2. Pressing the LOC switch on the terminal controller.

3. Pressing CONTROL and SHIFT and RETURN together at the keyboard.

2.3 SYSTEM MODE

The system mode of operation is the normal operating mode of the GRAPHIC 7. Initialization in the system mode occurs under any of the following conditions:

1. When primary ac power is applied to the terminal controller.

2. When the SYS (SYSTEM) switch on the terminal controller is pressed.

3. When the GRAPHIC 7 is in the local operating mode and S is typed on the keyboard.

4. When the GRAPHIC 7 is in the local operating mode and 157760G RETURN is typed on the keyboard.

5. When the GRAPHIC 7 is in the system operating mode and an IZ message is sent from the host computer to the GRAPHIC 7.

6. When an initialize signal is sent from the host computer to the GRAPHIC 7 via the parallel interface or the multiport serial interface.

7. When the GRAPHIC 7 is in the teletypewriter emulation mode (paragraph 2.2.2.5) and octal code 035 (ASCII control character GS Group Separator) is generated by the host computer or by pressing function key F13 on the keyboard.

Initialization in the system mode automatically causes the built-in diagnostic routines to be performed and the results sent in an error status message to the host computer. The diagnostic routines are the same as those run during local mode initialization (paragraph 2.2.1) except that, of the two interface diagnostics, only the one associated with communications to the host computer is performed. A checksum of GCP+ stored in read only memory is also calculated and the results included in the error status message to the host computer.

In the system mode, responses to all operator actions are determined by the application program in the host computer. Control is exercised and data is transferred by means of messages sent between the host computer and the terminal controller. Refer to Section 5 for a complete description of the form and content of these messages.

SECTION 3

EQUIPMENT DESCRIPTION

This section contains detailed descriptions of the components of the GRAPHIC 7 system in the following order:

1. Terminal controller
2. Display indicators
3. Data entry devices
4. Hardcopy options
5. Power and environmental requirements

3.1 TERMINAL CONTROLLER

The terminal controller consists of a card cage and a power supply. The terminal controller circuit cards comprise two interconnected groups (see figures 3-1 and 3-2).

Display Processor Group

Display processor

Read/write memory

Graphic controller (common to both groups

Multiport serial interface (optional)

Parallel interface (optional)

Expansion module (optional)

Floating point converter (optional)

2D/3D coordinate converter (optional)

Graphic Controller Group

Graphic controller (common to both groups)

Character generator

Ramp generator (or ramp/conic generator option)

Y-axis D/A converter

X-axis D/A converter

Output channel

2D coordinate converter (optional)

The circuit cards in the display processor group are interconnected by a common processor bus containing data, address, and control lines. This group is controlled by the display processor card. The circuit cards in the display processor group handle communications with the host computer and direct the operation of the circuit cards in the graphic controller group.

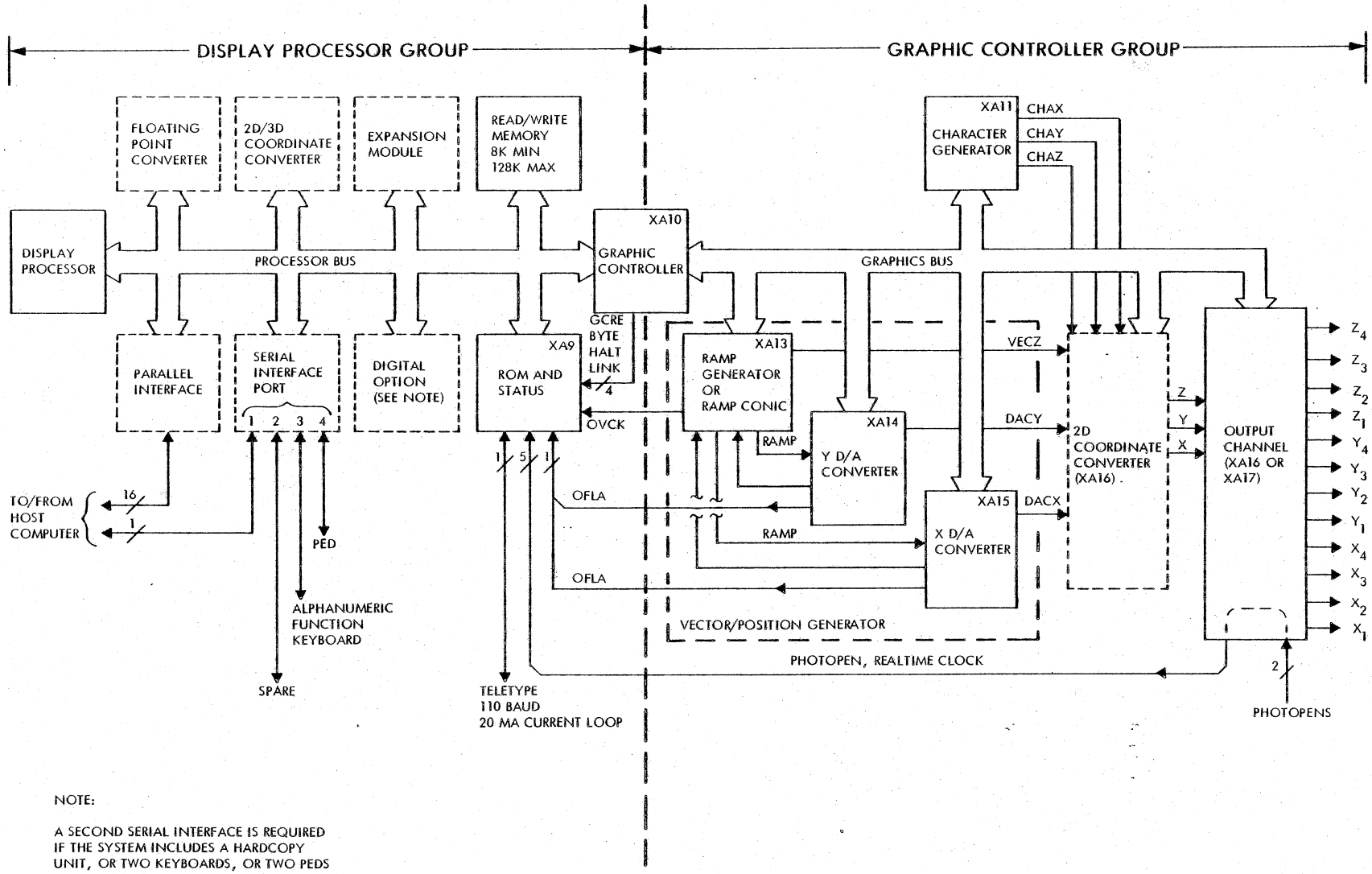
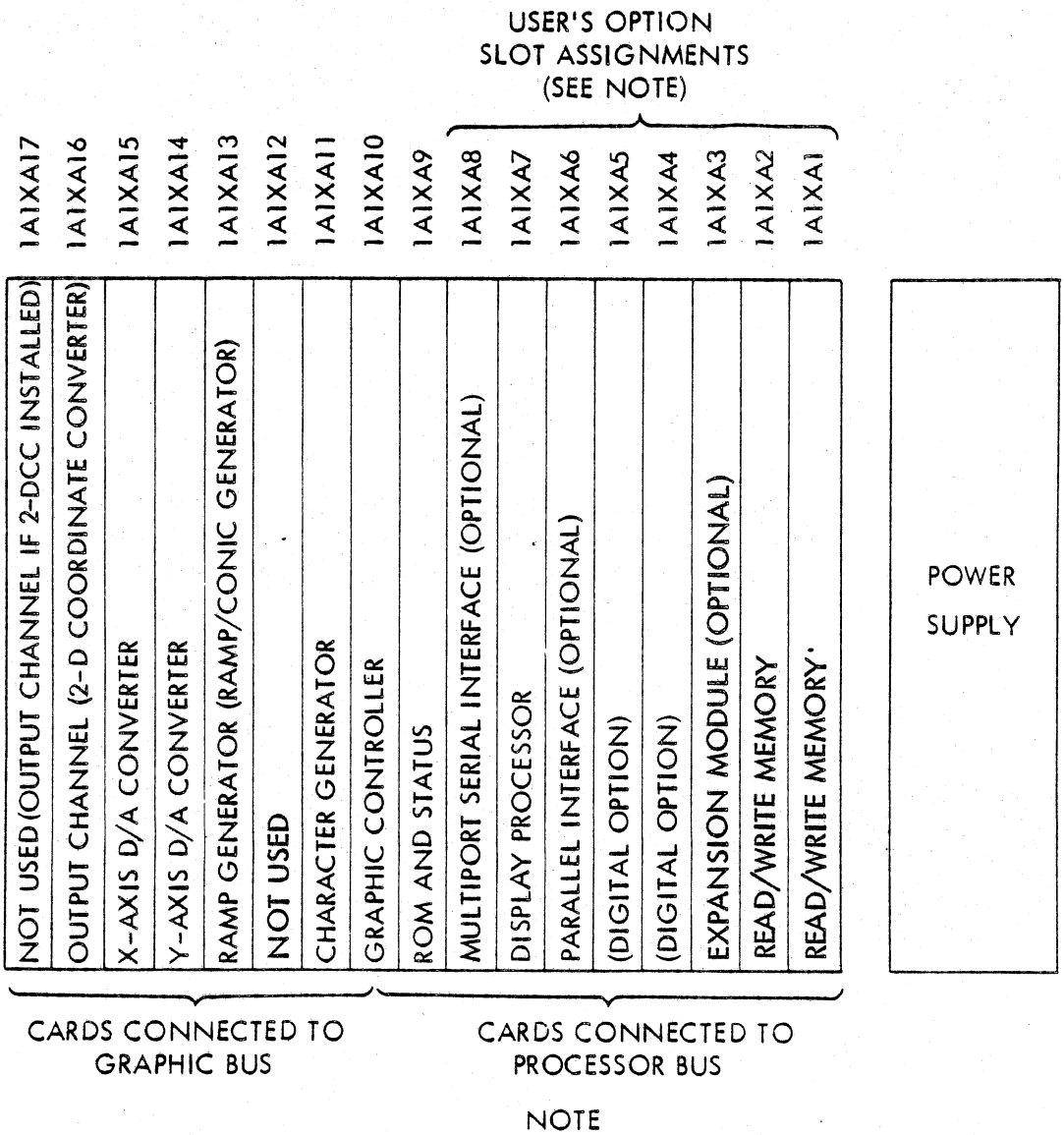


Figure 3-1. Terminal Controller Diagram



NOTE

The backplane wiring for the card cage is identical for card slots 1A1XA1 through 1A1XA8, making the designated card placement for those slots arbitrary. Except for the read/write memory cards, the cards in these eight slots can be interchanged to reassign processor bus control priorities as desired, with the bus control priority grant function being passed in card slot sequence from the highest-priority slot (1A1XA1) toward the lowest-priority card (graphic controller 1A1XA10). Relocatable cards must be placed in adjacent slots (1A1XA8, 1A1XA7, 1A1XA6, etc., in that order); leaving any one of these slots vacant would break the priority chain, which could result in unit malfunction. The read/write memory cards are passive circuits that are accessed by the processor bus but do not seize bus control; their grant outputs never go false. Accordingly, read/write memory cards should be placed in available position (usually spaced for better heat dissipation) toward the highest-priority slot.

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Figure 3-2. GRAPHIC 7 Card Locations

The circuit cards in the graphic controller group are interconnected by a common graphic bus containing data and control lines. This group is controlled by the microprocessor on the graphic controller card, and directs the development of images on the display indicators and the associated hardcopy unit.

The following paragraphs summarize the functions of the terminal controller circuit cards.

3.1.1 DISPLAY PROCESSOR. The display processor card is a general purpose digital computer that runs the GCP+ and acts as master control for all devices connected to the processor bus. It contains eight high-speed general purpose registers that can be used as accumulators, pointers, index registers, or auto-indexing pointers in auto-increment and auto-decrement modes. Functions performed by the display processor include system initialization, interface handling, local data editing, and local generation of simple display images.

Instructions used for the display processor emulate the instructions set for the PDP-11® series of minicomputers manufactured by Digital Equipment Corporation (DEC®). They are fetched either from the GCP+ in read-only memory or from the read/write memory.

3.1.2 ROM AND STATUS LOGIC. The ROM and status logic card contains the read-only memory in which the GCP+ used to control the display processor is stored (refer to figure 3-3). This card also contains the display status and interrupt logic circuits, plus a serial interface port to which a teletypewriter may be connected for diagnostic purposes.

The standard read-only memory provided on the ROM and status logic card contains the GCP+ program. The GCP+ is approximately 6.6K 16-bit words. Like read/write memory, the read-only memory may be accessed to retrieve either 16-bit words or individual 8-bit bytes.

3.1.3 READ/WRITE MEMORY. The basic configuration of a GRAPHIC 7 terminal controller includes one card of random access read/write memory capable of storing 16K 16-bit words. The following options are available:

1. A single card of 32K word capacity.

2. A single card of 48K word capacity.

3. A single card of 64K word capacity.

4. A two-card configuration, in which the first card is 64K and the second card may be 16K, 32K, 48K or 64K.

Locations in the read/write memory are assigned addresses 000000_8 through 077777_8 (16K), 177777_8 (32K), 277777_8 (48K), 377777_8 (64K), or 777777_8 (128K). The memory card is divided into 4K "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.

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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

NOTE

Addresses listed are byte addresses. Each 16-bit word occupies two byte addresses. The last digit in the address is always even when the system is in WORD MODE, but may be odd when the system is in BYTE MODE. Memory address counters throughout the system increment by 2 in WORD MODE.

Figure 3-3. GRAPHIC 7 System Memory Map

Pages 6 and 7 are a special case. The addresses associated with page 6 are also the addresses associated with the GCP+ located in ROM on the ROM and Status card. An address in the range from 140000_8 through 157776_8 accesses the GCP+. However, through a special mapping technique, the display processor can access page 6 of the memory. The display processor is the only device that can access page 6.

Similarly, the addresses associated with page 7 are also the addresses associated with devices (device addresses). An address in the range from 160000_8 through 177776_8 accesses a particular device. However, through a special mapping technique, the display processor can access page 7. The display processor is the only device that can access page 7.

3.1.4 EXPANSION MODULE. The terminal controller can accommodate up to two expansion module cards. Each such card may contain up to 32 EPROMs, providing a maximum (per card) of 32K 16-bit words of non-volatile memory storage. These cards are generally used for special customer application programs.

Each group of two EPROMs on an expansion module card represents a 2048 x 16-bit option. This is the smallest grouping in which options are supplied.

3.1.5 MULTIPORT SERIAL INTERFACE. The multiport serial interface card contains four serial interface ports that operate in a serial asynchronous mode using RS232C or TTL voltage levels with standard transmission rates up to 19200 baud. In addition, the first port can be operated as a full RS232C asynchronous interface at transmission rates up to 19200 baud. For GCP+ applications, the maximum transmission rate supported is 9600 baud. Normally, the host computer is connected to the first port, which is compatible with the standard communication and terminal interfaces supplied by most computer manufacturers. The remaining three ports on the card are used for peripheral devices.

Two multiport serial interface cards may be installed in a terminal controller to handle additional peripheral devices if required.

3.1.6 PARALLEL INTERFACE. The parallel interface card allows high-speed host/GRAPHIC 7 communications with handshaking and can be operated in both DMA and programmed I/O modes. If a parallel interface card is installed in the terminal controller, the 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.

Contact Sanders to determine the current inventory of parallel interfaces for different host computers.

NOTE

Normally a single parallel interface card is installed in a terminal controller. For special applications, however, up to four parallel interface cards may be installed.

3.1.7 GRAPHIC CONTROLLER. The graphic controller card is a microcontroller that controls generation of the image on the display indicator. Instructions used by the graphic controller are fetched via the processor bus from either the read/write or the read-only memory. The complete series of sequential instructions that defines any particular display image is referred to as a refresh file. These instructions are described in Section 4.

The graphic controller may be considered as a device on the processor bus of the terminal controller. It contains its own set of registers that maintain instruction addresses, control fetch operations, and perform any branching that may be specified by non-graphic instructions. It also calculates relative data when required, loads data into appropriate registers, and initiates execution of refresh file instructions.

Status bits of the graphic controller are maintained by circuits on the ROM and status logic card. These bits, plus the graphic controller registers, are accessible to the display processor, which maintains control over the entire terminal controller.

3.1.8 2D/3D COORDINATE CONVERTER. The Model 5753 2D/3D coordinate converter converts the graphic display into a 3-dimensional display capable of independent dynamic manipulation of objects in apparent space. Among the functions provided are translation, scaling, rotation, windowing, independent display coordinate mapping, perspective, and zooming with perspective.

The perspective feature is especially useful for realistic viewing of an object. When using 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 be completely orthographic if the viewer does not wish to use the perspective feature.

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

3D 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 accomplished by scaling and changing the user's apparent perspective viewpoint.

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

The 2D/3D coordinate converter provides for both homogeneous and non-homogeneous matrix operation. Further, transformations of 2D images can be performed, including translation, rotation, scaling, and windowing.

Refer to Sanders' "2-D/3-D Coordinate Converter User's Manual" for programming instructions.

3.1.9 FLOATING-POINT CONVERTER. The Model 5744 floating-point converter option transforms incoming floating-point binary numbers into displayable numbers. The displayable numbers may be in any of 16 formats selected by the host. The bidirectional converter also converts the displayed numbers into floating-point binary for transmission back to the host.

The floating-point converter saves host computer time and storage resources by performing these conversions within the graphic terminal. It lets data 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.

3.1.10 VECTOR/POSITION GENERATOR. The vector/position generator comprises the ramp generator and the two digital-to-analog (D/A) converter cards. These cards operate together to produce CRT beam-positioning voltages as defined by digital X and Y coordinate instructions. They also generate unblanking signals to enable vectors to be drawn on the associated display indicators.

One D/A converter is used to address X coordinates on the face of the display indicator, while the other addresses Y coordinates. Each D/A converter can address 2048 coordinates, of which a nominal 1024 fall within the displayable area. The CRT beam is automatically blanked whenever it is moved to a coordinate that lies outside the displayable area (see figure 3-4).

