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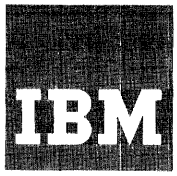

Systems Reference Library

IBM System/360 Component Description

IBM 2250 Display Unit Model 3

IBM 2840 Display Control Model 2

This document presents detailed information about IBM 2250 Display Unit Model 3/IBM 2840 Display Control Model 2 programming, operation, and special features. The material is presented with the assumption that the reader has read the IBM System/360 Principles of Operation manual, Form A22-6821.

The following publications may also be of interest to the reader:

- IBM System/360 Component Description:
  IBM 2250 Display Unit Model 1, Form A27-2701.
- IBM System/360 Component Description:
  IBM 2250 Display Unit, Model 2; IBM 2840 Display Control, Model 1, Form A27-2702.
- IBM System/360 Operating System, Graphic Programming Services for IBM 2250 Display Unit, Preliminary Specifications, Form C27-6909.

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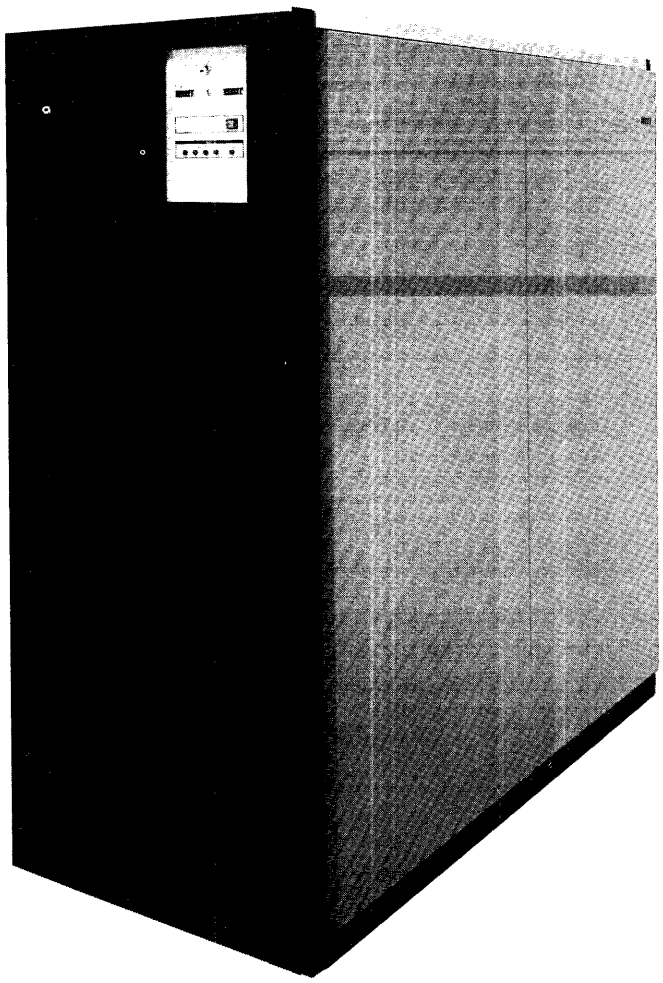
CONTENTS

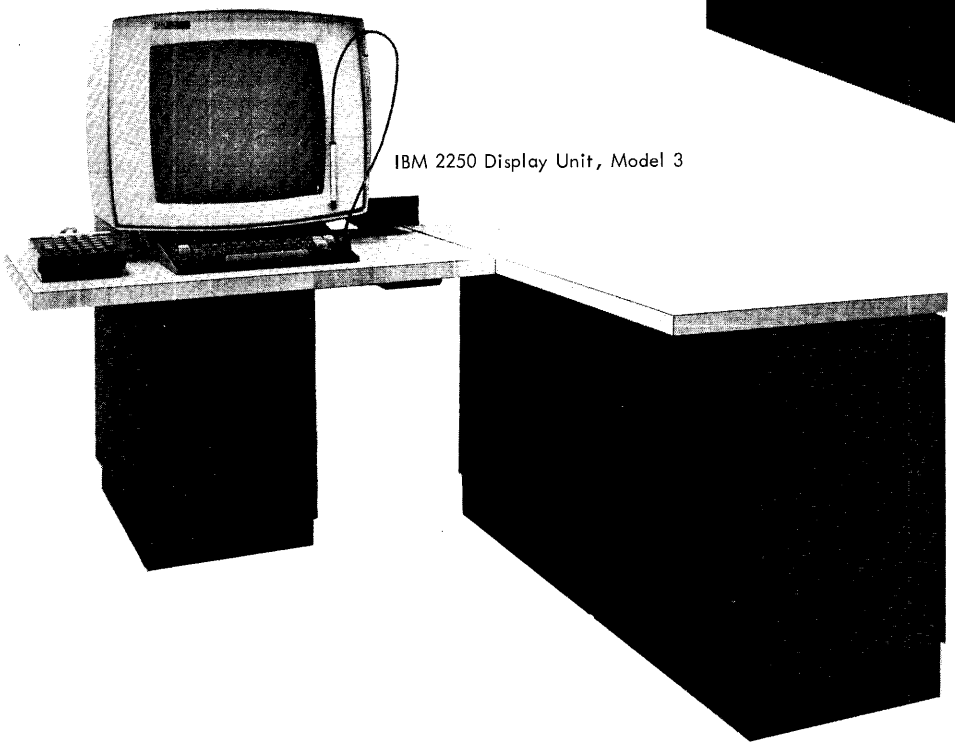
ILLUSTRATIONS

TABLES

IBM 2840 Display Control, Model 2



IBM 2250 Display Unit, Model 3



The IBM 2250 Display Unit Model 3 (Frontispiece) is a cathode-ray-tube (CRT) display console which can be attached to a System/360 via the IBM 2840 Display Control Model 2. Along with the capability of displaying graphic or alphanumeric information, the 2250 offers man-machine interaction through its light pen and two keyboards. Using these facilities, a programmer can furnish computer-aided design capabilities whereby the 2250 user can create, modify, and add graphic and alphanumeric data into the system through the display screen. This extension of the System/360 data processing power is useful (1) for handling the graphic information associated with scientific and engineering applications, and (2) for providing faster and more effective retrieval and graphic expression of management and business operating data.

Programming requirements for the 2250 differ from other I/O devices in that the 2840 Display Control has a buffer with logical capabilities that require programming. A buffer program consisting of buffer orders and data to be displayed can be developed either in final image form or as a framework to accept data (to be provided at object time) by the CPU program and to be transmitted via a channel to the 2840-2. Under control of this buffer program, the 2250-3 displays graphic images in the form of lines, points, and alphameric characters. Using the logical capabilities of the buffer and the light pen, programmed function keyboard, and alphameric keyboard, the programmer can design and implement his own tracking, sketching, or display manipulation techniques with minimum CPU interaction.

A buffer program consists of orders interleaved with data. The three major groups of orders are Graphic, Character, and Control. When decoded, an order sets a mode of operation which will be in effect until another order is encountered. All data in between is processed in that mode. Hence, an order requesting absolute vectors will put the 2250/2840 in Absolute Vector mode, and all following data will be treated as the absolute X, Y end points of vectors to be displayed until the next order is encountered. Available in conjunction with this basic principle is the ability to control light-pen responses in the 2840/2250. These orders can condition the 2840/2250 to accept light-pen detects until another light-pen order resets the condition. A light-pen detect on any displayed information between these two orders is then accepted and passed on to the program for processing. In addition, immediate action orders allow direct transferring, movement of data and/or addresses, and storage of the deflection registers into a buffer location.

Each 2250-3 can operate up to 2,000 ft. from the 2840-2, allowing access to the computer from the user's normal working area. Furthermore, sharing of the common control unit (the 2840-2) by several 2250-3's results in more economical configurations for the multiconsole environment.

The 2840-2 can control the operation of up to four 2250-3 Display Units (Figure 1). Light-pen tracking can be performed simultaneously by the user of each 2250 with no interference to System/360. Attachment of the 2840-2 to System/360 (CPU) and CPU main storage is via either a selector or multiplexor channel; it uses one of the eight control unit positions on the channel interface. The channel provides the 2840-2 with the data to be displayed and with the control information necessary to direct the operation of the 2840-2 and associated display units. Buffer storage in the 2840 stores digitally coded images for each attached 2250-3. The buffer enables image regeneration as well as message composition from the 2250 alphameric keyboards; this allows the 2840-2 and attached 2250-3's to operate concurrently with the computer system, freeing the CPU and the channel for other functions. Buffer storage areas are program-assignable for any attached 2250-3 and can be varied under program control. The 2840-2 controls the operation of each attached 2250-3. By means of shared circuitry and interleaved operations in the 2840-2, each 2250-3 can be operated independently, and different images can be generated simultaneously on each display.

The basic 2250-3 (without special features) provides the ability to display graphic information in

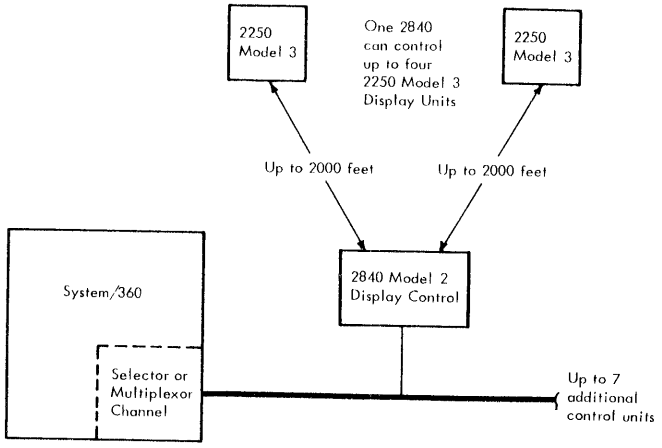


Figure 1. Attachment of 2840-2/2250-3 Configuration to System/360

absolute or incremental mode in the form of points or straight lines in any direction; it can also display alphameric characters (alphabetics, numerics, and special symbols). In addition, a light pen is provided with the basic 2250-3. For increased intercommunication between the user and the controlling program, two keyboards are available as special features:

Alphameric Keyboard - Provides a typewriter-like keyboard with which the user can perform editing functions and compose messages consisting of letters, numbers, and/or special symbols for entry into 2840 buffer and CPU main storage.

Programmed Function Keyboard - Provides communication between the user and the computer. The keyboard consist of keys, indicators, and sensing switches for use with replaceable descriptive overlays. The function of each key and indicator, which is program-defined, is identified to the program by the overlay coding and to the user by symbols on the overlay. The program associated with the overlay code and the selected key then directs the requested operation. For example, as a result of a key depression, the program might direct the computer to enlarge, reduce, or delete the image displayed by the associated 2250.

When a 2250 is not in the same room with the 2840 and the CPU, a telephone should be near the 2250 so that the 2250 operator can communicate with the CPU installation.

The basic 2840-2 contains a 32,768-byte core buffer, order mode control, and a character generator. The character generator can translate one System/360 eight-bit byte representation from an alphameric character into a sequence of signals, which, when converted to analog deflection signals by the 2250-3, causes the character to be drawn on the 2250-3 CRT display area. A standard character set of 63 alphabetics, numerics, and special symbols is provided; two character sizes are program-selectable. The basic 2840-2 can attach to, and control, two 2250-3's. Two special features are available for increased 2840-2 attachment capability:

Display Multiplexor - Allows attachment of two additional 2250 Model 3 Display Units to the 2840-2. A maximum of one display multiplexor feature can be installed on one 2840-2, allowing attachment of up to four 2250-3's.

Film Unit Attachment - Provides for the attachment and control of an IBM 2280 Film Recorder or an IBM 2282 Film Recorder/Scanner. A film unit attached to a 2840 time-shares both the buffer storage and the character generator with any attached 2250. A maximum of four 2250-3's or three 2250-3's and one film unit can be attached to one 2840-2.

GENERAL

Each 2250-3, under control of a 2840-2, generates images on the 12-inch by 12-inch usable display area of a 21-inch cathode-ray tube (CRT). An image can be composed of straight lines (vectors), points, standard characters (in two sizes), and special characters formed with vectors and points (Figure 2).

A visible display is produced when an electron beam in the CRT strikes the phosphor-coated CRT screen, causing the portion of the coating struck by the beam to glow briefly. Normally, the glow fades within a fraction of a second, too soon for the human eye to carefully perceive and identify the image. For this reason, the display must be redrawn continuously (regenerated) at a rate that will cause the display to appear steady and stationary to the observer. Regeneration is performed automatically, under control of a program in the 2840. The 2840 accomplishes regeneration by continuously retransmitting control and display data to the 2250; this data can be modified during regeneration by the 2840, as directed by the buffer program and/or the CPU program, to update or change the display. The 2250 also performs various nondisplay services for the user by providing the interface between the user and the problem program with the following devices:

1. Programmed function keyboard. Provides keys and overlays for user communication

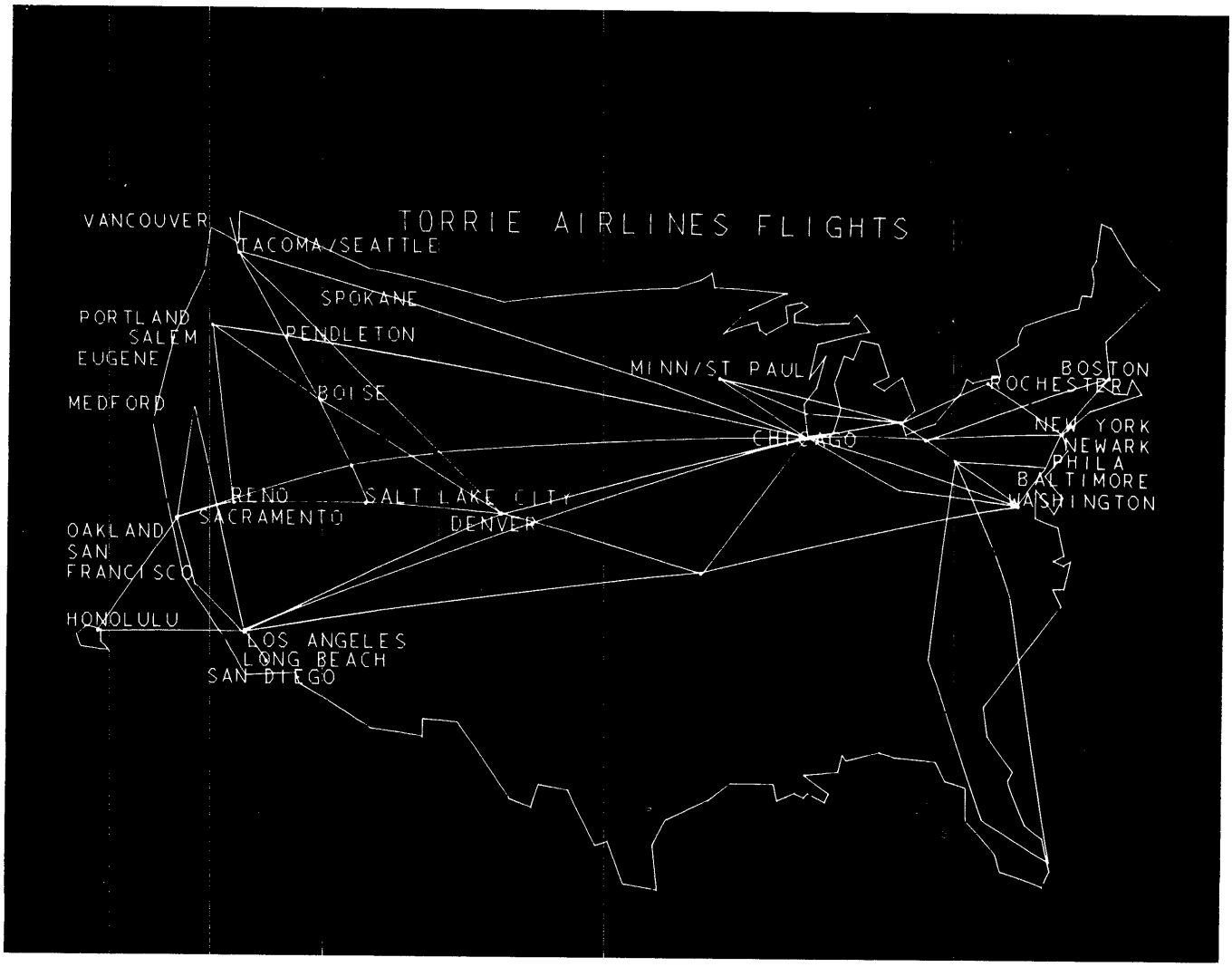


Figure 2. Example of a 2250 Display

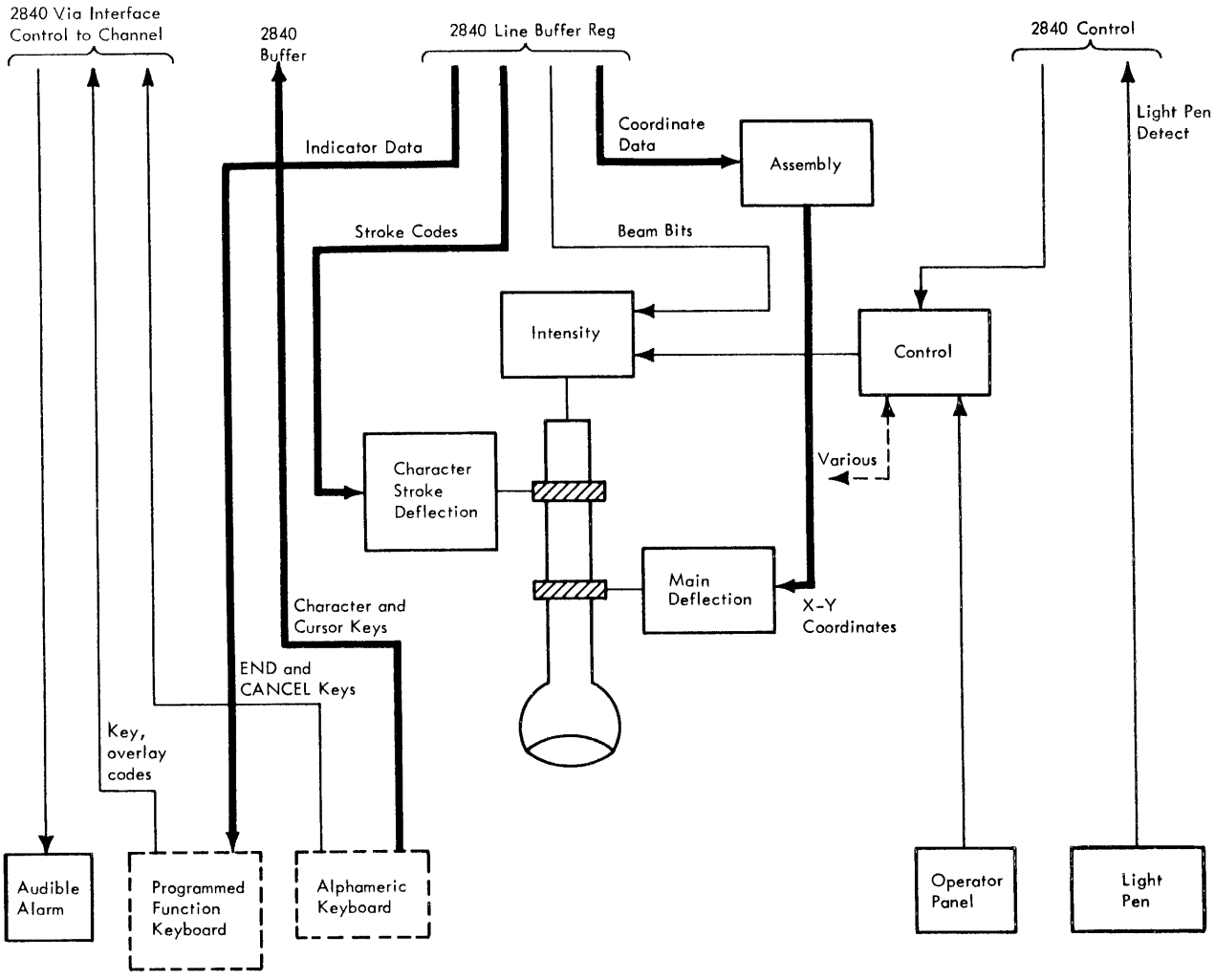
to the program and indicators for program communication to the user.

2. Alphameric keyboard. Enables the user to change, edit, or create character displays.
3. Light pen. Supplies the buffer address of a vector, point, or character at which the user is pointing a pen-like device. This information can be used for operations as determined by the program, by the alphameric keyboard, or by the programmed function keyboard. The light pen thus enables the user to enter and manipulate graphic information.
4. Audible alarm (single-stroke buzzer). Enables the program to inform the operator that action is required.

The functional sections of the 2250 are shown in Figure 3. The functions represented by solid blocks are provided in the basic units, whereas those represented by dashed blocks are available as special features. Heavy connecting lines represent data flow; the light lines represent control signal routing.

DISPLAYS

Information positioning on the 2250 display area is controlled by a display program resident in the 2840 buffer. This buffer program is prepared by the main CPU and is sent to the buffer via a standard I/O channel operation. The program specifies electron beam deflection to horizontal (X) and vertical (Y) coordinates on a virtual square grid composed of



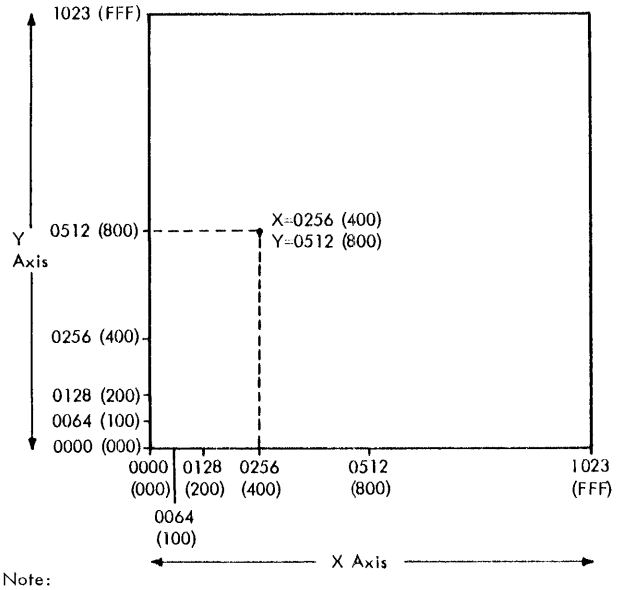
Notes:
1. Dashed blocks represent special feature functions.
2. Heavy lines represent data flow.

Figure 3. Functional Sections of a 2250-3

possible electron-beam-deflection end points. This grid covers (logically) the 12-inch by 12-inch display area on the face of the CRT; it comprises 1,024 equally spaced X positions and 1,024 equally spaced Y positions (Figure 4).

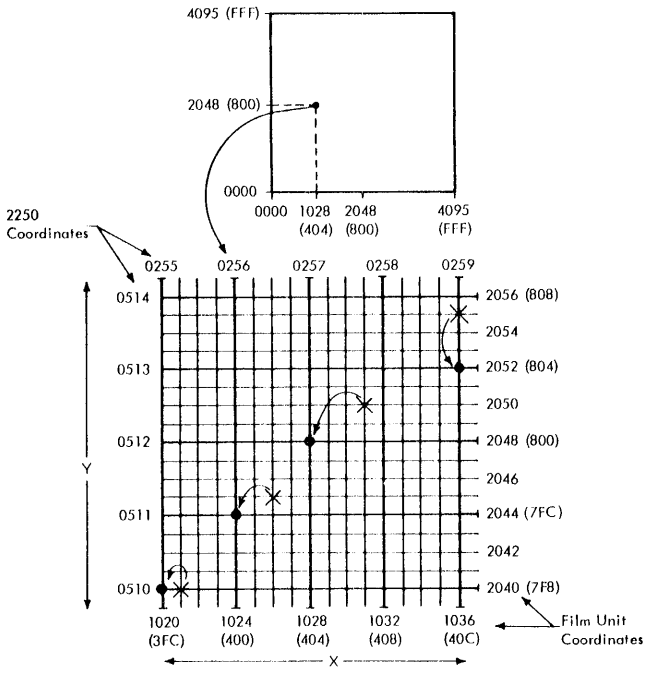
Positioning data in the display program selects the X and Y coordinates for each element of a 2250 display (each point, line end point, and character area centroid). This same data can also control the IBM 2280 Film Recorder. The grid of addressable coordinates for a 2250 or 2280 device is called its "raster". The space between two sequentially addressable lines on the raster is called a raster unit. A 2250 raster unit represents 1/1,023 of the image, whereas a 2280 raster unit represents 1/4,095 of the same image; this reflects the difference in address resolution.

The data format in the 2840 provides for the 4,096-by-4,096-position grid of the 2280 and 2282 film units. The 2250 maintains program compatibility with the film units by disregarding the two low-order bits (binary) of the 4,096-by-4,096 X and Y coordinates. For example, a binary configuration 1111 1111 1111 (4,095 decimal) in the 2840 is interpreted by the 2250 as 1111 1111 11, or 1,023 decimal. Thus, each display element is positioned by the 2250 at a set of 1,024-by-1,024 2250 coordinates that are virtually equivalent to the set of 4,096-by-4,096 film unit coordinates. The maximum shift in the image caused by this conversion is three-fourths of a 2250-raster unit (three 2280 raster units), a shift that is not noticeable to the user (Figure 5).



Note:
Numbers in parentheses are hexadecimal equivalents of the coordinates as they appear (in 12-bit form) in the 2840 buffer.

Figure 4. Display Area Coordinate Addressing System



Notes:
1. X Position specified by 2840 data.
2. ● Position selected by 2250 from this data.
3. Numbers in parentheses are hexadecimal equivalents.

Figure 5. Examples of Display Area Coordinate Address Modification by the 2250

NOTE: Subsequent use of the term "raster unit" in this publication refers to 1/1,023 of the image. Also, this 1,023-by-1,023-raster unit grid is called the "reference" grid.

Vectors and Points

During vector or point display operations, positioning data from the 2840 directs electron beam movement (deflection) on the 1,023-by-1,023 raster unit display area. The 2840 first sets the 2250 mode of operation (in this case, to display vectors or points). It then transmits a set of positioning data to the 2250 for each vector or point to be displayed.

Each set of positioning data addresses one X, Y coordinate to which the electron beam is to be repositioned. Beam deflection is always from the previously addressed coordinate, where the beam is currently positioned, to the new coordinate. If vectors are specified by the 2840, the beam is turned on as it is being repositioned, displaying a line between the current position and the new coordinate specified; if points are specified, the beam is turned on after it has been repositioned, displaying a point at the new coordinate. Points plotted 4 or more raster units apart can be distinguished by the user as distinct points.

The 2250 can also "position" the electron beam without causing a visible line or point to appear on the display. This capability is used (1) to select a starting location for displaying characters and (2) to start the display of a new set of vectors. Each set of positioning data from the 2840 contains a beam control (blanking) bit, which specifies whether the 2250 is to display (unblank) or is not to display (blank) the resulting vector or point.

Control signals from the 2840 specify not only the type of operation (vector or point) to be performed but, also, a coding format for positioning data that will be used during the operation. Positioning data can be in either of two basic coding formats, absolute or incremental.

Absolute positioning data specifies the actual X, Y coordinates to which the beam is to be deflected. Each group of four eight-bit absolute data bytes addresses one coordinate on the reference grid (i.e., X = 0512 , Y = 1016).

Incremental positioning data specifies the amount and direction of beam deflection relative to the current beam position. Each pair of eight-bit incremental data bytes specifies one increment (up to X = +63 or -64, Y = +63 or -64, a displacement of 0.74 inch) of beam deflection. For example, if the current beam position on the reference grid is X = 0512, Y = 1016, and if a pair of incremental data bytes specifies X = +20, Y = -40, beam deflection will be to position X = 0532, Y = 0976 on the reference grid. Thus, the ±X, ±Y incremental value is added to the absolute value of the current beam position, resulting in a new absolute value for the new beam position.

When incremental data causes the beam to move outside the reference grid area but when a total displacement of 1,023 raster units beyond the perimeter in the X or Y direction is not exceeded, the vectors and/or points so displaced will be blanked. The X, Y deflection registers will contain the value of a wrap-around position. Unless the displacement limit of 1,023 raster units is exceeded, the displaced beam can be returned to the normal grid area; then, displaying will resume when positioning data specifies an unblanked deflection that is entirely within the normal display area.

