SDS

Scientific Data Systems
A XEROX COMPANY

XDS SIGMA GRAPHIC DISPLAY UNIT

MODEL 7580

Reference Manual

Price: $ .75

GRAPHIC DISPLAY UNIT REFERENCE MANUAL

for

XDS SIGMA COMPUTERS

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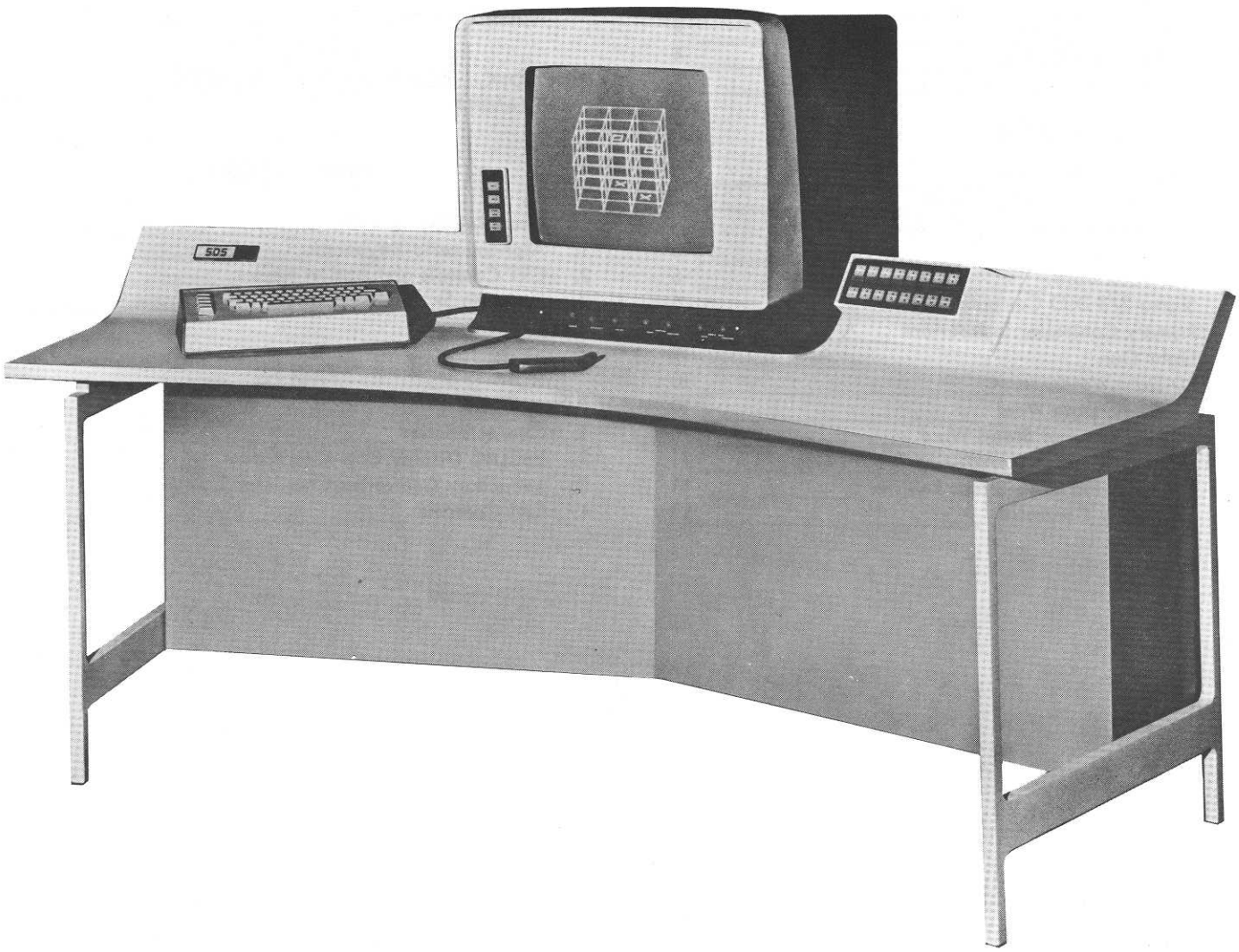
RELATED PUBLICATIONS

Title	Publication No.
XDS Sigma 7 Computer Reference Manual	90 09 50
XDS Sigma 5 Computer Reference Manual	90 09 59
XDS Sigma 3 Computer Reference Manual	90 15 92
XDS Sigma 2 Computer Reference Manual	90 09 64
XDS Sigma 5/7 Symbol/Meta-Symbol Reference Manual	90 09 52
XDS Sigma 2/3 Extended Symbol Reference Manual	90 10 52
XDS Sigma 2 Symbol Reference Manual	90 10 51
XDS Sigma Computer Systems Interface Design Manual	90 99 73

CONTENTS

ILLUSTRATIONS

TABLES



Graphic Display Unit

1. GENERAL DESCRIPTION

INTRODUCTION

The XDS Model 7580 Graphic Display Unit consists of a cathode ray tube (CRT), light gun, and various function switches and action keys. The equipment is designed to promote rapid interaction between operator and computer system, and thereby increase throughput in applications such as logic design systems, data display, management information systems (spot inventory checking, statistical analysis, etc.), numerical analysis, and other projects benefiting from rapid changing of parameters and immediate examination of their effects.

The Graphic Display Unit is physically divided into two parts: display console and primary controller. The display console is a free-standing unit connected by cable to the primary controller. The primary controller is housed in a standard Sigma I/O cabinet.

The primary controller controls all data flow between the display buffer (in the Sigma memory) and the display console. Because the primary controller connects directly to a Sigma memory port, the data stored in memory refreshes the display automatically without the need for CPU intervention. Branch instructions within the display data allow the display to be changed within microseconds without requiring data to be moved from one memory location to another.

The primary controller offers a number of features that contribute to the unit's versatility and ease of use:

1. Choice of absolute or relative coordinates simplifies display manipulations.
2. Up to three sets of coordinates per data word achieve maximum memory utilization.
3. Automatic blinking under program control of any displayed item draws operator's attention to specific areas of the display.
4. Inhibition of light-gun sensing for selected portions of the displayed data allows use of non-sensed "background" information.
5. Two levels of display intensification plus blanking.
6. Automatic refresh with no CPU attention required.
7. Priority interrupt levels to enable program intervention, when required.
8. Subroutining capability when information is repeated in different screen positions reduces core memory requirements.
9. Error checking for memory parity errors, illegal attempts to access protected portions of memory, and screen overflow.

Functional subsystems housed in the display console are the display generators containing the electronics for controlling movement of the electron beam in the CRT; an alphanumeric keyboard that allows the operator to communicate via alphanumeric characters with the central processing unit (CPU); function switches and action keys that allow the operator to rapidly specify functions to be performed; and a light gun that allows the operator to feed back positional data to the CPU or to identify a specific displayed item to which he is pointing.