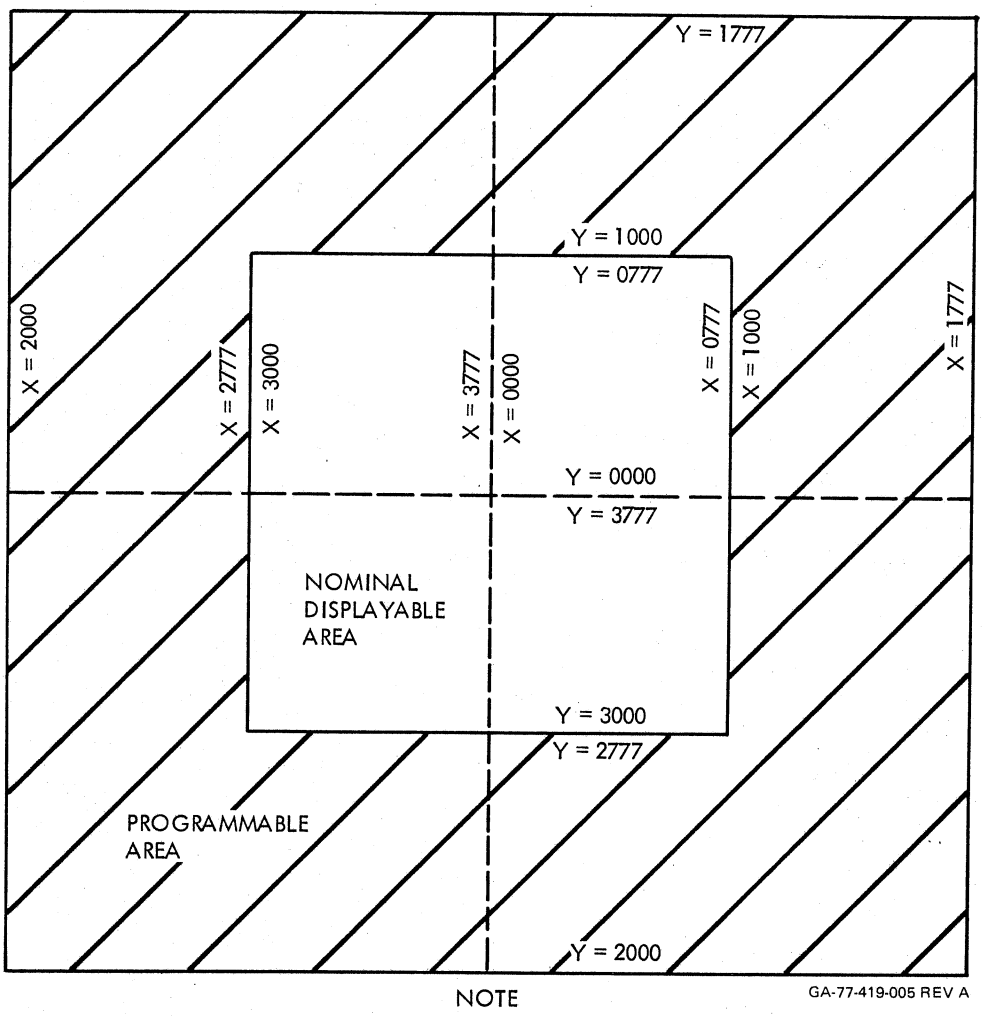
Beam positioning and vector drawing instructions may specify either absolute or relative data. Absolute data specifies the locations of particular coordinates, whereas relative data specifies locations in terms of the distance moved from the previous location.

The vector/position generator provides analog positioning voltages for the display indicators in accordance with digital XY coordinate instructions. The generator also provides synchronous unblank control to construct continuous vectors between any two designated end points.

The vector-position generator features constant velocity vector generation. Uniform vector brightness is achieved by allowing the electron beam to trace a vector at a constant speed, regardless of vector length or angle with respect to the X or Y axes.

The generator uses adaptive timing, which allows each vector only the time required by its length. Since the average vector length is considerable less than full screen, the average time allowed a vector is much less than for full screen vectors, and maximum display use is realized.

The basic vector writing rate may, under program control, be decreased to accommodate slow devices. Vectors may be written on slow display devices (such as storage scopes) or on fast graphic displays by using the programmable speed control.



COORDINATE DESIGNATIONS ARE IN OCTAL FORMAT.

Figure 3-4. Programmable vs Displayable Areas

Figure 3-5 shows the functions of the vector/position generator. There are four program-selectable line structures for any vector: solid, dotted, dashed, and center line. Line structures are developed by the Z signal, which controls CRT beam unblanking.

Vectors can be written at two different speeds and at eight different intensity levels under program control. The vector generator features good vector closure and excellent linearity.

The display instruction set allows absolute or relative moves or draws. The relative function is particularly important when a pattern is repeated in various screen locations. In this case, the pattern can be a subroutine and addressed relatively. This procedure can save considerable memory space.

Figure 3-6 shows a typical example of a vector sequence for drawing a full screen box. The instruction sequence is listed with the figure. The load, move,

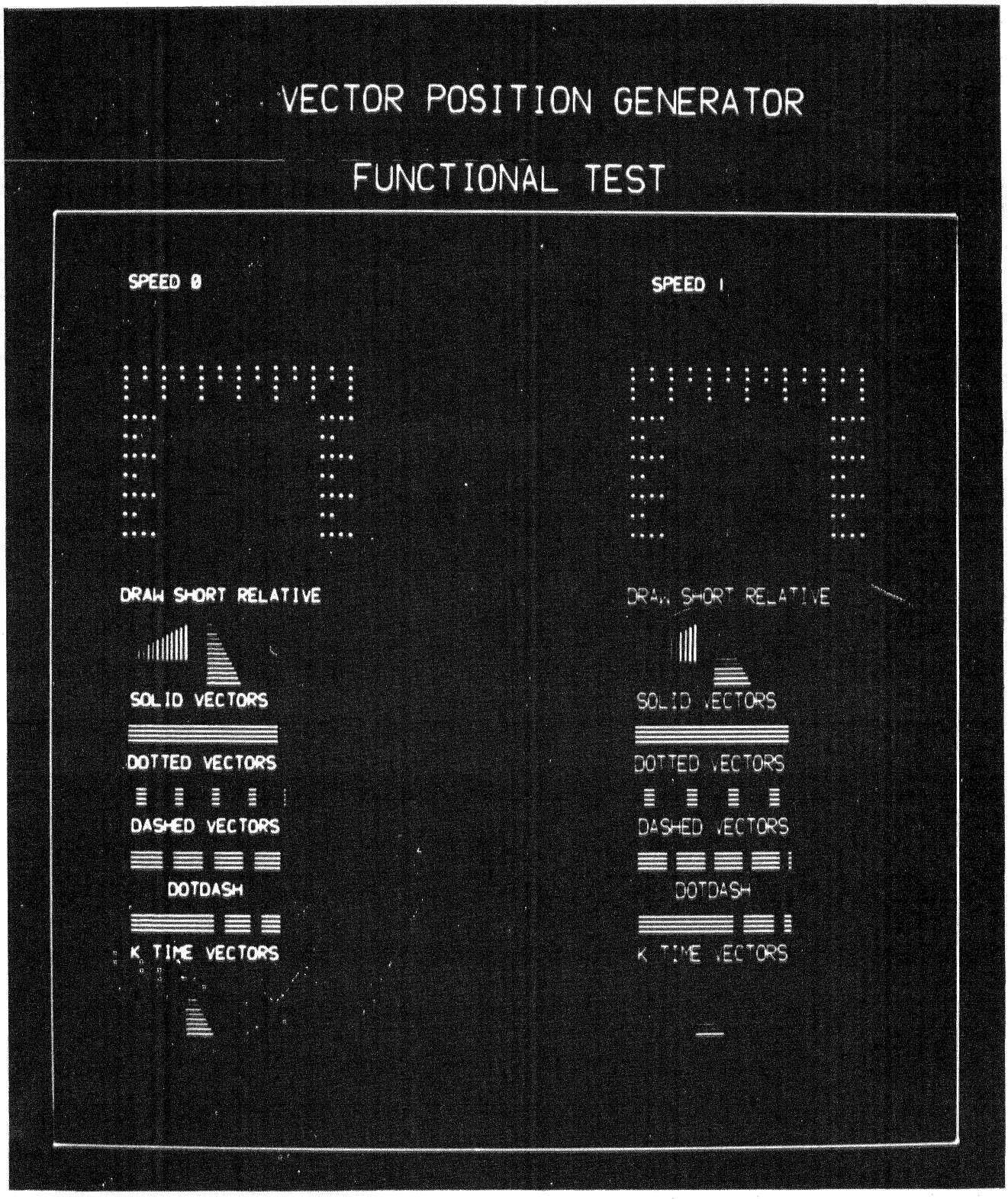


Figure 3-5. Vector/Position Generator Functions

MOVE/ VECTOR SEQUENCE	PROGRAM INSTRUCTION	LABEL	ASSEMBLY MNEMONIC	COMMENT/MEANING
	013707	START	LDDZ <ALL,BLOFF,LINE,BR7>	
	016310		LDDP <FAST,F60,NOPP,NOROTATE,C50>	
	003000		IZPR	;INITIALIZE RAMP
	020000		LDXA,0	;RELOCATE DISPLAY BEAM
	060000		MVYA,0	; AT CENTER OF CRT SCREEN
	007000		WATE	;WAIT FOR FRAME SYNC
(1)	020777		LDXA +511	;LOAD +511 AS X-AXIS ADDRESS
	060777		MVYA +511	;LOAD +511 AS Y-AXIS ADDRESS, THEN MOVE BEAM
(2)	023000		LDXA -512	;LOAD -512 AS X-AXIS ADDRESS
	043000		DRYA -512	;LOAD -512 AS Y-AXIS ADDRESS, THEN DRAW VECTOR
(3)	050777		MVXA +511	;LOAD +511 AS X-AXIS ADDRESS, THEN MOVE BEAM
(4)	023000		LDXA -512	;LOAD -512 AS X-AXIS ADDRESS
	040777		DRYA +511	;LOAD +511 AS Y-AXIS ADDRESS, THEN DRAW VECTOR
(5)	050000		MVXA 0	;LOAD 0 AS X-AXIS ADDRESS, THEN MOVE BEAM
(6)	043000		DRYA -512	;LOAD -512 AS Y-AXIS ADDRESS, THEN DRAW VECTOR
(7)	020777		LDXA +511	;LOAD +511 AS X-AXIS ADDRESS
	060000		MVYA 0	;LOAD 0 AS Y-AXIS ADDRESS, THEN MOVE BEAM
(8)	033000		DRXA -512	;LOAD -512 AS X-AXIS ADDRESS, THEN DRAW VECTOR
(9)	063000		MVYA -512	;LOAD -512 AS Y-AXIS ADDRESS, THEN MOVE BEAM
(10)	030777		DRXA +511	;LOAD +511 AS X-AXIS ADDRESS, THEN DRAW VECTOR
(11)	040777		DRYA +511	;LOAD +511 AS Y-AXIS ADDRESS, THEN DRAW VECTOR
(12)	03300		DRXA -512	;LOAD -512 AS X-AXIS ADDRESS, THEN DRAW VECTOR
(13)	043000		DRYA -512	;LOAD -512 AS Y-AXIS ADDRESS, THEN DRAW VECTOR
(14)	023076		LDXA -450	;LOAD -450 AS X-AXIS ADDRESS
	063076		MVYA -450	;LOAD -450 AS Y-AXIS ADDRESS, THEN MOVE BEAM
(15)	045604		DRYR +900	;DRAW VECTOR 900 UNITS UP RELATIVE CURRENT POSITION
(16)	035604		DRXA +900	;DRAW VECTOR 900 UNITS TO RIGHT RELATIVE CURRENT POSITION
(17)	046174		DRYR -900	;DRAW VECTOR 900 UNITS DOWN RELATIVE CURRENT POSITION
(18)	036174		DRXR -900	;DRAW VECTOR 900 UNITS TO LEFT RELATIVE CURRENT POSITION
(19)	005704		JMPR START	;REPEAT SAME LOOP INDEFINITIELY

RESULTANT CRT PATTERN ON DISPLAY INDICATOR (FROM FRONT)

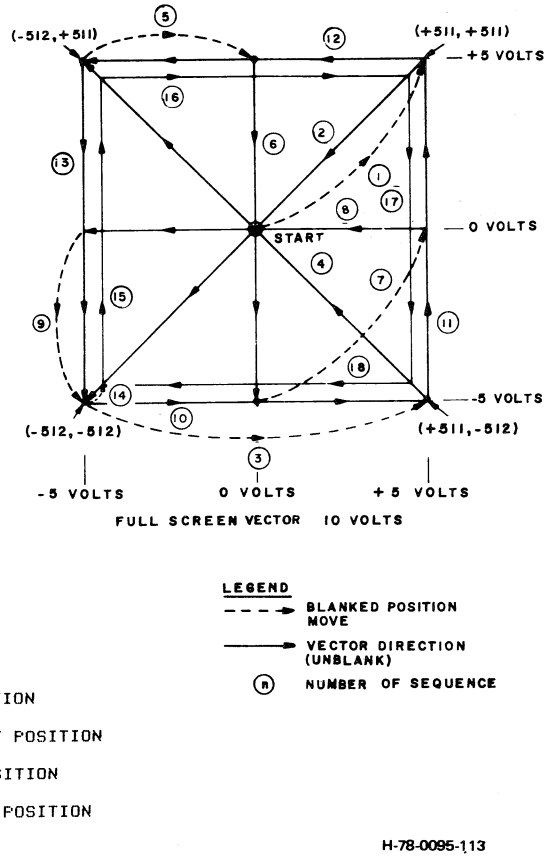


Figure 3-6. Vector/Position Generator Pattern Development

and draw instructions shown are normally included with other instructions that set up the output channel, frame sync, and the jump to the beginning of the display file. The instructions are listed in octal.

3.1.11 CHARACTER GENERATOR. The character generator card contains read-only memories that store information for drawing characters in accordance with instructions received on the graphic bus from the graphic controller. The basic set of characters supplied with the character generator ROMs is a standard set of 96 ASCII characters (figure 3-7). When the ASCII code corresponding to the desired character is applied to the ROMs, the character is drawn at the position determined by the vector/position generator.

As determined by instructions from the graphic controller, characters of four different sizes can be generated, and the characters can be made to blink. Characters may also be rotated 90^{o} counterclockwise to accommodate vertical writing requirements.

Space is provided on the character generator card for additional ROMs so that additional characters can be generated. ROMs for six groups of 16 characters can be added to provide a total of up to 192 standard and special characters.

3.1.12 RAMP/CONIC GENERATOR OPTION. The ramp/conic generator option generates X, Y, and Z waveforms that produce an ellipse of 90^{o} segments thereof on the display indicator. The lengths of the semimajor and semiminor axes are independently programmable from zero to half-screen. The axes of all ellipses are constrained to lie parallel to the X and Y display axes.

Any combination of 90^{o} arc segments of an ellipse may be displayed under program control, also with the constraint that these arcs are in the normal quadrant position. The center of any ellipse is located at any point that can be addressed by the vector/position generator. Brightness variations among ellipses of different sizes are minimized by causing the ellipse drawing time to be approximately proportional to the circumference of the ellipse.

3.1.13 OUTPUT CHANNEL. The output channel card contains four Z, four X-axis and four Y-axis outputs. Thus up to four display indicators and/or hardcopy units can each be driven by its own unique output channel. Program control lets the four Z outputs be blanked and unblanked selectively, so that the same or different images can be sent to each of the output devices as required.

The GRAPHIC 7 system software can operate two output channel cards, for a total of eight different displays (data load permitting). Output channel select circuitry on the output channel cards select or deselect the card as required. Each output channel is selected at turn-on and stays selected until the proper instruction is executed by the program to deselect it. When only one output channel is used in a system, the program does not have to select the output channel; it already selected at turn-on.

Channel 4, under software control, can be made to carry either its own display or that of any of the other three channels. This feature lets a hardcopy unit be connected to channel 4, but make hardcopies of any channel.

Figure 3-7. Basic Character Set

The output channel card contains intensity control circuits and a blink oscillator. The intensity control circuits (under program control) give a choice of eight different intensity levels for the Z outputs. A single bit enables or disables the blink oscillator.

When a four-color display indicator is used, the Z outputs also carry the color select commands. The color select circuitry executes the color select instruction by sending the proper serial bit stream to the selected display indicator.

The output channel card also provides timing signals to the graphic controller and processes PHOTOPEN signals. In normal system installations, each of the output devices connected to an output channel card can be located up to 50 cable-feet away with no degradation in performance.

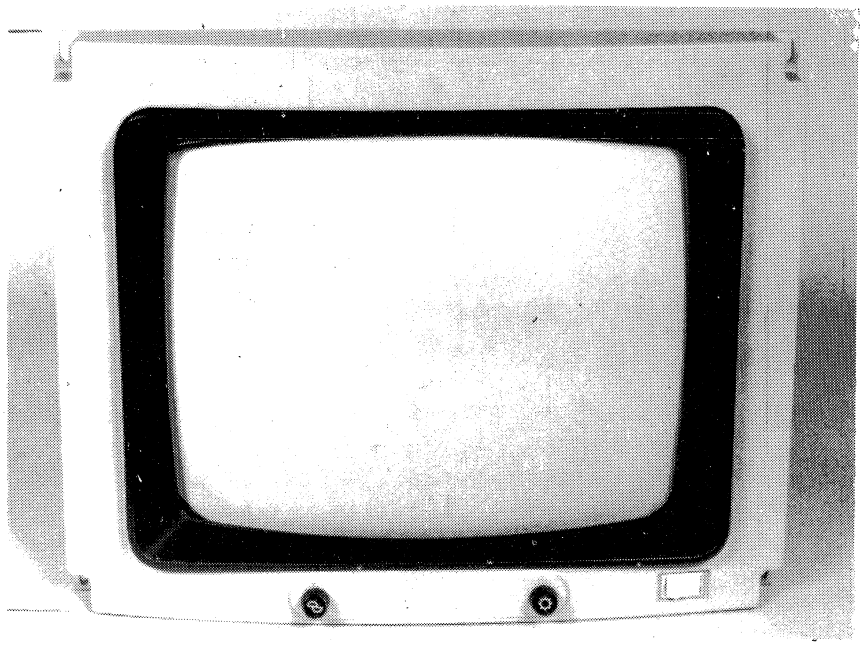
3.1.14 2D COORDINATE CONVERTER. A 2D coordinate converter card is available as an option for the GRAPHIC 7. This option permits components of a displayed image to be rotated and/or translated on the CRT screen as determined by software instructions. Refer to Sander's "Model 5752 2-D Coordinate Converter Technical Manual."