When a portion of a display is blanked because of a beam displacement condition, the 2840 program can specify an absolute positioning operation to the 2250,which will reset the displacement blanking condition. However, if the first absolute data bytes received by the 2250 following this positioning operation specify an unblanked vector, a line will be drawn from the wrap-around position to the specified location.

Electron beam deflection to the previously addressed coordinate can still be in progress when the next coordinate data is received. When the deflection currently in process is completed, the blanking bit is sent to the intensity control section, and the new X, Y coordinates are sent to the main deflection section.

The main deflection section applies X and Y analog values for the current beam position to the deflection coil of the CRT until new positioning data is received. When the new data is received, the analog values start changing to reflect the new position. As the analog values change, the beam moves, causing the image to be displayed. If the blanking bit specifies a blanked vector or point, the beam moves without being displayed. If the blanking bit specifies an unblanked vector or point, the electron beam is deflected and unblanked, as required, to form a vector or point as previously specified by the 2840.

The X, Y position registers in the main deflection section always contain the absolute X, Y address of the current beam position in digital form; the 2840 can retrieve this data and the blanking bit, reconstructing the most recent positioning data.

Characters

A standard set of characters can be displayed in either of two sizes by a 2250; this set consists of 63 alphabetics, numerics, and special symbols (Figure 6). Any characters that are not in this set can be created with vectors and/or points.

In Character mode, the X, Y coordinate (on the 1,024-by-1,024 reference grid) at which the electron beam is currently positioned becomes the center point of a basic-size or large-size character area. The 2840 specifies the character size, which is maintained throughout one Character mode operation. The beam must be positioned by the program to a starting coordinate by a blanked point or vector before a character display operation is started. The character area is divided into a grid format of 8X-by-8Y addressable points of which 7X and 8Y are used (Figure 7). Character grid points do not coincide with the 1,024-by-1,024 main deflection grid points. Characters are drawn in this area with a series of high-speed deflections, or "strokes". An average of six such strokes is required to form one character. Each stroke end point is specified by an X, Y character grid coordinate sent from 2840 to the character deflection section (Figure 3). This section converts each coordinate to X and Y analog signals, which are applied to the high-speed character stroke deflection coil of the CRT.

The main deflection system and the character deflection system operate independently. The main deflection system maintains the current beam position (the center point of the character grid) by

Character Codes (Hexadecimal) (see notes)																
Bits 4-7	Bits 0-3															
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL				SP	&	-									0
1							/		A*	J*			A	J		1
2									B*	K*	S*		B	K	S	2
3									C*	L*	T*		C	L	T	3
4									D*	M*	U*		D	M	U	4
5		NL*							E*	N*	V*		E	N	V	5
6									F*	O*	W*		F	O	W	6
7									G*	P*	X*		G	P	X	7
8									H*	Q*	Y*		H	Q	Y	8
9									I*	R*	Z*		I	R	Z	9
A					¢	!		:								
B					.	$	,	#								
C					<	*	%	@								
D					(	)	_	'								
E					+	;	>	=								
F					|	¬	?	"								

Legend:

* Codes (in addition to undefined codes) not assigned by the alphameric keyboard

SP - Space

NUL - Null

NL - New Line

Examples:

Character	Byte Code
A	81 or C1
9	F9
%	6C
NUL	00

Note:

Character code assignments other than those shown within the heavily outlined portions of the chart above are undefined. If an undefined character code is programmed, the character that will be displayed is not specified. The character displayed by the 2250 Model 3 for a given undefined character code may be different for other devices IBM reserves the right to change at any time the character displayed by the 2250 for an undefined character code.

Figure 6. Character Set and Code Assignments

supplying a constant X and Y analog voltage to the main deflection yoke. At the same time, the character deflection system forms a character by moving the beam at high speed between various addressed points in the character grid area. Figure 8 illustrates the strokes used to form the character "A" and shows the character sizes in inches.

Table 1 lists the characteristics of a character display. Character spacing (Figure 9) is an automatic function of the 2250. After each character is formed, the main deflection system automatically moves the electron beam in the +X direction to the new character area center point. The beam is moved a distance of 14 raster units (when displaying basic-size characters) or 21 raster units (when displaying large-size characters). The program can initiate additional spaces of 14 or 21 raster units each by specifying space characters to the 2840.

Table 1. Character Display Characteristics

Characteristics	Character Size	
	Basic	Large
Characters per line (max.)	74	49
Lines per display (max.)	52	35
Number of characters on display (max.)	3,848	1,715
Character spacing (raster units)	14	21
Line spacing (raster units)	20	30

Hence, one space character results in a distance of 28 or 42 raster units between the center point of the previously specified character area and the center point of the next character area. The null character does not cause a display and does not affect character-spacing circuitry.

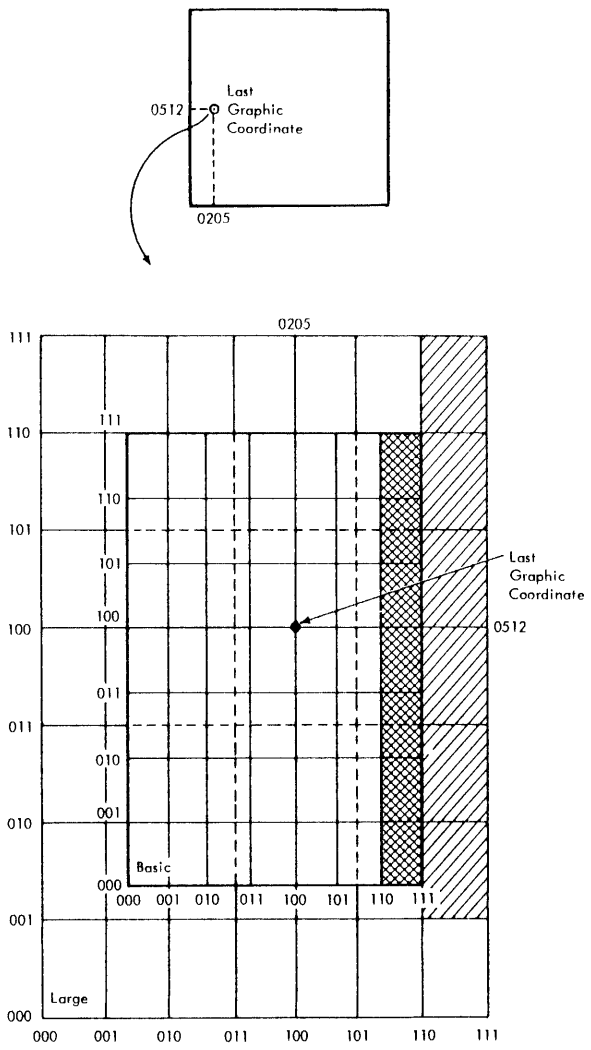


Figure 7. Character Grid Coordinate System

Line spacing is initiated either by the program or by the 2250. The program initiates a line space by specifying a new line (NL) character to the 2840. The 2840, in turn, decodes the character and sends resulting signals to the 2250 main deflection section, which repositions the electron beam to the first character area center point of a new line. The new line is 20 or 30 raster units below the previous line, depending on the character size; the first character area center point of a new line is always at X = 0000. Successive NL characters cause successive lines to be stepped.

If an NL code is not specified, the 2250 displays characters to the end of a line, automatically steps to a new line, and continues the display. The 2250 performs automatic line spacing whenever the last character formed is so near the right boundary of the display area that character spacing cannot be completed. This occurs when the center point of the last character formed is to the right of X = 1,009 (basic size) or X = 1,002 (large size).

The 2250 automatically positions the beam for a new line at the top of the display area (X = 0000, Y = 1023) only when the last line is so near the lower boundary that line spacing cannot be completed. This occurs when the line is below Y = 0,020 (basic size) or Y = 0,030 (large size).

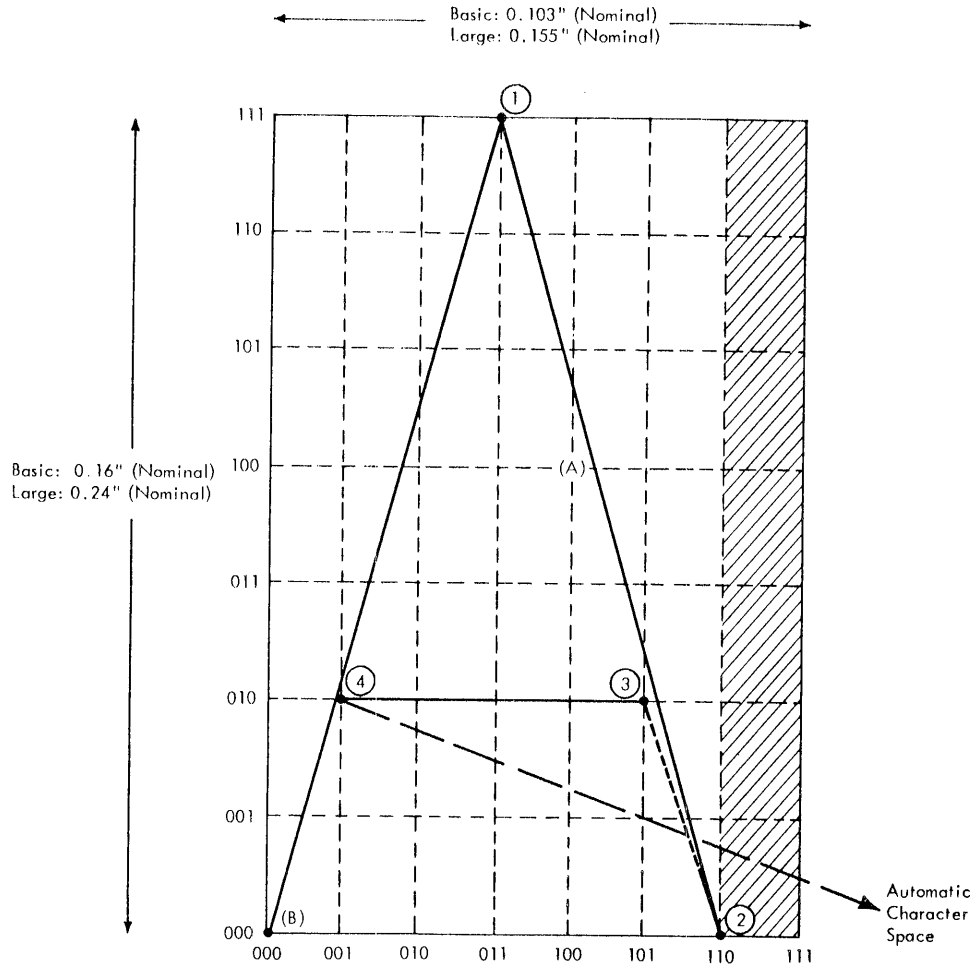
LIGHT PEN

The light pen is a fiber-optic pen-like device (Figure 10). The user communicates with the computer or the 2840-2 by pointing the light pen at the section of the displayed image (character, vector, or point) that he wants to identify to the program. When the light pen is in the desired position, the user presses the pen tip against the CRT faceplate to activate the tip switch, enabling light-pen operation. The light pen detects light from the CRT beam when the beam passes within the field of view of the pen. One detect can occur for each activation of the switch. Subsequent action is determined by the buffer program. This action could be an interrupt of the CPU program or a logical buffer action such as transfer to a new buffer address, store X, Y registers, etc.

The buffer program can also cause the light-pen switch to be bypassed so that the switch open/closed condition will not affect light-pen detects. When the light pen is continually activated by the program, a detect can occur each time the unblanked beam passes within the field of view of the light pen. This "continuous detects" mode of operation can be used in graphic design operations such as light-pen tracking. In addition, the buffer program can disable the light pen as certain information is being displayed, inhibiting light-pen detects on that information.

ALPHAMERIC KEYBOARD

This feature provides a typewriter-like keyboard from which the user can compose and/or modify messages on the CRT display area. Message areas on the display can be protected from keyboard action by the program. A dash-like mark, called a cursor, is displayed beneath a character or character position to indicate (to the user) where a character can be modified or inserted by keyboard action. For example, when a cursor is displayed under one character in a line of characters, that character can be changed or blanked by keyboard action. Also, if a cursor is displayed under a position without a character, a character can be inserted in that position by keyboard action. A cursor can also appear beneath a protected character position; however, that position cannot be used for character insertion or modification from the keyboard.



Notes:

1. Deflection AB is a function of entering character mode; upon leaving character mode, the beam is repositioned to point A of the next character grid.

2. Circled numbers refer to the sequence in which the deflection end points are addressed.

Figure 8. Strokes That Form the Letter "A"

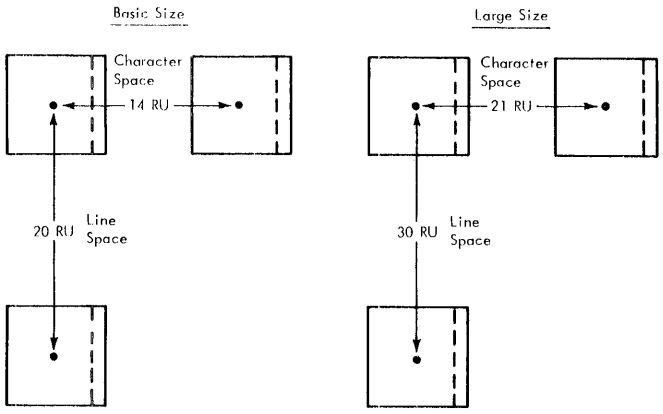


Figure 9. Character and Line Spaces

As messages are being composed or altered by the alphameric keyboard, the changes are inserted in the displayed data during the normal display regeneration cycle. This allows the user to verify the message and make corrections as necessary. The user indicates end of message by depressing the ALT and END keys, which generate both an interrupt to the CPU and data for program interpretation and action.

The keyboard (Figure 11) contains 44 keys and a space bar, which provide a selection of 63 standard characters. Alphabetic keys compose upper-case characters regardless of the status of the shift key. In addition to the standard character keys, the following function keys are provided:

ALT: When depressed with the SHIFT key released, allows selection of the Null, End, or Cancel

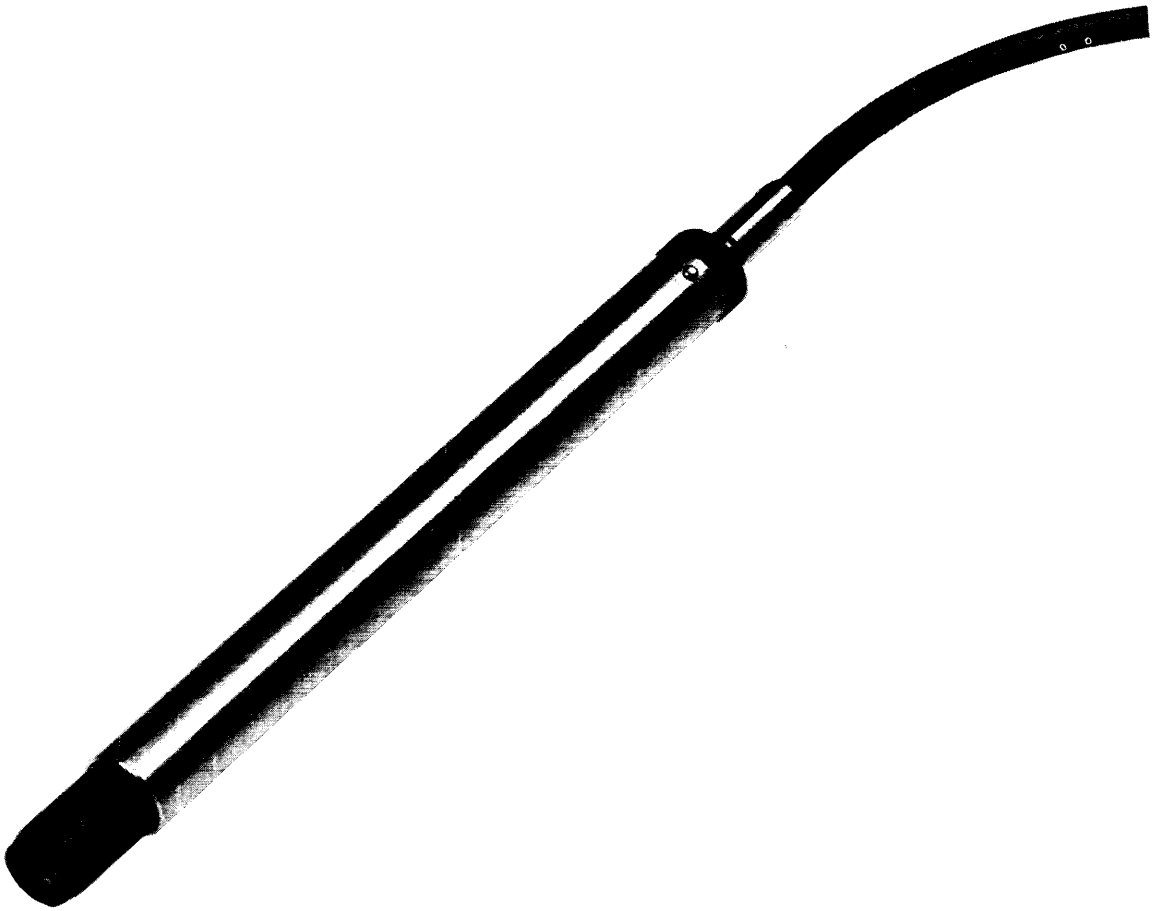


Figure 10. Fiber Optic Light Pen

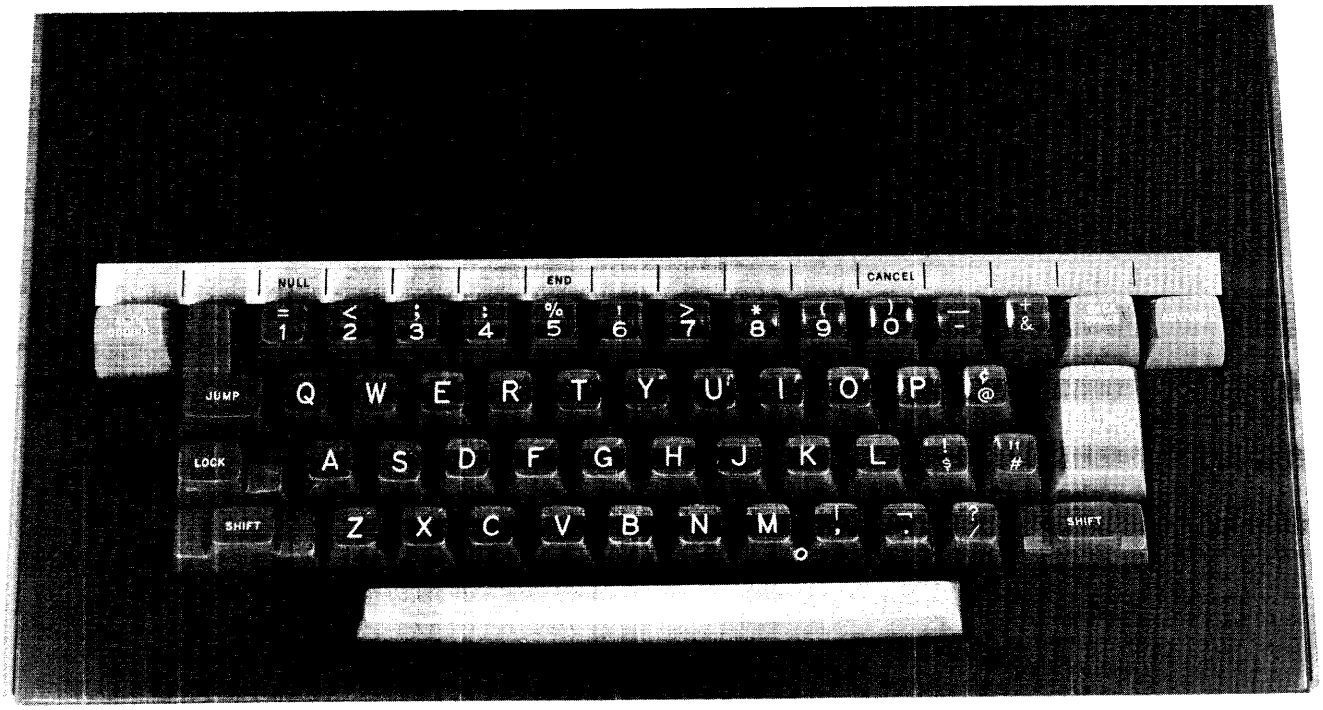


Figure 11. Alphameric Keyboard

function. When depressed with the SHIFT key, unlocks the keyboard.

SHIFT: When depressed, allows selection of the upper character by dual-character keys. When released, the lower character can be selected. The SHIFT key must be released when using the End, Cancel, or Null function. When depressed with the ALT key, unlocks the keyboard.

LOCK: While depressed, locks the SHIFT key in the depressed position.

END: Causes a CPU interrupt. It informs the program that a manual alphameric keyboard operation is completed.

CANCEL: Causes a CPU interrupt. The function of this key is determined by the application program; one possible function might be to provide the user with a method of requesting a program subroutine.

JUMP: Moves the cursor in the forward direction from its current position to the first character position of the next unprotected character area. This area may be before the cursor starting position if all positions following the cursor starting position are protected. If the cursor is in a protected character area, and if the display does not have an unprotected area (this is a programming error), depressing the JUMP key initiates a continuous search by the 2840 for an unprotected area. The display continues to cycle during this search; however, it cannot be changed or stopped by the channel program. Recovery can be made by disabling the 2250 or by a reset at the CPU.

ADVANCE: Advances the cursor one character position without changing the characters displayed. If the cursor is under the last character position of the unprotected area, it will not advance.

BACKSPACE: Backspaces the cursor one character position without changing the characters displayed. If the cursor is under the first character position of the character area, the cursor will not backspace.

CONTINUOUS: Allows continuous automatic operation of an ADVANCE, BACKSPACE, SPACE, NULL, alphameric, or special character key at the rate of the regeneration cycle.

The cursor symbol is displayed under the character position at which the character selected by the user at the alphameric keyboard will be placed. The user can move the cursor to any desired position within a protected or unprotected area into the next unprotected area only by the JUMP key or by the program. A cursor must be inserted by the program if keyboard operations are required. If the cursor is in a protected character area, it must be moved to an unprotected area by the JUMP key before the character keys become effective. Cursor operation in a protected area is the same as in an unprotected area except that a character cannot be inserted or changed from the keyboard.

When the cursor is inserted by the program into a buffer location that contains a null, the cursor is not displayed. The program must not insert a cursor into a new line (NL) position. If the user attempts to insert a character into a position where the character is actually a null character, the character will be inserted in the position containing the cursor, and all other characters to the right of the null will be shifted one character space to the right to make room for the new character. This shifting may cause automatic linespacing (if the last character in the line should be sufficiently to the right side of the display area so that the shift causes it to start a new line). The cursor will skip over the NL character when it is encountered as a result of each keyboard action. The NL character must not be either the first or the last character in a Character mode.

As each character position is used by the keyboard, the cursor is automatically displayed at the next sequential character position until it is in the last character position of the unprotected area. When this occurs, the cursor remains assigned to the last position until repositioned by the program or by the JUMP or BACKSPACE key. When a cursor is not in the buffer, the JUMP, ADVANCE and BACKSPACE keys are inactive, and keyboard lockup will not occur.

PROGRAMMED FUNCTION KEYBOARD

The programmed function keyboard (Figure 12) contains 32 keys, 32 indicators, and eight switches to sense the code punched into the overlay. The application program defines the function of each key and indicator. Each of 256 possible overlays identifies the function of the keys and indicators, both to the operator and to the CPU program. Each key can initiate a subroutine associated with the respective overlay program. When a key is pressed, the keyboard is electrically locked (keys can be pressed, but they will have no effect). The overlay sensing switch configuration is sent to the program with each key code, thereby identifying the overlay being used. The program then acts on the displayed image as directed by the program subroutine associated with the key and overlay codes. For example, the subroutine might direct the 2250 to enlarge, reduce, or delete the displayed images.

Plastic overlays (PN 5704496) are available directly from the DP Administration Operations Office (AOO). One overlay punch (PN 5704549) per installation is furnished to each customer at no charge. Additional punches can be ordered on an MES from IBM Kingston.

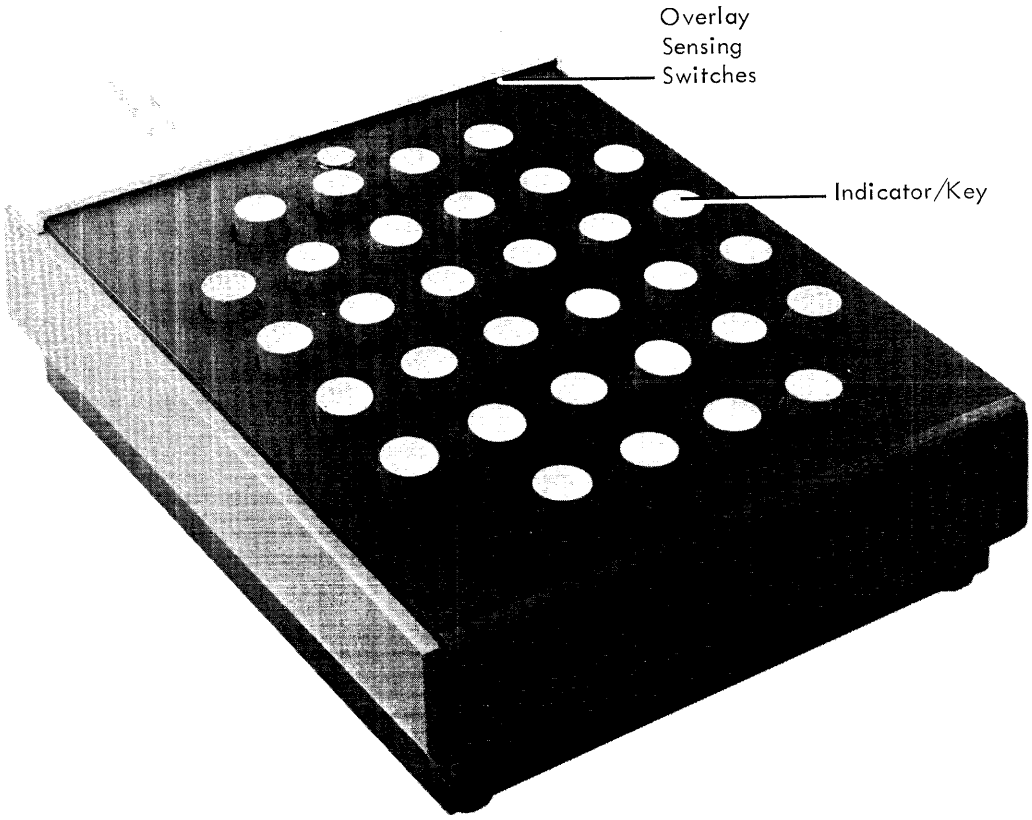


Figure 12. Programmed Function Keyboard

Each of the 32 programmed function keyboard keys has a built-in indicator. Operation of these indicators is independent of the operation of the keys; however, the indicators can be used for associated functions such as informing the operator of keys that can be, or have been, activated.

Operations performed by 2250 Model 3 Display Units are controlled by a 2840 Model 2 Display Control. All attached 2250's share the 2840 buffer (Figure 13), which is used for display regeneration. A buffer program comprising image data bytes and associated control bytes is received from the channel and placed into the buffer under channel program control. These bytes are then used by the 2840 to maintain display regeneration simultaneously for the associated 2250's. This process frees the channel and the CPU for other operations during display regeneration.

The basic 2840 buffer can store up to 32,768 bytes of information. The byte storage locations are assigned sequential permanent addresses, 0 through 32,767. During display operations, bytes are retrieved from the buffer in pairs, as needed by the attached 2250's: one from an even-numbered address and one from the next sequential odd-numbered address. (Wrap-around will occur in this buffer if the last two bytes are not occupied by a Transfer order.) Maximum time to retrieve a byte pair from the buffer during display operations is 2.0 μs, a maximum effective data rate of 1.0 μs per byte.

The buffer area (block of buffer locations) used with each 2250 is assigned in the buffer program. Two or more 2250's can display the same image from the same buffer area, or each 2250 can display from different buffer areas. The size of each assigned buffer area is determined by the buffer program and is, therefore, variable. An address register associated with each 2250 specifies the buffer location at which data for that 2250 will be stored or from which it will be retrieved. These address registers are loaded initially by the CPU program; they can then be automatically stepped by buffer addressing circuitry, altered by buffer control circuitry, or reloaded by a channel program.

