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IBM System/360 Component Description

IBM 2250 Display Unit Model 1

This publication contains detailed information on programming, operation, and special features of the IBM 2250 Display Unit Model 1. The material is presented with the assumption that the reader has read the *IBM System/360 Principles of Operation* manual, Form GA22-6821.

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

- *IBM System/360 Component Description: IBM 2250 Display Unit Model 3; IBM 2840 Display Control Model 2*, Form GA27-2721.
- *IBM System/360 Operating System Graphic Programming Services for IBM 2250 Display Unit, Model 1*, Form GC27-6921.



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This edition, Form GA27-2701-3, incorporates information contained in Technical Newsletter N27-2933 pertaining to the display copier attachment feature. This edition obsoletes Form GA27-2701-2 and Technical Newsletter N27-2933. Changes are indicated by a vertical line to the left of the change.

A form is provided at the back of this publication for reader's comments. If the form has been removed, comments may be addressed to: IBM Systems Development Division, Product Publications, Dept. 520, Neighborhood Road, Bldg. 960-1, Kingston, N.Y., 12401

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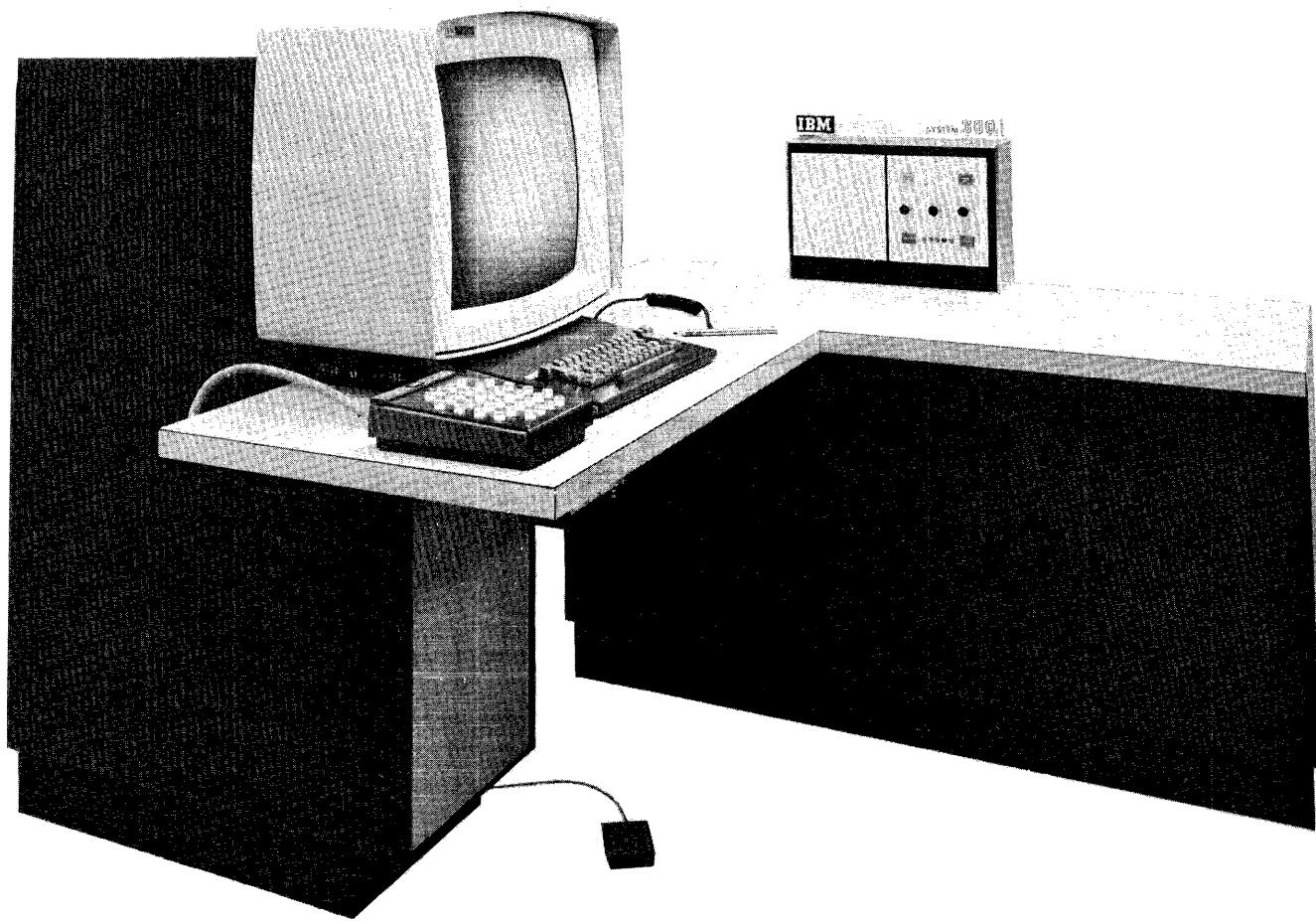
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IBM 2250 Display Unit, Model 1

The IBM 2250 Display Unit, Model 1 (Frontispiece) extends the data processing power of System/360 computers (1) to handle the graphic information associated with scientific and engineering design applications, and (2) to provide faster and more effective retrieval and graphic expression of management and business operating data.

The 2250 is organized around a cathode-ray tube (CRT) on which computer-programmed graphic and alphameric information is displayed at high speed, thereby providing visual communication between a computer and its user (Figure 1). In addition, keyboards and a light pen provide the user with a versatile means of entering and modifying computer information. With the 2250, then, the user has

direct and rapid access to stored data which can be scanned visually, selected, processed, modified, and redisplayed in alphameric and graphic representation.

Either a selector or a multiplexer channel can be used to attach the 2250 to the System/360 processor (Figure 2). Each 2250 takes the position of a control unit (up to eight control units can be attached to a channel). The channel transfers to the 2250 both the data to be displayed and the control information necessary to direct the operation of the 2250. The basic (without features) 2250 displays graphic information in the form of points, horizontal and vertical vectors of unrestricted length, and 45-degree vectors of limited length. This information can be used to form such

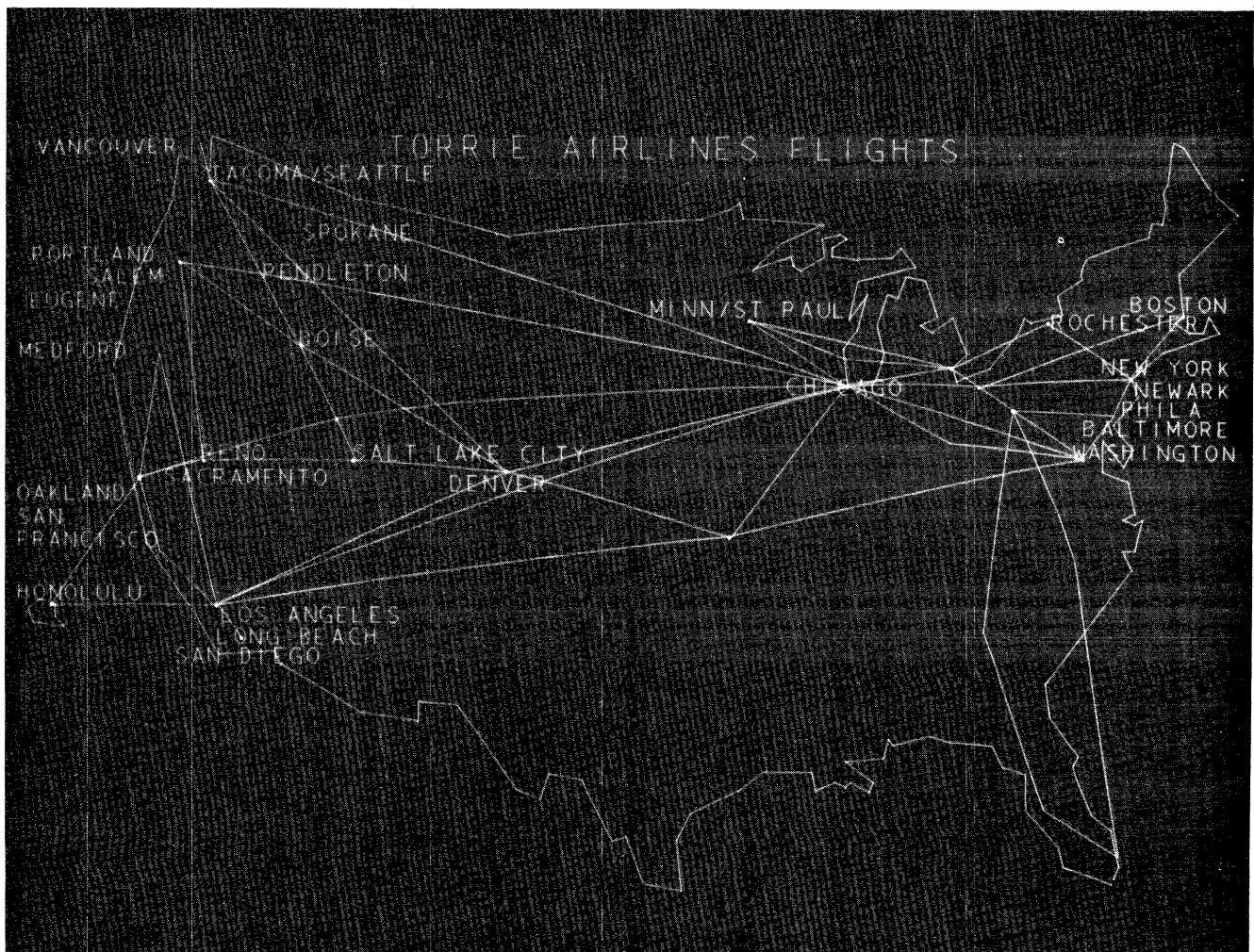
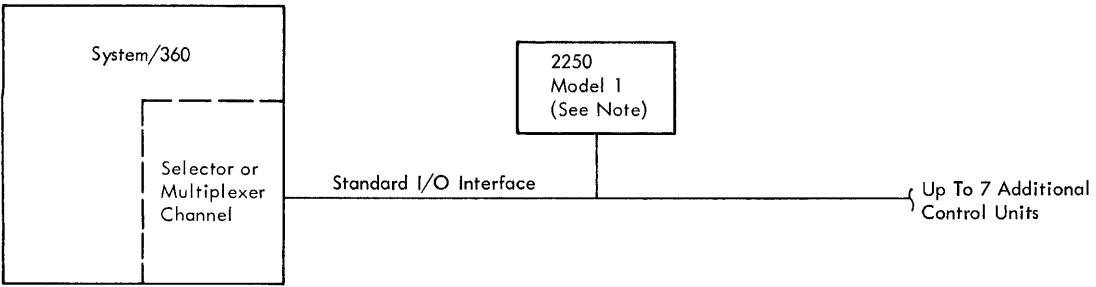


Figure 1. Example of a 2250 Display



Note:

The internal cable resistance of the Select In/Select Out line on the I/O interface is 1.5 ohms (max.); the other interface bus lines are 0.1 ohm (max.) each.

Figure 2. Attachment of the 2250 to System/360

displays as characters, graphics, charts, and sketches. For increased capability of the 2250, the following special features are available:

Absolute Vectors and Control - Allows vectors of any length at any angle to be drawn on the CRT.

Buffer Storage - Provides the 2250 with a local buffer in which to store images for display regeneration purposes. Use of a buffer enables the 2250 to operate concurrently with the computer system, freeing main storage and the channel for other functions. Buffer sizes of 4,096 and 8,192 bytes are available. One buffer storage (either size) is required per 2250.

Character Generator - Enables the 2250 to translate one System/360 eight-bit-byte representation of an alphabetic character into a sequence of analog signals necessary to trace the character on the CRT display area. A standard character set of 63 alphabets, numerics, and special symbols is provided; two character sizes are program-selectable.

Alphabetic Keyboard - Provides a typewriter-like keyboard with which the user can perform editing functions or compose messages consisting of letters, numbers, or symbols. Messages are sent to the buffer when the 2250 is equipped with a character generator; otherwise, the messages are sent directly to the computer.

Programmed Function Keyboard - Consists of keys, indicators, and sensing switches for use with replaceable descriptive overlays. The function of each key and indicator is computer program defined and is identified to the user and the program by the overlay coding. The computer acts on the displayed image as directed by the program subroutine associated with the overlay code and the key selected. For example, the program might direct the computer to enlarge, reduce, or delete the image displayed.

Light Pen Detect - Enables the user to communicate with the computer by pointing a pen-like device at a portion of the displayed image, identifying that portion to the computer for action determined by the computer program. By appropriate programming, the user may add, delete, or rearrange displayed data with the light pen.

Operator Control Panel - Allows the operator at a 2250 to maintain basic control over the System/360 computer(s) in his installation; this panel is functionally part of the CPU. This feature can only be used with System/360 Models 50, 65, 75, and 85; a maximum of two operator control panels can be installed on one 2250.

A 2250 equipped with the buffer storage, character generator, and alphabetic keyboard features, has, by virtue of these features, processor-independent editing and message-entry capabilities. Alphabetic keyboard data can be entered and displayed without direct computer interaction. A special symbol, called a cursor, is displayed on the CRT display area to mark the position at which alphabetic keyboard data can be entered. This cursor is initially positioned by the program and subsequently positioned by the alphabetic keyboard or by the program.

Graphic Design - Provides expanded light-pen capabilities and additional modes for drawing vectors. A fiber-optic light pen is furnished with this feature. This feature would replace the light-pen-detect feature (both features cannot be on the same 2250). The absolute vectors and control feature are prerequisites for the graphic design feature. Using new orders provided by this feature, the programmer has access to light-pen controls that enable the implementation of System/360 programs for light-pen tracking and sketching. Images can be created and modified using the System/360 program to interpret and respond to light-pen detections. The graphic design feature also provides incremental (or relative) point-plotting and vector drawing capabilities. This means that (1) more information can be displayed on the 2250, (2) more display data can be stored in the buffer, and (3) image movement is easier to accomplish.

In summary, the graphic design feature enables the user to:

1. Program a tracking symbol and, with the light pen, cause the System/360 program to move this symbol across the screen. Thus, sketching ability is provided, permitting the user to use the light pen to establish a position on the display screen where data is not

already displayed, to reposition images on the display screen in response to light-pen movement, and to establish a point or a vector, using the light pen. Note that if updating the tracking pattern via the CPU interface causes the average regeneration time to exceed 25 ms, flicker may be noticeable.

