THEORY OF OPERATION

OF

DISPLAY SYSTEM

FOR

AN/FSQ-7 COMBAT DIRECTION CENTRAL

AND

AN/FSQ-8 COMBAT CONTROL CENTRAL

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CHAPTER 1
GENERAL THEORY OF CRT's

1.1 INTRODUCTION TO CRT's

Since the end function of the Display System is to present the information output of the Central Computer System, the displaying element or CRT's can be considered the heart of this system.

Four types of CRT's, grouped into two functional classifications, are used for display: three SD CRT's and one DD CRT. The SD CRT's present situation information; the DD CRT presents digital information. The type of information (message) that each CRT can present is given in detail in Parts 3 and 4. Figure 2—1 illustrates the relative configuration of each type of CRT. Figure 2—2, in the form of a simplified flow block diagram, shows the relation of the CRT's to the major elements of the Display System. The display indicator section (DDIS and SDIS) represents, in each block, one of many replica units that are driven collectively, in each group, by a DDGE and SDGE. Comprehensive block diagrams are shown in those sections of this manual which discuss each CRT type in detail.

Figure 2—1. CRT Types Used in Display System

1.2 DISPLAY SYSTEM CRT's

The CRT types commonly known and used for oscillographic or picture displays contain four essential parts: an evacuated glass envelope, an electron gun that will generate and shoot a stream of electrons, a means of deflecting the electron stream and a screen which transforms the electrical energy of the electron stream into light. The CRT's used in the Display System operate on the same basic principles; only additional elements have been added to further control and direct the electron stream for character display.

1.2.1 Electron Gun

The electron gun consists of a separately heated cathode that acts as a source of electrons, a control grid that limits the number of electrons traveling toward the screen, a first (or focusing) anode, and a second (or accelerating) anode. Voltages applied to the first and second anodes accelerate the electrons and cause them to be focused into a narrow beam. The cathode, control grid, and first and second anodes physically have their axes coincident with the axis of the tube. Electrons leave the heated cathode in random directions, but most

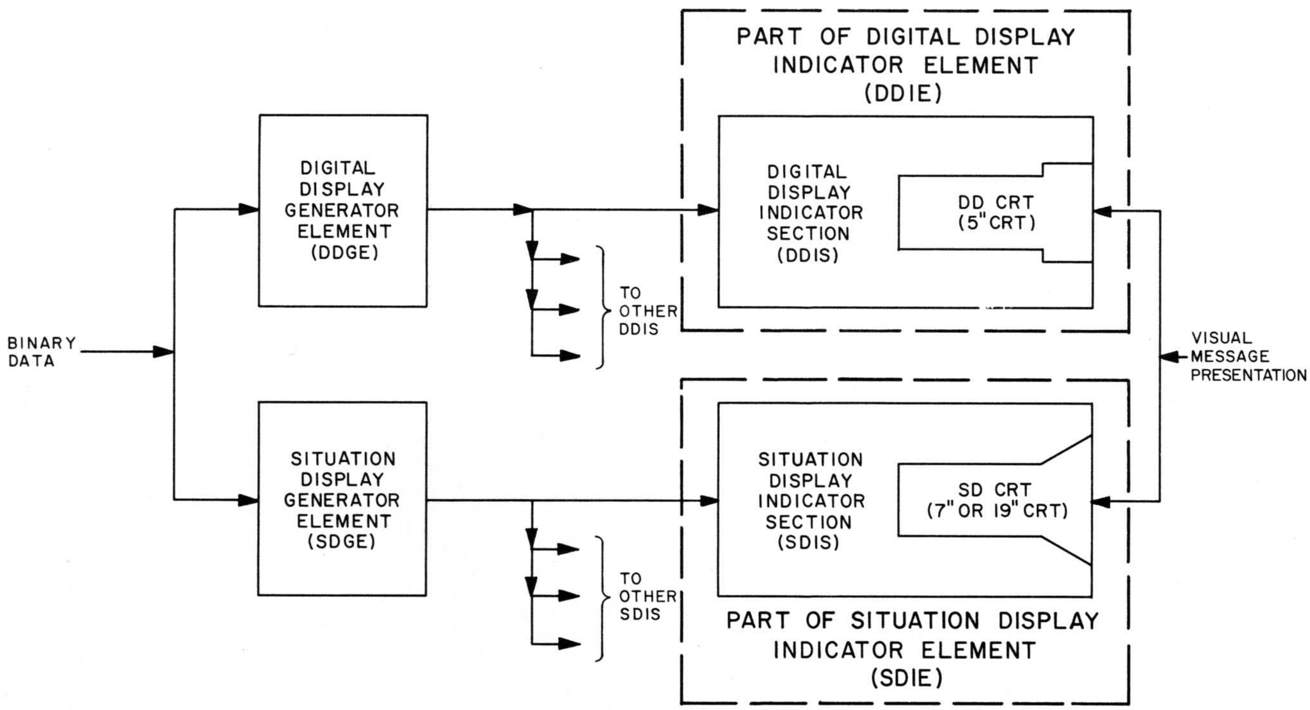


Figure 2–2. Relation of Display Tubes to Elements of the Display System, Block Diagram

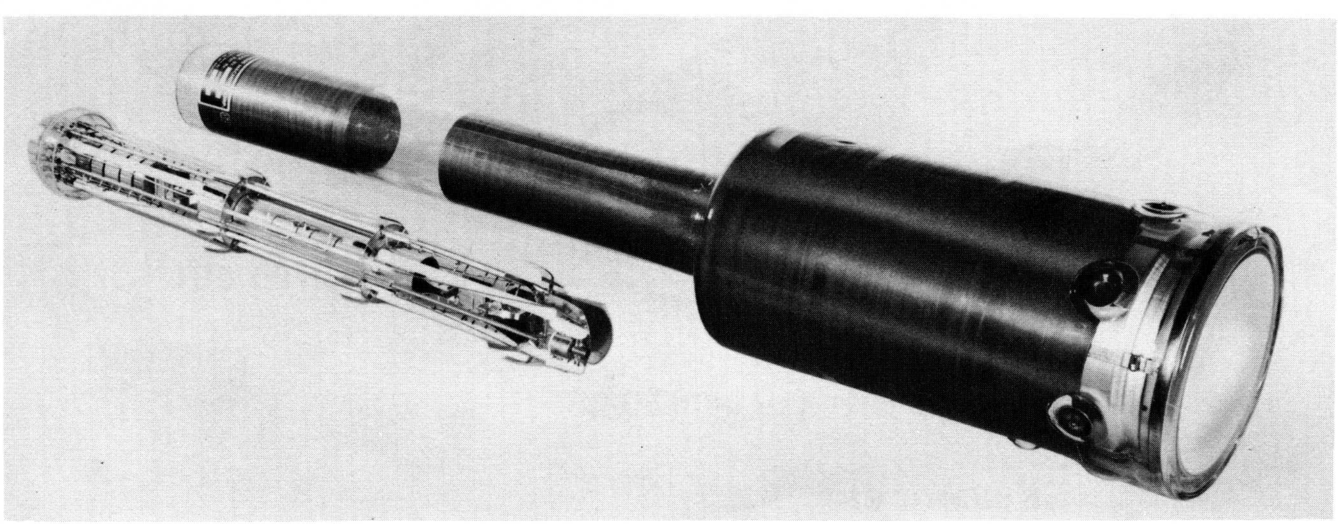


Figure 2–3. Electron Gun Removed from 5-Inch DD CRT

of them are converged toward the axis of the tube by the action of the electric field between the cathode and the control grid. Figure 2–3 shows the electron gun removed from the 5-inch DD CRT.

The electrons pass through a space within the first anode that is almost field-free and enter the space within the first and second anodes, creating an axial field. As the electrons leave this field, their paths become less rapidly convergent. However, they are still headed toward the axis and will meet at a point. If this point is at the screen, it is said to be in focus. The forces producing convergence of the beam depend on the ratio of the voltages applied to the first and second anodes. By adjusting either of these two voltages, the point of convergency may be changed. Focus is usually controlled by adjusting the first-anode voltage.

The beam may be focused on the screen either by an electrostatic field or by a magnetic field. Similarly, the beam may be deflected on the screen either by an electric or a magnetic field.

1.2.2 Screen Phosphors

To convert the energy of the electron beam into visible light, the area where the beam strikes is coated with a phosphor material which emits light when bombarded with electrons of sufficiently high velocities. This phenomenon is called fluorescence. The continuance of light output, for a short time after bombardment has ceased, is called phosphorescence. All fluorescent materials are associated with a characteristic relationship between the intensity of the emitted light and the colors contained in that light. Some emit a green light; others, yellow, blue, orange, etc., depending upon the phosphor or mixture of phosphors used.

All fluorescent materials have some afterglow or phosphorescence, but the duration of the afterglow (or persistence) varies with the material as well as with the energy in the beam.

1.2.3 Persistence of Phosphors

The persistence of the screen is generally designated by a "P number". In applications where a CRT is used for observing periodic phenomena, which occur at a low repetition rate, a screen material on which the image will linger is desirable. Such a tube is described as a "long persistence" tube. Where the image changes rapidly, a "short persistence" tube is employed. If the application is such that a tube display will be photographed, as well as observed directly, a phosphor having a spectral light output in the blue range is used.

Of the Display System CRT's, the 19-inch SD CRT used in the camera console and the 7-inch SD CRT used in the PRR have P11 phosphors. The other 19-inch SD CRT, although identical in every other respect, has a P14 phosphor, and is used in the SD consoles. The 5-inch DD CRT employs a P1 phosphor.

The characteristic features of the fluorescent screens used in the Display System CRT's are:

Phosphor-P1	Produces a brilliant spot having green fluorescence and medium persistence.
Phosphor-P11	Produces a brilliant actinic spot of bluish fluorescence of short persistence. This color is effective for photographic applications because of the sensitivity of the film emulsion to blue light.
Phosphor-P14	A medium-long persistence cascade (2-layer) screen. During excitation by the electron beam, the phosphor exhibits purple fluorescence of short persistence. After excitation, it exhibits an orange phosphorescence which persists a little over a minute.

To maintain uniform screen potential, increase light output, and improve contrast, metal-backed phosphors are used where practicable. It has been established that a major increase in light is obtained if a large fraction of the light from the bombarded side of the screen is reflected through the screen. The lighter elements such as aluminum or beryllium make a suitable reflecting film on the back of a phosphor screen. Aluminum is used almost exclusively because it is more easily adaptable for screen application.

1.2.4 Envelope Coating

Practically all CRT's are coated on the inside of the glass envelope or bulb with a conductive coating. The coating generally used is a trade-named preparation of graphite. The main function of this coating is to attract any secondary electrons emitted by the fluorescent screen. (Different methods of application may be used to achieve specific characteristics, as in the Display System CRT's.) If electrons were allowed to pile up on the screen, it would soon acquire a large negative voltage which would interfere with the normal operation of the CRT. However, when the beam strikes the screen, some of the energy is used to knock off electrons. Such electrons are known as secondary electrons and may be considered to have been emitted from the fluorescent screen. If the number of secondary electrons equals the number that originally strikes the screen, there will be no change in the screen voltage. The tube will thus continue to operate properly.

Another use of graphite coating is to provide shielding for the electron beam. In some CRT's there is no metallic accelerating anode; the dag coating is electrically connected to perform this function in addition to those previously explained.

CHAPTER 2
19-INCH SD CRT's

2.1 GENERAL

The SD CRT is a character-display type of CRT that was specifically designed to display characters in an SD message format. The message so presented is a function of analog voltages since the information represented on the discrete proportionment of the CRT is fundamentally that of an analog device.

The tube primarily contains an electron gun, character selection plates, matrix, convergence coil, character position and compensation plates, and a deflection coil. With the exception of the convergence and deflection coils, the elements are contained within the evacuated tube.

Figure 2–4 shows two distinct structural sizes of SD CRT's. The larger (19-inch) CRT is made in two types for the Display System. One type is installed in the SD console; the other is in the SD camera console. A still picture camera is mounted above the tube in the SD camera console, as illustrated in figure 2–5. Both these tubes are identical physically and electrically; the sole difference is in the screen phosphors. For the SD camera application, the phosphor is of the P11 type; so is the other CRT used for recording purposes, the 7-inch SD CRT. Figure 2–6 is a schematic representation of the 19-inch SD CRT symbol.

In the SD CRT tubes, the electron gun shoots a stream of electrons toward the screen. But this stream is intercepted by various elements that control, direct, and shape the beam to impinge a particular character and/or vector on a desired section of the screen. With the aid of the schematicized view shown in figure 2–6, the path of a hypothetical electron can be followed.

The electron stream from the gun is deflected both vertically and horizontally to direct the beam to the selected character in the matrix. The matrix (fig. 2–7), in the form of a supported metal disk, has 63 characters cut through the metal; the remaining area in the 8 x 8 row format is left untouched as a beam inhibitor for blank space representation. The electron flow directed to the selected character in the disk is formed or extruded through the character matrix in the shape of the character selected. Figure 2–8 is a greatly enlarged section of the character matrix. This extruded or stenciled beam of electrons now is headed toward the character position and compensation plates, but its path is affected by the magnetic field of the convergence coil.

2.1.1 Convergence Coil

The convergence coil is a 3-coil assembly externally mounted around the gun envelope. The entire assembly contains a deflection trim coil, the convergence coil proper, and a selection trim coil.

The effect of the convergence coil assembly on the electron beam is to simultaneously spiral the stenciled beam on its own axis and on the zero axis so that it is displaced by a rotational deflection through 90 degrees. Figure 2–9 shows the effect of the convergence coil on the character-formed electron beam.

2.1.2 Trim Coils

Current through the windings of the selection trim coil sets up a magnetic field which opposes the field of the convergence coil in the area of the selection plates. This neutralizes the convergence coil effect on the selection plates and, with the deflection trim coil, effectively isolates the convergence coil field from affecting the character selection, and character positioning and compensation plates. Similarly, the deflection trim coil individually neutralizes the field effect on the deflection plates and, with the selection trim coil, isolates the other elements from the convergence field effect.

2.1.3 Character Position and Compensation Plates

The beam now reaches the character positioning and compensation plates where the plates compensate for the original deflection imparted to the electron beam and simultaneously reorient the beam by deflection, to position the character properly in the message.

2.1.4 Deflection Coil

The electron beam, now a properly positioned character in a message format, is impinged on the selected portion of the screen by the deflection coil. The deflection coil field determines the area of the viewing screen in which the message is to be displayed. The deflection currents energizing the coil are held constant until all the characters in a message have been displayed.

2.1.5 Viewing Screen and Message Format

The electron beam, in striking the solid materials of the phosphors, causes the latter to become luminous in the characteristic shape of the beam. A message similar to the typical display shown in figure 4–1 can appear on the viewing side of the CRT face plate. The details of the formation of such a display is given in Part 4.

The character matrix, of which a single character has been illustrated as an example, has a total of 64 possible selections in a pattern of eight columns and eight rows. (One space in the pattern is left intact to permit empty space-blank presentation in a message format.) These characters are the elements of messages that can be displayed on the face of the SD CRT. Figure 2–8 shows the arrangement of the characters in the matrix. The binary addresses along the vertical and horizontal columns are references that are used and explained fully in Part 4. The selection of a column and row is initiated by three binary digits (3 bits) in each axis. The intersection of the selected column and row is the selected character.