ORDERS

The buffer program consists of orders interleaved with data. Orders are interpreted by the 2840 as requests to perform logical operations such as unconditional transfers or requests to decode subsequent data in any one of the available data modes (e.g., Point Plot, Large Character, etc.). The data bytes following each order contain information necessary to define points, vectors, or characters. Display layout sheets (Form No. X27-2950), which can be ordered through the local IBM branch office, aid in the planning and programming of display patterns.

Order Format

An order is composed of two, four, or six consecutive bytes. The first two bytes are always the set mode (SM) byte and a mode control (MC) byte. The SM byte contains a fixed code (hexadecimal 2A) that marks the beginning of a new order. The MC byte contains a variable code. Because a variable number of associated data bytes can immediately follow an order, the unique SM byte is provided to allow 2840 circuitry to detect the presence of a new order. The SM byte must always be located at an even-numbered buffer address, and the MC byte must immediately follow the SM byte.

The SM byte resets, modifies, or clears the present mode of operation, and the associated MC byte defines the new mode of operation. The display unit remains in the new mode until another order is received from the buffer and is executed. Once an order to enter a mode has been executed, each even-address byte thereafter is checked to determine whether it contains the SM code (indicating the start of a new order). When a four- or six-byte order (such as Transfer or Move Immediate Address) is executed, only the first even byte is checked for an SM code; each even byte after the complete order is checked as in other modes.

If an undefined order is decoded, the existing mode is reset, and the order is processed as a 2-Byte No-Op. The 2840 then continues by checking each even byte for an SM code.

Orders used in the 2840 are divided into four groups, or modes: Graphic, Character, Control, and Light Pen. The orders in each mode are listed in Table 2. They are also described, by mode, in the following paragraphs. Both the SM and MC bytes are coded in hexadecimal, which is described in Appendix A.

Graphic Mode Orders

Graphic mode orders are used for point and vector plotting and for electron beam positioning. These orders are normally followed in a buffer program by data bytes; they are sent by the 2840 to the 2250 associated with the buffer program. In either Graphic mode (Absolute or Incremental), data is transferred from the data register to the associated 2250. It is transferred from the buffer to the data registers as needed by the individual 2250's.

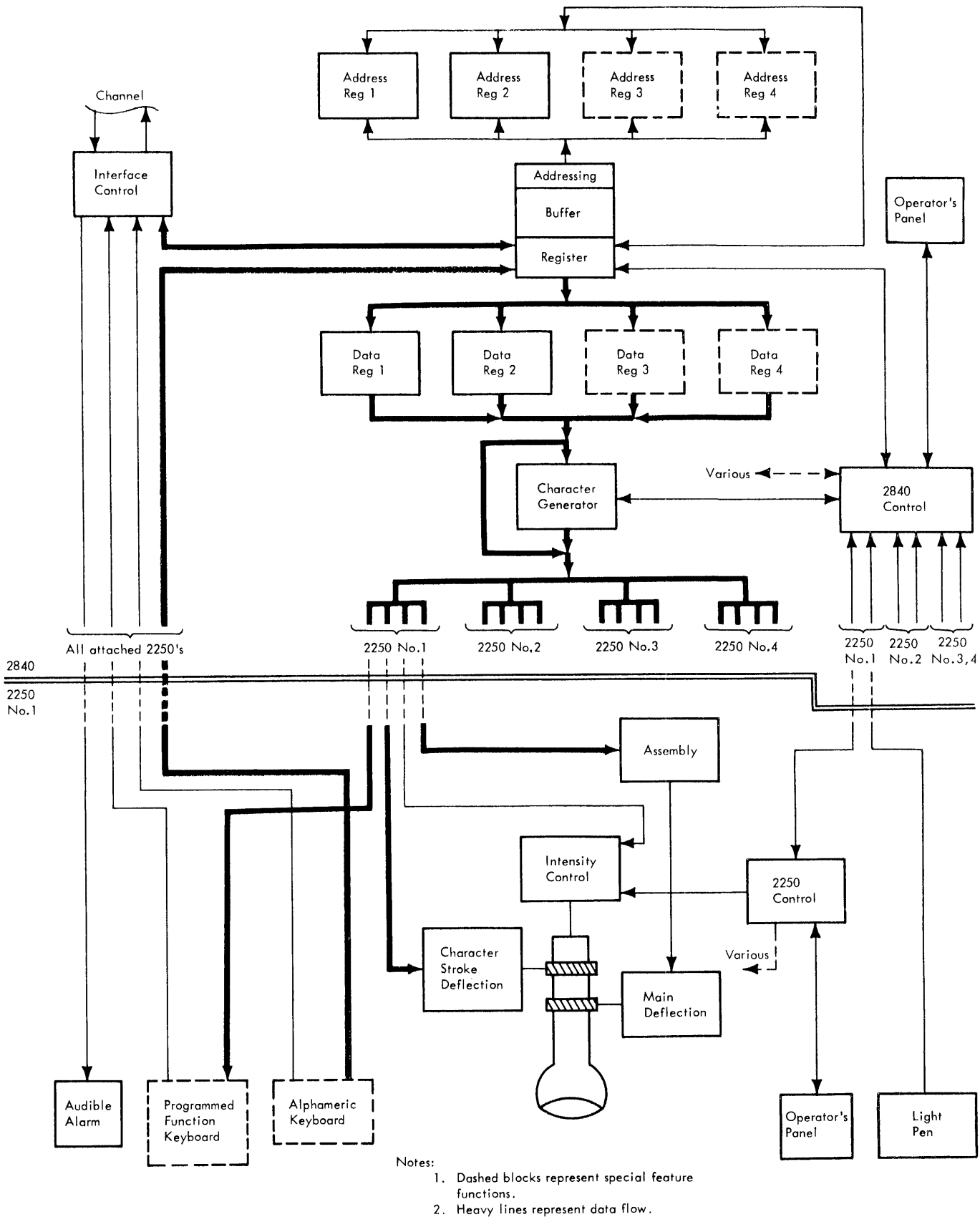


Figure 13. Functional Sections of the 2840-2 and a 2250-3

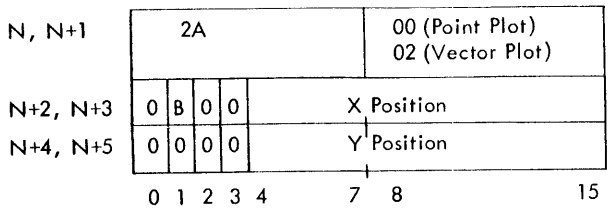
Table 2. Mode Orders

Mode	Orders		Mnemonic[1]	SM	MC
Graphic	Enter Graphic Mode, Absolute Point Plotting		GEPM (A) (ABS)	2A	00
	Enter Graphic Mode, Absolute Vector		GEVM (A) (ABS)	2A	02
	Enter Point Plot Incremental, 2 Byte Mode		GEIP2	2A	04
	Enter Vector Plot Incremental, 2 Byte Mode		GEVI2	2A	05
Character	Enter Character Mode Fixed, Basic Size (unprotected)		GECF (B) (BASIC)	2A	40[2]
	Enter Character Mode Fixed, Large Size (unprotected)		GECF (L) (LARGE)	2A	41[3]
	Enter Character Mode Protected, Basic Size		GECP (B) (BASIC)	2A	44
	Enter Character Mode Protected, Large Size		GECP (L) (LARGE)	2A	45
Control	Enter 2-Byte No-Op	2-Byte Class	GNOP2	2A	80
	End Order Sequence	2-Byte Class	GEOS	2A	81
	Start Regeneration Timer	2-Byte Class	GSRT	2A	82
	Enter 4-Byte No-Op	4-Byte Class	GNOP4	2A	C0
	Transfer Unconditional	4-Byte Class	GTRU (ADDR)	2A	FF
	Store X, Y Deflection Registers in Buffer	4-Byte Class	GSXY (ADDR)	2A	EA
	Move Immediate Address	6-Byte Class	GMVA (ADDR, LOC)	2A	EB
	Move Immediate Data	6-Byte Class	GMVD (ADDR, LOC)	2A	EC
Light Pen	Defer Response to Light-Pen Detects	2-Byte Class	GDRD	2A	83
	Enable Switch Detect Operation	2-Byte Class	GESD	2A	84
	Disable Light-Pen Detects	2-Byte Class	GDPD	2A	85
	Enable No Switch Detects Operation	2-Byte Class	GENSD	2A	86
	Permit Detect Interrupt	2-Byte Class	GPDI	2A	87
	Transfer on Deferred Detects	4-Byte Class	GTDD (ADDR)	2A	FC
	Transfer on No Detect	4-Byte Class	GTND (ADDR)	2A	FD

NOTES:

1. Parameters are shown after various mnemonics; parentheses indicate optional parameters (any one of the parenthesized parameters after the mnemonic can be used). The mnemonics shown are those used by IBM Type I Programming Support Packages.
2. An MC code of 50 or 52 can also be used: GECV (B) (BASIC) (S) (SMALL).
3. An MC code of 51 can also be used: GECV (L) (LARGE).

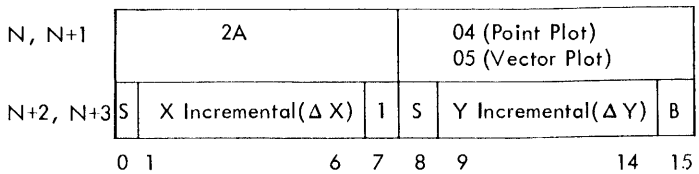
Absolute Graphic Orders (GEPM and GEVM)



Two orders, Enter Graphic Mode Absolute Point Plotting and Enter Graphic Mode Absolute Vector, provide the capability of displaying a graphic image by addressing the actual reference grid coordinates to which the electron beam is to move. Each group of four absolute data bytes identifies one beam deflection end point.

A vector or point is displayed when the blanking bit (B) is 0, and the beam is positioned without causing a display when the blanking bit is 1. An isolated line drawn between two arbitrary points requires a vector with a 1 blanking bit (no display) followed by a vector with a 0 blanking bit (drawing the line). For improved image accuracy on complete images that are displayed in less than 25 ms, the beam should be returned to the center of the display area (X = 512, Y = 512) after the image is displayed.

Incremental Graphic Orders (GEPI2 and GEVI2)



Two orders, Enter Point Plot Incremental Two Byte Mode and Enter Vector Plot Incremental Two Byte Mode, provide the capability of displaying a graphic image by specifying incremental displacement from an absolute beam position. A maximum displacement of +63 or -64 raster units can be specified for X and for Y. Each displacement value can be positive or negative. When negative, the data is presented in two's complement form (see Glossary). The incremental X and Y values are added to the absolute X and Y values (the current beam position), providing a new absolute value for the new beam position.

The two S-bits in each pair of incremental data bytes define the signs of the X and Y increments. A 0 sign bit signifies a positive number, whereas a 1 sign bit signifies a negative number in two's complement form. The blanking (B) bit associated with the new absolute value is a 0 when a point or vector is to be displayed. When the B-bit is a 1, indicating a blank vector, the beam is not intensified as it is moved to the new position. Note that bit 7 of the even data byte must always be a 1 so that the data cannot be interpreted as a set mode code.

Vector or point deflections in the Incremental mode start at the current beam position and end at an X, Y position determined as follows:

X new = X current ± ΔX

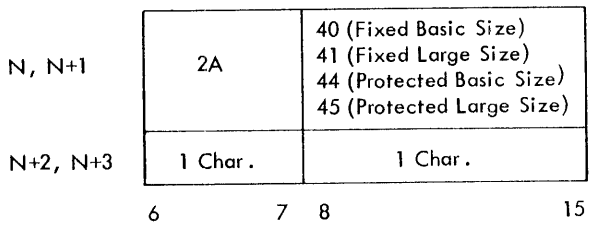
Y new = Y current ± ΔY

a string of incremental vectors or points can be moved about the screen without affecting their length or orientation by modifying the starting position of the first vector or point in the string.

In the two-byte Incremental mode, each X and Y displacement of the beam falls into the range 0 to +63 or -64 raster units (0 to 0.74 inch). When the X or Y increment causes the beam to move outside the 1,024 raster unit image area, the point or entire vector will be blanked, as will all subsequent display data until the beam is returned to the usable image area. The beam can be returned in either of two ways: by incremental movement in the opposite direction, or by displaying any absolute point or vector.

If the first absolute data bytes received by the 2250 after the beam is returned specify an unblanked vector, a line will be drawn from a wrap-around position to the specified location.

Character Mode Orders (GECF Basic or Large and GECP Basic or Large)



Each Character mode order (1) prepares the 2840 to operate with character data bytes, (2) specifies whether these bytes are to be protected against manual alteration, and (3) prepares the 2250 to display standard characters in the specified size. Character data bytes are stored in sequential buffer locations following the order. Each data byte contains the code of an alphameric or control character from the standard character set (Figure 6). For

example, the letter G is specified when a data byte is coded C7 (hexadecimal).

When an Enter Character Mode order is detected, the 2840 control section prepares the character generator for operation. Then, each pair of character data bytes read from the buffer following the order is transferred from the buffer to the data register associated with the 2250 for which the data is being provided. The first of these two bytes is then transferred to the character generator, which, in turn, transfers a series of bytes to the 2250. These bytes contain the stroke codes (X, Y character grid coordinates) required by the 2250 to form the character specified by the data byte. When more than one 2250 is in Character mode, the character generator provides stroke bytes to each 2250 as required. When the proper number of stroke codes are generated for the character selected by the first data byte in a data register, the second data byte is transferred to the character generator, initiating the generation of a new series of stroke bytes.

The Space code causes the generation of a signal that initiates one character space operation by the 2250 main deflection section. Each of the other 62 legitimate character codes causes a series of coded stroke bytes to be generated.

New line characters can appear anywhere in the string of character data except in the position immediately preceding or following an order; null characters can appear anywhere in the string. Because the null character requires a data byte, it can be used for reserving, initializing, or filling out a string of character bytes to satisfy a control boundary requirement.

Characters selected at an alphameric keyboard can be entered into a portion of the buffer area in which the block of data is preceded by an unprotected Character Mode order. When received by the 2840, the character code is inserted into the buffer location to which the cursor is assigned, replacing the code currently in the location, and the cursor is automatically assigned to the next sequential location. A cursor inserted into the buffer by the channel program identifies the specific buffer byte location into which a keyboard character can be entered. The 2840 interrogates the 2250 to determine whether an alphameric keyboard key is depressed. If any key other than END or CANCEL is depressed, the 2250 responds with the code of the depressed key.

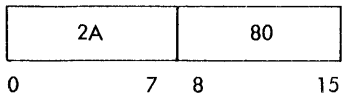
The assignment of a cursor to a buffer location does not disturb the data in that location. When a buffer location contains a cursor, and a character is read for display regeneration, the character in that location is handled in a normal manner by the 2840. When the 2840 receives the code of the ADVANCE, BACKSPACE, or JUMP key in response to the interrogation, the cursor is moved accordingly, but data in the location is not changed. When a message is completed, the user can signal the channel program by pressing the END key. The program can then retrieve all or part of the message from the 2840 buffer and store it in CPU main storage, either in place of the message that was changed or modified, or elsewhere in main storage.

The character represented by the first data byte following an Enter Character Mode order is drawn on the CRT display area at the coordinate at which the beam was last positioned. Therefore, the beam is normally moved to a desired starting location by a blanked Graphic mode vector or point before entering Character mode. Automatic spacing circuitry in the 2250 then controls the spacing between successive characters and between lines. Spacing can be accomplished through alphameric keyboard operations such as Space and Jump, or it may be accomplished through programmed Graphic mode operations.

Control Mode Orders

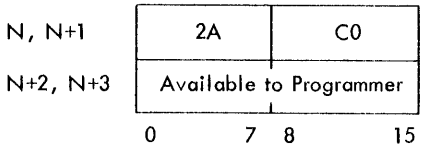
Control mode orders are used to maintain and/or to change the status of regeneration for a 2250.

2-Byte No-Op (GNOP2)



The SM-MC byte pair constitutes the complete order. This order causes the 2840 to reset either Character mode or Graphic mode, if existent, and to perform no operation with subsequent data bytes from the buffer area until the next SM code is found at an even address.

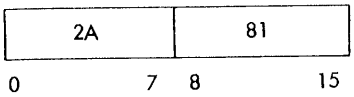
4-Byte No-Op (GNOP4)



This SM-MC byte pair requires any two additional bytes to complete the four-byte order. This order causes the 2840 to reset the last mode and to perform no operation (both with the last two bytes of the order and with subsequent data bytes from the buffer area) until the next SM code is encountered in an even location. This order can be used as a No

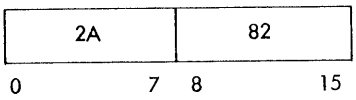
Operation/Transfer Unconditional switch by having the address portion of a Transfer Unconditional order located in the second two bytes and the 4-Byte No-Op SM-MC in the first two bytes. The program can then replace this MC byte in the buffer with the MC byte of a Transfer Unconditional order, changing the regeneration sequence.

End Order Sequence (GEOS)



This control order terminates regeneration for the associated 2250. It causes the Attention and Unit Check bits to be set in the status byte and the End Order Sequence bit to be set in sense byte 1.

Start Regeneration Timer (GSRT)



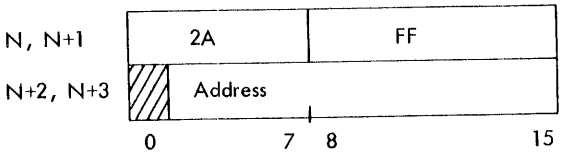
This order prevents displays with short buffer programs from using unnecessary buffer cycles, thereby freeing buffer cycles for other display programs. One 25-ms regeneration timer is provided in the 2840 for each attached 2250. The operation of each timer is independent of the others. Buffer service following the Start Regeneration Timer order is delayed if the timer for the associated 2250 has not completed the current 25-ms time period. When the time period is completed, the timer is restarted, and buffer service for image regeneration is resumed.

The Start Regeneration Timer control order must be included in each regeneration sequence. The regeneration rate is variable up to a rate of 40 cps (25 ms frame time) and is determined by the regeneration timer or by the amount of displayed information. (Messages that require less than 25 ms to regenerate will be displayed at the maximum rate of 40 cps.) A steady display image can be obtained with a regeneration rate of 30 to 40 cps.

The Start Regeneration Timer order also initiates interrogation of the 2250. Each time this order is decoded, the 2250 being serviced is interrogated to determine if a programmed-function key or alphameric key is depressed. Keyboard operations, programmed-function and alphameric, will not be recognized by the 2840 during regeneration unless this order is used in the regeneration sequence.

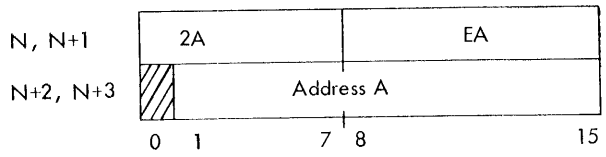
In addition, this order resets the 2250 to normal Light Pen mode as does the Enable Switch Detect Operation order. It resets these orders: Disable Light Pen Detects, Enable No Switch Detects Operation, and Defer Response to Light Pen Detects.

Transfer Unconditional (GTRU)



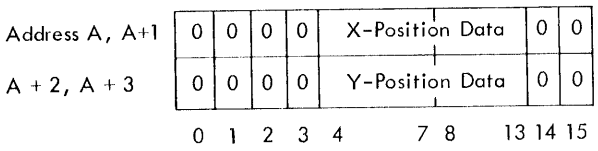
This four-byte order causes a transfer of control in the buffer program to the location identified by the address in the last two bytes of the order. If that location does not have an even address and does not contain an SM code, sequential buffer locations are read until an SM code is decoded in an even location. To maintain regeneration of the display, the end of a buffer area assigned to a 2250 normally contains a Transfer Unconditional order so that control is continually returned to the first location of that assigned buffer area. Use of the Move Immediate Address order (GMVA) allows the address portion of this order to be changed dynamically for logical control of the buffer program.

Store X-Y Deflection Registers in Buffer (GSXY)



This order causes 10 bits of X-position data and 10 bits of Y-position data from the X-Y deflection registers of the selected 2250 to be stored into buffer locations specified by the order. Address A identifies the first even buffer location of the sequential buffer locations to be used for storing the X and Y data.

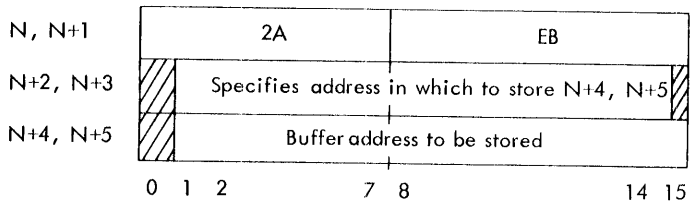
The format of the X and Y position data stored in the buffer is:



When the X-Y position data is loaded into the four buffer bytes, zeros are set into bits 0 through 3, 14, and 15. The cursor bits for these locations are also reset to zero.

Upon execution of the Store X-Y Deflection Registers in Buffer order, buffer regeneration continues from location N + 4.

Move Immediate Address (GMVA)



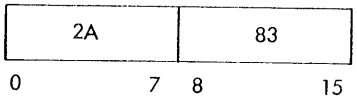
This six-byte order enables an address located in the buffer program to be relocated to another portion of the buffer.

The address stored in locations N + 2 and N + 3 specifies the buffer location at which the address stored in locations N + 4 and N + 5 is to be inserted. Note that bit 15 of the address specified in N + 2 and N + 3 is not checked; therefore, an even address is always selected, regardless of whether bit 15 is a 0 or a 1. Alter execution of this order, the next order for the 2250 receiving service will be taken from address N + 6. If location N + 4 contains an SM byte, the SM byte will be treated as part of an address, not as an order during execution of the Move Immediate Address order.

Move Immediate Data (GMVD)

This order is identical in format (except for the MC code, which is EC) and execution with the Move Immediate Address order. However, locations N + 4 and N + 5 normally contain data instead of an address.

Light Pen Mode Orders



Light pen mode orders are used primarily for graphic design operations.

Defer Response to Light Pen Detects (GDRD)

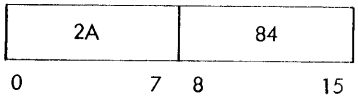
This order is executed for a 2250 only when an Enable Switch Detect Operation order or an Enable No Switch Detect Operation order is active for the 2250. Following the decoding of a Defer Response to Light Pen Detects order, the occurrence of one or more light-pen detects at the 2250 is remembered as associated with that 2250.

The remembered, or "pending", detect condition is held until any one of three orders is encountered in the buffer program for the 2250. These orders and the actions they cause when a detect condition is pending are as follows:

1. Transfer on Deferred Detect - Regeneration for the 2250 continues from the buffer address specified in this order.
2. Transfer on No Detect - This order causes no operation.
3. Permit Detect Interrupts - Generates a light-pen interrupt to the channel.

The two transfer orders reset the pending detect condition and permit a new deferred detect condition to occur. The deferred response mode established by the Defer Response to Light Pen Detects order is reset only by a Permit Detect Interrupts order or by a Start Regeneration Timer order.

Enable Switch Detect Operation (GESD)



This order causes the 2250 to operate in the normal Light Pen Detect mode. Each detect is controlled by the light-pen switch and is synchronized with the Start Regeneration Timer order.

Two orders cause the 2250 to leave the normal Detect mode: Enable No Switch Detect Operation, and Disable Light Pen Detects. The 2250 is reset to normal Detect mode either by an Enable Switch Detect Operation order or by a Start Regeneration Timer order. In normal Detect mode, the sequence of conditions that results in a detect is as follows:

1. The light-pen switch is closed.
2. A Start Regeneration Timer order is encountered following switch closure.
3. The 2250 is in normal Detect mode at the time displayed information is viewed by the light pen (i.e., at the time the information is displayed for detection).

Since light-pen detection depends on this sequence of events, a detect will occur on the first character, point, or vector that is displayed within the light-pen field of view following execution of the Start Regeneration Timer order; thus, a hierarchy of detects can be established by the programmer.

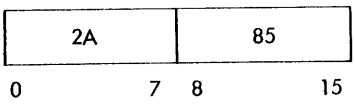
Only one normal light-pen detect can occur for each switch closure.

If a normal detect occurs, and if the 2250 is not in the Defer Response to Light Pen Detects mode, a light-pen interrupt is presented to the channel when the 2840 status and sense registers are available, and regeneration for the 2250 stops immediately. If the 2250 is also in the Defer Response to Light Pen Detects mode and a normal light pen detect occurs, regeneration for the 2250 continues, a light-pen

interrupt does not occur, and the detect condition is remembered.

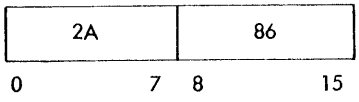
Either of two orders, Disable Light Pen Detects or Enable No Switch Detects Operation, causes the 2250 to exit from the normal Light Pen mode.

Disable Light Pen Detects (GDPD)



Light-pen detects transmitted after execution of this order are ignored. This disabled detection condition continues for the given 2250 until reset or overridden by any of the following orders: Enable Switch Detect Operation, Enable No Switch Detect Operation, or Start Regeneration Timer. In turn, the Disable Light Pen Detects order resets Enable Switch Detect Operation mode and Enable No Switch Detect Operation mode.

Enable No Switch Detects Operation (GENSD)



This order permits light-pen detects to occur independently of light-pen switch action or of Start Regeneration Timer order synchronization. In the Enable No Switch Detects Operation mode, a series of sequential asynchronous light-pen detects can be generated. This is a continuous detect mode.

This order causes the 2250 to exit from the Enable Switch Detect Operation or the Disable Light Pen Detects mode. A light-pen detect occurs when the following conditions are satisfied:

1. The light-pen switch is either closed or not closed.
2. The light-pen is conditioned by the Enable No Switch Detects Operation order, and displayed information is viewed by the pen.

The servicing of an Enable No Switch Detects Operation light-pen detect does not reset the light-pen switch, does not affect Start Regeneration Timer order synchronization associated with the Enable Switch Detect Operation mode, and does not affect any subsequent occurrence of a normal detect.

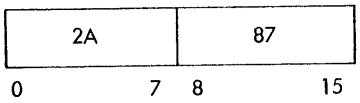
Thus, execution of this order causes top switch control of the light pen to be completely bypassed; the switch open/closed condition will not affect light-pen detection. This mode of operation continues until reset or overridden by the Start Regeneration Timer, Enable Switch Detect Operation, or Disable Light Pen Detects order. Detection and transfers in this mode will not be counted as the single response of the Enable Switch Detect Operation mode.

Light-pen detects transmitted after execution of the Enable No Switch Detects Operation order perform one of the following functions:

1. Stop regeneration, set the light-pen detect occurrence condition, and interrupt the processor when not in the Deferred Detect Response mode.
2. Be remembered within the 2250-3/2840-2 when in the Deferred Detect Response mode.

This order resets or overrides the Enable Switch Detect Operation mode and the Disable Light Pen Detects mode. The Enable Switch Detect Operation mode status of synchronization, detection , and transfer is maintained during overriding operation in the Enable No Switch Detects Operation mode. Light-pen detection, detect transfer, and no-detect transfer in this mode are independent of synchronization with the Start Regeneration Timer order and are accepted and processed in unlimited quantities as determined by the buffer program. The light-pen detect occurrence condition is reset only by encountering a GSRT, a GENSD or a GDRD order.

Permit Detect Interrupt (GDPI)

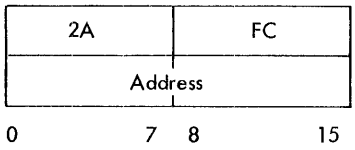


This order resets the Deferred Detect Response mode and causes a light-pen interrupt if a detect is pending. It also resets the pending detect. When a normal or continuous light-pen detect is deferred (is being remembered because the display unit is in the deferred mode) and a Permit Detect Interrupt order is encountered, the deferred light-pen detect is serviced as follows:

1. Regeneration for the selected 2250 is stopped immediately.
2. A light-pen interrupt is presented to the channel when the 2840 status and sense registers become available.
3. The buffer address presented as sense data in response to a Sense command from the channel will be the even address of the Permit Detect Interrupt order.
4. The deferred light-pen detect condition is reset.