The display generators provide for hardware generation of: vectors, points, characters in three sizes, and a raster for sensing of light gun position.

The character generator generates 64 characters in three sizes. Characters can be positioned randomly or in adjacent positions to form horizontally placed character combinations. Character drawing time is a function of the size of characters, providing an undistorted, constant-intensity alphanumeric display.

The dot generator allows dots to be plotted on the screen at varying speeds, depending on spacing of the dots. A raster generator allows the unit to detect the position of the light gun when the gun is pointed at unlighted areas of the display screen. No "tracking" routines are needed, thus freeing the CPU for other tasks.

The nominal display area of the 21-inch CRT is 10 inches square. This viewing area accommodates 1024 divisions (raster units) along each of the X and Y axes. Point resolution in the viewing area is approximately 0.010 inch.

The alphanumeric keyboard allows input of the entire set of 64 displayable characters. It also contains five special cursor-motion keys. The function keyboard consists of 16 function switches. In addition, there are four interrupt-generating action keys.

The light gun consists of a photomultiplier and associated control electronics. A thumb switch permits the light gun to respond to light radiation emitted from the face of the CRT. When activated, the light gun detects light from the CRT inside an area defined by a circle of light projected from the light gun onto the CRT faceplate.

Table 1 lists the characteristics of the Graphic Display Unit.

Table 1. Characteristics

CRT Characteristics	
CRT Size	21 in.
Display Area	10 in. by 10 in.
Deflection Method	Electromagnetic
Focusing Method	Electrostatic
Screen Color	Green
Phosphor Type	P31
Stability	± 2%
Repeatability	± 0.5%
Operating Characteristics	
Vector Generator	
Short	0.25 in. coordinates (max.)
Long	Full screen coordinates (max.)
Character Generator	Stroke (continuous line)
Character Size	5/32 in., 5/16 in., and 5/8 in. high
Raster Count	1024 points by 1024 points (total of 1,048,576 points)
Raster Interval	0.01 in. by 0.01 in. (approx.)
Spot Diameter	0.02 in.
Display Speeds	
Points Spaced Less than 1/2 in.	9 μsec
Points Spaced Greater than 1/2 in.	15 μsec
Vectors Shorter than 1/4 in.	6 μsec
Vectors Longer than 1/4 in.	41 μsec

Table 1. Characteristics (cont.)

Operating Characteristics (cont.)	
Character Generator	65 to 73 μsec per 5/32-inch character
Character Positioning Time	7 μsec (<0.5 in.) 13 μsec (>0.5 in.)
Drawing Rate (Normal Size)	
Space, New Line	13 μsec
Average character drawing rate based on a character-to space ratio of 4.5 to 1.	57 μsec (17,600 char/sec.)
The drawing rate for blanked elements is the same as the rates for intensified elements given above.	
Environmental Characteristics	
Temperature	50° F to 104° F
Humidity	10% to 90%
Power Requirements	115 vac ± 10%, 60 Hz ± 2 Hz, 20 amp
Cable Length	
Controller to Console	75 ft (max.)
Physical Characteristics (Console)	
Width	90 in.
Depth	
Overall	51 in.
Desk Top	17 in.
Height	
Overall	53 in.
Desk Top	29 in.
Weight	550 lbs (approx.)

2. FUNCTIONAL DESCRIPTION

The Graphic Display Unit consists of two major components: display console and Primary Controller (PC), housed in a standard Sigma I/O cabinet.

The PC communicates with the CPU via the External Interface Feature (DIO) which is program-controlled by READ DIRECT and WRITE DIRECT instructions. For details, please consult the applicable computer reference manual and the Interface Design Manual (see Related Publications).

The PC directly accesses the computer memory for instructions. It interprets these instructions and generates the codes that the secondary controller requires for drawing displays.

DISPLAY CONSOLE

The display console houses a CRT display system, an alphanumeric keyboard, sixteen function switches, four action keys, and a light gun. The display system consists of a 21-inch CRT, point generator, vector generators, character generator, and raster (view area) generator. The CRT has a nominal viewing area of 100 square inches (10 by 10), with 1024 points along each axis (1,048,576 points in the viewing area). The resolution of each point is approximately 0.01 inch. The vector generators produce vectors at rates dependent on the choice of either "long" or "short" modes (see Chapter 3, Primary Controller Instructions, Format 1). The character generator produces three sizes of characters: 0.18 inch high by 0.12 inch wide; 0.36 inch high by 0.24 inch wide; and 0.72 inch high by 0.48 inch wide. There are 64 characters in the set. Drawing time is a function of the character and its size.

The raster generator scans the viewing area for light gun activation in areas not intensified by display patterns. The light gun is fibre optic/photomultiplier type with a thumb-operated interlock switch.

The alphanumeric keyboard is shown in Figure 1. The keyboard may be linked to either of the two connectors on the display console table top. Once connected, the keyboard may be moved to any desired location on the table top. The keyboard has 57 code generating keys (including the space bar) plus two shift keys and a repeat key. Each time a key is pressed, it generates an interrupt. The keys are EBCDIC coded, and input to the CPU is via direct I/O. There are five cursor function keys: UP, DOWN, RIGHT, LEFT, and HOME.

The 16 function switches (see Figure 3) are programmed by the user to fit his particular needs and may be labeled with a replaceable overlay. These switches are located on a fixed panel to the right of the CRT. There are also four action keys (see Figure 2) producing the same level interrupt as a keyboard depression. They are located on the CRT bezel and are labeled INT1, INT2, STORE, and RESET. STORE and RESET are intended for use with XDS software but may be programmed by the user for his own needs.

INTERFACE

The Graphic Display Unit is compatible with the complete line of Sigma CPUs; however, the Sigma 2/3 interface requires a Sigma 5/7 external memory link. The CPU memory port used must be dedicated exclusively to the Graphic Display Unit. One port may accommodate up to four Graphic