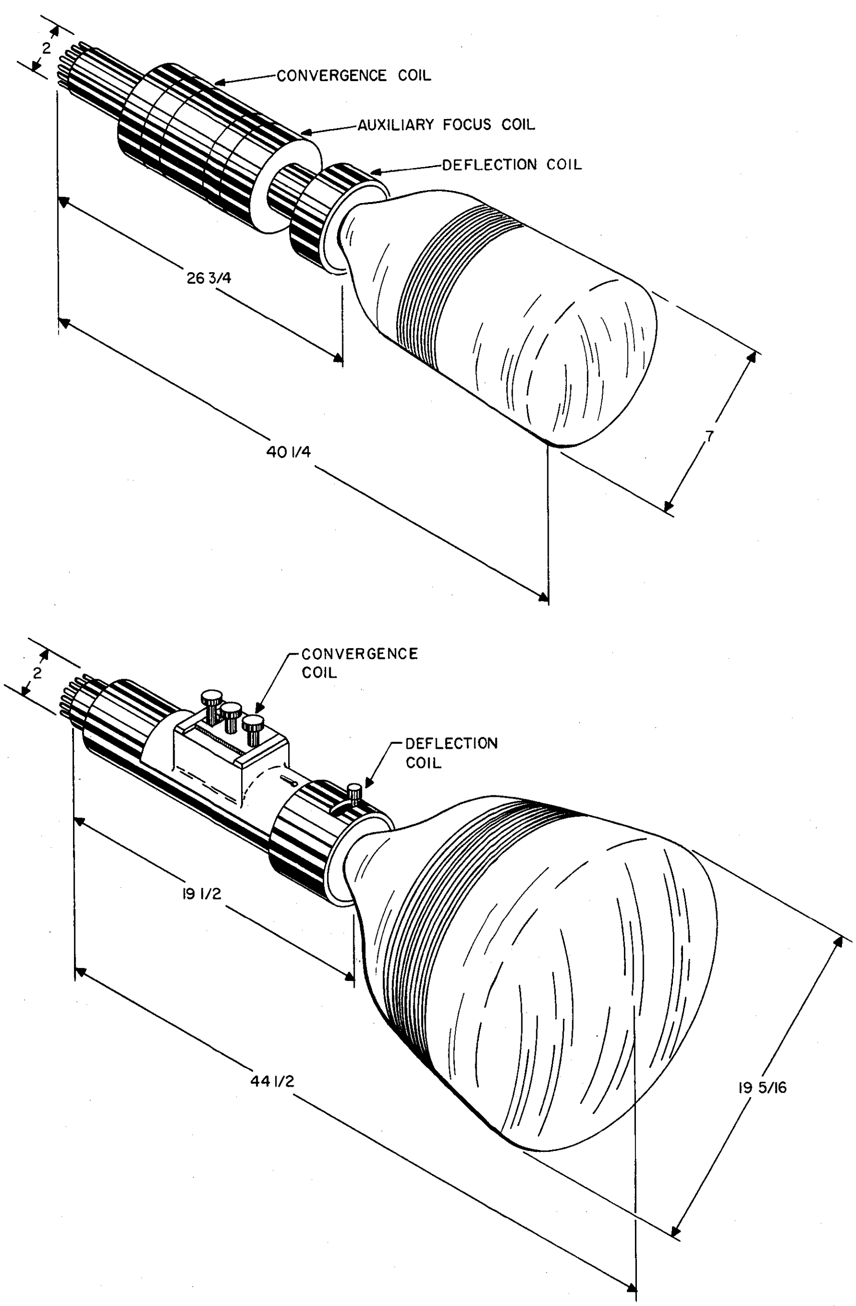


Figure 2–4. SD CRT Dimensions

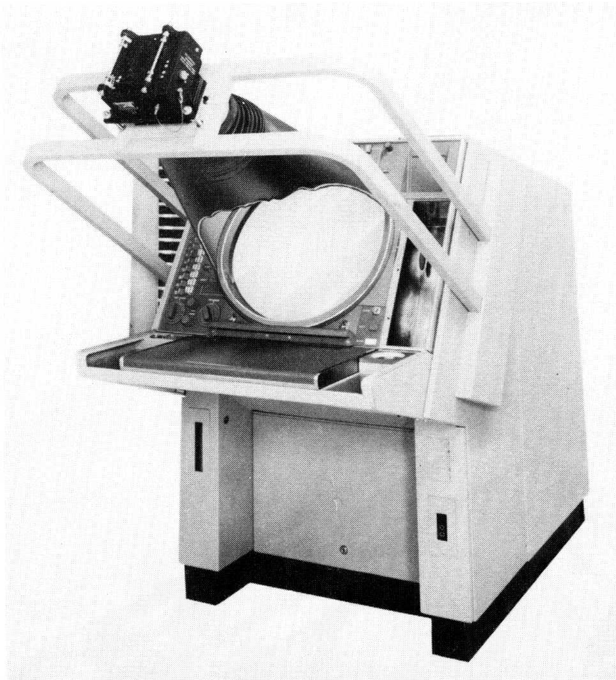


Figure 2–5. 19-Inch SD CRT Employed with Still Picture Camera

2.1.6 Post-Acceleration Coating

The unconventional shape of the SD CRT, for a round-face tube, is due to its unusual requirements. The need to display characters over the entire area of a 19-inch screen, and the necessary high intensity of illumination for their display, made this shape optically desirable. In order to realize the required amount of illumination, it was necessary to increase the energy of the beam. Because of the optical properties of the tube, beam energy had to be obtained by post acceleration. This post-acceleration potential is developed across the helical accelerator (often referred to as a dag coating). The helical accelerator is located in the portion of the envelope between the deflection coil and the screen. The accelerator is a continuous spiral of electrically resistive material, ruled on the inner surface of the bell portion of the envelope extending to nearly 7 inches. The conductive coating bands of the helix are about 0.050 inch in width, spaced 10 turns to the inch. The total length of the helix is approximately 375 feet; it has a total resistance of about 100 megohms.

This type of accelerator has several advantages over types consisting of one or more bands of material, particularly, less distortion of the character-shaped beam.

2.2 SD CRT FUNCTIONAL OPERATION

The display, which appears on the face plate of the SD CRT in the form of a message, may consist of characters and/or vectors. The character is electron-beam-shaped when the beam is intercepted in its path by the selected character cutout in the matrix. The vector, however, is formed by the electron having been first brought to a pinpoint focus and then directed through a non-restricting aperture in the matrix. The beam is then swept in a given direction for a given distance to produce the desired vector display. The type of presentation, as a display, can then be considered to be dependent upon the control and operation of the CRT elements.

Table 2–1 is a list of the controls and functions given each element to produce either a character or a vector in the display. This table, in the form of a summary, is given in greater detail in Part 4. The function of each element for a particular display is also given in detail in Part 4.

In making use of this table, and the subsequent text, it is assumed that the reader is familiar with the special circuits (see Special Circuits Manual, 3-3-0) that

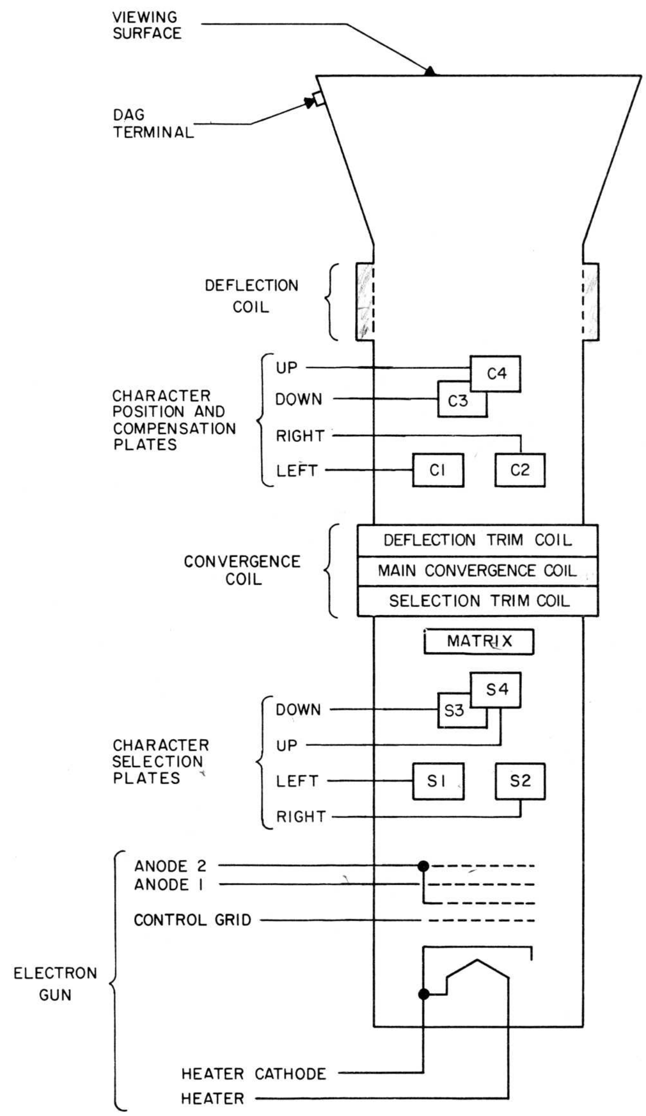


Figure 2–6. 19-inch SD CRT Symbol

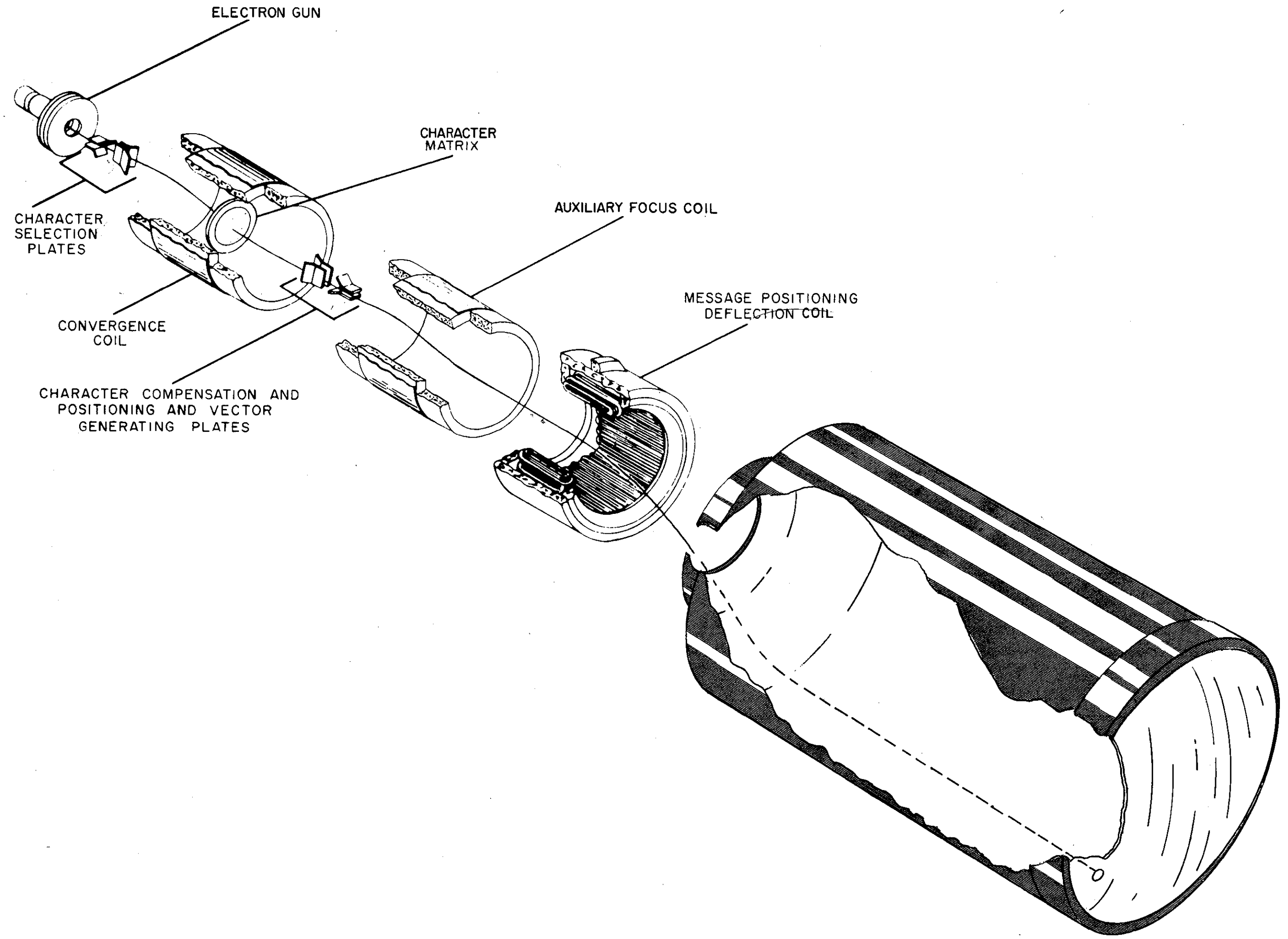


Figure 2–7. 7-Inch SD CRT, Cutaway View

power and control the Display System and therefore the CRT's.

Under functional requirement No. 2, the focus function ensures uniform passage of the electron beam through the matrix and a resultant pinpoint-dot image on the viewing screen of the SD CRT. The defocus function ensures complete inclusion of a selected character within the cross-sectional area of the electron beam. The differences in functional requirement No. 5 are in degree. For character display, the beam can be aimed at any one of 64 positions on the matrix-disk: 63 individual characters or the blank portion of the matrix. For vector display, the beam is directed at one symbol of the matrix. Figure 2–8 shows an illustration of the character-forming matrix with binary addresses. Projecting the X-axis binary address of 111 and the Y-axis binary address of 111, the intersection will be seen as a square cutout in the matrix. Requirement No. 6 is allied to No. 2. If a defocused beam (as it would be for a character) were directed at the vector aperture, the beam would be extruded through in the characteristic form of a square. The image on the screen would there-

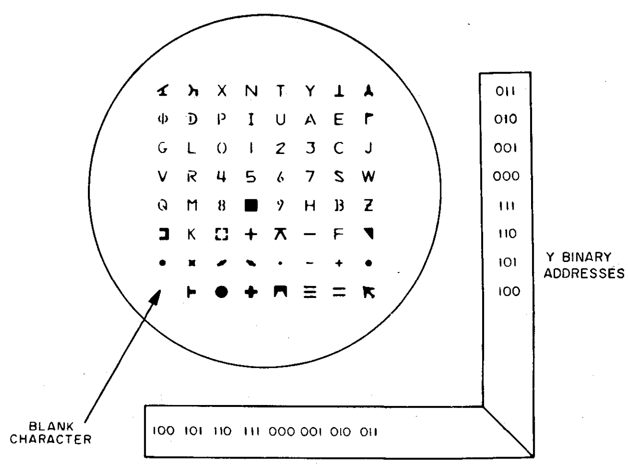


Figure 2–8. SD Matrix Array With Binary Addresses

fore be an enlarged filled-in square. The pinpoint-focused beam, because of its much smaller relative area, passes through the same aperture unchanged and is impinged on the screen as an electron spot. In that instant, function No. 10 takes over, and the spot is swept into a line for a given direction and distance by the application of a sweep voltage. It is these two elements that determine the generation of either a character or a vector.

2.2.1 Character Display, Detailed Operation

The following text, which parallels the introduction to the basic operation of the CRT's, contains a detailed discussion of the generated electron beam and how it is affected on its way to the screen. Individual functional requirements and associated tube elements are dealt with in the sequence established in table 2–1.

2.2.1.1 Electron Beam Generation

The electron beam is generated by the electron gun element in the SD CRT. Figure 2–10 is a simplified schematic drawing of the electron gun and its relative location within the envelope of the SD CRT. Fig. 2–11 is a block diagram of the control and supply voltages required to generate the electron beam. The detailed discussion of Display System CRT operation is keyed to the referenced illustrations and text and should be consulted for ready analysis.

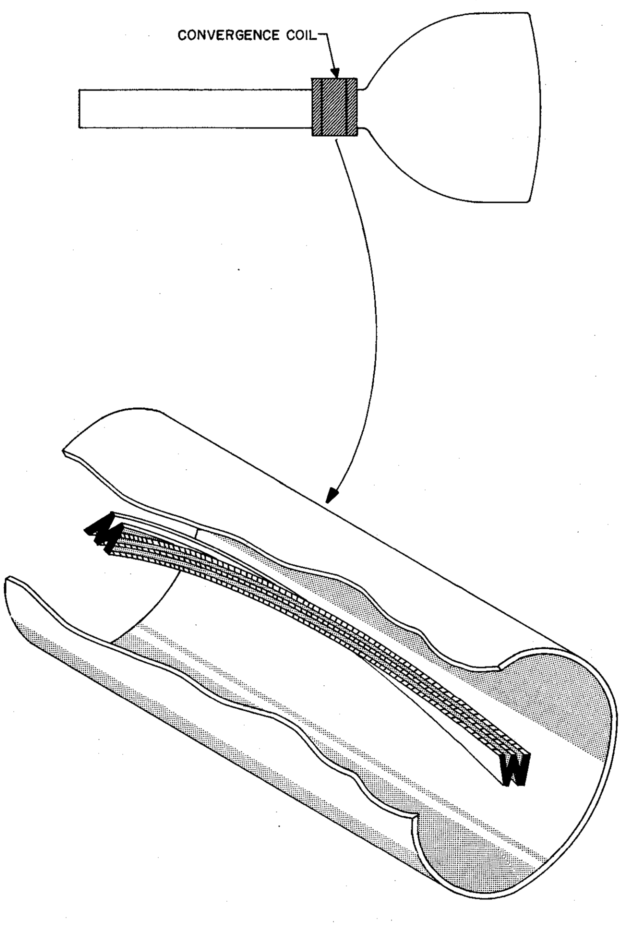


Figure 2–9. Convergent and Rotational Effect of Convergence Coil on Electron Beam

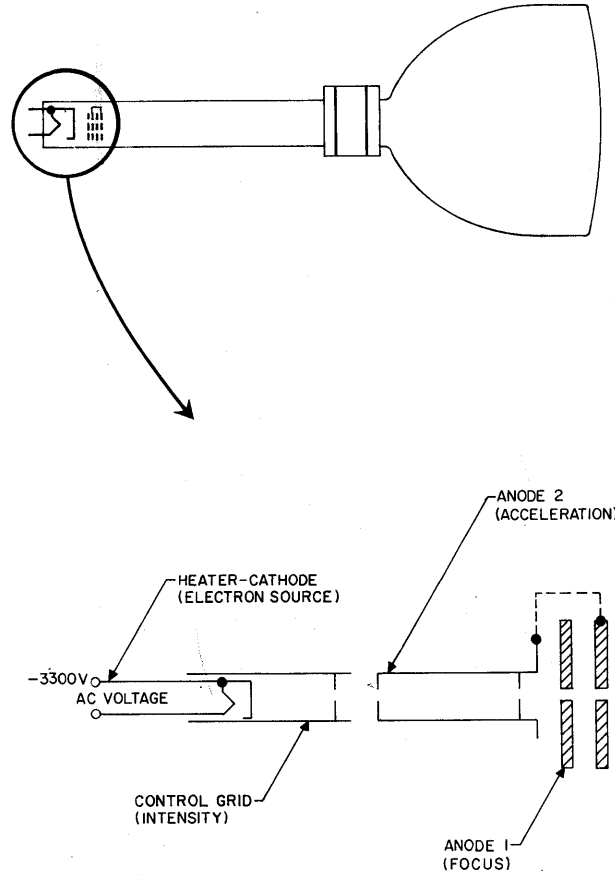


Figure 2–10. Electron Gun, Elements and Control Functions

The potentials applied to the elements of the electron gun determine the characteristics (blanked and unblanked, intensity, and cross-sectional area) of the electron beam. The SD CRT is blanked (electrons cannot pass through control grid aperture) by the fixed bias on the control grid. An intensity gate applied to the control grid unblanks the SD CRT. The magnitude of the gate controls the image intensity (the quantity of electrons passing through the aperture to the tube). The electrostatic field between the control grid and anode 2 is a fixed electron lens which focuses the electron beam on the aperture in anode 2. This anode and the accelerating potential applied to it produce a concentrated beam of high-velocity electrons coincident with the longitudinal axis of the tube. At this point, unimpeded progress of the beam would result in a circular image greater in cross-sectional area than the area originally at anode 2. To overcome this projecting increase in area, anode 1 (focusing anode) is physically located adjacent to anode 2. The electrostatic field between anode 1 and the two elements of anode 2 form a second electron lens which will overcome the dispersive effect of mutual repulsion between the electrons. A fixed-focus potential applied to anode 1 is adjustable and is set to produce a pinpoint image on the viewing screen of the SD CRT.