3.2 DISPLAY INDICATORS

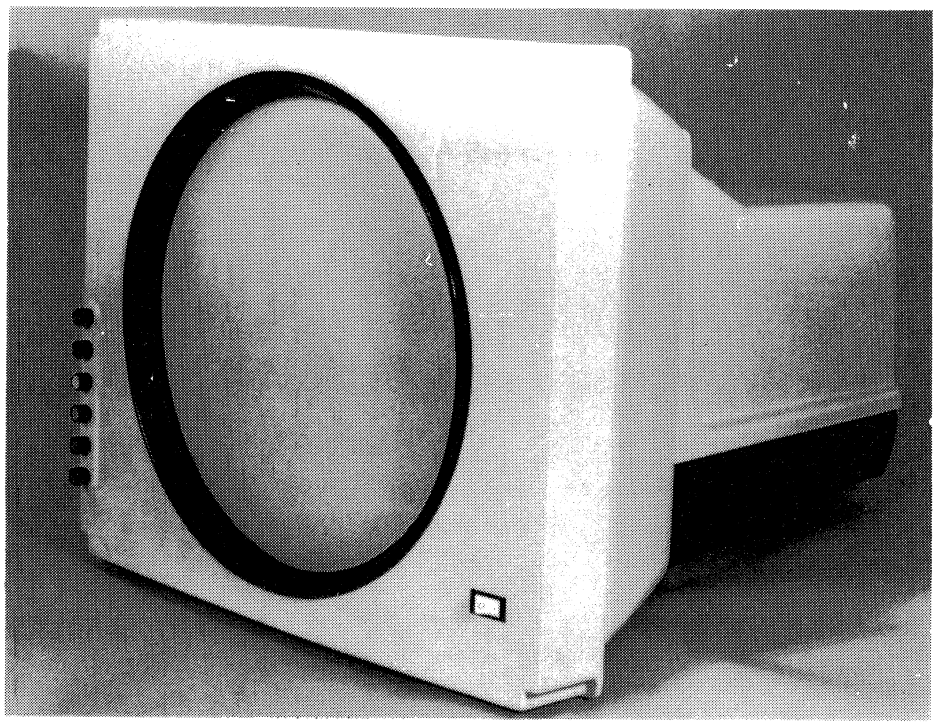
The GRAPHIC 7 display indicator is a self-contained unit, available in the following configurations (see figure 3-8):

MODEL NO.	DESCRIPTION
730	Monochrome, 21-inch rectangular CRT, horizontal, desk top
731	Monochrome, 21-inch rectangular CRT, horizontal, 24-inch rack
732	Monochrome, 21-inch rectangular CRT, vertical, desk top
733	Monochrome, 21-inch rectangular CRT, vertical, 19-inch rack
740	Four-color, 21-inch rectangular CRT, horizontal, desk top
741	Four-color, 21-inch rectangular CRT, horizontal, 24-inch rack
742	Four-color, 21-inch rectangular CRT, vertical, desk top
743	Four-color, 21-inch rectangular CRT, vertical, 19-inch rack
750	Monochrome, 23-inch round CRT, desk top
753	Monochrome, 23-inch round CRT, rack mount
760	Four-color, 23-inch round CRT, desk top
763	Four-color, 23-inch round CRT, rack mount

The CRTs are available in a variety of phosphors: P40, P31, P39, P39D for monochrome, P49 for color.



80-132-118



80-822-006

Figure 3-8. Typical Display Indicators

The rectangular CRT provides a nominal 12 by 12-inch display area, which can be modified to a nominal 12 by 16-inch display area. The display area of the round CRT has a nominal 20-inch diameter. Figure 3-9 shows the programmable vs. viewing areas for round tubes.

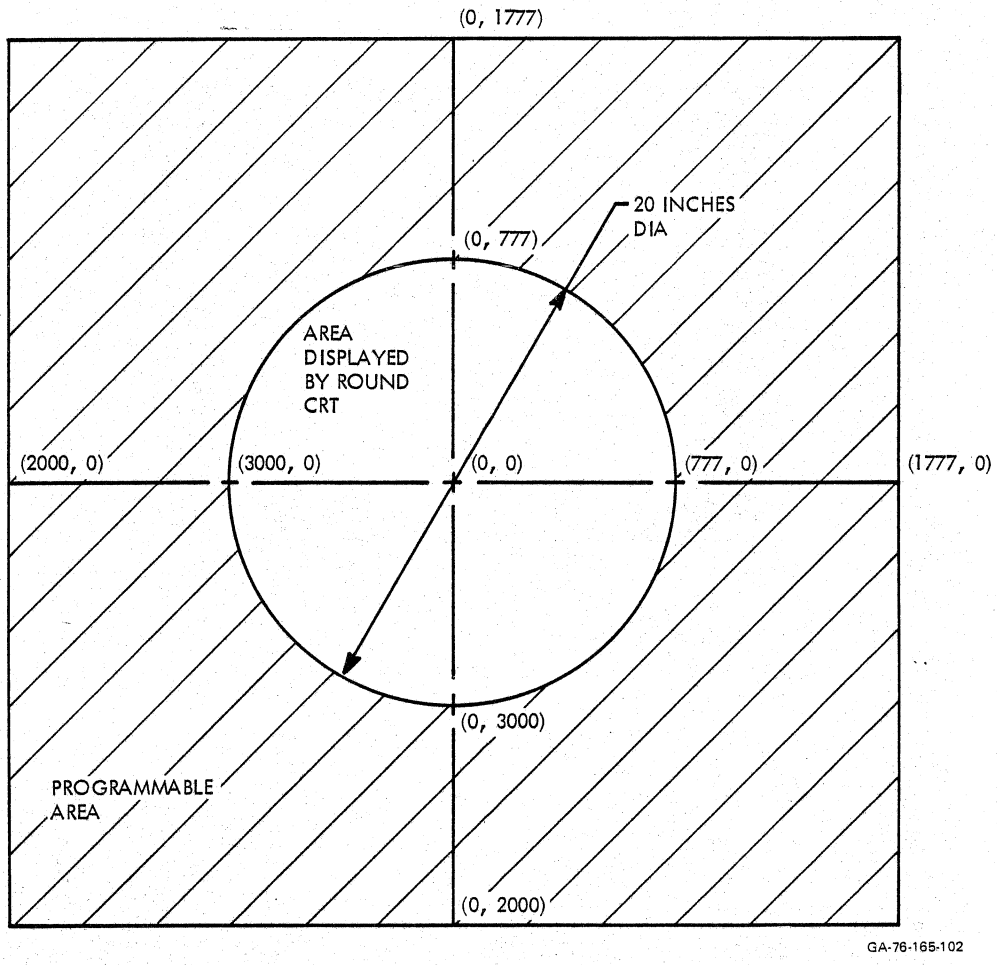


Figure 3-9. Programmable vs Viewing Areas for Round Tubes

Each display indicator can be configured to operate on input voltages of 100 to 120 Vac or 200 to 240 Vac.

Front panel controls include the power on/off switch, the focus adjustment, the brightness control, and (where applicable) red, green, yellow, and orange brightness controls. At the rear of the display indicator are a resettable circuit breaker and a self-test pushbutton. The desk top models have plastic covers which are easily removed to gain access to interior components.

All connections from the terminal controller are made at the rear of the display indicator. The desk top models also have an accessory panel below the display indicator. Accessory devices (keyboard, PHOTOPEN, trackball, forcestick, or data tablet) connect to the front of the accessory panel. Connections from the accessory panel to the terminal controller and the display indicator are at the rear.

The display indicator receives X-axis (horizontal), Y-axis (vertical), and Z (intensity) signals from the output channel card in the terminal controller in the form of analog voltages. In the display indicator, these signals are amplified and applied to the deflection yoke of the CRT (the X-axis and Y-axis signals control beam movement on the CRT screen) and to the CRT cathode (the Z signal controls beam intensity) to produce the display. In addition, the Z channel for the four-color display indicators decodes pulse groups that contain the color select information.

The display indicator (figure 3-10) consists of a CRT with an electromagnetic deflection system; a high voltage power supply assembly; a low voltage power supply assembly; a video amplifier assembly that includes a CRT and amplifier protect circuit; an arc protect circuit; and an off-line pattern generator.

A neutral density, contrast enhancement, tempered glass implosion panel bonded to the face of the tube protects the operator against the effects of an implosion.

The electromagnetic deflection system consists of two identical deflection amplifiers and a wide-bandwidth 20-microhenry yoke. The deflection chain is designed to handle the bandwidth requirements of both vectors and symbols. It includes self-protection circuits against improper dc operating voltages, transient overdrive inputs, or excessive current. Excessive current trips the main circuit breaker.

The high voltage power supply operates from a +24V input and produces the following outputs:

+15 kV or +18 kV ± 5% for the CRT anode

-900V ± 6% for the focus grid

-35V ± 5% for the intensity grid

+350V to +700V (adjustable) for the screen grid

The high voltage power supply is controlled by an externally generated ENABLE signal that occurs only when the dc voltage levels within the video amplifier are correct and there is sufficient X or Y deflection activity to warrant unblanking the CRT.

The low voltage power supply operates from 43 to 63 Hz power sources within the ranges of 100V to 120V or 200V to 240V.

The low voltage power supply produces the following outputs:

±38V ± 15% at 1A

±24V ± 15% at 20A

6.3 Vac ± 15% at 0.66A

115 Vac ± 15% at 0.2A

The video amplifier controls the beam intensity. Incoming signal is delayed to compensate for delays in the deflection amplifier. The video amplifier controls

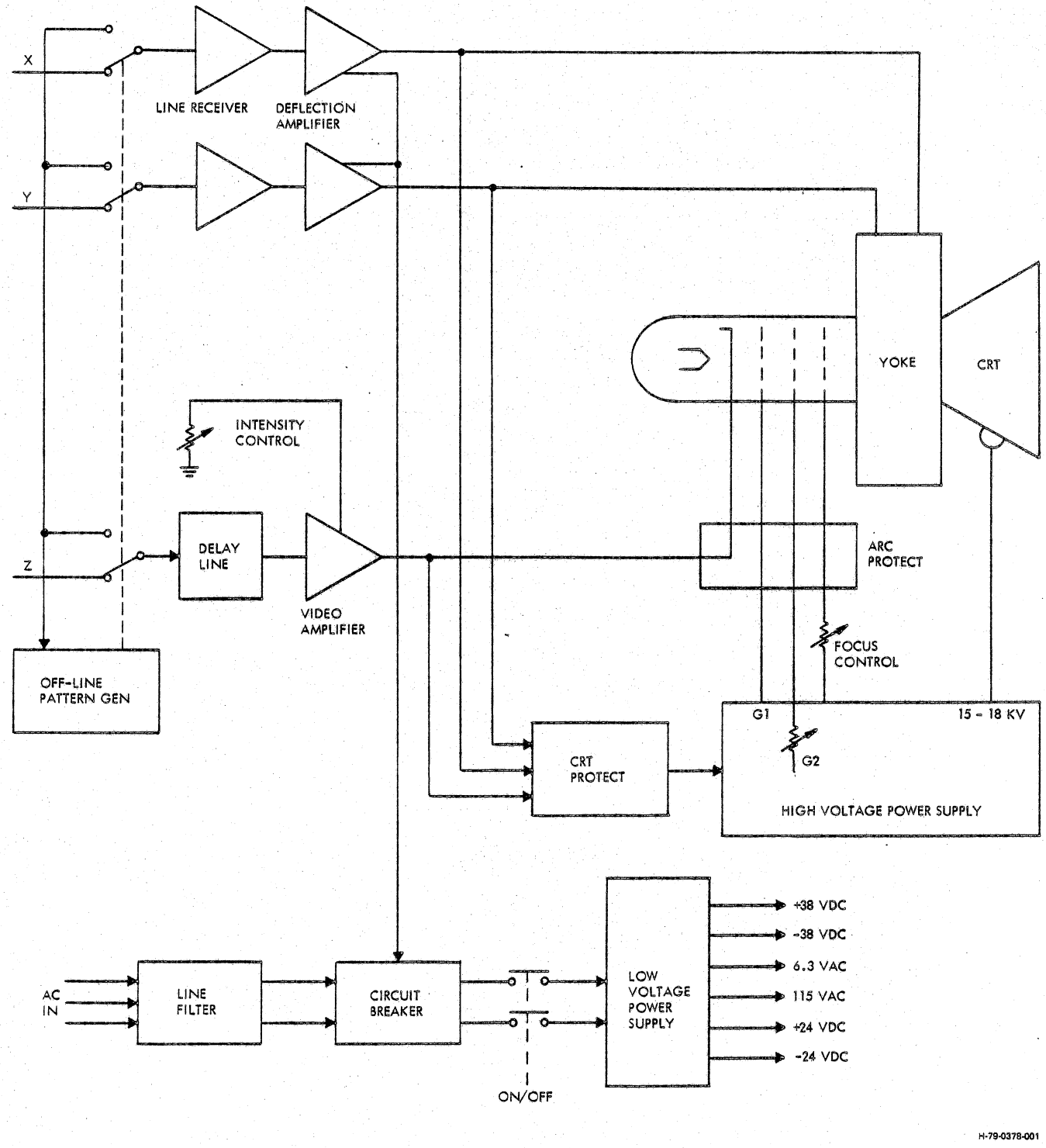


Figure 3-10. Display Indicator Block Diagram (Monochrome)

the high voltage power supply; the video amplifier determines the correct dc operating voltage and senses the magnitude of deflection activity with respect to the video drive requirements.

In four-color systems, the card that holds the video amplifier also contains the color decoding circuits and various compensation and linearity adjustment circuits.

The video amplifier assembly also contains the off-line pattern generator that generates a circular pattern for an operational confidence check.

The arc protect assembly contains passive components that limit CRT arc-over voltages to safe current-limited levels.

The magnetic deflection amplifiers are direct-coupled feedback amplifiers featuring a wideband frequency response. This allows character, vector, and positioning waveforms to be processed by a single deflection system. The resultant indicator is simple and reliable. A high quality image is achieved by using an all-magnetic system.

The deflection yoke is an advanced design; reliability and design simplicity are prime considerations. The yoke is specifically designed for signals such as random beam positioning and high-speed symbol writing; it has low residual effects, wide bandwidth, and high efficiency.

The cathode ray tubes used in the GRAPHIC 7 display indicators are similar in construction except for size and shape. The CRTs use magnetic deflection and have low-voltage electrostatic focus guns whose advanced design and construction contribute to the high quality image.

3.3 DATA ENTRY DEVICES

Data entry devices include keyboards, PHOTOPEN, trackball, forcestick, and data tablet.

3.3.1 KEYBOARDS.

The Model 5783 alphanumeric/function keyboard and the Model 5784 lighted alphanumeric/function keyboard (figure 3-11) are full ASCII data entry devices used with the GRAPHIC 7 system.

The keyboard interfaces with the GRAPHIC 7 terminal controller. The terminal controller supplies power to the keyboard. Data goes from the keyboard to the terminal controller. In the Model 5784, lamp-lighting data goes from the terminal controller to the keyboard.

Each keyboard is self-contained in its own housing; it is designed for desk top. See Section 7 for specifications.

The keyboard contains three separate key sets: (a) a main block of 55 ASCII alphanumeric, symbol, and special purpose keys; (b) a 4 x 4 matrix of 16 function keys to the right (the matrix keyboard); and (c) a row of 16 function keys across the top (the function keyboard).

Figure 3-11. Model 5784 Keyboard

Both models have a lamp in the CAPS LOCK key. In addition, the Model 5784 contains a lamp in each matrix key and function key.

The keyboard interfaces to the GRAPHIC 7 terminal controller through a single multiconductor cable that connects to one of four ports on the multiport serial interface (port 3 if one multiport serial interface is used, ports 3 or 7 if two interfaces are used). The cable also carries power from the terminal controller to the keyboard.

Keyboard data is generated in the keyboard assembly as parallel character codes. Data transfer to the terminal controller is serial, RS232C at 9600 baud.

The flow of keyboard data to the terminal controller is asynchronous from the terminal controller's point of view. The keyboard controls the timing of the data flow. The GRAPHIC 7 firmware controls acceptance and use of the data.

The flow of lamp-lighting data to the keyboard is under resynchronized timing control of the Model 5784.

All function, matrix, and alphanumeric keys are momentary-action switches; each transmits a unique 8-bit code when pressed. Each key is so encoded that partially pressing any combination of code generating keys cannot duplicate the code of another key. The keyboard has an N-Key rollover feature; if two or more keys are pressed at once, the code for the first key pressed goes on the data lines. When the first key is released, the code for the second key pressed is present and stable on the data lines.

The keyboard has an internal repeat function on all encoded keys. If a key is held down, the character repeats at a 10 Hz rate after a 1-second delay. This feature can be removed as an option.

The codes generated by the alphanumeric and symbol keys are modified when the CTRL (control) key, the SHIFT key, or both the CTRL and SHIFT keys are pressed.

When the CAPS LOCK key is pressed, a red lamp in the key cap lights and the alphanumeric keyboard becomes the equivalent of a teletypewriter keyboard.

Figure 3-12 shows the keyboard layout and octal codes.

The keyboard also contains an audible alarm that is activated by ASCII code 007_8. The alarm produces a 0.5 second tone at 1000 Hz.

The keyboards are commercial units built to Sanders' specifications. The units are supplied under manufacturer's warranty to Sanders and are not field repairable.

3.3.2 PHOTOPEN. The PHOTOPEN is a small hand-held device that detects light from data displayed on the CRT of a display indicator. Detected light is converted into an electrical input to identify the specific data at which the PHOTOPEN is pointed. The excellent resolving capability of the PHOTOPEN lets individual characters and even displayed points of light be distinguished.

A switch in the PHOTOPEN is actuated when the PHOTOPEN is pressed against the CRT screen. Actuation of this switch is processed as determined by program control. GCP+ provided with the GRAPHIC 7 can support up to two PHOTOPENs.

3.3.3 TRACKBALL, FORCESTICK, AND DATA TABLET. See figure 3-13. These position entry devices are used as determined by program control to move a cursor and/or data displayed on the CRT screen. Movement initiated by the trackball is proportional to the speed and direction in which the trackball is rolled. Movement initiated by the forcestick is proportional to the direction and force of forcestick deflection. Movement initiated by a data tablet is proportional to the speed and direction of movement of the data tablet stylus along the tablet surface.

These position entry devices connect to ports on the multiport serial interface card in the terminal controller. They receive their operating power through the same cable.

The data tablet surface area is 11 by 11 inches. It operates on the principle of magnetic coupling between the pen stylus and active surface. A switch on the data tablet rear panel gives a choice of run line mode or point mode. The data tablet enclosure is made of heat-drawn plastic.