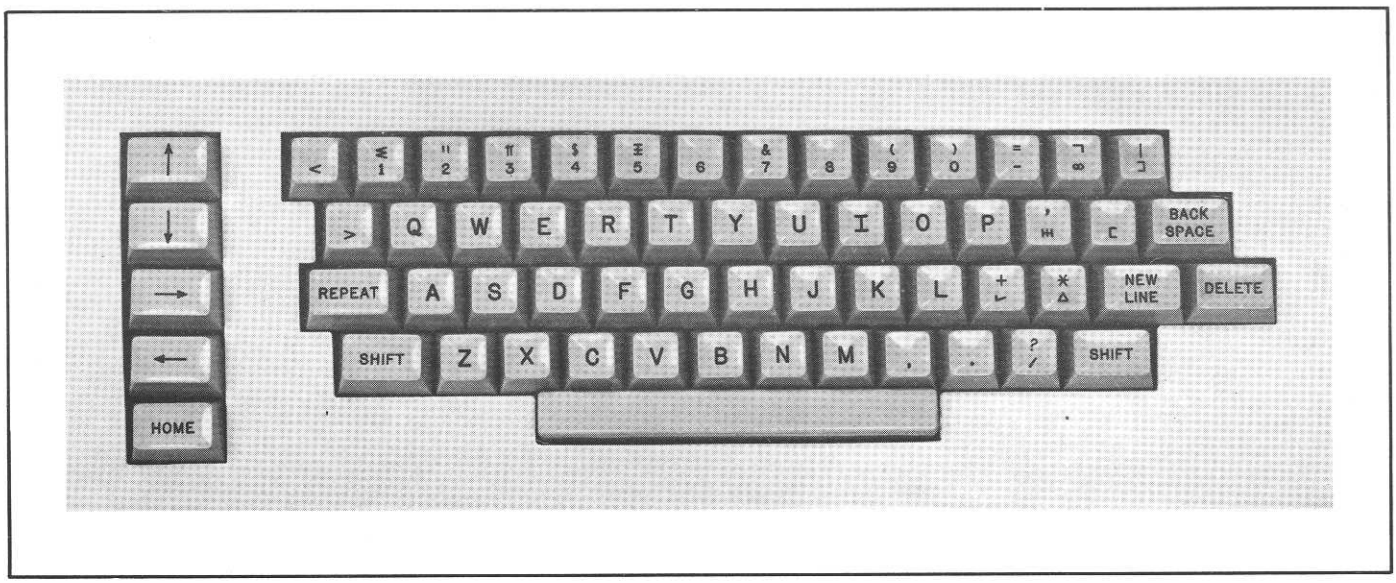


Figure 1. Alphanumeric Keyboard

Display Units. A Sigma 2/3 system operates similarly to the Sigma 5/7 system, except for the necessity of the Sigma 5/7 memory and the Model 8050 or 8150 Memory Adapter which packs two Sigma 2/3 words in one Sigma 5/7 word.

PRIMARY CONTROLLER

The Primary Controller (PC) consists of four module cases containing Sigma 5/7 memory interface logic, direct I/O interface logic, Sigma external interrupt interface logic, and Graphic Display Unit instruction set logic which produces commands for the display generators. The Graphic Display Unit instruction set includes (1) long points or vectors (one per memory word) ranging up to full screen size with relative or absolute coordinate assignment; (2) short points or vectors (three per word) ranging up to 15 raster unit X and Y lengths with relative coordinate assignment; (3) random characters (one per word) with absolute or relative position assignment; (4) tabular characters (four per word) with automatic beam positioning between characters; (5) character size control; (6) display intensity level control; (7) unconditional branch; (8) subroutine branch; and (9) miscellaneous additional display parameters.

PROTECTED MEMORY

The Graphic Display Unit may be used in systems where portions of memory should be "protected" so that the display Primary Controller cannot write into them. To this end, five toggle switches mounted on a printed circuit board in the PC permit specification (at time of installation) of a lower boundary for display system memory accesses. If the PC's address register ever contains five high-order bits that are algebraically less than the binary number represented by these five switches, PC operations are terminated and an error interrupt is generated.

RUN/IDLE CONDITIONS

The PC is either in the "run" condition, in which it is allowed to access memory, or it is in the "idle" condition, in which it is not allowed to access memory. The "run" condition permits either synchronous or asynchronous refreshing of the display image, depending on a bit in the control instruction (see "Format 5, Control Instruction" in Chapter 3). If this bit is set (synchronous), the display is refreshed a maximum of 60 times per second. This method is recommended because asynchronous refreshing may occur much more rapidly and could burn the CRT. Also, asynchronous refreshing may often cause swimming images.

3. PROGRAM INTERFACE

The Graphic Display Unit is controlled through the Direct I/O Interface of the computer.

The data word associated with the Write Direct (WD) instruction is transmitted to the Primary Controller to begin or halt display operations and to perform other control functions. The data word transmitted to the computer as the result of executing a Read Direct (RD) instruction either contains general status information pertaining to the Primary Controller or contains status information on the keyboard, action keys, or function switches.

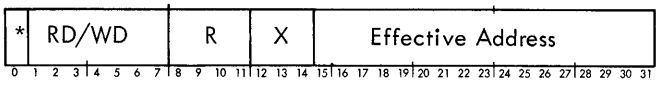
Following execution of the WD instruction, special display instructions, accessed automatically from memory by the Primary Controller, produce the points, vectors, characters, and various display operations that comprise the display pattern.

DIRECT I/O INTERFACE

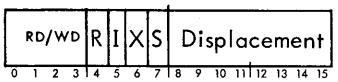
The Direct I/O Interface allows the computer program to control the state of the Primary Controller and to read into the computer the CPU status of light gun, error indicators, alphanumeric keyboard, action keys, and function switches. The format of the RD/WD Direct I/O Instructions is shown below.

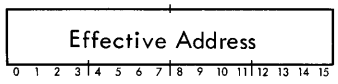
RD/WD INSTRUCTION WORDS

SIGMA 5/7 COMPUTER



SIGMA 2/3 COMPUTER

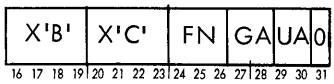




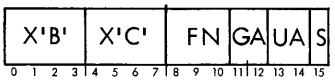
EFFECTIVE ADDRESS OF RD/WD INSTRUCTION WORD

The 16 low-order bits, the effective address, of the READ DIRECT or WRITE DIRECT instruction are allocated as follows:

SIGMA 5/7 COMPUTER



SIGMA 2/3 COMPUTER



where

Bits 16-23 (0-7 for Sigma 2/3) are always X'BC'.

FN is RD or WD Function:

000 = Control WRITE DIRECT

001 = PC Status READ DIRECT

010 = Keyboard Status READ DIRECT

GA is group address, defining one of four groups of four Graphic Display Units, each group connected to a unique Sigma 5/7 memory port.

UA is unit address, defining one of four Graphic Display Units within a group.

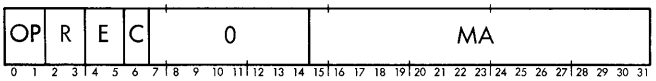
S is submultiplex bit, required for Sigma 2/3 Direct I/O:

0 Bits 0-15 of WD or RD data to be transmitted.

1 Bits 16-31 of WD or RD data to be transmitted.

WD DATA WORD

The 32-bit data word sent to the Primary Controller (PC) as a result of executing a WD instruction may cause the controller to accept an initial memory address, and/or a command to begin or end operations, and/or a command controlling the light gun. Format of the data word associated with WD is



where

OP is the display operation code:

00 No action. This instruction updates the PC's raster and light-gun-enable flip-flops without altering the condition of the PC.

01 Enter "run" condition and transfer display instructions starting at the location specified by the current contents of the address register. If PC is already in "run", this instruction is ignored and status return to CC3† is 1.

†CC3 and CC4 correspond to the Overflow and Carry indicators, respectively, in the Sigma 2/3.

