# VISUAL DISPLAY



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# FOREWORD

The purpose of this display equipment manual is to both inform the student of current progress in the display field of computer peripheral equipment, and give him a working knowledge of the principles involved.

This volume encompasses the visual displays area, including basic cathode ray tube operation; display types and applications; symbol and vector formation; and other circuitry. It is recommended that the student use the workbook questions found at the end of each section to evaluate his own understanding of the course. The Glossary in Appendix B should prove to be a useful addition to his computer terminology vocabulary. It is suggested that as new definitions are provided they should be added to this list.

In any technical writing effort, possibilities of errors are always present. Although Control Data Institute makes a conscious effort to minimize errors in its publications, errors are nevertheless inevitable. If you would like to make the existence of errors known, or would like to make comments or suggestions concerning the manual, you might find the Comments Sheet at the end of the manual to be of help. Forward your comments to the Educational Development Section, Control Data Institute, 3255 Hennepin Avenue South, Minneapolis, Minnesota 55408.

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# INTRODUCTION

This manual gives a comprehensive description of the basic logical and circuit theory common to most display equipments. It consists of nine sections:

Section I, Display Equipment in General - describes the basic function and types of display equipment.

Section II, Unit Monitor - covers the circuitry located or closely associated with a crt.

Section III, Comparative Displays - provides an overall look at several typical display systems, theory applications, and optional auxilliary equipment.

Section IV, Analog Circuitry - provides an introduction to analog equipment and circuitry necessary to convert a digital signal to an analog signal and transmit the signal.

Section V, Base Positioning - describes how the beam is deflected to a specific coordinate position on the crt screen, how that area may be addressed, and various modes of addressing.

Section VI, Symbol Formation - contains a detailed explanation of how a symbol is formed on the crt screen, including an introduction to the diode matrix.

Section VII, Vector and Line Generation - distinguishes between the two methods of forming straight lines between two given points on the crt screen and describes the circuitry involved for each method.

Appendix A, Logical Circuitry - introduces logical circuitry unique to the visual displays area, including chip circuitry.

Appendix B, Glossary - Defines terms useful in the understanding of display equipment.

Workbook - at the end of each section a group of questions will be found relating to the material presented in the section. These should assist in classroom discussion and in a comprehensive understanding of the material presented within the text and the classroom.

# SECTION I

# SECTION I

## DISPLAY EQUIPMENT IN GENERAL

Of the existing computer input devices; typewriter, line printer, data plotters, etc., there has been a gap in capability. There has not been a machine made capable of producing both tabular or written data as well as tables, graphs, maps, geometric designs, and of giving rapid access to this information. Over the past ten years a system with these capabilities has been developed.

The Cathode Ray Tube (CRT) display has evolved from the radar planned position indicator system, with only a radar sweep and no computerized data, to a more complex system with both computerized data and radar functions, to the commercial applications used today. The use of the CRT display configuration is limited only to the users imagination. Uses to date have been with maps, three dimensional pictures, directory listings, inventories, schedules, credit, airline scheduling, automotive design and many others.

As it can be seen the CRT display is an element essential to any effective communication between the computer and its user. Much of the value of the computer depends on its ability to provide responses in most any form. In essence the basic function of display equipment is to interpret digital data for presentation on a cathode ray tube. This could take the form of symbols, numbers, the alphabet, vectors or lines and dots.

A minimum display system would consist of a data source, controller, and a display console. The data source furnishes digital data to be displayed while the display controller receives and converts digital data to analog signals. In addition, the controller receives and/or generates the various control signals for the unit monitor. The circuitry of the unit monitor applies the analog signals to the deflection plates and/or coils of the Cathode Ray Tube, and in addition controls the blanking, focus and intensity.

### MODES OF OPERATION

Most units, with the exception of design applied systems, are equipped to operate within a page display mode. For our purposes, we may compare the operation to that of a typewriter. With this mode of operation, necessity of prepositioning of every character on the face of the CRT is eliminated and in automatic sequence increments characters left to right as though the CRT were the page on a typewriter. A typical CDC display will produce 64 lines of 128 characters each.

The advantages of a system of this type are obvious, by being capable of typing an entire page of data, or dumping an entire table of data, we are able to delete or make changes in a moment rather than go to the trouble of producing a new data card and re-entering the information.

The second mode of operation is the plotter mode, allowing individual plotting of characters and painting of vectors and lines under computer control.

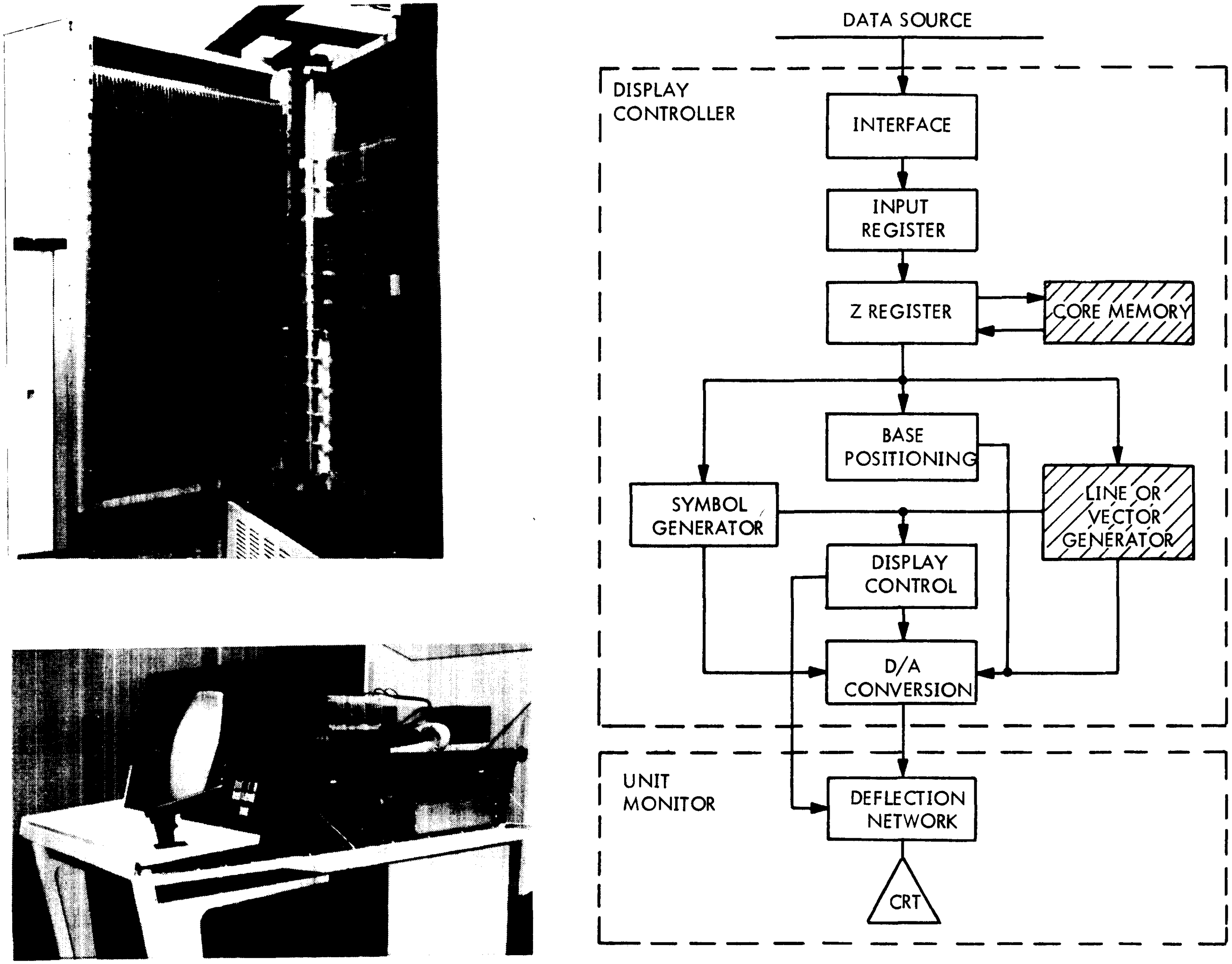
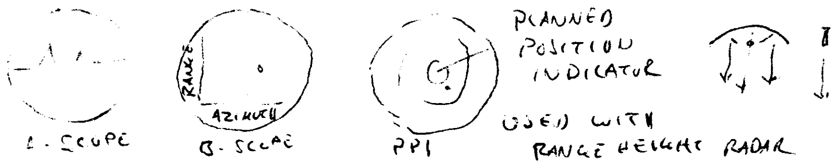



Figure 1-1 TYPICAL DISPLAY CONTROLLER AND UNIT MONITOR




Various control words would identify the type of symbol to be produced and would activate the circuitry needed for its production.

TYPICAL DISPLAY CONFIGURATION

Figure 1-1 illustrates the typical display configuration. The display controller is the most significant of the units since it contains nearly all the circuitry necessary to provide a display. Forcing a computer to wait for an entire display to be painted would not be practical. Therefore, the display controller will usually contain a memory system for storing the display to be presented as well as the control words involved. This system allows continuous regeneration of the display which will be discussed at a later time. The display controller will allow console selection of the units of the system requiring a display and will allow unblanking (turning on the CRT) for the CRT or CRT's selected. The typical display system, utilizing I/O operation will allow input by keyboard, light pencil and track ball.

The keyboard will allow message construction with a capability of direct entry or page entry. In either case, correction of errors or changes of information is allowed by simply referencing the area of the display involved. The keyboard is very similar to that of the standard I/O typewriter except that operation is virtually noiseless.

The light pencil and trackball are used to reference a given coordinate position on the face of the CRT. Together with the switches and indicators also located in the display console, they are the key to the advantages offered by the display system.

The complex display system has a capability of additional unit monitors. The unit monitor consists of individual operator controls and is capable of individual displays which operate through time sharing in conjunction with the other monitors. For an example, one system is capable of four unit monitors.

The display system, although it has the advantage of speed does not directly provide an immediate permanent record of the data displayed. For this reason, additional equipment provides a record according to need.

The hard copy recorder is capable of providing a quick-look print, or a permanent copy on a continuous roll of photographically sensitive paper. Approximate speed is ten frames or images per second.

The microfilm recorder consists of a five inch CRT and a thirty five or sixteen millimeter (mm) shutterless camera. The exposure of the film is accomplished by computer controlled or manual film advance and a one time paint of the image to be photographed on the extremely high resolution CRT. Film advance rate approximates fifteen frames per second for 16mm and thirty frames per second for 35mm. The film is processed off line at a speed allowing virtually unlimited reproduction.

Another unique system of limited application is the rapid process projection display. In this method a rapid processing system allows photographing of the information on a small CRT, rapid developing and projection of the film on a large movie type screen. The total time from display to projection with this type system is somewhat less than eight seconds. Another system similar to this allows projection of the image from a CRT onto a thin film of oil, and then projection through this oil film onto a screen.

## DISPLAY REGENERATION

Although the phosphor used in display CRT's is of a high persistancy (glows for a period of time after the beam has left), it is suitable only for photographic purposes if the display is painted just once. Therefore the display must be regenerated at a rate that permits the eye to see it with even intensity and without flicker. The lowest rate now considered is thirty times per second although early displays ranged as low as sixteen times per second. Normal range is forty to sixty times per second. The upper limit is the safe rate to prevent phosphor damage from overactivation.

Several methods of regeneration are used in displays. One of the simplest is to use the computer and output the same image over and over until released. The disadvantage of this is the computer is tied up completely with this one job.

An alternate method, widely used, which frees the computer to do other jobs while awaiting your response utilizes a disk or drum storage. The display image is written on the disk or drum; then the display controller reads the image from the disk or drum. With a disk/drum rotation speed of 3600 rpm the rate would be sixty images per second, at 2400 rpm the rate would be forty images per second, and at 1800 rpm a rate of thirty images per second would be achieved. At 1800 rpm and less, two or more identical images are sequentially written.

A method used where a disk/drum is not desirable or too costly is the display controller memory. This memory is identical to that used in computers. It usually has a volume of 2048 decimal words of thirty-six bits each. Although it is an addressable type memory it normally has a sequentially addressed read or write during the regeneration cycle. As each word is read from memory it is sent through a function translator to control the display accordingly. A control word at the end of the image could trigger a new cycle, saving time, as long as the rate is maintained between the forty to sixty images.

A magnetic tape handler can be utilized with a memory type controller when several sequential pages or images are to be displayed. An image is read from tape to memory and then it is displayed. Upon release a new image is read and displayed. The magnetic tape could be used to store a large number of pages for future reference with relative ease.

EARLY SYSTEMS 16 XPS
TV EVERY OTHER LINE 60 XPS 30 XPS NEW AC.
MODERN 30 XPS.