When a Permit Detect Interrupt order is encountered and a deferred light-pen detect condition is not outstanding, the Deferred Detect Response mode is reset; however, the conditions for allowing a normal detect are not reset.

Transfer On Deferred Detects (GTDD)

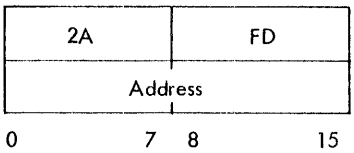


This four-byte order causes a transfer of buffer program operation to any specified buffer address if a deferred detect response is pending at the time of execution. The new buffer address is contained in the second byte pair of this order. If a detect response is not pending, the buffer program continues with the next sequential order.

When a Transfer On Deferred Detects order is encountered, and when a deferred light-pen detect is outstanding (the 2250 is in the Deferred Detect mode):

1. The regeneration sequence for the selected 2250 branches to a buffer location specified in the last two bytes of this order.
2. The deferred light-pen detect condition is reset, and no further deferred or nondeferred light-pen detects can occur until the conditions for a normal or a continuous light-pen detect are again satisfied. (GENSD mode will not be reset.)

Transfer On No Detect (GTND)



This order causes the transfer of buffer operations to a specified buffer address if the conditions for either a normal detect or a continuous detect are satisfied but a detect has not occurred. When this order is decoded, regeneration continues from the address specified in the last two bytes of this order if any one of the following three sets of conditions is satisfied:

1.
   a. The light-pen switch is closed.
   b. Since closing the light-pen switch, a Start Regeneration Timer order was encountered.
   c. When the Transfer On No Detect order is encountered, the light pen is enabled by the Enter Switch Detect Operation order or by the Start Regeneration Timer order.
   d. Since satisfying conditions a, b, and c, a detect on displayed information did not occur.
2.
   a. The light-pen switch is either closed or open.
   b. The light pen is enabled by the Enable No Switch Detects Operation order, and the 2250 is in the Defer Response to Light Pen Detects mode.
   c. When the Transfer on No Detect order is encountered, conditions a and b are satisfied, and a deferred detect is not outstanding.
3.
   a. The light-pen switch is either closed or open.
   b. The light pen is enabled by the Enter No Switch Detects Operation order, and the 2250 is not in the Defer Response to Light Pen Detects mode.
   c. When the Transfer on No Detect order is encountered, conditions a and b are satisfied, and the light-pen detect occurrence condition, as described in Enable No Switch Detect Operation, is not set.

One transfer due to the Transfer on No Detect operation is allowed in each regeneration cycle if the transfer is made from the program sections being controlled by the Normal Pen Detect Mode. This is equivalent to the one normal pen detect interrupt allowed under the same conditions. However, each section of buffer program controlled by the Enable No Switch Detects Operation order is allowed one transfer due to the Transfer on No Detects Operation order.

When the Transfer On No Detect order is encountered and the conditions for transfer are not satisfied, the order causes no operation, and a deferred light-pen detect condition, if existent, is reset.

DISPLAY REGENERATION

Display regeneration is initiated by the channel program, which specifies a starting buffer location for the selected 2250. Two bytes, one from the specified location and one from the next sequential location, are then read from the buffer. These bytes should be the Set Mode (SM) and the Mode Code (MC) of an order. If the first byte does not contain the SM code, additional byte pairs are read sequentially from the buffer until an SM code is decoded in the first byte of a byte pair. The MC byte of the order is then decoded. The Start Regeneration Timer order, GSRT, is normally the first order in the regeneration sequence. (This order must be included in each regeneration sequence.) After the first order is decoded and executed, the 2840 control section requests buffer

service (two more bytes from the buffer), continuing regeneration. Thereafter, byte pairs are retrieved from the buffer as required by the 2840 circuitry and the 2250's being serviced.

When displays are being regenerated simultaneously for more than 2250, the 2840 alternately checks each 2250 and associated 2840 circuitry to determine whether it requires service and provides this service as necessary. For example, if data bytes are needed for 2250 No. 1 (Figure 13), the contents of address register 1 are used to read two bytes from the buffer: one from the addressed buffer location and one from the next sequential buffer location. Also, the contents of address register 1 are stepped by 2 in preparation for the next service sequence. The 2840 then determines whether 2250 No. 2 needs data bytes; if it does, the contents of address register 2 are used to read two bytes from the buffer in an operation similar to that described for 2250 No. 1.

During display regeneration, each byte pair read from the buffer (except the second byte pair of a four-byte order or the second and third byte pairs of a six-byte order) is checked for an SM code in the first byte. The presence of an SM code identifies the byte pair as either a complete order or the first byte pair of an order; the absence of an SM code in the first byte identifies the byte pair as data.

When the first byte for a specific 2250 contains the SM code, the second byte (MC byte) is decoded, and resulting signals are sent to the 2840 control section. These signals set up the various conditions necessary for proper interpretation of subsequent data or orders for the 2250. The data for each 2250 is interpreted as defined by the last order decoded for that 2250.

Buffer service requests for each 2250 are satisfied sequentially. The next two bytes read from the buffer for 2250 No. 1 are either another order, the second two bytes of a four- or six-byte order, the third two bytes of a six-byte order, or graphic or character data. Operation with another order is the same as just described. The second two bytes of a four- or six-byte order will be either no-op'ed (Enter 4-Byte No-Op) or passed to address register 1, the address register associated with 2250 No. 1 (Transfer Unconditional).

Each Graphic and Character mode order is normally followed by a series of data bytes. These bytes are stored in consecutive buffer locations following the associated order. Every byte pair containing data is checked for an SM code in the buffer register; therefore, orders can follow orders without intervening data. When an SM is not found, the byte pair is transferred to the data register associated with the 2250 being serviced (for example, data register 1 when the data is for 2250 No. 1).

Once the byte pair is in the data register, the specific Character mode or Graphic mode order last decoded for the associated 2250 determines how the two bytes will be used. Data bytes following a Graphic mode order are transferred directly to the appropriate 2250, whereas the data bytes following a Character mode order are transferred to the character generator.

The 2840 attempts to transfer bytes sequentially to all 2250's, either directly from the data registers or from the character generator. Byte transfer for a specific 2250 does not occur when certain control conditions exist (e.g., light-pen detect). If byte transfer for one 2250 halts, transfer continues for other 2250's.

Each pass through the regeneration sequence for a 2250 continues until a four-byte Transfer Unconditional order is decoded. This order is normally used to branch from the last address in the buffer area used by a 2250 to the first address of the area, completing a loop for regeneration of the image. In this way, the display is repetitively rewritten, or regenerated, from bytes in the same buffer area. Regeneration continues automatically until stopped by the channel program, by a parity check, by an End Order Sequence order, or by a light-pen interrupt.

DISPLAY REGENERATION TIMING

The execution time available to display a flicker-free image is 25 ms. An image that requires less than 25 ms display time is held to a regeneration rate of 40 cps by the Start Regeneration Timer order so that a constant intensity level is maintained. An image that requires more than 25 ms display time has a regeneration rate of less than 40 cps, a rate that may result in objectionable flicker.

The execution time of a display program is determined by the order execution time, the data display time, and the buffer access time. Also affecting execution are the number of 2250's operating simultaneously and the length of cable attaching each 2250 to the common 2840.

Because of the many variables involved, it is impractical to attempt precise computations of execution times. Instead, these paragraphs present a qualitative description of system operation, followed by results for specific test cases. Execution times for other images can be approximated by interpolation.

All 2250's attached to a common 2840 share the 2840 buffer cycles. This sharing is accomplished with interleaved accesses to the buffer. Each order requires one or more buffer accesses; the data for each line or point requires one access for Incremental mode and two accesses for Absolute mode,

and one access is required for each pair of characters. Buffer access time is 2 μs per byte pair.

Each 2250 is polled sequentially by address for buffer service requests, starting with the 2250 having the next-higher address from the 2250 currently receiving service. Thus, all 2250's have equal priority in the polling sequence, regardless of address assignment. Polling is accomplished concurrently with buffer service; therefore, buffer efficiency approaches 100 percent during periods of high demand.

The execution time required for the order portion of a display program can be computed by (1) summing the number of order byte-pairs in the individual display program for each 2250 and (2) multiplying the total by 2 μs. The result of this calculation is then subtracted from 25 ms to determine the time available for actual image display. It is therefore desirable to minimize the number of orders in each 2250 display program.

Beam positioning time is obtained in one of two ways:

(1) If $N < 16$,
Positioning time = 8 μs, or

(2) If $N > 16$,
Positioning time = $8 + 92\left(\frac{N-16}{1007}\right)$ μs,
where: N = number of raster units of the axis (X or Y) having the greater change. For example, when the X-axis change is 100 raster units and the Y-axis change is 1,023 raster units (full scale deflection), N is equal to 1023.

NOTE: Add 1 μs to the beam-positioning time calculated for each unblanked point; this allows for intensification after beam motion is complete.

These methods of computing beam-positioning time can also be used to compute Character mode flyback time (the time to reposition the beam to the start of a new line). However, the beam-positioning time in Graphic mode is not equivalent to actual elapsed time between adjacent beam deflections and cannot be used to compute execution time for a display program. Fetching of the next Graphic mode X-Y coordinate is overlapped with beam motion for the current X-Y coordinate. This fetch time includes polling for 2250 buffer service requests, buffer access, decision and data flow logic delays, and cable delays. The sum of these delays often exceeds beam-positioning time, resulting in a wait between adjacent beam deflections.

Fetch time imposes a minimum effective Graphic mode cycle time of 11.8 μs per absolute deflection and 9.0 μs per incremental deflection. When several consoles are operating simultaneously, the fetch time increases, as does the minimum cycle time.

For example, assume that four 2250's are simultaneously drawing absolute vectors that require 8 μs each for beam-positioning. Eight buffer accesses, totaling 16 μs, are required for each group of four vectors. Therefore, the effective Graphic mode cycle time is at least 16 μs even though beam-positioning requires only 8 μs. If all four 2250's were drawing absolute vectors with beam positioning time greater than 16 μs, the Graphic mode cycle time would be approximately equal to beam-positioning time.

Tables 3 and 4 list the number of vectors that can be displayed by a 2250 during one 25-ms (40 cps) regeneration cycle and during one 33.3-ms (30 cps) regeneration cycle, respectively, when operating in various system configurations. The messages used to obtain the figures in these tables contained one Enter Graphic Mode order, one Start Regeneration Timer order, and one Transfer Unconditional order.

Character execution time is dependent on the number of strokes required to draw the character. An average of six strokes is required per visible character. The space (blank), null, and new line characters are each equivalent to a one-stroke visible character. A text message that contains a normal complement of spaces will average five strokes per character position. Flyback time can be computed from the beam-positioning formula presented earlier in this section. For practical purposes, total message flyback time is proportional to the number of character in a message and is almost independent of the number of lines used to display the message; this assumes that all lines start at the left margin (X = 0000) and that new line characters terminate each line after the last visible character.

The number of characters that can be displayed per console in 25 ms is determined by the number of 2250's displaying simultaneously and by the cable length. Buffer access delay does not impact character message size as heavily as it impacts graphics. The reasons for this are twofold. First, a character is stored in the buffer as one byte of data; therefore, one buffer access will fetch two characters (this is one-fourth the number of accesses required for absolute vectors). Secondly, the individual strokes that compose the characters are generated by a logic matrix which operates independently of the buffer and which can service several 2250's simultaneously.

Tables 5 and 6 list the number of characters that can be displayed per console in 25 ms (40 cps) and in 33.3 ms (30 cps), respectively, (as determined for several system configurations). The message

Table 3. Displayable Vectors Per 2250-3 at a Regeneration Rate of 40 cps

Cable Length, 2250-3 to 2840-2 (Feet)	Vector Length	Vector Length		No. of Displays Attached to 2840-2							
				1		2		3		4	
		Raster Units	Inches*	Max. # of Vectors	Inches* of Line	Max. # of Vectors	Inches* of Line	Max. # of Vectors	Inches* of Line	Max. # of Vectors	Inches* of Line
100	Incremental	16	0.188	2800	526	2800	526	2800	526	2800	526
		31	0.363	2400	870	2400	870	2400	870	2400	870
		63	0.739	1825	1350	1825	1350	1825	1350	1825	1350
	Absolute	16	0.188	2125	400	2125	400	1875	353	1400	263
		31	0.363	2070	752	2070	752	1875	680	1400	508
		63	0.739	1825	1350	1825	1350	1825	1350	1400	1035
		127	1.49	1250	1865	1250	1865	1250	1865	1250	1865
		511	5.99	465	2790	465	2790	465	2790	465	2790
		1023	12.0	250	3000	250	3000	250	3000	250	3000
1000	Incremental	16	0.188	2625	494	2625	494	2625	494	2625	494
		31	0.363	2400	870	2400	870	2400	870	2400	870
		63	0.739	1825	1350	1825	1350	1825	1350	1825	1350
	Absolute	16	0.188	1900	358	1900	358	1875	353	1400	263
		31	0.363	1820	660	1820	660	1810	658	1400	508
		63	0.739	1550	1147	1550	1147	1550	1147	1400	1035
		127	1.49	1250	1865	1250	1865	1250	1865	1250	1865
		511	5.99	465	2790	465	2790	465	2790	465	2790
		1023	12.0	250	3000	250	3000	250	3000	250	3000
2000	Incremental	16	0.188	2275	428	2275	428	2275	428	2275	428
		31	0.363	2275	825	2275	825	2275	825	2275	825
		63	0.739	1825	1350	1825	1350	1825	1350	1825	1350
	Absolute	16	0.188	1700	320	1700	320	1700	320	1400	263
		31	0.363	1630	592	1630	592	1630	592	1400	508
		63	0.739	1400	1035	1400	1035	1400	1035	1400	1035
		127	1.49	1250	1865	1250	1865	1250	1865	1250	1865
		511	5.99	465	2790	465	2790	465	2790	465	2790
		1023	12.0	250	3000	250	3000	250	3000	250	3000

*All figures involving inches are worst-case since they reflect only the X or Y component of the line (whichever is longer). Thus if all lines were at 45-degree angles, the total line length would increase by a factor of $\sqrt{2}$ or 1.414.

used to obtain this data consisted of text material (Lincoln's Gettysburg Address), one Enter Character Mode order, one Start Regeneration Timer order, and one Transfer Unconditional order.

Execution times for messages with mixed graphic and character data can be approximated by prorating Tables 3 or 5 and 4 or 6, depending on the regeneration rate. For example, assume that four 2250's are each displaying 200 basic-size characters and 1,050 absolute vectors that are each 63 raster units long. Also assume that the cable length is 100 feet for each 2250. The calculation of approximate execute time for this example using Table 3 and 5 is:

$$\text{Execution time} = \left(\frac{200}{2000} + \frac{1050}{1400}\right) 25 \text{ ms}$$
$$= (0.1 + 0.75)\ 25$$
$$= 21.3 \text{ ms.}$$

Table 4. Displayable Vectors Per 2250-3 at a Regeneration Rate of 30 cps

Cable Length, 2250-3 to 2840-2 (Feet)	Vector Type	Vector Length		No. of Displays Attached to 2840-2							
		Raster Units	Inches*	1		2		3		4	
				Max. # of Vectors	Inches* of Line	Max. # of Vectors	Inches* of Line	Max. # of Vectors	Inches* of Line	Max. # of Vectors	Inches* of Line
100	Incremental	16	0.188	3730	700	3730	700	3730	700	3730	700
		31	0.363	3200	1160	3200	1160	3200	1160	3200	1160
		63	0.739	2430	1795	2430	1795	2430	1795	2430	1795
	Absolute	16	0.188	2835	533	2835	533	2500	470	1868	351
		31	0.363	2760	1001	2760	1001	2500	907	1868	678
		63	0.739	2430	1795	2430	1795	2430	1795	1868	1380
		127	1.49	1665	2480	1665	2480	1665	2480	1665	2480
		511	5.99	620	3715	620	3715	620	3715	620	3715
		1023	12.0	333	4000	333	4000	333	4000	333	4000
1000	Incremental	16	0.188	3500	658	3500	658	3500	658	3500	658
		31	0.363	3200	1160	3200	1160	3200	1160	3200	1160
		63	0.739	2430	1795	2430	1795	2430	1795	2430	1795
	Absolute	16	0.188	2530	475	2530	475	2500	470	1868	351
		31	0.363	2430	880	2430	880	2415	877	1868	678
		63	0.739	2060	1523	2060	1523	2060	1523	1868	1380
		127	1.49	1665	2480	1665	2480	1665	2480	1665	2480
		511	5.99	620	3715	620	3715	620	3715	620	3715
		1023	12.0	333	4000	333	4000	333	4000	333	4000
2000	Incremental	16	0.188	3040	570	3040	570	3040	570	3040	570
		31	0.363	3040	1100	3040	1100	3040	1100	3040	1100
		63	0.739	2430	1795	2430	1795	2430	1795	2430	1795
	Absolute	16	0.188	2265	426	2265	426	2265	426	1868	351
		31	0.363	2175	790	2175	790	2175	790	1868	678
		63	0.739	1868	1380	1868	1380	1868	1380	1868	1380
		127	1.49	1665	2480	1665	2480	1665	2480	1665	2480
		511	5.99	620	3715	620	3715	620	3715	620	3715
		1023	12.0	333	4000	333	4000	333	4000	333	4000

*All figures involving inches are worst-case since they reflect only the X or Y component of the line (whichever is longer). Thus if all lines were at 45-degree angles, the total line length would increase by a factor of $\sqrt{2}$ or 1.414.

Table 5. Displayable Characters Per 2250-3 at a Regeneration Rate of 40 cps

Cable Length 2250-3 to 2840-2 (Feet)	Character Size	No. of Displays Attached to 2840-2			
		1	2	3	4
100	Basic (.16" high)	2100	2100	2000	2000
	Large (.24" high)	1750	1750	1650	1650
1000	Basic	2000	2000	1950	1950
	Large	1750	1750	1650	1650
2000	Basic	1750	1750	1700	1700
	Large	1500	1500	1400	1400

Notes: The number of characters shown in this table is based on standard English text messages and includes one Enter Character Mode order, one SRT order, and one Transfer order, plus the flyback times between successive lines of text.

The character densities listed in this table are theoretical. For large-size characters, densities of over 1715 exceed the maximum character density of the display area.

Table 6. Displayable Characters per 2250-3 at a Regeneration Rate of 30 cps

Cable Length 2250-3 to 2840-2 (Feet)	Character Size	No. of Displays Attached to 2840-2			
		1	2	3	4
100	Basic (.16" high)	2800	2800	2666	2666
	Large (.24" high)	2333	2333	2200	2200
1000	Basic	2666	2666	2600	2600
	Large	2333	2333	2200	2200
2000	Basic	2333	2333	2266	2266
	Large	2000	2000	1866	1866

Notes: The number of characters shown in this table is based on standard English text messages and includes one Enter Character Mode order, one SRT order, and one Transfer order, plus the flyback times between successive lines of text.

The character densities listed in this table are theoretical. For large-size characters, densities of over 1715 exceed the maximum character density of the display area.

The 2840-2 attaches to either a multiplexor or a selector channel of System/360 via the standard input/output (I/O) interface (Figure 2). Multiplexor channel operations are in the Burst mode. The channel, in turn, is attached to main storage and to the central processing unit (CPU).

The channel program controls all 2840 operations by transmitting information across the interface. This information is composed of (1) address bytes, which select one control unit (2840) and one device (2250) attached to the control unit; (2) command bytes, which specify the type of operation to be performed by the 2840 for that 2250; (3) data bytes, which are stored in the buffer for use as orders and associated display data during display regeneration; and (4) various control signals. Status bytes, which are automatically generated by the 2840, inform the channel program of the general condition of a 2250 and the 2840 at various stages of an operation.

INTERFACE OPERATIONS

The interface operations discussed briefly in the following paragraphs are described in more detail in the IBM System/360 Principles of Operation manual (SRL A22-6821). The CPU program initiates 2840 operations with a Start I/O instruction. This instruction identifies the I/O control unit and device (in this case, the 2840 and a 2250) and causes the channel to fetch the channel address word (CAW) from a fixed location in main storage. The CAW contains the storage protection key and the location in main storage from which the channel subsequently fetches the first channel control word (CCW). The CCW specifies the command to be executed and the number and address in CPU main storage of any bytes to be transmitted.

The channel then attempts to select the 2840 and a 2250 by sending a unique address byte to the 2840 and other control units on the channel or subchannel. Each control unit and device controlled by the channel has a unique address. The address byte for a 2840/2250 configuration is coded as follows:

XXXXXXXX

2840 Address — 2250 Address

If the 2840 recognizes this address byte, it logically connects to the channel and responds to the selection by returning the address byte to the channel. The channel subsequently sends the command code over the interface, and the 2840 responds with a status byte indicating whether it can execute the command. If execution of the command involves the transfer of data, the channel is set up to respond automatically to service requests from the 2840, and the 2840 assumes further control of the operation. The operation of a command can be terminated either by the channel or by the 2840.

When the channel has transferred the information specified by a CCW, it can continue the activity initiated by Start I/O by fetching a new CCW, thereby restarting the cycle. The fetching of this new CCW is called "chaining", and the CCW's belonging to such a sequence are said to be chained. All CCW's in a chain apply to the control unit (2840) and the device (2250) specified in the original Start I/O instruction. Two types of chaining are provided: data chaining and command chaining. During data chaining, the new CCW fetched by the channel defines a new main storage area for the original command. During command chaining, the new CCW fetched by the channel specifies a new command.

All display regeneration must be stopped during interface activity in which data is transmitted to or from the 2840. Interface activity for such commands as Set Programmed Function Indicators, Set Audible Alarm, No Operation, and Sense do not affect display operations; therefore, it is not required to stop regeneration when using these commands. When a sequence of unchained commands is presented across the interface, the buffer attempts display regeneration for all but the addressed 2250 during the period between the interface disconnect and the start of a new command. This condition of the buffer initiating regeneration for short intervals can be avoided by command chaining. Regeneration is stopped during the period when command chaining is in effect across the interface. When the chained sequence is completed, regeneration is continued.

The device status byte (Table 7) is sent to the channel (1) as a response to initial selection of the 2840, (2) when an interrupt condition occurs, and/or (3) during the ending phase of a 2840 operation involving data transfer between the 2840 and the channel. During the initial selection sequence, the status byte is sent to the channel after a command is received. An all-zero status byte is sent when the command is accepted by the 2840; it is also sent in response to a Test I/O instruction if no status is pending. The Unit Check bit is set if the command is not accepted by the 2840 because of program or equipment error. The Device End and

Table 7. Status Byte Bit Assignments

Bit	Name	Condition
0	Attention	Indicates a request for service from alphameric keyboard or programmed function keyboard; program should respond by issuing a Read Manual Input command. Also, the setting of both the Attention bit and the Unit Check bit indicates an interrupt condition, such as light-pen detect or data check during the regeneration cycle. The program should respond by issuing a Sense command.
1	Status Modifier	Set with the Busy bit to indicate pending status for a 2250 other than the addressed 2250.
2	Control Unit End	Set following a Busy, Status Modifier condition when the pending or stacked status is cleared to indicate that the accompanying status is the outstanding status.
3	Busy	Set in response to all commands if an interruption condition exists. The outstanding status accompanies the busy indication. The Busy bit is also set with the Status Modifier bit to indicate pending or stacked status for a 2250 which is not addressed.
4	Channel End	Set when the transfer of data and control information between the 2840 and the channel is complete. Both Channel End and Device End will be set for an ending status.
5	Device End	Set when the 2840 has completed operation on a command and is prepared to accept a new command. Both Device End and Channel End will be set for an ending status.
6	Unit Check	Set when an unusual program or equipment condition is detected at the 2840. The program should always respond by issuing a Sense command for further definition of the condition. If command execution has started, the Channel End and Device End bits also are set. If the condition is detected during regeneration, the Attention bit is set in addition to the Unit Check bit. Both the Attention bit and the Unit Check bit are set to indicate a light-pen detect condition, an End Order Sequence order, or a Data Check.
7	Unit Exception	Not used.

Channel End bits are set in response to commands that do not cause data transfer (Set Audible Alarm, Control No-Op, Insert Cursor, and Remove Cursor). When status is pending for a device (a previous status byte is awaiting transfer to the channel) the status byte, with the Busy bit set, is sent to the channel in response to all commands for that device; the command is not accepted by the 2840. For a Test I/O instruction, the pending status byte is presented without the Busy bit set.

A status byte is sent to the channel during an ending operation that is at the completion of a 2840 operation involving data transfer with the channel. The ending operation status byte always relates to the command operation just ending. The normal ending status byte will have only the Channel End and Device End bits set. Any error condition associated with the operation just executed will cause additional status bits to be set. Ending status causes an I/O interrupt unless chaining is specified.

When an interrupt condition occurs while the 2840 is operating asynchronously (not selected by the channel), the Attention bit or both the Attention bit and the Unit Check bit will be set in the status byte. An interrupt condition can be caused by a light-pen detect, a programmed function key activation, an alphameric keyboard END or CANCEL key activation, an End Order Sequence order, a buffer parity error, etc. When an interrupt condition occurs, the 2840 requests selection from the channel and sends the status byte to the channel when selection is accomplished. This status byte will be in the CSW stored by the I/O interrupt generated by the channel. The status byte is reset by the 2840 after the status information has been accepted by the channel.

COMMANDS

Four basic types of command are used with the 2840: Write, Read, Control, and Sense. The Write command initiates data transfer into the 2840 buffer area for the selected 2250. Read commands cause data transfer from the 2840 buffer or from the selected 2250 registers (programmed function keyboard, X Y position registers, etc.), via the 2840, to the channel. Control commands initiate the setting of programmed function indicators, activate a single-stroke audible alarm at the selected 2250 (which attracts operator attention to the display unit), and control display regeneration and cursor insertion. The Sense command causes the transfer of sense data to the channel; this data indicates various control and/or check conditions in the 2840 and a 2250.

The specific commands, their codes, and the minimum features required for their use are listed in Table 8. The coding is in hexadecimal, which is shown in Appendix A. In addition to the four basic types of commands, the 2840 responds to the Test I/O and Halt I/O CPU instructions. The commands accepted as valid by the 2840 depend on the features attached to the selected 2250. When a command that refers to an optional feature is presented and the selected 2250 does not have that feature, the command is treated as invalid and is rejected, causing no 2840/2250 operation.

Table 8. Commands Used with the 2840-2

Channel Command	2250 Command	Command Code	Feature Requirements* Alphameric Keyboard	Programmed Function Keyboard
Write	Write Buffer	01		
Read	Read Buffer	02		
	Read Manual Input	0E	X (or)	X
	Read Cursor	06	X	
	Read XY Position Registers	12		
	Read Output Registers**	0A		
Control	No Operation	03		
	Set Buffer Address Register and Start	27		
	Set Buffer Address Register and Stop	07		
	Insert Cursor	0F	X	
	Remove Cursor	1F	X	
	Set Programmed Function Indicators	1B		X
	Set Audible Alarm	0B		
Sense	Sense	04		

*X - The special feature required for operation of the command.
Blank - The special features that do not affect operation of the command.

**Read Output Registers is a diagnostic command which is accepted and performed only when the 2840 CE key switch is in the CE position and the CHECK STOP switch is in the DEVICE STOP position. The command causes four 2840 registers to be read out.

When loading the buffer, bytes are normally received from the channel in the following sequence:

1. A unit address byte, which selects the 2840 and a 2250. This selection is accomplished in the 2840 interface control section.
2. A Set Buffer Address Register and Stop command, which stops regeneration for the selected 2250 (if in progress) and initiates a request to the channel for two address bytes. When received, these two address bytes are passed by the interface control section and the buffer register to the address register associated with the selected 2250, selecting a buffer starting address.
3. A Write Buffer command, which specifies that a buffer write operation is to be performed and initiates a request to the channel for data bytes. When received, these data bytes are written into consecutive buffer locations, starting at the location specified by the address register.
4. If operating with an alphameric keyboard, a Set Buffer Address Register and Stop command, which selects the address for insertion, can be followed by an Insert Cursor command, which causes a cursor to be inserted.

Display generation for a 2250 is initiated in the following sequence:

1. A unit address byte is received from the channel, selecting the 2840 and the 2250 at which the display is to be generated.
2. A Set Buffer Address and Start command is received from the channel; this command initiates a request to the channel for two address bytes. When received, the address bytes are placed in the address register for the selected 2250, specifying the buffer location at which byte retrieval for display generation will start. The command then allows the 2840 to read two bytes from the buffer, thereby initiating display generation.