10 Halt. Terminate all operations without altering the address register or any "repeat" state flip-flops and go to "idle" condition. If the PC is already in "idle", this instruction is ignored and status return to CC3† is 1.

11 Enter "run" condition and start transferring display instruction after first loading the memory address (bits 15-31 of this instruction) into the address register and resetting the "repeat" state flip-flops. If PC is already in "run", this instruction is ignored and status return to CC3† is 1.

R is the raster enable:

00 No change
01 Disable raster
10 Enable raster

E is the light gun enable:

00 No change
01 Disable light gun
10 Enable light gun, single hit mode
11 Enable light gun, multiple hit mode

C Clears all registers and all control flip-flops and sets PC to "idle" (1 = clear; 0 = do not clear). This function simulates System Reset via computer Processor Control Panel.

MA is the memory address from which the next display instruction is to be taken. Valid only if OP is 11.

The RD instruction causes status words to be returned to the CPU. These status words are explained later under "RD Data Words".

SIGMA 2/3 DIO COMPATIBILITY

The data words described for the RD/WD instructions are 32-bit words, that is, for a Sigma 5/7 DIO interface. The Graphic Display Unit also provides for a mode of operation employing a 16-bit DIO interface.

The purpose of this alternative operating mode is to permit the PC to be controlled by a Sigma 2/3 in spite of the fact that the PC can only be connected to Sigma 5/7 memory. This capability is primarily for applications where a "peripheral display processor" (Sigma 2/3) is used for control of the display subsystem in a Sigma 5/7 system. An 8050 or 8150 32-bit External Memory Adapter is a prerequisite for this configuration.

The choice of operating mode for RD/WD instructions is made via a toggle switch in the PC. Hence, Sigma 2/3 RD/WD effective addresses have bit 15 reserved to permit programmer specification of which portion of each data word is to be read or written with the RD/WD instruction.

†CC3 and CC4 correspond to the Overflow and Carry indicators, respectively, in the Sigma 2/3.

For Sigma 2/3 operation, it is not necessary to transfer the least significant 16 bits (16-31) if the data is of no consequence, as in a control WRITE DIRECT with the OP field ≠ 11. If bits 16-31 are required they must be transferred before bits 0-15. The programmer must be sure that the PC is in "idle" condition before transferring bits 16-31 of a WD data word.

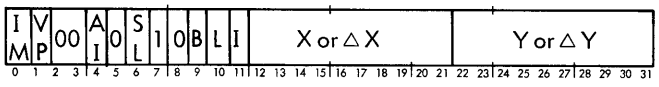
PRIMARY CONTROLLER INSTRUCTIONS

The PC is operable in one of two states, "normal" or "repeat", with "normal" defined as the initial state. The PC is activated by instructions in one of the five different formats shown below. In the "normal" state, the instructions accessed from memory are assumed to be Format 1, 3, or 5, as determined by bits 7 and 8 of these words. The PC enters the "repeat" state only upon receipt of a Format-1 instruction with bit 0 equalling 1, or a Format-3 instruction with bits 0-7 equal to X'27' or X'37'. The Format-1 instruction introduces the Format-2 repeat instruction, and the Format-3 instruction introduces the Format-4 repeat instruction. The PC returns to the "normal" state only on receipt of a Format-2 instruction with bit 0 set or a Format-4 instruction with X'27' or X'37' in any one of its four character fields (the remainder of the instruction, if any, is ignored).

Upon accession of an instruction from memory, the PC generates a 24-bit instruction for use by the Secondary Controller. The Secondary Controller is described later in this chapter.

The five different Primary Controller instruction formats are explained below.

Format 1. Long Point/Vector



where

IM indicates that the PC is to enter the "repeat" state (1 = yes; 0 = no). A Format-2 instruction is expected to follow if "repeat" is specified.

PV selects point (0) or vector (1).

AI indicates absolute (0) or incremental (1) coordinates.

SL selects normal (0) or short line, high-speed (1) vector generator.

10 in bits 7 and 8 define the instruction as Format 1.

B is blink control (1 = blink; 0 = do not blink). The blink frequency is 3.75 cycles/second. Blinking continues until the order is changed by a Format-1 or Format-3 instruction word.

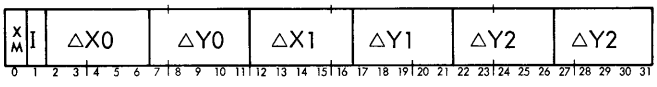
L inhibits light gun (1 = yes; 0 = no). Order is valid until changed by a Format-1 or Format-3 instruction word.

I intensifies in accordance with Format-5 instruction word (1 = yes; 0 = blank). Order is valid until changed by a Format-1, Format-2 or Format-3 instruction word.

X, Y Absolute X, Y coordinates of point or end of vector, specified in raster units. (AI = 0.)

△X, Y Incremental values, in signed two's complement form, of X, Y coordinates relative to current beam position. (AI = 1.) Incremental range on either axis is -512 to +511 raster units. Incremental overflow or underflow on either or both axes will cause an error code to be generated along with a PC status interrupt. Also, PC goes to "idle", leaving X and Y registers and "repeat" state flip-flops unchanged.

Format 2. Short Incremental Point/Vector



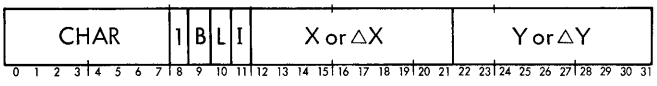
where

XM specifies exit from "repeat" state (1 = yes; 0 = no).

I is the intensity bit (same as in Format-1 word).

The three pairs of incremental coordinates in this instruction word are in signed two's complement form. Maximum increment value for each is ±15 raster units. An increment of -16 in any X field causes the PC to disregard that and all following fields in the word. The next word is processed normally. Overflow or underflow on either axis cause the same results as described for Format 1. In addition, the last correct vector is pointed to by the LOC field in the PC READ DIRECT status word (explained under "RD Data Words" later in this chapter). If LOC = 0, the error occurred in △X(Y) 1 of the current instruction; if LOC = 1, error occurred in △X(Y) 2 of the current instruction; and if LOC = 2, error occurred in the following instruction.

Format 3. Random Character



where

CHAR is an EBCDIC character code. The following are control codes from the EBCDIC set, which cause special responses:

X'27' enters "repeat" state and defines X and Y as absolute starting coordinates for the characters in the Format-4 word to follow.

X'37' is the same as X'27' except that bits 12-31 are interpreted as signed two's complement increments to the X and Y registers.

X'15' is a New Line. To obtain new lines for double and quadruple size characters, two or four X'15's, respectively, must be specified. Bits 12-31 are always interpreted as signed two's complement coordinate increments and are algebraicly added to the contents of the PC's X and Y registers. The X register is then reset and the Y register is decremented by 1.5 times a normal character height.

X'00', X'40', X'C0' create spaces. Bits 12-31 are defined as absolute coordinates and are loaded into the X and Y registers. The X register is then incremented by 1.5 times the character size to provide a space on the line.