A defocus gate applied to anode 1 superimposes a positive voltage level on the fixed focus potential. This changes the focal effect of the electron lens to broaden the beam (increase its cross-sectional area).

The heater voltage is supplied from a transformer winding of the high-voltage unit, model A (AHVU). The cathode voltage is fixed at —3,300V, obtained from the high-voltage power supply, model C (CHVP). The cathode voltage return is tied to one side of the filament.

The control grid is biased by a voltage obtained from AHVU. This voltage is adjustable between fixed potentials (—3,450 and —3,300V by an intensity control in AHVU.) The bias on the control grid is sufficient to cut off the flow of electrons to the screen (blanked). The variable gate amplifier, model A (AVGA), output is fed to the control grid through AHVU and is the source of intensity gates (unblanking). The intensity gate signal will overcome the cutoff bias on the control grid and cause it to conduct electrons, illuminating the screen and therefore unblanking it. Anode 2 is maintained at +45V by AHVU. The voltage differential between the cathode and anode 2 (3,345V) is the accelerating potential for the electrons emitted by the cathode. The potential on anode 1 is adjusted to a fixed voltage (between —2,700 and —2,300V) by the setting of a focus control in AHVU. The resultant electrostatic field set up between anodes 1 and 2 determines the cross-sectional area of the electron beam. A defocus gate, supplied by the variable gate amplifier, model B (BVGA), is fed to anode 1 through AHVU. This defocus gate is used to vary the cross-sectional area of the electron beam.

The potentials applied to the elements of the electron gun determine the characteristics (blanked and unblanked, intensity, and cross-sectional area) of the electron beam.

2.2.1.2 Character Selection

The character selection plates of the SD CRT, in association with the matrix, select a specific character for display. The following theory of character selection operation explains the method of deflection and the origin of deflection voltage. Figure 2—12 is a simplified drawing of the character selection plates. The insert drawing shows the approximate location of the plates within the envelope of the SD CRT. Figure 2—13 is a block diagram of the circuits located in the SDGE and the model A high-voltage unit, which are associated with the SD CRT.

A significant feature should be noted before proceeding. In figure 2—13, the horizontal selection decoder feeds the vertical character selection plates. This would appear to be an obvious error, but the effect of the convergence coil (refer to 2.1.1) on the path of the electron beam makes this necessary. The electron beam rotates 90 degrees in passing through the convergence coil area of the magnetic field. To compensate for this effect, the matrix is reoriented 90 degrees in the counter direction. The 90-degree rotation has the effect of interchanging the X and Y axis. For this reason, X-axis selection voltages must be applied to the vertical selection

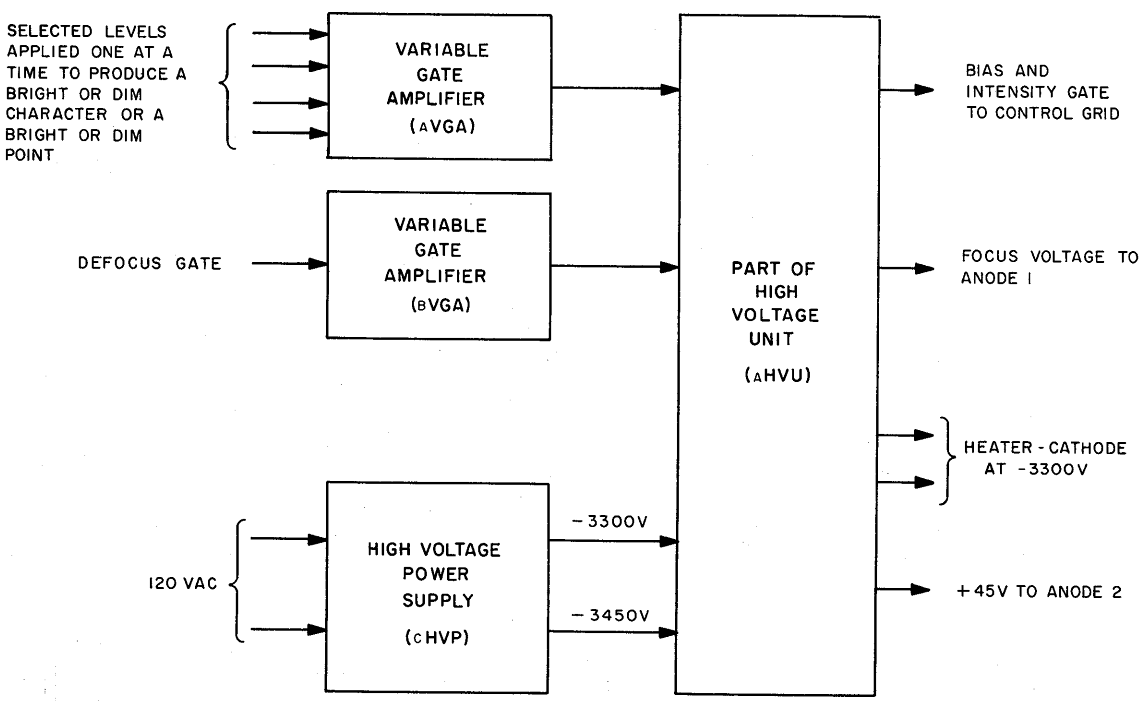


Figure 2—11. Electron Gun, Control and Supply Voltages, Block Diagram

TABLE 2–1. SD CRT FUNCTIONAL REQUIREMENTS AND ASSOCIATED TUBE ELEMENTS

	FUNCTIONAL REQUIREMENTS		
NUMBER	CHARACTER DISPLAY	VECTOR DISPLAY	SD CRT ELEMENT
1.	Generate an electron beam.	Generate an electron beam.	Electron gun
2.	Defocus the beam.	Focus the beam.	Anode 1
3.	Intensify (bright or dim) the beam.	Intensify (bright or dim) the beam.	Control grid
4.	Accelerate the beam.	Accelerate the beam.	Anode 2
5.	Aim the beam at a character.	Aim the beam through the vector aperture.	Character selection plates
6.	Form the beam in the shape of the character.	Pass focused beam unchanged.	Matrix
7.	Spiral the beam through 90 (450) degrees and make it intersect the longitudinal axis of the SD CRT.	Spiral the beam through 90 (450) degrees and make it intersect the longitudinal axis of the SD CRT.	Convergence coil
8.	Cancel deflection applied in No. 5, above.	Cancel deflection applied in No. 5, above.	–
9.	Position character-formed beam in the required location in the message format.	Position the pinpoint-focused beam in the required location in the message format.	One set of character compensation, character position, and vector generation plates
10.	–	Sweep the beam in a given direction through a given distance.	–
11.	Position the message on the face of the SD CRT.	Position the message on the face of the SD CRT.	Deflection yoke

plates. Similarly, the Y-axis selection voltages must be applied to the horizontal selection plates.

The character selection plates generate electrostatic-deflecting fields as a function of analog voltages. An electron beam passing through such a field is deflected in the direction of the more positive plate. The beam deflection is proportional to the voltage differential applied to the plates (forward velocity is assumed constant). Figure 2–12 shows the path of an electron beam under three different conditions. Path A depicts an undeflected electron beam. The voltages on plates U and D are equal and the voltages on plates L and R are equal. Path B represents an electron beam deflected in the vertical position only. To produce this result, deflection plate U is positive with respect to plate D. Plates L and R still have an equal potential. Path C represents an electron beam deflected both vertically and horizontally. To achieve this effect, plates U and L are each more positive than plates D and R, respectively. By the application of appropriate voltages to the deflection plates, the electron beam is accurately directed to any selected point on the reference plane or, as is physically the case, the character matrix.

The character selection voltages are generated in the SDGE (fig. 2–13). Binary input levels are applied to two 3-bit decoders, one decoder for each axis (X-Y) of deflection. The two decoders are packaged as a single unit and designated as the 6-bit binary decoder. There are eight combinations of binary levels for each axis. As a result of these inputs, the binary decoder produces an analog voltage output at one of eight possible corresponding levels. Each level corresponds to a row (X-axis) or column (Y-axis) in the character matrix. These analog levels are fed to the analog driver which drives the corresponding selection-centering and amplitude-control circuits. The control circuits are tied to their respective character-selection plates as indicated in figure 2–13.

2.2.1.3 Electron Beam Shaping

As described in the introduction (par. 1.1 of this part), the electron beam is formed and shaped as an extrusion or stenciling of the particular character cutout in the matrix (fig. 2–14). There are 63 such characters in an equidistant format of eight columns and eight rows. There is a blank space for the missing 64th character to permit space-blank presentation in a message format. The size of the characters in the matrix is about 1/10 the size of that area presented on the screen by the projected numbers, letters, or symbols which are the characters in a typical display message.

Besides the character representation, another important factor in the formation of the beam is its cross-sectional area. The area of the beam must be greater than the cutout area in the matrix for full character extrusion.

For vector generation or point selection, the beam is first reduced to a focused point for unimpeded progress through the vector aperture in the matrix. Figure 2–15 illustrates the relative area requirements for the electron beam.

2.2.1.4 Electron Beam Convergence

The character selection plates divert the electron beam from its axial path in the SD CRT. To overcome this effect, the beam must be converged to nearly its original shape and course for further control. The convergence coil is used to counteract the effect of the

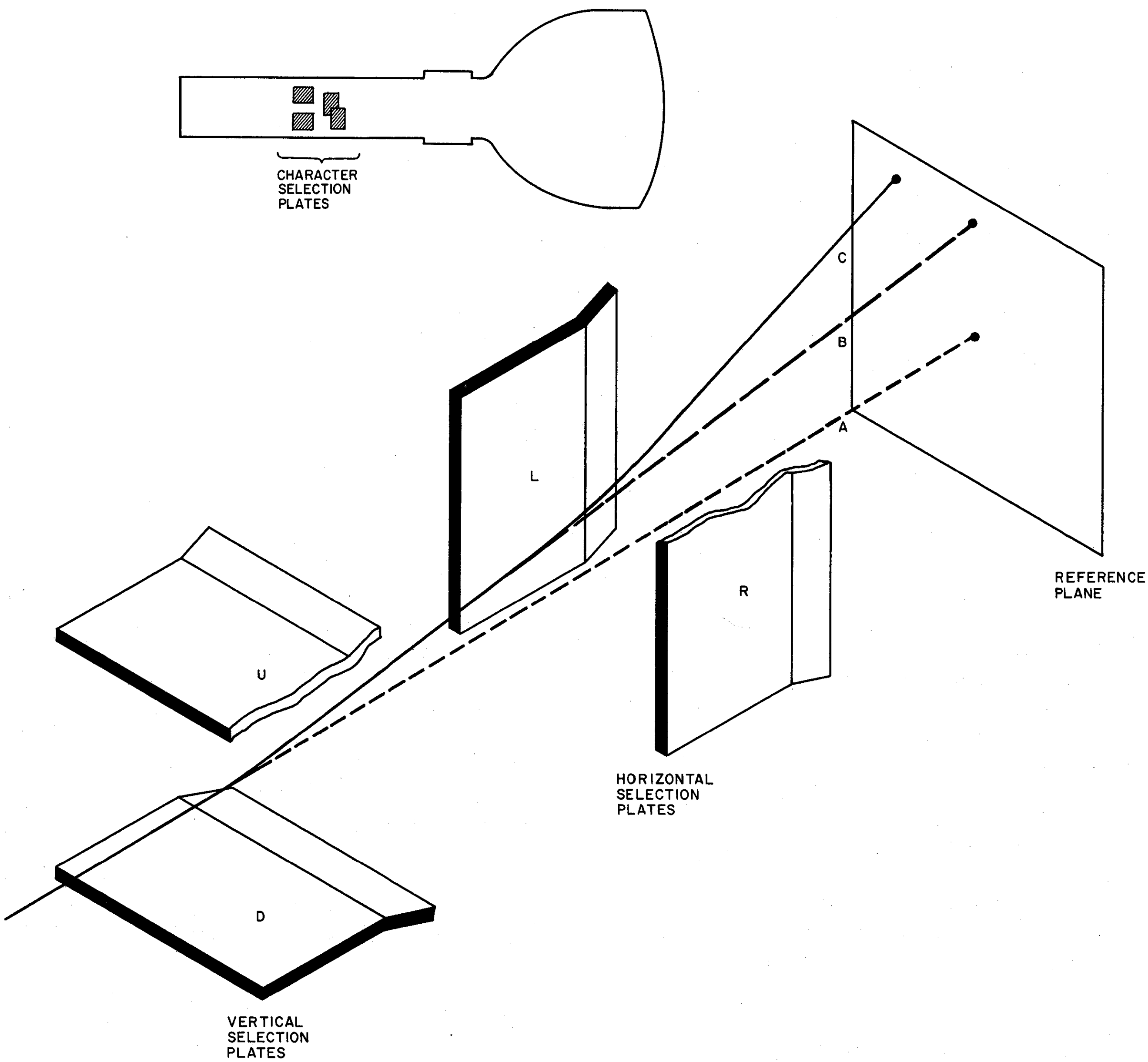


Figure 2–12. Character Selection Plates, Effect on Electron Beam

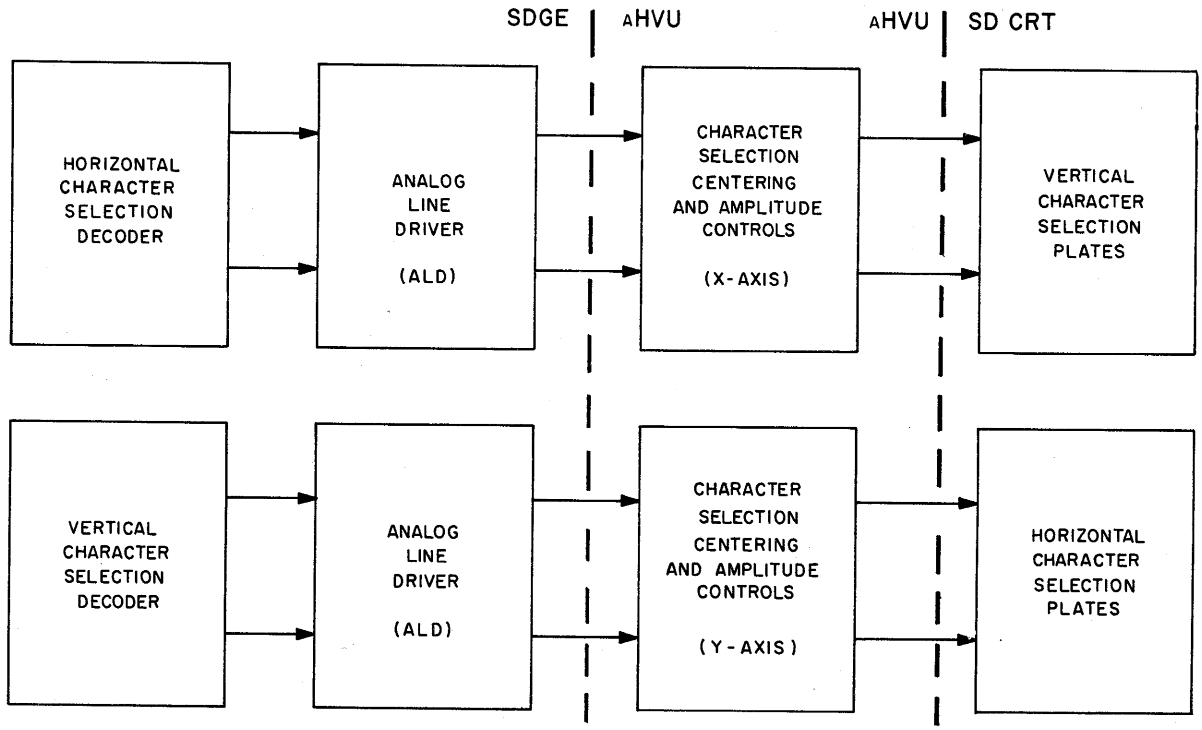


Figure 2—13. Character Selection Control Circuits, Block Diagram

character-selection plates on the beam. The deflection imparted to the beam by the selection plates is designed to intersect the matrix at the selected character. In figure 2—16, where this intersection is illustrated, the focusing effect of the convergence coil's magnetic field can be followed, from left to right.