The above sequence can then be repeated for another 2250. Display regeneration for all 2250s is interrupted while display generation is being initiated for any 2250.

Programming Note: Unless bit 34 (the Suppress Incorrect Length Indication bit) of the Read Buffer or Write Buffer CCW is a 1, the channel program will be terminated, even if the CCW Command Chaining bit is on.

Write Buffer Command

The Write Buffer command causes the data bytes received by the 2840 following the command to be placed into consecutive buffer locations at a maximum rate of 1.9 μs per byte (526,000 bytes per second) into the buffer. If regeneration is in progress when the Write Buffer command is received, the command will not be accepted, the Unit Check bit will be set in the status byte, and the Command Reject and Buffer Running bits will be set in the sense byte.

The normal sequence for buffer write operations begins, after selection of a 2250, with a Set Buffer Address Register and Stop control command followed by a Write Buffer command. Command chaining can be used. The Set Buffer Address Register and Stop command stops regeneration and sets the buffer addressing circuitry for the selected 2250 to the address at which writing is to start. The data bytes following the Write Buffer command are stored in consecutive buffer locations. In the write operation, data transmission is terminated under channel byte count control. Once the data is written, display generation can be started by a Set Buffer Address Register and Start command. If the channel attempts to write past the last buffer location, wrap-around occurs (writing continues from the first buffer location); this destroys any data previously stored in these locations. Writing into a buffer location that contains a cursor causes the cursor to be removed.

All data bytes are parity checked as they are received from the interface. Detection of a data parity error does not terminate the write operation; however, it does cause the Unit Check bit to be set in the status byte. The Unit Check indication is sent to the channel as part of ending status when the write operation is completed. A data parity error also causes the Bus Out Check bit to be set in the sense byte. No parity correction is performed on data bytes with parity errors. In response to the unit check status, the program should issue a Sense command for further definition of the check condition. Then, after analyzing the sense data, the CPU should correct the data in the buffer by rewriting. Since the 2840 does not perform parity correction on the data byte(s) with bad parity, an attempt by the program to start regeneration without correcting the data in the buffer will result in a buffer-parity-initiated interrupt.

Read Commands

Read commands initiate information transfer from the 2840 or from the selected 2250, via the 2840, to the channel at a maximum rate of 1.9 μs per byte. Several types of Read commands can be used, depending on the optional features installed in the 2250 (Table 8). Any Read command bit configuration that is not valid for the selected 2250 causes the setting of the Unit Check bit in the status byte and the Command Reject bit in the sense byte.

Read Buffer Command

This command causes the transfer of sequential buffer data bytes to the channel via the I/O interface. Buffer regeneration for the selected 2250 must be stopped for this command to operate; failure to stop regeneration causes the Unit Check bit (in the status byte) and the Command Reject and Buffer Running bits (in the sense byte) to be set.

The Set Buffer Address Register and Stop control command stops regeneration for the selected 2250 and specifies the first buffer location to be read. Command chaining can be used. Once buffer regeneration is stopped, single or multiple read operations can be performed. The read operation is terminated by channel byte count control, which determines that the number of bytes specified by the program have been read. If the channel attempts to read past the last buffer location, wrap-around occurs (reading continues from the first buffer location). Note that whenever a location that contains a cursor is read, only the data, not the cursor, is sent to the channel.

All bytes are checked for correct parity as they are read from the buffer. Detection of a parity error does not terminate the read operation (parity is corrected on data being sent to the channel), but does cause the Unit Check bit to be set in the status byte. This status is sent to the channel when the read operation is completed. A parity error also causes to the Data Check bit to be set in the sense byte. In response to the Unit Check status, the program should issue a Sense command for further definition of the check condition. A Set Buffer Address Register and Start command is used to continue regeneration for the selected 2250 after the Read Buffer command is completed.

Read Manual Input Command

This command is used to transfer alphameric keyboard or programmed function keyboard information to the channel. Activation of the alphameric keyboard END or CANCEL key or any programmed function key causes the Attention bit to be set in the status byte when the 2250 is interrogated and if the status and sense registers are clear. The 2840 interrogates the 2250 when regeneration is in progress. When regeneration is not in progress, the regeneration timer is automatically restarted when the time period expires. In this case, interrogation of the 2250 for attention status occurs each time the timer is automatically restarted. The attention status is passed to the channel at the earliest appropriate time, such as at the end of current channel operations, causing an I/O interrupt. If the 2840 cannot pass this status to the channel before the next 2250 is interrogated, the status of the next 2250 is not accepted by the 2840 until the 2840 status and sense registers have been cleared by the 2840 - channel interface operations. When a key is activated, the keyboard remains locked until

status is presented to the channel. The channel program must then respond with a Read Manual Input command to determine which key was pressed. This command does not affect buffer operation. The 2840 responds to the Read Manual Input command by sending three bytes to the channel.

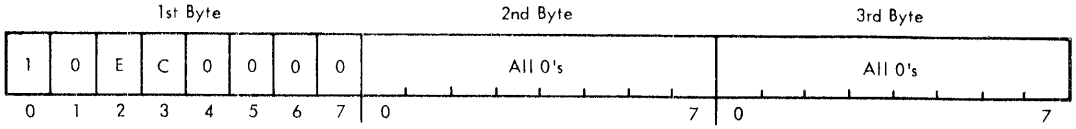
If an alphameric keyboard END or CANCEL key caused the attention status, the 2840 will send the three bytes shown in Figure 14(a) to the channel in response to a Read Manual Input command. Bit 0 of byte 0 is set to a 1 to indicate to the program that an alphameric key has been depressed. Bytes 1 and 2 will always contain all 0's.

If the programmed function keyboard caused the attention status, the 2840 sends the three bytes shown in Figure 14(b) to the channel in response to a Read Manual Input command. Bit 1 of byte 0 is set to a 1 to indicate to the program that one of the 32 programmed function keys has been depressed. Byte 1 contains a five-bit binary key code which corresponds to this key.

Byte 2 contains an eight-bit binary code which represents one of 256 possible keyboard overlays. Figure 15 is a drawing of an overlay. Note that the top edge of the overlay has punch positions numbered 0 through 7. These positions correspond to byte 2, bits 0 through 7, of the Read Manual Input command response. When an overlay punch position is punched, a 1 appears in the corresponding bit position in byte 2 of the command response. (Punch 7 is least significant.) For example, if overlay punch positions 3, 5, and 7 are punched, byte 2 of the command response is 00010101, or hexadecimal 15. Overlays can be marked by typewriter, ball-point pen, pencil, etc. A clear lacquer spray is suggested for fixing the markings on the overlay (to prevent smudging).

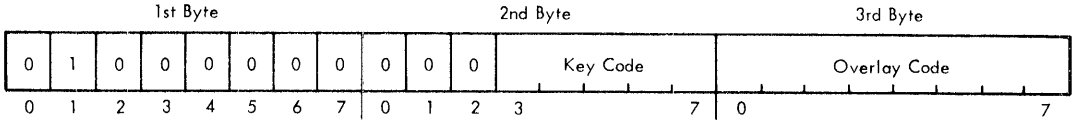
Once a key on the alphameric or programmed function keyboard has been depressed, its keyboard is locked. The alphameric keyboard is reset (1) when

a. Alphameric Keyboard



Notes:
1. Bit 0 of 1st byte is a 1, indicating response is for alphameric keyboard.
2. Bit 2 of 1st byte is a 1 when the END key causes the Attention status.
3. Bit 3 of 1st byte is a 1 when the CANCEL key causes the Attention status.

b. Programmed Function Keyboard



Notes:
1. Bit 1 of 1st byte is a 1, indicating response is for programmed function keyboard.
2. The relationship of key code in 2nd byte to the depressed key is:

Depressed Key	Key Code (Bits 3-7)
0	00000
1	00001
≈	≈
30	11110
31	11111

3. The relationship of the overlay code to the overlay punches is:

Overlay Punch	Overlay Code
None	00000000
7	00000001
6	00000010
6 and 7	00000011
≈	≈
0 thru 6	11111110
0 thru 7 or No overlay	11111111

Figure 14. Read Manual Input Command Response

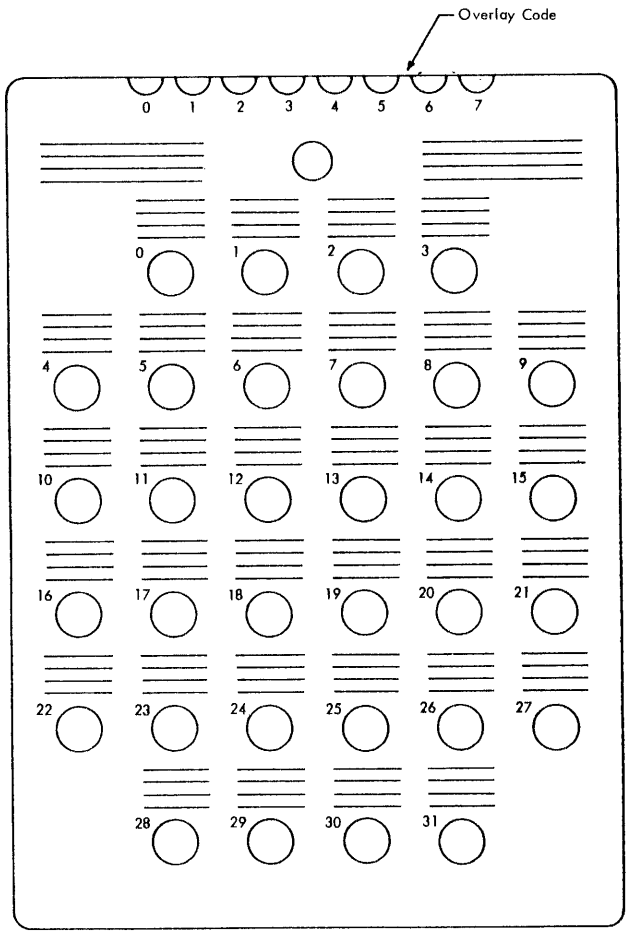


Figure 15. Programmed Function Keyboard Overlay (Top View)

an alphameric keyboard character is stored in the buffer, (2) after a Read Manual Input command is executed, or (3) when the alphameric keyboard SHIFT and ALT keys are simultaneously depressed.

Read Cursor Command

With the Read Cursor command, as with the Read Buffer command, data bytes are taken sequentially from the buffer area of the selected 2250 and passed to the channel. The distinction is in the termination. Data transmission is terminated in a Read Cursor operation by whichever of the following occurs first:

1. Channel byte count control determines that the number of bytes specified by the program have been read.
2. A buffer location to which a cursor is assigned is read.

When a cursor is encountered during a Read Cursor operation, the code 0001 1010 (hexadecimal 1A) is transmitted to the channel; the byte from the location to which the cursor is assigned is not transmitted. (Note that whenever the buffer location that is assigned a cursor is read during a read buffer operation, only the byte in that location, not the cursor code, is transmitted to the channel.) The Read Cursor command, with the skip flag set in the CCW, can be used with the Sense command to find the buffer address to which the cursor is assigned.

Buffer regeneration for the selected 2250 must be stopped for this command to operate; failure to stop regeneration causes the Unit Check status bit and the Command Reject and Buffer Running sense bits to be set. A Set Buffer Address Register and Start command is used to start regeneration for the selected 2250 after the Read Cursor operation is completed.

Read XY Position Registers

This command can be used both for obtaining light-pen detect data and for diagnostic purposes. It allows the CPU program to determine the values in the 2250 main deflection registers. In response to this command, the 2250 sends four bytes of XY data to the channel in the same format as the four Absolute Graphic mode data bytes (refer to Order description). If this command is issued by the program in response to a light-pen detect on graphic data (point or vector), the XY position data returned by the 2250 will be the X and Y coordinate of the end point of the graphic data causing the detect. If the light-pen detect was on a character, the position data is the X and Y coordinates of the center point of the next character following the character causing the detect (see Figure 9). Regeneration for the selected 2250 must have stopped before this command is issued; failure to stop regeneration causes the Unit Check status bit and the Command Reject and Buffer Running sense bits to set.

Control Commands

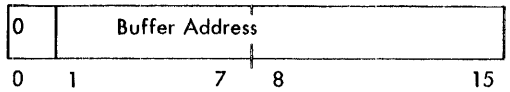
Several control commands can be used, depending on the optional features installed in the selected 2250 (Table 8). Any control command bit configuration that is not valid for the selected 2250 causes the setting of the Unit Check bit in the status byte and the Command Reject bit in the sense byte.

No Operation Command

This command performs no operation. It is an immediate command, and data bytes are not transferred.

Set Buffer Address Register and Start Command

This four-byte command initiates display regeneration for the selected 2250. It is normally used after, and can be chained to, a Write Buffer, Read Buffer, Read Cursor, Insert Cursor, and Remove Cursor command. The second two bytes of this command specify the buffer location at which regeneration should start:



Any even buffer address from 0 through 32, 766 can be specified.

The first two bytes of this command cause regeneration of all attached displays to stop and cause a request for two bytes (a buffer address) from the channel. These bytes, when received at the interface control section, are passed to the address register for the selected 2250. The command then enables display regeneration for the selected 2250 by allowing two bytes to be read from the buffer; the first byte is from the location addressed by the command, and the second byte is from the next consecutive location. These should be the first two bytes of an order, initiating regeneration operations in the 2840 and the 2250. Regeneration of the other attached displays then continues automatically.

The buffer starting location selected by this command should always have an even-numbered address and should always contain the first (SM) byte of an order. If both conditions are not met, sequential buffer locations are read and decoded in the buffer register until an SM byte is decoded from an even address; at this time, the byte in the next sequential address is read and decoded, starting the regeneration operation.

Programming Note: The Set Buffer Address Register and Start command resets Graphic or Character mode, if active, in the selected 2250.

Set Buffer Address Register and Stop Command

This command can be used to stop regeneration for a selected 2250. It causes regeneration to stop, if in progress, and initiates a request to the channel for two buffer address bytes. When received from the channel, these two bytes are placed, via the interface control section and the buffer register (Figure 13), into the address register for the selected 2250. The address bytes are coded as shown for the Set Buffer Address Register and Start command. The Set Buffer Address Register and Stop command will usually precede Write, Read, Insert Cursor, or Remove Cursor commands and may be chained to commands that specify these operations.

Set Audible Alarm Command

This immediate command causes activation, for a short period, of a buzzer (single-stroke audible alarm) at the selected 2250.

Programming Note: Bit 34 of the Set Audible Alarm CCW (the Suppress Incorrect Length Indicator bit) should be a 1.

Set Programmed Function Indicators Command

This command is used to light and extinguish programmed function keyboard indicators as specified in four data bytes that follow the command byte. These indicators, numbered 0 to 31 (Figure 12), are associated with the four data bytes as follows:

Byte	Bit Position							
	0	1	2	3	4	5	6	7
0	0	1	2	3	4	5	6	7
1	8	9	10	11	12	13	14	15
2	16	17	18	19	20	21	22	23
3	24	25	26	27	28	29	30	31

An indicator will be on (lit) when its associated data bit is a 1; it will be off if its associated data bit is a 0. The operation of this command does not affect regeneration.

Insert Cursor Command

This immediate command must be preceded by a Set Buffer Address Register and Stop command which stops regeneration for the selected 2250, if in progress, and identifies the buffer location to which the cursor is to be assigned. The cursor indication for the addressed buffer location is then set without disturbing the data byte in that location. If a Set Buffer Address Register and Stop command is not issued before the Insert Cursor command when the buffer is operating, the Insert Cursor command is rejected, the Unit Check bit is set in the status byte, and the Command Reject and Buffer Running bits are set in the sense byte. Once inserted, the cursor can be repositioned with alphameric keyboard action, with a Set Buffer Address Register and Stop command followed either by a Remove Cursor command or an Insert Cursor command, or with a Set Buffer Address and Stop command and an Insert Cursor command followed by a Write Buffer command (replacing the character at the cursor position) and an Insert Cursor command.

Programming Notes:

(1) Bit 34 of the Insert Cursor CCW must be a 1.
(2) The cursor must be inserted in a character data field only. When stored in any other field, the cursor is not displayed, and it cannot be controlled by keyboard action. However, if a Read Cursor command is executed, the buffer location is read, and command operation is terminated.
(3) Only one cursor can exist in an even-odd byte pair. Either the Insert Cursor command or the keyboard will remove the existing cursor from the byte pair while inserting the new cursor.
(4) If more than one cursor is inserted in the buffer, the first one in a character area following the Start Regeneration Timer order is the one that functions with the keyboard.

The cursor should not be inserted into a buffer program that does not have an unprotected character area. If the cursor is placed in a protected area of such a program and the JUMP key is pressed at a 2250, regeneration continues for the 2250. However, the 2840 continuously searches for an unprotected character area in the display program for the 2250 and will not operate any commands (except No Op) received while the 2250 causing the search is selected, even though the 2840 responds with normal initial status. Channel recovery from an unexecuted command can be accomplished with a Halt I/O instruction. Buffer program recovery can be accomplished by logically disabling the 2840 on the 2250 causing the search or by performing a reset at the CPU.

Remove Cursor Command

This immediate command must be preceded by a Set Buffer Address Register and Stop command, which stops regeneration for the selected 2250, if in progress, and identifies the buffer location from which the cursor assignment is to be removed. The cursor indication for the addressed buffer location is then cleared. Failure to precede this command with a Set Buffer Address Register and Stop command causes the same actions as described for the Insert Cursor command. Note that any time data is written into a buffer location, the cursor indication for that location is automatically cleared. If the buffer does not contain a cursor, this order is fully executed but will appear as a No-Op to the programmer.
Programming Note: Bit 34 of the Remove Cursor CCW must be a 1.

Sense Command

This command is used to obtain data relative to unit status and to a light-pen detect address; it can be issued by the program at any time. A Sense command is the normal response from the program to an interrupt caused by Unit Check status. (The various status and sense bit combinations are given in Appendix B.)

The information provided by the 2840 in response to this command is more detailed than that supplied in the status byte. In response to the Sense command, the 2840 can return four bytes of sense information. The first two bytes contain error and control information, and the last two bytes contain the current contents of the selected 2250's address register. If regeneration for the selected 2250 has not been stopped before a Sense command is issued, the last two sense bytes will contain a meaningless address and the Buffer Running bit (byte 0, bit 6) will be set. The sense bit assignments are shown in Table 9.
Programming Note: Channel End and Device End are the initial status response to a Sense command that is issued to a 2250 which did not cause the interrupt. Thus, issuing more than one Sense command to a selected 2250 causes this status response if a subsequent interrupt condition has occurred for another 2250.

Table 9. Sense Bit Assignments

Byte	Bit	Name	Indication
0	0	Command Reject	Indicates invalid modifier bit in command, or indicates invalid command sequence.
0	1	Intervention Required	Not used.
0	2	Bus Out Check	Indicates a Bus Out parity error on a command or data byte.
0	3	Equipment Check	Indicates a parity error on data received at 2250.
0	4	Data Check	Set when a buffer parity error occurs either during a read operation or during buffer regeneration.
0	5	Overrun	Not used.
0	6	Buffer Running	Indicates regeneration is in process for the selected 2250.
0	7		Not used.
1	0	Light Pen Detect	Set when the light-pen detect occurs.
1	1	End Order Sequence	Set when regeneration for the selected 2250 is stopped by an End Order Sequence control order.

Table 9. Sense Bit Assignment (cont)

Byte	Bit	Name	Indication
1	2	Character Mode	Set when in Character mode; clear when in Graphic mode. Used with Light Pen Detect bit.
1	3		Not used.
1	4		Not used.
1	5	2840 Output Check	Indicates a parity error in 2840 on data transmitted to a 2250.
1	6	2840 Input Check	Indicates a parity error in 2840 on data received from a 2250.
1	7		Not used.
2	0		Not used
2	1	Bit 15 (High-Order Bit)	Contents of the address register associated with the selected 2250. These bits are meaningless except during the following conditions: 1. When Light Pen Detect bit set (not deferred detect) - Address of character causing detect or first byte of X Y data for point or vector causing detect. Used with Character Mode bit. 2. When Light Pen Detect bit set (deferred detect and Permit Detect Interrupt order) - Even address of the Permit Detect Interrupt order. 3. When End Order Sequence bit is set - Address of location immediately following 2-byte End Order Sequence order. 4. When Data Check bit is set during regeneration - Address of byte with bad parity. (During read or write, the buffer address register contains the address at which the next byte will be written or read.) 5. At the completion of a Read Cursor command - Address of location immediately following location (1) to which cursor is assigned, or (2) at which the CCW count became zero, terminating the operation.
2	2	Bit 14	
2	3	Bit 13	
2	4	Bit 12	
2	5	Bit 11	
2	6	Bit 10	
2	7	Bit 9	
3	0	Bit 8	
3	1	Bit 7	
3	2	Bit 6	
3	3	Bit 5	
3	4	Bit 4	
3	5	Bit 3	
3	6	Bit 2	
3	7	Bit 1 (Low-Order Bit)	

The information in sense bytes 0 and 1 (except Buffer Running and Character mode) is reset by either of the following conditions:

1. The next command, even if invalid or with bad parity, with the exception of Sense or Control No Operation unless status is stacked.
2. A new status condition if the Sense command has been issued previously for the data presently in the sense register.

The information in all sense bytes is reset by a machine reset or a system reset.

INSTRUCTIONS

The normal interaction between the 2840 and its host CPU is controlled by channel commands. Only two CPU instructions, Test I/O and Halt I/O, give the CPU program a means of direct access to the 2840.

Test I/O

The unit will respond to the Test I/O instruction with a status byte. If there is no outstanding status information, an all-zero status byte will be sent.

Halt I/O

A CPU-executed Halt I/O instruction causes the channel to disconnect from the 2840, resulting in termination of the current I/O operation. (The Halt I/O instruction stops all channel operation with the selected 2840.) This does not affect display regeneration that is currently in progress.

The Halt I/O instruction can be issued at various phases of interface activity. If the Halt I/O instruction is issued after initial status and before ending status, the 2840 responds by sending a status byte to the channel. This status byte has the Channel End, Device End, and any error-condition bits set. At all other times, the status byte is not sent to the channel. If a Halt I/O is issued when the 2840 has pending status, the Halt I/O is executed, and the pending status is preserved and presented to the channel after the instruction has been completed.

EXAMPLES OF 2840/2250 OPERATIONS

The following examples illustrate regeneration, alphameric-keyboard, and normal light-pen-detect operations with a sample buffer program. Descriptions of the common and status sequences associated with these operations and descriptions of how these operations affect the buffer program and the display are also included. System/360 programming is not discussed.

Example 1: Displaying an Image on One 2250

A. Problem: Display a box and alphabetic characters (Figure 16) on the CRT display area of a

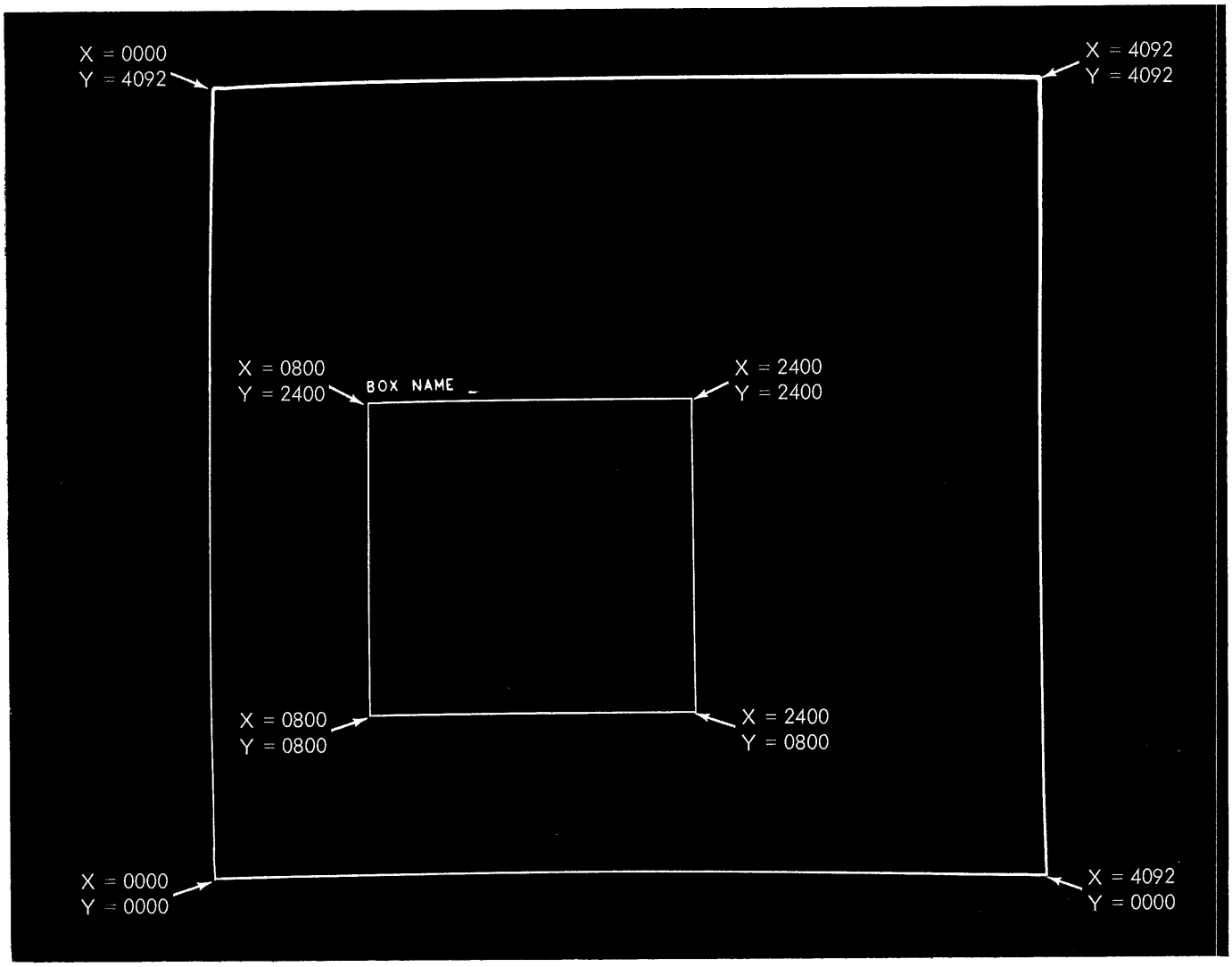


Figure 16. Buffer Program Example Display

2250 which is equipped with an alphameric keyboard, and allow characters selected at the alphameric keyboard to be displayed.

B. Command sequence executed by the 2840:

1. Set Buffer Address Register and Stop - address N. Stops regeneration for the selected 2250, if in progress, and sets the associated buffer address register to N, defining the first location of the buffer area to be used for the selected 2250.
2. Write Buffer: Causes the transfer of orders and data (Table 10) from the channel to consecutive buffer locations, starting at location N. This block of orders and data will be used to generate the desired image.
3. Set Buffer Address Register and Stop - address N + 42: Sets the associated buffer address register to N + 42.
4. Insert Cursor: Causes a cursor to be inserted in location N + 42. When the display is initiated, a cursor is displayed on the CRT display area in the position selected for buffer location N + 42, signifying to the operator that a character can be inserted from the keyboard. When a character is inserted, the cursor automatically moves to the next sequential location.
5. Set Buffer Address Register and Start - address N: Sets the associated buffer address register to N, disconnects the 2840 from the channel if it is the last command in the chain (thereby allowing the channel to perform operations with other devices), allows regeneration to continue for other 2250's, and initiates a buffer service request for the 2250 associated

with buffer area N through N + 51. Regeneration for this 2250 starts from location N. The display is then generated and regenerated under control of the orders and data read from the buffer as described in the "Function" column of Table 10.