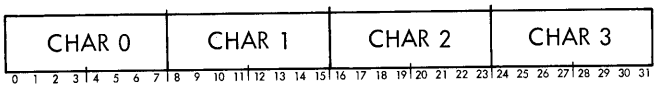
X'80' creates space. Same as above except that bits 12-31 are signed two's complement coordinate increments.

The above control character codes use only 7 of the 256 possible values in CHAR. The remaining 249 are truncated to their low-order 6 bits to access one of 64 locations beginning at the low-access boundary of the PC. These 64 locations must contain 23-bit character generating codes which are supplied by the programmer. These 23-bit codes are sent from the Primary Controller to the Secondary Controller (SC), which performs the actual display functions, (see Secondary Controller later in this chapter). Table 2 shows the 8-bit EBCDIC codes for the standard character set. Table 3 shows the 23-bit SC codes.

After X and Y updating, the X register is incremented by 1.5 times the character width (automatic beam control).

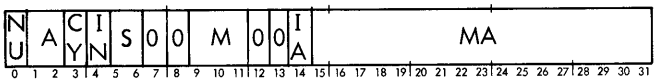
All other bits specified in the Format-3 word have the same meaning as in Format 1, except bit 8 which specifies that this is a Format-3 word.

Format 4. Tabular Characters



CHAR 0 - CHAR 3 are tabular characters. Each CHARn field is examined in sequence and, if its value is not one of the special character codes, is sent to the SC for display as previously explained for Format-3 instruction words. The special character codes produce the same effects described under Format 3, except X'27' and X'37', which perform identically in causing an exit from the "repeat" state, and indicating that the instruction word following the Format-4 instruction word should be Format 1, 3, or 5.

Format 5. Control Instruction



where

NU is the null (no-op.) control bit. If NU = 0 there is no action, except that the address register is

incremented and the PC goes on to the next instruction. If NU = 1, the control fields of the instruction have the following meaning:

A is the special action field.

00 No special action, except that the S and M fields are loaded into the PC.

01 Bits 15-31 are loaded into the PC address register and execution continues from that location (unconditional branch).

11 The PC increments the address register (ADR) by one and loads the contents of the address register into the PC's write buffer register (WBR). The effective address of the instruction (after indirect addressing) is loaded into the PC address register. The PC then constructs a Format-5 instruction in the WBR with the current character size and intensity, and an address in bits 15-31 equal to the previous contents of the ADR incremented by one. This word is stored in memory at the address pointed to by ADR (the effective address of the instruction). Execution continues after ADR is incremented by one.

CY causes PC to enter "cycle" state (CY = 1), (see "Refreshing" later in this chapter).

IN causes PC status interrupt if set.

S is character size.

00 retain current size

01 normal size

10 double size

11 quadruple size

00 in bits 7 and 8 define the instruction as Format 5.

M is intensity level.

000 retain current intensity

001 blanked

010 normal

011 bright

IA indicates whether address in MA field is indirect (1 = yes; 0 = no). Unlimited levels of indirect addressing are permitted.

MA is the memory address field.

Table 2. EBCDIC Display Character Codes

		Least Significant Digit															
Most Significant Digit	Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
	Binary	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
0	0000								DEL							Home	↑
1	0001						NL	BS									↓
2	0010								PREA								→
3	0011								PRER								←
4	0100	Space										[	.	<	(	+	|
5	0101	&										]	$	*	)	√	¬
6	0110	-	/									Σ	,	∫	∞	>	?
7	0111											Δ	π	⊢⊣	'	=	"
8	1000																
9	1001																
A	1010																
B	1011																
C	1100		A	B	C	D	E	F	G	H	I						
D	1101		J	K	L	M	N	O	P	Q	R						
E	1110			S	T	U	V	W	X	Y	Z						
F	1111	0	1	2	3	4	5	6	7	8	9						

Displayable

Table 3. Secondary Controller Character Codes

Table Location	23-Bit Code	Character	Table Location	23-Bit Code	Character
X000	00884228	Space (not used)	X020	00800840	-
X001	009CEC50	A	X021	00C01000	/
X002	00BCAD3C	B	X022	008DE37C	S
X003	008CE70C	C	X023	008622A8	T
X004	009CA51C	D	X024	0090871C	U
X005	0084AD04	E	X025	00C89428	V
X006	0084AC28	F	X026	00D08411	W
X007	008CE75C	G	X027	00C8522B	X
X008	00908C50	H	X028	008850AA	Y
X009	008621A4	I	X029	00C43104	Z
X00A	0080A500	[	X02A	00C42106	Σ
X00B	00C00D80	.	X02B	00C00C00	,
X00C	00801001	<	X02C	008629C4	‡
X00D	0080E700	(	X02D	00BFE000	∞
X00E	008208C0	+	X02E	00C8402A	>
X00F	00820080	1	X02F	00BC6080	?
X010	0083EF0D	&	X030	00DCF71C	0
X011	0090031C	J	X031	008A22A8	1
X012	00889C29	K	X032	00BC6D24	2
X013	00888524	L	X033	0084337C	3
X014	00909412	M	X034	00908A50	4
X015	00908413	N	X035	0084AB7C	5
X016	009CE71C	O	X036	008CEF7C	6
X017	00BCAC08	P	X037	00C43208	7
X018	009CE71D	Q	X038	00BDEF3C	8
X019	00BCAC09	R	X039	009DE35C	9
X01A	00940014	]	X03A	00C00105	Δ
X01B	008FE3FC	$	X03B	00966090	π
X01C	00C218C3	*	X03C	00928CD0	⊣
X01D	009C001C	)	X03D	00822002	'
X01E	00C81408	√	X03E	00842A48	=
X01F	00942010	¬	X03F	00920000	"

LIGHT GUN

A "hit" is an output signal from the light gun that occurs when all of the following conditions prevail:

1. Light gun switch is pressed.
2. Light gun senses the CRT beam within its prescribed area.
3. Light gun is not inhibited (L = 0).
4. Light gun is enabled for either single or multiple hits.

When the light gun is enabled for single hits, it is automatically disabled by the PC after the first hit. To reenable it, a control WD instruction must be executed by the CPU and the trigger switch on the light gun must be released and redepressed. When the gun is enabled for multiple hits and the light gun switch remains depressed, the PC reacts to only the first hit sensed after each 60-Hz clock pulse. Thus, the maximum number of hits processed is 60 per second in multiple mode (30 per second during raster scan when no visible light is detected).

Immediately after transfer of each display command to the SC, the PC stores the location of the command in the Read Direct Buffer (RDB) along with the instruction format number and the LOC number, until a hit occurs. After a hit, the PC inhibits further loading of the RDB until the PC Status Interrupt is cleared.

If a hit occurs during a raster scan, the hit coordinates and special format number (7) to indicate raster scan are stored in the RDB.