3.4 HARDCOPY OPTIONS

The hardcopy unit (figure 3-14) produces paper copies from the random-scan X-axis, Y-axis, and Z signals of the terminal controller. The unit produces high contrast black and white or gray scale copies within seconds, using a clean, dry process. The unit is completely self-contained, has a built-in stacking tray,

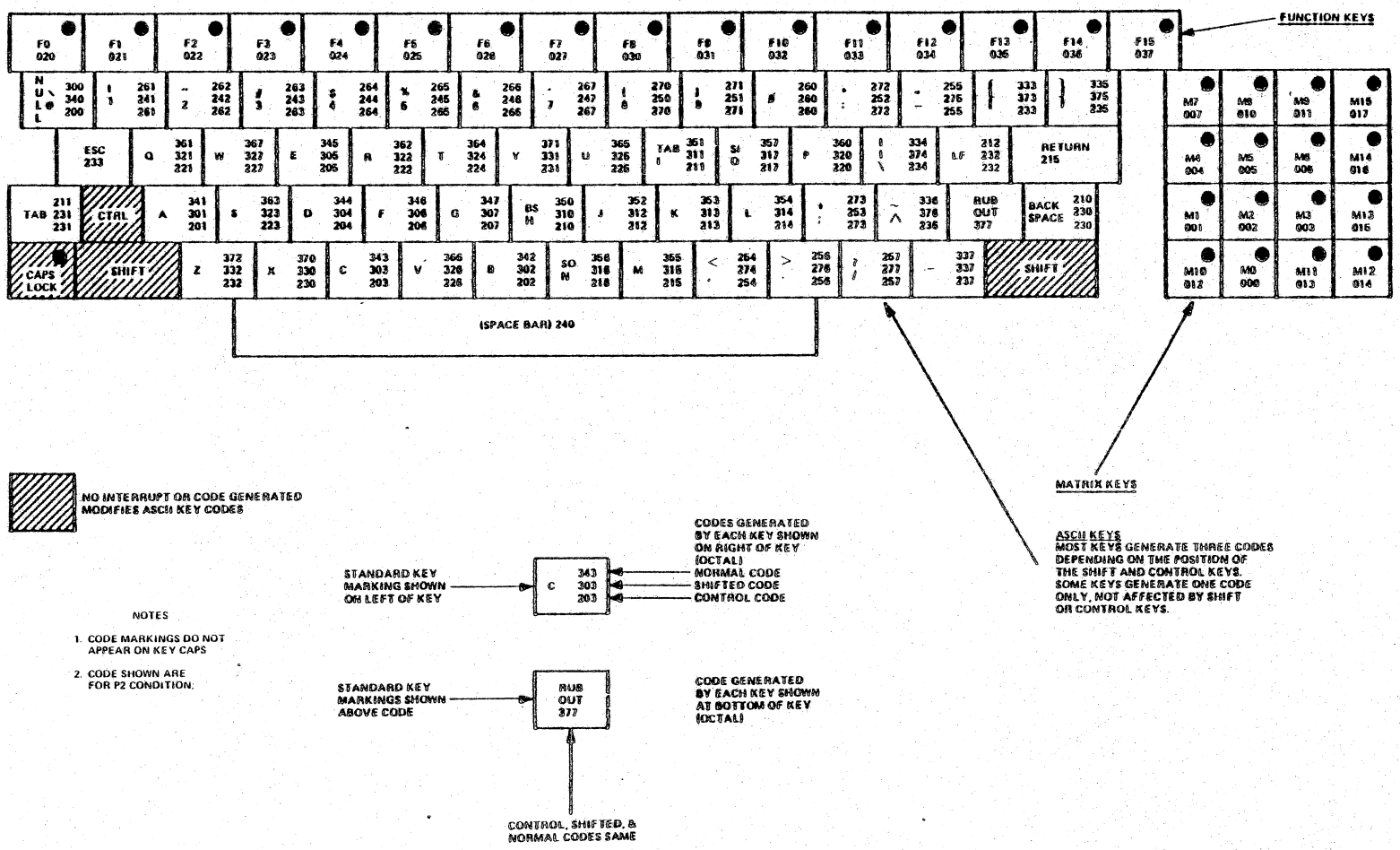
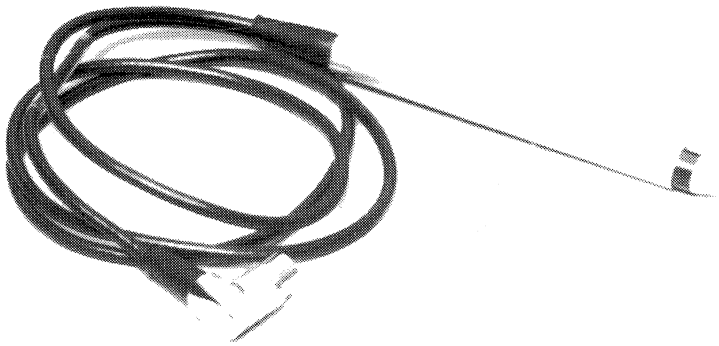
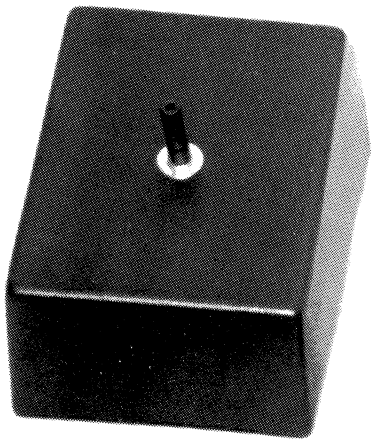


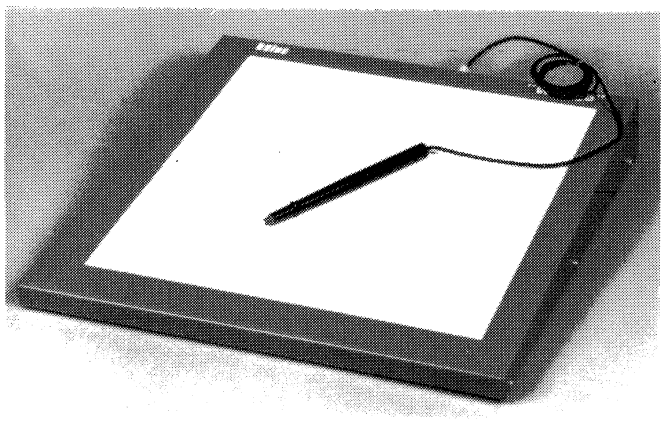
Figure 3-12. Keyboard Layout and Octal Codes



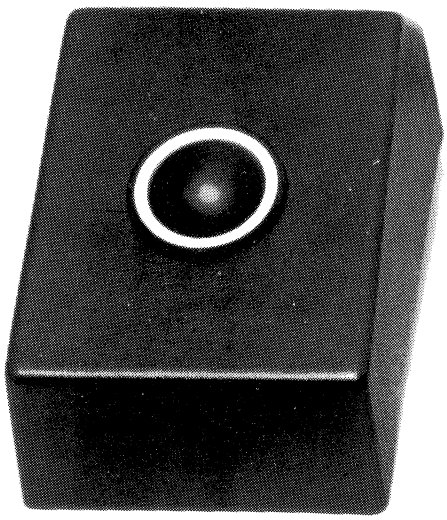
Photopen



Forcestick



Data Tablet



Trackball

Figure 3-13. Position Entry Devices

and is mounted on castors for easy movement. The hardcopy unit connects to the terminal controller through three coaxial cables. Operation is as simple as pushing a button. Remote operation is provided for, allowing control from a simple remote switch or from a complex computer system.

The hardcopy unit is basically a Tektronix 4632 Video Hard Copy Unit that Sanders modifies to make it compatible with the GRAPHIC 7 system. The unit uses 3M brand, type 777 Dry-Silver Paper. The process is dry and stable and allows clean, conventional paper handling.

The Model 770 hardcopy unit operates on 100 Vac, 120 Vac, 220 Vac, or 240 Vac, as specified by the customer.

The hardcopy unit is normally configured to produce copies with a 4:3 vertical-to-horizontal aspect ratio. The aspect ratio can be changed to 1:1 by screwdriver adjustments on one of the circuit cards. Picture orientation can be changed at any time by swapping the X-axis and Y-axis input cables and reversing the horizontal connections to the deflection yoke.

Operating controls on the hardcopy unit include a circuit breaker on the ac power distribution panel (on the cabinet), a power switch on the hardcopy unit itself, a PRINT pushbutton on the hardcopy unit, and a light/dark control on the hardcopy unit.

Sanders also offers a multiplex switch option (Model 775) (figure 3-15). The multiplex switch lets a single hardcopy unit service up to four GRAPHIC 7 terminal controllers. The multiplex switch controls operation of the hardcopy unit and causes copies to be made on a first come, first served basis.

The multiplex switch is a 19-inch panel that is normally mounted in the hardcopy unit cabinet. Its controls include a power on/off switch, power indicator, and mode select switch.

The multiplex switch has two modes of operation: automatic and manual. In the automatic mode, the multiplex switch can switch the X-axis, Y-axis and Z lines from four terminal controllers to a single hardcopy unit. In the manual mode, one of the four terminal controllers is selected by the MODE switch on the front panel.

3.5 POWER AND ENVIRONMENTAL REQUIREMENTS

Depending on the system options selected, the terminal controller will require from 250W to 800W of single-phase primary power. The power source must be within six feet of the terminal controller. The terminal controller can operate with inputs of 100 Vac to 120 Vac or 220 Vac to 240 Vac, as specified by the customer.

The terminal controller fits a 10.5-inch vertical space in a standard 19-inch equipment rack, either directly or on slides.

As an option, the controller can be supplied in a stand-alone cabinet unit. The cabinet is 30 inches (76.2 cm) high, 23 inches (58.4 cm) wide, 30 inches (76.2 cm) deep, and rolls on four castors. An input power control panel (located in

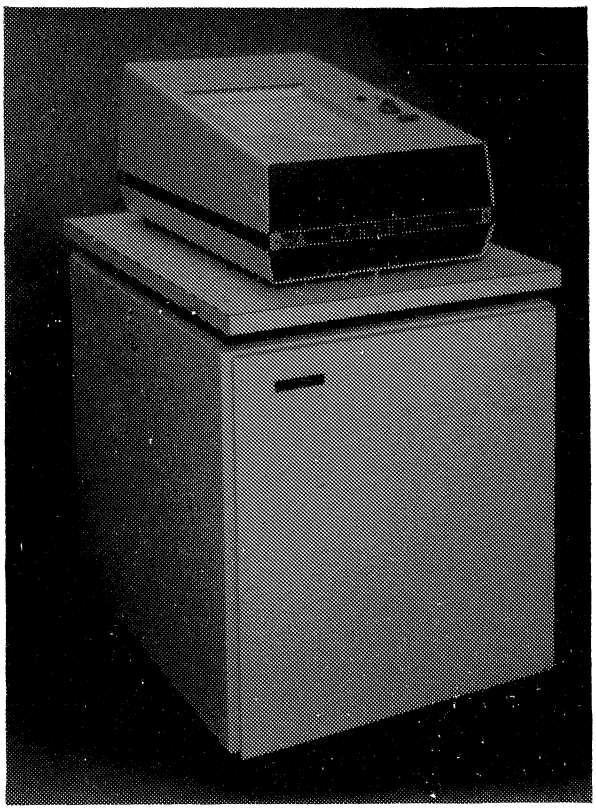


Figure 3-14. Hardcopy Unit

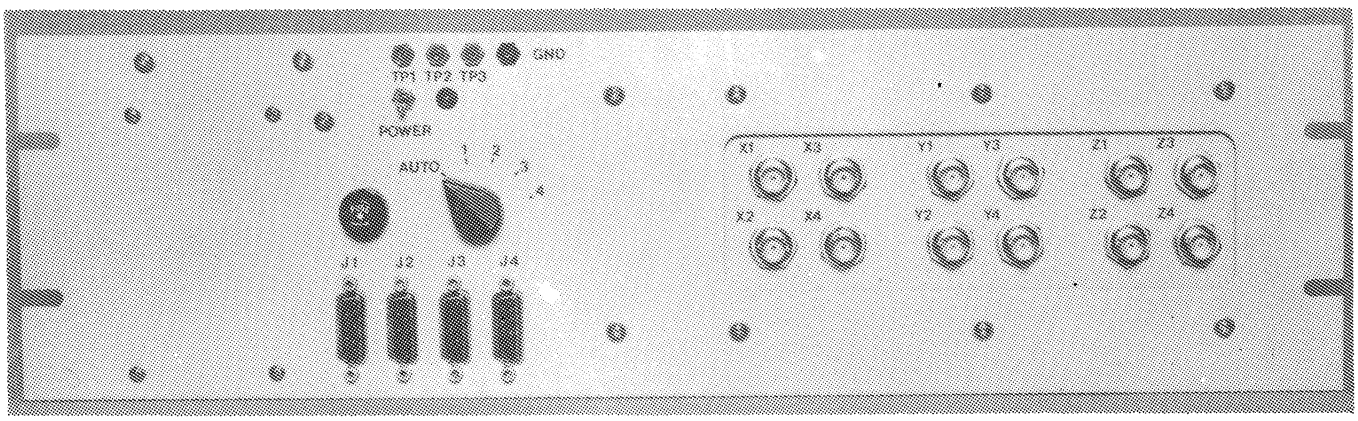


Figure 3-15. Multiplex Switch

the lower front of the equipment cabinet) contains a fuse, a power receptacle, and a removable configuration plug. All connections to the terminal controller are made at the rear of the cabinet.

The terminal controller and its associated display indicators should be plugged into the same power phase.

SECTION 4

GRAPHIC 7 INSTRUCTIONS

4.1 PROGRAMMING INSTRUCTIONS

The terminal controller executes two categories of instructions: those executed by the display processor and those executed by the graphic controller. The two microcontrollers operate independently of one another but share the common memory, gaining access through the processor bus.

4.2 DISPLAY PROCESSOR INSTRUCTIONS

The display processor emulates a minicomputer of the PDP-11® type, manufactured by Digital Equipment Corporation. This display processor is capable of executing the standard set of instructions used for the PDP 11/05 minicomputer, plus the following PDP 11/34 instructions:

SXT	sign extend	RTT	return from interrupt
XOR	exclusive or	MUL	multiply
MARK	mark	DIV	divide
SOB	subtract one and branch	ASH	shift arithmetically
SPL	set priority level	ASHC	arithmetic shift combined

User software may be prepared using standard DEC® mnemonics.

For details concerning PDP-11 instructions, see the DEC PDP-11/04/34/45/55/60 Processor Handbook.

An additional instruction that can be executed by the display processor is EXCQ (exchange register Q). The EXCQ instruction causes the contents of register Q to be exchanged with the contents of a specified general register. Its primary purpose is to provide a means of retrieving the contents of the program counter following the execution of a HALT instruction. When a HALT instruction is executed, the contents of the program counter are stored in register Q. The EXCQ instruction can then be used to move the value to a general register so that it can be processed as required.

4.3 GRAPHIC CONTROLLER INSTRUCTIONS

The graphic controller instruction set comprises 40 instructions that control the generation of the image that is displayed. These instructions consist of four basic types: beam control instructions, sequence control instructions, register instructions, and display control instructions.

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- Beam control instructions determine the basic positioning and unblanking of the CRT beam for the purpose of drawing vectors, conics, and characters.

- Sequence control instructions direct the graphic controller to jump, branch, halt, or wait as required for proper program execution.

- Register instructions let data be manipulated, using the four general purpose registers and the stack pointer of the graphic controller.

- Display instructions let various parameters be established or modified as required to achieve the desired display image characteristics.

NOTE

Macros written in MACRO-11 assembly language are available for GRAPHIC 7 users. These macros can be used to assemble all the graphic controller instructions plus some useful instruction sequences.

Figure 3-6 shows a sample graphic program. The complete file of instructions that defines a particular display image is called a refresh file. This file, which may be located in ROM and/or RAM, is accessed by the graphic controller and executed in its entirety at a rate of 60, 40, or 30 Hz (programmable) to create a visible image on the display indicator.

The following paragraphs describe the function of each graphic controller instruction.

4.3.1 BEAM CONTROL INSTRUCTIONS. Beam control instructions include load, move, draw, text, and conic instructions. See table 4-1.

Table 4-1. Beam Control Instructions

INSTRUCTION CODE INSTRUCTION NAME	DESCRIPTION
LDXA Load X absolute LDXR Load X relative	Load instructions specify X-axis positions on the CRT screen in terms of absolute data (specific coordinate) or relative data lengths along X axis. These instructions do not initiate beam motion. Beam motion is initiated by move or draw instructions, which contain the corresponding data for Y-axis positions. Except for short relative moves or draws, if both X and Y axis data are to be changed, a load instruction must precede a move or draw instruction.

Table 4-1. Beam Control Instructions (Cont)

INSTRUCTION CODE INSTRUCTION NAME	DESCRIPTION
MVXA Move X absolute MVXR Move X relative MVYA Move Y absolute MVYR Move Y relative MVSR Move short relative	Move instructions specify X and/or Y axis positions on the screen in terms of absolute data or relative data and initiate blanked beam motion to a new position. Except for a move short relative instruction, a load instruction must precede a move instruction when both X and Y axis data are to be changed.
DRXA Draw X absolute DRXR Draw X relative DRYA Draw Y absolute DRYR Draw Y relative DRSR Draw short relative PPLR Point plot relative	Draw instructions are similar to move instructions except that they cause unblanked beam motion so vectors can be drawn. A point plot relative instruction causes the beam to move blanked to a new position, then unblank momentarily to display a point.
CHAR Draw single character TXT Draw two tabular characters	The CHAR instruction causes a single steady or blinking character to be drawn at the current beam position. The TXT instruction lets two characters be drawn; the beam position increments automatically when each is completed. Character size and orientation are not included in these instructions; they are part of the display control instructions. NOTE To display special characters or symbols, the data field of the first CHAR instruction must contain the SHIFT OUT code. Subsequent CHAR or TXT instructions display the selected special symbols.

Table 4-1. Beam Control Instructions (Cont)

INSTRUCTION CODE INSTRUCTION NAME	DESCRIPTION
LDKX Load conic X register DRKY Draw conic Y	These instructions are used with the optional ramp/conic generator card to specify 90° segments and axis lengths of ellipses to be displayed. The LDKX instruction specifies X axis data but does not initiate beam motion. The DRKY instruction specifies Y axis data and initiates beam motion in both axes. Bits in both instructions specify which 90° signals are unblanked when an ellipse is drawn. All ellipse axes lie parallel to the display indicator's X and Y axes. NOTE Both instructions are required, even when the parameters specified by one instruction do not change. If the draw instruction is used alone, the display is a circle with a radius equal to the Y semi-axis length.

4.3.2 SEQUENCE CONTROL INSTRUCTIONS. Sequence control instructions include unconditional jump, conditional jump, subroutine, linkage, halt, and wait. See table 4-2.

Table 4-2. Sequence Control Instructions

INSTRUCTION CODE INSTRUCTION NAME	DESCRIPTION
JUMP Jump JRMP Jump relative JMPR Jump short relative or no operation	Unconditional jump instructions let program control of the graphic controller be transferred directly or indirectly to a specific address in memory (absolute jump) or to an address removed from the current location by a specified increment (relative jump). The JMPR instruction can also be used as a no-op instruction by specifying a jump increment of zero bytes.
JMPZ Jump if display register 0 contents - 0 JPRZ Jump relative if display register 0 contents = 0	Conditional jump instructions let program control be transferred or continue in normal sequence, as determined by testing the contents of general purpose register 0. JMPZ causes a conditional jump, direct or indirect, to a specific address in memory. JPRZ causes a conditional jump to an address removed from the current location by a specified increment.

Table 4-2. Sequence Control Instructions (Cont)

INSTRUCTION CODE INSTRUCTION NAME	DESCRIPTION
CALL Call subroutine	Calls a subroutine located at a specific address in memory.
CALR Call relative	Calls a subroutine at an address removed from the current location by a specified increment.
RTRN Return	Return from subroutine; normally the last instruction of the subroutine.
JMPM Jump and mark	Permits direct or indirect calls to subroutines at specific memory locations.
LINK Synchronized linkage	Effects synchronized linkage between a program being executed by the graphic controller and a program being executed by the display processor. The additional power of the display processor can be used to modify or process the refresh file data.
HREF Halt refresh	The graphic controller halts and sends an interrupt to the display processor.
WATE Wait	Synchronizes processing of a refresh file to correspond with the selected refresh rate.