2. Obtain light-pen detects that are independent of the light-pen switch.
3. Inhibit, in the display program, light-pen detects on selected display information.
4. Code graphic information for display in Incremental mode; this enables more data to be stored in the buffer and mode information to be displayed, and facilitates the repositioning of any item drawn in incremental mode.

These capabilities are achieved under program control by the addition of six buffer orders. Prerequisite for the graphic design feature is the absolute vectors and control feature. Display (buffer) programs written for the 2250 Model 1 equipped with the graphic design feature can be operated in their entirety by a 2840 Model 2/2250 Model 3.

Control Unit Isolation - Allows the operator to turn power on or off at the 2250 without interfering with the rest of the system. This feature is standard on 2250-1's shipped after December 29, 1967.

Display Copier Attachment - Permits attachment of an IBM 2285 Display Copier to the 2250; a buffer and the absolute vectors and control feature are required on the 2250. The publication *Component Description, IBM 2285 Display Copier*, Form GA27-2730 contains a functional description of, and operator procedures for, the 2285. The 2285 is a free-standing, nonprogrammed 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.

Principles of Operation

GENERAL

The 2250 Display Unit, Model 1, without special features can display graphic data in the form of points, horizontal and vertical vectors of unrestricted length, and 45-degree vectors of limited length. With the addition of the absolute vector graphics feature, vectors of any length at any angle can be displayed. The display of each point or vector is specified by four data bytes from the buffer. Characters can

be displayed by the basic 2250 by using a series of programmed points and/or vectors. With the addition of the character generator feature, high-speed, computer-independent formation of characters can be accomplished by the 2250; each character is selected for display by one 8-bit data byte from the buffer. Various types of 2250 displays and the features required (if any) to obtain each type of display are shown in Figure 3.

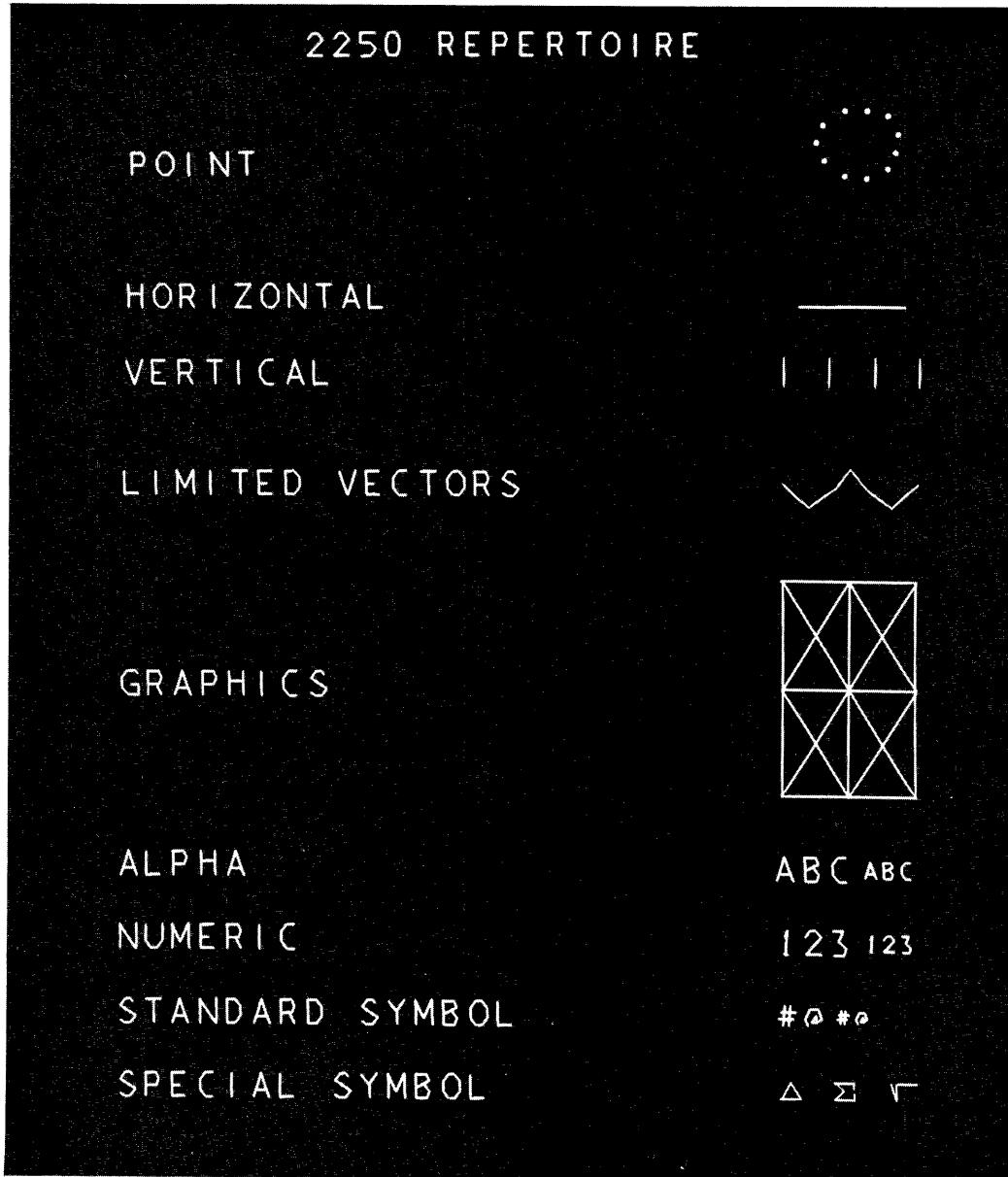


Figure 3. Types of 2250 Displays

A display program in the 2250 buffer positions information on the 2250 display area by specifying the horizontal (X) and vertical (Y) coordinates on a virtual square grid composed of possible electron-beam-deflection endpoints. This grid covers the 12-inch by 12-inch display area on the face of the CRT, and comprises 1,024 equally spaced X positions and 1,024 equally spaced Y positions (Figure 4).

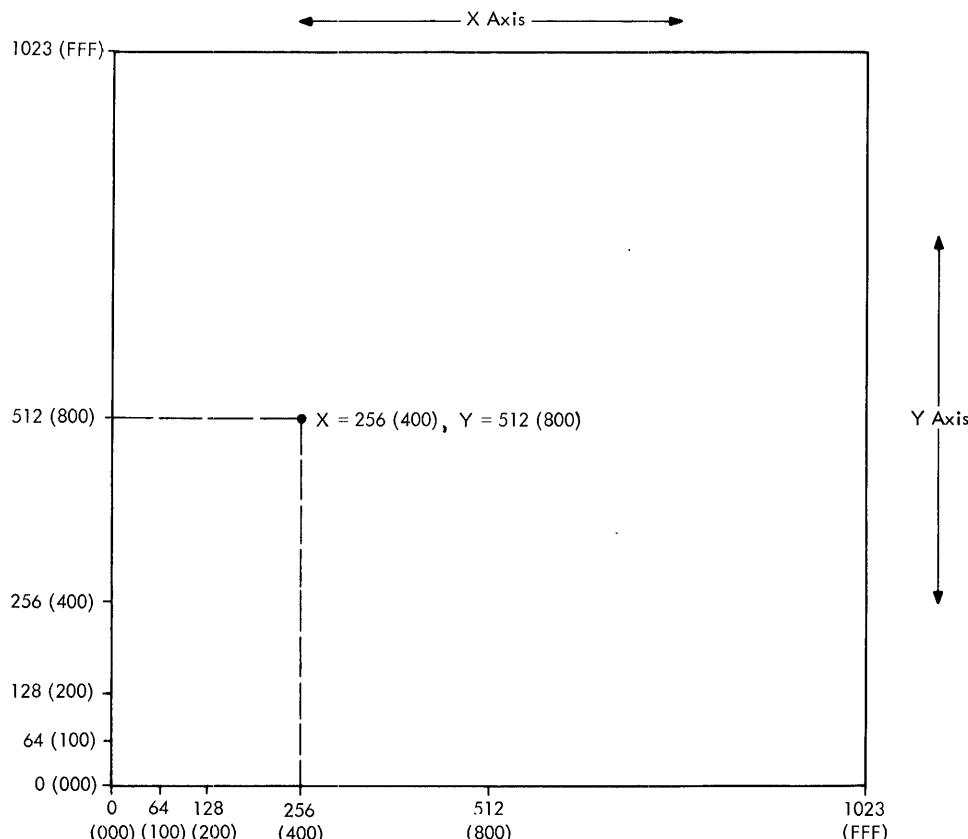
The X and Y coordinates of each display element (each point, line end-point, and character are centroid) are specified by data in the display program. This data can control 2250 Models 1, 2, and 3. The grid of addressable coordinates for a device is called its raster, and the space between two addressable lines on the raster is called a raster unit. A 2250 raster unit represents 1/1,023 of the image. However, the data format in the 2840-1 and -2 (which control the 2250-2 and -3 respectively) provides for a 4,096-by-4,096-position grid. Graphic data for the 2250-1, as for the 2840, must be coded to the base 4,096. The two low-order binary bits of the 4,096-by-4,096 X and Y coordinates are truncated within the 2250, and each

element is positioned on an adjacent coordinate of the 1,024-by-1,024-position display area. This truncation causes a maximum shift of three-fourths of a raster unit, a shift in the image that is not noticeable to the user (see Figure 5).

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.

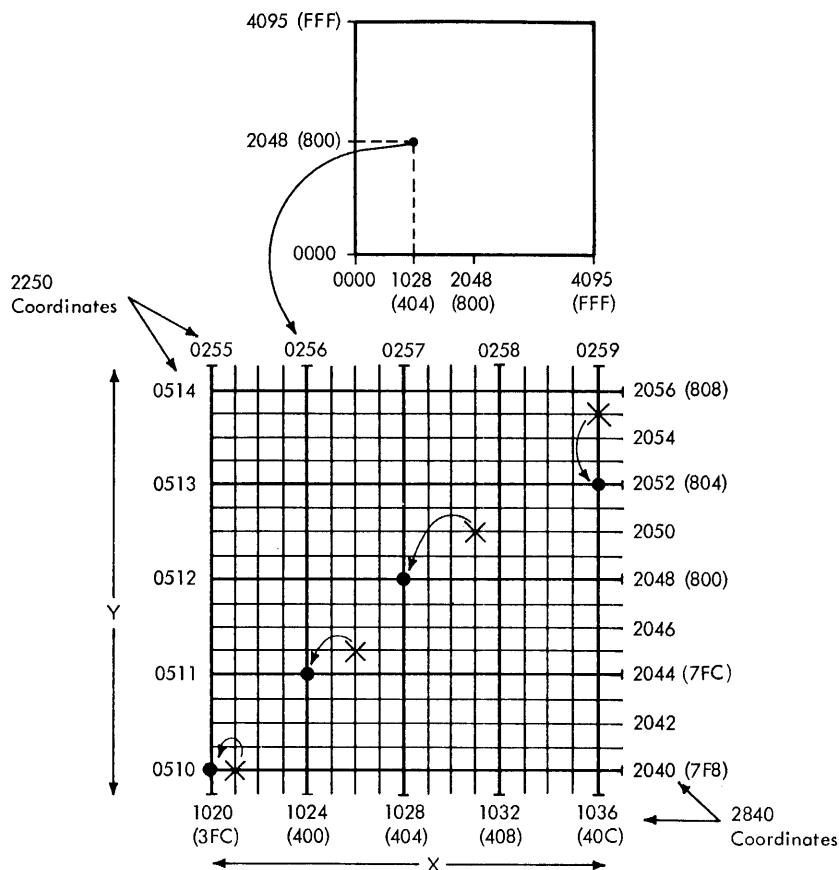
PROGRAMMING NOTE: Failure to program the 2250-1 to the base 4096 will result in a display that is resolved within the lower left quadrant of the display area.

Beam movement is always from the preceding addressed end point to the next addressed end point. If the beam is on while it is being moved, a vector will be displayed between the end points; if the beam is unblanked only after it has been moved, a point will be displayed. Points plotted four or more raster units apart can be distinguished as discrete points.



Note:
Numbers in parentheses are hexadecimal
equivalents (base 4096).

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 (base 4096)

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

The visible display on the face of the CRT is produced by the action of an electron beam hitting a phosphor coating, causing the coating to glow briefly. Normally, the glow fades within a fraction of a second, too quickly for the human eye to perceive and identify the image accurately. Therefore, the display must be continuously redrawn (regenerated) at such a rate that it appears steady and stationary to the observer. Regeneration is performed automatically under buffer control. Because of this, I/O interface activity is required only when new image data is being sent to the buffer, thereby freeing the channel and main storage for other operations.

The functional sections of the 2250 are shown in Figure 6. Functions represented by solid blocks are provided in the basic 2250, whereas those represented by dashed blocks are available as optional features. Dark connecting lines on the figure show data flow; the light lines show control-signal routing. The following paragraphs first present a description of the general operation of the basic 2250. This is followed by a description of each feature and its operation with the basic 2250 and with other features.

BASIC 2250

The interface control section connects the 2250 to the System/360 central processing unit (CPU) and to main storage via a selector or multiplexer channel. Channel operations are in burst mode.