The PC terminates the light-gun processing by generating an even-numbered (high-priority) interrupt and setting the hit interrupt flag. The contents of RDB cannot be altered until the interrupt is cleared. The PC goes to "idle" immediately after a light gun hit to allow sufficient time to completely identify the hit. The PC can be switched to the "run" condition at any time by executing a control WD instruction with OP = 01.

If the raster is enabled when the trigger is pressed, the Graphic Display Unit will wait for two refresh clock pulses to occur before starting the raster scan. This allows a

complete refresh frame to be displayed before the raster starts. If a hit occurs on this display, there will be no raster scan.

To the user, the raster appears to be a faint horizontal trace of light that moves rapidly down the CRT screen from top to bottom and repeats. A raster scan is a series of four raster unit lines connected head to tail along the X-axis. When the lines reach the right hand display boundary they wrap around (as the Y-axis is decremented by 6 raster units) and start again. Due to this method of generation and the hardware delays involved, there is a variation between the actual X,Y coordinates and the ones supplied with the PC status word on a light gun hit. Specifically, the error is caused by:

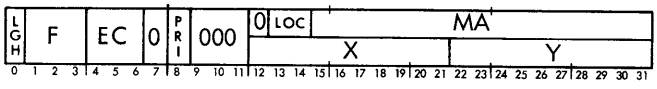
1. The four-raster-unit resolution of the raster gun. Error here varies from zero to three raster units.
2. A fixed error of positive multiples of four raster units caused by hardware delays.

RD DATA WORDS

The RD instruction causes the PC to return two different data words to the CPU depending on the function code (FN) specified in the RD instruction. If FN was 001 (PC Status READ DIRECT) the data word will describe various status conditions in the Primary Controller. If FN was 010 (Keyboard Status READ DIRECT) the data word will describe the settings of the action keys, function switches, and last character key pressed on the display keyboard.

RD PC DATA WORD

The PC status word format, shown below, is used primarily in conjunction with the light gun feature, but is also available for general status checking:



where

LGH is light gun "hit" interrupt pending (1 = hit). Clearing the interrupt resets LGH to 0.

F is the format number (see "Primary Controller Instructions") of the instruction pointed to by bits 15-31 (address of instruction that caused the light gun hit indicated by bit 0). If the hit was caused by a raster scan, F will equal 111.

EC is error code:

000 No error interrupt pending

001 A memory access was attempted to non-existent memory.

010 Memory parity error.

011 A memory access was attempted to an area below that specified by the memory boundary selector switches.

100 Not assigned.

101 X Register will overflow if the incremental coordinate defined by the current instruction is added to the previous position (note that PC position registers contain the last valid position).

110 Y Register will overflow if the incremental coordinate defined by the current instruction is added to the previous position.

111 X and Y Registers will both overflow if the incremental coordinates defined by the current instruction are added to the previous position.

Clearing the interrupt resets the EC field to 000. All of the errors listed above cause the PC to go to the "idle" state. The address register and repeat flip-flops are not changed. The F, LOC, and MA fields will identify the last element displayed successfully before the error occurred (except for memory parity error, where MA is the instruction address at the time of the error). To return the PC to "run", a control WRITE DIRECT is required.

PRI is program requested interrupt pending (PC Status interrupt bit 4 set in Format-5 Instruction). PRI is reset by clearing the PC Status Interrupt.

LOC is a pointer to the vector or point if F = 010 (Format 2) or character if F = 100 (Format 4) that caused a light gun hit. In the case of an error (EC $\neq$ 000) it is a pointer to the last correct vector or point if F = 010 (Format 2) or to the last correct character if F = 100 (Format 4). LOC is always 0 with any other instruction format.

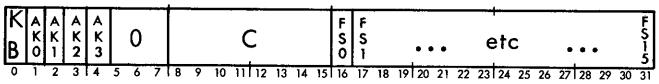
MA is memory address of the instruction from which the last display element sent to the secondary controller originated (provided F $\neq$ 111 and EC = 000). (MA defines the instruction causing a light gun hit, or the instruction executed before the one causing an error, or the one causing the error. See EC above.)

X, Y are the coordinates of a light gun hit caused during a raster scan (F = 111).

RD KEYBOARD STATUS WORD

If the FN field in the RD instruction contained 010 (Keyboard Status READ DIRECT) a 32-bit data word will be returned to the CPU and will describe the settings of the action keys, function keys, and last character key pressed on the display keyboard. The action keys

are momentary, nonlighted and the function switches are alternate action, split indicator. The format of the keyboard status word is



where

KB indicates a keyboard depression (1 = yes, 0 = no).

AKn indicates action key pressed (1 = pressed, 0 = not pressed).

C is character (in EBCDIC) from keyboard buffer register (last key pressed).

FSn indicates function switch status (1 = on - upper half lit; 0 = off - lower half lit).

CC3 (Overflow bit in Sigma 2/3) may be ignored.

CC4 (Carry bit in Sigma 2/3) is set if any of bits 0-4 are set in the status word. Clearing the keyboard will clear bits 0-4.

Depressing any action key will cause an interrupt to be generated. Depressing a second action key while the interrupt is still pending will cause the corresponding AKn indicator in the RD keyboard status word to be set but no additional interrupt will be generated. If the second key is depressed after the keyboard RD is executed but before the interrupt is cleared, the key action will be lost.

CONDITION CODE STATUS RETURNS

In response to a control WD or a PC Status RD instruction the PC returns the following status information to CC3 and CC4 (O and C in Sigma 2/3):

CC3(O)	CC4(C)		
X	0	PC in "idle"	Prior to execution of WD
X	1	PC in "run"	Prior to execution of WD
0	X	WD successful	
1	X	WD unsuccessful	

INTERRUPTS

The PC requires an Interrupt Level Pair to provide even-numbered (higher priority) and odd-numbered (lower priority) interrupt levels. The even-numbered (higher priority) interrupt level is the PC interrupt that is triggered by any of the following:

1. Attempt to access nonexistent location in memory.
2. Attempt to access out-of-bounds area in memory.
3. Memory Parity error.
4. A Light gun hit.
5. Overflow of incremental coordinate data.
6. Bit 4 (PC Status Interrupt) set in a Format-5 control instruction word.

These interrupts are signalled in the data word response to a PC Status RD instruction. The PC error, the light gun hit, and the program interrupt signals are reset by the trailing edge of the feedback signal from the interrupt level.

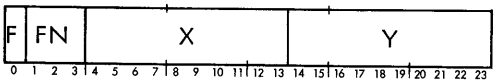
The odd-numbered (lower priority) interrupt level is used exclusively with the alphanumeric keyboard and the action key panels. Pressing any key (except SHIFT or REPEAT) on the alphanumeric keyboard generates a keyboard interrupt and transmits the corresponding character to the PC. Pressing the REPEAT key generates 3.75 interrupts per second, transmitting to the PC the last character pressed. Note that it is not necessary to continue depressing the character key while repeating. Pressing a key before the RD instruction for a preceding keyboard operation has been executed will result in the loss of that previous character.