As seen in figure 2—16, if the four electron beam paths are extended in a straight line from the point of emergence from the deflection plates to each of the four selected characters, the individual beam paths are obviously divergent. Before any one of the beams (the four beams represent four typical characters) can be further controlled, the beam must be returned to the same focal point on the longitudinal axis. This is effected by generating a uniform magnetic field whose lines of flux are parallel to the axis of convergence. This magnetic field is created by the SD CRT convergence coil.

Figure 2—17 shows the convergence effect of the magnetic field caused by the convergence coil. The heavy lines, running from left to right, represent the beam paths of four different respective characters. Each is initially deflected to a different point through the character matrix. The individual beams continue in straight lines to the convergence coil area, where each enters the magnetic field at a different angle. The convergence force of the field on the electron beam is proportional to the angle of deflection. Consequently, the outer beams are subjected to a greater bending force than the inner beams, with the result that all deflected beams ultimately intersect at one focal point on the longitudinal axis. In addition to the convergent effect of the magnetic field, a rotational or spiraling force is exerted on the electron beam.

The sum of the forces exerted on the electrons in the beam produces a resultant which imparts a sideward and inward (convergent) force on a beam. Figure 2—9 shows the combined effects of these forces on an electron beam stenciled by the character W. The angle formed by the electron beam and the longitudinal axis of the SD CRT (after the beam leaves the mag-

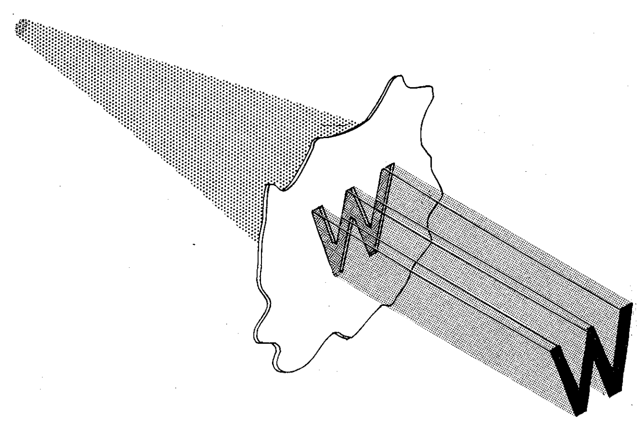


Figure 2—14. Character-Matrix Effect on Electron Beam

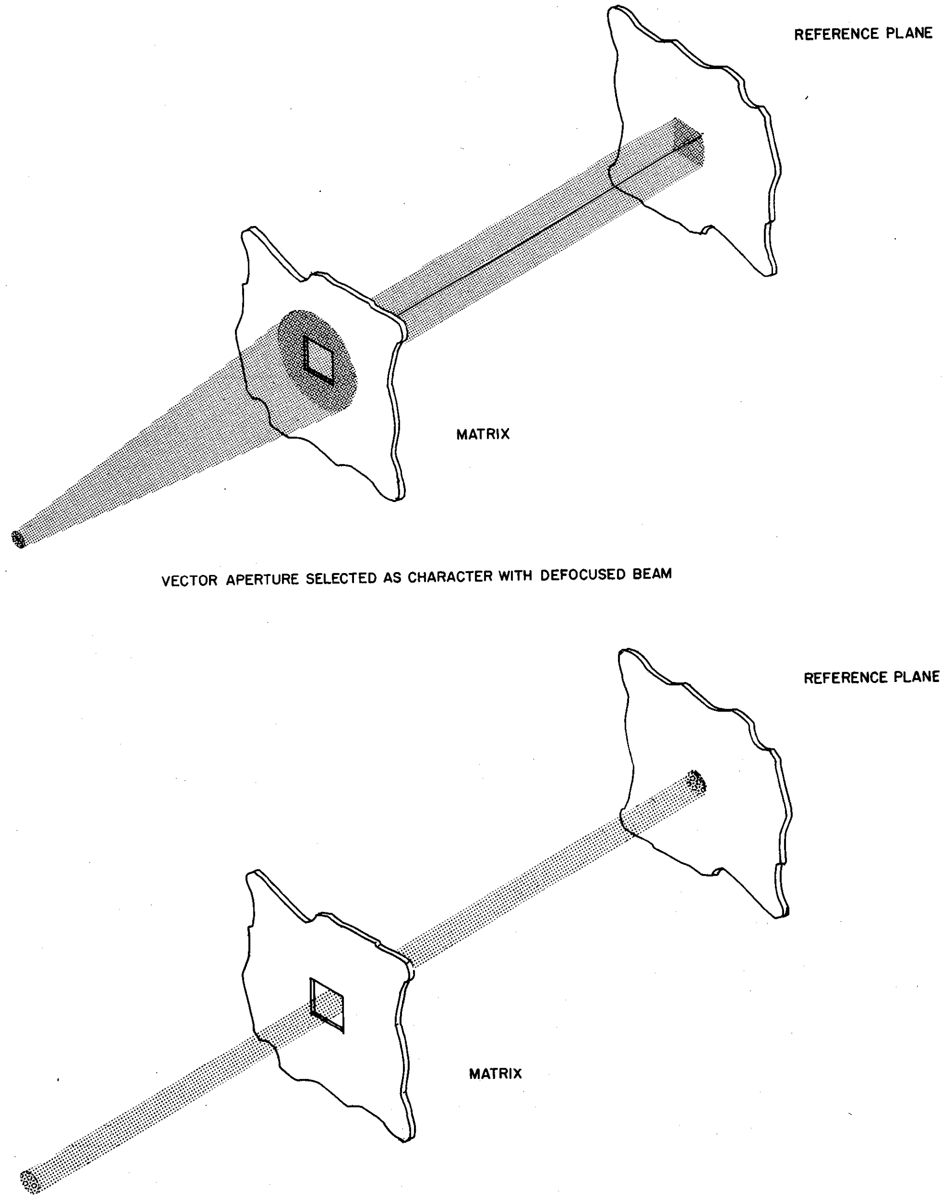


Figure 2–15. Relative Area of Defocused and Focused Beam through Square Aperture

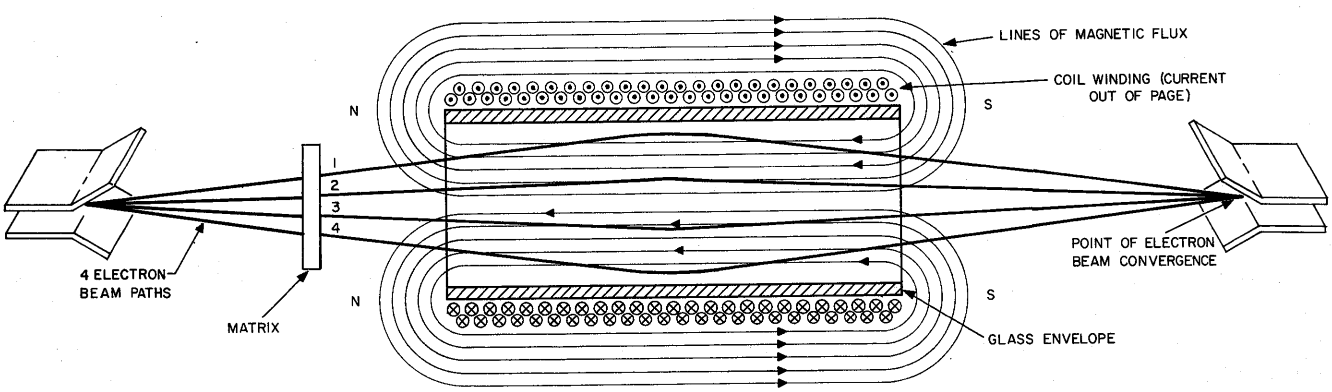


Figure 2–16. Focusing Effect of Convergence Coil Magnetic Field

netic field) is identical with the angle of deflection imparted by the character selection plates.

The circuits which control the extent of rotation and ensure a constant point of convergence of the electron beams are shown in block form in figure 2–18. This point of convergence and the degree of rotation are a function of magnetic field strength and electron beam velocity. Convergence coil current determines magnetic field strength; accelerating potential determines beam velocity. If either varies, the point of convergence and degree of rotation will vary, producing misalignment and tilting of characters in a message display. The model A convergence current regulator (ACCR) controls convergence coil current to prevent any variation.

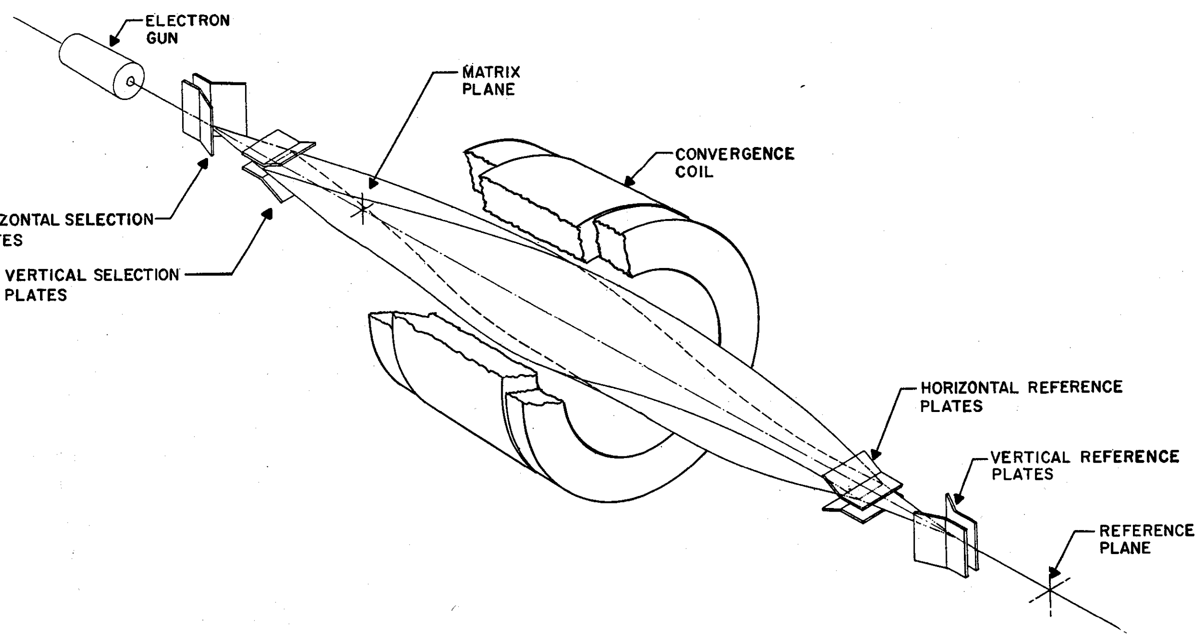


Figure 2–17. Effect of Convergence Coil in Returning All Beams to Reference Plane Axis

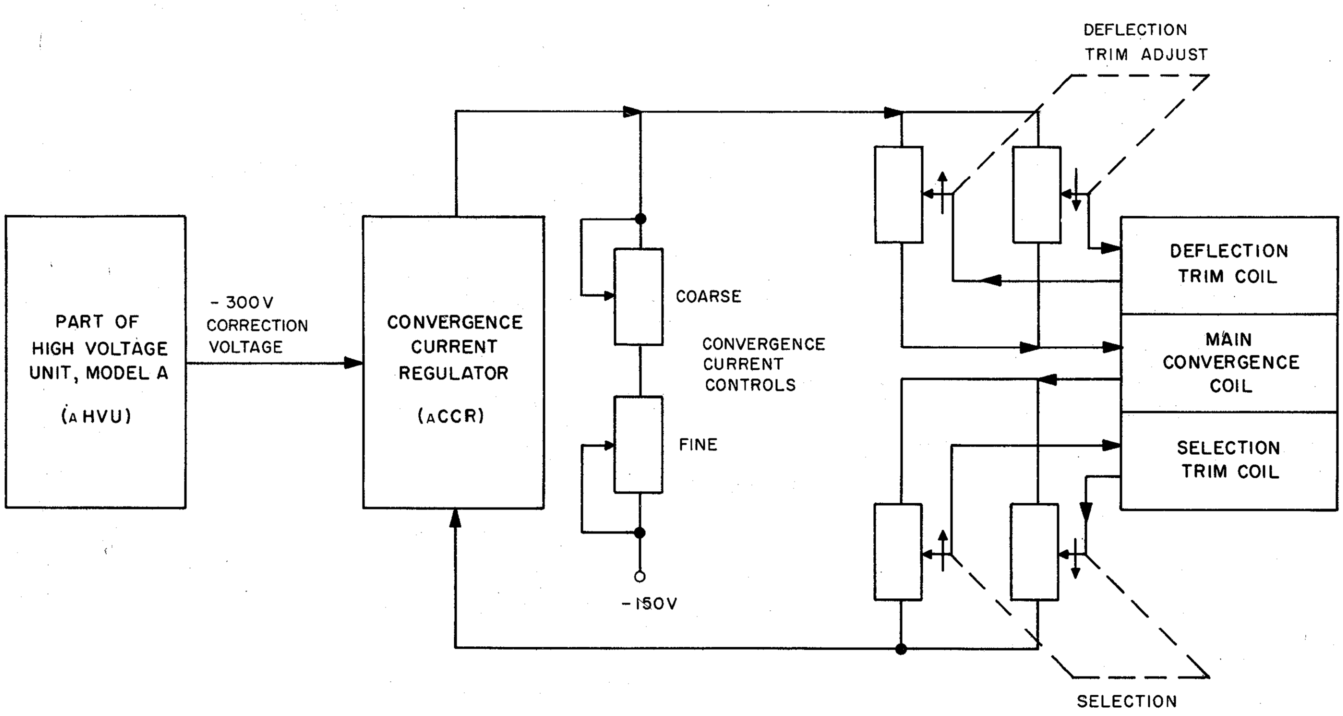


Figure 2–18. Convergence Coil Assembly and Associated Circuits, Block Diagram

The model A high-voltage unit provides a correction voltage which varies about a nominal voltage of —300V. This variation is proportional to accelerating voltage variations. The ACCR output current is a function of this correction voltage variation and compensates for electron beam velocity variations. Thus, if the beam speeds up, the magnetic field is strengthened. If the electron beam slows down, the magnetic field is weakened. Nominal magnetic field strength is set by means of the convergence current controls. These controls have the greatest influence on beam rotation and point of convergence. Final adjustments are made with the selection and deflection trim adjustments.

The selection trim coil serves two functions. It isolates the selection plates from the convergence coil magnetic field and permits precise adjustment of rotation within a range of approximately 4 degrees. The deflection trim coil also serves a dual purpose. It enables precise control of the point of convergence within the area of compensation and positioning plates, and isolates the convergence coil magnetic field from these plates.

2.2.1.5 Character Compensation and Positioning

After leaving the convergence coil area, the electron beam passes between the compensation and positioning deflection plates. The method of deflection is the same as that discussed in paragraph 2.2.1.2. Figure 2—19 shows the approximate location of the character compensation and positioning plates within the tube envelope.

The circuits providing the control voltages to the deflection plates are shown in block form in figure 2—20. Binary position and compensation-determining levels are converted into analog voltages by the respective decoder in the SDGE. The analog voltages are fed through the model A high-voltage unit AHVU to the deflection plates of the SD CRT by the respective analog line drivers (ALD). The compensation voltages are the character selection voltages with reversed polarity, which nullify the character selection deflection and make the electron beam coincident with the longitudinal axis of the SD CRT. Applied simultaneously, the positioning voltages impart a new deflection to the electron beam which positions the selected character in the required location within a message format. In effect, the compensation and position plates straighten out the beam and reposition it. The vector-generation function of these plates is discussed in paragraph 2.2.2.

2.2.1.6 Message Deflection

Each message unit, consisting of a vector and/or character, is deflected to a particular location on the viewing screen of the SD CRT by the deflection coil. Figure 2—21 shows the coil with one pair of deflection windings. The inset drawing shows the approximate location of the coil around the neck of the tube envelope. The coil is wound on a square form. There are two windings. The black winding on the top and bottom sides of the coil is a continuity between the power supply and the deflection driver (DEF); similarly, the white winding is continuous to the control circuits.