SMALL SCALE - ALPHANUMERIC ONLY
LARGE SCALE - ALSO GRAPHIC CAPABILITIES.

TYPES OF DISPLAY SYSTEMS

Three systems of display have been found in common usage. They are the Stencil or Shaped Beam Display System, the Visual Point Plotter System, and the Painted Beam System. Of the three systems only two tube types are used.

SHAPED BEAM TUBE

One of the first and easiest methods of placing a symbol on the face of a CRT was the Shaped Beam Display. In this method the name means exactly what it says. The particular character or symbol desired was formed by forcing a loosely focused beam through a stencil of the character or symbol. In this manner the beam takes the shape of the character or symbol and through additional deflection hardware is placed in the proper position on the face of the tube.

CONSTRUCTION

In external appearance the shaped beam tube resembles any other type CRT with the exception of a longer neck. This is to accommodate the recentering coil and extra deflection hardware.

The difference between a shaped beam tube and a standard CRT lies in internal construction. The cathode, control grid, focus and acceleration anodes, and the first deflection plates are similar in the two tubes. At this point in a shaped beam tube a new element is inserted and the neck lengthened. This new element is a flat, thin metal disk with its flat surface at right angles with the beam path. By means of a photo etching process, a stencil of usually sixty-four characters and symbols is formed in an eight by eight matrix in this disk. The disk is approximately the size of a half dollar but the entire matrix only occupies an area of about a half inch square. From this you could gather that the characters are very small and would require magnification to view. This magnification does occur due to the normal spread of the beam in its travel to the face of the tube.

OPERATION

The stencil is between two deflection areas. The first area of deflection encountered by the beam is used to select the proper character. The sixty-four characters and symbols could be represented by an octal code of ØØ through 77. By placing the characters and symbols in an eight by eight matrix, each row could be selected much in the same way as an address in a core memory. Figure 1-2 shows a typical matrix and character codes. As you will observe, the horizontal rows are selected by digit and the vertical columns by the second. You should also note that the codes for the alphanumeric, standard punctuation marks and symbols for selection of positions on the matrix have been derived from translation from internal BCD.

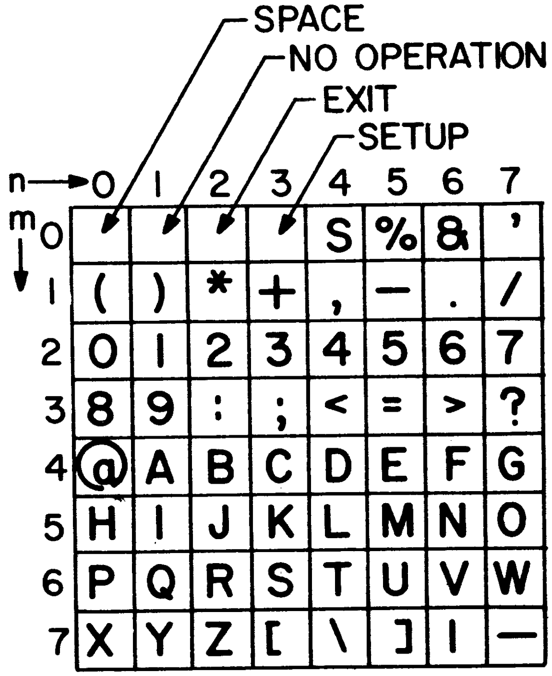



FIGURE I-2 SYMBOL MATRIX

DOT MATRIX 5X7
7X9

Refer to Figure 1-3 for the following discussion. With a character code of ØØ all H---- and V---- terms are in the clear state. L1-0 and L2-0 will have grounds on the corresponding resistors. S200 and S100 will have ground out also, while S201 and S101 will have a high positive potential out. This will draw the beam to the upper left corner of the eight by eight matrix as indicated by the X. As the horizontal and vertical sections are identical only the horizontal will be discussed at this time. It can be readily seen that by setting and clearing the appropriate flip-flops (H1----) to correspond with an octal digit of the character code, eight distinct resistance values could be obtained to feed the S10-terms. If these eight distinct values of resistance were used to shunt a negative bias voltage to ground, the S10-terms would have eight distinct output voltages. These could range from near ground to some high positive potential. As the value of the octal digit increases so does the amount of negative bias shunted to ground. Therefore the output of S101 would approach ground as it conducted heavier. S100 in turn would conduct less and its output would move toward a higher positive potential, thereby attracting the beam toward the H2 plate as the H1 plate now has less attraction. In this manner eight distinct locations could be selected horizontally on the stencil matrix. Assuming this to be also true in the vertical circuits all sixty-four locations could be selected in this manner.

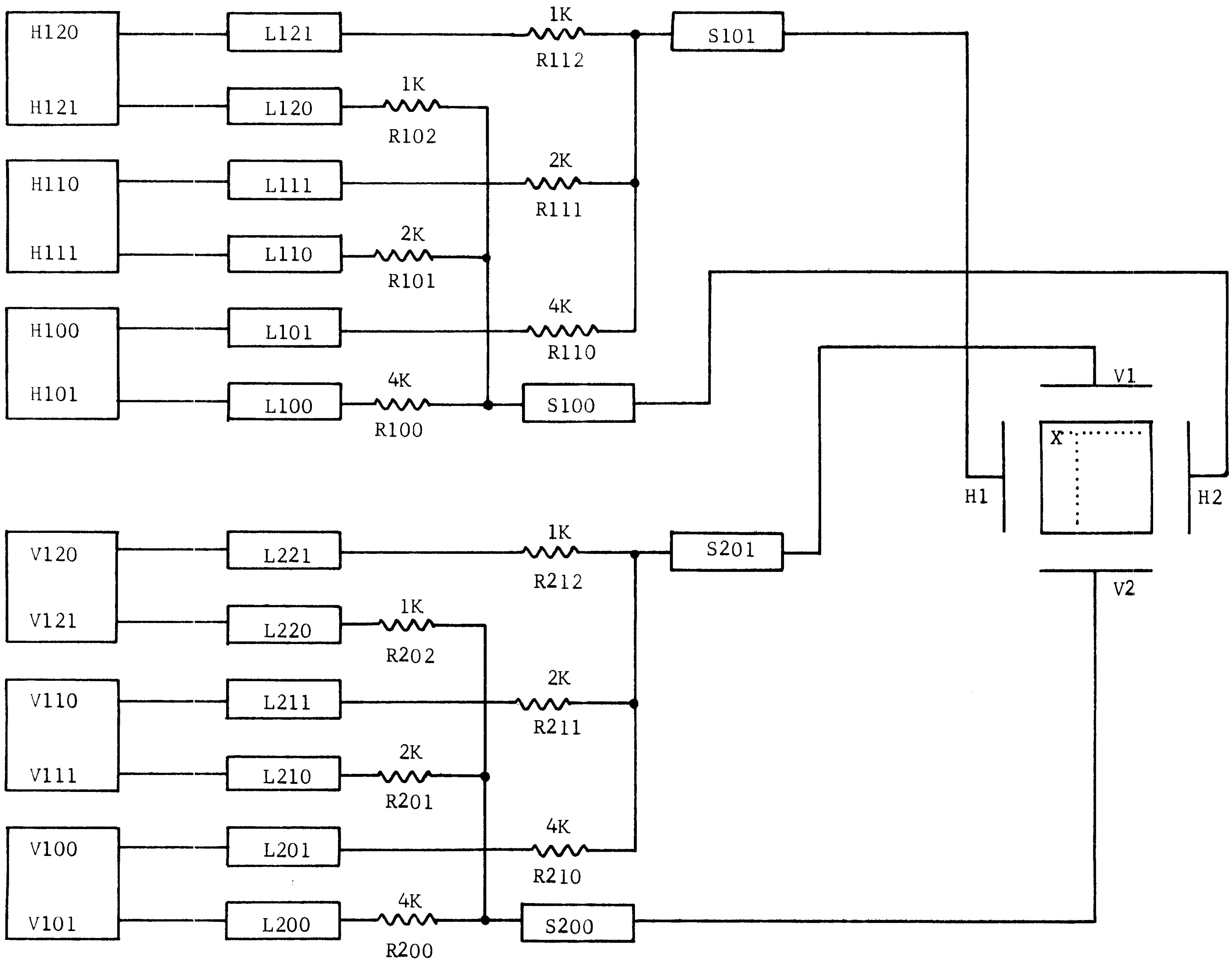



Figure 1-3. Character Selection

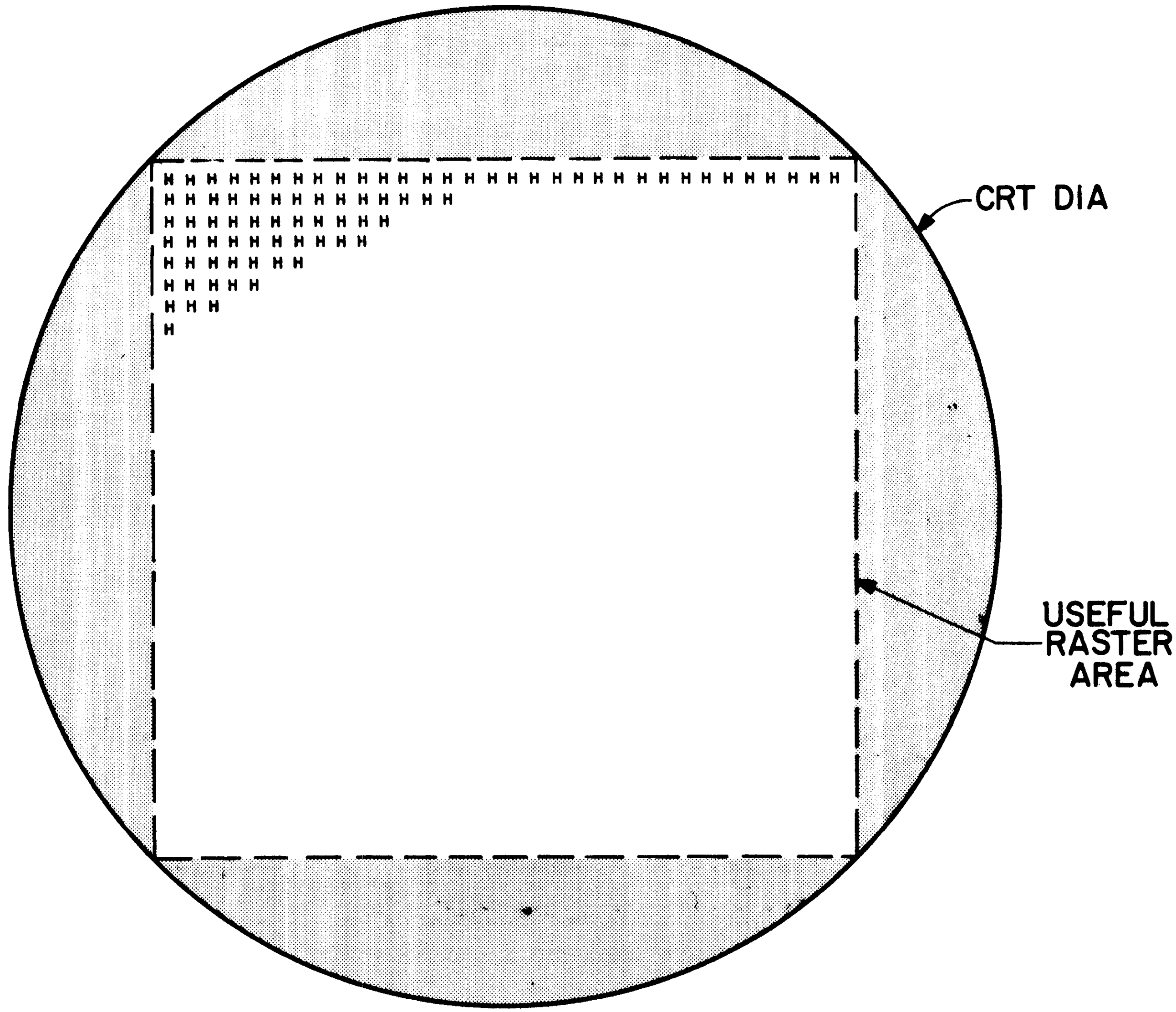



Figure 1-4.  Useful Raster Coordinate System

After the character selection is made and the beam turned on the shaped beam moves into the area of the recentering coil. This coil does exactly as the name implies. It brings the shaped beam back into the center of the tube so that compensation will not be needed because of character selection displacement. In this manner the base positioning plates always see the beam at the same place. One fault of this system is the rotation that is imparted to the beam while it is in the field of the coil. The longer the beam is in the field the greater the rotation. With a dot this is no problem but with a shaped beam you would have characters lying on their sides. To compensate for this the matrix is rotated 90° from vertical and the coil width is such that the beam is turned upright again.