SECONDARY CONTROLLER

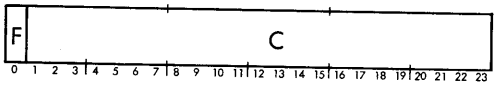
The Secondary Controller (SC) consists of a CRT display coupler, a character generator, a vector generator, and a light gun. The SC sends pulses to the PC every 16.6 milliseconds for refresh clocking. It receives from the PC 24-bit words that, depending on the format of the word, direct the SC to either perform a function or display a character. The SC receives additional parameter control signals with either format.

The following are the two SC word formats:

Format I



Format II



where

F is format indicator (0 = I, 1 = II)

FN is display function code:

- 0 position a character
- 1-3 unassigned
- 4 produce point display
- 5 produce intensified point display
- 6 draw vector
- 7 draw intensified vector

X, Y are the coordinates of the display position, point, or vector end point. The 0, 0 coordinates of the screen are at the lower left-hand corner. The upper limit coordinates (1023, 1023) are at the upper right-hand corner of the screen. When a character is drawn, the coordinates specify the lower left-hand corner of the character.

C is a 23-bit code. These codes are shown in Tables 2 and 3.

PROGRAMMING CONSIDERATIONS

The correct way to position the CRT beam to a vector starting position is to use a Format-1 instruction with the I bit = 0 (blank the vector) and the PV bit = 1 (vector). The SL bit may be set only if the beam is to move 0.25 inch or less along any axis and the next vector is to be short. The Appendix shows a sample program.

REFRESHING

The Graphic Display Unit has two methods of frame refreshing, synchronous (60-Hz clock) and asynchronous. The 60-Hz (16.6 millisecond) clock in the Secondary Controller (SC) sends pulses to the Primary Controller (PC). If the CY bit in the Format-5 word is set, the PC will wait until the next SC refresh clock pulse before executing the next instruction. Note that the refresh rate will be 33.2 milliseconds if the frame execution time exceeds 16.6 milliseconds; this may cause visible flicker.

Asynchronous refreshing (CY = 0) occurs each time a Format-5 instruction branches back to the beginning of the frame. Asynchronous refreshing should only be used in frames exceeding 16 milliseconds execution time to avoid burning the CRT. Its use even then may cause swimming images.

4. OPERATIONS

INTRODUCTION

The Graphic Display Unit contains four sets of controls: keyboard, action keys, function switches, and CRT controls (analog).

The Keyboard (Figure 1) keys generate odd-numbered (low-level) interrupts which, ordinarily, should be processed to echo the character or perform the function indicated. The cursor keys can be programmed to move a program-generated cursor, in the direction indicated, any desired number of raster units. A logical spot for the HOME position is the upper left corner of the screen.

Action keys (Figure 2) generate odd-numbered (low-level) computer interrupts that are program associated with desired actions like initializing, alerting, breaking a sequence, alert to read function switches, etc.

Function switches (Figure 3) are completely program controlled and may be associated with any display function the programmer desires. The functions labeled in the illustration are on a replaceable overlay. They pertain only to an XDS application, and are not intended as guides for user software. (L. P. stands for Light Pen, which has been referred to as light gun throughout this manual).

The CRT analog controls shown in Figure 2 and explained in Table 4 are for controlling the display characteristics of the CRT.

Table 4. CRT Controls

Control Indicator	Type	Function
PUSH ON	Illuminated alternate action push-button switch	Connects power to display unit. Light indicates that power is on.
INTENSITY	Potentiometer	Controls brightness of display. Clockwise rotation increases brightness.
FOCUS	Potentiometer	Controls sharpness of image.
VERTICAL GAIN	Potentiometer	Adjusts length of vertical axis. Clockwise rotation increases length.

Table 4. CRT Controls (cont.)

Control Indicator	Type	Function
VERTICAL POSITION	Potentiometer	Adjusts vertical position of image on screen.
HORIZONTAL GAIN	Potentiometer	Adjusts length of horizontal axis. Clockwise rotation increases length.
HORIZONTAL POSITION	Potentiometer	Adjusts horizontal position of image on screen.

OPERATING INSTRUCTIONS

1. Set INTENSITY and FOCUS controls to full counterclockwise position (lowest setting).
2. Set POSITION controls to midrange.
3. Push POWER switch on. Allow one-minute warmup.
4. Start program.
5. Rotate INTENSITY control clockwise to obtain CRT display.

   Caution: Do not attempt to obtain a display before end of one-minute warmup. CRT may be damaged if warmup time is not allowed.

6. Rotate FOCUS controls until display is sharp.
7. Adjust POSITION controls for desired horizontal and vertical trace position on CRT screen.
8. Select desired display size with GAIN controls.
9. Set INTENSITY and FOCUS controls to full counterclockwise position before turning power off.

   Caution: To avoid damaging CRT, do not let beam remain stationary and do not turn intensity too high. When trying a new program, turn intensity down, then increase gradually while program is running.