Table 10. Buffer Program Example

Buffer Location	Content	Function
N, N+1	2A/82	Start Regeneration Timer order.
N+2, +3	2A/02	Enter Graphic Mode, Absolute Vector order.
N+4, +5	B, 800	Blanked beam moved to position
N+6, +7	800	800X, 800Y, establishing starting point for drawing box.
N+8, +9	UB, 2400	Unblanked beam moved to location
N+10, +11	800	2400X, drawing bottom horizontal line.
N+12, +13	UB, 2400	Unblanked beam moved to location
N+14, +15	2400	2400Y, drawing right vertical line.
N+16, +17	UB, 800	Unblanked beam moved to location
N+18, +19	2400	800X, drawing top horizontal line.
N+20, +21	UB, 800	Unblanked beam moved to location
N+22, +23	800	800Y, drawing left vertical line and completing box.
N+24, +25	B, 400	Blanked beam moved to position
N+26, +27	2800	400X, 2800Y, establishing starting point for plotting characters.
N+28, +29	2A/44	Enter Character Mode Protected Basic order.
N+30, +31	B/O	The word "BOX" followed by a space
N+32, +33	X/SP	is plotted.
N+34, +35	N/A	The word "NAME" is plotted.
N+36, +37		
N+38, +39	SP/NULL	Space after "NAME"; NULL makes next byte an even byte.
N+40, +41	2A/40 or 41	Enter Character Mode Fixed (Basic or Large size) order (unprotected).
N+42, +43	SP/SP	Blank spaces for operator to key in
N+44, +45	SP/SP	box name. First character of name
N+46, +47	SP/SP	is keyed into location N + 42, where cursor is positioned (previously inserted by channel program); cursor then moves to N + 43.
N+48, +49	2A/FF	Transfer Unconditional order to lo-
N+50, +51	N	cation N, regenerating the display.

Example 2: Normal Light Pen Detect Operation - 2250 Equipped with Programmed Function Keyboard

A. Problem: With a light pen, delete a line from the box drawn in Example 1.

B. Sequence:

1. At programmed function keyboard, the operator inserts the proper overlay and presses the key that indicates the delete function to the program, causing an I/O interrupt with the Attention bit set in the CSW.
2. The program responds to the I/O interrupt with a Read Manual Input command.
3. The 2840 responds to this command with (1) a data byte that specifies to the program that the interrupt was caused by the programmed function keyboard, (2) the code of the pressed key, and (3) the code of the overlay. (The Channel End and Device End status bits signal the end of this command.) The overlay and key are associated with a CPU program routine. This routine determines, from the command response information, that the operator desires to delete a portion of the display and will use the light pen to indicate the specific portion to be deleted. The program then waits for a light-pen detect condition.
4. The operator activates the light pen on the line to be deleted, initiating all asynchronous status with the Attention and Unit Check bits set in the CSW, causing an I/O interrupt.
5. The program responds to this interrupt with a Sense command.
6. The 2840 responds to the Sense command with four bytes, which inform the CPU that the light pen has been activated and indicate the first of the four buffer locations at which the coordinates of the selected line are stored. For example, if the bottom horizontal line of the box shown on Figure 16 activates the light pen, buffer address N + 8 is returned to the channel. (The Channel End and Device End status bits signal the end of this command.)
7. The CPU program determines, from the sense data, the line to be deleted. One method the program can use to delete the line is to retransmit the byte in location N + 8 (the first X byte), but with the blanking bit set to 1, specifying a blanked vector. In this way, the beam is properly positioned to draw the right vertical line of the box. The following command and data sequence received by the 2840 could be used:
   a. Command: Set Buffer Address Register and Stop, Address N + 8.

b. Command: Write
c. Data: First byte of X data with blanking bit set to 1.
d. Command: Set Buffer Address and Start, Address N.

Example 3: Alphameric Keyboard Operation

A. Problem: With the buffer contents the same as in Example 1, and with the display regenerating, insert a box name using the alphameric keyboard.

B. Sequence:

1. The operator observes the cursor to determine where the first character will be inserted. The cursor inserted in buffer location N + 42 is displayed two spaces to the right of E in the word NAME (Figure 16, Table 10). Note that the cursor bit in a buffer location is not associated with the data bits in that location; this bit causes a cursor to be displayed beneath the character selected by the data bits. In this example, the data bits in locations N + 42 through N + 47 specify space codes, causing six consecutive spaces to be left on the display for the insertion of data.
2. The operator presses a key on the alphameric keyboard: either a character key (to insert a character) or the space bar (to move to the next position without displaying a character). In either case, the cursor automatically moves to the next position.
3. The operator inserts the box name in the manner described in sequence 2, using a maximum of six positions. The characters that have been inserted are stored in buffer locations N + 42 through N + 47 and are displayed on the CRT display area. If buffer location N + 47 is used for insertions, the cursor remains in that location until it is moved (either by program or by the alphameric keyboard BACKSPACE or JUMP key). If the JUMP key is activated, the cursor is moved to location N + 42, which, because of regeneration, is the first location following N + 49 that contains unprotected data.
4. The operator checks the name and makes changes, as necessary, by positioning the cursor with the BACKSPACE, ADVANCE, and/or JUMP key and keying in the desired change.
5. When the desired message is displayed, the operator presses the END key, locking the keyboard and setting the Attention bit in the status byte.
6. The program responds to the I/O interrupt and CSW containing Attention status with a Read Manual Input command.
7. The 2840 responds to this command with three bytes that specify to the program that the Attention status was caused by the alphameric keyboard END key.
8. The program then analyzes this information and issues the following command sequence to retrieve the inserted data:
   a. Set Buffer Address Register and Stop, address N + 42.
   b. Read Buffer, specifying a byte count of 6 to the channel.

GRAPHIC DESIGN OPERATIONS

The following paragraphs describe graphic design techniques that can be programmed for a 2250-3. Included are sample buffer programs which illustrate several of these techniques.

Entities

In general, data will be composed of vectors, points, and characters; these groups are called entities. The 2250-3/2840-2 orders provide great flexibility in the storage, linkage, pen detection, identification, and manipulation of such entities. A sample entity is shown in Table 11.

Table 11. Sample Entity Routine

Buffer Location	Contents	Comments
E, E + 1	GDPD	
+ 2	GMVD	
+ 4	Adr	Program-specified location for
+ 6	LABEL	saving Entry name (i.e., LABEL)
+ 8	GDRD	Entry
+10	GEPM or GEVM	
+12	X	
+14	Y	
+16	GEVI2	
+18	X, Y	
+20	X, Y	
+22	GTDD	
+24	Adr E	
+26	GENSD	
+28	GTRU	Exit
E+30, E+31	Adr (next)	

At entry, the Defer Response to Light Pen Detects order defers detects on any element of the entity to be deferred to a single sampling time of

the Transfer on Deferred Detects order. Thus, all elements are logically a single entity for detection. A single Defer Response to Light Pen Detects order could serve for all entities. The Enter Graphic Mode, Absolute Point Plotting order initiates the entity at an absolute point so that it can only be moved on the screen by a change in the data contained within the entity. The Enter Graphic Mode, Absolute Vector order also has been used. The X-Y value may be modified directly by a Store X-Y Deflection Registers in Buffer order in the tracking subroutine. The Enter Vector Incremental order maintains the physical relationship of elements of an entity while taking advantage of the compact data storage format of two-byte vectors.

When no element of the entity is within the light-pen field of view, the Transfer on Deferred Detects order is not executed, and the next order will be the Enable No Switch Detects Operation order. When any element of the entity is within the light-pen field view, the buffer program is transferred to location E. When an entity has been detected and a Transfer on Deferred Detects order has been executed, it is necessary to perform such operations as storing entity identification. In many applications, an immediate interruption is not desired. The Disabled Pen Detects order permits the buffer program to proceed to the next entity without looping on the Transfer on Deferred Detects order.

The Move Immediate Data order stores the entity identification, LABEL, in a program-specified location for future input to the CPU. The Enable No Switch Detect Operation order resets the Disable Pen Detects mode before proceeding to the next entity. Then, the Transfer Unconditional order links each entity to the next (or back to) Start Regeneration Timer order. Additional data can be added to the buffer program by modifying the address in the Transfer Unconditional order location of the last entity in the current program.

Buffer Subroutines

Individual image subroutines, programmed with incremental orders, can be displayed in multiple screen locations by positioning the beam initially with an absolute blanked vector and transferring control to the subroutine. The subroutine is set up initially by moving a return address into a transfer instruction which is the last executable order in the subroutine.

Input by Light Pen Search

The simplest form of graphic input is implemented by touching the light pen to the screen, indicating the entry of a single graphic coordinate. The operator positions the pen and presses the light-pen switch to indicate to the buffer program that the pen position is to be read.

An incremental Graphic mode order or a Character mode order can be used to generate a raster scan of the display screen. The CPU will be interrupted upon detection of a raster element, and the X-Y position of the light pen can be determined from the character, point, or vector end point position by executing a Read X-Y Position Registers command.

Input By Light Pen Tracking

Many graphic input applications require feedback to the user. This can be accomplished by light-pen tracking with a buffer program that displays a pattern at the current light-pen position. Key elements of light-pen tracking are the display of a position-indicating pattern, sensing light-pen positions relative to the current pattern position, updating the pattern position to the new location, and storing the coordinates of the new pattern position for future updating or input to the CPU. This tracking operation can be coupled with a light-pen search routine if the initial light-pen position is not known. A sample tracking routine is shown in Table 12.

Feedback by Light Pen Tracking History

In sketching- or drafting-type operations, the user requires feedback that indicates not only where the light pen is but, also, where it has been. The simplest form of tracking history, a straight line, can be programmed in conjunction with the tracking subroutine. This can be accomplished by transferring to a tracking subroutine immediately after displaying the starting point of the straight line. The location of the pen pattern on the screen is specified by an unblanked absolute vector instead of by a point. Each time the location of the pattern is updated, the end point is established automatically at the new position. This technique is generally known as "rubber-banding".

Tracking history for curved lines and for groups of straight lines can be displayed in a variety of ways; these involve various amounts of CPU assistance and buffer programs of varying complexity. The key considerations of this operation are (1) when and where to fix a point on the path of the light-pen movement (determined by the program or by the user depressing a programmed function key to indicate the need for storage to the program) and (2) where to store the fixed points (vector end points) in the buffer (controlled by the program). (See Table 11 for sample routine to accomplish this.)

Table 12. Feedback by Light Pen Tracking History, Example Routine

Entity Routine

Symbolic Location	Buffer Location	Contents	Function
Entity 1	E, E+1	GEVM	First center point
	2	X, B	(saved).
	4	Y	
Point 1	6	GTRU	Transfer to tracking
	8	Track	routine. 2nd center point (saved).
Point 2	10	GTRU	Transfer to tracking
	12	Track	routine. 3rd center point (saved).
Point 3	14	GTRU	Transfer to tracking
	16	Track	routine. 4th center point (saved).
Point 4	18	GTRU	Transfer to tracking
	20	Track	routine. 5th center point (saved).
Point N	E+N-6	GTRU	Last point to be
	E+N-4	Track	saved this entity.
	E+N-2	GTRU	Transfer to remain-
	E+N	REST	der of regeneration program.
Tracking Routine			
TRACK	T, T+1	GEVM	End point of rubber-
	2	X, UB	band from last point
	4	Y	stored in ENTITY.
	6	GTDD	Clear pending de-
	8	A	tects.
A	10	GDRD	Defer response to light-pen detects.
	12	GENSD	Enable No Switch Detect Operation.
B	14	GEPM	Display center
	16	X, UB	dot. Symbol po-
	18	Y	sition.
	20	GTND	Transfer to M if
	22	M	center dot is not detected.
C	24	GMVA	Reset lock to per-
	26	N	mit raster search
	28	P	("lock on").
	30	GEPI2	Display right dot.
	32	+16, 0, UB	
	34	GTND	Transfer to location
	36	H	H if right dot is not detected.
	38	GEPI2	Display left dot.
	40	-32, 0, UB	
	42	GTND	Transfer to location
	44	J	J if left dot is not detected.
D	46	GEPI2	Recenter beam; all
	T+48, T+49	+16, 0, B	3 points detected.

Table 12. Feedback by Light Pen Tracking History, Example Routine (Cont)

Symbolic Location	Buffer Location	Contents	Function
E	T+50, T+51	GEPI2	
	52	0, +16, UB	Display upper dot.
	54	GTND	Transfer to location
	56	K	K if upper dot is not detected.
	58	GEPI2	Display lower dot.
	60	0, -32, UB	
	62	GTND	Transfer to location
	64	L	L if lower dot is not detected.
F	66	GEPI2	Recenter beam;
	68	0, +16, B	all points detected.
G	70	GSXY	Update symbol
	72	B	position.
	74	GTRU	Transfer uncondi-
	76	EXIT	tionally to routine exit.
H	78	GEPI2	Display left dot;
	80	-32, 0, UB	right dot not de-
	82	GTDD	tected. If left dot is de-
	84	E	tected, transfer to location E with left dot new center in X.
	86	GTRU	Transfer to location
	88	M	M for center dot detected; left and right dots not detected.
J	90	GEPI2	Move beam to right
	92	+32, 0, B	dot position; left dot not detected.
	94	GTRU	Transfer to location
	96	E	E with right dot new center in X.
K	98	GEPI2	Display lower dot;
	100	0, -32, UB	upper dot not de-
	102	GTDD	tected. Transfer to location
	104	G	G with lower dot new center in Y.
	106	GTRU	Transfer to location
	108	M	M for center dot detected; upper and lower dots not detected.
L	110	GEPI2	Move beam to up-
	112	0, +32, B	per dot position.
M	114	GTRU	Transfer to location
	T+116, T+117	G	G with upper dot new Y center.

Table 12. Feedback by Light Pen Tracking History, Example Routine (Cont)

Symbolic Location	Buffer Location	Contents	Function
	T+118, T+119	GEPI2	Display right, left,
	120	+16, 0, UB	upper, and lower
	122	-32, 0, UB	dot, and return
	124	+16, +16, UB	beam to center
	126	0, -32, UB	point.
	128	0, +16, B	
N	130	GTRU	"Lock On" switch
	132	P or EXIT	Address is set to P by C, set to EXIT by Q.
P	134	GEVI2	
	136	-128, +128, B	Display horizontal
	138	+256, 0, UB	vector along Y = 128.
	140	GTDD	Transfer to location
	142	R	R for isolation of vector segment causing detect.
	144	GEVI2	Display 256 RU
	146	-256, -64, B	horizontal vector
	148	+256, 0, UB	along Y = +64.
	150	GTDD	Transfer to location
	152	R	R for isolation of vector segment causing detect.
	154	GEVI2	Display 256 RU
	156	-256, -64, B	horizontal vector
	158	+256, 0, UB	along Y = 0.
	160	GTDD	Transfer to location
	162	R	R for isolation of vector segment causing detect.
	164	GEVI2	Display 256 RU
	166	-256, -64, B	horizontal vector
	168	+256, 0, UB	along Y = 64.
	170	GTDD	Transfer to location
	172	R	R for isolation of vector segment causing detect.
	174	GEVI2	Display 256 RU
	176	-256, -64, B	horizontal vector
	178	+256, 0, UB	along Y = 12.
	180	GTDD	Transfer to location
	182	R	R for isolation of vector segment causing detect.
Q	184	GMVA	Turn off Lock On
	186	N	switch.
	188	EXIT	
R	190	GTRU	Leave search;
	T+192, T+193	EXIT	transfer to routine exit; no display detected.

Table 12. Feedback by Light Pen Tracking History, Example Routine (Cont)

Symbolic Location	Buffer Location	Contents	Function
	T+194, T+195	GEVI2	Display far right
	196	-64, 0, UB	quarter (segment) of vector detected.
	198	GTDD	Transfer to location
	200	S	S for beam positioning to center of segment.
	202	GEVI2	Display right-center
	204	-64, 0, UB	quarter (segment) of vector detected.
	206	GTDD	Transfer to location
	208	S	S for beam positioning to center of segment.
	210	GEVI2	Display left-center
	212	-64, 0, UB	quarter (segment) of vector detected.
	214	GTDD	Transfer to location
	216	S	S for beam positioning to center of segment.
	218	GEVI2	Display for left
	220	-64, 0, UB	quarter (segment) of vector detected.
	222	GTDD	Transfer to location
	224	S	S for beam positioning to center of segment.
	226	GTRU	Transfer to routine
	228	EXIT	exit; no detect on segments.
S	230	GEVI2	Position to center
	232	+32, 0, B	of detected vector segment.
	234	GTRU	Transfer to symbol
	236	G	position update.
EXIT	238	GPDI	Permit light-pen detect interrupts.
	240	GESD	Enable light-pen switch detect operations.
	242	GTRU	Transfer to Decision routine.
	244	NEXT	
	246	GSXY	Update center
	T+248, T+249	TRACK+2	point position for start of next pass.
Decision Routine			
NEXT	D, D+1	GESD	Enable switch detects.
	D+2, D+3	GDRD	Defer response to light-pen detects.

Table 12. Feedback by Light Pen Tracking History, Example Routine (Cont)

Symbolic Location	Buffer Location	Contents	Function
	D+4, D+5	GEPI2	Intensify current beam position.
	6	X=0, Y=0, UB	Intensify current beam position.
	8	GTDD	If point at current beam position is detected, store the point location; branch to store subroutine.
	10	STORE	
	12	GTRU	Nothing to store; continue with rest of regeneration program.
	D+14, +15	REST	
Store Routine			
STORE	S, S+1	GSXY	Store current beam location in Entity.
AA	2	POINT 1	
	4	GTRU	Transfer to update subroutine.
BB	6	CC	
CC	8	GMVA	Modify location AA to contain Entity location (Point 2) to be used during next pass.
	10	AA	
	12	POINT 2	
	14	GMVA	Modify location BB to contain Store location (DD) to be used during next pass.
	16	BB	
	18	DD	
	20	GTRU	Continue with rest of regeneration program.
	22	REST	
DD	24	GMVA	Modify location AA to contain Entity location (Point 3) to be used during next pass.
	26	AA	
	28	POINT 3	
	30	GMVA	Modify location BB to contain Store location (EE) to be used during next pass.
	32	BB	
	34	EE	
	36	GTRU	Continue with rest of regeneration program.
	38	REST	
EE	40	GMVA	Modify location AA to contain Entity location (Point 4) to be used during next pass.
	42	AA	
	S+44, S+45	POINT 4	
	S+N	EOS	Terminate buffer program operations with the associated 2250. Table Overflow.
REST	S+N+2	—	Remainder of regeneration program.

Table 12. Feedback by Light Pen Tracking History, Example Routine (Cont)

Table 12 (an example of a buffer program) illustrates the use of the logical orders available on the 2840-2. The buffer program must first be prepared by the System/360 program and then transmitted to the 2840-2, using System/360 I/O commands. It demonstrates one means of programming light-pen tracking, rubber-banding, and storing data into a predefined framework without interrupting the CPU. Orders are coded in the mnemonics used by IBM type 1 support (as an aid to order identification).

The example program is divided into four parts, or routines, as shown in Figure 17. The basic functions of these routines are as follows:

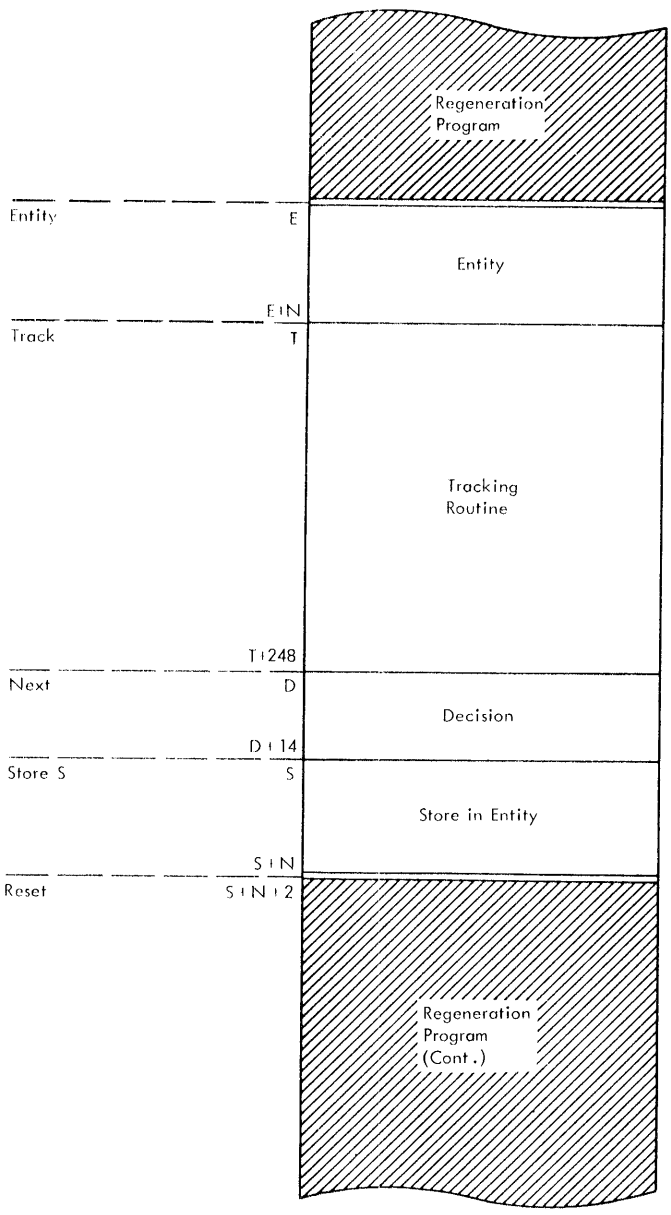
1. Entity - The predefined area for storage of data supplied by the user. When the entity table is complete it will contain a Graphic mode order, a series of absolute X, Y positions which will be displayed, and a transfer to the next predefined area in the buffer program to maintain continuity of regeneration.

2. Tracking - calculates the current light-pen position in relation to the previous position. The first four bytes cause a vector to be displayed from the last position saved in the entity to the tracking pattern implementing the rubber-band effect.

3. Decision - Determines whether the user desires the current light-pen position to become an entity. If he does, the Store routine is executed; if he does not, the next buffer program for the 2250 is started.

4. Store in Entity - Stores each entity at sequential locations in the entity routine.

Figure 18 is a flow diagram of the example program. The program first attempts to detect the light-pen position in relation to the pattern of points shown in Figure 19. It can track light-pen movement with this pattern as long as the center point and the left or the right point followed by either the upper or the lower point are detected.



Note:
It is not required that routines be located sequentially in the buffer.

Figure 17. Sequence of Routines in Light Pen Tracking History Programming Example

If none of these conditions are met, the routine attempts to locate the light-pen position by displaying a vector pattern (Figure 20). If a vector in this pattern is detected by the light pen, the vector is immediately regenerated in four equal segments to further localize the light-pen position. When a segment is detected, the center location of the detected segment becomes the current entity; thus, this segment center location will be the center of the point pattern when displayed during the next program pass.