At this point the beam enters the base positioning deflection platex/coils. With similar circuitry as that used in character selection the beam can now be placed as desired on the face of the tube. It should be noted that although the circuitry is similar, it is much more intricate. Figure 1-4 demonstrates the raster area of the CRT and a test portion of display symbols. Figure 1-5 illustrates CRT addressing which will be discussed in a later section.

Vectors or lines are similarly drawn in all systems. As we will go into them in great detail in a later chapter we will not discuss them here.

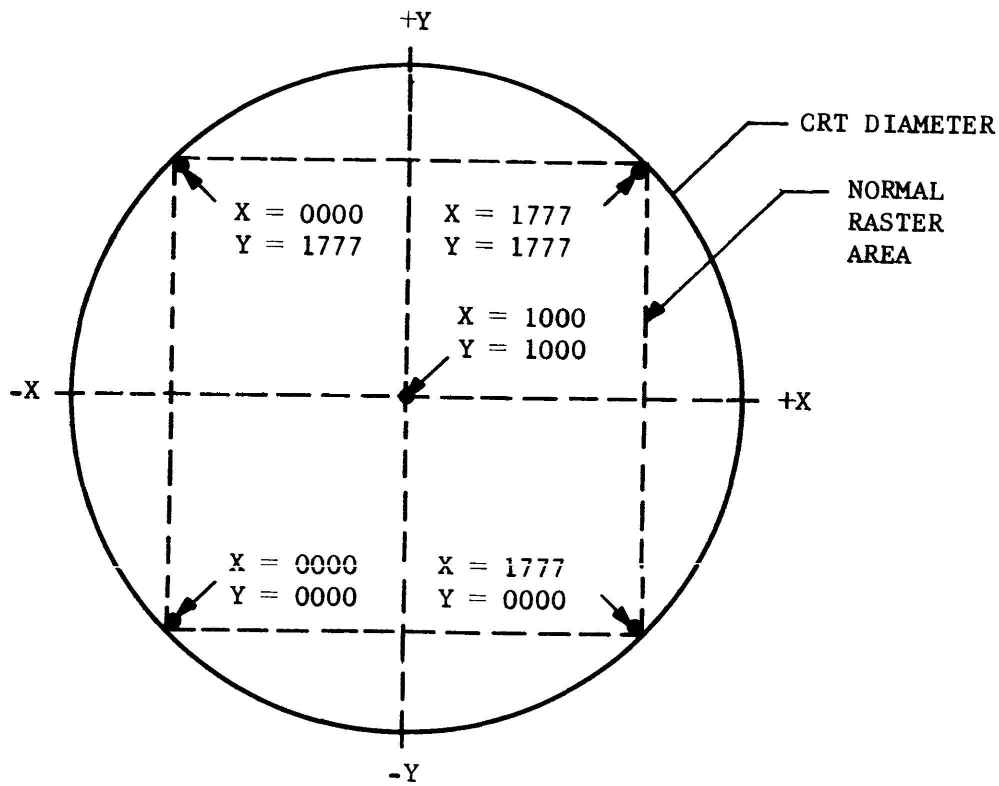



Figure 1-5. Base Positioning Coordinate System

25

272 / 274 { DIGIGRAPHICS CONSOLE TO 6K 7K

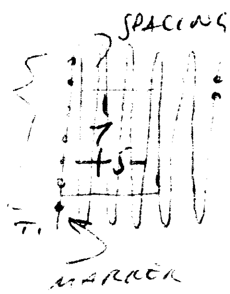
POINT PLOT SYSTEM

The second system, that of the Point Plot System, was designed to overcome the disadvantages of the Shaped Beam Display. By programming ten bit horizontal and vertical coordinates a dot of light was displayed on the face of the CRT. By careful and intricate programming a series of dots could form any size or shape of character or a line could be drawn. The only limitation to this system was the size of the program required for a detailed display.

PAINTED BEAM DISPLAYS

The Painted Beam System, the most widely used, overcame all the disadvantages of previous systems at the cost of more hardware. The additional cost though is offset by not requiring a special CRT with a stencil and savings in programming. The Painted Beam Display relies entirely upon analog signals for painting of characters. The face of the CRT is divided into a coordinate grid pattern for positioning purposes and the grid pattern is divided into letter matrix blocks consisting of 7 X 7 or 9 X 9 or 14 X 14 grid pattern blocks. Each character is then constructed by individual CRT beam movements generated by a timed diode matrix which will be discussed later in greater detail. The remaining chapters in this manual cover the entire display with the same detail.

DOT MATRIX




200 NS TIME INTENSIFIED FOR 100 NS

2 DIDDLE PULSES BETWEEN CHARACTERS

TIMING INCORRECT:
HORIZONTAL ON BLANK SOLID LINE ACROSS SCREEN
OR BLANK SOME CHARACTER MISSING

TIMING FOR EACH LINE GIVING PULSES
AND TIMING 1-10 FOR EACH PULSE
X COUNT LINES CHARACTER
Y COUNT LINES

1.0 µs

12 µs / character

DOT
STROKE
SCAN
LISSAJOUS

## BASIC DISPLAYS COURSE
## HOMEWORK QUESTIONS

1. What are the standard sizes of CRTs used with display monitors?

   SEE 1-10

   7X7" 14" 19"X22"

2. What process would be followed when operating in the line printer mode?

   COPY WOULD BE MADE ON PRINTER FROM CRT

3. What process would be used within the plotter mode of operation?

4. Give the control word configuration for the line printer mode; plot symbol.

5. What would be the maximum capability of plotting points with 11 bits of x and y positioning words?

6. What would be the maximum number of characters available with a 6 bit character code?

7. What is the purpose of display regeneration?

8. List the advantages of design by computers.

9. Describe the selection and painting of a symbol in a shaped beam tube.

10. Decreasing unblanking time would have what effect on the display of a symbol on the shaped beam tube?

# SECTION II

## SECTION II

## UNIT MONITOR

The unit monitor, or display station, is the basic functional element of the display system. Its function will vary from that of the compact Control Data 211 (Figure 2-1) to that of the 250 or 280 (Figure 2-2), performing either simple data retrieval and input via a typewriter keyboard and display, or the very complex functions of design augmentation. In any display unit monitor, however, certain basic rules of construction must be adhered to.

The unit monitor will consist of a cathode ray tube, either very small, as in the case of microfilm recorder monitors, or 22 inch and larger CRTs used in design and plotting applications. Actual application will be treated to a greater extent in Chapter III of this manual.

In addition to a CRT, the unit monitor will also have the necessary associated circuitry - two high voltage power supplies, powerful deflection amplifiers, high voltage division for the purpose of supplying the proper voltages to the CRT, etc. Each of these components will be treated in turn.

### CATHODE RAY TUBE

The CRT is the basic element of display equipment. It is through the CRT that the visible display is produced; and through digital and analog display control circuitry, meaningful presentation is obtained.

The CRT may be divided into its functional units - the electron gun; the enclosure, or tube itself; the shaping and deflection control; and intensity and display screen.

Extreme caution should be taken when working with the cathode ray tube. Due to the evacuation of air from the tube, atmospheric pressure over the entire surface reaches several hundred pounds. Jarring, scratching, or even sudden changes in temperature (thermal shock) may result in implosion of the tube and serious injury. The CRT should always be stored in suitable containers and transported, removed, and replaced with caution.

The high voltage system of the CRT utilizes lethal voltages. Take extreme caution when checking voltages within the CRT cabinet. Before touching components within the high voltage supply, power should be removed and the outputs discharged.

Figure 2-3 illustrates a typical cathode ray tube of the type used in display monitors. The electron gun, emitting a stream of electrons, consists of the heater and cathode, the control grid, focus anode and accelerating anode. All voltage application to the CRT are through a jack arrangement at the base of the tube with the exception of the aquadag, or post accelerator voltage applied to a connector on the side of the tube. A high voltage applied to the heater

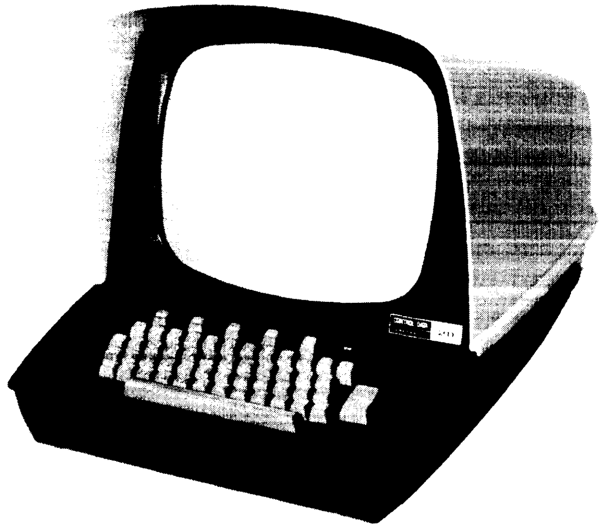


Figure 2-1. Control Data 211, Entry Display System

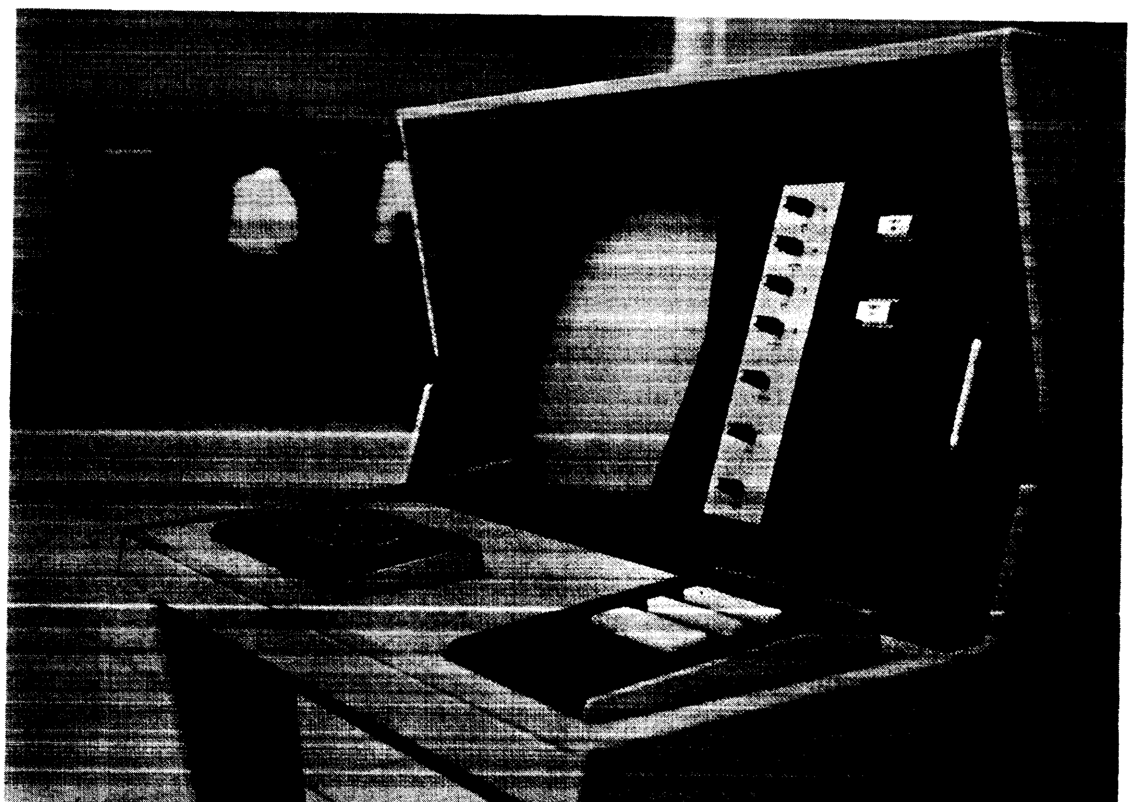


Figure 2-2. Display Monitor, Control Data 250

filament emits electrons from the cathode. These emitted electrons are shaped into a stream and passed through a hole in the center of the control grid. The voltage potential on the control grid is adjustable by a control on the display monitor called intensity. Any symbol to be displayed would be "unblanked", that is intensified, by a positive pulse of a specific duration and amplitude being applied to this grid.

Emitted electrons are accelerated by the focusing anode and further accelerated by the accelerating anode. The focusing anode potential in conjunction with the accelerating anode serves to bring the electron beam down to a small diameter as it approaches the face of the CRT. The action of the focusing anode may be compared to that of a focusing lens in a movie projector, acting in opposition to the natural spread of the electron beam. The accelerating anode serves to further accelerate the electrons toward the face of the CRT and to control the shape of the beam, attempting at all times to produce a circular beam.