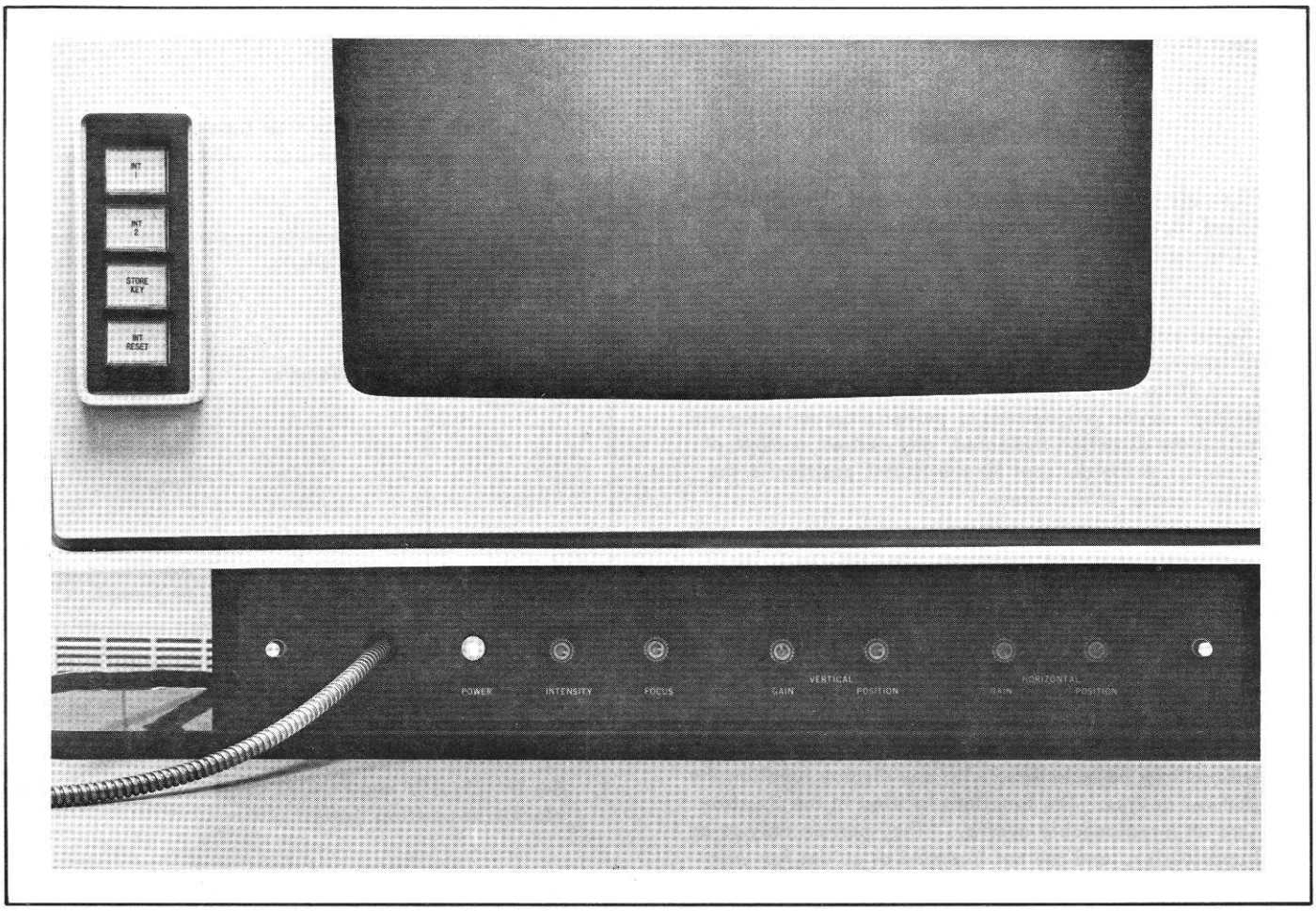


Figure 2. CRT Controls and Action Keys

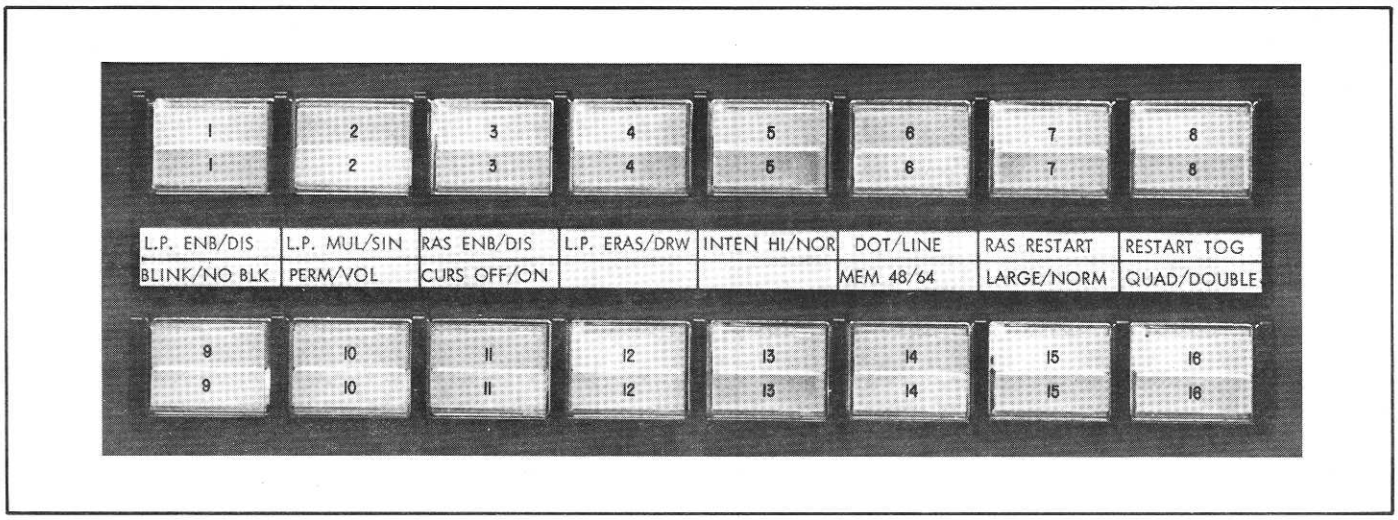


Figure 3. Function Switches

APPENDIX. SIGMA 5/7 PROGRAMMING EXAMPLES

The following coding sequence for an XDS Sigma 5 or 7 Computer shows one of the display operations of the Graphic Display Unit. This program constructs a display pattern to draw a vector from coordinates 100,100 to 500,500 and starts the display. The display pattern is then accessed automatically by the Primary Controller and provides a continuous display while placing absolutely no constraints upon the CPU.

Label	Command	Argument	Comments
DV	LW, 10	CX1	Starting X coordinate.
	SLS, 10	10	Shift left.
	OR, 10	CY1	Combine with Y coordinate.
	OR, 10	L(X'41000000')	Combine with control bits. (Note that the control bits define a blanked vector.)
	STW, 10	VIMGE1	Store in list.
	LW, 10	CX2	Ending X coordinate.
	SLS, 10	10	Shift left.
	OR, 10	CY2	Combine with Y coordinate.
	OR, 10	L(X'41100000')	Combine with control bits (intensified vector).
	STW, 10	VIMGE2	Store in list.
	LI, 2	VIMGE	Load image address.
	OR, 2	L(X'C0000000')	Combine WD control bits.
	WD, 2	X'BC00'	Start display.
	RD, 0	X'BC20'	Check Primary Controller for WD successful.
	BCS, 2	$ - 1	Not successful.
	B	*11	Exit.
*			
CX1	DATA	100	X coordinate.
CY1	DATA	100	Y coordinate.
CX2	DATA	500	X coordinate.
CY2	DATA	500	Y coordinate.
*			
	ORG	X'1000'	
VIMGE	DATA	X'82200000'	Set size and intensity.
VIMGE1	DATA	X'41000000'	Position beam at start.
VIMGE2	DATA	X'41100000'	Vector end.
	DATA	X'B0001000'	Cycle and jump to VIMGE.
*			
	END		

XDS

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701 South Aviation Blvd. / El Segundo, California 90245 (213) 772-4511 / Cable SCIDATA / Telex 674839 / TWX 910-325-6908

EASTERN TECHNOLOGY CENTER
12150 Parklawn Drive
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Executive Center
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(703) 497-6811

Washington (D.C.) Operations

*2351 Research Blvd.
Rockville, Maryland 20850
(301) 948-8190

Canada

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(613) 722-8387

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Calgary 2, Alberta
(403) 265-8134

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Trans-Canada Highway
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INTERNATIONAL OFFICES & REPRESENTATIVES

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England
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Yvelines
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Israel

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Haifa
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*Regional Headquarters