Buffer storage provides the display unit with a local 4.2-usec buffer in which to store images for regeneration purposes. Buffer sizes of 4,096 and 8,192 bytes are available. One buffer storage feature (either size buffer) is required per 2250. The buffer enables the 2250 to operate concurrently with the CPU, freeing main storage and the channel for other functions. Transfer of the image from main storage to the 2250 buffer is required only once, thus relieving the program of directing the display regeneration. In addition, the buffer can be used with the character generator and alphabetic keyboard features to edit or assemble messages before they are transferred to CPU main storage. Selection of the 2250 by the channel is accomplished in the interface control section. Following selection, a command byte is received from the channel by the interface control section, where it is parity checked,

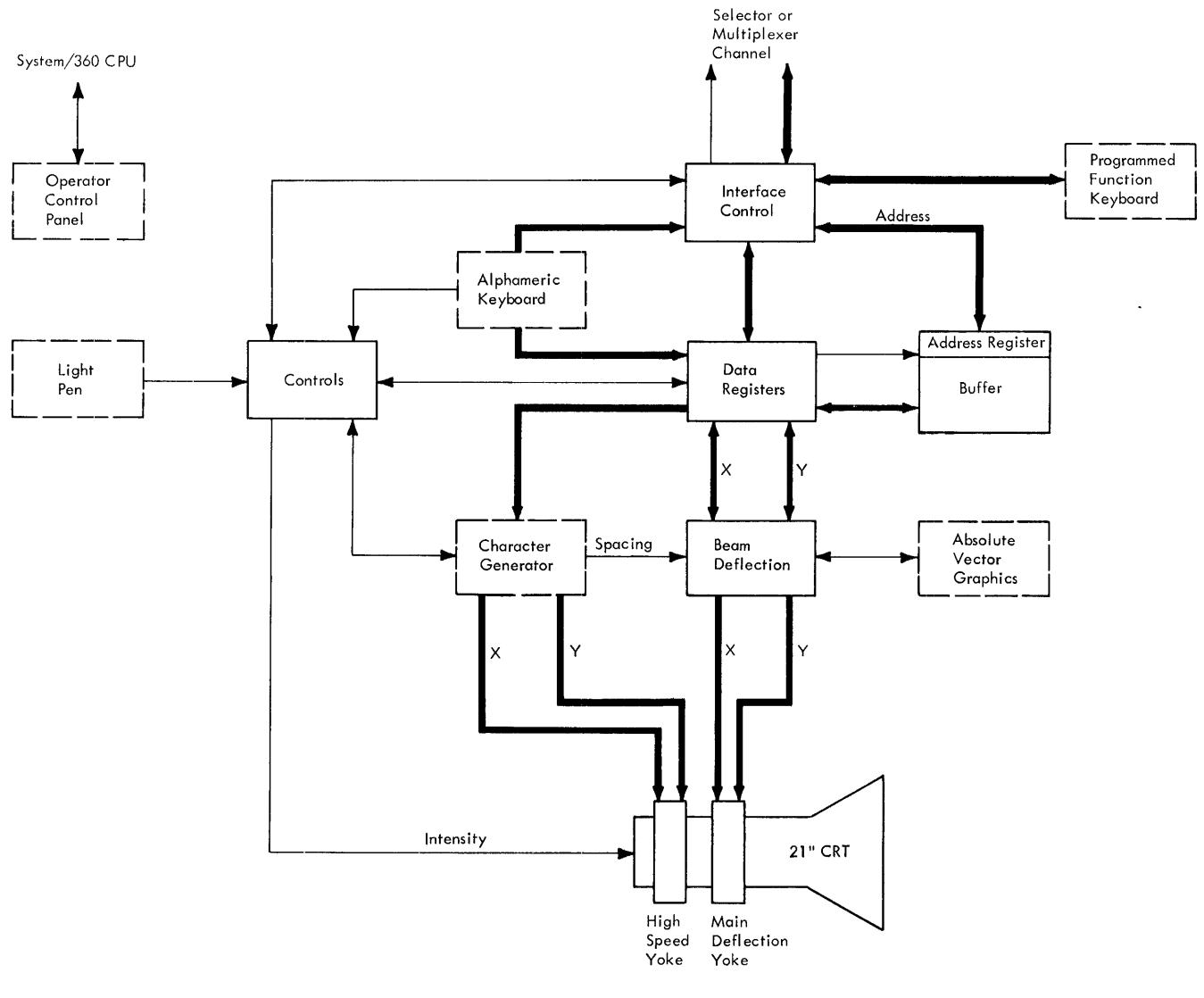


Figure 6. Basic Block Diagram of the 2250, Model 1

decoded, and checked for validity. If the command is valid for the basic 2250, appropriate control signals are sent to the controls section and, when required, to the interface control section as a request for data bytes from the channel. All data from the channel is initially stored in the buffer. This data is then transferred to the data registers section, where the orders are decoded, initiating a display.

Normally, bytes are received from the channel by a 2250 in the following sequence:

1. A command is issued, which stops display regeneration and initiates a request by the interface control section for two address bytes. These two address bytes, which are passed by the interface control section directly to the buffer address register, select a buffer starting location.

2. A command is then issued which specified that a buffer write operation is to be performed and initiates a request for data bytes. These data bytes are written into consecutive buffer location, starting at the location selected by the two address bytes previously placed in the buffer address register. The data bytes are passed to the buffer by the data registers section. (The data registers section performs no decoding as data is being written into the buffer; decoding is performed only when data is read from the buffer for display.)
3. A command then starts display generation and initiates a request by the interface control section for two address bytes. The address bytes, which specify the first buffer address to be read, are passed by the interface control section directly to the buffer address

register. The command then initiates the reading of successive buffer locations, starting with the location selected by the address bytes.

Data bytes read from the buffer are passed serially to the data registers section, where orders are decoded, control signals are routed, and deflection data is passed to the beam deflection section, initiating the display. The data registers section determines whether the byte contains order data or actual coordinate data. Two-byte orders must precede a string of coordinate data bytes and specify how these data bytes are to be used (such as for point plotting or vector plotting). The first byte of an order is uniquely coded to inform the 2250 that an order is being received; the next sequential byte, the second half of the order, generates appropriate control signals to the controls section.

Once appropriate orders are received and decoded, coordinate data bytes are passed serially to the data registers section. Four data bytes are required to address a specific point on the CRT display area: ten bits identify the X coordinate of the end point, ten bits identify the Y coordinate of the end point, one bit (called the blanking bit) specifies electron beam blanking (beam off) or unblanking (beam on), and the remaining bits perform special control functions or are not used. When the first four data bytes that follow the order are received by the data registers section, the blanking bit is sent to the control section, and the ten X bits and ten Y bits are transferred at the same time to X and Y position registers in the beam deflection section. Then, the coordinate bits are converted simultaneously to an X analog signal and a Y analog signal. These signals are applied to the deflection yoke of the tube, causing the electron beam to move to the specified coordinate on the CRT display area. The blanking bit specifies, in the controls section, whether the beam will be blanked or unblanked.

Horizontal and vertical vectors of any length and vectors of 45 degrees from the horizontal and vertical (to a maximum length of 20 raster units in both the X and Y direction) can be plotted by the basic 2250.

Data bytes are read from successive buffer locations until a special order (Transfer Unconditional) is decoded. The Transfer Unconditional order (described in Programming section) is used for branching within the display order program and, in particular, to complete a loop for regeneration of the image. Two bytes from the buffer, following the Transfer Unconditional order, specify the new buffer address at which reading is to restart (for regeneration, the location of the first byte of the block of data that has just been displayed). The block of data is again sequentially read out, and the display is rewritten. This regeneration operation continues automatically until stopped by a command from the channel, by a buffer parity check, or by activation of the 2250 light pen or a terminating order.

SPECIAL FEATURES

Absolute Vectors and Control

This feature provides for drawing vectors from any point to any other point in the 1,024-by-1,024 raster unit grid. Such extension of the basic vector capability provides for vectors of unrestricted length at any angle. This feature becomes a functional part of the beam deflection circuitry.

Character Generator

The character generator feature can be used on a 2250 Model 1 to significantly reduce the time required to display characters. Instead of using the computer to create a character out of individually addressed points or vectors, the display unit uses the character generator to translate the one byte representation of the character into the sequence of analog signals that cause the electron beam deflections necessary to trace the character on the face of the CRT. The display of a character requires an average of six such deflections.

The standard set of characters that can be displayed by the 2250 consists of 63 alphabets, numerics, and special symbols (Figure 7). Either of two character sizes can be selected by programming; basic, or large (1-1/2 times basic size). The basic-size characters provide 3,848 character positions on 52 lines of 74 characters each. The large-size characters provide 1,715 character positions on 35 lines of 49 characters each. An unlimited number of special symbols outside the set provided and symbols of any size can still be formed by individually addressed points and/or vectors.

When the 2250 is equipped with the character generator feature, character data can be interleaved with graphic data. Each block of data will be preceded by an order which specifies the operation to be performed with the data. When an order specifies that subsequent bytes are character data, the data bytes are sequentially received by the Data Registers section from the buffer and passed to the Character Generator section. Each data byte is decoded and converted into a series of analog signals which are applied to a high-speed yoke on the CRT. These signals cause the electron beam to trace the specified character on the face of the CRT in the size specified by the order. The first character of a group of characters is plotted on the face of the CRT at the coordinate position where the electron beam was last positioned. This position becomes the center point of the area in which the character is drawn. (Normally, a blanked graphic display operation is programmed to position the beam to a desired starting location before the character display operation is initiated.) Spacing circuitry supplied with the character generator feature then automatically controls the spacing between characters and the spacing between lines of characters.

		Character Codes (see note)															
		Bits 0 - 3															
Bits 4-7		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		Rsv'd				¢	!	:									
B						.	\$,	#								
C						<	*	%	@								
D						()	—	'								
E						+	;	>	=								
F							—	?	"								

Legend:

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

SP - Space

NUL - Null

NL - New Line

Examples:

Character	Byte Code
A	B1 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 1 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 7. Character Set and Code Assignment

Alphanumeric Keyboard

The alphanumeric keyboard feature is a typewriter-like keyboard and associated circuitry that can be used on the 2250. With this feature, the user can perform editing functions or compose messages consisting of letters, numbers, or symbols (Figure 7) for entry into the display unit. (The keyboard is described in greater detail in the Controls and Indicators section.)

A 2250 equipped with an alphanumeric keyboard and a character generator enables messages to be entered into a portion of the buffer selected by the operator (as allowed by the program) for message composition from the keyboard. As the message is composed, it is displayed on the CRT for verification and then transferred on demand to main storage. A symbol called the cursor is shown on the face of the CRT to identify the position at which the next character from the keyboard will be displayed. The cursor symbol is a dash displayed beneath the character position as

an aid to the operator. It can be positioned by programming or by using the keyboard.

If the 2250 is not equipped with a character generator, each selected character is sent to CPU main storage in response to a program-initiated read operation. The character is stored in a portion of main storage selected by the program for message composition from the 2250 keyboard. Once stored, the character may become part of the display.

Programmed Function Keyboard

The programmed function keyboard consists of 32 keys, 8 overlay code sensing switches, 32 indicators, and associated logic. The function of each key and indicator is program-defined and may be further identified by interchangeable coded overlays. Each of 256 possible overlays is identified by its own discrete eight-bit code and may have its own interpretive program in the CPU. When a

key is pressed, an attention signal is sent to the channel. The program then responds with a command that initiates transfer of the key identity and the eight-bit overlay code. Each key can initiate a subroutine associated with the respective overlay program. The program acts on the displayed image as directed by a subroutine associated with the overlay code and key selected. For example, the subroutine might direct the program to enlarge, reduce, or delete the image displayed.

Each of the 32 keys has a built-in indicator. The 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 the keys that can be, or have been, activated). The program controls the lighting and extinguishing of the indicators with a command and four associated bytes. The programmed function keyboard is further described in the Controls and Indicators section of this document.

Light-Pen Detect

The light-pen detect feature provides the user with a pen-like device (Figure 8) containing a light-sensitive element, and a special light-pen foot switch. The user communicates with the program by pointing the light pen at the section of the image (character, vector, or point) that he wants to detect on the CRT. Once the light pen is properly positioned, the user depresses the foot switch, enabling the light pen. The light from the CRT beam is detected by the light pen when the beam passes within the field of view of the pen. (One detect will occur for each depression of the foot switch.) When the light-pen detect occurs, regeneration is immediately stopped, and a status byte is sent to the channel, resulting in a channel status word being stored in main storage. The program should respond to this status with a Sense command (described in Programming section). Subsequent interrupts will not be presented by the 2250 until the sense data is reset as described in the Programming section under "Sense Command". The sense bytes sent to the CPU in response to the Sense command indicate that a light pen detect has occurred and the type of data that was detected (character or graphic). This data can then be interpreted by the program. The sense bytes sent to the CPU also include the buffer address setting at the time the light pen was activated; this buffer address can then be interpreted by the program. (Note that regeneration is restarted under program control.) The user, then, has identified a section of the image for action as determined by the program. By using the light pen with appropriate keyboard action and programming, the user can add, delete, or rearrange displayed data.

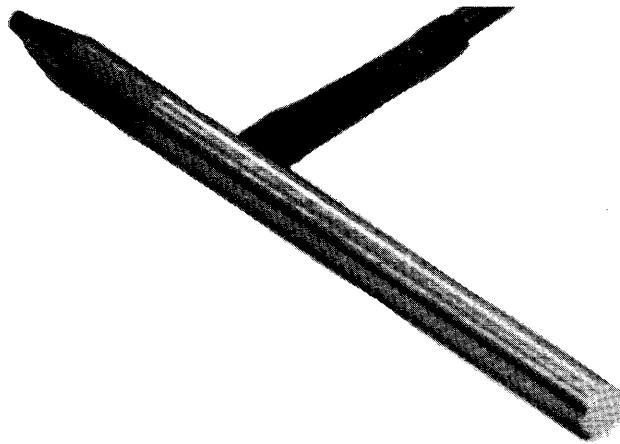


Figure 8. Light Pen (Light Pen Detect Feature)

Operator Control Panel

An important application of the 2250-1 is its use as a system operator console in computer installations. When installed, the operator control panel becomes an integral part of the System/360 CPU. It consists of switches and indicators which allow the operator to communicate with, and maintain basic control over, the System/360 computers in his installation. The operator control panel can be used only with System/360 Models 50, 65, 75, and 85. A maximum of two operator control panels can be installed on a 2250-1 Display Unit.

Graphic Design

This feature adds six graphic orders, which provide an additional type of vector data and provide controls to enable light pen tracking. When this feature is installed, electron beam positioning can be accomplished in either of two modes: Absolute or Incremental. The individual Absolute and Incremental mode operations are specified by order codes, and the beam deflections for each operation are specified by sequential groups of data bytes. Absolute positioning data specifies the actual X and Y coordinates (on the reference grid) to which the beam is to be deflected. Each group of four absolute data bytes addresses one set of coordinates on the reference grid (e.g., X = 0512, Y = 1016).

Each pair of incremental data bytes specifies the amount of beam deflection in the X and Y directions from the current beam position. The amount of each X and Y beam displacement falls in the range 0 to +63 or 0 to -64 raster units (0 to 0.74 inch). 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 $\pm X$, $\pm Y$ incremental value is added to the absolute value of the current beam position, resulting in a new absolute value for the new beam position. Each pair of incremental data bytes specifies beam blanking or unblanking for that incremental vector or point.