Upon leaving the accelerating anode the normal tendency of the electron beam is to bombard the center of the CRT screen. Due to the phosphorescent property of the coating on the screen, a dot will appear which may be varied in intensity by the intentensity potentiameter, usually found on the unit monitor control panel, in size and clarity of the focus control, and in shape by the ostigmatism control.

Different CRTs are rated according to the amount of control which may be obtained over the electron beam. Generally, consideration is given to resolution, the ability to distinguish between points displayed, and persistency which, as has already been discussed, affects the final display by determining the need for a given regeneration rate.

The position at which the electron beam strikes the face of the CRT is controllable by the deflection control circuits. Figure 2-4 illustrates electrostatic deflection, ie., movement of the electron beam by means of an electric field generated by two sets of deflection plates, X and Y, each of the plates of a set having opposite polarity of applied voltage. The other alternative of deflection control is electromagnetic deflection, utilizing external coils attached around the neck of the CRT. An electric field is set up by the coils, allowing control of the position of the electron beam. Here, the construction of the CRT itself becomes simplified. Both electrostatic and electromagnetic deflection may be found in commercial display equipment. Analog voltages, varying over the scale necessary to obtain full raster coverage, will be applied to these X and Y deflection inputs, controlling the display that is observed and allowing display of vectors and symbols in the nanosecond range.

If at any time only a bright dot appears at one point on the face of the CRT the intensity control should be immediately turned down. Otherwise, the electron beam will burn through the phosphor. It is generally good practice to power up and power down with the intensigy set at the minimum level.

Dust and humidity, unless properly controlled, may cause problems such as arcing from one element to another or to ground in the monitor.

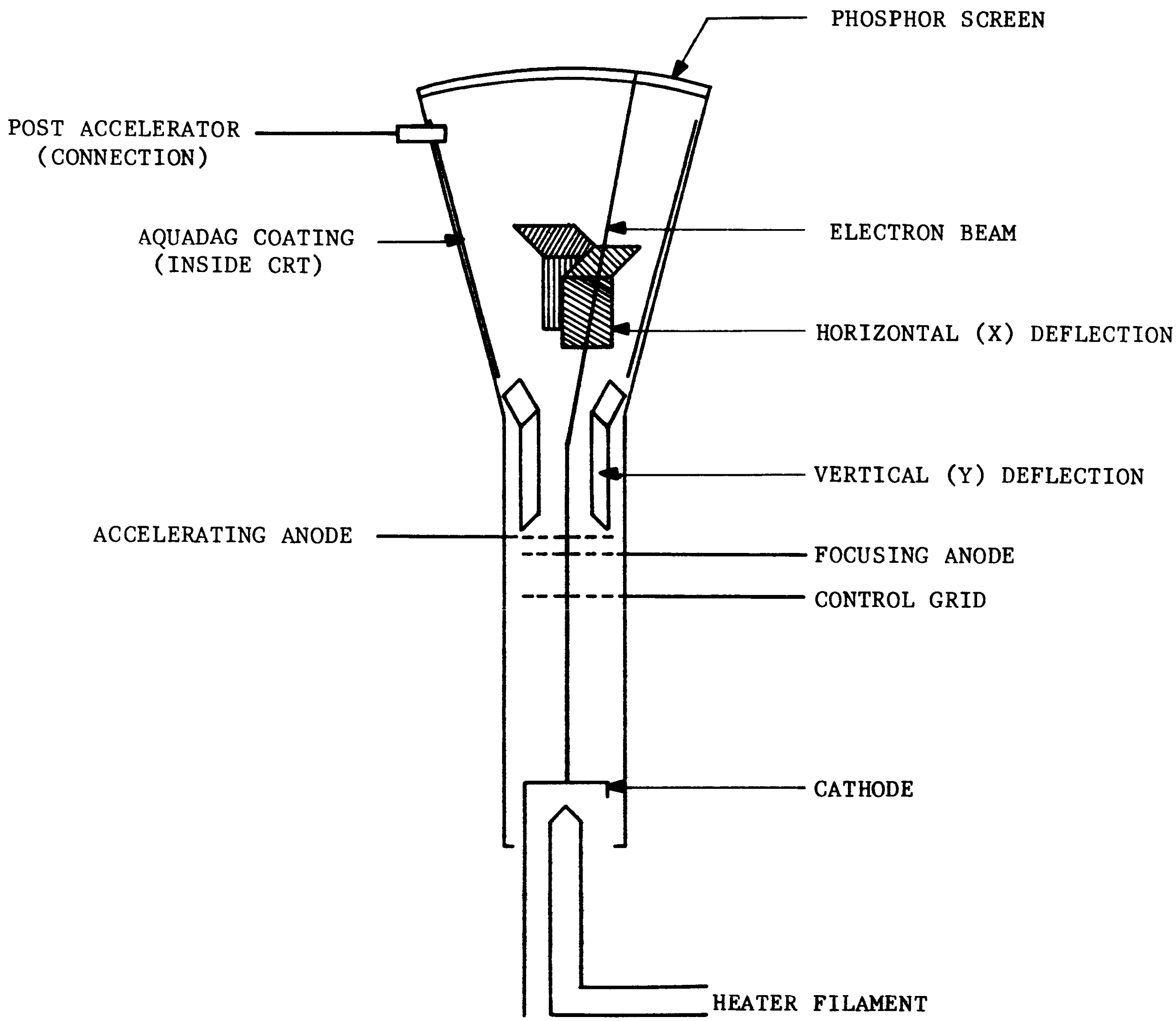



Figure 2-3. Basic Cathode Ray Tube

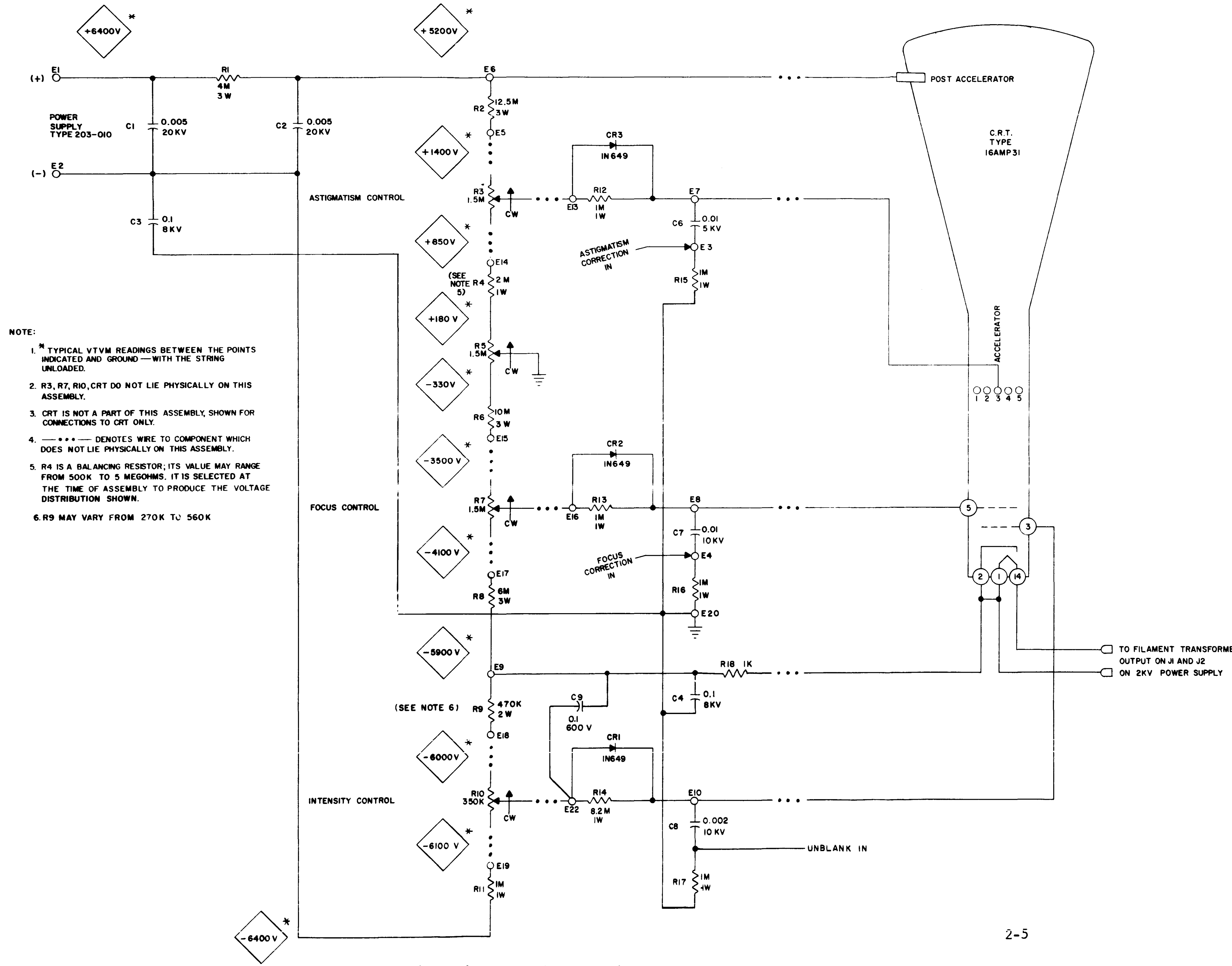





Figure 2-4. Schematic Diagram Voltage Divider

## HIGH-VOLTAGE DIVIDER

Capacitors, fixed resistors, and variable resistors compose the high-voltage divider. The variable resistors are potentiometers located on a panel most frequently referred to as the CRT panel. The controls provide a means of manually adjusting astigmatism, focus, and intensity voltages. Another variable resistor, mounted on the shield of the high-voltage system case, provides a means of adjusting the relationship between the accelerator voltage and the deflection plates. All the high voltage resistors in the voltage divider are delicate and require careful handling.

A resistance-capacitance filter, connected between positive and negative terminals of the high-voltage divider, reduces high-voltage ripple to a level low enough to prevent flickering of the CRT image. The high-voltage supply must provide 1 to 2 kv more than is needed by the CRT to compensate for the voltage drop produced by the current passing through resistive elements of the filter.

The voltage-divider network contains three coupling capacitors. One of these couples the unblank voltage to the CRT control grid, one couples the focus correction voltage to the focus correction grid, and the third couples the astigmatism correction voltage to the accelerator electrode. Unblank circuitry operates at the highest difference of potential; ie, the grid is the electrical point in the CRT furthest from the ground potential. The coupling capacitor, which couples the unblank voltage into the CRT, is the most critical capacitor in the high-voltage divider. A dc restorer circuit, consisting of a diode and a resistor located between the intensity control and the unblank voltage inputs, returns the ac coupled unblank voltage system, the level determined by the INTENSITY control. In a typical high-voltage system, the unblank coupling capacitor has approximately 5 kv to 10 kv between terminals.

A schematic diagram of the high-voltage network for a specific unit monitor is included in the Customer Engineering Manual supplied with the unit. Figure 2-4, Schematic Diagram, Voltage Divider illustrates one treatment of voltage application to the CRT. Voltages applied will differ from unit to unit according to circuit needs.

Extreme caution should be taken when working in the area of the high-voltage divider. For test equipment protection a high-voltage probe should always be used when connecting the oscilloscope to the output of the focus and astigmatism amplifier or to the input of the high-voltage divider. The high voltage should always be removed at the control panel before connecting a probe to any point in this area.