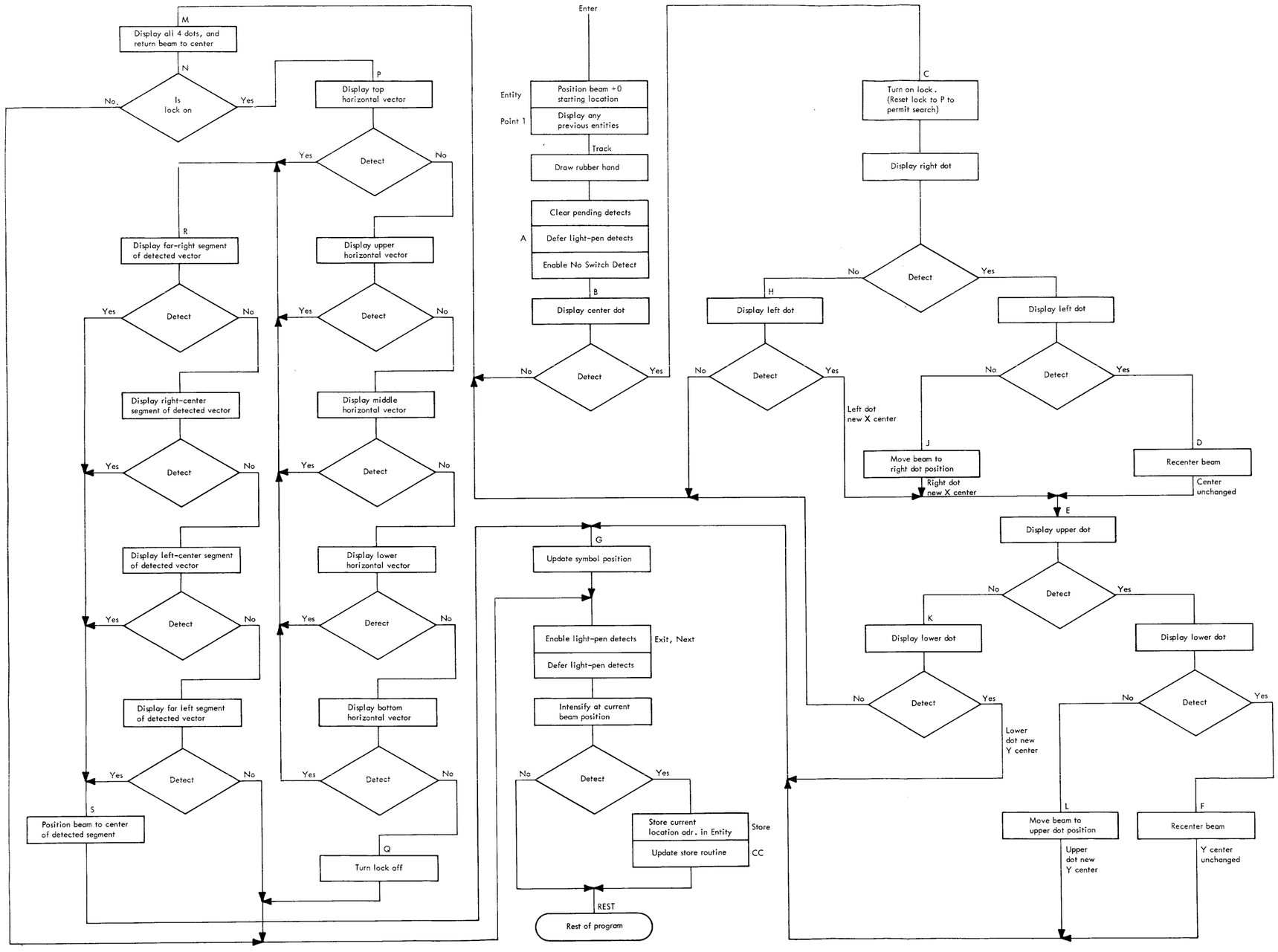


Figure 18. Flow Diagram of Example Program

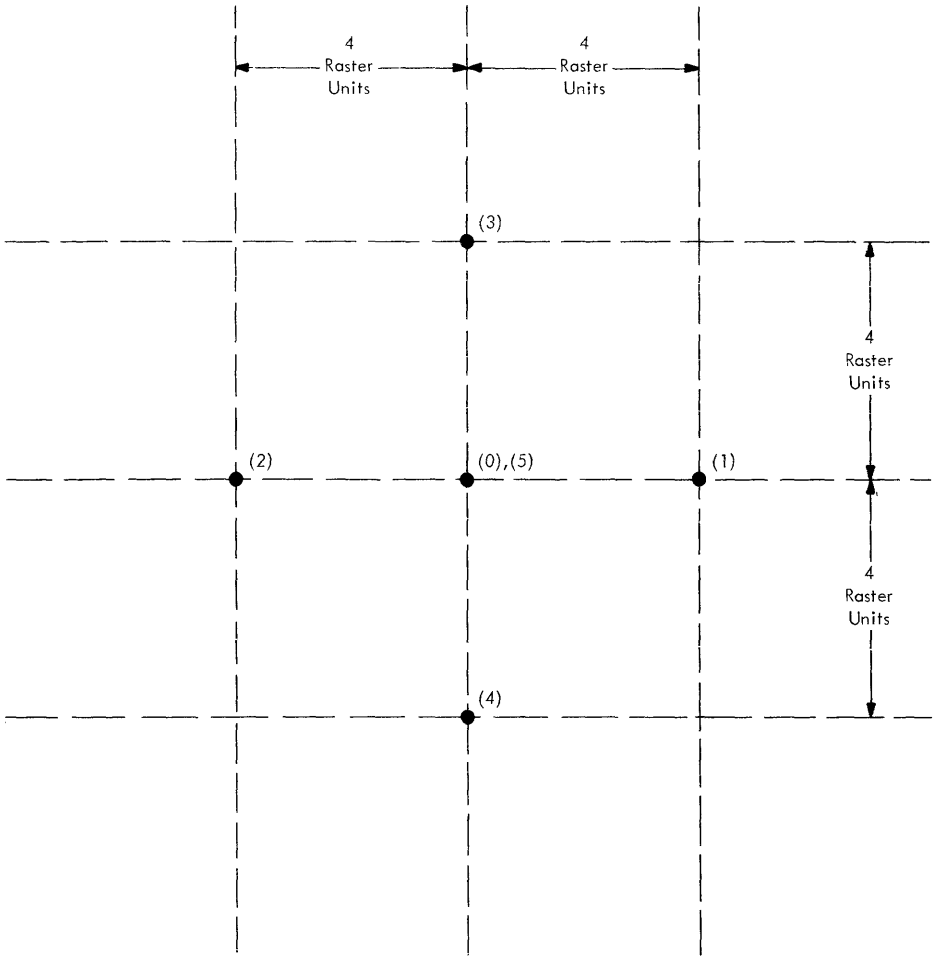
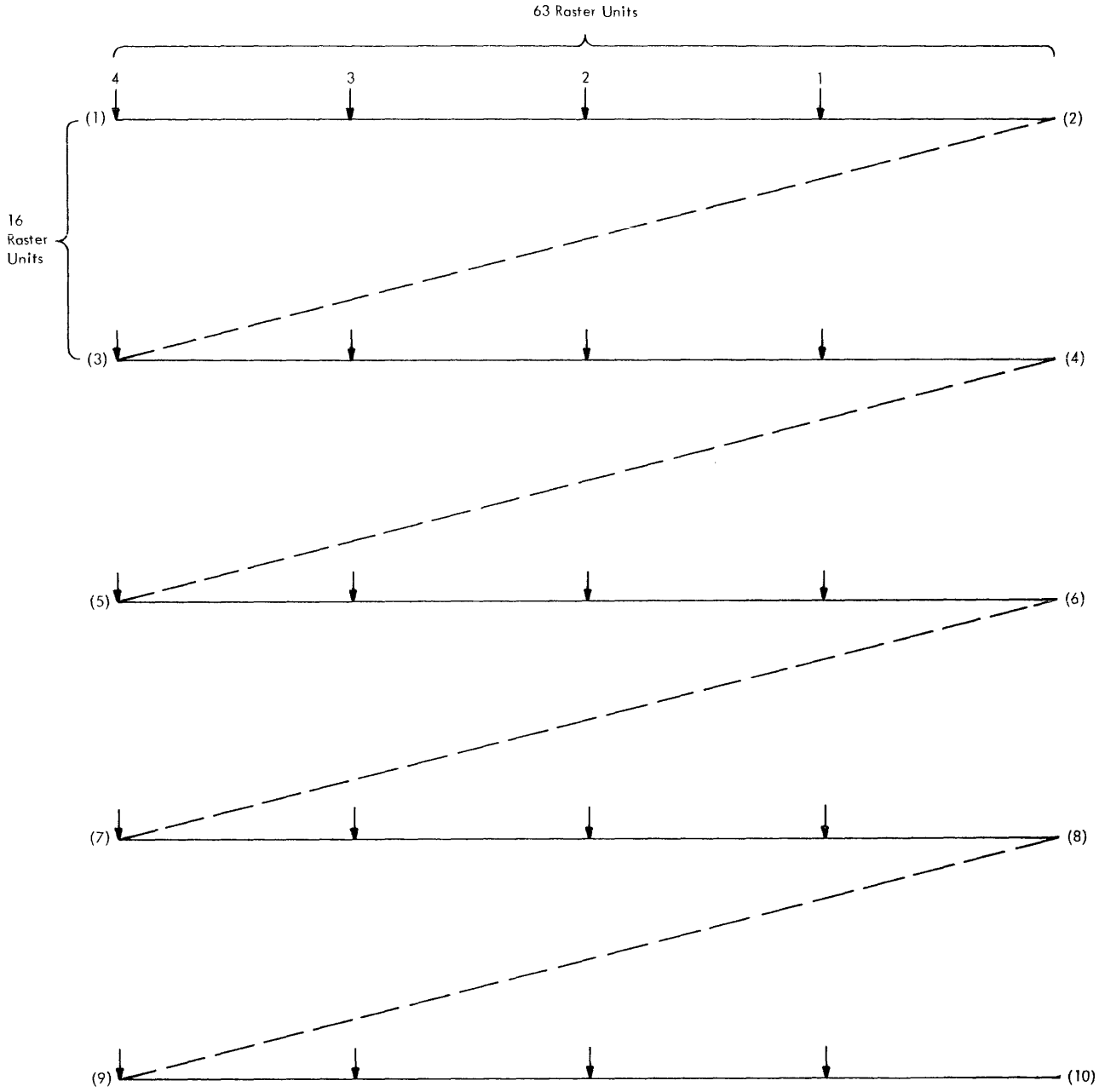


Figure 19. Point Pattern Used in Example Program



Notes:

1. Numbers in parentheses denote sequence in which vector end points are addressed.
2. Dashed lines represent blanked vectors.
3. Numbers above arrows denote sequence in which vector segment end points are addressed.

Figure 20. Vector Pattern Used in Example Program

BASIC OPERATOR CONTROLS AND INDICATORS

All 2250 Display Units are equipped with the following basic controls and indicators (Figure 21):

POWER ON key/indicator: Applies power to the 2250; indicator is lit when power is applied. (The time delay between activation of this key and the appearance of a display is nominally 25 seconds, which allows for circuit warmup.)

POWER OFF key: Removes power from the 2250.

BRIGHTNESS Control: Controls the light intensity of the overall display for a given regeneration rate. It should be in a setting that allows point plots, end points, short-length vectors and character strokes to be visible while the Dynamic Vector Intensity and Dynamic Character Intensity controls are fully counterclockwise. If this causes a display in which character and line intensity is not uniform, the appropriate dynamic control can be used to optimize the intensity. Failure to follow this procedure may result in faulty light-pen operation.

DYNAMIC VECTOR INTENSITY control: Controls line/vector light intensity.

DYNAMIC CHARACTER INTENSITY control: Controls character light intensity.

The 2840 is equipped with the following operator controls and indicators (Figure 22):

POWER ON key/indicator: Applies power to the 2840; indicator lights when power is applied.

POWER OFF IF IN LOCAL KEY: Removes power from the 2840 if the internal REMOTE-LOCAL key is in the local position.

NOTE: Any power on-off transition in the 2840 while the CPU is running will cause system errors.

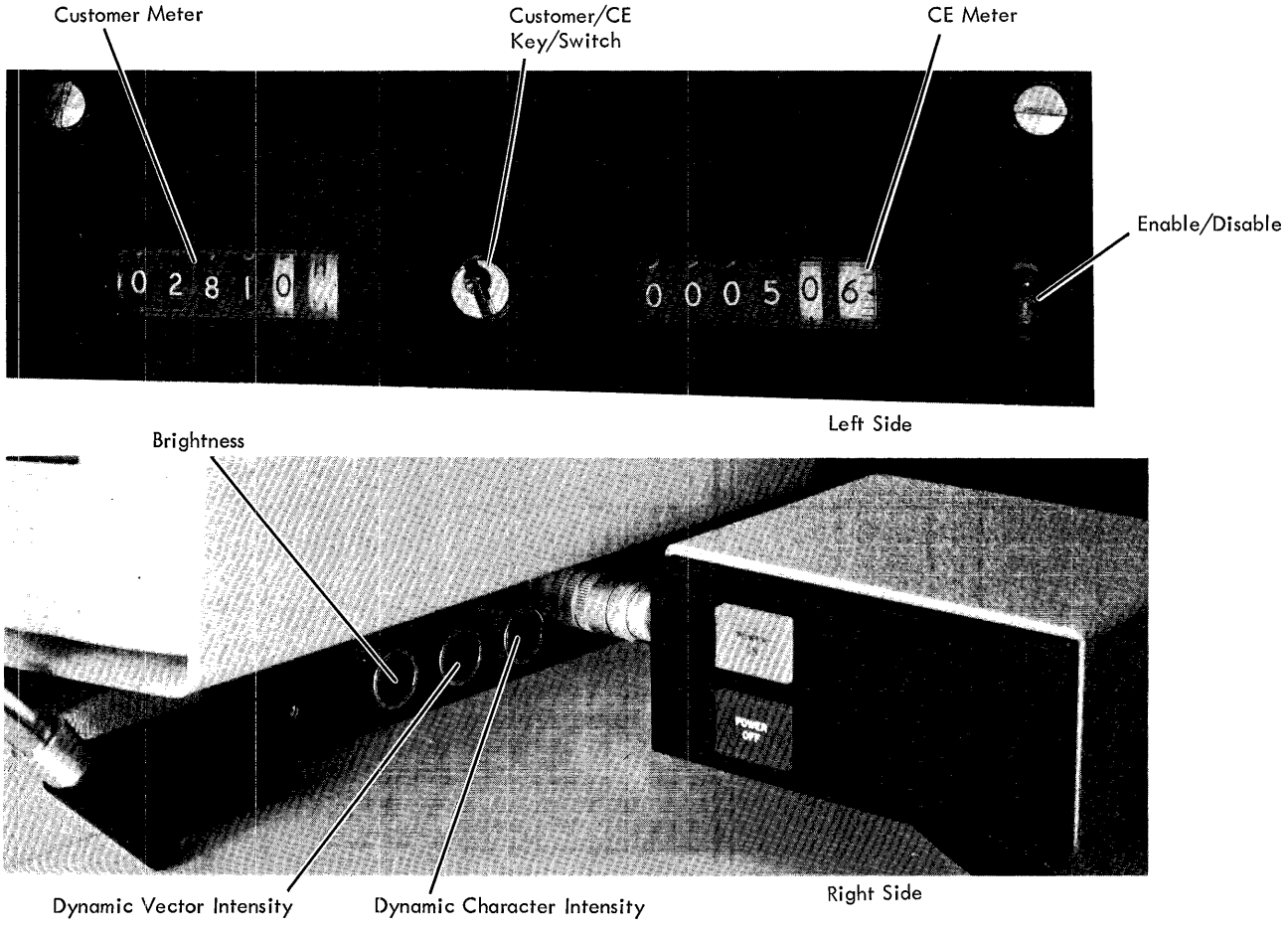


Figure 21. 2250-3 Operator Controls and Indicators

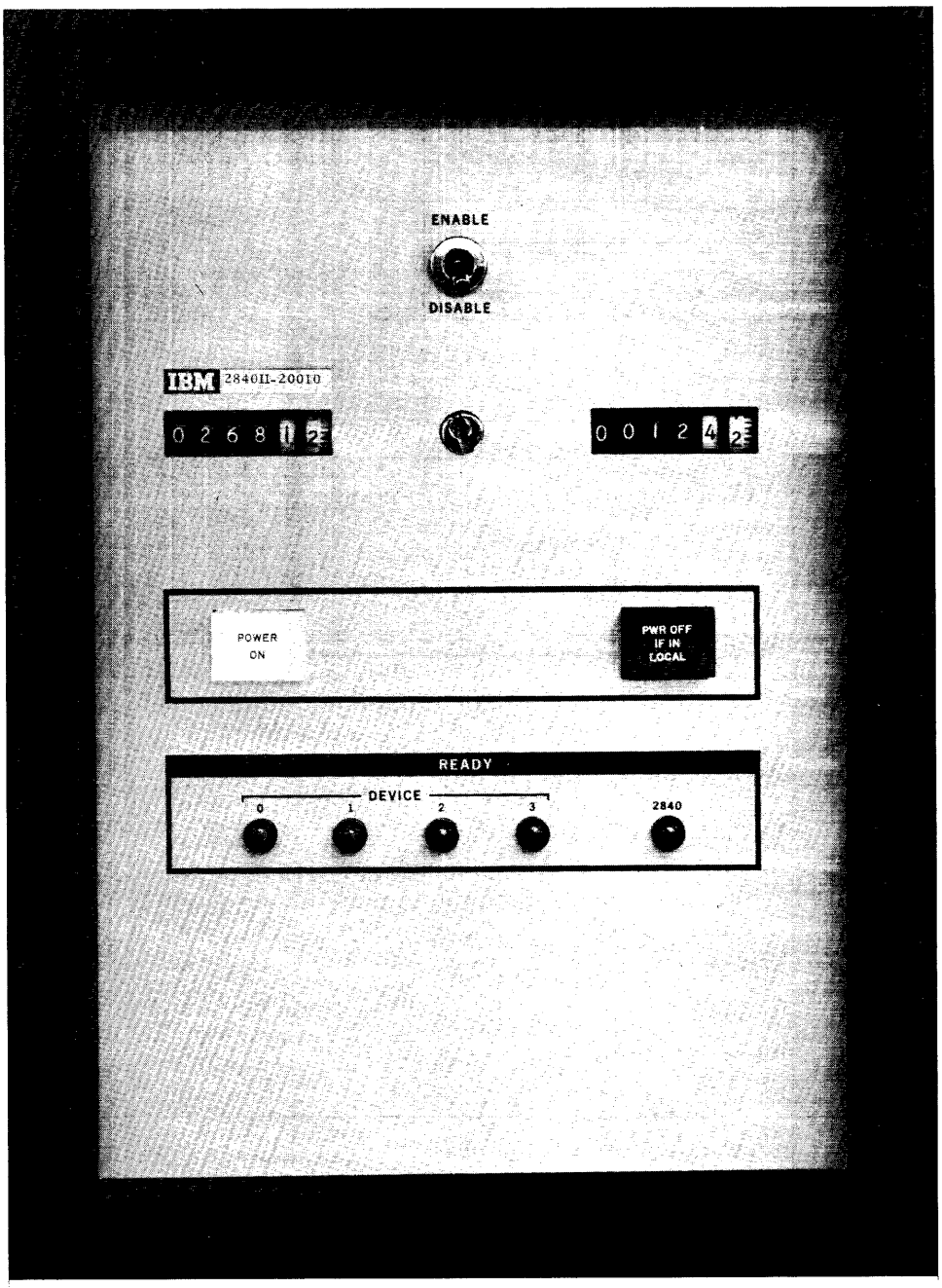


Figure 22. 2840-2 Operator Panel

READY indicators

a. DEVICE 0 through 3: Each indicator is lit when its associated 2250 is in the ready condition (power on and logically enabled).
b. 2840: Lit when the 2840 is in the ready condition.

METERING

Each 2840 and 2250 is equipped with the following meters and controls (Figures 21 and 22):

Customer Meter: Records time when the unit is logically enabled and the CE key is in the customer position.

CE (Customer Engineer) Meter: Records time when selected by the CE key switch.

Enable Switch: Allows the unit to become logically enabled or disabled.

CE Key Switch: Determines which meter (customer or CE) will be used to record time.

The customer meter on a unit that is logically disabled will be prevented from recording time,

and the unit is prevented from operating. When a unit CE key switch is in the customer engineer position, the CE meter on the unit will record time, and the customer meter will be inoperative. When a 2840 customer meter is recording time, a signal is sent to all attached 2250 display units, allowing the 2250 meters to record time. The CPU cluster meter is conditioned to record time when the 2840 is operating with the channel.

Meter operation for the 2840 is as follows:

1. The 2840 customer or CE meter will record time when the 2840 is enabled and the CPU cluster meter is running or when the 2840 is enabled and the buffer is running.
2. The 2840 customer meter will record time when item 1 is satisfied and the 2840 CE switch is not in the CE position.
3. The 2840 CE meter will run when item 1 is satisfied and the 2840 CE switch is in the CE position.
4. The 2840 will be logically disabled when the following conditions occur simultaneously for a minimum period of 1 μs:
   a. The 2840 ENABLE/DISABLE switch is in the DISABLE position.
   b. The CPU is in the Stopped or Wait state.
   c. Channel interface activity is not in progress (i.e., the 2840 and any attached devices are not selected).
   d. Command chaining is not indicated for any attached device.
   e. Status is not stacked or pending for any attached device.
   f. Status associated with a command sequence (such as Device End) is not outstanding (applicable only when a film unit is attached).

Meter Operation for a 2250 is as follows:

1. The 2250 customer meter will run when the 2250 is enabled, the 2840 is recording time on the 2840 customer meter, and the 2250 CE switch is not in the CE position.
2. The 2250 CE meter will run when the 2250 is enabled, the 2840 is recording time on the 2840 customer meter, and the 2250 CE switch is in the CE position.
3. A 2250 will be logically disabled when the following conditions occur simultaneously for a minimum period of 1 μs:
   a. The 2250 ENABLE/DISABLE switch is in the DISABLE position.
   b. Items 4b through 4e under "Meter operation for the 2840" are satisfied.

When a power-on reset, system reset, or initial program load reset is issued to the 2840 and attached devices, these units assume the state designated by their Enable switches regardless of the enable/disable interlocking conditions described above. A selective reset will not directly cause the selected unit to assume the state designated by its switch.

APPENDIX A: HEXADECIMAL-DECIMAL CONVERSION

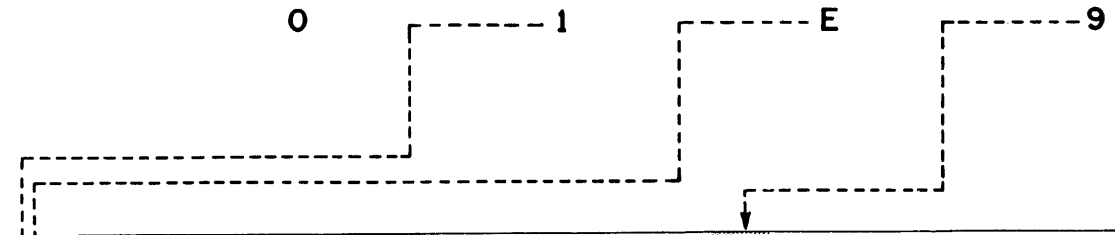
The table in this appendix provides for direct conversion of decimal and hexadecimal numbers in these ranges:

Hexadecimal	Decimal
000 to FFF	0000 to 4095

For numbers outside the range of the table, add the following values to the table figures:

Hexadecimal	Decimal
1000	4096
2000	8192
3000	12288

Hexadecimal	Decimal
4000	16384
5000	20480
6000	24576
7000	28672
8000	32768
9000	36864
A000	40960
B000	45056
C000	49152
D000	53248
E000	57344
F000	61440



	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00 _	0000	0001	0002	0003	0004	0005	0006	0007	0008	0009	0010	0011	0012	0013	0014	0015
01 _	0016	0017	0018	0019	0020	0021	0022	0023	0024	0025	0026	0027	0028	0029	0030	0031
02 _	0032	0033	0034	0035	0036	0037	0038	0039	0040	0041	0042	0043	0044	0045	0046	0047
03 _	0048	0049	0050	0051	0052	0053	0054	0055	0056	0057	0058	0059	0060	0061	0062	0063
04 _	0064	0065	0066	0067	0068	0069	0070	0071	0072	0073	0074	0075	0076	0077	0078	0079
05 _	0080	0081	0082	0083	0084	0085	0086	0087	0088	0089	0090	0091	0092	0093	0094	0095
06 _	0096	0097	0098	0099	0100	0101	0102	0103	0104	0105	0106	0107	0108	0109	0110	0111
07 _	0112	0113	0114	0115	0116	0117	0118	0119	0120	0121	0122	0123	0124	0125	0126	0127
08 _	0128	0129	0130	0131	0132	0133	0134	0135	0136	0137	0138	0139	0140	0141	0142	0143
09 _	0144	0145	0146	0147	0148	0149	0150	0151	0152	0153	0154	0155	0156	0157	0158	0159
0A _	0160	0161	0162	0163	0164	0165	0166	0167	0168	0169	0170	0171	0172	0173	0174	0175
0B _	0176	0177	0178	0179	0180	0181	0182	0183	0184	0185	0186	0187	0188	0189	0190	0191
0C _	0192	0193	0194	0195	0196	0197	0198	0199	0200	0201	0202	0203	0204	0205	0206	0207
0D _	0208	0209	0210	0211	0212	0213	0214	0215	0216	0217	0218	0219	0220	0221	0222	0223
0E _	0224	0225	0226	0227	0228	0229	0230	0231	0232	0233	0234	0235	0236	0237	0238	0239
0F _	0240	0241	0242	0243	0244	0245	0246	0247	0248	0249	0250	0251	0252	0253	0254	0255
10 _	0256	0257	0258	0259	0260	0261	0262	0263	0264	0265	0266	0267	0268	0269	0270	0271
11 _	0272	0273	0274	0275	0276	0277	0278	0279	0280	0281	0282	0283	0284	0285	0286	0287
12 _	0288	0289	0290	0291	0292	0293	0294	0295	0296	0297	0298	0299	0300	0301	0302	0303
13 _	0304	0305	0306	0307	0308	0309	0310	0311	0312	0313	0314	0315	0316	0317	0318	0319
14 _	0320	0321	0322	0323	0324	0325	0326	0327	0328	0329	0330	0331	0332	0333	0334	0335
15 _	0336	0337	0338	0339	0340	0341	0342	0343	0344	0345	0346	0347	0348	0349	0350	0351
16 _	0352	0353	0354	0355	0356	0357	0358	0359	0360	0361	0362	0363	0364	0365	0366	0367
17 _	0368	0369	0370	0371	0372	0373	0374	0375	0376	0377	0378	0379	0380	0381	0382	0383
18 _	0384	0385	0386	0387	0388	0389	0390	0391	0392	0393	0394	0395	0396	0397	0398	0399
19 _	0400	0401	0402	0403	0404	0405	0406	0407	0408	0409	0410	0411	0412	0413	0414	0415
1A _	0416	0417	0418	0419	0420	0421	0422	0423	0424	0425	0426	0427	0428	0429	0430	0431
1B _	0432	0433	0434	0435	0436	0437	0438	0439	0440	0441	0442	0443	0444	0445	0446	0447
1C _	0448	0449	0450	0451	0452	0453	0454	0455	0456	0457	0458	0459	0460	0461	0462	0463
1D _	0464	0465	0466	0467	0468	0469	0470	0471	0472	0473	0474	0475	0476	0477	0478	0479
1E _	0480	0481	0482	0483	0484	0485	0486	0487	0488	0489	0490	0491	0492	0493	0494	0495
1F _	0496	0497	0498	0499	0500	0501	0502	0503	0504	0505	0506	0507	0508	0509	0510	0511

11313

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
20_	0512	0513	0514	0515	0516	0517	0518	0519	0520	0521	0522	0523	0524	0525	0526	0527
21_	0528	0529	0530	0531	0532	0533	0534	0535	0536	0537	0538	0539	0540	0541	0542	0543
22_	0544	0545	0546	0547	0548	0549	0550	0551	0552	0553	0554	0555	0556	0557	0558	0559
23_	0560	0561	0562	0563	0564	0565	0566	0567	0568	0569	0570	0571	0572	0573	0574	0575
24_	0576	0577	0578	0579	0580	0581	0582	0583	0584	0585	0586	0587	0588	0589	0590	0591
25_	0592	0593	0594	0595	0596	0597	0598	0599	0600	0601	0602	0603	0604	0605	0606	0607
26_	0608	0609	0610	0611	0612	0613	0614	0615	0616	0617	0618	0619	0620	0621	0622	0623
27_	0624	0625	0626	0627	0628	0629	0630	0631	0632	0633	0634	0635	0636	0637	0638	0639
28_	0640	0641	0642	0643	0644	0645	0646	0647	0648	0649	0650	0651	0652	0653	0654	0655
29_	0656	0657	0658	0659	0660	0661	0662	0663	0664	0665	0666	0667	0668	0669	0670	0671
2A_	0672	0673	0674	0675	0676	0677	0678	0679	0680	0681	0682	0683	0684	0685	0686	0687
2B_	0688	0689	0690	0691	0692	0693	0694	0695	0696	0697	0698	0699	0700	0701	0702	0703
2C_	0704	0705	0706	0707	0708	0709	0710	0711	0712	0713	0714	0715	0716	0717	0718	0719
2D_	0720	0721	0722	0723	0724	0725	0726	0727	0728	0729	0730	0731	0732	0733	0734	0735
2E_	0736	0737	0738	0739	0740	0741	0742	0743	0744	0745	0746	0747	0748	0749	0750	0751
2F_	0752	0753	0754	0755	0756	0757	0758	0759	0760	0761	0762	0763	0764	0765	0766	0767
30_	0768	0769	0770	0771	0772	0773	0774	0775	0776	0777	0778	0779	0780	0781	0782	0783
31_	0784	0785	0786	0787	0788	0789	0790	0791	0792	0793	0794	0795	0796	0797	0798	0799
32_	0800	0801	0802	0803	0804	0805	0806	0807	0808	0809	0810	0811	0812	0813	0814	0815
33_	0816	0817	0818	0819	0820	0821	0822	0823	0824	0825	0826	0827	0828	0829	0830	0831
34_	0832	0833	0834	0835	0836	0837	0838	0839	0840	0841	0842	0843	0844	0845	0846	0847
35_	0848	0849	0850	0851	0852	0853	0854	0855	0856	0857	0858	0859	0860	0861	0862	0863
36_	0864	0865	0866	0867	0868	0869	0870	0871	0872	0873	0874	0875	0876	0877	0878	0879
37_	0880	0881	0882	0883	0884	0885	0886	0887	0888	0889	0890	0891	0892	0893	0894	0895
38_	0896	0897	0898	0899	0900	0901	0902	0903	0904	0905	0906	0907	0908	0909	0910	0911
39_	0912	0913	0914	0915	0916	0917	0918	0919	0920	0921	0922	0923	0924	0925	0926	0927
3A_	0928	0929	0930	0931	0932	0933	0934	0935	0936	0937	0938	0939	0940	0941	0942	0943
3B_	0944	0945	0946	0947	0948	0949	0950	0951	0952	0953	0954	0955	0956	0957	0958	0959
3C_	0960	0961	0962	0963	0964	0965	0966	0967	0968	0969	0970	0971	0972	0973	0974	0975
3D_	0976	0977	0978	0979	0980	0981	0982	0983	0984	0985	0986	0987	0988	0989	0990	0991
3E_	0992	0993	0994	0995	0996	0997	0998	0999	1000	1001	1002	1003	1004	1005	1006	1007
3F_	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
40_	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039
41_	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055
42_	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071
43_	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087
44_	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103
45_	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119
46_	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135
47_	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151
48_	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167
49_	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183
4A_	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199
4B_	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215
4C_	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1231
4D_	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241	1242	1243	1244	1245	1246	1247
4E_	1248	1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260	1261	1262	1263
4F_	1264	1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279
50_	1280	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295
51_	1296	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311
52_	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327
53_	1328	1329	1330	1331	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	1342	1343
54_	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356	1357	1358	1359
55_	1360	1361	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	1373	1374	1375
56_	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391
57_	1392	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404	1405	1406	1407
58_	1408	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423
59_	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	1434	1435	1436	1437	1438	1439
5A_	1440	1441	1442	1443	1444	1445	1446	1447	1448	1449	1450	1451	1452	1453	1454	1455
5B_	1456	1457	1458	1459	1460	1461	1462	1463	1464	1465	1466	1467	1468	1469	1470	1471
5C_	1472	1473	1474	1475	1476	1477	1478	1479	1480	1481	1482	1483	1484	1485	1486	1487
5D_	1488	1489	1490	1491	1492	1493	1494	1495	1496	1497	1498	1499	1500	1501	1502	1503
5E_	1504	1505	1506	1507	1508	1509	1510	1511	1512	1513	1514	1515	1516	1517	1518	1519
5F_	1520	1521	1522	1523	1524	1525	1526	1527	1528	1529	1530	1531	1532	1533	1534	1535