The fiber-optic light pen (Figure 9) provided with the graphic design feature allows fast detection response for light-pen tracking and similar operations. This pen is equipped with a spring-loaded tip switch which replaces the foot switch provided with the light-pen detect special feature. Orders added with this feature can enable or disable light pen detects, and can permit light pen detects to occur independently of light pen switch action.

Isolation Feature

This feature is standard on 2250-1's shipped after December 29, 1967. It adds an indicator (labeled "I/O INTF DSBLD") under the left side of the console desk. The indicator is used with the Enable/Disable, POWER ON, and POWER OFF switches to turn power on or off at the 2250 without interfering with the rest of the system, as described in the Controls and Indicators section of this publication.

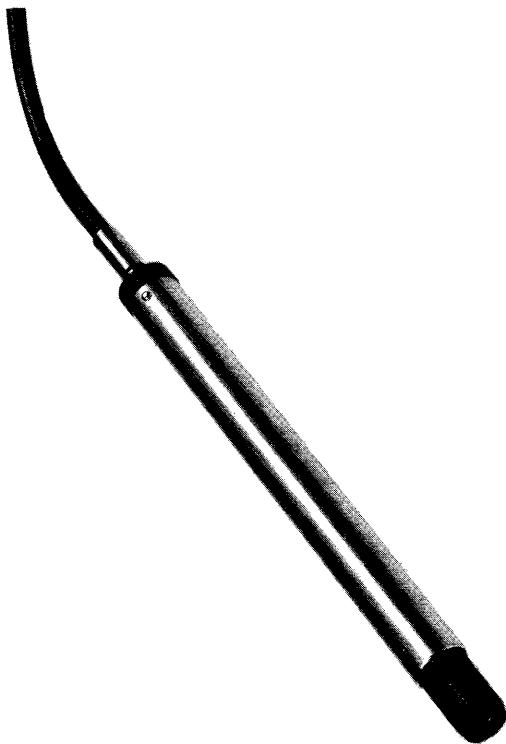


Figure 9. Fiber-Optic Light Pen (Graphic Design Feature)

Programming

GENERAL

The 2250 Display Unit Model 1 is connected to the channel by the System/360 standard I/O interface. Using this interface, the channel sends three types of information to the 2250 in addition to various control signals: unit address, command, and data. The unit address bytes are used for selection of the 2250. The command bytes specify the type of operation to be performed. Data bytes are transmitted only by Write commands and certain Control commands.

The data bytes specified by Write commands are written directly into the buffer; these bytes are then retrieved from the buffer by the 2250, orders are decoded, and a display is generated. In addition to the Control command and data that light and/or extinguish programmed function indicators, other Control commands and associated data are used for buffer addressing.

The 2250 sends three types of bytes to the channel: status, sense, and data. Status bytes are generated automatically by the 2250 to inform the channel and program of the condition of the 2250 at various stages of an operation and may be stored in the channel status word (CSW). Sense bytes inform the program of specific conditions encountered in the 2250. They are sent only in response to a program-generated Sense command; a special status bit (Unit Check) informs the program that further definition can be obtained from the sense bytes. Data bytes are sent to the channel by the 2250 in response to a Read command; they are read from a keyboard, the buffer, or the XY position registers.

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 (Form GA22-6821). The program initiates 2250 operations with a Start I/O instruction in the CPU. This instruction identifies the I/O device (in this case, the 2250) and causes the channel to fetch the channel address word (CAW) from a fixed location in main storage. The CAW designates 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 CPU storage address of any bytes to be retransmitted.

The channel next attempts to select the 2250 by sending a unique address byte to the 2250 and other units on the

channel or subchannel. The 2250 recognizes this address, logically connects itself 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 2250 responds with a status byte indicating whether it can execute the command. If the operation of the command involves the transfer of data, the channel is set up to respond to service requests from the 2250 and assumes further control of the operation. The operation of a command is terminated either by the channel or by the 2250.

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, 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 I/O device specified in the original Start I/O. Two types of chaining are provided: chaining of data bytes and chaining of commands. 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.

The device status byte (Table 1) is sent to the channel as a response to initial selection of the 2250 when an interrupt condition occurs, and/or during the ending phase of a 2250 operation involving data transfer between the 2250 and the channel. During the 2250 initial selection sequence, the status byte is sent to the channel after a command is received. An all-zero status byte is sent when a data command is accepted by the 2250; it is also sent in response to a Test I/O command if other status is not pending. The Unit Check bit will be set if the command is not accepted by the 2250 because of program or equipment error. The Device End and Channel End bits will be set in response to commands that do not cause data transfer (Set Audible Alarm, control No Operation, Insert Cursor, and Remove Cursor). When status is pending or stacked (a previous status byte is awaiting transfer to the channel), the waiting status byte, with its Busy bit set, is sent to the channel in response to any command other than Test I/O; the command is not accepted by the 2250. For a Test I/O instruction the waiting status byte is presented without the Busy bit set.

In an ending operation, a status byte is sent to the channel at the completion of a 2250 operation involving data transfer. 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.

Table 1. Device Status Byte (CSW Byte 4)

Bit	Name	Condition
0	Attention	Indicates a request for service from alphanumeric keyboard or programmed function keyboard; the program should respond by issuing a Read Manual Input command. Also, setting of both Attention bit and Unit Check bit indicates an interrupt condition, such as light-pen detect or data check during regeneration cycle; the program should respond by issuing a Sense command.
1	Status Modifier	Not used.
2	Control Unit End	Not used.
3	Busy	Set indicates, during initial selection, that a stacked or pending status condition exists. Used as a response to all commands (except Test I/O) during initial selection when a stacked or pending status condition exists; the outstanding status bit is also sent to the channel.
4	Channel End	Set when transfer of data and control information between the 2250 and channel is complete. Both Channel End and Device End are set for an ending status.
5	Device End	Set when 2250 has completed operation of a command and is prepared to accept a new command. Both Device End and Channel End are set for ending status.
6	Unit Check	Set when a program or equipment condition is detected at the 2250. Subsequent interrupts will not be presented by the 2250 until the sense data is reset. The program should respond by issuing a Sense command for further definition of the condition. The Unit Check

Table 1. Device Status Byte (CSW Byte 4) (Cont)

Bit	Name	Condition
7	Unit Exception	bit will be the only status bit set if condition is detected before 2250 takes action in response to the command. If command execution has started, Channel End and Device End bits will also be set. If condition is detected during regeneration, Attention bit will be set in addition to Unit Check bit. Both Attention bit and Unit Check bit will be set to indicate a light-pen detect condition, and End Order Sequence order, or a data check. Not used.

When an interrupt condition occurs asynchronously (2250 not selected by the channel), the Attention bit only of both the Attention bit and either the Unit Check bit or the Busy bit will be set in the status byte. An interrupt condition can be caused by a light-pen detect, an alphanumeric keyboard or programmed function keyboard activation, a buffer parity error or an end-order sequence. When an interrupt status occurs, the 2250 requests selection from the channel and sends the status bytes to the channel when selection is accomplished. Thus, status will be in the CSW stored by the channel-generated I/O interrupt.

The status byte is reset in the 2250 after the status information has been accepted by the channel.

COMMANDS

Four basic classes of commands are used with the 2250: Write, Read, Control, and Sense. The Write command initiates data transfer into the buffer. Read commands cause data transfer from the 2250 (buffer, alphanumeric keyboard, etc.) to the channel. Control commands initiate the setting of programmed function keyboard indicators and activate a single-stroke audible alarm which attracts operator attention to the display unit, and also control display regeneration and cursor insertion. The Sense command causes transfer of 2250 sense bytes to the channel; these bytes indicate various control and/or check conditions in the 2250.

The specific 2250 commands, their codes and mnemonics, and the minimum features required for their use are listed in Table 2. The coding is in hexadecimal, which is shown in Appendix A. In addition to the four basic types of commands, the 2250 response to the Test I/O and Halt I/O CPU instructions. The commands accepted as valid by the addressed 2250 depend on the

Table 2. Commands Used by 2250, Model 1

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

*X = The special feature is required for operation of the command.

Blank = The special feature does not affect operation of the command.

features attached to the 2250. When a command that refers to an optional feature is presented to a 2250 that does not have that optional feature, the command is treated as invalid and is rejected; this results in no 2250 operation.

PROGRAMMING NOTE: Unless bit 34 (the Suppress Incorrect Length Indication bit) of each Read and Write Buffer CCW is a 1, the channel program will be terminated, even if the CCW Command Chaining bit is a 1.

Write Command

The Write Buffer command causes the data bytes specified by the CCW address and count fields to be placed into buffer storage at a rate of 3.6 usec per byte. Buffer regeneration must be stopped before an attempt to write into the buffer. If regeneration is in progress when the Write Buffer command is received, the command will be rejected, 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 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 and Stop command stops regeneration and sets the buffer address register to the address at which writing is to start. The data bytes transmitted by the Write Buffer command are stored in consecutive buffer locations, with the buffer address register stepped by 1 after each byte is stored. In the write operation, data transmission is terminated under channel byte count control. If the channel attempts to write past the last buffer location, wraparound will occur (writing will

continue from the first buffer location); this will destroy any data previously stored in these locations. Note that writing into a buffer location that contains a cursor will cause the cursor to be removed.

All data bytes are parity checked as they are received from the interface. Detection of a data parity error will not terminate the write operation. However, the Unit Check bit will be set in the status byte and sent to the channel when the operation is normally terminated. The Bus-Out Check bit will be set in the sense byte. No parity correction is performed on data bytes with parity errors, and such bytes are stored, with bad parity, in the buffer. 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 program should correct the data in the buffer by rewriting. Since the 2250 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 setting of the Data Check sense bit and the Attention and Unit Check bits in the CSW stored by an I/O interrupt.

Read Commands

Read commands initiate information transfer from the 2250 to the channel. Up to four types of Read commands can be used, depending on the optional features installed in the 2250 (Table 2). Any Read command bit configuration that is not valid for the addressed 2250 will cause the setting of the Unit Check bit in the status byte and the Command Reject bit in the sense byte.

Read Buffer

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

The Read Buffer command should be preceded by a Set Buffer Address Register and Stop control command, which stops regeneration and specifies the first buffer location to be read. Command chaining can be used for single or multiple read operations. The read operation is terminated by channel byte count control, which determines that the number of bytes specified by the program has been read. If the channel attempts to read past the last buffer location, wraparound will occur (reading will continue from the first buffer location). Note that whenever a location that contains a cursor is read, only the data, and 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 will not terminate the read operation; however, the Unit Check bit will be set in the status byte. This status then will be sent to the channel when the read operation is normally terminated. Also, the Data Check bit will 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.

Read Manual Input

This command is used to transfer alphabetic keyboard or programmed function keyboard information to the channel. In a 2250 with the character generator feature, activation of the alphabetic keyboard END or CANCEL key or activation of any programmed function keyboard key causes the Attention bit to be set in the status byte. At the end of current interface operation, the attention status is passed to the channel, which causes an I/O interrupt. The program then responds with a Read Manual Input command (this command does not affect buffer operation). The 2250 responds to the Read Manual Input command by sending three bytes to the channel.

The alphabetic keyboard byte format is as follows:

Byte 0

1	0	E	C	0	0	0	0
0	1	2	3	4	5	6	7

E = 1 if END key depressed

C = 1 if CANCEL key depressed

Byte 1

c	c	c	c	c	c	c	c
0	1	2	3	4	5	6	7

c = 8-bit code derived from figure 7 only when the 2250 is not buffered or is buffered without a character generator and a character key is pressed; under all other conditions, byte 1 will be all zeros.

Byte 2

0	0	0	0	0	0	0	0
0	1	2	3	4	5	6	7

Bit 0 of byte 0 is set to a 1 to indicate to the program that an alphabetic key has been depressed. Bit 2 or 3 of byte 0 is also set to a 1 when the END or CANCEL key is depressed. When the 2250 does not contain a character generator feature, byte 1 will contain an 8-bit character code corresponding to an alphabetic keyboard key. When the 2250 does contain the character generator and buffer features, byte 1 will contain all 0's. Byte 2 will always contain all 0's.

Once a key on the alphabetic or program function keyboard has been depressed, the keyboard is locked. The keyboard is reset either (1) when an alphabetic keyboard character is stored in the buffer, (2) after a Read Manual Input command is executed, or (3) when the SHIFT and ALT keys are simultaneously depressed. It is suggested that the problem program issue a Read Manual Input Command before using the 2250; this will enable the keyboards, which may have been left locked by a previous job.

The byte format for the programmed function keyboard is as follows:

Byte 0

0	1	0	0	0	0	0	0
0	1	2	3	4	5	6	7

Byte 1 (Key Code, see Figure 17)

0	0	0	c	c	c	c	c
0	1	2	3	4	5	6	7

Key Code (c)

0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	1
30	1	1	1	1	1	0	
31	1	1	1	1	1	1	

Byte 2 (Overlay Code, see Figure 17)

c	c	c	c	c	c	c	c
0	1	2	3	4	5	6	7

Overlay Punches

None	Code(c)
7	0 0 0 0 0 0 0 0
0 thru 6	1 1 1 1 1 1 1 0
0 thru 7 or no overlay used	1 1 1 1 1 1 1 1

Bit 1 of byte 0 is set to indicate to the program that a programmed function key has been depressed. Byte 1 contains a 5-bit binary key code which corresponds to one of 32 keys depressed. Byte 2 contains an 8-bit binary code which represents one of 256 possible keyboard overlays.

Read Cursor

With the Read Cursor command, as with the Read Buffer command, data bytes are taken sequentially from the buffer 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. After the cursor position is read and transmitted as a 0001 1010 code (1A hexadecimal).
2. Channel byte count control determines that the number of bytes specified by the program have been read.

During a Read Cursor operation, the code 0001 1010 is transmitted, and data transmission is terminated when the character position being read out corresponds to the cursor position. The character code corresponding to the cursor position is not transmitted. Data transmission can also be terminated by channel byte count equalling zero before the cursor position is reached. Note that during a read buffer operation, whenever the buffer location read out corresponds to the cursor position, only the data is transmitted; the cursor is not read out to the channel. This command, with the CCW Skip flag set, can be used with the Sense command to find the buffer address of the cursor.