4.3.3 REGISTER INSTRUCTIONS. Register instructions are used to load data into general purpose registers of the graphic controller, to modify register contents, and to control graphic controller stack operations. Register instructions also let data be loaded into registers of optional devices that may be connected to the graphic bus. See table 4-3.

Table 4-3. Register Instructions

INSTRUCTION CODE INSTRUCTION NAME	DESCRIPTION
LDDI Load display register immediate	Loads data into the specified display register.
LDSP Load stack pointer	Loads a specific address into the stack pointer.
LDRI Load device register immediate	Loads data into the specified register of the specified device.

Table 4-3. Register Instructions (Cont)

INSTRUCTION CODE INSTRUCTION NAME	DESCRIPTION
---- Hardcopy display select	Selects the display whose image is to be duplicated by the hardcopy unit.
---- Color select	Selects the color to be drawn on the selected display.
ADDI Add to display register immediate	Adds specified data to the specified display register.
SAVD Save display register	Saves specified display register.
RESD Restore display register	Restores specified display register.

4.3.4 DISPLAY CONTROL INSTRUCTIONS. Display control instructions establish and/or change various display parameters as required. See table 4-4.

Table 4-4. Display Control Instructions

INSTRUCTION CODE INSTRUCTION NAME	DESCRIPTION
LDDP Load display parameter register	Contains instructions for: writing speed enable, writing speed select, frame sync select, PHOTOPEN select change enable, PHOTOPEN select, character parameter change enable, character orientation, and character size.
LDDZ Load display Z register	Contains instructions for: display select change enable, display select, blink select, line structure select, and gray level select.
LDTI Load text increment register	Sets spacing between characters.
IZPR Initialize	Lets definite hardware conditions be established before a refresh file is processed.

4.4 REGISTERS

The display processor, graphic controller, and interfaces in the GRAPHIC 7 contain registers. The following paragraphs describe the applications of these registers.

4.4.1 DISPLAY PROCESSOR REGISTERS. The display processor contains eight general purpose registers, R0 through R7. These registers function in a manner similar to the corresponding registers in the PDP-11. Details concerning the applications and formats of these registers appear in the PDP-11/04/34/45/55/60 Processor Handbook. Addresses are not assigned to the display processor registers.

4.4.2 GRAPHIC CONTROLLER REGISTERS. The graphic controller registers include processor registers, function registers, sense and mask registers, and function control registers. The processor registers and function registers are 16-bit registers. Table 4-5 lists and describes the graphic controller registers.

Table 4-5. Graphic Controller Registers

REGISTER CODE REGISTER NAME OCTAL ADDRESS	DESCRIPTION
DR0 through DR3 General purpose register n 165002 (DR0) 165004 (DR1) 165032 (DR2) 165034 (DR3) DSP Stack pointer 165000 DPC Program counter 165006 DIR Display instruction register 165010	The processor registers are the general working registers of the graphic controller. When the graphic controller is halted, the contents of each can be read by the display processor using programmed data transfers.
DXR X position register 165020 DYR Y position register 165022 DCR Display character register 165024	The function registers in the graphic controller correspond to registers located on circuit cards that are connected to the graphic bus. These registers are loaded by graphic controller instructions as required to control the functions performed by the circuit cards. Each function register has an octal address; when the graphic controller is halted, the display processor can read the contents of the registers using programmed data transfers.

Table 4-5. Graphic Controller Registers (Cont)

REGISTER CODE REGISTER NAME OCTAL ADDRESS	DESCRIPTION
DTI Text increment register 165012	
KXR Conic X data register 165026	
KYR Conic Y data register 165030	
DZR Display Z register 165016	
DPR Display parameter register 165014	
PGR Graphic controller page register 165014	
PR1 through PR3 Display processor page registers 172342 (PR1) 172344 (PR2) 172346 (PR3)	
SENS Sense register 177660	The sense register indicates PHOTOPEN activity and the halt status of the graphic controller.
MKR Mask register 177662	The mask register enables the graphic controller to report conditions to the display processor on an interrupt basis. Bits in the mask register can be set or cleared as required by the display processor using programmed data transfers.
FUNS Function control stop register 165040	The function control stop register is used to halt the graphic controller.

Table 4-5. Graphic Controller Registers (Cont)

REGISTER CODE REGISTER NAME OCTAL ADDRESS	DESCRIPTION
FUNC Function control continue register 165036	The function control continue register is used to restart the graphic controller after it has been halted.

4.4.3 INTERFACE REGISTERS. There are registers associated with the various serial and parallel interface ports of the GRAPHIC 7.

4.4.3.1 Serial Interface Registers. Up to nine serial interface ports are available for external devices to communicate with the GRAPHIC 7. One (the TTY interface) is located on the ROM and status logic card; four are located on each multiport serial interface card.

Four registers are associated with each serial interface port; see table 4-6. Each register has an octal address and can be accessed as required by the display processor.

Table 4-6. Serial Interface Registers

REGISTER CODE REGISTER NAME	OCTAL ADDRESS	FUNCTIONS
RSRn Receive status register n	176500 (RSR1) 176510 (RSR2) 176520 (RSR3) 176530 (RSR4) 176540 (RSR5) 176550 (RSR6) 176560 (RSR7) 176570 (RSR8) 177560 (TTYRSR)	Contain information on: Ring indicator* Clear to send* Carrier detect* Data set ready* Receiver done Receiver interrupt enable Request to send* Data terminal ready* Reader enable
* - these functions available only at RSR1 and RSR5.		
RDBn Receive data buffer n	176502 (RDB1) 176512 (RDB2) 176522 (RDB3) 176532 (RDB4) 176542 (RDB5) 176552 (RDB6) 176562 (RDB7) 176572 (RDB8) 177562 (TTYRDB)	Contain information on: Error Overrun error Parity error*
* - these functions available only at RDB1 and RDB5.		

Table 4-6. Serial Interface Registers (Cont)

REGISTER CODE REGISTER NAME	OCTAL ADDRESS	FUNCTIONS
TSRn Transmit status register n	176504 (TSR1) 176514 (TSR2) 176524 (TSR3) 176534 (TSR4) 176544 (TSR5) 176554 (TSR6) 176564 (TSR7) 176574 (TSR8) 177564 (TTYTSR)	Contain information on: Transmit ready Transmit interrupt enable
TDBn Transmit data buffer n	176506 (TDB1) 176516 (TDB2) 176526 (TDB3) 176536 (TDB4) 176546 (TDB5) 176556 (TDB6) 176566 (TDB7) 176576 (TDB8) 177566 (TTYTDB)	Contain the code of the character that is to be transmitted to the external device.

4.4.3.2 Parallel Interface Registers. Up to four parallel interfaces can be used by external devices to communicate with the GRAPHIC 7; each external device requires its own parallel interface. Each parallel interface contains four registers: word count register, memory address register, status register, and data register. Each register has an octal address and can be accessed as required by the display processor. See table 4-7.

Table 4-7. Parallel Interface Registers

REGISTER CODE REGISTER NAME	OCTAL ADDRESS	FUNCTIONS
WCRn Word count register	172410 (WCR1) 172430 (WCR2) 172450 (WCR3) 172470 (WCR4)	During a DMA operation, the display processor writes into these registers the two's complement of the number of words to be transferred between the GRAPHIC 7 and the host computer. Each time the parallel interface completes a transfer, the word count increments by one. When word count = 0, the parallel interface generates an interrupt to the display processor.
MARn Memory address register n	172412 (MAR1) 172432 (MAR2) 172452 (MAR3) 172472 (MAR4)	During a DMA operation, the display processor writes into the memory address register the memory address of the first word to be transferred between the GRAPHIC 7 and the host computer. Each

Table 4-7. Parallel Interface Registers (Cont)

REGISTER CODE REGISTER NAME	OCTAL ADDRESS	FUNCTIONS
		time the parallel interface completes a transfer, the memory address register increments by two bytes.
STRn Status register n	172414 (STR1) 172434 (STR2) 172454 (STR3) 172474 (STR4)	Contain information on: Input not ready Input interrupt enable Input word request Attention interrupt enable Attention no. 1 Attention no. 2 Word count = 0 Output control Output interrupt enable Output word received DMA complete DMA I/O mode Address bit 16 Address bit 17
DRn Input/output data register n	172416 (DR1) 172436 (DR2) 172456 (DR3) 172476 (DR4)	These are dual registers serving as input data registers or output data registers. In the output mode, the contents reflect the states of the data lines from the host computer until the program reads the data. In the input mode, the contents of this register are presented directly to the host computer.

SECTION 5

DISPLAY SYSTEM FIRMWARE/SOFTWARE

The standard GRAPHIC 7 is supplied with the Graphic Control Program (GCP+) in read-only memory. Optional software includes the remote-based Fortran Support Program (FSP) and the Graphics Emulator Tektronix (GET-2). The following paragraphs describe these three firmware/software programs.

5.1 GCP+

The standard graphic control program (GCP+) handles all the tasks for the GRAPHIC 7 that must normally be programmed for other display systems. The programmer, therefore, need only be concerned with the generation of software for the host computer. Specific tasks performed by GCP+ with no requirement for host intervention include:

- Routine housekeeping
- Handling of all operator inputs
- Handling of trackball/forcestick or data tablet manipulations
- Handling of all graphic controller interrupts
- Automatic handling of PHOTOPEN strikes and the associated data
- Insertion of keyboard data directly into a refresh file
- Formatting of messages for GRAPHIC 7-to-host communications

When the GRAPHIC 7 is initialized in the system mode, all peripheral devices are automatically initialized without any action by the host and GCP+ is able to accept messages from the host. As determined by the host application program, the GRAPHIC 7 is also enabled to format and transmit various types of messages to the host. The host application program determines the manner in which data in messages from the GRAPHIC 7 will be processed and the type of data that will be returned in messages to the GRAPHIC 7. For controlling these operations, the application programmer has full access to all control registers of the terminal controller.

Generation of all display instruction codes and management of the refresh file must be accomplished by the application program resident in the host computer or by software down-loaded into the GRAPHIC 7. For most computers, display instruction macros can be used to simplify this task. Extended macro assemblers that contain the display instruction macros already exist for some computers. Other methods of generating display instruction codes include host-resident graphic support packages and data statements. A package of this type available as an option for the GRAPHIC 7 is the remote-based FORTRAN support package (FSP).

5.1.1 HOST/GRAPHIC 7 COMMUNICATIONS. All communications between the host computer and the GRAPHIC 7 are handled by GCP+. Transmissions in either direction are called messages. Each message begins with a command header that contains two ASCII characters to define the message type. The header is then followed by as many 16-bit words as are needed to transmit the associated data.

5.1.1.1 Serial Interface Communications. When communications with the host computer are handled over a serial interface, the data portion of each message must be converted to an ASCII format. This translation is required for messages transmitted in either direction. For GRAPHIC 7-to-host messages, the translation is done by GCP+. For host-to-GRAPHIC 7 messages, the host computer must make the translation and GCP+ restores the data to its original format. The resulting messages, regardless of content, consist entirely of the alphanumeric ASCII characters A through Z and 0 through 9, terminated with the ASCII code for CARRIAGE RETURN. This translation ensures that no ASCII code is transmitted that might intefere with a host operating system or with the serial interface itself.

ASCII characters used in message command headers are limited to G through Z. Since these headers are originally generated in ASCII format, no translation is needed. Translation is needed only for the information contained in the associated data words. The information in these words is translated into ASCII characters 0 through 9 and A through F (the hexadecimal equivalent of a 4-bit nibble).

5.1.1.2 Parallel Interface Communications. When communications between the host computer and the GRAPHIC 7 are handled over a parallel interface, messages in both directions are transmitted in the binary 16-bit word format in which they were originally constituted. No translation of the data words is needed and no end-of-message indicator is required. ASCII codes are used for the two characters in the command header, as they are for serial communications.

5.1.2 HOST/GRAPHIC 7 MESSAGES. There are eleven different groups of messages transmitted between the host computer and the GRAPHIC 7, as follows:

1. Initialize and error messages.
2. Establish I/O transmission mode (polling/non-polling)
3. Memory-related messages
4. Interrupt-related messages
5. Keyboard-related messages
6. Position entry device-related messages
7. PHOTOPEN-related messages
8. Hardcopy messages
9. Fortran support (FSP) messages
10. Option messages
11. 3D coordinate converter messages.

5.1.2.1 Initialize and Error Messages. See table 5-1.

Table 5-1. Initialize and Error Messages

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
IZ INITIALIZE 044532 Host to G7	A single-word message that causes the GRAPHIC 7 to initialize in the system operating mode. The display indicator(s) goes blank; keyboards and PEDs are enabled; built-in diagnostic tests are performed; and the results of the diagnostic tests are reported back to the host computer in an XX message.
XX ERROR STATUS 054130 G7 to Host	Whenever the GRAPHIC 7 is initialized in the system mode, it sends an XX message to the host computer to indicate the results of the diagnostic tests performed and the ROM checksum calculated during the initialization routine. When the GRAPHIC 7 is operating in the system mode and error detection has been enabled, XX messages are also automatically sent whenever the GCP+ senses an error condition. XX is a 4-word message; there are four types of XX messages with slightly different formats, as follows: The initialization XX message indicates the results of the diagnostic tests and the ROM checksum. The diagnostic tests check the parallel interface, graphic controller, display processor, read/write memory, and (if used) the 3D coordinate converter. The normal running XX message identifies any of the following errors: incorrect command header format sent by host computer; unidentified internal interrupt detected by display processor; GCP+ serial interface buffer is full; GCP+ serial interface buffer is 7/8 full; and command header not recognized by GCP+. A buffer XX message is sent when no output buffer is available to GCP+ for a message to be sent to the host computer. Word 2 of the XX message contains the command header of the message that could not be sent to the host computer. A character overrun XX message is sent whenever a character overrun condition or parity error is detected at the serial interface port used for communications with the host computer.

5.1.2.2 Establish I/O Transmission Mode (Polling/Non-polling). See table 5-2.

Table 5-2. Establish I/O Transmission Mode Messages

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
IM INITIALIZE I/O MESSAGE FORMATS 044515 Host to G7	Used to activate or deactivate error detection and to initialize GCP+ to operate in either a polling or non-polling mode.
PL POLL GRAPHIC 7 FOR NEXT MESSAGE 050114 Host to G7	The host computer sends this message to request that the GRAPHIC 7 send its next message. This command works in conjunction with the way the IM command has initialized GCP+.
NM NO MESSAGES READY 047115 G7 to host	GCP+ sends this message in response to the PL command if the output buffer is empty and the poll message bit had been set by the IM command.
NO NO OPERATION 047117 Host to G7	The NO message causes no operation to be performed by GCP+. NO messages are used primarily as fillers when the host computer application program requires that all messages sent to the GRAPHIC 7 have the same length.

5.1.2.3 Memory-Related Messages. See table 5-3.

Table 5-3. Memory-Related Messages

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
MS MEMORY BANK SELECT 046523 Host to G7	The MS message selects the desired memory bank. If the GRAPHIC 7 system contain a large memory system, this message should be sent before the host-to-GRAPHIC 7 messages MU, SU, SP, GI, MS, IP, IT, TK, ZR, ZT, MI, and GU; and before the GRAPHIC 7-to-host messages RI, XX, PN, PT, HI, and XI. When GCP+ is initialized, bank 0 is selected by default.
MU MEMORY UPDATE 046525 Host to G7	The MU message is a variable length message used to load data into the GRAPHIC 7 read/write memory. Word 1 contains the starting address in memory (an even number). Word 2 contains the number of words to be

Table 5-3. Memory-Related Messages (Cont)

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
	loaded. Following words contain the data. When the host computer sends an MU message to the GRAPHIC 7, GCP+ halts the graphic controller and blanks the display indicator. The GRAPHIC 7 remains halted until the host computer sends a KP or SP message.
SU SELECTIVE UPDATE 051525 Host to G7	The SU message is a variable length message that operates exactly the same as MU except that the graphic controller is not halted. If an SU message is used to update a refresh file currently being processed by the graphic controller, the file must remain valid as each data word is replaced. More commonly, an SU message is used to load a new refresh file into a different area of memory while the graphic controller is processing an older file. After the new file is loaded, an SP message from the host computer causes the graphic controller to process the new file.
RU REGISTER UPDATE 051125 Host to G7	The RU message is available length message used to update a series of registers in the I/O address area of the hardware. Any number of successive registers can be updated in a single message. If the GRAPHIC 7 contains a large memory system, memory mapping must be considered in the preparation of this message.
SP START PICTURE 051520 Host to G7	The SP message is a 2-word message that causes the graphic controller to begin processing a refresh file starting at the address specified in word 1.
HP HALT PICTURE 051520 Host to G7	The HP message (one word) causes GCP+ to halt the graphic controller and blank the display indicator. The refresh file is not changed; the graphic controller program counter remains pointing to the location of the next instruction to be processed. The graphic controller remains halted until the host computer sends an SP or KP message.
KP CONTINUE PICTURE 045520 Host to G7	The KP message is a single-word message that restarts the graphic controller at its next instruction.

Table 5-3. Memory-Related Messages (Cont)

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
TK TRANSFER CONTROL 052113 Host to G7	The TK message (2 words) causes the display processor to stop processing GCP+ and start processing the program that begins at the address specified in word 1. This message is intended for advanced applications to let the display processor process a program other than GCP+. Such a program would be down-loaded from the host computer (using an MU message), then started by the TK message. After control has been transferred, no further communications via GCP+ are possible unless the new program deliberately reenters GCP+.
GI GIVE IMAGE 043511 Host to G7	The GI message (3 words) causes GCP+ to send back to the host computer the contents of the GRAPHIC 7 memory beginning at the address specified in word 1 and ending when the number of words requested in word 2 have been sent. In response to a GI message, GCP+ sends an RI message followed by a VL message. The RI message indicates the length of the VL message; the VL message contains the data.
RI RETURN MESSAGE 051111 G7 to host	GCP+ returns an RI message to the host computer in response to a GI message. Word 1 specifies the starting address of the data to be transferred, word 2 specifies the number of words to be transferred, and word 3 identifies the memory bank number. Followed immediately by a VL message.
VL VARIABLE LENGTH 053114 G7 to host	Word 1 contains the same data as word 2 of the preceding RI message. Words 2 through n contain the requested data.
GR GIVE REGISTER 043522 Host to G7	The host computer sends GR to obtain the contents of the GRAPHIC 7 register specified by the register address in word 1. The contents of any register that has an assigned address may be obtained.
RR RETURN REGISTER 051122 G7 to host	GCP+ responds to a GR message by sending an RR message. Word 1 is always the same as word 1 of the GR message. Word 2 contains the requested data. Word 3 contains all zeros.