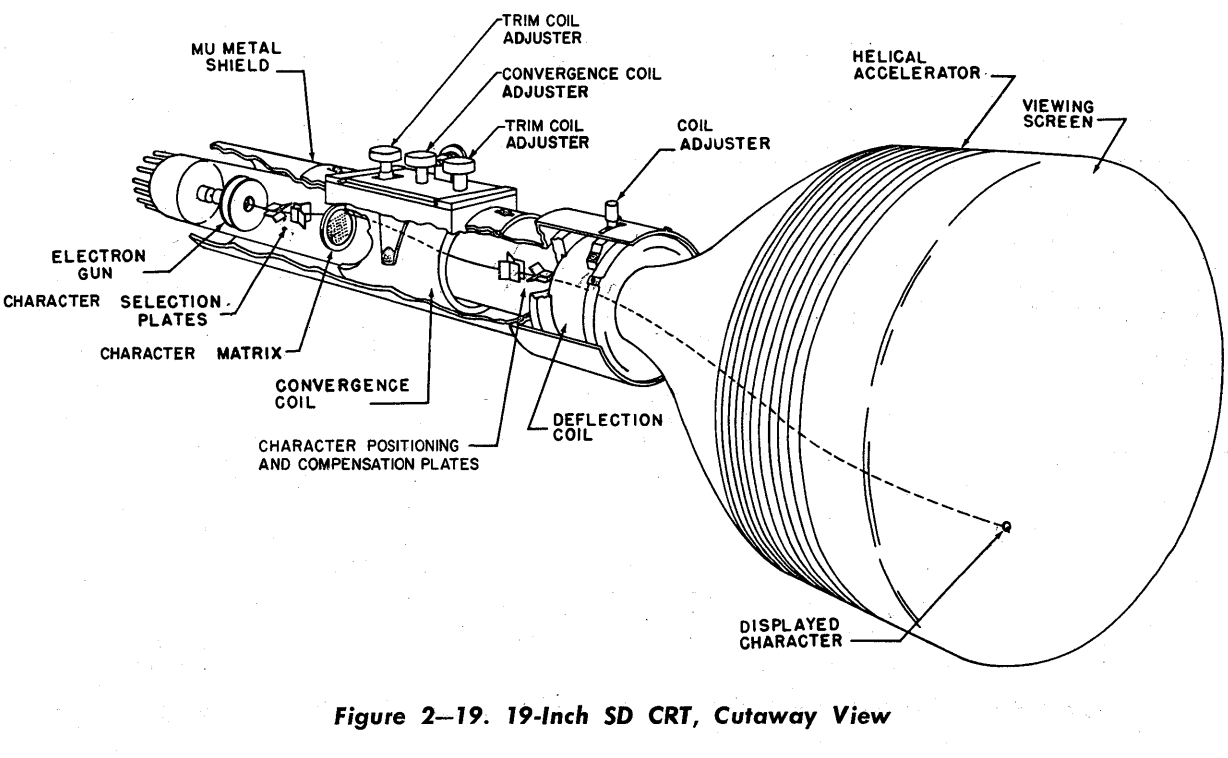


Figure 2—19. 19-Inch SD CRT, Cutaway View

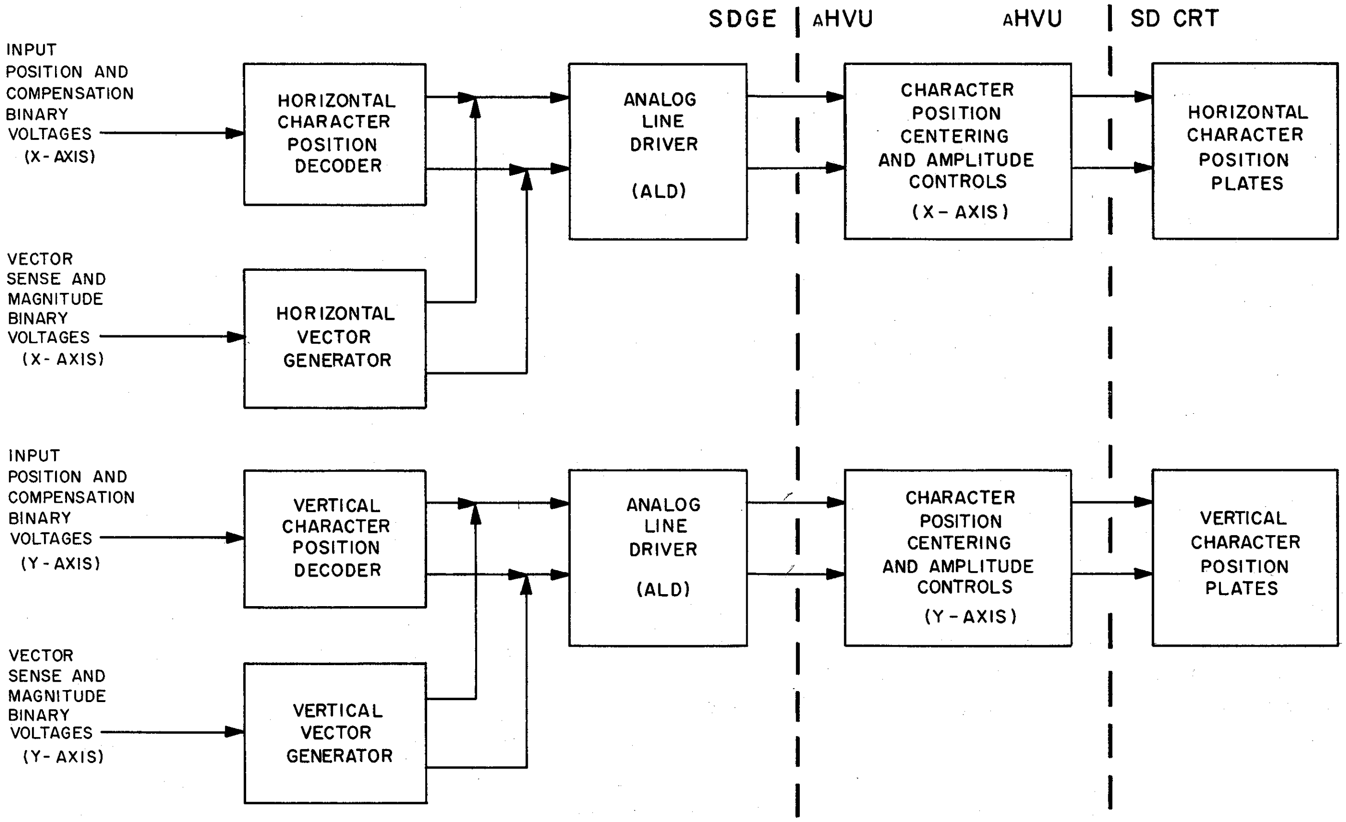


Figure 2—20. Character Position, Compensation, and Vector Generation Control Circuits, Block Diagram

Electron flow through the black winding generates a magnetic field of opposing polarity to that generated by the white winding. The vertical sides of the coil (not shown in figure) have the same type of windings. This results in a magnetic field of variable strength and reversible polarity that can be generated along each axis (horizontal and vertical) with the neck of the SD CRT. The magnetic field strength is a function of the magnitude of the electron flow. The polarity of the field is determined by the winding which carries the greater electron flow.

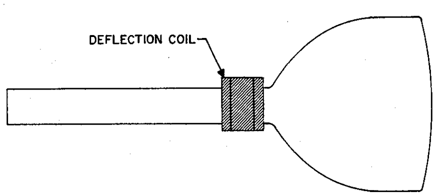
Figure 2—22 illustrates the field-generating properties of the windings on one vertical side of the coil. The discussion concerning these windings applies equally to the windings on each of the other three sides of the coil. Solid and dashed lines are used to distinguish between the two windings and their respective fields. As shown, electronic flow in the solid-line winding (I_2) is in a counterclockwise direction and produces a north pole at the top of both vertical coil members. Electron flow (I_1) in the dashed-line winding is in a clockwise direction and produces a north pole at the bottom of both vertical coil members. With I_2 greater than I_1, the solid-line magnetic field is the stronger. An electron beam directed into the page is deflected to the right. With I_1 greater than I_2, the dashed-line magnetic field is stronger, and an electron beam directed into the page is deflected to the left. With I_1 equal to I_2, the magnetic fields are completely neutralized, and the beam is not deflected. Thus, horizontal deflection is a function of the electron flow in the vertical coil windings. Similarly, vertical deflection is a function of the electron flow in the horizontal coil windings. The electron flow in the vertical windings is controlled by two tubes operating in push-pull. An increase in I_1 occurs simultaneously with a like decrease in I_2.

Figure 2—23 is a block diagram of the circuits which are utilized in message-positioning. The 10-bit binary decoder produces an analog voltage as a function of 10 binary levels. There is one decoder for each deflection axis. The decoder outputs are applied to the respective deflection amplifier and driver together with a reference level from the decoder simulator. The deflection drivers and amplifiers maintain a linear relationship between this analog voltage input and the currents supplied to the windings in the deflection coil. Thus, a direct relationship between digital-positioning information and message-deflecting currents is established to permit precise positioning (within 1/1024 increment of total deflection along either axis) of a message on the viewing screen of the SD CRT.

2.2.1.7 Character Display Summary

An intensity gate and a defocus gate applied to the appropriate elements in the electron gun provide an electron beam of a large cross-sectional area. The beam is accelerated toward the character selection plates. Analog voltages applied to these plates deflect the electron beam to a character on the character matrix. The electron beam, in passing through the matrix, is extruded into the shape representing the character and enters the magnetic field of the convergence coil. The magnetic field converges the beam to intersect the longitudinal axis of the SD CRT in the area of the character position and compensation plates.

Analog compensation voltages applied to the character-position plates bend the beam to coincide with the longitudinal axis of the SD CRT. Simultaneously, analog-positioning voltages applied to these plates deflect the electron beam to the required position in the message format. The electron beam next enters the deflection coil area. Analog currents in the deflection coil windings generate a magnetic field which deflects the electron beam to the required point on the viewing screen of the SD CRT.



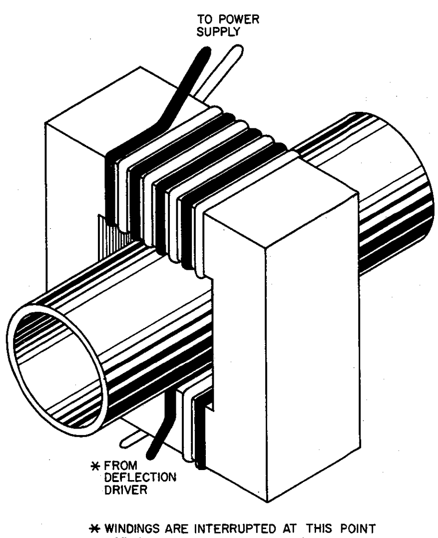


Figure 2–21. Deflection Coil, Horizontal Windings, Simplified Drawing

Note

During convergence, the magnetic field rotates the electron beam by 90 degrees in a counterclockwise direction (viewed from the face). The character matrix is oriented in a position (rotated 90 degrees from the vertical in a clockwise direction) to compensate for the rotation caused by the convergence coil.

2.2.2 Vector Display, Detailed Operation

The procedure for producing a vector is summarized in table 2–1. A discussion of the vector display operation follows.

The vector intensity gate unblanks the SD CRT. The gate width is 50 μsec, twice as long as the character intensity gate. Two factors determine the characteristics of the vector intensity gate. First, the vector is generated by a moving electron spot or point. The intensity of the point must be increased to produce a vector with an overall intensity equal to the intensity of the character. Second, all vectors are generated in the same length of time, irrespective of vector size. When a dim image of a vector is required, the intensity gate is correspondingly reduced in amplitude. Refer to the discussion of the model A variable gate amplifier for a more detailed discussion of the intensity gates.

The electron beam must have the smallest cross-sectional area possible. The focus adjustment in high-voltage unit model A determines this area. A focus gate can be considered the absence of a defocus gate. In the absence of the latter, the adjusted focus of the electron beam prevails. As shown in figure 2–15, this adjustment permits unchanged passage of the electron beam through the character matrix.

The character selection plates deflect the electron beam into and through the vector aperture in the character matrix. The convergence coil directs the beam at the point of convergence between the character position and compensation plates. Here, as in character display, the beam is returned to the longitudinal axis of the SD CRT by the application of analog voltages opposite in polarity to the character selection analog voltages. Simultaneous with the application of these correction voltages, analog vector-positioning voltages are applied, deflecting the electron beam to the vector point of origin in the message format. Immediately thereafter, sweep voltages are superimposed on these voltages at the character position plates. The electron beam is swept by the varying pairs of potential (X and Y), producing a straight-line image of the required direction and length.

The entire message presentation (or format), of which the vector is a part, is positioned on the face of the SD CRT by the deflection coil.

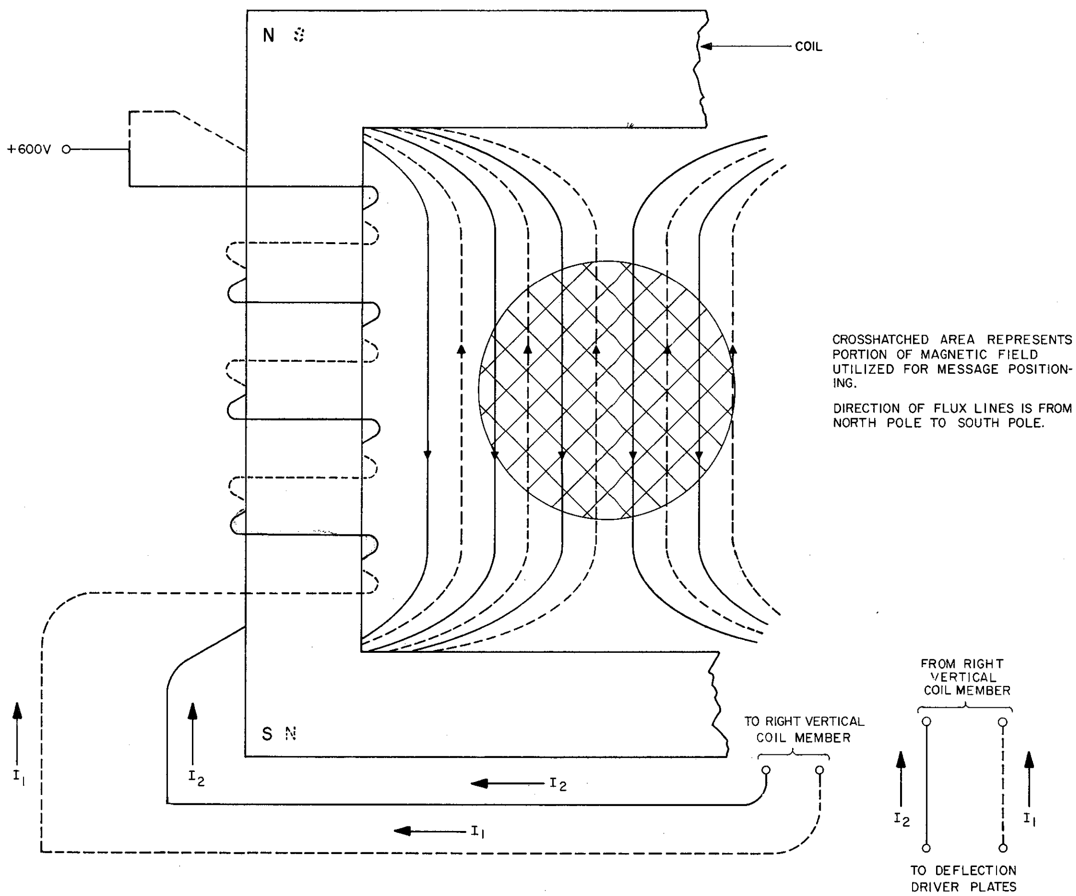


Figure 2—22. Deflection Coil, Magnetic Field Diagram

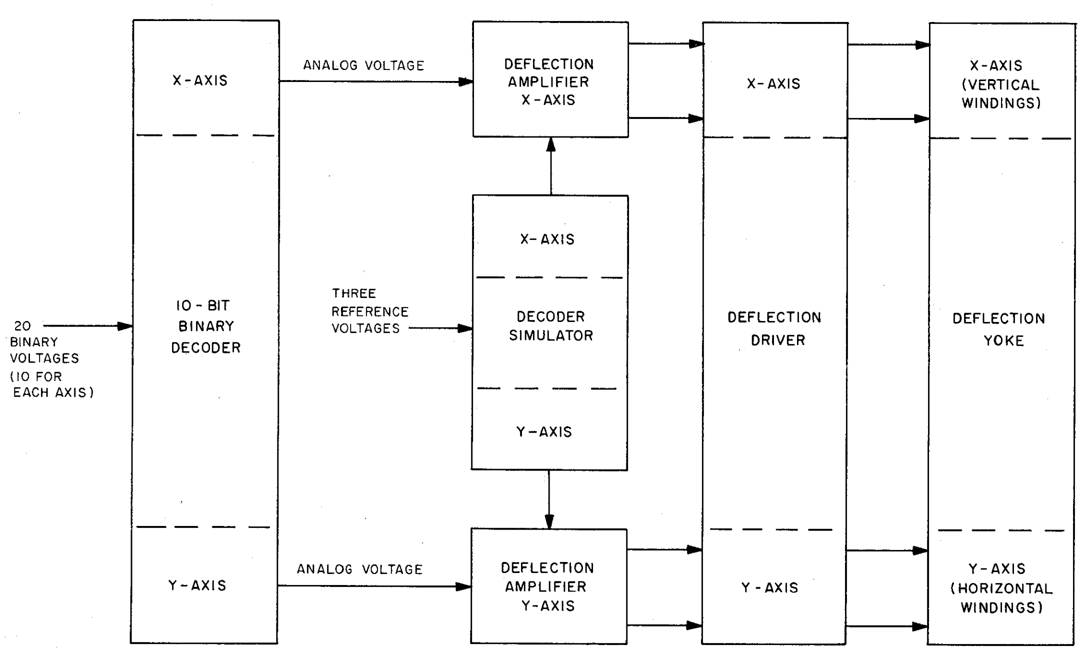


Figure 2—23. Message-Positioning Control Circuits, Block Diagram

CHAPTER 3
7-INCH SD CRT

3.1 GENERAL

The 7-inch SD CRT is similar, operationally, to the 19-inch SD CRT except with respect to the following: the location of the character matrix, flexible placement of the convergence coil, and the addition of an auxiliary focus coil. Figure 2–24 is a schematic representation of the 7-inch SD CRT symbol.