Read XY Position Registers

This command can be used for diagnostic purposes and to obtain light-pen detect data. It enables the CPU program to compare the data in the 2250 X and Y position registers with an expected value. In response to this command, the 2250 sends four bytes of XY position register data to the channel in the same format as the four Graphic Mode data bytes (refer to Order description). Regeneration must be stopped prior to issuing this command or the command will be rejected. 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 coordinates of the end point of the graphic data causing the detect. If the light-pen detect was on a character, the XY data are the X and Y coordinates of the next character following the character causing the detect.

Control Commands

Up to seven control commands can be used, depending on the type of optional features installed in the 2250 (Table 2). Any control command bit configuration that is not valid

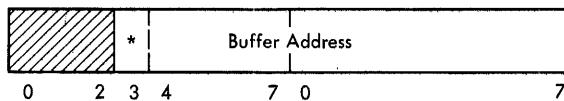
for the 2250 will cause the setting of the Unit Check bit in the status byte and the Command Reject bit in the sense byte.

No Operation

This command performs no operation. It is an immediate command; i.e., no data bytes are transferred and an I/O interrupt is not generated by ending status unless it is the last command of a chain.

Set Buffer Address Register and Start

This command enables the buffer to start regeneration at a specified location. It normally follows a Read Buffer, Read Cursor, Write Buffer, Insert Cursor, or Remove Cursor command. The Set Buffer Address Register and Start command first causes buffer operation to stop. Two address bytes received from the channel following the command are then placed into the buffer address register, and buffer operations are started from this addressed location. (The start location should always have an even address and contain the first byte (SM byte) of an order; if both of these conditions are not met, sequential buffer locations are read until an SM byte is found in an even location). Regeneration starts from the location containing the SM byte. The two address bytes transferred by this command are coded as follows:



*Most significant bit if addressing 8,192-byte buffer; this bit not used (bit 4 is most significant bit) if addressing 4,096-byte buffer.

PROGRAMMING NOTES:

1. Graphic or Character modes, if active at the 2250, is not reset by this command.
2. A byte count of 2 should be in the CCW, and a buffer address should be in the two main storage bytes addressed by the CCW.
3. If this command is issued when the buffer does not contain an SM byte in an even location, the 2250 search for this byte will continue to loop until the 2250 is given a system reset or is logically disabled; recovery cannot be accomplished by the program (instruction or command).

Set Buffer Address Register and Stop

This command can be used to stop regeneration. It causes buffer operation to stop and two address bytes received from the channel following the command to be placed into the buffer address register. The address bytes are coded as shown for the Set Buffer Address Register and Start command. The Set Buffer Address Register and Stop

command usually precedes a write, read, or cursor operation and may be chained to commands that specify these operations.

PROGRAMMING NOTES:

1. Graphic or Character modes, if active at the 2250, is not reset by this command.
2. A byte count of 2 should be in the CCW, and a buffer address should be in the two main storage bytes addressed by the CCW.

Set Audible Alarm

This immediate command causes activation of the single-stroke audible alarm at the 2250.

PROGRAMMING NOTE: Bit 34 of the Set Audible Alarm CCW must be a 1.

Set Programmed Function Indicators

This command is used to light and extinguish programmed function keyboard indicators as specified by a mask in four data bytes; these bytes are in the data field specified by the data address in the CCW of the subject control command. Indicators, numbered 0 to 31, are associated with the four data bytes as follows:

Indicators	Data Byte
0-7	0
8-15	1
16-23	2
24-31	3

Any data bit that is a 1 causes its associated indicator to light; any data bit that is a 0 causes its associated indicator to extinguish. The operation of this command does not affect regeneration and therefore may be issued at any time.

Insert Cursor

This immediate command should be preceded by a Set Buffer Address Register and Stop command, which identifies the buffer address into which the cursor is to be placed. The cursor indication for the addressed buffer location is then set. If a Set Buffer Address Register and Stop command is not issued prior to 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.

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. However, the 2250 continuously searches for an unprotected character area in the buffer program and will not honor any commands (except No Op) even though the 2250 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 2250 or by performing a reset at the CPU.

Remove Cursor

This immediate command should be preceded by a Set Buffer Address Register and Stop command, which identifies the buffer address from which the cursor 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 when the buffer is running causes the same actions as described for the Insert Cursor command. Note that any time data is written into a buffer location, a cursor in that location is automatically cleared.

PROGRAMMING NOTE: Bit 34 of the Remove Cursor CCW must be a 1.

Sense Command

This command, used to obtain data relative to unit status, can be issued by the program at any time. A Sense command is the normal response from the program to a Unit Check status interrupt. (The various interrupt conditions and associated status and sense bits are given in Appendix A.) The information provided by this command is more detailed than that supplied by the unit status bytes. In response to the Sense CCW with a byte count of 4, the unit returns four bytes of sense information which are placed in main storage at the address given in the CCW. The first two bytes contain error and control information; the last two bytes contain the current buffer address. Regeneration should be stopped before a Sense command is issued; otherwise the Character Mode bit and the last two sense bytes will contain zeros and the Buffer Running bit (byte 0, bit 6) will be set. The sense byte bit assignments are shown in Table 3.

Table 3. Sense Bytes

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 parity error on Bus Out on a command or data byte.
0	3	Equipment Check	Not used.
0	4	Data Check	Set when a buffer parity error occurs either during a read operation or during image regeneration.
0	5	Overrun	Not used.
0	6	Buffer Running	Indicates buffer is regenerating.
0	7		Reserved.
1	0	Light-Pen Detect	Set when the light pen is activated and detects a line, point, or character.
1	1	End Order Sequence	Buffer regeneration stopped by End Order Sequence control order.
1	2	Character Mode	Set when in character mode, clear when not in character mode. Used with LP Detect bit.
1	3		Reserved.
1	4		Reserved.
1	5		Reserved.
1	6		Reserved.
1	7		Reserved.
2	0		Reserved.
2	1		Reserved.
2	2		Reserved.
2	3	Bit 13 (High Order Bit)	Buffer Address Register contents:

Table 3. Sense Bytes (Cont)

Byte	Bit	Name	Indication
2	4	Bit 12	1. With Light-Pen Detect bit set - Address of character causing detect or first byte of XY data for point, line, or vector causing detect. Used with Character Mode bit.
2	5	Bit 11	
2	6	Bit 10	
2	7	Bit 9	
3	0	Bit 8	
3	1	Bit 7	2. With End Order Sequence bit set - Address of location immediately following 2-byte End Order Sequence order.
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)	3. With Data Check bit set - During regeneration, address of byte with bad parity; during read or write, the buffer address register contents are the address of the next byte that would be written or read.
			4. With Bus Out Check bit set - Buffer address register contents are the same as for read or write.

The information in sense bytes 0 and 1, except the buffer Running and Character Mode bits, is reset by any of the following conditions:

1. Unless status is stacked, the next command (even if invalid or with bad parity). Exceptions are Sense, Test I/O, and No Operation, which never reset sense bits.
2. By a new status condition if the Sense command has been issued previously for the data presently in the sense register.

Test I/O

The unit responds to the Test I/O instruction with a status byte. If there is no outstanding status information, an all-zero status byte is sent. A non-zero status byte will be stored in the CSW and condition code 01 will be set.

Halt I/O

A CPU-executed Halt I/O instruction causes the channel to disconnect from the 2250, resulting in termination of the current channel operation and the I/O operation of the

selected device. The Halt I/O does not cause the selected display unit with the buffer storage feature to stop regeneration.

The Halt I/O instruction can be issued at various phases of interface activity. If there is no interface activity, the instruction first causes selection of the addressed 2250. In response to Halt I/O, the 2250 sends a status byte (Channel End and Device End bits set, and any error condition) after the instruction is completed only if the Halt I/O is issued after initial status and before ending status. At all other times, the status byte is not sent to the channel. If a Halt I/O is issued when the 2250 has stacked status, it is executed, and the status is preserved and presented to the channel after the instruction has been completed.

ORDERS

Once the 2250 is addressed and has accepted a Write command, data bytes are received from the I/O interface. These data bytes contain orders interleaved with actual data. Orders are interpreted by the 2250 as requests to perform certain operations (plot points, display characters, etc.). The data bytes following each order contain information necessary to perform the specified operation.

A group of orders and interleaved data must be transferred only once to the buffer; they are then retrieved by the 2250 directly from the buffer to maintain display regeneration without further access to main storage or the channel.

Order Format

An order consists of two consecutive bytes, the Set Mode (SM) and the Mode Control (MC) byte. The SM byte contains a fixed code (hexadecimal 2A); the MC byte contains a variable code.

Because a variable number of associated data bytes can immediately follow an MC byte, the unique SM byte is provided to allow 2250 circuitry to detect the presence of a new order. The SM byte must always be located at an even-numbered buffer address.

The SM byte resets 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 and executed. Once a mode other than Transfer Unconditional or Enter 4-Byte No-Op is entered, each even byte thereafter is checked to determine whether it contains the SM code (indicating the start of a new mode). Once Transfer Unconditional or Enter 4-Byte No-Op mode is entered, checking resumes at the new buffer address established by the transfer or by the 4-byte skip.

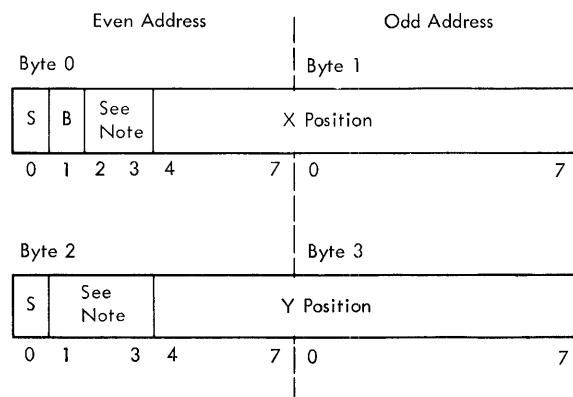
The mode orders, listed in Table 4, are described in the following paragraphs. Both the SM and MC bytes are coded in hexadecimal.

Graphic Mode Orders

Graphic mode orders are used for point and vector plotting and for electron beam positioning. The orders are normally followed by data bytes which identify each beam deflection end point. Each end point vector plotting position must be identified by an X and Y beam coordinate or, for incremental vectors, by ΔX and ΔY displacement values.

Absolute Graphic Orders

The Enter Graphic Mode orders indicate that the buffer locations following such orders contain absolute X, Y display coordinates. Four data bytes are used to identify one absolute X, Y coordinate on the CRT display area, as follows:



Note: These bits must be the same as the sign (S) bit.

The sign (S) bits are assigned internally, as are bits 2 and 3 in byte 0 and bits 1-3 in byte 3, and are normally 0. The signs and associated bits have no graphic function. Beam intensification of the X, Y coordinate is controlled by the blanking bit (B); the beam will be intensified (unblanked) when the blanking bit is a 0 and will not be intensified (will be blanked) when the blanking bit is a 1.

PROGRAMMING NOTE: Absolute coordinates must be programmed to the base 4096; if 1024 is used as a base, positioning will be restricted to within lower left quadrant of the display area.

The Point Plotting mode is used to position the electron beam at a specified location on the CRT display area and intensify, or not intensify, the beam at that specified location as determined by the beam bit. Two main purposes for positioning the beam without displaying the point are (1) to select a starting location for displaying characters in the Character mode, and (2) to start the display of a new set of vectors. Following execution of a Set Buffer Address Register and Start command, the beam position is undefined. Therefore, a blanked absolute point or vector operation must be performed to place the beam at the desired starting location before initiating the display.

Table 4. Orders Used by 2250, Model 1

Mode	Order	Mnemonic ⁽³⁾	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 ⁽²⁾	GEPI2	2A	04
	Enter Vector Plot Incremental, 2 Byte Mode ⁽²⁾	GEVI2	2A	05
Character ⁽¹⁾	Enter Character Mode Fixed, Basic Size (Unprotected)	GECF (B) (BASIC)	2A	40 ⁽⁴⁾
	Enter Character Mode Fixed, Large Size (Unprotected)	GECF (L) (LARGE)	2A	41 ⁽⁵⁾
	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	GNOP2	2A	80
	End Order Sequence	GEOS	2A	81
	Start Regeneration Timer	GSRT	2A	82
	Enter 4-Byte No-Op	GNOP4	2A	C0
	Transfer Unconditional	GTRU (ADDR)	2A	FF
Light Pen ⁽²⁾	Enable Switch Detect Operation	GESD	2A	84
	Disable Light-Pen Detects	GDPD	2A	85
	Enable No Switch Detects Operation	GENSD	2A	86
	Transfer On No Detect (4 Byte) ⁽⁶⁾	GTND (ADDR)	2A	FD

Notes:

1. Character mode orders are used only with the character generator feature; if an order is used without this feature, it is treated as a 2-Byte No-Op.
2. Light-pen and Graphic Mode Incremental orders are operational only when the 2250 is equipped with the graphic-design, and absolute-vector-graphics features. When the 2250 is not equipped with these features, the orders are treated as 2-Byte or (for Transfer On No Detect) 4-Byte No-Ops.
3. The mnemonics listed are those used by IBM Type 1 programming support packages. Parameters are shown after each mnemonic; parentheses indicate optional parameters (any one of the parenthesized parameters after the mnemonic can be used).
4. An MC code of 50 or 52, GECV (B) (BASIC) (S) (SMALL), can be used for compatibility with the IBM 2280 and 2282 film units but normally should not be used for other purposes.
5. An MC code of 51, GECV (L) (LARGE), can be used for compatibility with the IBM 2280 and 2282 film units but normally should not be used for other purposes.
6. Treated as a 4-Byte No-Op if 2250 is in the Disable Light Pen Detects mode.

For 2250's without the vector graphics feature, the absolute graphic modes are used to draw horizontal vectors along the X-axis, vertical vectors along the Y-axis, and vectors at a 45-degree angle; this mode can also be used for beam positioning. The 45-degree vector capability is included so that characters can be generated in the Vector mode; this capability should not be used for X- or Y-axis distances of greater than 20 raster units since the resulting vectors may not be straight. With the absolute vector graphics feature, straight vectors can be drawn between any two addressable points on the CRT display area.

2250's without the character generator feature can form characters using vectors. Vectors may similarly be used to form special characters not provided in the standard character set used by the character generator.