5.1.2.4 Interrupt-Related Messages. See table 5-4.

Table 5-4. Interrupt-Related Messages

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
IK INTERRUPT CONTROL 044513 Host to G7	The IK message (2 words) is used to enable or disable certain GCP+ functions and to determine conditions under which the graphic controller can interrupt the display processor. Word 1 contains the selected mask bits and directly replaces the contents of the graphic controller mask register; word 1 also enables serial interface ports and sets internal software flags as required.
IS ENABLE SELECTED INTERRUPTS 044523 Host to G7	The IS message (2 words) selectively enables mask register-associated interrupts.
ZI DISABLE SELECTED INTERRUPTS 055111 Host to G7	The ZI message (2 words) selectively disables mask register-associated interrupts.
HI HALT INTERRUPT 044111 G7 to host	When the graphic controller halt interrupt to the display processor is enabled (by an IK or IS message), GCP+ sends an HI message to the host computer each time the graphic controller executes an HREF instruction. Word 1 contains the contents of the graphic controller program counter; word 2 contains the contents of the graphic controller instruction register.
XI X OR Y POSITION OVERFLOW INTERRUPT 054111 G7 to host	When the graphic controller X or Y position overflow interrupt to the display processor is enabled, GCP+ sends an XI message to the host computer whenever the graphic controller determines that an X or Y position overflow condition has been created. Word 1 contains the contents of the graphic controller program counter; words 2 and 3 contain the contents of the X and Y position registers respectively.

5.1.2.5 Keyboard-Related Messages. See table 5-5.

Table 5-5. Keyboard-Related Messages

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
ZR INITIALIZE SCRATCHPAD FOR ALPHANUMERIC KEYBOARD NO. 1 055122 Host to G7	The ZR message (3 words) establishes parameters for handling alphanumeric characters on a line basis from keyboard no. 1. It is used in conjunction with a scratchpad area of the refresh file. The ZR message causes GCP+ to begin collecting characters from the keyboard and store them in the refresh file starting at the address specified in word 1 of the message. Word 2 specifies the total number of characters that may be collected (this number may be less than the scratchpad capacity). Characters are collected until the total count specified in word 2 is reached; then GCP+ sends an XR message to the host computer. RETURN, which may be typed at any time, terminates collection of characters and causes GCP+ to send an XR message to the host computer. The host computer can then obtain the contents of the scratchpad by sending a GI message. Characters collected in the scratchpad remain there until they are cleared by a ZS, SU, or MU message from the host computer; or they are replaced when another ZR message from the host computer causes the scratchpad to be reused; or the operator types RUB OUT. Each RUB OUT strike deletes the last character in the scratchpad. When the host computer sends a ZR message containing all zeros, GCP+ goes out of scratchpad mode and sends a KY message each time a character is typed.
ZT INITIALIZE SCRATCHPAD FOR ALPHANUMERIC KEYBOARD NO. 2 055124 Host to G7	Same as the ZR message, except that it applies to alphanumeric keyboard no. 2. Typing RETURN causes GCP+ to send an XT message to the host computer.
ZS ZERO OUT SCRATCHPAD NO. 1 055123 Host to G7	The ZS message causes GCP+ to replace all characters in scratchpad no. 1 with spaces. The scratchpad pointer is repositioned to the beginning of the scratchpad area.

Table 5-5. Keyboard-Related Messages (Cont)

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
ZU ZERO OUT SCRATCHPAD NO. 2 055125 Host to G7	Same as ZS, but used for scratchpad no. 2.
LK LIGHT KEYS ON FUNCTION KEYBOARD NO. 1 046113 Host to G7	LK is a 3-word message that lights function and/or matrix keys on keyboard no. 1. Word 1 lights the individual function keys, word 2 lights the individual matrix keys.
LT LIGHT KEYS ON FUNCTION KEYBOARD NO. 2 046124 Host to G7	Same as the LK message, except applies to function keyboard no. 2.
KY ALPHANUMERIC KEYBOARD NO. 1 045531 G7 to host	GCP+ sends a KY message to the host computer each time an alphanumeric key is typed, if the following conditions are met: the keyboard is enabled (by an IK message) and the keyboard is not operating in the scratchpad mode. Each KY message sent to the host computer contains the ASCII code for a single alphanumeric character. Keyboards are automatically enabled by GCP+ when the GRAPHIC 7 is initialized in the system mode.
KT ALPHANUMERIC KEYBOARD NO. 2 045524 G7 to host	Same as the KY message, except applies to alphanumeric keyboard no. 2.
XR SCRATCHPAD READY FOR ALPHANUMERIC KEYBOARD NO. 1 054122 G7 to host	GCP+ sends an XR message to the host computer whenever alphanumeric keyboard no. 1 is operated in the scratchpad mode and either the scratchpad becomes full or the RETURN key is typed. Word 1 contains the character count. The host computer responds with a GI message to obtain the scratchpad contents.
XT SCRATCH PAD READY FOR ALPHANUMERIC KEYBOARD NO. 2 054124 G7 to host	Same as the XR message, except applies to the scratchpad for alphanumeric keyboard no. 2.

Table 5-5. Keyboard-Related Messages (Cont)

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
RK FUNCTION KEYBOARD NO. 1 051113 G7 to host	If function keyboard no. 1 is enabled, GCP+ sends an RK message to the host computer each time a function or matrix key is struck. Word 1 contains the code for the function or matrix key.
RL FUNCTION KEYBOARD NO. 2 051114 G7 to host	Same as the RK message but applies to function keyboard no. 2.

5.1.2.6 Position Entry Device-Related Messages. See table 5-6.

Table 5-6. Position Entry Device-Related Messages

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
TM ASSIGN DATA TABLET AS PED NO. 1 052115 Host to G7	This message instructs the GCP+ to interpret all PED no. 1 messages as coming from a data tablet. (By default, GCP+ is initialized to interpret PED no. 1 messages as coming from a trackball or forcestick.)
TN ASSIGN DATA TABLET AS PED NO. 2 052116 Host to G7	Same as the TM message but applies to PED no. 2.
IP INITIALIZE PED NO. 1 044520 Host to G7	The IP message (3 words) establishes the operating mode for the trackball, forcestick, or data tablet identified as PED no. 1. Modes are defined as follows: Mode 0: data tablet automatic tracking mode. GRAPHIC 7 sends 100 RP messages per second to host computer as long as data tablet pen switch is pressed. A variable delay can be introduced between the time of pressing the switch and sending the first RP message. Position coordinate data is absolute.

Table 5-6. Position Entry Device-Related Messages (Cont)

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
	Mode 1: trackball/forcestick automatic mode. GRAPHIC 7 sends relative displacement data to host computer every time the PED interrupts the display processor. Mode 2: PED request mode. GRAPHIC 7 sends absolute position data to the host computer in response to a GP message. Mode 3: PED tracking mode. Same as mode 2, plus GCP+ continuously updates the refresh file to reflect the latest PED position at all times.
IT INITIALIZE PED NO. 2 044524 Host to G7	Same as the IP message, but applied to PED no. 2.
GS GET STATUS OF PEDS 043523 Host to G7	The GS message requests the current status of each PED. The GCP+ returns the status to the host computer in the form of an RT message. GS and RT are maintenance-type messages. They can be used to validate the modes and PED types established by the IP, IT, TM, and TN messages.
RT RETURN PED STATUS 051124 G7 to host	GCP+ sends the RT message to the host computer in response to a GS message. Word 1 contains the software status of each PED.
GP GIVE PED NO. 1 043520 Host to G7	The GP message requests the current absolute coordinate data for PED no. 1.
GT GIVE PED NO. 2. 043524 Host to G7	The GT message requests the current absolute coordinate data for PED no. 2.
RP RETURN PED NO. 1. 051120 G7 to host	The RP message contains the current absolute coordinate data for PED no. 1. Word 1 contains the mode. Words 2 and 3 contain the X and Y position data, respectively.
RW RETURN PED NO. 2 051127 G7 to host	Same as the RP message, but contains the data for PED no. 2.

5.1.2.7 PHOTOPEN-Related Messages. See table 5-7.

Table 5-7. PHOTOPEN-Related Messages

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
PM CHANGE PHOTOPEN NO. 1 MODE 050115 Host to G7	Establishes the operating mode for PHOTOPEN no. 1: strike or scan. GCP+ initializes to the strike mode. In the strike mode, GCP+ sends a PN message to the host computer when it detects a strike. The scan mode is used to identify the X, Y coordinates for a blank area on the screen. In the scan mode, when the PHOTOPEN switch is pressed, a grid pattern is flashed on the screen. When the PHOTOPEN detects light, the grid pattern is removed and GCP+ sends a PN message to the host computer containing the X, Y coordinates of the blank area selected by the PHOTOPEN.
PP CHANGE PHOTOPEN NO. 2 MODE 050120 Host to G7	Same as the PM message, except applies to PHOTOPEN no. 2.
SL LINK APPLICATION PROGRAM TO SCAN ROUTINE 046123 Host to G7	The SL message is used to link the PHOTOPEN scan routine to the GCP+ application refresh program. Word 1 contains the address in the user's refresh to link the scan routine.
PN RETURN PHOTOPEN NO. 1 STRIKE/SCAN 050116 G7 to host	GCP+ returns PN messages to the host computer in response to PHOTOPEN activity. PN messages can be generated in the strike or scan modes. The meaning for PN messages in the GCP+ environment and the FSP environment are slightly different. In the strike mode, GCP+ sends a PN message to the host computer when the PHOTOPEN detects light. If the PHOTOPEN item number flag had been previously set, word 1 contains the contents of the graphic controller general purpose register 1 (DR1) at the time the strike occurred. If the PHOTOPEN item number flag is cleared, word 1 contains the contents of the graphic controller program counter. In all PN messages, words 2 and 3 contain the contents of the graphic controller X and Y position registers respectively.

Table 5-7. PHOTOPEN-Related Messages (Cont)

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
	In the scan mode in the GCP+ environment, word 1 is all zeros. Words 2 and 3 contain the X and Y coordinates selected by the operator when the scan pattern was flashed on the display indicator. In the FSP environment strike mode, word 1 contains the address of the FSP PHOTOPEN table. The information in the table is retrieved by sending a GI message to GCP+ with a word count of 6. The information in the FSP PHOTOPEN table is as follows: ADDRESS OR PHOTOPEN STRIKE — Word 1 TYPE OF OBJECT — Word 2 ADDRESS OF CALLING PAGE — Word 3 BANK OF CALLING PAGE — Word 4 TEXT BYTE — Word 5 ITEM NUMBER — Word 6 The types of objects that can be identified are: text, vector, conic, point, and short vector. In the FSP environment, a scan mode PN message is the same as in the GCP+ environment. PHOTOPENs are not automatically enabled when the GRAPHIC 7 is initialized in the system mode.
PT RETURN PHOTOPEN NO. 2 STRIKE/SCAN 050124 G7 to host	Same as the PN message, except applies to PHOTOPEN no. 2.

Table 5-7. PHOTOPEN-Related Messages (Cont)

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
SW PHOTOPEN NO. 1 SWITCH ACTUATED 051527 G7 to host	When PHOTOPEN no. 1 switch interrupts are enabled, GCP+ sends an SW message to the host computer each time the switch is pressed. PHOTOPEN switch interrupts are not enabled when the GRAPHIC 7 is initialized in the system mode.
ST PHOTOPEN NO. 2 SWITCH ACTUATED 051524 G7 to host	Same as for SW message, but used for PHOTOPEN no. 2 switch interrupts.

5.1.2.8 Hardcopy Messages. See table 5-8.

Table 5-8. Hardcopy Messages

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
HY INITIATE HARDCOPY 044131 Host to G7	Requests a hardcopy of the image currently being directed to display #4.
HK HARDCOPY COMPLETED 044113 G7 to host	The HK message is returned to the host computer on completion of the hardcopy cycle.

5.1.2.9 Fortran Support (FSP) Messages. See table 5-9.

Table 5-9. Fortran Support Messages

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
IG INITIALIZE GCP+ TO SUPPORT FSP 044507 Host to G7	The IG message initializes GCP+ to operate in the Fortran support program (FSP) environment (see paragraph 5.2).

Table 5-9. Fortran Support Messages (Cont)

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
RG RETURN FSP TABLE ADDRESS 051107 G7 to host	The RG message is returned to the host computer in response to the IG message. Word 1 contains the starting address of the FSP table in GRAPHIC 7 memory. This table contains all key addresses associated with the FSP refresh program that is started by the IG message. The adresses contained in this table are retrieved by sending a GI message with a word count of 10_8. The FSP table always resides in bank 0 and contains the following information.
GU GRAPHIC UPDATE 043525 Host to G7	GU is a variable-length message used to load data into the GRAPHIC 7 read/write memory. It is a special form of the MU and SU messages. Word 1 contains the load address. Word 2 contains the number of words to be loaded. Words 3 through n contain the data.
MI MOVE IMAGE 046511 Host to G7	The MI message permits the copying of sections of refresh files to other areas of memory. Word 1 contains the refresh start address. Word 2 contains the number of words to be moved. Word 3 contains the new refresh start address.
NP ENABLE BOX DISPLAY 047120 Host to G7	The NP message enables the box display on selected indicators when operating in the FSP environment. Word 1 identifies the indicators.

STARTING ADDRESS OF USER REFRESH	Word 1
ADDRESS OF ERROR CODE IN ERROR ROUTINE	Word 2
ADDRESS OF LDDZ IN SCRATCHPAD 1	Word 3
ADDRESS OF LDDZ IN SCRATCHPAD 2	Word 4
ADDRESS OF DEFAULT PED 1 SYMBOL	Word 5
ADDRESS OF DEFAULT PED 2 SYMBOL	Word 6
GCP+ RAM CONFIGURATION WORD	Word 7
CGP+ EXPANSION LOW BOUNDARY (PHYSICAL ADDRESS)	Word 8

Table 5-9. Fortran Support Messages (Cont)

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
ZP DISABLE BOX DISPLAY 055120 Host to G7	The ZP message disables the box display on selected indicators when operating in the FSP environment. Word 1 identifies the indicators.
NN ENABLE ERROR NUMBER 047116 Host to G7	The NN message enables the error number display on selected indicators when operating in the FSP environment. These error numbers are updated by FSP to give the user a visual indication that an error has occurred. Word 1 identifies the indicators.
ZN DISABLE ERROR NUMBER 055116 Host to G7	The ZN message removes the error number display from selected indicators when operating in the FSP environment. Word 1 identifies the indicators.
LM LARGE MEMORY IN USE FOR FSP 046115 Host to G7	The LM message informs GCP+ that refresh data may reside in several banks. When the LM message is issued, a special halt interrupt vector is established. Coded halts with an associated DR3 value (address) pass the required arguments so the display processor can allow subroutines to be executed from bank to bank. The display processor Q register is used for a private graphics stack pointer. Additional instructions are used to make subroutine calls between different banks in the FSP environment. Word 1 contains an instruction to load the subroutine address into general purpose register 3 (DR3). Word 2 contains the starting address of the subroutine, relative to the beginning of the bank where the subroutine is stored. Word 3 contains the coded halt.

5.1.2.10 Packed Vector Mode. Packed vector mode is primarily intended for serial users running in the FSP environment. Using packed vector mode can result in a 4:1 speed increase when inserting absolute move (LDXA, MVYA) and absolute draw (LDXA, DRYA) instruction into refresh.

When packed vector mode is used, a coded PV message is sent to the GRAPHIC 7. The PV message contains a series of ASCII characters that reflect the moves and draws that should be stored in refresh. The GRAPHIC 7 decodes the PV message and generates the equivalent LDXA, MVYA, and DRYA instructions and stores them in refresh.

Two modes are available: add and edit. For add mode, an appropriate return instruction is added to the end of the refresh code created from the data bytes contained in the PV message. If no LM message has been sent, the standard return (octal code 2300) is added to refresh. If an LM message has been sent, the coded return (octal code 0) is added to refresh. For edit mode, no return instruction is added to refresh.

5.1.2.11 Option Support. Software options allow the GRAPHIC 7 to expand into a more specialized system while maintaining a common firmware program (i.e., GCP+). GCP+ includes a method for the user to load, test, initialize, and link several options together to enhance system requirements. There are a variety of option types that can be supported by GCP+, such as:

1. Sanders-developed software to support a present or future option, such as GCP+ messages to provide sophisticated 3D coordinate converter support at the GRAPHIC 7 end.

2. Customer-developed software to meet a unique requirement, such as local editing of text at the GRAPHIC 7 end.

3. Sanders-developed control programs that effectively replace the GCP+ program.

4. Customer-developed control programs that effectively replace the GCP+ program.

Normally the option software is stored on the expansion module. GCP+ also supports the downloading of options from a host computer. See table 5-10.

Table 5-10. Option Group Messages

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
IY INITIALIZE 2 044531 Host to G7	IY is a 2-word message that performs one of the following actions: load all system automatic load options; unload all options; load specified option (if unloaded), initialize option, and update option status.
GO GIVE OPTION STATUS 043517 Host to G7	GO is a 2-word message that lets the host computer verify the status of an option. Word 1 identifies the options (either all or one specified option). The GRAPHIC 7 responds by sending an RO message; if all options are specified, the RO message is followed by a VL message.
RO RETURN OPTION 051117 G7 to host	For a single option status return: word 1 contains the option identification and status; word 2 contains the option initialization address, word 3 contains the option last address + 2.

Table 5-10. Option Group Messages (Cont)

COMMAND HEADER COMMAND NAME COMMAND CODE DIRECTION	DESCRIPTION
	For a multiple option status return: word 2 contains the number of words to be transferred. Words 1 and 3 contain all zeros. In the following VL message, word 1 contains the number of words to be transferred; words 2 through n contain the option identification and status (one option per word).

5.2 FORTRAN SUPPORT PROGRAM

5.2.1 SUBROUTINE CONCEPT. FSP is a collection of 61 FORTRAN-callable subroutines. The routines require little knowledge of the GRAPHIC 7 terminal, yet give the user maximum use of its interactive abilities.

FSP is designed to run in any host computer which supports FORTRAN and has a minimum word length of 16 bits. The actual hardware method by which the GRAPHIC 7 terminal is connected to the host is of no concern to FSP since it is I/O independent. I/O considerations such as parallel or serial interfaces, half or full-duplex, selector or multiplexer channels, etc., are incorporated in the customer supplied I/O driver and hardware interface, leaving FSP computer independent. Depending on the host computer, Sanders, by special request, will supply the I/O driver.

5.2.1.1 Structure. FSP employs the distributed processing approach, because it requires and makes extensive use of the Graphic Control Program Enhanced (GCP+) which is resident in read-only memory in the GRAPHIC 7.

Figure 5-1 shows that the application program uses FSP by making calls to the various subroutines. FSP formats GCP+ compatible messages and transmits them to the GRAPHIC 7 terminal via the MSGOUT subroutine (provided by the customer). The GCP+ receives and processes the message to produce the desired results. FSP also receives and interprets messages from the GCP+ response to a POLL request. These messages contain PHOTOPEN, keyboard, and position entry devices information. GCP+ sends messages to FSP only when polled. Each message (input or output) contains a header word to identify the message and the remainder of the message. FSP may send a message to the GCP+ at any time.