The character matrix in the 7-inch tube is located in the center of the convergence field. In the 19-inch tube, the matrix is fixed at the electron gun end of the convergence field. The convergence coil can be moved and set-positioned along the neck of the 7-inch CRT. The 19-inch SD CRT convergence coil, as such, is fixed. The auxiliary focus coil employed on the 7-inch tube is used to ensure maximum definition of display. This tube is used exclusively for photographic reproduction, thus making extreme definition essential for subsequent large-screen image projection. As a further aid to faithful photographic recording, the viewing screen phosphor emits a blue light to which photographic emulsions are sensitive. This P11 phosphor is also employed for the 19-inch SD CRT used in the camera console.

With the exception of the differences already enumerated, the 7-inch SD CRT is very much the same as the 19-inch SD CRT. Therefore, for detailed operation, reference should be made to the 19-inch tubes. The following discussions are limited to the differences only. Figure 2–7 is a cutaway view of the 7-inch SD CRT, showing the location of the character matrix and the focus coil.

3.1.1 Auxiliary Focus Coil

The object of this additional coil, as previously stated, is to ensure sharply defined displays necessary for reproduction. It does this by realigning the electrons diverging from the beam proper. These electrons would normally be projected as blurred, indistinct images. With the aid of the auxiliary focus coil, the projecting and deflected electrons are compelled to follow a path that will make them meet with the main body or beam of electrons that come into the focus coil field. See figure 2–25. The size of this path is such that electrons which are far off the longitudinal axis of the beam will come into the magnetic field almost parallel to the axis. All electrons will now be heading directly toward the crossover point with the same velocity and at the same time. If all the electrons now require the same

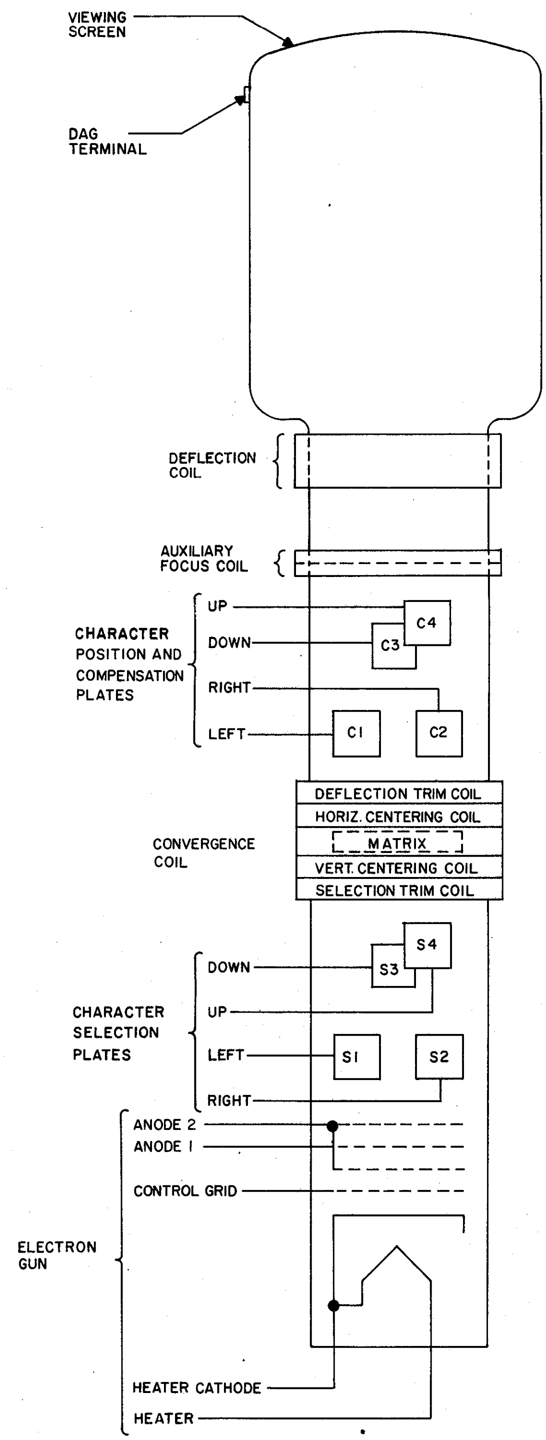


Figure 2–24. 7-inch SD CRT Symbol

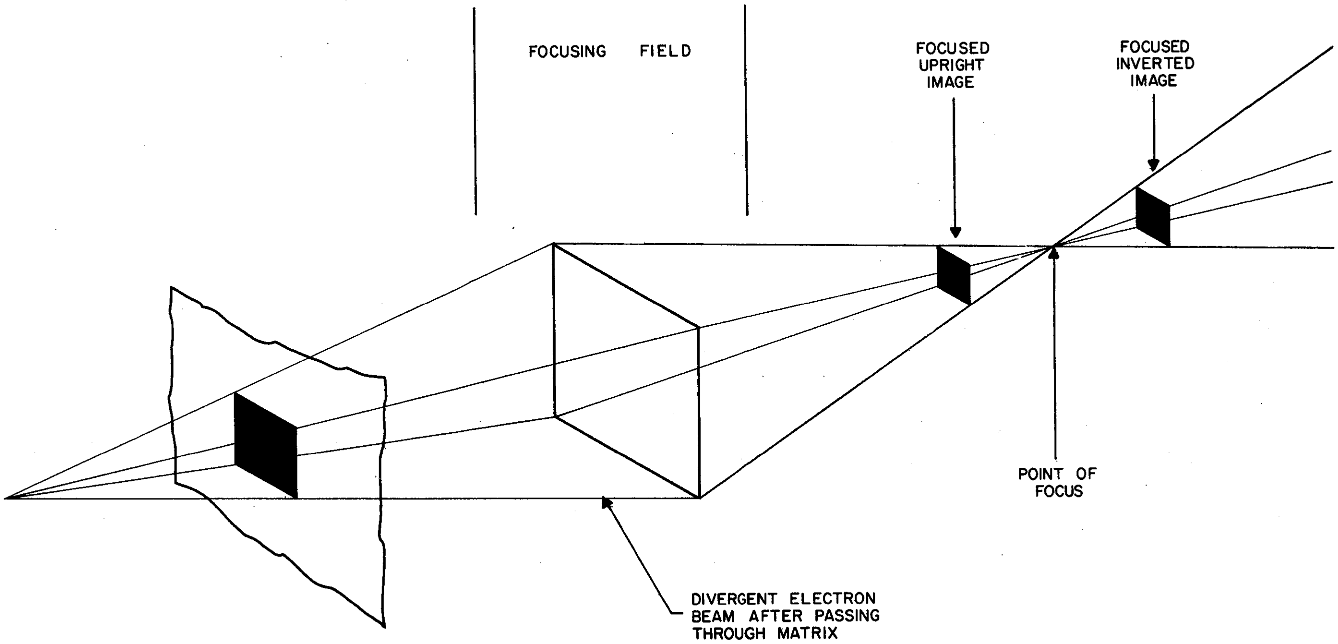


Figure 2–25. Focusing Coil Effect on Character-Formed Electron Beam

length of time to pass through the magnetic field, they will meet at a common point. If the strength of the magnetic field is adjusted so this common point is at the fluorescent screen of the tube, the beam will be sharply defined and capable of being recorded for large-screen projection.

As is the case with the convergence coil, or any device producing a magnetic field, a spiral rotation is imparted to the electron beam by the focus field. This is offset by an opposing field produced by a bucking winding of the dual-winding focus coil. Therefore, no additional compensation for rotation is necessary for the focus-coil field effect.

3.1.2 Character Matrix Location

The location of the character matrix is not the same as it is in the 19-inch SD CRT. The placement of the 7-inch matrix in the center of the convergence field was again an effort to obtain maximum display recording quality.

Ideal character-forming of the beam is accomplished if the electron beam enters the character matrix perpendicular to the plane of the matrix. This, of course, is the logical physical placement for electron-beam character-stenciling, with minimum distortion. As shown in figure 2–16, the electron beam enters the convergence field at a deflection angle. However, in the center of the field the angle of deflection becomes zero, and the electron beam is parallel to the axis of the tube. It is at this point in the field that the character matrix in the 7-inch SD CRT is located. The spiraling effect of the convergence field imparts a 90-degree rotation to the cross-sectional area of the electron beam. Since the character matrix is located in the center of this field, the beam is rotated 45 degrees before it reaches the focus coil field. It will be remembered that the 19-inch SD CRT matrix was placed before the convergence coil field, thus imparting a 90-degree rotation to the emanating beam. In the manufacture of the 7-inch tube, the matrix is physically counter-rotated to its normal axis to offset the rotation of the beam, so that the image is upright on the viewing screen.

3.1.3 Convergence Coil

The 7-inch convergence coil has the same function as the 19-inch convergence coil. They differ only in the adjustments and physical method of coil placement about the neck of the tube. The 7-inch tube coil is mounted to an inner mu-metal shield which rides along a slot in the main shield by means of a screw-thread device. See figure 5–6. The point of convergence and isolation of the convergence field are established by the manual-positioning of the convergence coil. The coil mount is designed to accomplish this with a minimum of adjustment.

In addition to the differences already mentioned, the convergence coil on the 7-inch CRT has an extra winding. This winding is a horizontal and vertical centering coil superimposed on the convergence coil. This coil, in the form of a quad pancake winding, is arranged so that the field of one pair of coils will affect the X axis of the electron beam; the field of the other pair, the Y axis. In this way, it is possible to control the yaw, pitch, and vertical and horizontal positioning of the electron beam. These controls bring the beam up into reference as required. The field strength adjustments of the vertical and horizontal centering coils are controlled from the operating position of the PRRE unit.

CHAPTER 4
5-INCH DD CRT

4.1 GENERAL

The DD CRT (performs the same basic operation as SD CRT's) displays characters (fig. 2–26) as a function of the analog voltages applied to its electrodes. Figure 2–27 is the symbol used to represent the DD CRT in schematic diagrams.

The two types of tubes can best be compared by referring to figures 2–28 and 2–29. It can be seen that the DD CRT employs electrostatic deflection by means of deflection plates. The SD CRT uses a deflection coil for magnetic deflection, to position the message on a predetermined portion of the screen. The DD tube employs a storage element to enable a continuous display, if so desired, on the viewing screen. This storage element consists of a flood gun (electron gun) and three grids between the flood gun and the phosphor of the viewing screeen. These grids or coatings are called storage mesh, collector mesh, and ion repeller mesh, in line from the phosphor to the flood gun.

The phosphor of the DD CRT viewing screen is of such short persistence that it enables the instantaneous erasure of a message. This is a functional requirement of the tube. For this reason, the methods of creating an image on the face plate of the DD CRT differ from those of the SD CRT. With the exception of these major differences, the other elements of the DD tube function in much the same manner as comparable elements in the SD CRT. The physical dimensions of the DD CRT are given in figure 2–28.

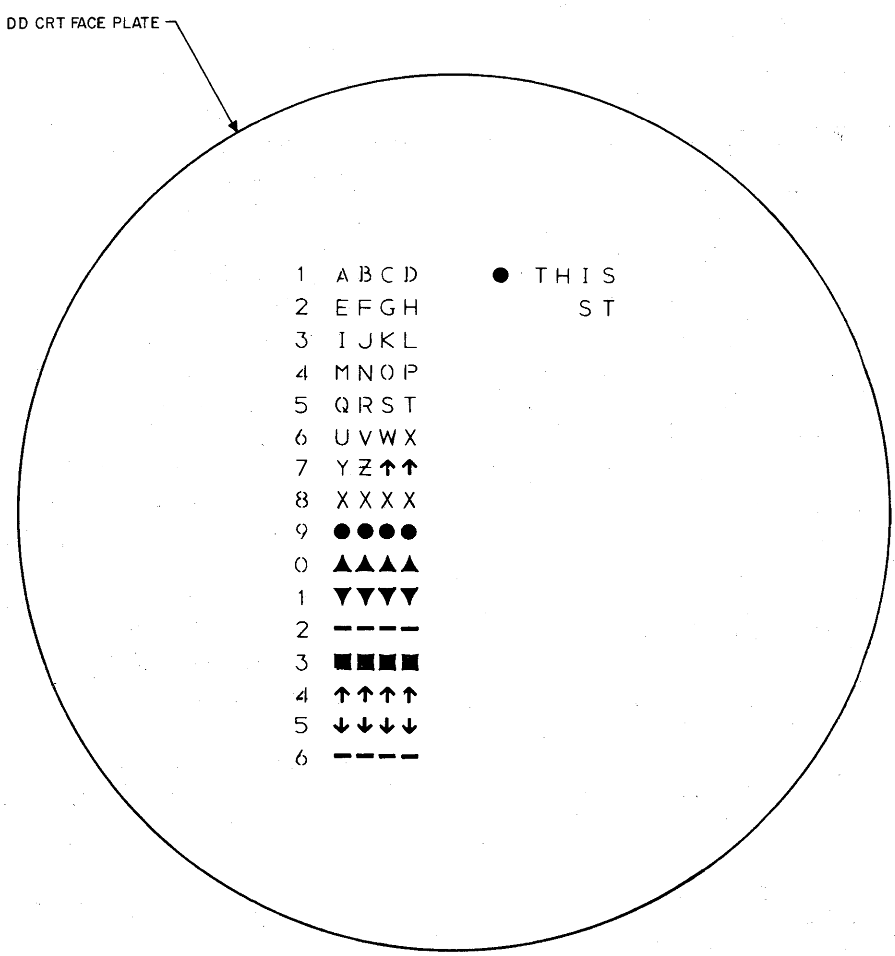


Figure 2–26. Typical Digital Display Characters

4.1.1 Basic Operation

The image displayed on the DD CRT is initiated in the same manner as that in the other CRT's described. The electron gun generates a beam of electrons each time the control grid is fed a positive-going voltage. The beam is then deflected through the desired character in the character matrix by the character selection plates. The resultant stenciled beam is shaped in the form of the selected character. The rotated beam is returned to the longitudinal axis of the tube by the convergence coil before it reaches the character compensation plates. The character deflection plates position the character-formed beam to the proper location in the message format. The beam continues to the storage mesh where it writes the character into the mesh.

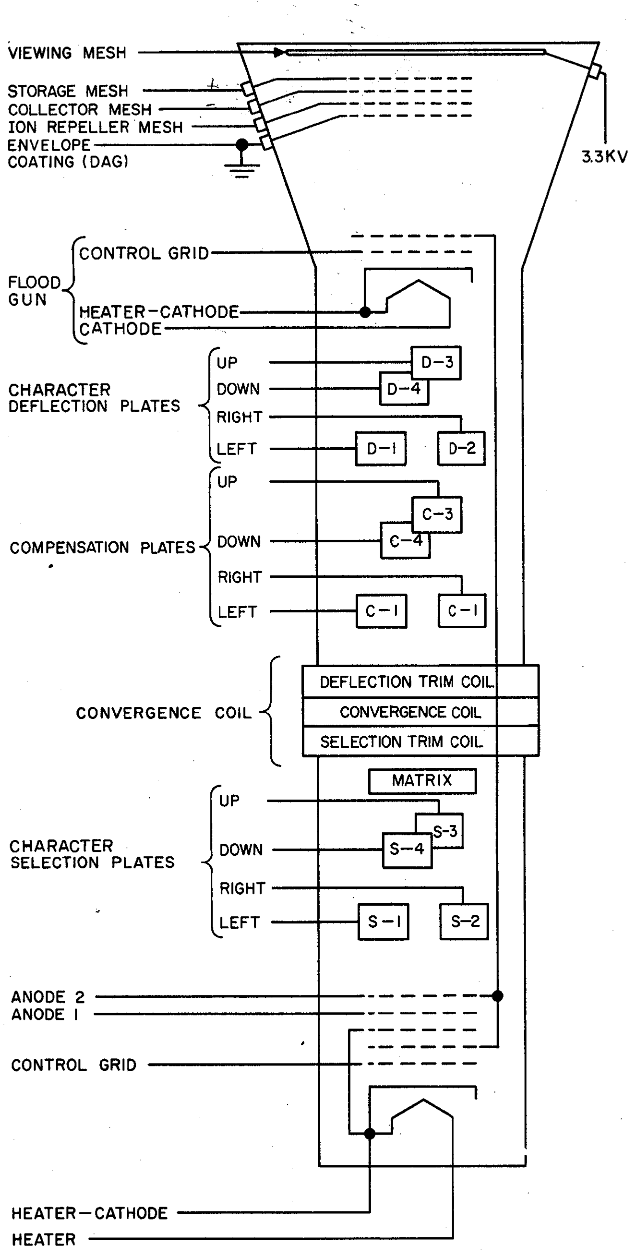


Figure 2—27. DD CRT Symbol

The flood gun is a constant source of low-velocity electrons. These electrons are sprayed out in the shape of a cone with the apex at the emitter of the flood gun and the base of the cone at the phosphors. The base covers the entire viewing surface of the tube. This spray of electrons passes through the electron-transparent portions of the storage mesh to impinge on the phosphors and produce a visual display of the character written on the storage mesh.