11314

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
60_	1536	1537	1538	1539	1540	1541	1542	1543	1544	1545	1546	1547	1548	1549	1550	1551
61_	1552	1553	1554	1555	1556	1557	1558	1559	1560	1561	1562	1563	1564	1565	1566	1567
62_	1568	1569	1570	1571	1572	1573	1574	1575	1576	1577	1578	1579	1580	1581	1582	1583
63_	1584	1585	1586	1587	1588	1589	1590	1591	1592	1593	1594	1595	1596	1597	1598	1599
64_	1600	1601	1602	1603	1604	1605	1606	1607	1608	1609	1610	1611	1612	1613	1614	1615
65_	1616	1617	1618	1619	1620	1621	1622	1623	1624	1625	1626	1627	1628	1629	1630	1631
66_	1632	1633	1634	1635	1636	1637	1638	1639	1640	1641	1642	1643	1644	1645	1646	1647
67_	1648	1649	1650	1651	1652	1653	1654	1655	1656	1657	1658	1659	1660	1661	1662	1663
68_	1664	1665	1666	1667	1668	1669	1670	1671	1672	1673	1674	1675	1676	1677	1678	1679
69_	1680	1681	1682	1683	1684	1685	1686	1687	1688	1689	1690	1691	1692	1693	1694	1695
6A_	1696	1697	1698	1699	1700	1701	1702	1703	1704	1705	1706	1707	1708	1709	1710	1711
6B_	1712	1713	1714	1715	1716	1717	1718	1719	1720	1721	1722	1723	1724	1725	1726	1727
6C_	1728	1729	1730	1731	1732	1733	1734	1735	1736	1737	1738	1739	1740	1741	1742	1743
6D_	1744	1745	1746	1747	1748	1749	1750	1751	1752	1753	1754	1755	1756	1757	1758	1759
6E_	1760	1761	1762	1763	1764	1765	1766	1767	1768	1769	1770	1771	1772	1773	1774	1775
6F_	1776	1777	1778	1779	1780	1781	1782	1783	1784	1785	1786	1787	1788	1789	1790	1791
70_	1792	1793	1794	1795	1796	1797	1798	1799	1800	1801	1802	1803	1804	1805	1806	1807
71_	1808	1809	1810	1811	1812	1813	1814	1815	1816	1817	1818	1819	1820	1821	1822	1823
72_	1824	1825	1826	1827	1828	1829	1830	1831	1832	1833	1834	1835	1836	1837	1838	1839
73_	1840	1841	1842	1843	1844	1845	1846	1847	1848	1849	1850	1851	1852	1853	1854	1855
74_	1856	1857	1858	1859	1860	1861	1862	1863	1864	1865	1866	1867	1868	1869	1870	1871
75_	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887
76_	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903
77_	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
78_	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
79_	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
7A_	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
7B_	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
7C_	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
7D_	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
7E_	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
7F_	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
80_	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063
81_	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079
82_	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095
83_	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111
84_	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127
85_	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143
86_	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159
87_	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175
88_	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191
89_	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207
8A_	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223
8B_	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239
8C_	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255
8D_	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271
8E_	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287
8F_	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303
90_	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319
91_	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335
92_	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351
93_	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367
94_	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383
95_	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399
96_	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415
97_	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431
98_	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447
99_	2448	2449	2450	2451	2452	2453	2454	2455	2456	2457	2458	2459	2460	2461	2462	2463
9A_	2464	2465	2466	2467	2468	2469	2470	2471	2472	2473	2474	2475	2476	2477	2478	2479
9B_	2480	2481	2482	2483	2484	2485	2486	2487	2488	2489	2490	2491	2492	2493	2494	2495
9C_	2496	2497	2498	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509	2510	2511
9D_	2512	2513	2514	2515	2516	2517	2518	2519	2520	2521	2522	2523	2524	2525	2526	2527
9E_	2528	2529	2530	2531	2532	2533	2534	2535	2536	2537	2538	2539	2540	2541	2542	2543
9F_	2544	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557	2558	2559

11315

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
A0 _	2560	2561	2562	2563	2564	2565	2566	2567	2568	2569	2570	2571	2572	2573	2574	2575
A1 _	2576	2577	2578	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	2589	2590	2591
A2 _	2592	2593	2594	2595	2596	2597	2598	2599	2600	2601	2602	2603	2604	2605	2606	2607
A3 _	2608	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	2619	2620	2621	2622	2623
A4 _	2624	2625	2626	2627	2628	2629	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639
A5 _	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	2650	2651	2652	2653	2654	2655
A6 _	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	2671
A7 _	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	2687
A8 _	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	2703
A9 _	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	2719
AA _	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	2735
AB _	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751
AC _	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765	2766	2767
AD _	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	2783
AE _	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	2799
AF _	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813	2814	2815
B0 _	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2831
B1 _	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	2847
B2 _	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863
B3 _	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	2879
B4 _	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	2895
B5 _	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909	2910	2911
B6 _	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925	2926	2927
B7 _	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941	2942	2943
B8 _	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957	2958	2959
B9 _	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	2974	2975
BA _	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	2989	2990	2991
BB _	2992	2993	2994	2995	2996	2997	2998	2999	3000	3001	3002	3003	3004	3005	3006	3007
BC _	3008	3009	3010	3011	3012	3013	3014	3015	3016	3017	3018	3019	3020	3021	3022	3023
BD _	3024	3025	3026	3027	3028	3029	3030	3031	3032	3033	3034	3035	3036	3037	3038	3039
BE _	3040	3041	3042	3043	3044	3045	3046	3047	3048	3049	3050	3051	3052	3053	3054	3055
BF _	3056	3057	3058	3059	3060	3061	3062	3063	3064	3065	3066	3067	3068	3069	3070	3071

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
C0 _	3072	3073	3074	3075	3076	3077	3078	3079	3080	3081	3082	3083	3084	3085	3086	3087
C1 _	3088	3089	3090	3091	3092	3093	3094	3095	3096	3097	3098	3099	3100	3101	3102	3103
C2 _	3104	3105	3106	3107	3108	3109	3110	3111	3112	3113	3114	3115	3116	3117	3118	3119
C3 _	3120	3121	3122	3123	3124	3125	3126	3127	3128	3129	3130	3131	3132	3133	3134	3135
C4 _	3136	3137	3138	3139	3140	3141	3142	3143	3144	3145	3146	3147	3148	3149	3150	3151
C5 _	3152	3153	3154	3155	3156	3157	3158	3159	3160	3161	3162	3163	3164	3165	3166	3167
C6 _	3168	3169	3170	3171	3172	3173	3174	3175	3176	3177	3178	3179	3180	3181	3182	3183
C7 _	3184	3185	3186	3187	3188	3189	3190	3191	3192	3193	3194	3195	3196	3197	3198	3199
C8 _	3200	3201	3202	3203	3204	3205	3206	3207	3208	3209	3210	3211	3212	3213	3214	3215
C9 _	3216	3217	3218	3219	3220	3221	3222	3223	3224	3225	3226	3227	3228	3229	3230	3231
CA _	3232	3233	3234	3235	3236	3237	3238	3239	3240	3241	3242	3243	3244	3245	3246	3247
CB _	3248	3249	3250	3251	3252	3253	3254	3255	3256	3257	3258	3259	3260	3261	3262	3263
CC _	3264	3265	3266	3267	3268	3269	3270	3271	3272	3273	3274	3275	3276	3277	3278	3279
CD _	3280	3281	3282	3283	3284	3285	3286	3287	3288	3289	3290	3291	3292	3293	3294	3295
CE _	3296	3297	3298	3299	3300	3301	3302	3303	3304	3305	3306	3307	3308	3309	3310	3311
CF _	3312	3313	3314	3315	3316	3317	3318	3319	3320	3321	3322	3323	3324	3325	3326	3327
D0 _	3328	3329	3330	3331	3332	3333	3334	3335	3336	3337	3338	3339	3340	3341	3342	3343
D1 _	3344	3345	3346	3347	3348	3349	3350	3351	3352	3353	3354	3355	3356	3357	3358	3359
D2 _	3360	3361	3362	3363	3364	3365	3366	3367	3368	3369	3370	3371	3372	3373	3374	3375
D3 _	3376	3377	3378	3379	3380	3381	3382	3383	3384	3385	3386	3387	3388	3389	3390	3391
D4 _	3392	3393	3394	3395	3396	3397	3398	3399	3400	3401	3402	3403	3404	3405	3406	3407
D5 _	3408	3409	3410	3411	3412	3413	3414	3415	3416	3417	3418	3419	3420	3421	3422	3423
D6 _	3424	3425	3426	3427	3428	3429	3430	3431	3432	3433	3434	3435	3436	3437	3438	3439
D7 _	3440	3441	3442	3443	3444	3445	3446	3447	3448	3449	3450	3451	3452	3453	3454	3455
D8 _	3456	3457	3458	3459	3460	3461	3462	3463	3464	3465	3466	3467	3468	3469	3470	3471
D9 _	3472	3473	3474	3475	3476	3477	3478	3479	3480	3481	3482	3483	3484	3485	3486	3487
DA _	3488	3489	3490	3491	3492	3493	3494	3495	3496	3497	3498	3499	3500	3501	3502	3503
DB _	3504	3505	3506	3507	3508	3509	3510	3511	3512	3513	3514	3515	3516	3517	3518	3519
DC _	3520	3521	3522	3523	3524	3525	3526	3527	3528	3529	3530	3531	3532	3533	3534	3535
DD _	3536	3537	3538	3539	3540	3541	3542	3543	3544	3545	3546	3547	3548	3549	3550	3551
DE _	3552	3553	3554	3555	3556	3557	3558	3559	3560	3561	3562	3563	3564	3565	3566	3567
DF _	3568	3569	3570	3571	3572	3573	3574	3575	3576	3577	3578	3579	3580	3581	3582	3583

11316

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
E0_	3584	3585	3586	3587	3583	3589	3590	3591	3592	3593	3594	3595	3596	3597	3598	3599
E1_	3600	3601	3602	3603	3604	3605	3606	3607	3608	3609	3610	3611	3612	3613	3614	3615
E2_	3616	3617	3618	3619	3620	3621	3622	3623	3624	3625	3626	3627	3628	3629	3630	3631
E3_	3632	3633	3634	3635	3636	3637	3638	3639	3640	3641	3642	3643	3644	3645	3646	3647
E4_	3648	3649	3650	3651	3652	3653	3654	3655	3656	3657	3658	3659	3660	3661	3662	3663
E5_	3664	3665	3666	3667	3668	3669	3670	3671	3672	3673	3674	3675	3676	3677	3678	3679
E6_	3680	3681	3682	3683	3684	3685	3686	3687	3688	3689	3690	3691	3692	3693	3694	3695
E7_	3696	3697	3698	3699	3700	3701	3702	3703	3704	3705	3706	3707	3708	3709	3710	3711
E8_	3712	3713	3714	3715	3716	3717	3718	3719	3720	3721	3722	3723	3724	3725	3726	3727
E9_	3728	3729	3730	3731	3732	3733	3734	3735	3736	3737	3738	3739	3740	3741	3742	3743
EA_	3744	3745	3746	3747	3748	3749	3750	3751	3752	3753	3754	3755	3756	3757	3758	3759
EB_	3760	3761	3762	3763	3764	3765	3766	3767	3768	3769	3770	3771	3772	3773	3774	3775
EC_	3776	3777	3778	3779	3780	3781	3782	3783	3784	3785	3786	3787	3788	3789	3790	3791
ED_	3792	3793	3794	3795	3796	3797	3798	3799	3800	3801	3802	3803	3804	3805	3806	3807
EE_	3808	3809	3810	3811	3812	3813	3814	3815	3816	3817	3818	3819	3820	3821	3822	3823
EF_	3824	3825	3826	3827	3828	3829	3830	3831	3832	3833	3834	3835	3836	3837	3838	3839
F0_	3840	3841	3842	3843	3844	3845	3846	3847	3848	3849	3850	3851	3852	3853	3854	3855
F1_	3856	3857	3858	3859	3860	3861	3862	3863	3864	3865	3866	3867	3868	3869	3870	3871
F2_	3872	3873	3874	3875	3876	3877	3878	3879	3880	3881	3882	3883	3884	3885	3886	3887
F3_	3888	3889	3890	3891	3892	3893	3894	3895	3896	3897	3898	3899	3900	3901	3902	3903
F4_	3904	3905	3906	3907	3908	3909	3910	3911	3912	3913	3914	3915	3916	3917	3918	3919
F5_	3920	3921	3922	3923	3924	3925	3926	3927	3928	3929	3930	3931	3932	3933	3934	3935
F6_	3936	3937	3938	3939	3940	3941	3942	3943	3944	3945	3946	3947	3948	3949	3950	3951
F7_	3952	3953	3954	3955	3956	3957	3958	3959	3960	3961	3962	3963	3964	3965	3966	3967
F8_	3968	3969	3970	3971	3972	3973	3974	3975	3976	3977	3978	3979	3980	3981	3982	3983
F9_	3984	3985	3986	3987	3988	3989	3990	3991	3992	3993	3994	3995	3996	3997	3998	3999
FA_	4000	4001	4002	4003	4004	4005	4006	4007	4008	4009	4010	4011	4012	4013	4014	4015
FB_	4016	4017	4018	4019	4020	4021	4022	4023	4024	4025	4026	4027	4028	4029	4030	4031
FC_	4032	4033	4034	4035	4036	4037	4038	4039	4040	4041	4042	4043	4044	4045	4046	4047
FD_	4048	4049	4050	4051	4052	4053	4054	4055	4056	4057	4058	4059	4060	4061	4062	4063
FE_	4064	4065	4066	4067	4068	4069	4070	4071	4072	4073	4074	4075	4076	4077	4078	4079
FF_	4080	4081	4082	4083	4084	4085	4086	4087	4088	4089	4090	4091	4092	4093	4094	4095

11317

Conditions	Status Bits Set	Sense Bits Set*
General Conditions		
1. Initial status response to any command except No-Op or to a Test I/O instruction; status not stacked.	All bits zero (indicates command accepted; for Test I/O indicates no status)	None
2. Initial status response to No Op command.	Channel End, Device End	None
3. Initial status response to any command when the selected 2250 has stacked status.	Busy plus outstanding status	None
4. Initial status response to Test I/O instruction when the selected 2250 has stacked status.	Outstanding status	None
5a. Initial status response to any command or to a Test I/O instruction when issued to a selected 2250 while status is stacked for a nonselected 2250.	Busy, Status Modifier	None
5b. After condition 5a occurs, initial status response to any command or Test I/O instruction for the 2250 that has stacked status.	Control Unit End, Busy (unless Test I/O), plus outstanding status.	None
6. Ending status for commands involving data transfer.	Device End, Channel End	None
7. Ending status for commands not involving data transfer (e.g., Remove Cursor), except No Op.	Device End, Channel End	None
8. Response to Halt I/O instruction when the Halt I/O is issued after initial status and before ending status.	Device End, Channel End	None
9. Initial status response to a Sense command when the Sense command is issued to a 2250 which did not cause the unit check.	Device End, Channel End	None
Manual Input Conditions		
1. Asynchronous status when the alphameric keyboard END or CANCEL key is pressed.	Attention	None
2. Asynchronous status when any programmed function keyboard key is pressed.	Attention	None
3. Light pen detect, which causes buffer to stop (Enable Switch Detect Operation, Enable No Switch Detect Operation, or Permit Detect Interrupts order active).	Attention, Unit Check	Light Pen, Buffer Address

Conditions	Status Bits Set	Sense Bits Set*
4. Asynchronous status when an End Order Sequence order is decoded.	Attention, Unit Check	End Order Sequence, Buffer Address
2840-Channel Error Conditions		
1. Initial status response to a command with invalid modifier bits. (3)	Unit Check	Command Reject
2. Initial status response to a command with bad parity. (2)	Unit Check	Bus Out Check
3. Initial status response to a Write Buffer, Read Buffer, Insert Cursor, Remove Cursor, or Read X-Y Position Register command when the buffer is running. (3)	Unit Check	Command Reject, Buffer Running
4. Ending status when write data from the channel contains a byte with bad parity. (2)	Device End, Channel End, Unit Check	Bus Out Check
5. Ending status when read data from the buffer contains a byte with bad parity. (5)	Device End, Channel End, Unit Check	Data Check
2840-2250 Error Conditions		
1. Asynchronous status when a buffer parity error is detected during regeneration. (4)	Attention, Unit Check	Data Check, Buffer Address
2. Asynchronous status when a parity error is detected, at 2840 output to 2250, in character or graphic data. (1)	Attention, Unit Check	2840 Output Check, Buffer Address
3. Asynchronous status when a parity error is detected, at 2840 input from a 2250, in data from the alphameric keyboard to the buffer. (1)	Attention, Unit Check	2840 Input Check, Character Mode, Buffer Address
4. Asynchronous status when a parity error is detected, at 2250 input, in character or graphic data. (1)	Attention, Unit Check	Equipment Check, Buffer Address
5. Asynchronous status when a parity error is detected on data from the 2250 X-Y deflection registers to the buffer during operation of a Store X, Y Deflection Registers in Buffer order. (1)	Attention, Unit Check	2840 Input Check, Buffer Address
6. Ending status when a parity error is detected, at 2840 output to a 2250, in data associated with Set Programmed Function Indicators command. (1)	Unit Check, Device End, Channel End	2840 Output Check, Buffer Address
7. Ending status when a parity error is detected, at 2250 input, in data associated with Set Programmed Function Indicators command. (1)	Unit Check, Device End, Channel End	Equipment Check, Buffer Address

Conditions	Status Bits Set	Sense Bits Set*
2840-2250 Error Conditions (Cont)		
8. Ending status when a parity error is detected, both at 2840 output to a 2250 and at 2250 input, in data associated with Set Programmed Function Indicators command. (1)	Unit Check, Device End, Channel End	Equipment Check, 2840 Output Check, Buffer Address
9. Ending status when a parity error is detected, at 2840 input (in Read Manual Input and Read X-Y Position Registers response data from a 2250). (1)	Unit Check, Device End, Channel End	2840 Input Check, Buffer Address

*A buffer address, while always included in sense data, is included in this column only when significant to the condition.

NOTES:

The following procedures for program recovery from errors are suggested. (As of the date of publication of this manual, error conditions not accompanied by Attention status are handled by the Operating System/360 standard error routines for graphic support provided by IBM.)

1. Record the error, and retry the operation once. On a second occurrence of the error, provide the operator with an error message, and consider the 2250 in question inoperative.
2. Record the error, and retry the operation once. On a second occurrence of the error, provide the operator with an error message, and consider the 2840 inoperative.
3. Terminate this task or job.
4. Record the error, and restart regeneration. If Data Check occurs a second time, rewrite the buffer and then restart regeneration. If Data Check occurs the third time, the 2250** might be inoperative for this buffer program; however, additional program tests can be performed to determine whether the error is transient. For example, an error that occurs twice at the same buffer address is probably permanent.
5. Record the error and retry the operation once. In a second occurrence of Data Check, rewrite the buffer or signal the operator to re-enter the message. If Data Check occurs upon reading the third time, provide the operator with a message, and consider the 2250** inoperative for this buffer program.

**The error is probably in the buffer area assigned to that 2250 but could be in the 2840 logic.

Absolute Point and Vector Plot Modes: A method of 2250 operation whereby each point position and vector end point is specified in four data bytes as an actual reference grid location.

Byte: Basic addressable unit of information consisting of eight bits.

Character Mode: A method of 2250 operation whereby characters can be displayed using the character generator feature.

Command: A coded byte from main storage that specifies, to the channel and the 2250, the operation to be performed.

End Point: The point (defined by an X and Y coordinate) on the CRT display area to which the electron beam is to be moved.

Graphic Mode: A method of 2250 operation whereby points and/or vectors can be displayed.

Image: The pattern of points, vectors, and/or characters displayed on the CRT display area during a display cycle.

Instruction: A program step that is decoded and executed by the CPU.

Incremental Point and Vector Plot Modes: A method of 2250 operation whereby each point position and vector end point is specified in two data bytes as ±X, ±Y raster unit displacement from the current beam position.

Order: Two or more coded bytes (Set Mode and Mode Control) from main storage (and contained in the 2840 buffer) that specify an operation or a mode of operation to the 2250. It is treated as data by the channel and is sent to the 2840 under command control.

Raster Unit: The distance between any two adjacent addressable points (in the X or Y direction) on the CRT display area.

Regeneration: The process of redisplaying an image, usually at such a rate (30 to 40 cps) that it appears steady and stationary to the observer.

Stacked Status: (1) Usually refers to the condition of the 2840 when pending status byte has been presented to the channel but has not been accepted by the channel because of channel activity; the stacked status condition is cleared when the channel accepts the status byte. (2) Also, the condition of a 2250 when it cannot pass a status condition to the 2840 because of status activity with another 2250. This stacked status is cleared when the 2840 accepts the status.

2'S Complement Notation: A method of representing negative binary numbers so that an algebraic sum will result when the negative number is added to another number. The negative number is obtained by (1) complementing each bit of the number, (2) adding a 1 to the low-order bit of the complement, and (3) making the sign bit a 1. For example, if an eight-bit register contains 223 (11011111), and 38 (00100110) is to be subtracted:

1. Complement the number to be subtracted	S11011001
2. Add 1 to the low order bit	+1
Result	S11011010
3. Make the sign bit (S) a 1	111011010

This configuration is then added to the register contents, resulting in subtraction (the end carry is not used for further computation of the result):

```
 11011111 = 223
+
 11011010 = 038 (reconfigured)
 --------
 10111001 = 185
```

Vector: A displayed line connecting any two addressable points on the raster unit grid.

INDEX

IBM **Technical Newsletter**

File Number	S360-03
Re: Form No.	A27-2721-0
This Newsletter No.	N27-2934
Date	July 1, 1969
Previous Newsletter Nos.	None

IBM SYSTEM/360 COMPONENT DESCRIPTION: IBM 2250 DISPLAY UNIT MODEL 3, IBM 2840 DISPLAY CONTROL MODEL 2

This Technical Newsletter provides a replacement page for IBM System/360 Component Description: IBM 2250 Display Unit Model 3, IBM 2840 Display Control Model 2, Form A27-2721-0. The following page is to be replaced:

6

The addition to text is indicated by a vertical line to the left of the addition.

Summary of Amendments: This Technical Newsletter adds information on the display copier attachment feature, which permits attachment to the 2250 of an IBM 2285 Display Copier.

File this cover letter at the back of the manual to provide a record of changes.

International Business Machines Corp., Product Publications Dept., Neighborhood Road, Kingston, N.Y. 12401

PRINTED IN U.S.A.

The IBM 2250 Display Unit Model 3 (Frontispiece) is a cathode-ray-tube (CRT) display console which can be attached to a System/360 via the IBM 2840 Display Control Model 2. Along with the capability of displaying graphic or alphanumeric information, the 2250 offers man-machine interaction through its light pen and two keyboards. Using these facilities, a programmer can furnish computer-aided design capabilities whereby the 2250 user can create, modify, and add graphic and alphanumeric data into the system through the display screen. This extension of the System/360 data processing power is useful (1) for handling the graphic information associated with scientific and engineering applications, and (2) for providing faster and more effective retrieval and graphic expression of management and business operating data.

Programming requirements for the 2250 differ from other I/O devices in that the 2840 Display Control has a buffer with logical capabilities that require programming. A buffer program consisting of buffer orders and data to be displayed can be developed either in final image form or as a framework to accept data (to be provided at object time) by the CPU program and to be transmitted via a channel to the 2840-2. Under control of this buffer program, the 2250-3 displays graphic images in the form of lines, points, and alphameric characters. Using the logical capabilities of the buffer and the light pen, programmed function keyboard, and alphameric keyboard, the programmer can design and implement his own tracking, sketching, or display manipulation techniques with minimum CPU interaction.

A buffer program consists of orders interleaved with data. The three major groups of orders are Graphic, Character, and Control. When decoded, an order sets a mode of operation which will be in effect until another order is encountered. All data in between is processed in that mode. Hence, an order requesting absolute vectors will put the 2250/2840 in Absolute Vector mode, and all following data will be treated as the absolute X, Y end points of vectors to be displayed until the next order is encountered. Available in conjunction with this basic principle is the ability to control light-pen responses in the 2840/2250. These orders can condition the 2840/2250 to accept light-pen detects until another light-pen order resets the condition. A light-pen detect on any displayed information between these two orders is then accepted and passed on to the program for processing. In addition, immediate action orders allow direct transferring, movement of data and/or addresses, and storage of the deflection registers into a buffer location.

Each 2250-3 can operate up to 2,000 ft. from the 2840-2, allowing access to the computer from the user's normal working area. Furthermore, sharing of the common control unit (the 2840-2) by several 2250-3's results in more economical configurations for the multiconsole environment.

The 2840-2 can control the operation of up to four 2250-3 Display Units (Figure 1). Light-pen tracking can be performed simultaneously by the user of each 2250 with no interference to System/360. Attachment of the 2840-2 to System/360 (CPU) and CPU main storage is via either a selector or multiplexor channel; it uses one of the eight control unit positions on the channel interface. The channel provides the 2840-2 with the data to be displayed and with the control information necessary to direct the operation of the 2840-2 and associated display units. Buffer storage in the 2840 stores digitally coded images for each attached 2250-3. The buffer enables image regeneration as well as message composition from the 2250 alphameric keyboards; this allows the 2840-2 and attached 2250-3's to operate concurrently with the computer system, freeing the CPU and the channel for other functions. Buffer storage areas are program-assignable for any attached 2250-3 and can be varied under program control. The 2840-2 controls the operation of each attached 2250-3. By means of shared circuitry and interleaved operations in the 2840-2, each 2250-3 can be operated independently, and different images can be generated simultaneously on each display.

The basic 2250-3 (without special features) provides the ability to display graphic information in

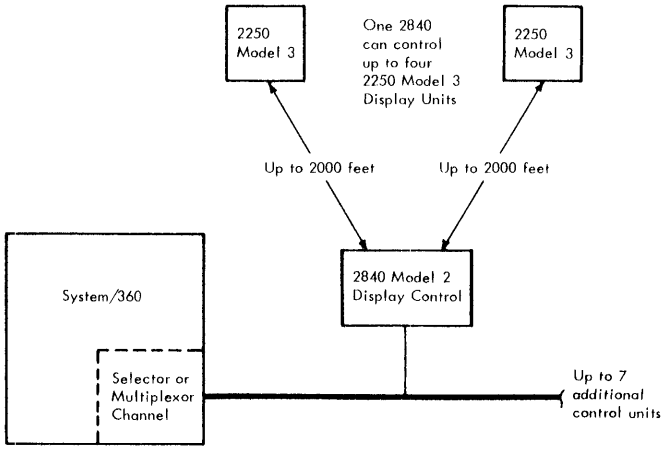


Figure 1. Attachment of 2840-2/2250-3 Configuration to System/360

absolute or incremental mode in the form of points or straight lines in any direction; it can also display alphameric characters (alphabetics, numerics, and special symbols). In addition, a light pen is provided with the basic 2250-3. For increased intercommunication between the user and the controlling program, two keyboards are available as special features:

Alphameric Keyboard - Provides a typewriter-like keyboard with which the user can perform editing functions and compose messages consisting of letters, numbers, and/or special symbols for entry into 2840 buffer and CPU main storage.

Programmed Function Keyboard - Provides communication between the user and the computer. The keyboard consist of keys, indicators, and sensing switches for use with replaceable descriptive overlays. The function of each key and indicator, which is program-defined, is identified to the program by the overlay coding and to the user by symbols on the overlay. The program associated with the overlay code and the selected key then directs the requested operation. For example, as a result of a key depression, the program might direct the computer to enlarge, reduce, or delete the image displayed by the associated 2250.

When a 2250 is not in the same room with the 2840 and the CPU, a telephone should be near the 2250 so that the 2250 operator can communicate with the CPU installation.

The basic 2840-2 contains a 32,768-byte core buffer, order mode control, and a character generator. The character generator can translate one System/360 eight-bit byte representation from an alphameric character into a sequence of signals, which, when converted to analog deflection signals by the 2250-3, causes the character to be drawn on the 2250-3 CRT display area. A standard character set of 63 alphabetics, numerics, and special symbols is provided; two character sizes are program-selectable. The basic 2840-2 can attach to, and control, two 2250-3's. Two special features are available for increased 2840-2 attachment capability:

Display Multiplexor - Allows attachment of two additional 2250 Model 3 Display Units to the 2840-2. A maximum of one display multiplexor feature can be installed on one 2840-2, allowing attachment of up to four 2250-3's.

Film Unit Attachment - Provides for the attachment and control of an IBM 2280 Film Recorder or an IBM 2282 Film Recorder/Scanner. A film unit attached to a 2840 time-shares both the buffer storage and the character generator with any attached 2250. A maximum of four 2250-3's or three 2250-3's and one film unit can be attached to one 2840-2.

Display Copier Attachment - Permits attachment of an IBM 2285 Display Copier to the 2250. The publication Component Description, IBM 2285 Display Copier, Form A27-2730 contains a functional description of, and operator procedures for, the 2285. The 2285 is a free-standing, non-programmed device; it provides, under 2250 operator control, 8-1/2 by 11-inch paper copies of the 2250 display image. Each copy consists of a black image on a light gray background. The 2285 is located beside the left edge of the 2250 reading board; in this position, the 2285 controls, indicators, and hopper (copy receptacle) are easily accessible to the 2250 operator. Basic power for the 2285 is provided by the 2250. Analog signals are switched from the 2250 to the 2285 during the paper-exposure portion of each copy cycle.

READER'S COMMENT FORM

IBM System/360 Component Description
IBM 2250 Display Unit Model 3
IBM 2840 Display Control Model 2

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