When operating in Graphic mode, the time required to deflect the electron beam a distance of 113 raster units or less is 16.8usec. The time required for deflection greater than 113 raster units is derived from the following formula:

$$\text{Deflection Time} = 83.2 \text{ usec} \times \frac{N-113}{910} + 16.8 \text{ usec},$$

where N is the 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 1023 raster units (full-scale deflection), the deflection time is determined as follows:

$$\begin{aligned} \text{Deflection Time} &= 83.2 \text{ usec} \times \frac{1023-113}{910} + 16.8 \text{ usec} \\ &= 100 \text{ usec} \end{aligned}$$

Table 5 shows the number of vectors, by length, that can be displayed at a regeneration rate of 40 cps.

PROGRAMMING NOTE: For improved image accuracy on complete images that are displayed in less than 25ms, the beam should be returned to the center of the display area ($X = 512$, $Y = 512$) after the image is displayed.

Incremental Graphic Orders

Two orders, Enter Point Plot Incremental, 2 Byte Mode and Enter Vector Plot Incremental, 2-Byte Mode, provide the capability of displaying a graphic image by specifying incremented displacement from an absolute beam position. The incremental X and Y can be of a positive or negative value. When negative, the data must be presented in 2's complement form. 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 format of each data byte pair that follows both incremental orders is:

S	X Increment	1	S	Y Increment	B*
0 1	6 7		0 1	6 7	

*Blanking bit: 0 = Unblank, 1 = Blank

The two S-bits define the signs of the X and Y increments. A 0 sign signifies a positive number, whereas a 1 sign signifies a negative number in 2's complement form. The B-bit is the blanking bit associated with the new absolute value. When the B-bit is a 1, indicating a blanked vector or point, the beam is not intensified as it is moved, or after it is moved, to the new position. When the B-bit is 0 in Point Plot mode, the beam is intensified at the deflection end point only; when the B-bit is 0 in Vector Plot mode, the beam is intensified as it is moved to the end point. 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. Figure 10 is a decimal-to-hexadecimal conversion chart for incremental deflections.

In 2-Byte Incremental mode, each X and Y displacement of the beam falls into the range of 0 to +63 or 0 to -64 raster units (0 to 0.74 inch). The time required for each incremental deflection of up to 15 raster units in length is less than 10.6usec, and deflections between 16 and 63 raster units in length require less than 14.5usec each. This is a result of short vector length and of reduced buffer access requirements (two data bytes per deflection instead of the four bytes required in Absolute mode). See Table 5 for the maximum number of incremental vectors that can be displayed at a 40 cps regeneration rate. If an increment specifies beam deflection outside a reference grid boundary, wraparound will occur; this wraparound will be visible if the beam is unblanked.

Table 5. Displayable Vectors at a Regeneration Rate of 40 CPS.

Vector Type	Vector Length		Max. No. of Vectors
	RU	Inches	
Absolute	16	0.188	1490
	31	0.363	1490
	63	0.739	1490
	127	1.49	1330
	512	5.99	465
	1023	12.0	250
Incremental	16	0.188	2720
	31	0.363	2630
	63	0.739	1920

Character Mode Orders

Two classes of character mode orders are used: protected, and unprotected. The two orders that compose each class specify a character size: basic, and large (1-1/2 times basic). Data following the protected character mode orders is protected from the insertion of a character from the alphabetic keyboard, even though a command-inserted cursor may be displayed. Unprotected data can be changed from the alphabetic keyboard. The groups of data bytes following the order byte correspond to characters to be displayed on the 2250: one byte corresponds to one character. All character codes shown in Figure 7 may be used on the 2250. The addressed 2250 remains in the designated character mode until a new SM code is recognized at an even byte.

The characteristics of a character display are listed in Figure 11. The position of the electron beam on the CRT display area is the center of the area in which the first character will be drawn. Since character deflection is independent of main deflection, the character center point can be at any reference grid coordinate; if the center point is on or near a coordinate where X or $Y = 0$ or 1,023, the entire character is displayed, even though up to half of the character falls outside the reference grid area. The beam is usually positioned by a blanked graphic mode point plot or vector order before entering the character mode. The spacing of subsequent characters is performed by main (graphic) deflection; the spacing distance is determined by the character size specified in the character mode order. The X axis deflection register is stepped after each character is written.

The new line (NL) character (hexadecimal 15) causes the X deflection register to be reset to 0 and causes the Y deflection register to be stepped down to the start of the next line (a distance dependent on the character size selected). The NL character may appear anywhere in the string of characters except in the position immediately preceding or following an order; successive NL characters will cause the Y deflection register to step down successive

Second Hex. Char. of Byte		Number of Raster Units																		
Unblank	Blank	-57	-49	-41	-33	-25	-17	-9	-1	+7	+15	+23	+31	+39	+47	+55	+63			
E	F	-57	-49	-41	-33	-25	-17	-9	-1	+7	+15	+23	+31	+39	+47	+55	+63			
C	D	-58	-50	-42	-34	-26	-18	-10	-2	+6	+14	+22	+30	+38	+46	+54	+62			
A	B	-59	-51	-43	-35	-27	-19	-11	-3	+5	+13	+21	+29	+37	+45	+53	+61			
8	9	-60	-52	-44	-36	-28	-20	-12	-4	+4	+12	+20	+28	+36	+44	+52	+60			
6	7	-61	-53	-45	-37	-29	-21	-13	-5	+3	+11	+19	+27	+35	+43	+51	+59			
4	5	-62	-54	-46	-38	-30	-22	-14	-6	+2	+10	+18	+26	+34	+42	+50	+58			
2	3	-63	-55	-47	-39	-31	-23	-15	-7	+1	+9	+17	+25	+33	+41	+49	+57			
0	1	-64	-56	-48	-40	-32	-24	-16	-8	+0	+8	+16	+24	+32	+40	+48	+56			
		8	9	A	B	C	D	E	F	0	1	2	3	4	5	6	7			
First Hex. Char. of Byte																				

Notes:

1. For even byte (ΔX), second hexadecimal character is always odd (1, 3, 5, 7, 9, B, D, or F)
2. For odd byte (ΔY), second hexadecimal character is odd if beam is to be blanked. If beam is to be unblanked, the second hexadecimal character is even (0, 2, 4, 6, 8, A, C, or E).

Figure 10. Decimal-Hexadecimal Conversion Chart for Incremental Deflections

lines. If an NL code is not programmed, the 2250 displays up to the end of a line, automatically steps down to the next line, and continues the display. The time required to reposition the beam to a new line (flyback time) is 8 usec when beam deflection is 16 raster units or less. When beam deflection is greater than 16 raster units, flyback time is derived from the following formula:

$$\text{Flyback Time} = 92 \text{ usec} \times \frac{N-16}{1007} + 8 \text{ usec}$$

where N is the number of raster units of the axis (X or Y) having the greater change (1023 maximum).

The null character (hexadecimal 00) causes no graphic display and does not affect character spacing circuitry. Thus, the X, Y beam position is the same before and after executing the null character. The null character can appear anywhere in the string of characters and can be repeated as necessary. (Because the null character occupies a data byte, it can be used for reserving, initializing, or filling out a group of character bytes to delimit a control boundary.)

Control Mode Orders

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

Enter 2-Byte No-Op

The SM-MC byte pair constitutes the complete order. The 2250 enters a No-Op mode, performing no operation other than stepping the buffer address register on subsequent data bytes until the next SM code is found in an even byte. Any

bytes between the No-Op order and the next SM code are ignored. No-Op mode is also entered when an invalid or unassigned MC code is decoded.

End-Order Sequence

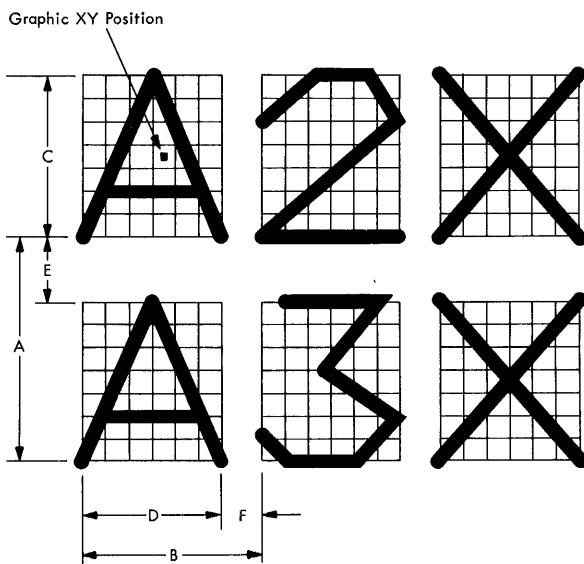
This control order terminates the regeneration cycle, causes the setting of the Attention and Unit Check bits in the status byte, and sets the End Order Sequence bit in sense byte 1.

Start Regeneration Timer

One 25-ms regeneration timer is provided in the 2250. Regeneration following the Start Regeneration Timer order is delayed if the timer has not completed the current 25-ms time period. When the time period is completed, the timer is restarted and image regeneration is resumed.

If the 2250 is equipped with a light pen or a keyboard, the Start Regeneration Timer control order must be included in each regeneration sequence. The regeneration rate is variable up to a rate of 40cps (25ms frame time) and is determined by the regeneration timer or by the amount of displayed information. (Messages that require up to 25ms to regenerate will be displayed at the maximum rate of 40cps.) A steady display image can be obtained with a regeneration rate of 30 to 40cps.

The Start Regeneration Timer order also initiates interrogation of the 2250 keyboards. Each time this order is decoded, the 2250 is interrogated to determine if a programmed-function key or alphanumeric key is depressed. Keyboard operations, programmed-function and



Legend	Characteristics	Character Size	
		Basic	Large
-	Characters per line (max.) (First character center at X = 000)	74	49
-	Lines per display (max.) (First line at Y = 1023)	52	35
-	Number of characters on display (max.)	3,848*	1,715
-	Displayable characters a regeneration rate of 40cps**	2,100	1,715
Spacing:			
A	Line	20 RU	30 RU
B	Character	14 RU	21 RU
C	Character area size, in raster units:		
	Height	14 RU	21 RU
D	Width	10 RU	15 RU
C	Character area size, in inches (nominal):		
	Height	0.16"	0.25"
D	Width	0.12"	0.18"
E	Distance between character areas:		
	Vertical	6 RU	9 RU
F	Horizontal	4 RU	6 RU
-	Displayed character time (includes average character time and adjacent character spacing).	14us	16us
-	Blank character time (includes adjacent character spacing)	6usec	9usec

*Not flicker-free display

**These figures are based on usage distribution of English language characters; the individual draw times depend on the number of strokes used to form each character.

Figure 11. Character Display Characteristics

alphabetic, will not be recognized during regeneration unless this order is used in the regeneration sequence.

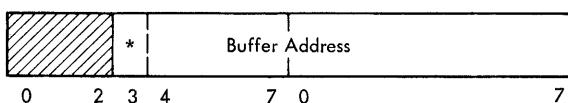
If the graphic design feature is installed, this order resets the 2250 to normal Light Pen mode as does the Enable Switch Detect Operation order. It resets these orders: Disable Light Pen Detects and Enable No Switch Detects Operation.

Enter 4-Byte No-Op

The SM-MC byte pair requires two additional bytes to complete the four-byte order. This order causes the 2250 to perform no operation with the last two bytes of the order and, then, to continue performing no operation with subsequent data bytes until the next XM code is found in an even byte. This order can be used as a No-Op/Transfer Unconditional switch by having a buffer location specified in bytes 2 and 3; byte 1, the MC byte, can then be changed by the program to a Transfer Unconditional order code, changing the regeneration sequence.

Transfer Unconditional

The SM-MC byte pair requires two additional bytes containing a buffer address to constitute the complete four-byte order. This buffer address specifies the location of the next buffer operation to be executed by the 2250. Each image to be regenerated must have the Transfer Unconditional control order as the last order in the sequence. The address contained in this order should point to the first order in the order sequence, thus closing the loop to enable regeneration of the image. If the location transferred to is not an even byte that contains an SM code, sequential buffer locations are read until an SM code is decoded in an even location. The format of the two address bytes in this order is as follows:



*Most significant bit if addressing 8,192-byte buffer; this bit not used (bit 4 is most significant bit) if addressing 4,096-byte buffer.

Light-Pen Mode Orders

Enable Switch Detect Operation

This order causes the 2250 to operate in the normal light-pen detect mode, as does the Start Regeneration Timer order. 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 light-pen detect mode. Enable No Switch Detect Operation and Disable Light Pen Detects; the Set Buffer Address Register

and Start and Set Buffer Address Register and Stop commands do not reset this mode. The 2250 is reset to normal light-pen detect mode either by an Enable Switch Detect Operation order or by a Start Regeneration Timer order. In normal light-pen detect mode, the sequence of events that results in a detect is:

1. The light pen switch is closed.
2. The Start Regeneration Timer order is encountered following switch closure.
3. The 2250 is in normal light-pen 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 is dependent on this sequence of events, a detect will occur on the first character, point, or vector that is displayed in 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 light-pen detect occurs, regeneration stops immediately, and a light-pen interrupt status (Attention and Unit Check bits set) is presented to the channel.

Disable Light Pen Detects

This order inhibits light-pen detects on all data that follows it in the buffer program. The disabled detection condition continues until reset by any of these orders: Enable Switch Detect Operation, Enable No Switch Detect Operation, or Start Regeneration Timer. In turn, the Disable Light Pen Detects order resets normal light-pen detect mode (established by either an Enable Switch Detect Operation Mode order or by a Start Regeneration Timer order) and Enable No Switch Detect Operation mode.

Enable No Switch Detect Operation

This order permits light-pen detects that are independent both of light pen switch action and of Start Regeneration Timer order synchronization. In the Enable No Switch Detect Operation mode, a series of sequential asynchronous light-pen detects can be generated. This is a continuous detect mode.

The Enable No Switch Detect Operation order causes the 2250 to exit from normal light-pen detect mode or from Disable Light-Pen Detects mode. A light-pen detect occurs when the following conditions are satisfied:

1. The light-pen is conditioned by the Enable No Switch Detect Operation order.
2. Displayed information is viewed by the pen.

Execution of this order causes tip-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 by a Start Regeneration Timer order, Enable Switch Detect Operation

order, or Disable Light Pen Detects order. A Set Buffer Address Register and Start or a Set Buffer Address Register and Stop command will not reset this mode.