A negative erase gate is applied to the collector and storage mesh. This, as mentioned previously, will make the storage mesh opaque to flood-gun electrons prior to writing a new message. Provision is also made for the manual-controlled erasure of the DD message.

4.1.2 Detailed Operation

The detailed operation of the DD CRT is confined to those areas which are peculiar to or different from the elemental operation of those tubes already described. However, the control circuits for all the DD CRT elements are discussed briefly and in the sequence listed in table 2—2.

4.1.2.1 Electron Gun

The electron gun of the DD CRT provides a defocused beam each time an intensity (unblanking) gate is applied to the control grid. (Fig. 2—30 is a block diagram of the control and supply voltage circuits for the electron gun.) Since the DD message consists of characters only, a defocus gate is not required (as was employed with the SD CRT) because the beam is normally defocused. Anode 1 voltage is supplied directly from the focus control in the BHVU. This control is adjusted to give the beam a cross-sectional area which will encompass the largest character cutout in the matrix. Once the proper adjustment is made, the beam will remain constant. The heater is supplied with 6.3V, one side of which is the —3,150V cathode return from the cHVP. The bias on the control grid keeps the tube at cutoff until overcome by the positive pulse of the intensity gate. This intensity gate or unblanking signal is fed through the cVGA and BHVU to the control grid of the electron gun. The electron beam will pass through the DD CRT to the storage mesh only when the intensity gate is present.

The accelerating anode (or anode 2) is tied to the +45V tap of a voltage divider in BHVU. This +45V added to the —3,150 cathode voltage provides an accelerating potential of 3,195V.

4.1.2.2 Character Selection

The character selection plates of the DD CRT function in much the same manner operationally as their counterparts in the SD CRT. Refer to paragraph 2.2.1.2

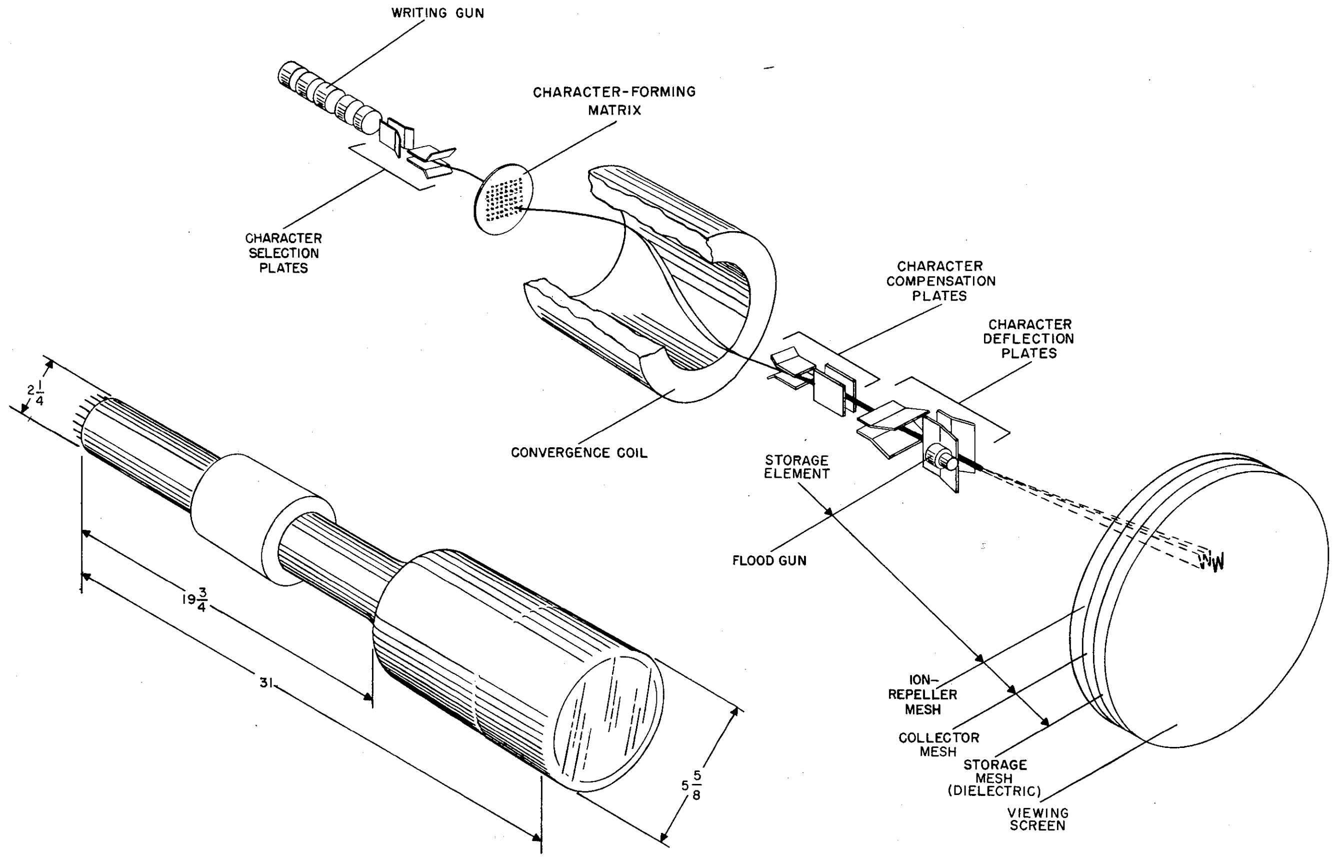


Figure 2–28. DD Cathode-Ray Tube

of Chapter 2 for a detailed explanation of the deflection necessary for character selection. Figure 2–31 is a block diagram of the control circuits for the character selection plates of the DD CRT. Binary levels applied to the character selection decoder are converted into corresponding analog voltages. These analog voltages are power-amplified by the analog line drivers and fed through the control networks to the selection plates. As with the SD CRT, the horizontal and vertical deflection voltages are applied to the vertical and horizontal plates, respectively. This is due to the mounting of the character-forming matrix (rotated 90 degrees clockwise viewed from the front) in a position to compensate for convergence coil rotation of the electron beam.

4.1.2.3 Electron Beam Convergence

The DD CRT convergence coil is identical in operation to the convergence coil in the SD CRT's. Refer to paragraph 2.2.1.4 of Chapter 2 for the detailed convergence coil function. Figure 2–32 is the block diagram of the DD CRT convergence coil control circuits. The trim coil current is controlled by a single potentiometer connected in parallel across the trim coil proper. This method of connection differs from the trim coil circuit in the SD CRT (fig. 2–18). However, the absence of vectors in DD messages permits this method of control. The point of convergence in the DD CRT corrects for selection beams of a relatively large cross-sectional area (compared to electron beams employed in vector generation) and is adjustable to the same precise limits as in the SD CRT. The trim coils, as well, have a degree of control precision of rotation and point of convergence comparable to the SD CRT's. The high-voltage units and convergence current regulators serve the same functions as their counterparts in the SD CRT control circuits.

4.1.2.4 Electron Beam Compensation

The character compensation plates electrostatically compensate for the deflection given the electron beam by the character selection plates. This compensation or neutralization of selection-plate effect results in the beam being made coincident with the longitudinal axis of the DD CRT.

Figure 2–33 is a block diagram of the character compensation circuits. Analog voltages derived from the character selection decoder are applied through the centering and amplitude controls to the compensation plates. The 180-degree reversal of selection voltages in each axis when applied to the selection makes the beam coincident with the tube axis.

4.1.2.5 Character Message Deflection

The DD CRT also employs electrostatic deflection for character positioning within the message format. A typical DD message is illustrated in figure 2–26. Counting circuits provide the necessary binary levels to shift the electron beam to each successive character position in a row and to each new line. The precise positioning of messages on a specific portion of the screen is not a requirement for digital display. Therefore, the complex magnetic deflection network of the SD CRT was not used.

Figure 2–34 is the block diagram of the special circuits which supply the analog control voltages to the character-deflection plates. Binary levels applied to the character position decoders are converted to corresponding centering and amplitude controls.

4.1.2.6 Flood Gun

The flood gun is essentially an electron gun specifically designed to supply the storage element with a consistent source of low-velocity electrons. This is necessary because ordinarily the short persistence time of the phosphors does not permit a character to be displayed for a prolonged period of time. The flood gun is a source for a continuous flood of electrons which maintains each successive selected character at uniform intensity during the complete DD message presentation. Without the flood gun, each character would be displayed for the duration of phosphor persistence only and then would quickly fade away.

Functionally, the flood gun is the same as the main electron gun of the DD CRT. The gun consists of a heater cathode control grid and an accelerating anode.

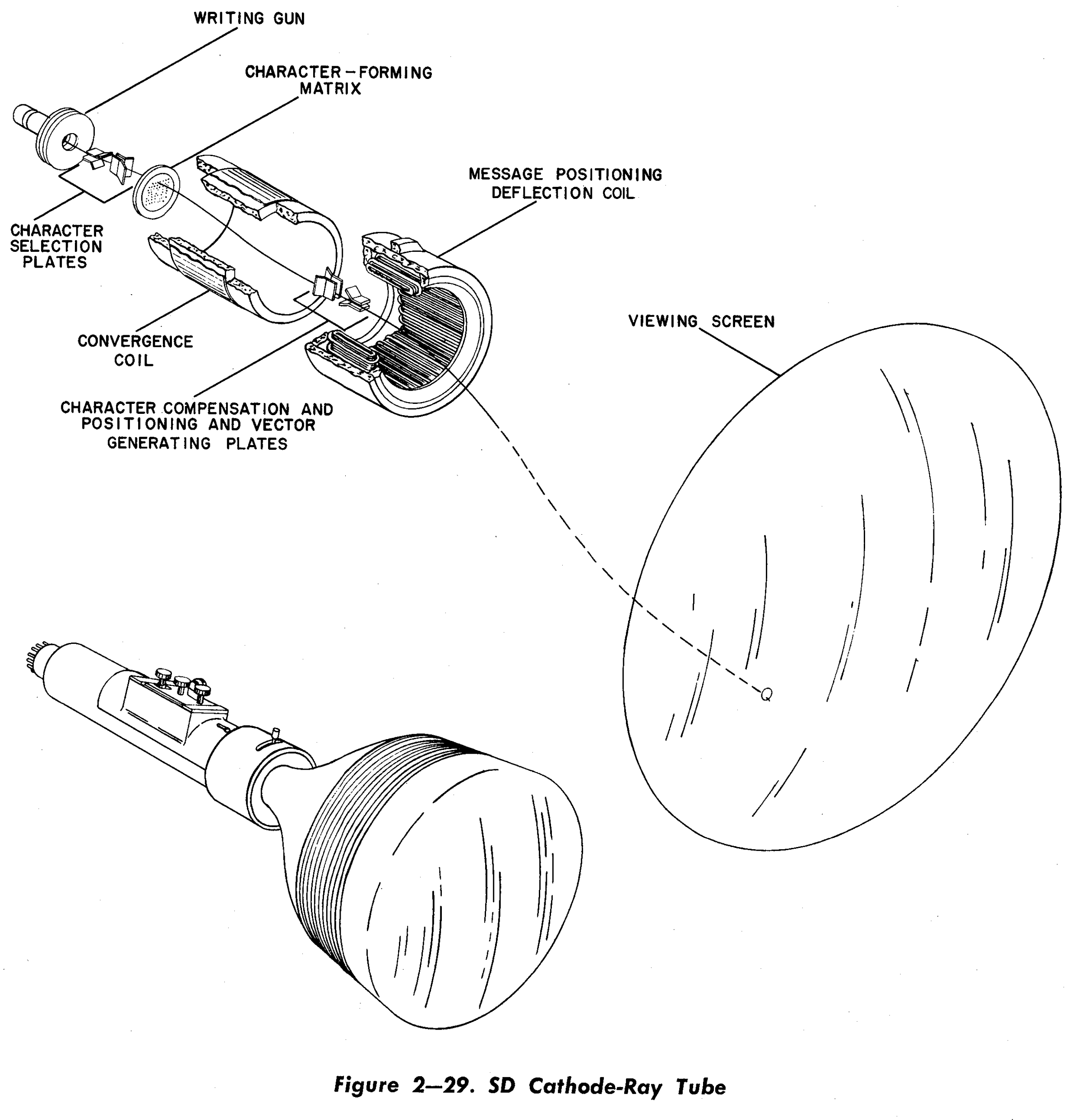


Figure 2–29. SD Cathode-Ray Tube

Figure 2–35 is a block diagram of the circuits associated with the storage element. The voltages for the flood gun are supplied by the model B high-voltage unit. The heater is supplied with 6.3Vac. The cathode voltage of −150V is returned to one side of the heater. The control grid is biased into conduction so that a continuous flow of electrons is supplied to and directed at the storage mesh. The accelerating anode is maintained at +45V. The total accelerating potential would thus be 200V. Compared with the 3,200V used to accelerate the main electron-gun beam, the flood gun can be considered a low-velocity electron emitter.

4.1.2.7 Collector Mesh

The collector mesh is a fine metallic screen which serves as the collector for secondary emission electrons from the storage mesh. The collector mesh potential is adjusted by the collector mesh level adjust potentiometer. This level is adjusted to provide the maximum collection of secondary emission electrons compatible with the passage of flood gun electrons. To increase this collection function, a positive contrast gate is applied to the collector mesh simultaneously with the impact of the high-velocity electron beam on the storage mesh. To erase the message, an erase gate (negative voltage) is applied to the collector and storage mesh. This gate places the collector at a lower potential than the flood gun anode. Low-velocity flood gun electrons are repelled by the collector mesh, interrupting the flood of electrons through the storage mesh to the phosphors. The short time of persistence of the phosphors causes the image to disappear instantaneously.

4.1.2.8 Storage Mesh

The storage mesh is fine metallic film-coated grid. This film has the property of high electron emission when bombarded by high-velocity electrons. Thus, when the high-velocity character-shaped beam impinges on the storage mesh, electrons are emitted by the film. As a result, the storage mesh acquires a positive charge at those points on the mesh where electrons have been emitted, producing a positive charged area in the shape of the character. Low-velocity electrons from the flood gun are attracted through this area to the phosphor, causing an image of the character to appear on the viewing screen. As long as this character-shaped area remains positively charged, flood gun-emitted electrons will maintain an image of the character on the face of the tube.

The storage mesh potential is set by the storage mesh level adjustment potentiometer (fig. 2–35). The mesh level control network holds the storage mesh at a more negative potential than the collector mesh to prevent the return of emitted electrons to the storage mesh. When the negative erase gate is applied to the collector and storage mesh, the positively charged areas attract electrons and become neutralized.

4.1.2.9 Ion Repeller Mesh

The ion repeller mesh deflects positively charged ions to the dag coating on the inner surface of the DD CRT. The bombardment of the phosphers by the high-velocity electrons generates these positively charged ions. The dag coating is maintained at ground potential and therefore attracts these positively charged particles.