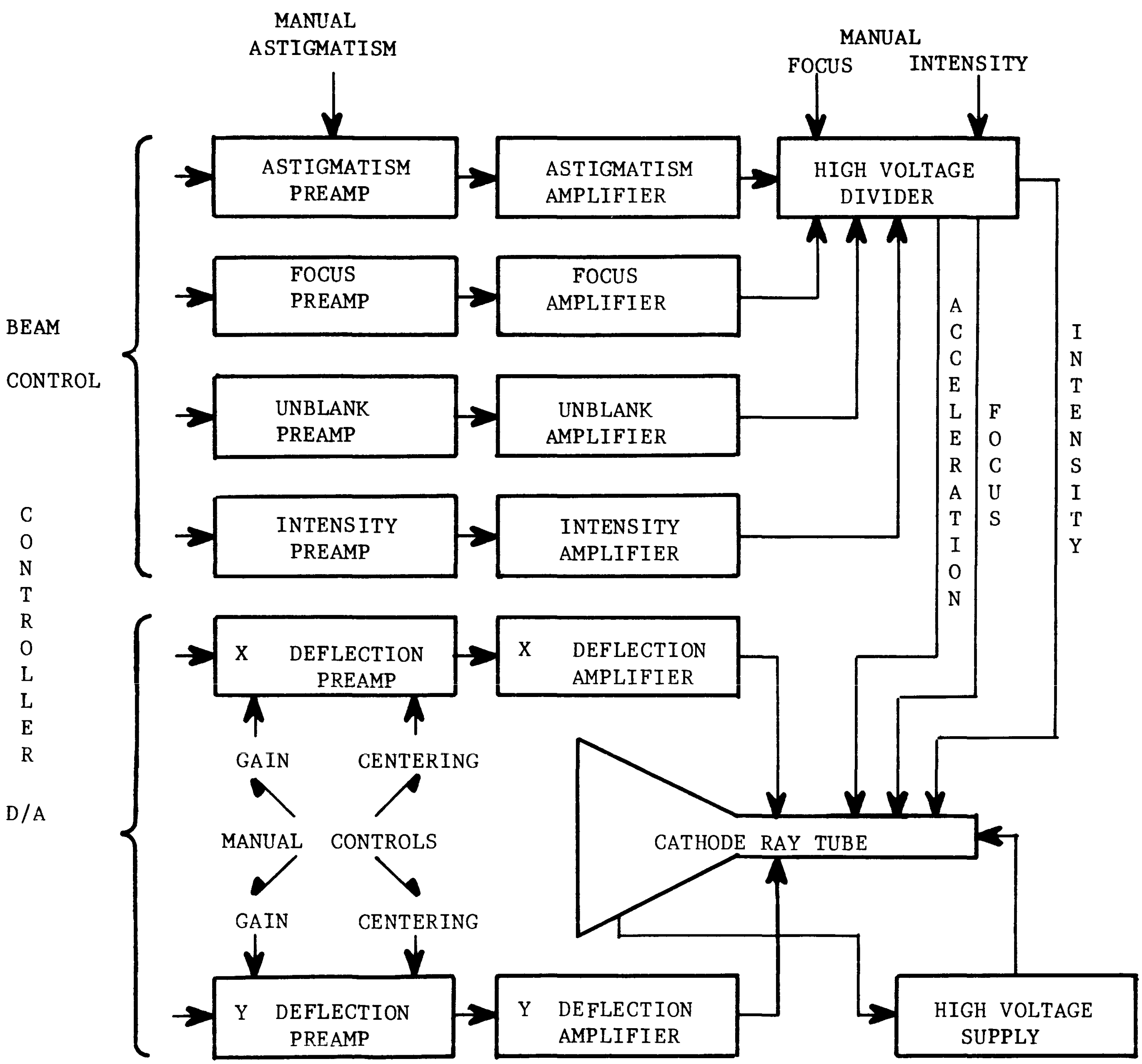



Figure 2-5. Unit Monitor Block Diagram

DEFLECTION CIRCUITRY

The deflection preamplifier and the deflection amplifier furnish voltages necessary for deflecting the CRT beam. Four deflection levels are applied to two 029 deflection preamplifier cards (Figure 2-6). Each 029 card contains two separate circuits, one for X or Y plus deflection and one for X or Y minus deflection. The four amplified deflection levels are sent to the four inputs to the push-pull deflection amplifier. Each deflection amplifier is a three-stage, balanced vacuum tube network. Vacuum tubes must be used because of the high voltages involved. The output tubes are beam power tetrodes, the plates of which are directly connected to the deflection plates of the CRT.

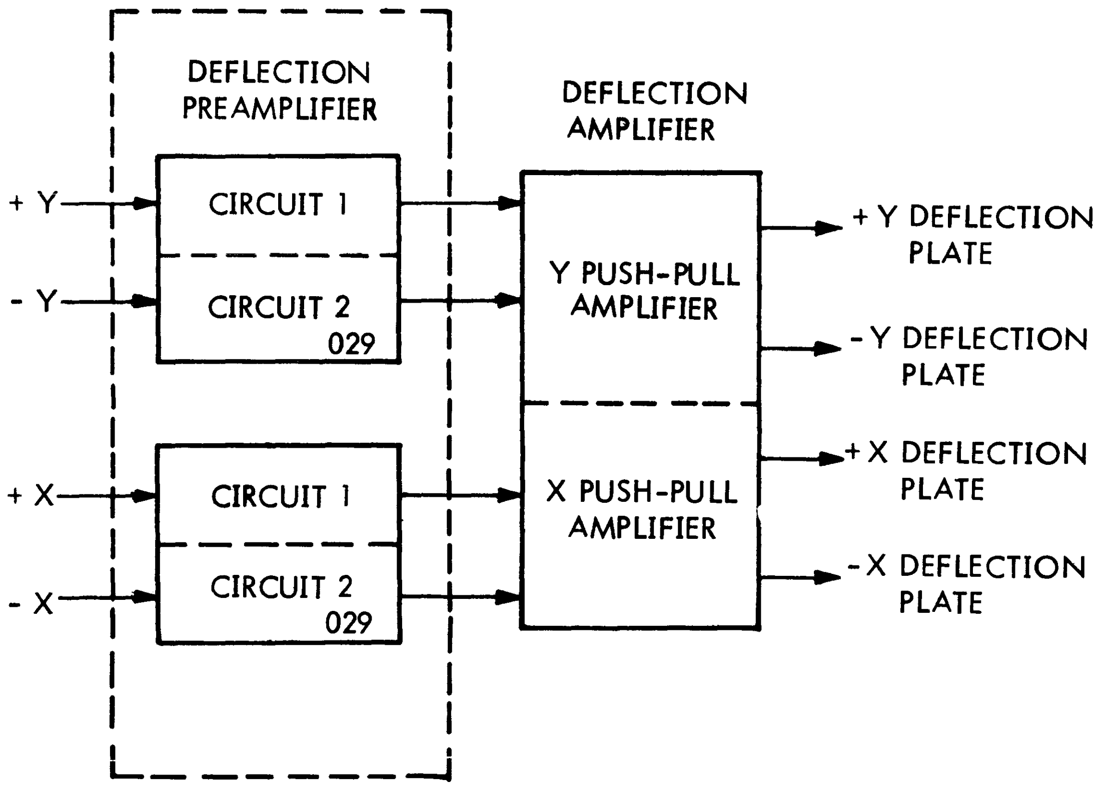



Figure 2-6. X, Y Deflection Network

## Deflection Preamplifier

As mentioned, two 029 deflection preamplifier card types are required in the deflection network with each card containing two identical circuits. One 029 card contains the circuitry for X, and the other, circuitry for Y. Looking at the schematic of an 029 card in Figure 2-7, it is readily seen that each circuit is a three-stage, dc, high-gain amplifier. A variable current level input produces a variable voltage level output, which is fed to the input of the push-pull deflection amplifier.

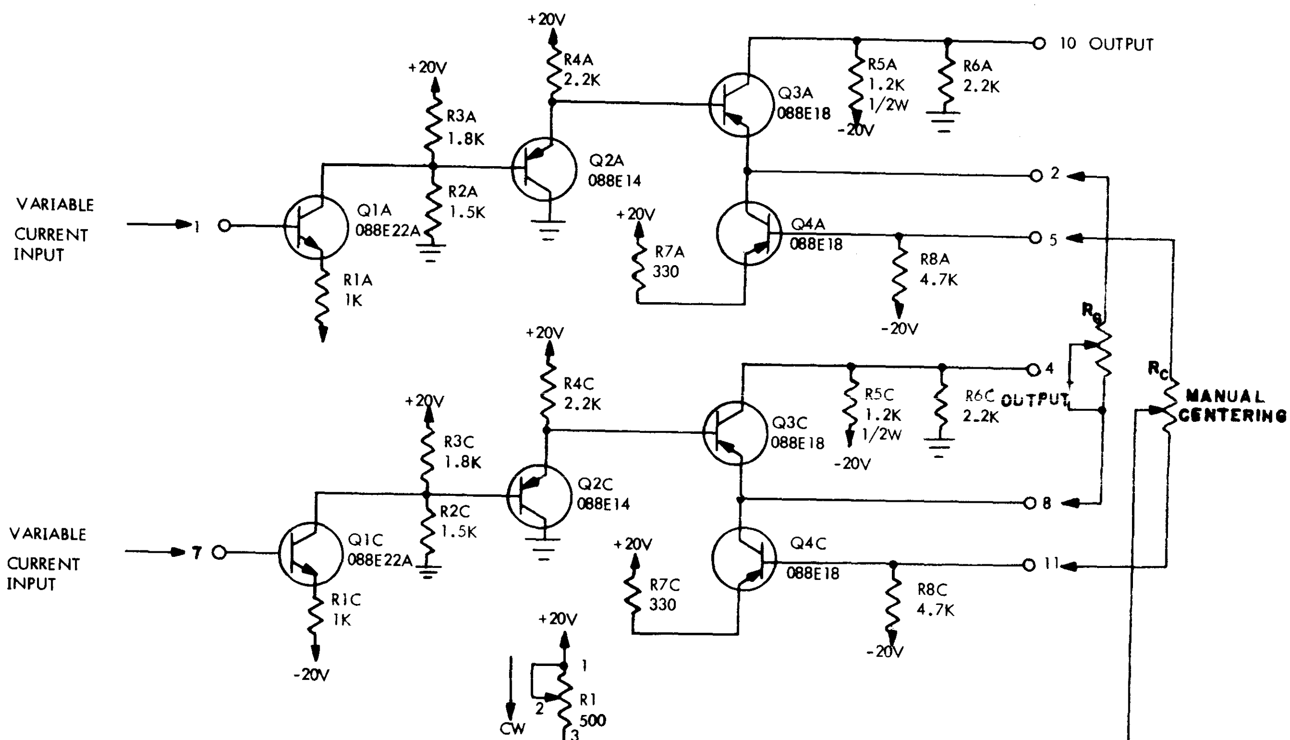



Figure 2-7. 029 Card - Deflection Preamplifier

Assume the X and Y position registers contain coordinates to position the beam at the center of the CRT. Using the Y deflection signal as an example, pins 1 and 7 of the 029 card receive equal analog signal input levels from the +Y and -Y line drivers, respectively. Each signal is amplified equally through its respective network and the resulting outputs at pins 4 and 10 are equal.

NOTE

Manual controls are provided to compensate for any differences in circuit components which might produce an unequal output for this condition.

The +Y and -Y outputs from the deflection preamplifier are further amplified by the deflection amplifier and then applied directly to the two Y deflection plates. Since the same deflection voltage level is applied to both +Y and -Y for this condition, there is no difference in potential between the two Y deflection plates. Applying the same analysis to the X deflection signals, there is no difference in potential between the X deflection plates and the beam is positioned at the center of the CRT screen.

Assume now the beam is to be moved to a new coordinate position in the +Y direction, the inputs to pins 1 and 7 of the 029 card become unequal because of inequality of the X and Y position registers. One output is pushed more positive and the other pulled more negative. The result following final amplification and transmission is a difference in potential between the two Y deflection plates which tends to move the beam to the new positive position.

Manual Gain Control

The 029 card has inputs from manual gain control on pins 2 and 8 as shown in Figure 2-7. Since there are two 029 cards, there is manual control for both X and Y gain.

Assume it is desired to increase the Y gain. For maximum gain the resistor Rg (Figure 2-7) is shorted out. As resistance is added to the emitters of Q3A and Q3C, the output level of the third stage decreases causing both +Y and -Y to contract on the CRT.

Manual Centering Control

The 029 card also has inputs from manual centering control on pins 5 and 11. There is both an X and Y centering control to move the entire display on the CRT.

The manual centering control is a voltage-divider network with Rc (Figure 2-7) tapped in the middle, the base of Q4A and Q4C are biased equally. Changing the voltage-divider action by moving the tap to a new position on Rc causes the transistor receiving the lower voltage from Rc to conduct less because of a decrease in negative bias at the base. The other transistor receives more voltage from the voltage-divider and, its base becomes biased more negative causing it to conduct more current. If Q4A is the transistor receiving the lower voltage from Rc, the decrease in conduction also causes Q3A to decrease its conduction, thus, resulting in a lower level output at pin 10. Since Q4C conducting more current, Q3C conducts more, and the output at pin 4 increases. The final result is a total shift in one given direction.

The control coming off pin 12 (Figure 2-7) is an overall centering control and its adjustment determines how great an effect the manual centering control has.

### Deflection Amplifier

Outputs from the two X preamplifier circuits and two Y preamplifier circuits feed an X and Y push-pull deflection amplifier, respectively. Figure 2-8 is a schematic diagram of the deflection amplifier network for a 19-inch diameter CRT. It consists of four identical three-stage amplifiers having the two X amplifiers connected in push-pull and the two Y amplifiers connected in push-pull.

Output signals from the preamplifier enter the respective X and Y push-pull circuits at the control grids of the A side of the dual triode amplifiers, V1A, V4A, V7A, and V10A. The B side of each dual triode input is connected in parallel with the A and B sides of its respective second-stage dual triodes for high-power amplification. Outputs resulting from the amplification accomplished by each of the three triodes in parallel go to the control grid of their respective beam power tetrode (V3, V6, V9, and V12). The cathodes of the two tetrodes receiving input signals from the X deflection circuitry are tied together, and the cathodes of the two tetrodes receiving signals from the Y deflection circuitry are tied together, thus, creating a push-pull effect at the output. The four outputs from the tetrodes feed directly to the X and Y CRT deflection plates.