During each regeneration cycle, light-pen detects can occur in two modes: Normal Light-Pen Detect and Enable No Switch Detect. Only one normal light-pen detect mode detect can occur per switch closure regardless of the number of times normal light-pen detect mode orders are executed during that cycle. In Enable No Switch Detects mode an unlimited number of detects can occur; detects in this mode and the single detect permitted in normal light-pen detect mode are mutually independent.

The first light-pen detect that occurs after execution of the Enable No Switch Detect Operation order causes regeneration to stop immediately, a light pen interrupt (Attention and Unit Check status bits set) to be presented to the channel, and a light-pen detect occurrence condition to be set; this condition inhibits execution of a Transfer On No Detect order until the condition is reset by a Start Regeneration Timer order or by another Enable No Switch Detect Operation order.

Light-pen detects and no-detect transfers in the Enable No Switch Detects Operation mode are accepted and processed in unlimited quantities as determined by the buffer program.

Transfer On No Detect

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

1. The light-pen light-pen switch is closed.
2. After the light-pen switch is closed, a Start Regeneration Timer order is encountered.
3. When the Transfer on No Detect order is encountered, the 2250 is in the normal light-pen mode.
4. After conditions 1 and 2 are satisfied, a normal light-pen detect does not occur on displayed information.

or

1. When the Transfer on No Detect order is encountered, the light pen is enabled by the Enable No Switch Detect Operation order, and the light pen detect occurrence condition is not set.
2. A light-pen detect has not occurred since the 2250 last entered the No Switch Detect mode.

Once the 2250 is in normal light-pen detect mode and a Transfer on No Detect order is executed, additional no-detect transfers or normal detects cannot occur until the conditions for a normal detect are again satisfied.

When the Transfer on No Detect order is encountered and the conditions for transfer are not satisfied, the order is executed as a 4-Byte No Op.

EXAMPLES OF 2250 OPERATIONS

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

Note: All graphic coordinates used in this section are to the base 4,096.

Example 1: Displaying an Image on a 2250

- A. Problem: Display a box and alphabetic characters (Figure 12) on the CRT display area of a 2250 which is equipped with an alphabetic keyboard, and allow characters selected at the alphabetic keyboard to be displayed.

- B. Command sequence executed by the 2250:

1. Set Buffer Address Register and Stop - address N: stops regeneration for the 2250, if in progress, and sets the buffer address register to N.
2. Write Buffer: causes the transfer of orders and data (Table 6) 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 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: (1) Sets the buffer address register to N, (2) disconnects the 2250 from the channel if it is the last command in the chain, generating an I/O interrupt (thereby allowing the channel to perform operations with other devices), and (3) initiates regeneration from sequential buffer locations starting at address N. The display is then regenerated under control of the orders and data read from the buffer as described in the "Function" column of Table 6.

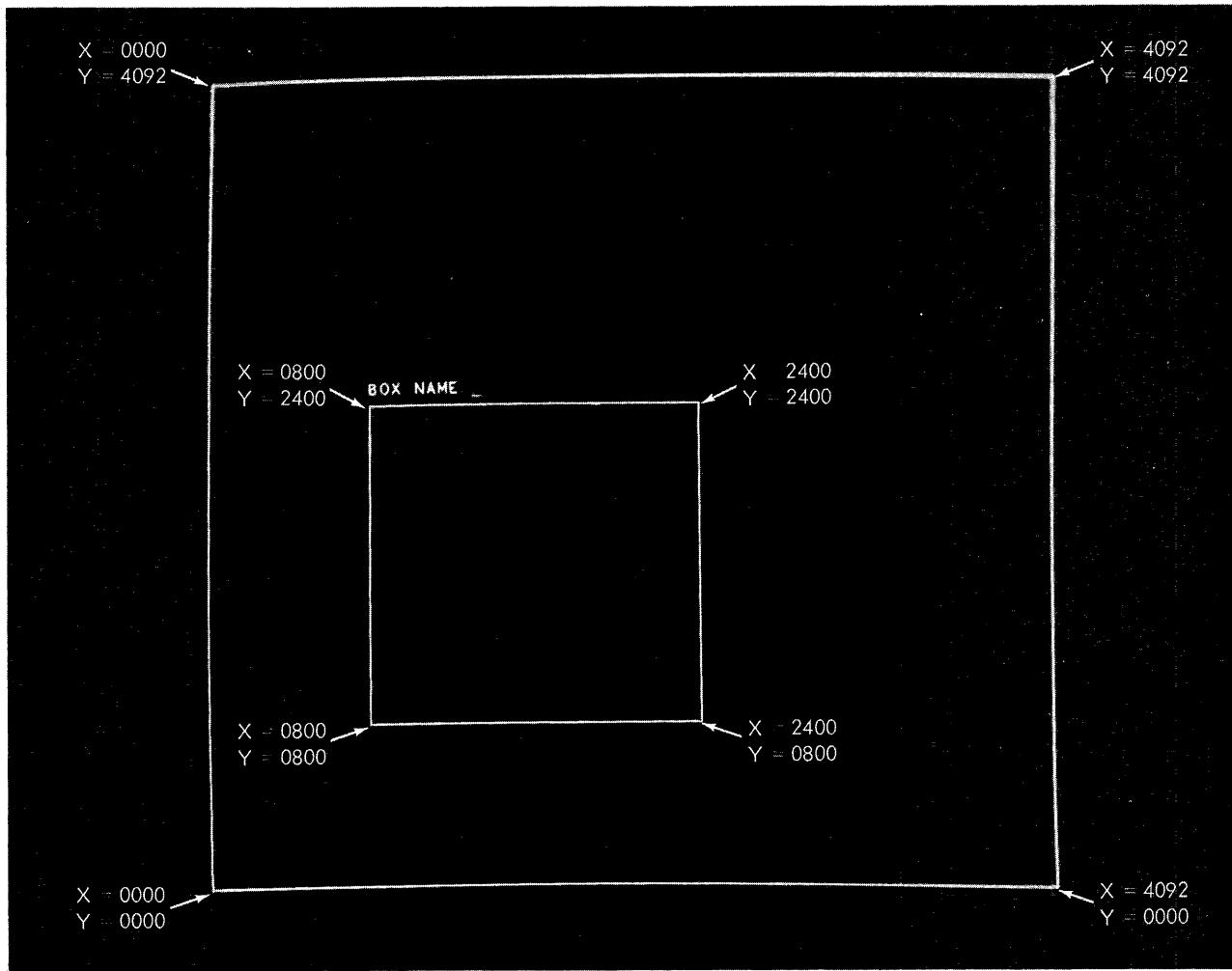


Figure 12. Programming Example Display

**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 the 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 2250 responds to this command with (1) 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 an I/O interrupt with the Attention and Unit Check bits set in the CSW.
5. The program responds to this interrupt with a Sense command.
6. The 2250 responds to the Sense command with four bytes, which inform the CPU program 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

Table 6. Example Sequence of Orders and Data in the Buffer

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

shown on Figure 12 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 could be received by the 2250:
- Command: Set Buffer Address Register and Stop, Address N + 8.

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

Example 3: Alphabetic Keyboard Operation

- Problem: With the buffer contents the same as in Example 1, and with the display regenerating, insert a box name using the alphabetic keyboard.
- Sequence:
 - 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 12, Table 6). 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 alphabetic 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 alphabetic 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 this interrupt with a Read Manual Input command.
7. The 2250 responds to this command with three bytes that specify to the program that the Attention status was caused by the alphabetic 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.

BASIC OPERATOR CONTROLS AND INDICATORS

All 2250 Display Units are equipped with the following basic controls and indicators (Figure 13):

POWER ON key/indicator: Applies power to the 2250; indicator is lit when power is on. (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 are 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; operational only when 2250 is equipped with character generator feature.

The following indicators are located under the front left side of the 2250 reading board (Figure 13):

CMND REJ - Lit when an invalid modifier bit is in a command or lit during an invalid command sequence.

BUS OUT CHECK - Lit when a parity error is detected in a command or data byte received from the channel via Bus Out.

DATA CHECK - Lit when a buffer parity error is detected either during execution of a Read Buffer or Cursor command or during image regeneration.

BUFFER RUNNING - Lit when display regeneration is in progress.

I/O INTF DSBLD - Lit when the 2250 is logically disabled and is on-line. This indicator is provided with the isolation feature to enable power on/off at the 2250 without interfering with the rest of the system (see procedure later in this section).

Note: Any power on/off transition in the 2250 while the CPU is running will cause system errors unless the 2250 is equipped with the isolation feature and the procedure for using this feature is followed.

METERING

Each 2250 is equipped with the following meters and controls:

Customer meter - Records customer time as described below.

CE (Customer Engineer) meter - Records time when selected by the CE key switch.

Enable switch - allows the 2250 to become logically enabled or disabled (on or off line).

CE key switch - Determines which meter (Customer or CE) will be used to record time.

The 2250 can be switched from logically enabled to logically disabled, or vice versa, only when the CPU is in a wait or stopped state. When the 2250 is logically disabled, the customer meter is prevented from operating.

When the CE key switch is in the CE position, the customer meter is inoperative, and time is recorded by the CE meter. When the CE key switch is not in the CE position, time is recorded on the customer meter, and the CE meter is inoperative. The 2250 records time either when it is logically enabled and the CPU cluster is recording time or when it is logically enabled and the buffer is operating the unit.

POWER ON/OFF PROCEDURE - 2250 WITH ISOLATION FEATURE

To turn power off when the 2250 is on line, use the following procedure:

1. Place Enable/Disable switch to down (disable) position.
2. When I/O INTF DSBLD indicator turns on, depress POWER OFF pushbutton.

Use the following procedure to apply power to the 2250:

1. Depress POWER ON pushbutton. Power will sequence on, the 2250 will be on line but disabled, and the I/O INTF DSBLD indicator will light.
2. To enable the 2250, place Enable/Disable switch to up (Enable) position. The 2250 will then become enabled when the CPU enters the Stopped or Wait state; at this time, the I/O INTF DSBLD indicator will turn off.

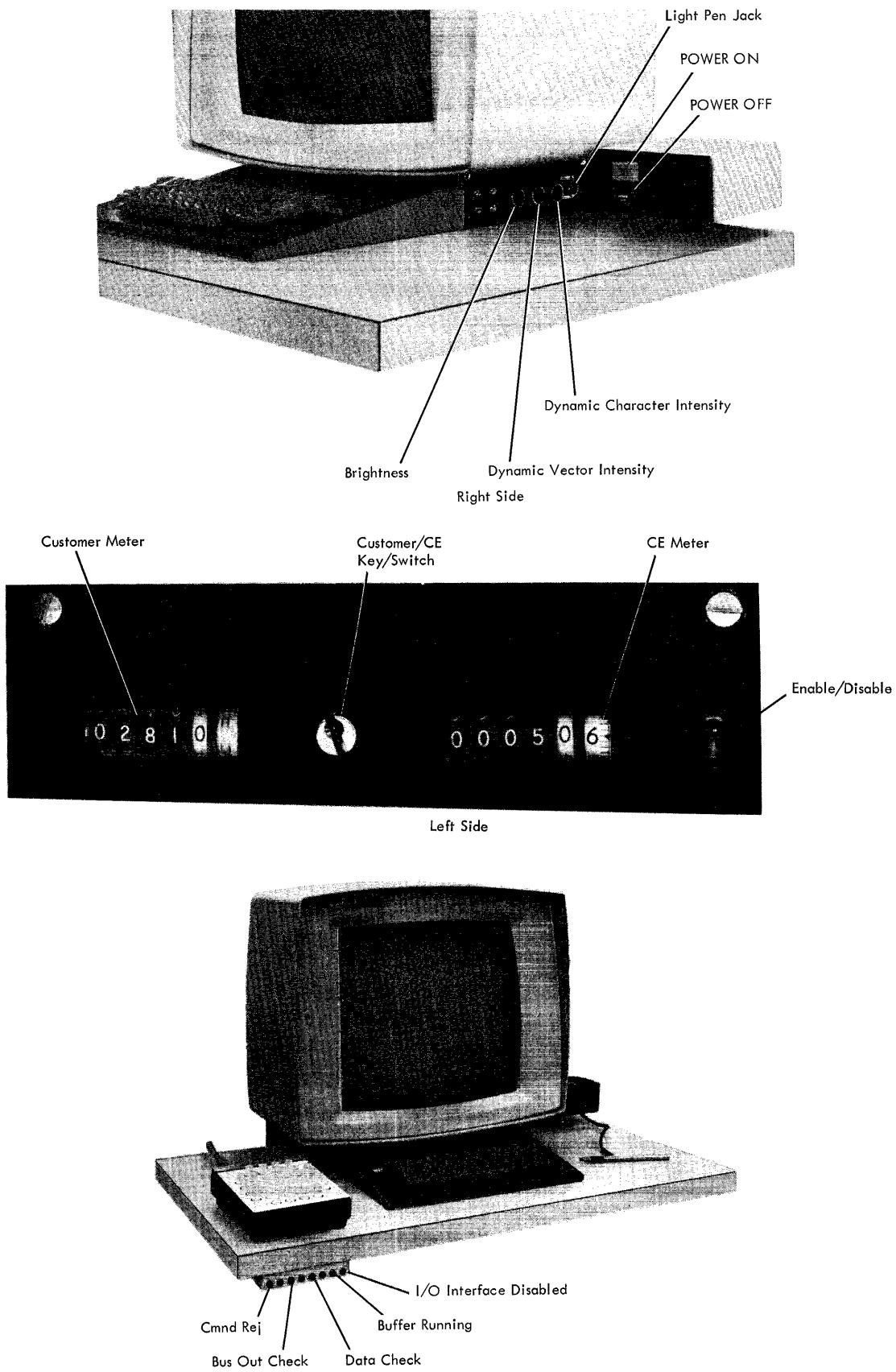


Figure 13. Basic Operator Controls and Indicators

OPERATOR CONTROL PANEL FEATURE

The following keys and indicators are provided on the Operator Control Panel (Figure 14):

POWER ON key - Applies dc power to all attached System/360 units.

POWER OFF key - Removes dc power from all attached System/360 units.

LOAD UNIT switches - Select unit to be used by the initial program load operation.

INTERRUPT key - Causes an external interrupt.

LOAD key - Causes a system reset followed by an initial load operation.

POWER ON indicator - Lit when dc power is applied to the attached System/360 units. This indicator is part of the POWER ON key assembly.