5.2.1.2 Error Detection Receiving. Errors generated in running FSP are detected and an error code is displayed in the upper left corner of the display screen. This error display area can be turned on or off (displayed or not displayed) by user calls to routines ENBERR, to turn error display on, or DSAERR to turn error display off. See the Programmer's Reference Manual for more detailed description of these routines.

Error detection is also available under program control. User calls to EVENT, the routine which polls the terminal for an event or request response, send back an event code indicating an error has been detected. The user can now call subroutine GETERR to retrieve the error code. Detailed description of these routines appear in the Programmer's Reference Manual.

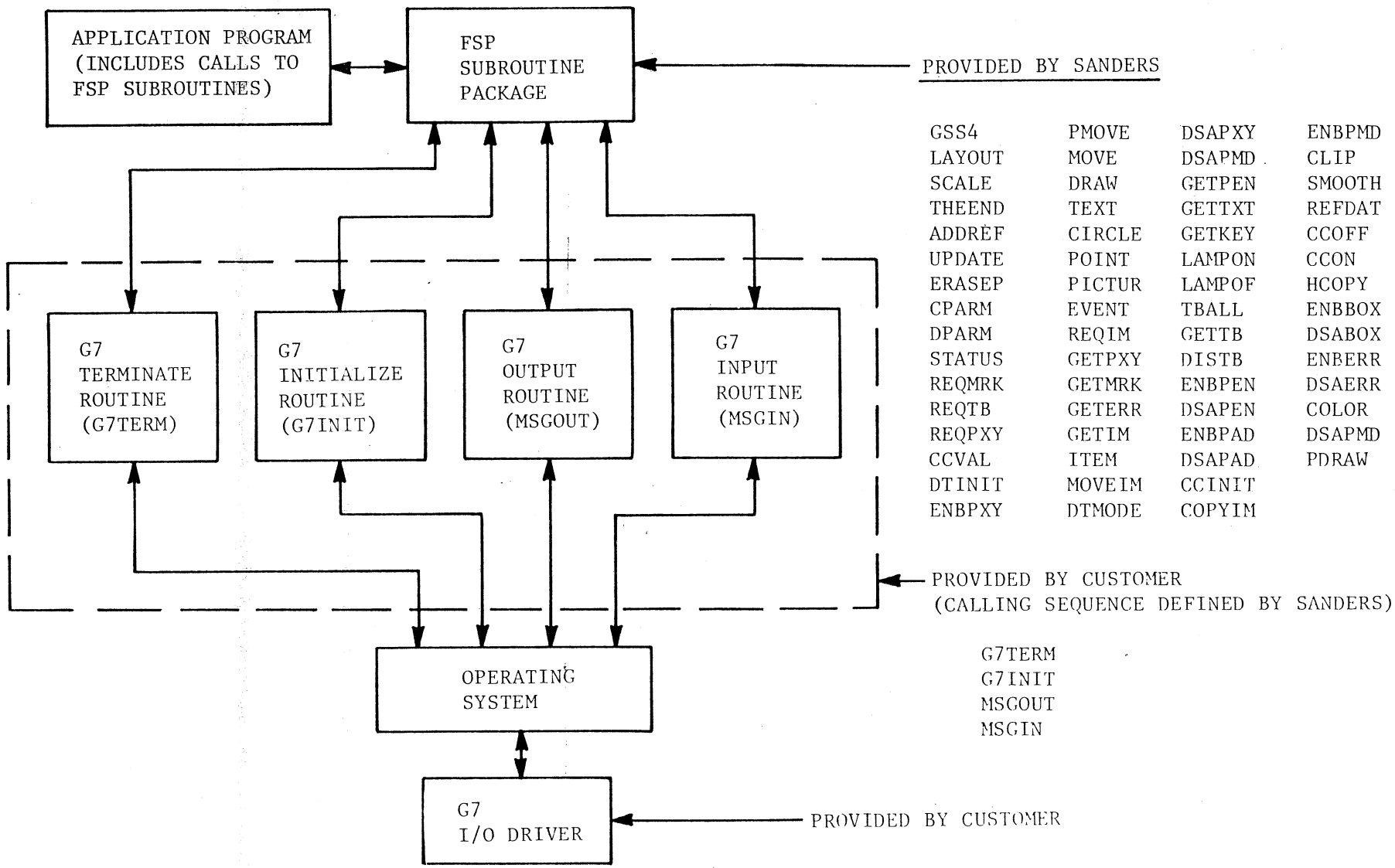

Figure 5-1. Host Computer Software Configuration for Terminal

5.2.2 FEATURES OF FSP. The standard features of FSP are specified below:

1. FORTRAN callable subroutines.

2. Distributed processing: some features are performed in the host computer, others in the GRAPHIC 7 terminal.

3. FSP is machine independent.

4. Refresh paging mechanism for organizing refresh data. This includes refresh subroutine capability.

5. Windowing of user data including:

   a. Data scaling: the conversion of user coordinates to refresh coordinates and vice versa.

   b. Image scissoring: truncating portions of a display that extend beyond the screen boundaries.

6. Modifying images presently displayed (selective updating).

7. Each copy of FSP in the host supports one GRAPHIC 7 controller with four CRT indicators, two keyboards, two trackballs or data tablets, two PHOTOPENs, conic generator, and 2D coordinate converters.

8. Operator interactions with application program:

   a. A/N keyboard

   b. Function keys

   c. Trackball, forcestick or data tablet

   d. PHOTOPEN

9. Generation of all refresh instructions including image generation commands (MOVE, DRAW, CIRCLE, POINT, TEXT).

10. Smoothing of user data to minimize the number of coordinates necessary for presenting a continuous line.

11. Local trackball operation performed at the terminal.

    a. Trackball symbol locally updated at the terminal.

    b. Symbol may be user defined or the default symbol.

12. Local keyboard manipulations performed at the terminal.

    a. Characters typed directly into a refresh scratch pad.

    b. Scratch pad area can be edited from the keyboard.

13. Local PHOTOPEN operations performed at the terminal.

    a. PHOTOPEN finder - The position of the PHOTOPEN on the screen is determined by the GCP+, by flashing a grid pattern locating the PHOTOPEN position.

14. Mass transfer of existing refresh data to the terminal. This allows for off-line generated refresh code to be passed directly to the GRAPHIC 7 terminal and inserted into the refresh memory without any additional processing.

15. All floating point arithmetic processing of FSP is done in the host computer. The GRAPHIC 7 GCP+ performs fixed point arithmetic.

16. For inserting refresh code, two modes of operation exist:

    a. Initial or additional data.

    b. Editing data (selective updating).

17. Hard copy capability. The application program can request that the image on the screen be hard copied on the Sanders hardcopy unit.

18. Displayed images can be rotated and translated on the CRT. Four subroutines exist for manipulating the coordinate converter hardware option.

19. All position data transmitted between host and GRAPHIC 7 is in screen coordinates.

5.2.3 FSP DISTRIBUTED PROCESSING. Graphics tasks are distributed between FSP in the host and GCP+ in the terminal as follows:

1. FSP Processing

    a. All floating conversion.

        (1) Scaling: conversion of user floating point coordinates to display coordinates.

        (2) Windowing: zooming and offsetting.

    b. Scissoring: the clipping of off screen data.

    c. Smoothing: the removing of unneeded points in defining a continuous line.

    d. Formatting and transmitting the message to the GRAPHIC 7 terminal.

    e. Receiving and converting all messages from the GRAPHIC 7 terminal to a manageable form for FORTRAN. This includes converting screen coordinates to floating point user coordinates.

    f. Controls refresh file management, LAYOUT.

2. GCP+ Processing

   a. Receives messages from the host computer.

   b. Processes messages from the host computer.

   c. Handles trackball/forcestick/data tablet manipulations and symbol.

   d. Finds the PHOTOPEN position on a blank screen.

   e. Displays A/N keyboard inputs on the screen in a predefined scratch pad area.

   f. Handles editing of text displayed in the scratch pad.

   g. Formats all messages to the host computer.

   h. Services all display interrupts.

   i. Services all display peripheral devices.

   j. Performs validation test and diagnostics.

5.2.4 FSP SUBROUTINE LIBRARY

1. Setup Routines
   - a. GSS4
   - b. LAYOUT
   - c. SCALE
   - d. ENBBOX
   - e. DSABOX
   - f. ENBERR
   - g. DSAERR
   - h. THEEND

2. Image Generation Routines
   - a. MOVE
   - b. DRAW
   - c. TEXT
   - d. POINT
   - e. CIRCLE
   - f. REFDAT

3. Page Management Routines
   - a. ADDREF
   - b. UPDATE
   - c. EASEP
   - d. PICTURE
   - e. REQMRK
   - f. GETMRK

4. Status Routines
   - a. CPARM
   - b. DPARM
   - c. STATUS
   - d. LAMPON
   - e. LAMPOF
   - f. COLOR

5. Event Routine
   - a. EVENT

6. Alphanumeric/Function Keyboard Routines
   - a. ENBPAD
   - b. DSAPAD
   - c. GETTXT
   - d. GETKEY

7. PHOTOPEN Item Routines
   - a. ENBPEN
   - b. DSAPEN
   - c. ITME
   - d. GETPEN

8. PHOTOPEN Scan Routines
   a. ENBPXY
   b. DSAPXY
   c. REQPXY
   d. GETPXY
9. Trackball/Forcestick/Joystick/ Data Tablet Routines
   a. REQTB
   b. GETTB
   c. DTINIT
   d. DTMODE
   e. REQPST
   f. GETPST
   g. TBALL
   h. DISTB
10. Miscellaneous Routines
   a. HCOPY
   b. MOVEIM
   c. COPYIM
   d. REQIM
   e. GETIM
   f. GETERR
11. Packed Vector Routines
   a. ENBPMD
   b. PDRAW
   c. PMOVE
   d. DSAPMD
12. Coordinate Converter Routines
   a. CCINIT
   b. CCVAL
   c. CCON
   d. CCOFF
13. Image Control Routines
   a. CLIP
   b. SMOOTH

5.2.5 HARDWARE CONFIGURATIONS SUPPORTED. FSP supports either one or two display stations. A display station may have the following equipment:

- Monitor
- Slave monitor
- PHOTOPEN
- Trackball or forcestick or data tablet
- Alphanumeric/function keyboard
- Hardcopy unit

The basic FSP supports the following hardware in the terminal controller:

- Memory configurations up to 128K
- Character generator
- Vector/position generator
- Ramp/conic generator
- 2D coordinate converter

5.2.6 PAGING CONCEPT. A GRAPHIC 7 may be configured to have up to four 32K banks of memory for a total of 128K of memory. GCP+ and the memory required to support it occupies approximately 9K of space in memory bank 0 and leaves approximately 23K of space for the user's refresh program. The entire 32K in memory banks 1, 2, and 3 is available for refresh. The approximate total useable refresh space in a 128K system, therefore, is 119K.

The following chart summarizes the amount of user refresh program space available for the various memory configurations:

Total Memory	User Refresh Space
16K	15K*
32K	23K
64K	55K
96K	87K
128K	119K

*This memory configuration is an exception.

FSP uses a paging and mark approach where the following definitions are used:

"Page" Definition

- A page is a contiguous block of memory locations.
- A page may range in size from 4 memory locations to 32K-4 memory locations.
- A maximum of 255 pages may be defined.
- A page is referred to by a numeric value which ranges from 1 to 255.
- A page normally contains refresh commands generated by the various calls to FSP.
- Pages are defined by a call to LAYOUT in the host but physically exist in the memory of the GRAPHIC 7.
- A page may not cross bank boundaries.
- Page 1 exists entirely in memory bank 0.
- Page 1 is always refreshed and can be thought of as the "mainline" refresh program.
- Pages 2 and above are not always refreshed and may be thought of as refresh subroutines.

"Mark" Definition

- A mark is a relative pointer into a page.
- Each page has a corresponding mark pointer associated with it.
- Mark values range from 0 to 32K-4; e.g., a mark value of 4 refers to the 5th memory location relative to the start of a page.
- The length of a page is defined in terms of marks.

The LAYOUT call allows the caller to define graphic pages (section up memory). The page and mark combination allow any memory location to be addressed by the FSP routine.

5.2.7 COORDINATE SYSTEM. The user can define the limits of the coordinate system he will use by calling subroutine SCALE with parameters defining the lower left and the upper right coordinates of the screen. FSP converts these floating point coordinates to integer display coordinates as the various FSP routines are called. It is the display coordinates which are passed to the GCP+ program. Without a call to SCALE, the user coordinate system is the same resolution as the display coordinate system. The lower left point is defined as (0.,0.) and the upper right point as (+1023.,+1023.). See the Programmer's Reference Manual for a detailed description of subroutine SCALE.

5.2.8 USE OF LABELLED COMMON. FSP uses labelled common. The user should be careful not to use these common block names within his program. These common blocks and their dimensions are as follows:

Common Block Name	Common Block Length (Words)
TERMB	279
COORD	9
PVMD	9
LAYOT	516
MAST	5
PERIPH	6
PEN2	2
PEN	1
LMEM	11
Total	838

5.3 GET-2 EMULATOR

The GRAPHIC 7 with the optional GET-2 (Graphics Emulator Tektronix) intelligence installed appears to a host computer as a Tektronix 4014-1 Terminal with the Enhanced Graphics Module (EGM) option. The GET-2 intelligence is in addition to the standard graphic control intelligence (GCP+) which is an integral part of every GRAPHIC 7 system.

GET-2 resides in the GRAPHIC 7 as firmware on the EPROM expansion module and is selected for execution either by host control or by local operator control. Once activated, GET-2 receives and processes control and data characters from the host in a manner similar to Tektronix. Control and data characters generated by GET-2 for transmission to the host are also Tektronix compatible.

Since a GRAPHIC 7 is refreshed calligraphic display and physically different from the Tektronix 4014-1 storage tube display, it is not possible to achieve an exact 100% emulation. Except for the extremely rare exception, however, GET-2 allows execution of all existing Tektronix programs without any modification.

GET-2 requires either a direct serial or modem interface to the host computer and supports speeds up to 9600 baud.

GET-2 supports a single display station which, as a minimum, contains a CRT and keyboard. The hardcopy device is optional (4014 or 4014-1) and the trackball or forcestick is optional if crosshair cursor control is required.

GET-2 Mode Support

- Alpha
- Graph
- Gin

GET-2 Control Character Processing

BEL	ETB	RS
BS	FF	SUB
CAN	FS	US
CR	GS	VT
ENQ	HT	
ESC	LF	

GET-2 Keys/Switches/Strapping

A visual menu approach is used for examining and changing the following switches, keys and strappings:

TTY lock	Copy control	Release
Terminal status	Echo	Error indicator
Gin mode	CR effect	Bell indicator
Margin control	LF effect	Page full indicator

GET-2 Function Keys

Three of the 16 function keys are reserved for GET-2 use:

Menu select

Page

Reset

GET-2 Enhanced Graphics Module (EGM)

Most of the features of the EGM are provided, including:

- 4096 x 4096
- Line types
- Incremental point plot
- Special point plot
- Point plot

Memory Considerations

8K words is the recommended memory required to satisfactorily use GET-2. This 8K includes the GET-2 intelligence itself (4K as firmware) and also 4K words of refresh memory. Since GET-2 maps host characters into GRAPHIC 7 refresh commands, the amount of refresh space must be considered. The above mentioned 4K of refresh memory is usually more than enough space for typical display presentations. The following chart shows the amount of GET-2 refresh space available for the various memory configurations supported by a GRAPHIC 7:

Memory Installed	GET-2 Refresh Available
16K*	11K
32K	19K
64K	19K
96K	19K
128K	19K

The above chart reflects the following considerations:

1. The 9K of overhead required by the standard intelligence (GCP+) in some memory configurations does not subtract from the useable memory (*).

2. 19K of refresh memory is more than sufficient refresh and therefore GET-2 does not utilize the extra memory provided by memory configurations larger than 32K.

Prerequisites

The following equipment is required for GET-2:

- Terminal controller
- Memory as determined by the above chart
- Multiport serial interface
- Keyboard
- Optional trackball or forcestick
- Optional hardcopy unit
- Display indicator
- Expansion module

Further detailed information is provided in the GET-2 users manual.

SECTION 6

SYSTEM SUPPORT

6.1 MAINTAINABILITY

Ease of maintenance was a prime consideration in the design of the GRAPHIC 7. 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.

6.1.1 MAINTENANCE CONCEPT. The GRAPHIC 7 maintenance concept consists of rapid, unambiguous on-site 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.

6.2 QUALITY ASSURANCE

Sanders inspection and quality control 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.

SECTION 7

GRAPHIC 7 SPECIFICATIONS

This section contains, in tabular form, the specifications for components of the GRAPHIC 7 system.