## UNBLANK CIRCUITRY

Unblank voltages developed in the unblank control logic determine the rate of conduction by the unblank amplifier. Output of the unblank amplifier enters the high-voltage divider through the coupling capacitor to the control grid circuit. The intensity control, normally located on the CRT control panel, provides base control reference which, when the unblank amplifier is not operating, causes the electron beam to excite the phosphor. The phosphor then emits light at the normal intensity level determined by the setting of the intensity control. When the unblank amplifier conducts completely, the control voltage is lowered to the point that the beam is not strong enough to cause the phosphor to emit light. Varying the rate of conduction of the unblank amplifier causes a variable intensity by changing the bias of the control grid. Figure 2-9 is a block diagram of the unblank network.

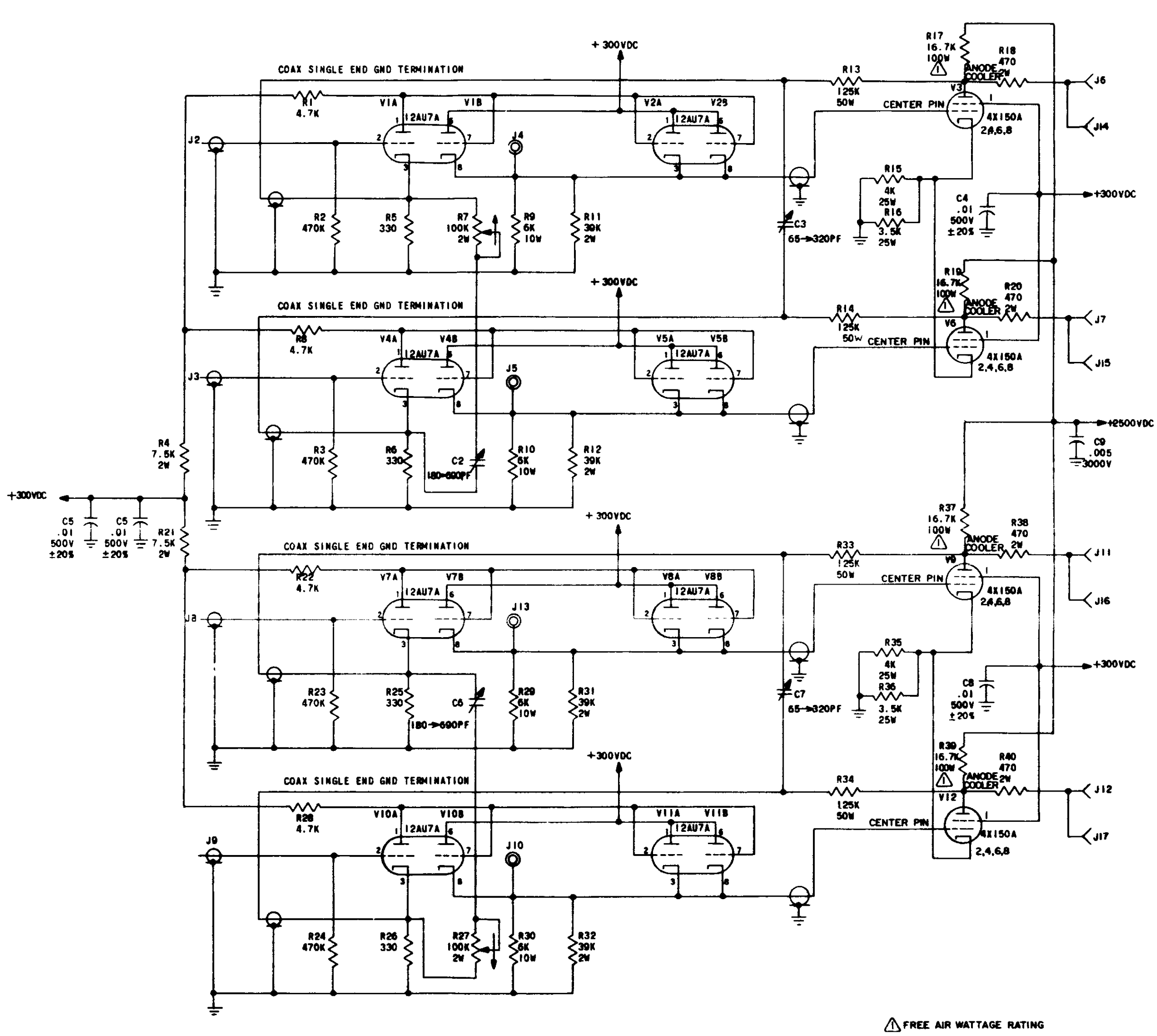


Figure 2-8. 19-Inch CRT Deflection Network

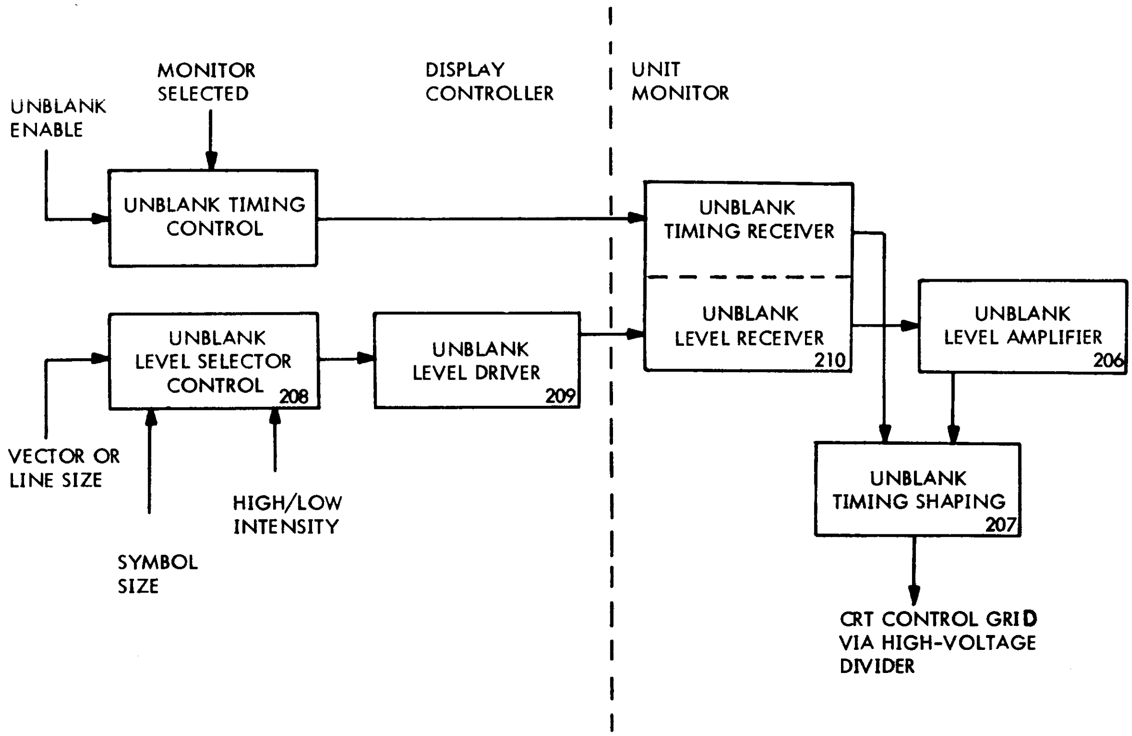



Figure 2-9. Unblank Network Block Diagram

UNBLANK CONTROL LOGIC

Although the unblank control logic is not located in the unit monitor, it is included in this section to further tie together the principles of the CRT beam intensity control.

Many equipments can display symbols and lines or vectors at two different intensity levels - normal and high. Besides the two intensity levels, each symbol size and each line or vector group has a separate intensity control. And then, of course, the CRT screen can be completely blanked or unblanked for a controlled interval of time. There are, thus, many factors controlling CRT beam intensity.

Shown in Figure 2-10 is the intensity control logic associated with an equipment capable of displaying vectors and four different symbol sizes: miniature, small, medium, and large. Setting the intensity FF enables symbol and vector inputs to Q202 and Q203, respectively. These two 208 cards are used for high intensity control in this example. Q200 and Q201 are enabled when the intensity FF is clear and are used for normal intensity control.

A 208 card contains four identical circuits having the outputs of each tied together (Figure 2-11). The outputs of all four 208 cards are then tied together and feed an unblank line driver. Since only one symbol size or vector length can be enabled at one given time, only one unblank level signal can be sent at a given time.

Assume a medium normal intensity symbol is to be formed on the display screen. J235 and J202 input a logical 1 to pin 7 of Q200. A -3-volt input on pin 7 of a 208 card (Figure 2-11) causes Q3 to conduct and produce an output voltage level determined by the setting of the output voltage-divider network (R12). This signal is then sent to the unblank amplifier network.

Note that a -3-volt input on any one of the remaining input pins (1, 4, or 10) produces the same action as described in the preceding paragraph; only a different transistor and voltage-divider network is excited for each input pin. Each symbol size and vector group has its own voltage divider intensity level control. There are maintenance adjustments only.

The output from the 208 unblank selector is fed to a 209 unblank driver which converts an unblank level current to a coaxial driving current. Up to six monitors can be driven from one 209 card (Figure 2-12). Q1 is a low impedance input driving a feedback amplifier, Q2 and Q3.