TABLE 2–2. DD CRT FUNCTIONAL REQUIREMENTS AND ASSOCIATED TUBE ELEMENTS

FUNCTIONAL REQUIREMENTS	DD CRT ELEMENT
Generate electron beam. Blank or unblank the beam.	Electron gun
Aim beam at a character.	Character selection plates
Form beam in shape of character.	Matrix
Make electron beam intersect the tube axis. (Beam spirals through 90 degrees in transit.)	Convergence coil
Cancel deflection applied by selection plates. Make beam coincident with tube axis.	Character compensation plates
Position character-formed beam in the required position in message format.	Character deflection plates
Display or erase message:	Storage element
a. Generate cone of low velocity electrons.	a. Flood gun
b. Store character.	b. Storage mesh
c. Intensify message (contrast gate) erase.	c. Storage mesh
d. Erase message (erase gate or manual).	d. Storage mesh
Deflect positive ions.	Ion repeller mesh
Collect secondary emission electrons.	Collector mesh

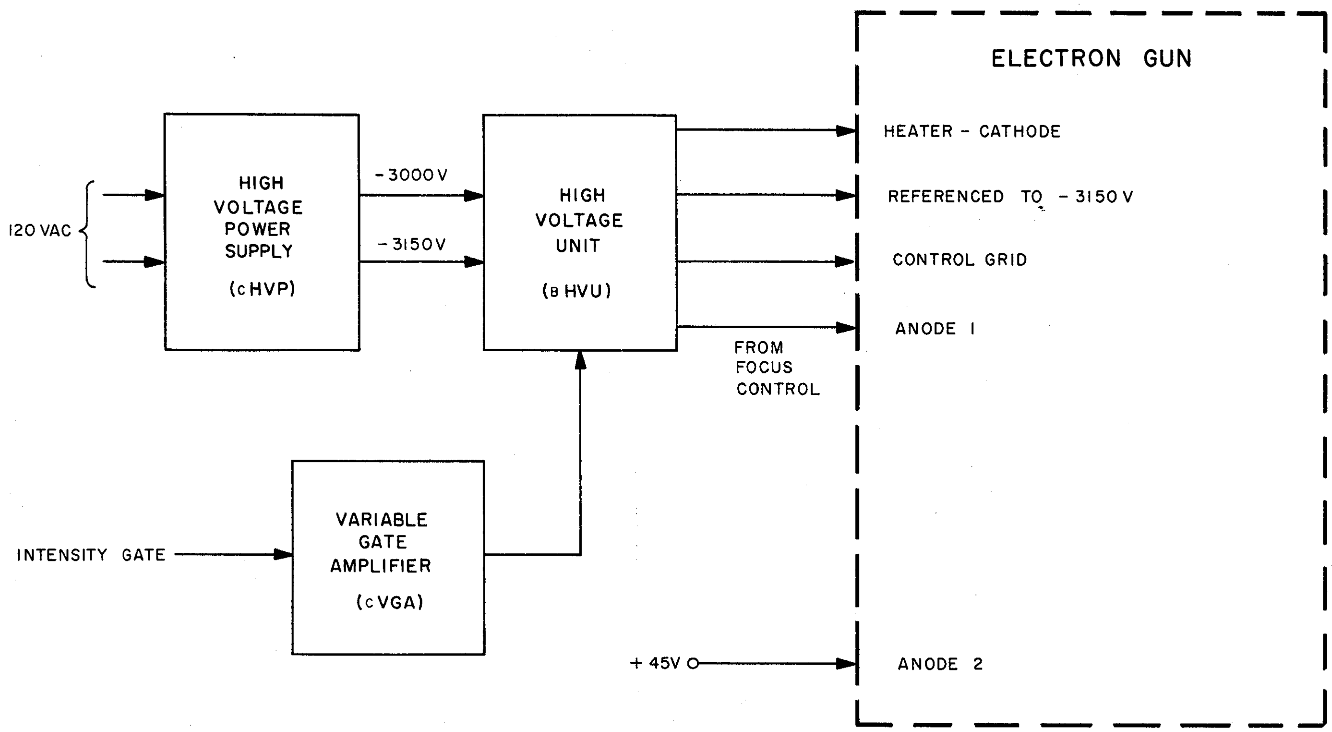


Figure 2–30. Electron Gun Control and Supply Circuits, Block Diagram

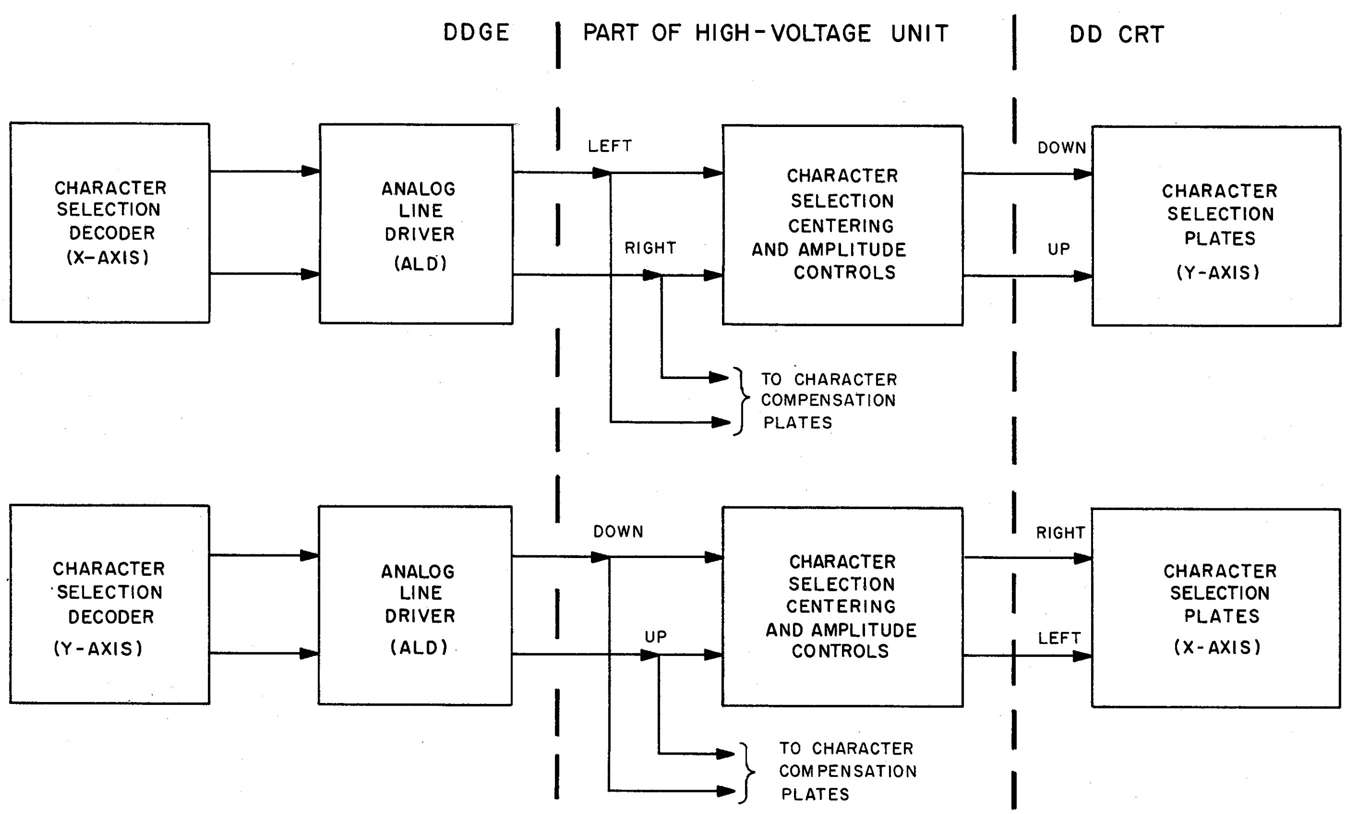


Figure 2–31. Character Selection Plates and Associated Circuits, Block Diagram

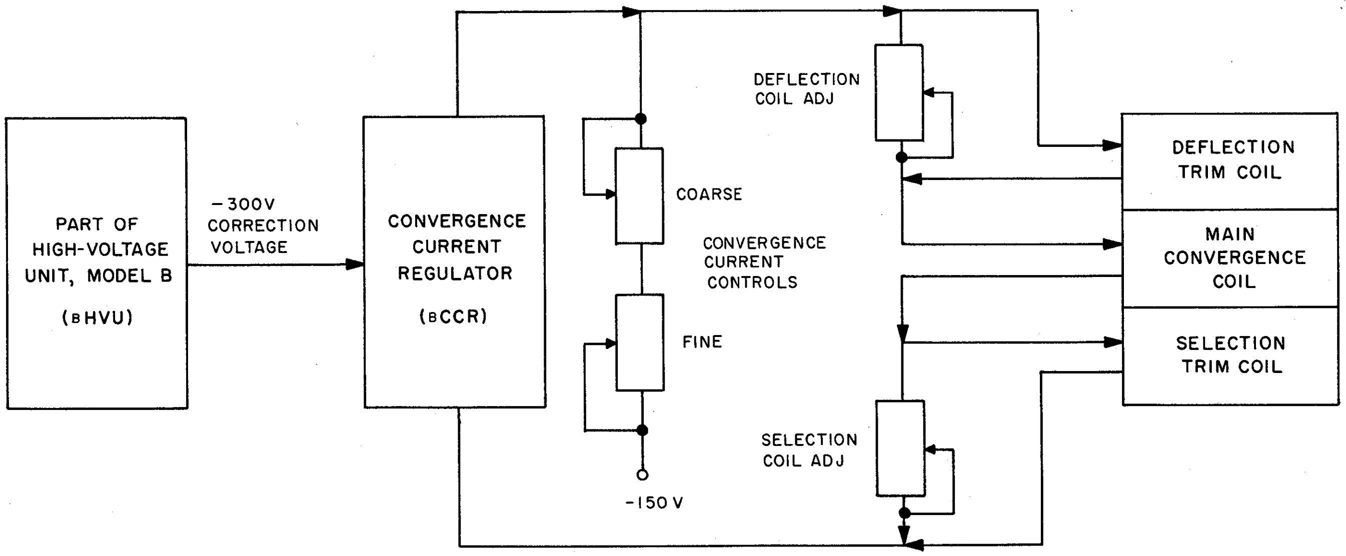


Figure 2-32. Convergence Coil Assembly and Associated Circuits, Block Diagram

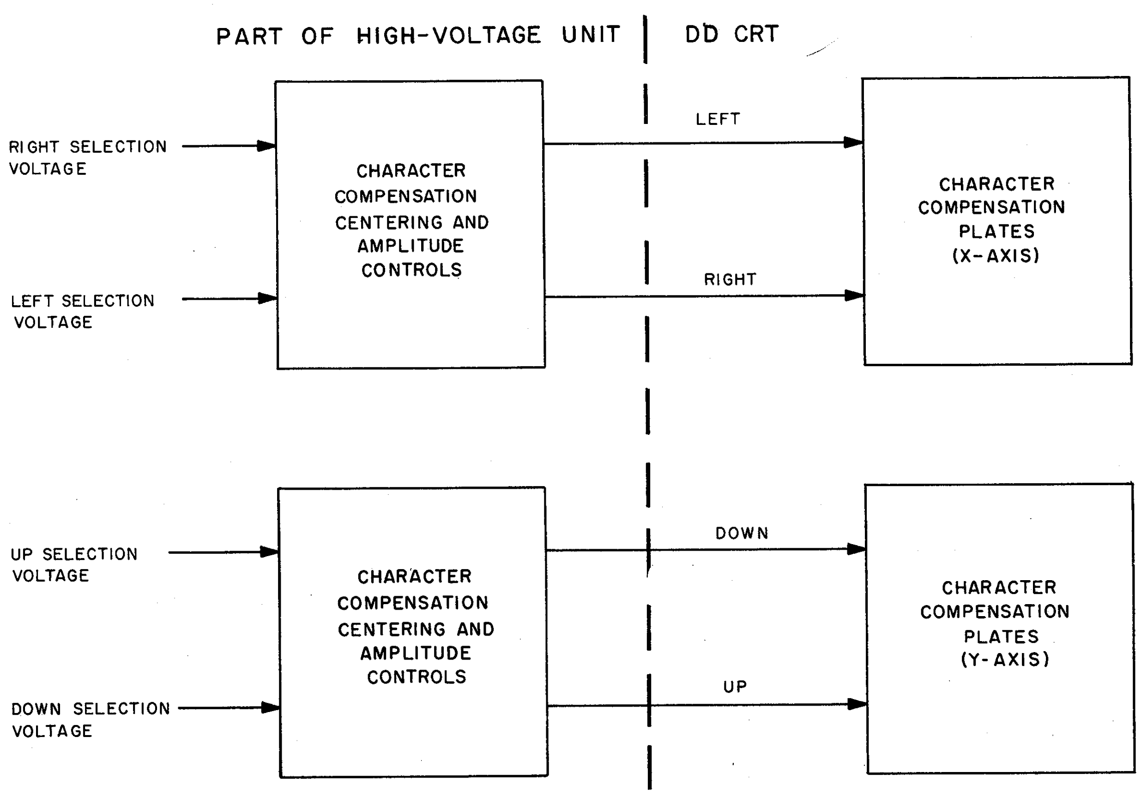


Figure 2-33. Character Compensation Plates and Associated Circuits, Block Diagram

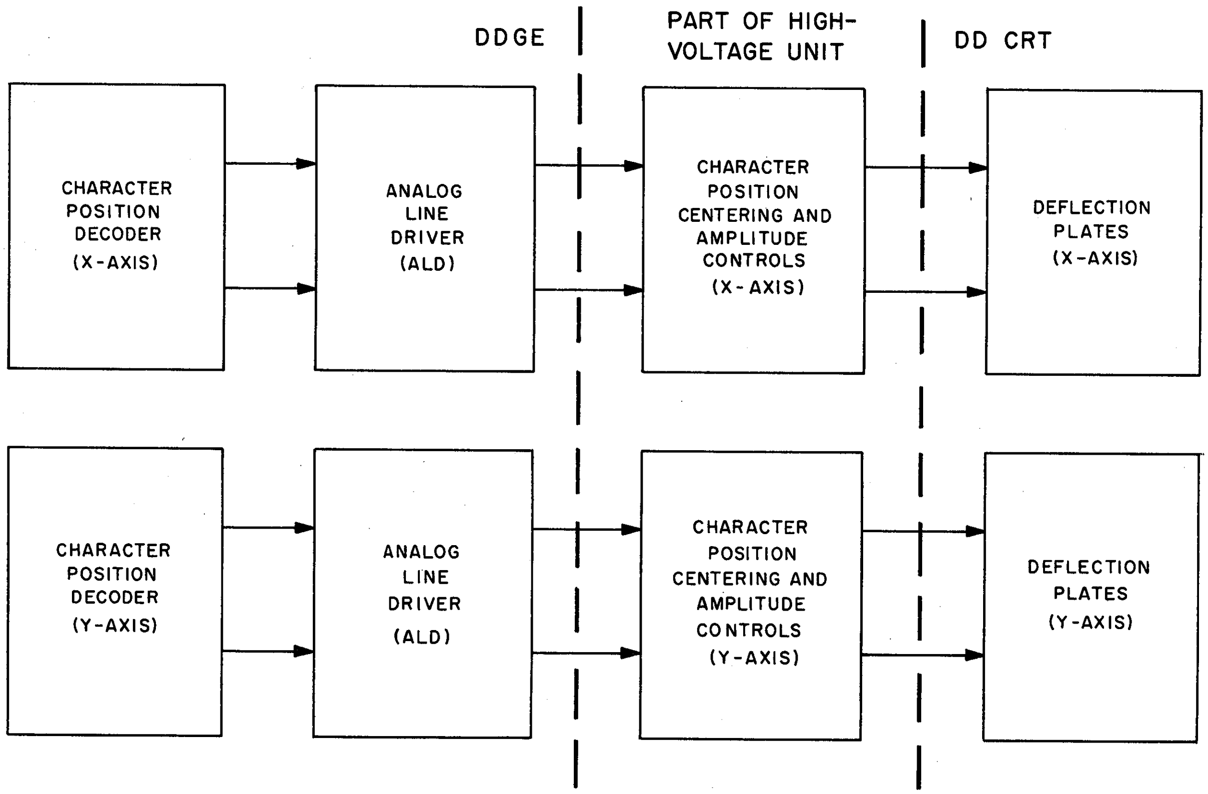


Figure 2–34. Character Deflection Plates and Associated Circuits, Block Diagram

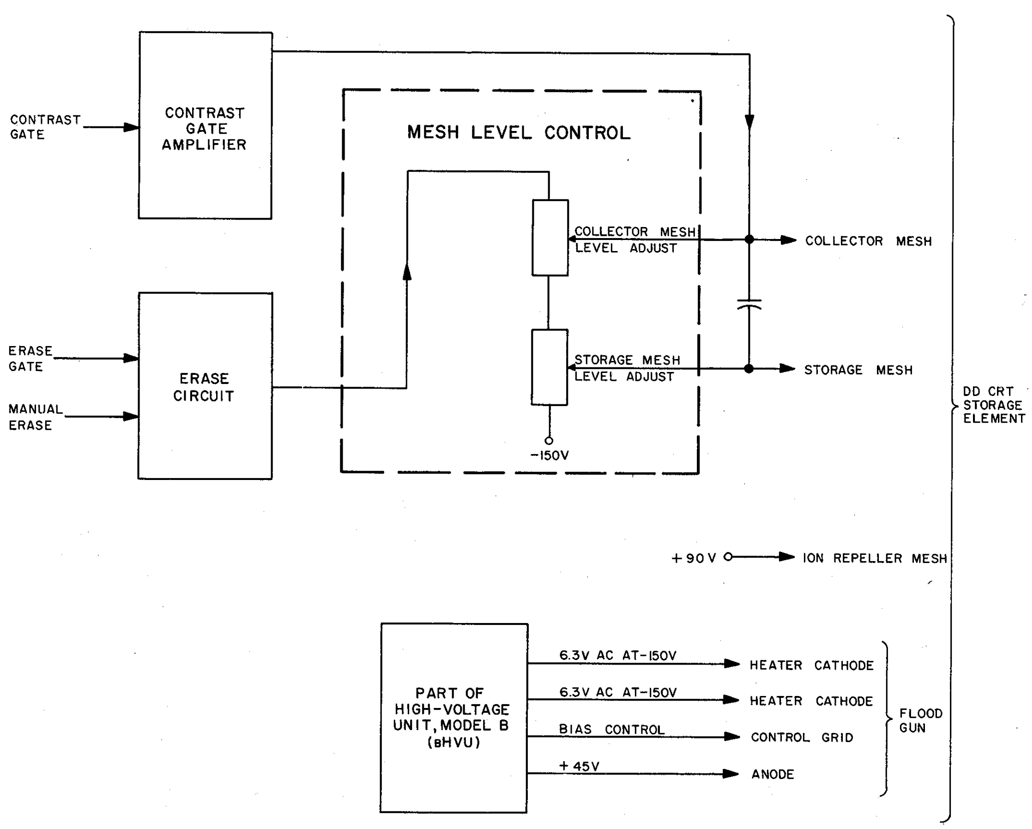


Figure 2–35. Storage Element and Associated Circuits, Block Diagram