SYSTEM indicator - Lit when the CPU usage meter is running.

WAIT indicator - Lit when the "Wait" bit in the program status word is set to 1.

MANUAL indicator - Lit when the CPU is in a stop condition.

TEST indicator - Lit when a customer engineer or operator key is not in the normal position.

LOAD indicator - Lit when the LOAD key is activated, indicating that the CPU is in the load condition.

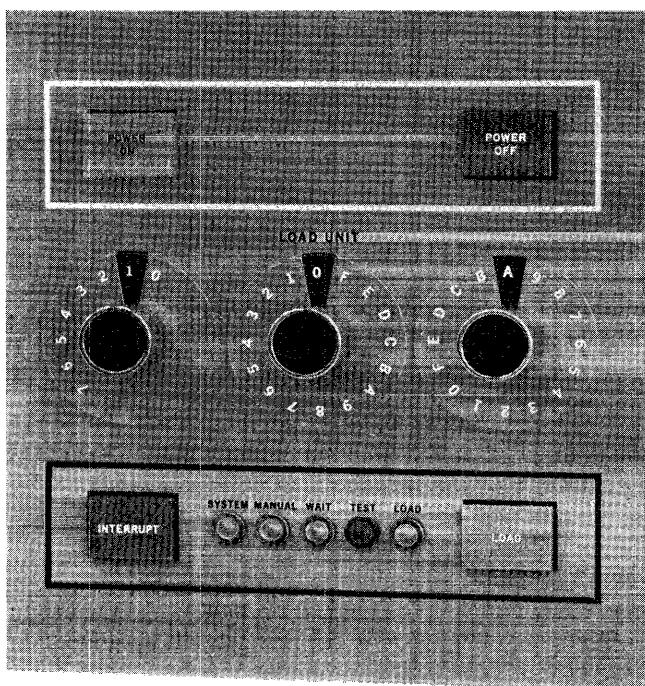


Figure 14. Operator Control Panel Feature

ALPHAMERIC KEYBOARD

The alphameric keyboard (Figure 15) contains 44 keys and a space bar which provide a selection of 64 standard characters for entry into the 2250 buffer or main storage. (Alphabetic keys compose upper-case characters regardless of the status of the shift key.) In addition to the standard character keys, the following keys are provided on all keyboards:

SHIFT - When depressed, allows selection of the upper character by a dual-character key. 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.

NULL - Enters a Null character (hexadecimal 00) into the buffer position occupied by the cursor.

END - Sets the End bit and Alphameric Keyboard bit in Read Manual Input command response byte 0, and sets the Attention bit in the status byte. Depressing this key may be used to signify the end of a manual alphameric keyboard operation to the program.

CANCEL - Sets the Cancel bit and Alphameric Keyboard bit in Read Manual Input command response byte 0, and sets the Attention bit in the status byte. The function of this key is determined by the program.

ALT - When depressed with the SHIFT key released, allows selection of the NULL, END, or CANCEL function. When depressed with the SHIFT key, unlocks the keyboard. To perform the NULL, END, or CANCEL function, ALT should be depressed and held before selecting the desired function.

The following key functions are also provided with an alphameric keyboard that is attached to a 2250 equipped with the character generator feature.

JUMP - Moves the cursor, in forward direction only, from its present buffer location (protected or unprotected) to the buffer location of the first character of the next block of unprotected character data.

ADVANCE - Advances the cursor one buffer position without changing the buffer data. If the cursor is positioned in the last character position of the character string, this key performs no function.

BACKSPACE - Backspaces the cursor one buffer position without changing the buffer data. If the cursor is positioned in the first character position of the character string, this key performs no function.

CONTINUE - Allows continuous automatic operation of an ADVANCE, BACKSPACE, SPACE, NULL, JUMP, or Alphameric/ Special Character key at the rate of the regeneration cycle.



Figure 15. Alphameric Keyboard

When the 2250 is equipped with the character generator feature, depression of a character key does not cause Attention status to be sent to the channel. Instead, the coded character data is inserted directly into the buffer position identified on the display by the cursor symbol. The cursor symbol is a dash displayed beneath the character position at which the character selected at the alphameric keyboard will be placed. As characters are entered, the cursor is automatically stepped to succeeding character positions. The cursor can be positioned manually by depressing the JUMP, ADVANCE, or BACKSPACE key. If a cursor is not displayed, characters cannot be inserted; in this case, a cursor must be inserted by the program. If the cursor is in a protected area, it must be moved to an unprotected area by the JUMP key before the character keys are effective. (Cursor operation in a protected area is the same as in an unprotected area except that keyboard data cannot be entered.) A cursor located in a buffer area containing an order followed by data bytes, up to a succeeding SM code, can be moved to any data byte location in that area by means of the BACKSPACE or ADVANCE keys. It can only be moved past the succeeding SM code by the JUMP key or by the program.

PROGRAMMED FUNCTION KEYBOARD

The programmed function keyboard (Figure 16) contains 32 keys, 32 indicators, and an overlay position with eight

sensing switches. The keys and indicators are numbered 0 through 31. One of 256 possible overlays identifies the function of the keys and indicators to the operator and the CPU program. The overlay sensing switch configuration is sent to the channel with each key code byte, thereby identifying the overlay being used. (See Read Manual Input command description). Figure 17 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 will appear in the corresponding bit position in byte 2 of the command response. (Punch 7 is the least significant.) For example, if overlay punch positions 3, 5, and 7 are punched, byte 2 of the command response will be 00010101 (21 decimal or 15 hexadecimal). If no overlay is used, this byte will contain all 1-bits. 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).

When a key is pressed, the keyboard is electrically locked (keys can be pressed, but will have no effect), and the Attention bit is set in the status byte. The 2250 then waits until present interface operations have terminated before sending the status byte to the channel. The program should respond to a set Attention bit by issuing a Read Manual Input command. This command initiates transfer of the three programmed function keyboard data bytes.

Each key has a physically associated indicator that can be lit or extinguished under program control. Indicators can be used to inform the operator that certain keys can be activated or that certain keys have been activated previously. Operation of the indicators is controlled by the program; therefore, the function of each indicator is determined by the program, not by the physically associated switch. The Set Programmed Function Indicators command uses four bytes of data to light or extinguish the indicators; each indicator is associated with a specific bit, 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

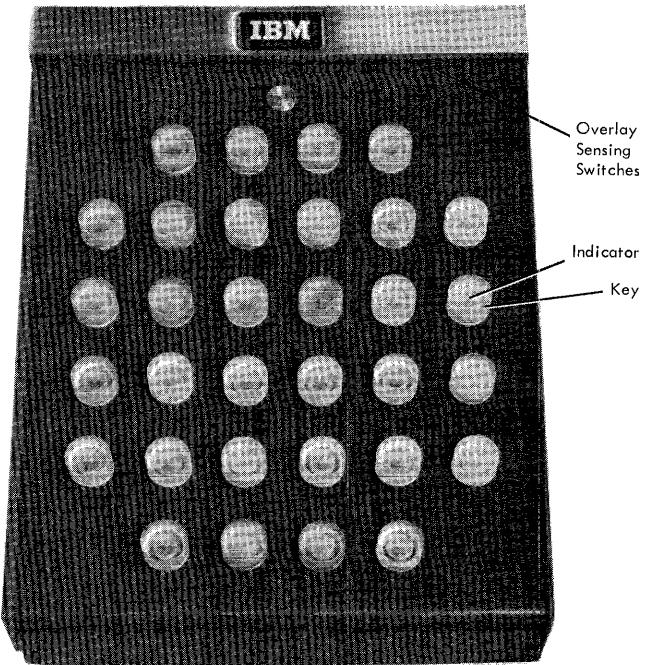


Figure 16. Programmed Function Keyboard

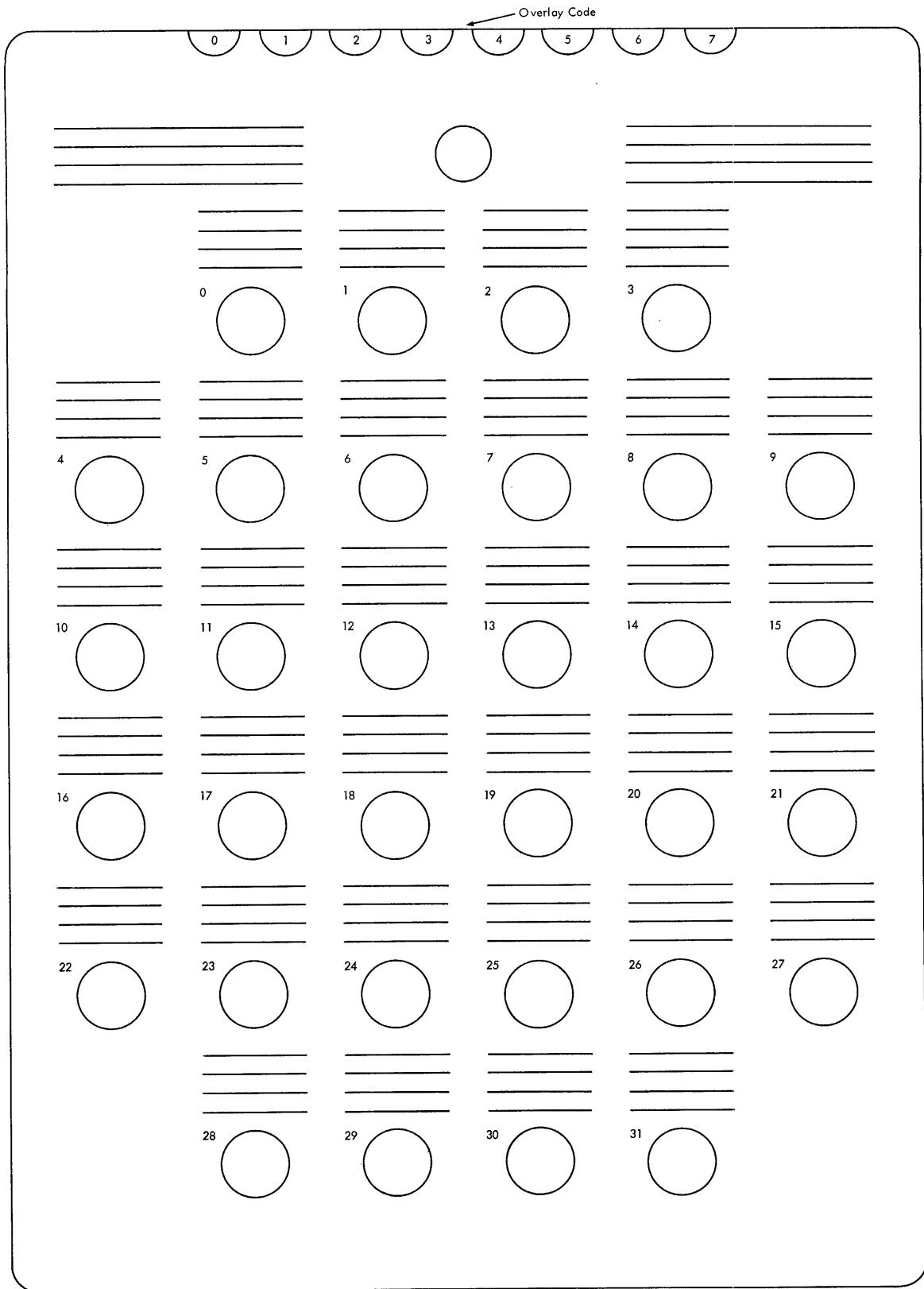


Figure 17. Programmed Function Keyboard Overlay

Appendix A: Status Conditions

Condition	Device Status Bits Set in CSW	Sense Bits Set
<u>General Conditions</u>		
1. Initial status in response to commands involving data transfer; status not stacked.	All bits zero (indicates command accepted; for Test I/O indicates no status).	None
2. Initial status in response to a command other than Test I/O when the selected 2250 has stacked status.	Busy, outstanding status	None
3. Initial status in response to Test I/O when the 2250 has stacked or pending status.	Outstanding status	None
4. Initial status for commands not involving data transfer (e.g., Remove Cursor, No Operation).	Device End, Channel End	None
5. Ending status for commands involving data transfer.	Device End, Channel End	None
6. In response after Halt I/O is completed, if the Halt I/O is issued after initial status and before ending status.	Device End, Channel End	None
<u>Interface Error Conditions</u>		
1. Initial status in response to a command with invalid modifier bits.	Unit Check	Command Reject
2. Initial status in response to a command with bad parity.	Unit Check	Bus Out Check
3. Initial status in response to a Write Buffer, Read Buffer, Read Cursor, Read XY Position Registers, Insert Cursor, or Remove Cursor command when the buffer is running (buffered 2250).	Unit Check	Command Reject Buffer Running
4. Ending status, when write data contains a byte with bad parity (buffered or unbuffered 2250).	Device End, Channel End, Unit Check	Bus Out Check
5. Ending status, when read buffer data contains a byte with bad parity (buffered 2250).	Device End, Channel End, Unit Check	Data Check
<u>Regeneration Error Condition</u>		
1. Asynchronous status when a buffer parity error is detected (buffered 2250).	Attention, Unit Check	Data Check, Buffer Address
<u>Manual Input Conditions</u>		
1. Asynchronous status (1) when any alphanumeric keyboard is pressed (without character generator), or (2) only when the END or CANCEL key is pressed (with character generator).	Attention	None
2. Asynchronous status resulting from a light-pen detect (buffer operation is stopped).	Attention, Unit Check	Light Pen, Buffer Address, Character Mode
3. Asynchronous status when an End Order Sequence order is decoded.	Attention, Unit Check	End Order Sequence, Buffer Address

Glossary

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: The first byte of a CCW from main storage that specifies, to the channel and the 2250, the operation to be performed.

End Point: The address 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 CPU-decoded program step executed in the CPU and, in the case of I/O instructions, in the channel.

Order: Two coded bytes (Set Mode and Mode Control) from main storage that specify a mode of operation to the 2250. It is treated as data by the channel and is sent to the 2250 by a Write command.

Pending Status: The condition of the 2250 when an outstanding status byte has not been sent to the channel because of channel activity; the pending-status condition is cleared when the status byte is sent.

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: The condition of the 2250 when an outstanding status byte has not been accepted by the channel because of channel activity; the stacked status condition is cleared when the channel accepts the status byte.

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

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