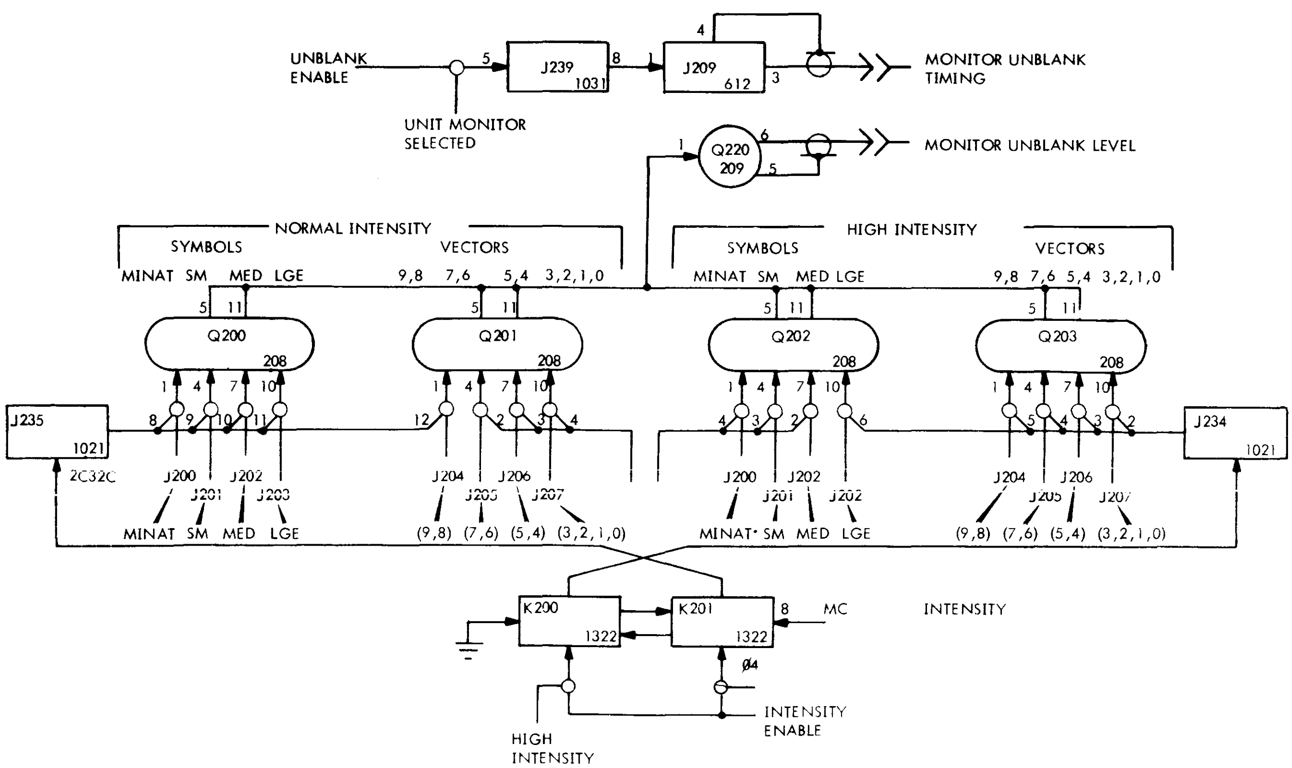



Figure 2-10. Intensity Control Logic

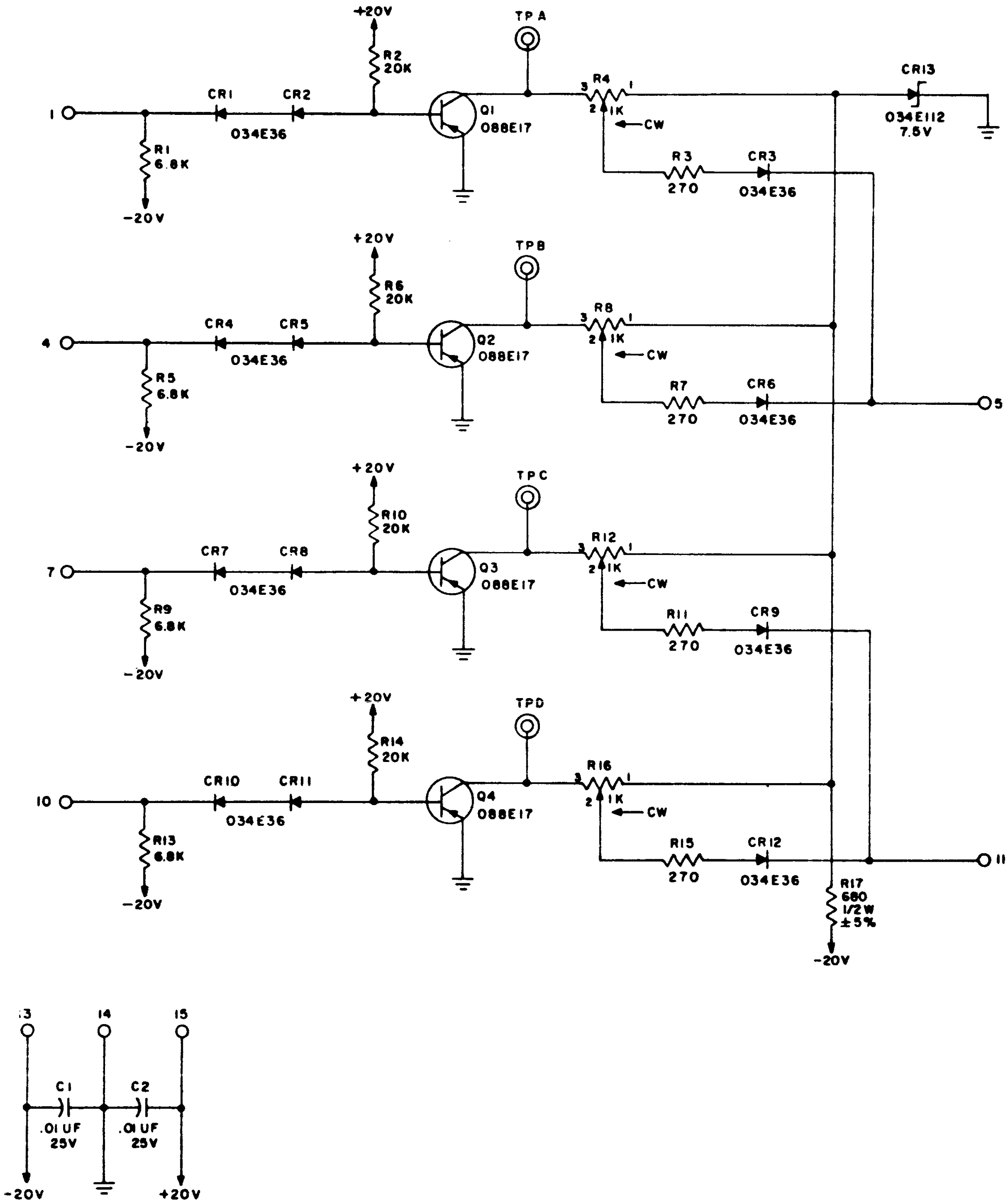



Figure 2-11. 208 Card - Unblank Level Selector

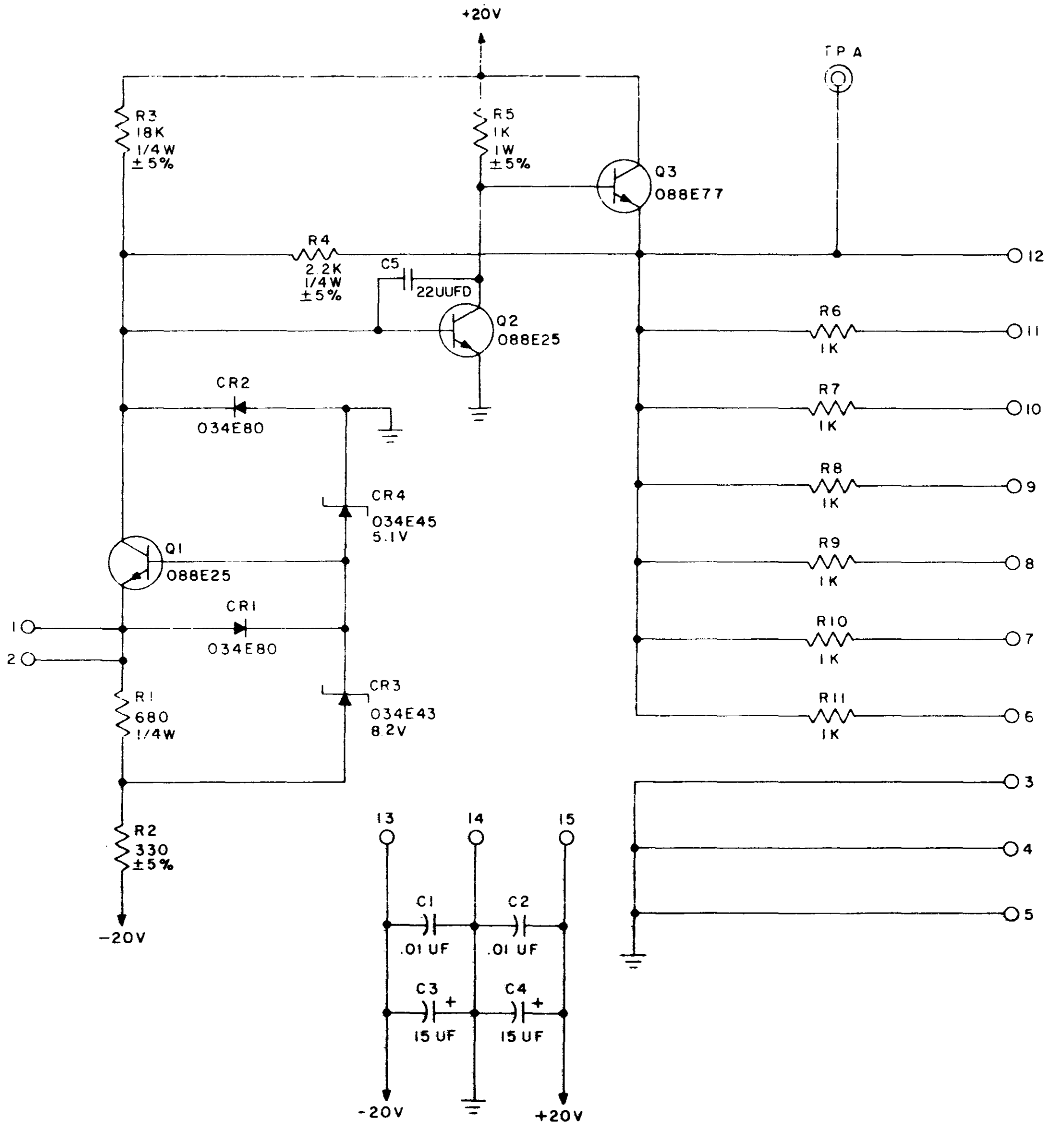



Figure 2-12. 209 Card - Unblank Level Driver

Q1 is originally conducting and places a -5.2 volts on pin 2. The -5.1 volts at the base of Q1 is maintained by zener diode CR4. An increasing input current amplitude causes Q1 to conduct less, and the voltage drop across R3 decreases. The base of Q2, now being more positive, conducts and the voltage drop across R5 increases. The base of Q3 becomes more negative and conduction decreases. The voltage across R6 through R11 produces a current which is the coaxial driving current.

UNBLANK LEVEL AND TIMING RECEIVER.

The unblank level and timing receiver, tape 210 card, contains two circuits. Circuit 1 (Figure 2-13) is used to amplify the coaxial driving current to an unblank level. Q1 and Q2 form a receiver/amplifier. Circuit 2 (Figure 2-13) is used to receive a logical level for timing. Q3 and Q4 form a receiver/inverter. The 210 card is located on the unit monitor.

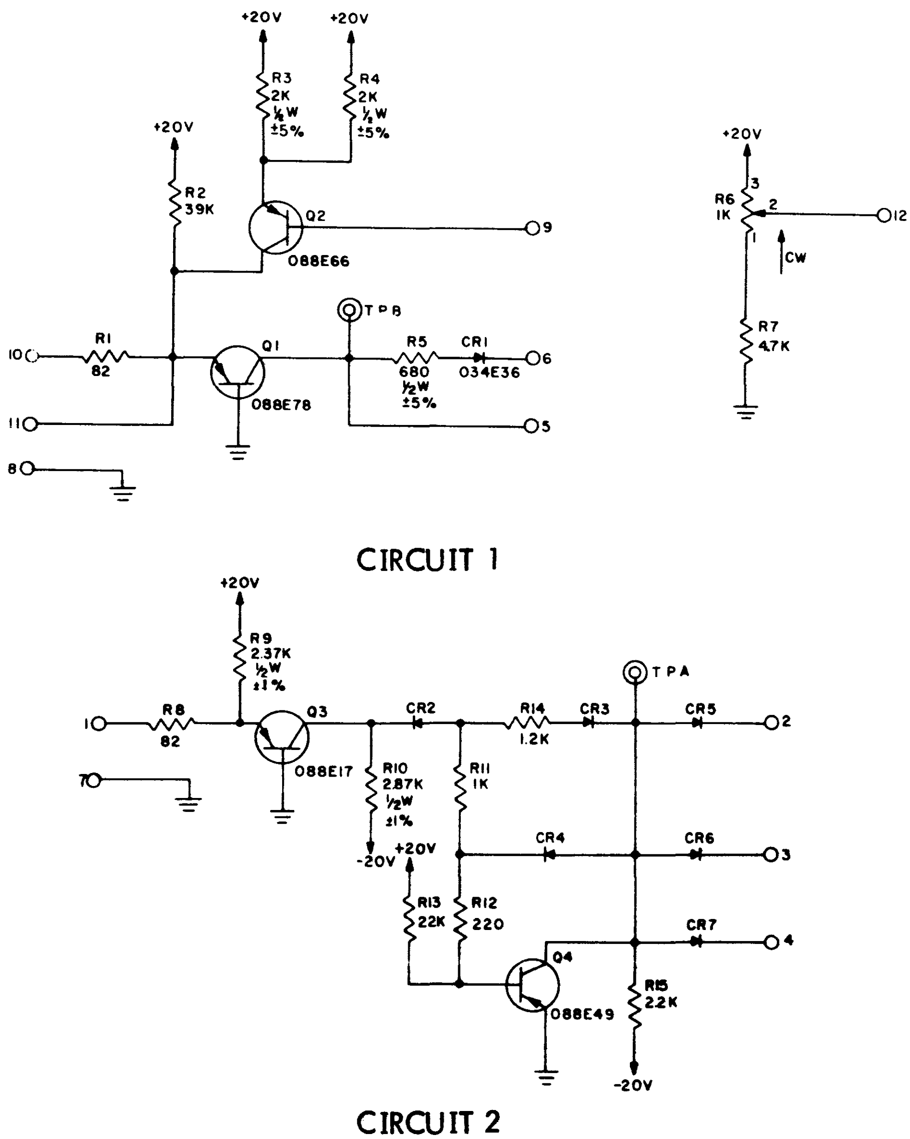



Figure 2-13. 210 Card - Unblank Level and Timing Receiver

Circuit 1

Q1 is a grounded base current amplifier conducting at a rate determined by the potential difference between the emitter and the base. Current flow is controlled by the voltage drop across R2. An increase in current through pin 10 and R1 decreases the conduction rate of Q1. R6, rotated clockwise, increases the intensity.

Circuit 2

Q3 is conducting at a rate determined by the potential difference across it. A negative input level through R8 drives Q3 to cutoff. The potential on the base of Q4 becomes more negative and Q4 starts conducting and a logical 0 (-0.5 volts) is placed across CR7 to output pin 4. When Q3 conducts more, due to a more positive input, Q4 goes toward cutoff lowering the output to a logical 1 (-3.0 volts).