Table 7-1. Terminal Controller Specifications

PHYSICAL CHARACTERISTICS	
Height	10.5 inches (26.8 cm)
Width	19.0 inches (48.2 cm), including mounting flanges
Depth	16.0 inches (40.6 cm)
Weight	55 lbs (25 kg) including circuit cards
CABINET CHARACTERISTICS	
Height	30 inches (76.2 cm)
Width	23 inches (58.4 cm)
Depth	30 inches (76.2 cm)
Weight	155 lbs (70.3 kg)
CIRCUIT CARD CHARACTERISTICS	
Height	12-3/8 inches (31.4 cm)
Width	7-3/4 inches (19.7 cm)
ENVIRONMENTAL CHARACTERISTICS	
Power source	100-120 Vac or 200-240 Vac, 48-63 Hz
Power	250 watts
Storage temperature	0^{o} to 50^{o}C
Operating temperature	15^{o} to 40^{o}C
Relative humidity	10% to 90%

Table 7-1. Terminal Controller Specifications (Cont)

DISPLAY PROCESSOR	
General purpose microprocessor	Yes
Word length	16 bits
Byte mode	8 bits
Instructions	more than 400
Registers	8
Software stacks	Yes
Automatic interrupt priority	Yes
Memory	16 bits
* ROM	8192 words
* RAM	16384 words
* RAM expansion to	131,072 words (less ROM)
DIGITAL INTERFACE OPTIONS	
Parallel	16 bits
Serial	RS232C
VECTOR/POSITION GENERATOR	
Addressable locations	2048 by 2048
Nominal viewing area	1024 by 1024
Line structures	4
Programmable speeds	2
Adaptive timing	Yes
CHARACTER GENERATOR	
Type	Cursive stroke
Standard character set	96 ASCII
User defined	Up to 96
Aspect ratio	3:2 (normal)
Rotation	90^{o} CCW
Character sizes	4
Tabular characters	Auto text spacing
High speed	2.4 us (typical) 3.0 us with tab
Programmable speeds	2
Adaptive timing	Yes

Table 7-1. Terminal Controller Specifications (Cont)

OUTPUT CHANNEL	
Number of displays	4
X axis channels	4
Y axis channels	4
Z channels	4
X, Y channels	-5V to +5V
Z channels (video	0 to 1.5V
Z channels (color)	-1.5V pulses
Impedance	75 ohms
Brightness levels	8
Blinking, adjustable	0.5 to 5.0 Hz

Table 7-2. Model 730 Series Display Indicator Specifications

PHYSICAL CHARACTERISTICS				
Dimensions	730	731	732	733
Height (inches)	21.4	19.0	24.0	24.0
(cm)	54.4	48.3	61.0	61.0
Width (inches)	23.5	24.0	23.2	18.3
(cm)	56.7	61.0	58.9	46.5
Depth (inches)	30.4	28.9	29.3	28.9
(cm)	77.2	73.4	74.4	73.4
Weight (lbs)	98	98	98	98
(kg)	44.5	44.5	44.5	44.5

ELECTRICAL CHARACTERISTICS	
Input power requirements, 110 Vac service	99-122 Vac, 60 Hz, 1 phase, 4.5A, 0.575 kVA worst case
Input power requirements, 220 Vac service	198-242 Vac, 50 Hz, 1 phase, 2.38A, 0.575 kVA worst case
Input power requirements 240 Vac service	216-264 Vac, 50 Hz, 1 phase, 2.18A, 0.575 kVA worst case

Table 7-2. Model 730 Series Display Indicator Specifications (Cont)

ENVIRONMENTAL CHARACTERISTICS	
Operating temperature range	+50°F to +95°F (+10°C to +35°C)
Operating temperature change	18°F/60 minutes (10°C/60 minutes)
Storage temperature range	+14°F to +122°F (-10°C to +50°C)
Storage temperature change	27°F/60 minutes (15°C/60 minutes)
Operating humidity range	20% to 80%
Storage humidity range	10% to 90%
Maximum operating altitude	10,000 feet (3,048 meters) above mean sea level
Safe operating shock	2g for 10 ms
Safe non-operating shock	3g for 10 ms
OPERATIONAL CHARACTERISTICS	
Display type	X, Y, Z with CRT readout
CRT	Single gun, 21-inch rectangular, P40 phosphor,* electromagnetic deflection, electrostatic focus
Maximum image size	12 by 12 inches** nominal
Video (Z) input	0 to +1.5V; 0V = screen blanked
Full screen deflection (X, Y)	X = ±5V, Y = ±5V
Line width	0.020 inch for P40, P31 phosphors 0.030 inch for P39, P39D phosphors
Ambient light (perpendicular to CRT)	35 foot candles (377 lux)
Recommended minimum refresh rate	P40 - at least 45 Hz P31 - at least 50 Hz
Contrast	4:1 (P40 phosphor at 60 Hz refresh rate)
Drift	0.25 inch (6.4 mm) in 8 hours
Jitter	Less than 0.010 inch (0.25 mm)
Intensity levels	At least 6 discernible levels
Geometric distortion	0.120 inch maximum
Vector linearity	±1% of vector length or ±0.020 inch, whichever is larger
Vector end point accuracy	Less than 0.020 inch for vectors up to 3 inches long; less than 0.025 inch for vectors longer than 3 inches
Repeatability	Less than 0.030 inch

* Optional phosphors available: P31, P39, P39D
**12 by 16 inches nominal available as an option

Table 7-3. Model 740 Series Display Indicator Specifications

PHYSICAL CHARACTERISTICS				
Dimensions	740	741	742	743
Height (inches)	21.4	19.0	24.0	24.0
(cm)	54.4	48.3	61.0	61.0
Width (inches)	23.5	24.0	21.3	19.0
(cm)	56.7	61.0	54.1	48.3
Depth (inches)	29.0	29.0	29.0	29.5
(cm)	73.7	73.7	73.7	74.9
Weight (lbs)	140	140	140	140
(kg)	63.6	63.6	63.6	63.6

ELECTRICAL CHARACTERISTICS	
Input power requirements	100, 110, 115, 120, 200, 208, 220, 230, 235, or 240 Vac ± 10%, 1 phase, 47 to 63 Hz, 400W (average)

ENVIRONMENTAL CHARACTERISTICS	
Operating temperature range	+15°C to +45°C (+59°F to +113°F)
Storage temperature range	-10°C to +55°C (+14°F to +131°F)
Relative humidity	10% to 90%, non-condensing

OPERATIONAL CHARACTERISTICS	
Display type	X, Y, Z with CRT readout
CRT	Single gun, 21-inch rectangular, P49 phosphor, electromagnetic deflection, electrostatic focus
Maximum image size	12 by 12 inches* nominal
Full screen deflection	X = ±5V, Y = ±5V; selectable 1K ohm or 75 ohm termination
Line width	0.015 inch (nominal)
Ambient light (perpendicular to CRT)	1 foot candle
Recommended minimum refresh rate	60 Hz
Line brightness	Red = 2 fl, orange = 3.5 fl, yellow = 8 fl, green = 32 fl at 350K inch/second
Contrast	4:1 minimum
Drift	0.25 inch (6.4 mm) in 8 hours

*12 by 16 inches available as an option

Table 7-3. Model 740 Series Display Indicator Specifications (Cont)

OPERATIONAL CHARACTERISTICS (Cont)	
Jitter	Less than 0.010 inch (0.25 mm)
Intensity levels	At least 6 discernible levels
Geometric distortion	Not more than 1% of full scale
Vector linearity	Not more than 1% of full scale or 0.1% for any 10% of full scale
Vector end point accuracy	0.020 inch
Repeatability	0.1% of full scale

Table 7-4. Model 760 Series Display Indicator Specifications

PHYSICAL CHARACTERISTICS	
Height	25.3 inches (64.3 cm)
Width	30 inches (76.2 cm)
Depth	34 inches (86.4 cm)
Weight	Approximately 175 lbs (79.5 kg)
ELECTRICAL CHARACTERISTICS	
Input power requirements	100, 110, 115, 120, 200, 208, 220, 230, 235, or 240 Vac ±10%, 1 phase, 47 to 63 Hz, 400W average
ENVIRONMENTAL CHARACTERISTICS	
Operating temperature range	+15°C to +45°C (+59°F to +113°F)
Storage temperature range	-10°C to +55°C (+14°F to +131°F)
Relative humidity	10% to 90%, non-condensing
OPERATIONAL CHARACTERISTICS	
Display type	X, Y, Z with CRT readout
CRT	Single gun, 23-inch round, P49 phosphor, electromagnetic deflection, electrostatic focus
Maximum image size	20 inches nominal diameter
Full screen deflection	X = ±5V, Y = ±5V; selectable 1K ohm or 75 ohm termination
Line width	0.015 inch (0.38 mm) (nominal)
Ambient light (perpendicular to CRT)	1 foot candle

Table 7-4. Model 760 Series Display Indicator Specifications (Cont)

OPERATIONAL CHARACTERISTICS (Cont)	
Recommended minimum refresh rate	60 Hz
Line brightness	Red = 2 fl, orange = 3.5 fl, yellow = 8.0 fl, green = 32 fl at 350K inches/second
Contrast	4:1 minimum
Drift	0.25 inch (6.4 mm) in 8 hours
Jitter	Less than 0.010 inch (0.25 mm)
Intensity levels	At least 6 discernible levels
Geometric distortion	Not more than 1% of full scale
Vector linearity	Not more than 1% of full scale or 0.1% for any 10% of full scale
Vector end point accuracy	0.020 inch (0.5 mm)
Repeatability	0.1% of full scale

Table 7-5. Models 5783/5784 Alphanumeric/Function Keyboard Specifications

PHYSICAL CHARACTERISTICS	
Height	3.7 inches (94 mm)
Width	18.75 inches (475 mm)
Depth	8.1 inches (206 mm)
Weight	7 lbs (3.2 kg)
ELECTRICAL CHARACTERISTICS	
Input power requirements	+5V ± 1%, 750 mA max +15V ± 1%, 50 mA max -15V ± 1%, 50 mA max
ENVIRONMENTAL CHARACTERISTICS	
Operating temperature range	$40^{\circ}F$ to $120^{\circ}F$ ($4^{\circ}C$ to $49^{\circ}C$)
Storage temperature range	$-40^{\circ}F$ to $140^{\circ}F$ ($-40^{\circ}C$ to $60^{\circ}C$)
Storage pressure range	19 to 32 inches Hg (483 to 813 mm Hg)
Humidity	5% to 95%, non-condensing

Table 7-5. Models 5783/5784 Alphanumeric/Function Keyboard Specifications (Cont)

OPERATIONAL CHARACTERISTICS	
Alphanumeric keys	55, momentary action, of which 50 are upper and lower case
Matrix keys	16, momentary action
Function keys	16, momentary action
Output levels	Logic low is 0.0 to +0.45V Logic high is +2.45 to +5.25V
Output signal characteristics	Serial, RS232 compatible, negative true; Rest = low Logic 1 = low Code = 10 bit (start bit, 8 data bits, stop bit)
Maximum cable length (keyboard to terminal controller)	Model 5783 - 50 feet Model 5784 - 50 feet

Table 7-6. Model 5786 Trackball Specifications

Height	3.3 inches (8.4 cm)
Width	5.0 inches (12.7 cm)
Depth	7.5 inches (19 cm)
Weight	3.0 lbs (1.36 kg)
Power requirements	+5V, 410 mA +15V, 20 mA
Operating temperature range	$59^{o}F$ to $104^{o}F$ ($15^{o}C$ to $40^{o}C$)
Humidity	10% to 90%
Ball diameter	2 inches (5.1 cm)
Force to move ball	15 grams (typical)
Cursor movement	300 display elements per ball revolution
Resolution	Within 1 display element in 1024
Mechanical action	Friction drive, spring loaded
Word repetition rate	37.5 words/second
Output code	256-bit binary words, 9600 baud, asynchronous
Signals levels	RS232C
Cable	6 feet supplied, 50 feet maximum length
Connector	Cannon DA-15P

Table 7-7. Model 5787 Forcestick Specifications

Height	3.3 inches (8.4 cm)
Width	5.0 inches (12.7 cm)
Depth	7.5 inches (19 cm)
Weight	2.5 lbs (1.15 kg)
Power requirements	+5V, 450 mA ±15V, 20 mA
Operating temperature range	59°F to 104°F (15°C to 40°C)
Humidity	10% to 90%
Force to move forcestick	37 grams minimum to 909 grams maximum
Cursor movement	1280 display elements/second maximum
Resolution	Within 1 display element in 1024
Mechanical action	Spring return to center
Word repetition rate	37.5 words/second
Output code	256-bit binary words, 9600 baud, asynchronous
Signal levels	RS232C
Cable	6 feet supplied, 50 feet maximum length
Connector	Cannon DA-15P

Table 7-8. Model 5781 PHOTOPEN Specifications

Length	6.0 inches (15.2 cm)
Diameter	0.6 inch (1.5 cm)
Weight (including cable)	4.0 ounces (112 grams)
Power requirement	+5V at 25 mA
Operating temperature range	+15°C to +40°C
Relative humidity	30% to 90%
Cable	58-inch, 4-wire, 5-pin connector
Sensitivity	10 foot-lamberts with 150 ns pulse on P31 phosphor at 60 Hz refresh rate (typical)
Response time	500 ns max (measured with 40 foot-lamberts with 150 ns pulse on P31 phosphor at 60 Hz)
Immunity	No false triggering caused by normal fluorescent or incandescent lamps producing 100 foot-lamberts at display level
Electromagnetic interference	Immune to normal computer and display system EMI

Table 7-8. Model 5781 PHOTOPEN Specifications (Cont)

Focal length	Optimized for 3/4-inch distance from lens to display screen phosphor plane
Spectral response	Approximately 4000Å to 11000Å
Manual switch	Solid-state switch activated by pressing PHOTOPEN tip against CRT face
Switch output	TTL signal compatible; logic high when switch not activated, logic low while switch is activated

Table 7-9. Model 5788 Data Tablet Specifications

Height	1-3/4 inches (4.4 cm)
Width	15-3/4 inches (40 cm)
Depth	15-3/4 inches (40 cm)
Weight	7 pounds (3.2 kg)
Power requirement	+15V, 150 mA
Operating temperature range	15°C to 40°C
Stylus length	5-1/2 inches (14 cm)
Stylus diameter	0.5 inch (1.3 cm)
Stylus cable length	40 inches (102 cm)
Active surface area	11 by 11 inches (28 cm by 28 cm)
Resolution	400 lines/inch (157 lines/cm)
Accuracy	0.025 inch (.60 mm)
Coordinate refresh rate	120 pairs/second
Operating modes	Point, run
Output configurations	Parallel, binary and BCD (option 1) Serial, TTL and RS232 (option 2)
Parallel outputs	Binary or BCD, switch selectable
Port size	8 bits
Data format	9 bytes/coordinate pair. Byte 1 = status. Bytes 2 through 5 = X data. Bytes 6 through 9 = Y data
Byte format	Bits 0-3 = data; bits 4-7 = byte address
Additional control lines	Data ready strobe
Output compatibility	TTL
Serial output data format	10 bytes/coordinate pair. Byte 1 = status. Bytes 2 through 5 = X data. Bytes 6 through 9 = Y data. Byte 10 = carriage return

Table 7-9. Model 5788 Data Tablet Specifications (Cont)

Byte format	ASCII
Baud rate	Externally programmable
Output compatibility	TTL, $\overline{\text{TTL}}$, RS232

Table 7-10. Model 770 Hardcopy Unit Specifications

Height	42 inches (106.7 cm)
Width	23 inches (58.4 cm)
Depth	30 inches (76.2 cm)
Weight	275 pounds (124.7 kg)
Power requirements	105-125 Vac, 50/60 Hz; 500W standby, 1000W operate. Can operate on inputs from 100 Vac to 240 Vac.
Operating temperature range	+15°C to +35°C
Storage temperature range	-15°C to +55°C
Relative humidity	To 90%, non-condensing
Paper size (nominal)	8-1/2 by 11 inches (21.6 by 27.9 cm)
Image size	6-3/8 by 8-1/2 inches (16.2 by 21.6 cm) or 7-1/2 inches (19.1 cm) square
Image gray scales	At least 5 discernible levels
Resolution	100 lines/inch (39 lines/cm)
Copy time (approximate)	18 seconds for first copy, 8 seconds each for additional copies
Warmup time	10 minutes
Input signal requirements	X deflection = ±5V, 75 ohms Y deflection = ±5V, 75 ohms Z = 0 to +1.5V, 75 ohms
Remote copy signal	Logic low for 200 us initiates copy command
End-of-copy output signal	Open collector; 10 to 20 us low after end-of-copy exposure time
Paper life (typical)	Approximately 6 months at 20°C Approximately 15 days at 30°C
Multiple input switching	Optional

Table 7-11. Model 575 Hardcopy Multiplex Switch Specifications

Height	5.25 inches (13.3 cm)
Width	19 inches (48.3 cm)
Depth	4 inches (10.2 cm)
Weight	6 pounds (2.7 kg)
Input power requirement	115 ± 10 Vac, 57-63 Hz
Operating temperature range	$15^{\circ}C$ to $40^{\circ}C$ ($59^{\circ}F$ to $104^{\circ}F$)
Storage temperature range	$0^{\circ}C$ to $50^{\circ}C$ ($32^{\circ}F$ to $122^{\circ}F$)
Humidity	10% to 90%, non-condensing
Operating modes	Automatic, manual
Input control signals	COPY REQUEST, a logic high pulse, initiates a copy sequence (both modes) END OF COPY, a logic high pulse from the hardcopy unit, tells the multiplex switch that the copy has been made (automatic mode)
Output control signals	REMOTE COPY, a logic high pulse to the hardcopy unit, initiates a copy sequence (automatic mode) XMIT, a logic high pulse to the terminal controller, indicates that the copy sequence is complete (automatic mode) or that a copy request has been acknowledged (manual mode)
Switched signals	X, Y video from the terminal controllers to the hardcopy unit, -5V to +5V, 75 ohms Z video from the terminal controllers to the hardcopy unit, 0V to +1.5V, 75 ohms
Logic levels	Logic high $\leq$ 2.4V Logic low $\geq$ 0.8V

SECTION 8

RELATED PUBLICATIONS

TITLE
GRAPHIC 7 SYSTEM AND SOFTWARE MANUALS
GRAPHIC 7 Technical Description
GRAPHIC 7 Acceptance Test Procedure
(GCP) Programmer's Reference Manual
GCP Source Listings (Release 2)
GCP Source Listings (Release 4)
GCP+ Programmer's Reference Manual
GCP+ Source Listings Version 0
GCP+ Source Listings Version 1
GSS-4 User's Manual
GSS-4 Version 1.1 Program Listings
Fortran Support Package User's Manual
Multitask User's Manual
Multitask Acceptance Test Procedure
Monitor Software Version 1.0 User's Manual
TERMINAL CONTROLLER MANUALS
Model 7709 Terminal Controller Maintenance Manual
Terminal Controller Maintenance Manual, Volume II, Diagrams and Parts Lists
Terminal Controller Power Supply Model MM23-E0647/115
TERMINAL CONTROLLER OPTIONS MANUALS
GRAPHIC 7 Options Reference Manual
Model 5843 Ramp/Conic Generator Technical Manual
Models 7702-7704 Large Read/Write Memory Technical Manual
Model 5752 2-D Coordinate Converter Technical Manual
Model 5753 2-D/3-D Coordinate Converter User's Manual
Model 7750 Expansion Module Technical Manual
GET-2 Tektronix Emulator User's Manual
GET-2 Tektronix Emulator Source Listing

PARALLEL INTERFACE MANUALS
Model 5716 Parallel Interface to SEL32; HSD-9132
Model 5719 Parallel Interface to Data General NOVA and ECLIPSE
Model 5721 Parallel Interface, NTDS Slow
Model 5722 Parallel Interface to Honeywell 516 DMC
DISPLAY INDICATOR MANUALS
Models 730-733 Monochrome Display Indicators Technical Manual
Models 740-743 Four-Color Display Indicators Technical Manual
Models 760, 763 Four-Color Display Indicators Technical Manual
KEYBOARD MANUAL
Model 5783 Alphanumeric Function Keyboard/Model 5784 Lighted Alphanumeric Function Keyboard
POSITION ENTRY DEVICES MANUALS
Model 5786 Trackball/Model 5787 Forcestick Entry Devices Technical Manual
WEDGE Data Tablet (Talos, Scottsdale, Arizona)
PHOTOPEN MANUAL
Model 5781 PHOTOPEN Unit Technical Manual
HARDCOPY MANUALS
Model 570 Hardcopy Unit Technical Manual
Model 0575 Hardcopy Multiplex Switch Technical Manual

THE INTENT AND PURPOSE OF THIS PUBLICATION IS TO PROVIDE ACCURATE AND MEANINGFUL INFORMATION TO SUPPORT EQUIPMENT MANUFACTURED BY SANDERS ASSOCIATES, INC. YOUR COMMENTS AND SUGGESTIONS ARE REQUESTED.

PLEASE USE THE FORM ON THE REVERSE SIDE TO REPORT ANY PROBLEMS YOU HAVE HAD WITH THIS PUBLICATION OR THE EQUIPMENT IT DESCRIBES.

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My problem is: hardware ☐ software ☐

firmware ☐ manual ☐

Description of problem (or suggestion for improvement):

Related tech manual number _____