## UNBLANK LEVEL AMPLIFIER.

The unblank level amplifier, type 206 card, converts a preselected unblank level current to a clamping voltage for determining unblank amplitude. Figure 2-14 is a schematic diagram of the 206 card. Q1 and Q2 form a current amplifier with a voltage output. Q3 is an output emitter-follower.

Q1 is conducting at a rate determined by the input signal current, the static current through R1, and the feedback current through R3 and R4. A decreasing input current amplitude drives Q1 towards cutoff and the base of Q2 goes more positive. Since Q2 is an emitter-follower, its emitter also goes more positive. The feedback current through R3 and R4 will increase until the sum of the currents, at the input, equal zero. An increasing current amplitude, at the input, causes Q1 to conduct more, driving the base of Q2 negative. The emitter of Q2 also goes negative, which in turn, decreases the feedback current through R3 and R4. This feedback current decreases until the sum of the currents, at the input, equal zero. In this fashion, the unblank voltage clamping level is varied by a changing input current level. Q3 is emitter-follower connected, providing a low impedance output circuit, serving as the actual output voltage clamp.

## UNBLANK TIMING/SHAPING CIRCUIT

The unblank timing/shaping circuit, type 207 card, enables the timed unblank pulse to the grid of the CRT. Figure 2-15 is a schematic diagram of the 207 card, Pin 11 receives the output voltage generated by the unblank timing receiver circuit (210 card). Q1 and Q3 enable the pulse to be formed and shaped through Q2.

With a logical 1 (-3.5 volts) applied to the base of Q1 through input pin 11, Q1 and Q3 conduct. Conduction of Q3 causes the collector to become negative, keeping Q2 cut off. With Q2 cut off pin 4 goes negative. This negative voltage, applied at the CRT control grid causes the electron beam to be cut off.

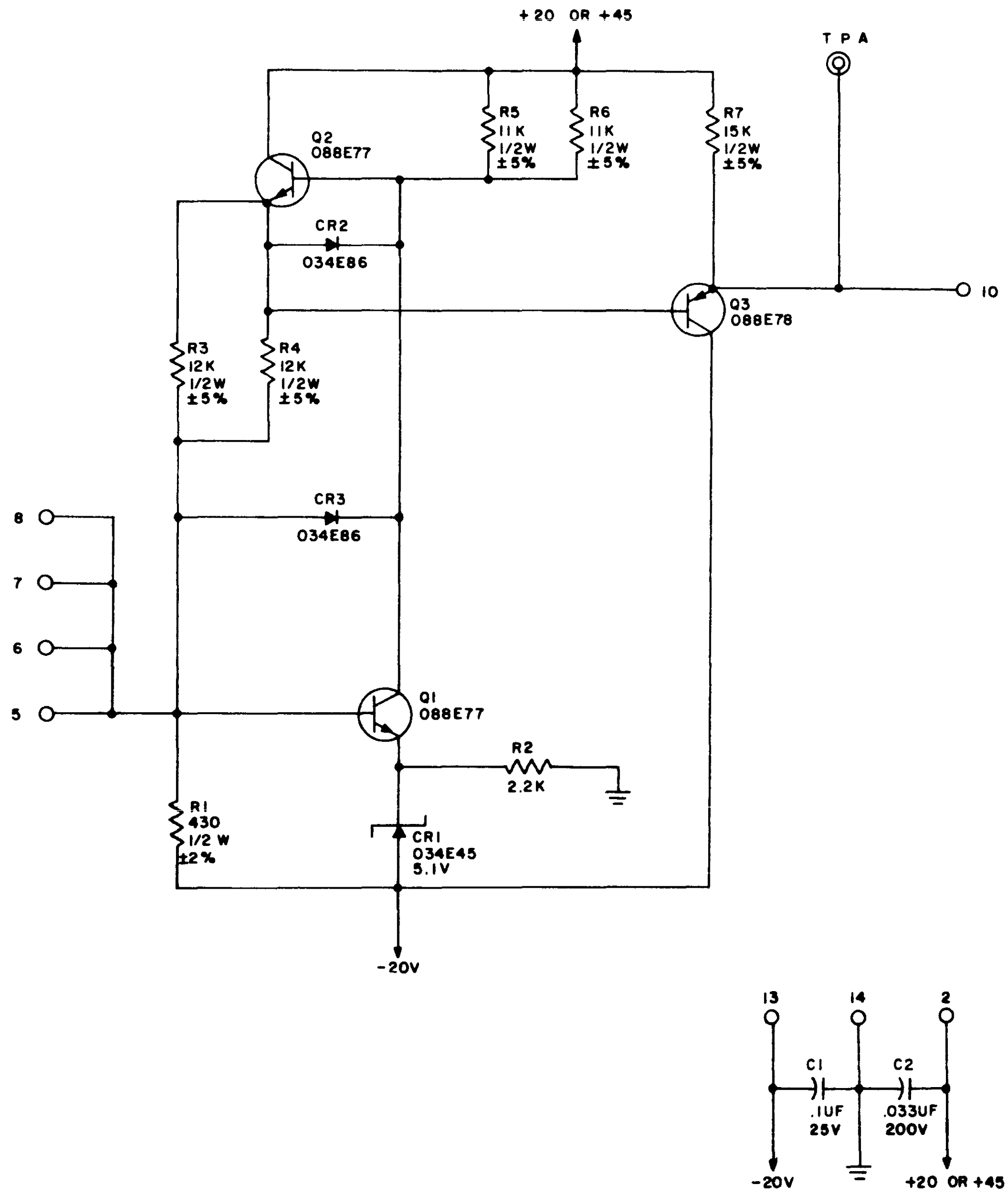



Figure 2-14. 206 Card - Unblank Level Amplifier

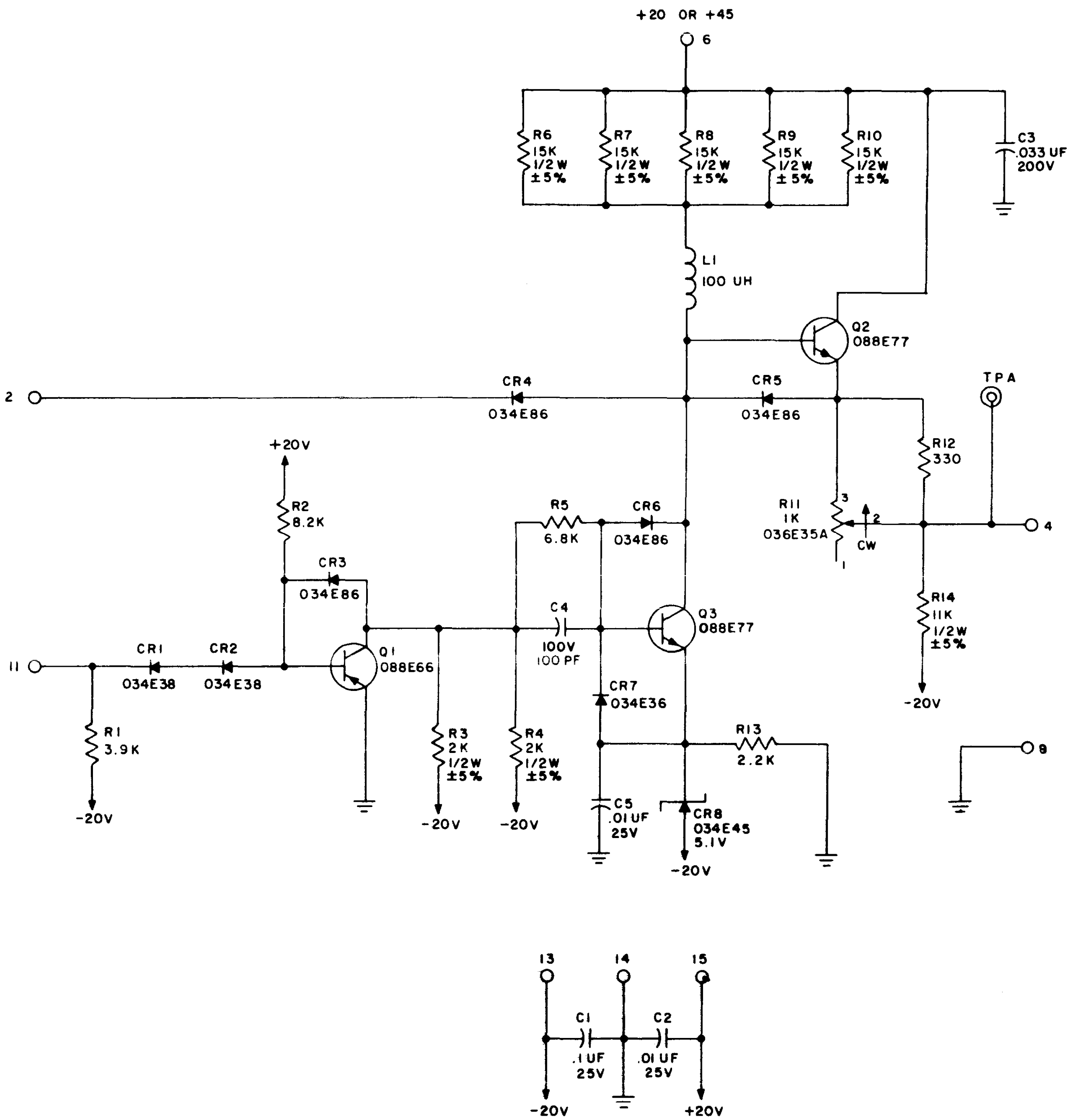



Figure 2-15. 207 Card - Unblank Time/Shaping Circuit

With a logic zero at pin 11, Q1 is cut off, Q3 is cut off allowing its collector to rise positive until it is clamped by the input voltage provided by the unblank level amplifier at pin 2. The resulting pulse is fed to the CRT through the output emitter follower, Q2. This positive voltage, at the control grid, causes the electron beam to be turned on.

Adjustment of R11 provides compensation for load variations.

FOCUS AND ASTIGMATISM CORRECTION

A varying focus and astigmatism voltage is needed to correct the focus of the beam over the entire raster area. Focus correction keeps beam diameter small and the astigmatism correction controls the shape of the beam.

Output of the focus and astigmatism circuits increase or decrease as X, Y deflection levels vary. This compensates for the defocusing effect on the CRT as the beam approaches the edges of the raster and keeps the beam in focus.

A network commonly used in display equipment for focus and astigmatism correction is shown in Figure 2-16.

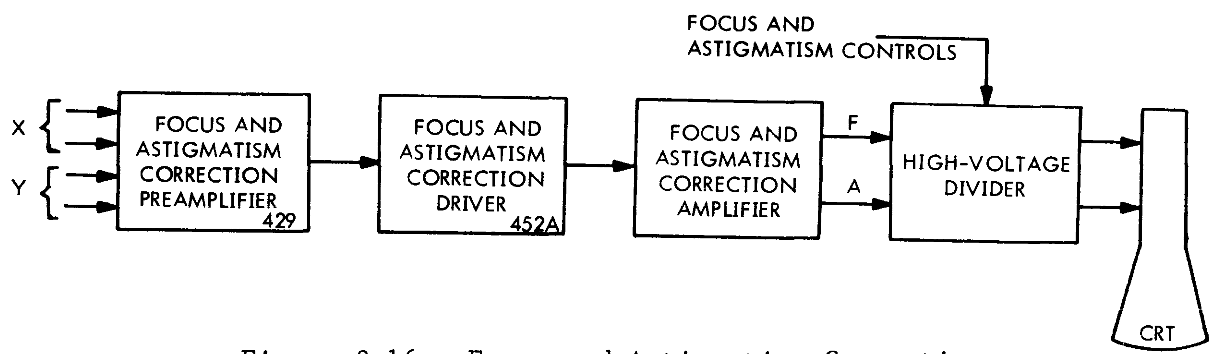



Figure 2-16. Focus and Astigmatism Correction

OPERATION

Deflection voltages fed to the correction preamplifier 429A card control the focus and astigmatism correction. The 429A card feeds a correction driver 452A card and the 452A card feeds the focus and astigmatism amplifier. The amplifier has two outputs; focus correction voltage and astigmatism correction voltage. Both outputs are coupled to the high-voltage divider where they modify static focus and astigmatism voltages set by manual controls. High-voltage divider potentials are applied to the CRT.

429A CARD

A 429A card (Figure 2-17) contains four potentiometers for adjusting overall gain, X, Y mix, focus level, and defocus level. Inputs to pins 1, 2, 4, and 5 are from X, Y deflection circuits. A logical 0 to pin 8 enables the dynamic focus or astigmatism function while a logical 1 disables the dynamic focus or astigmatism correction. Pin 3, the output, goes to a separate line driver type 452 amplifier.

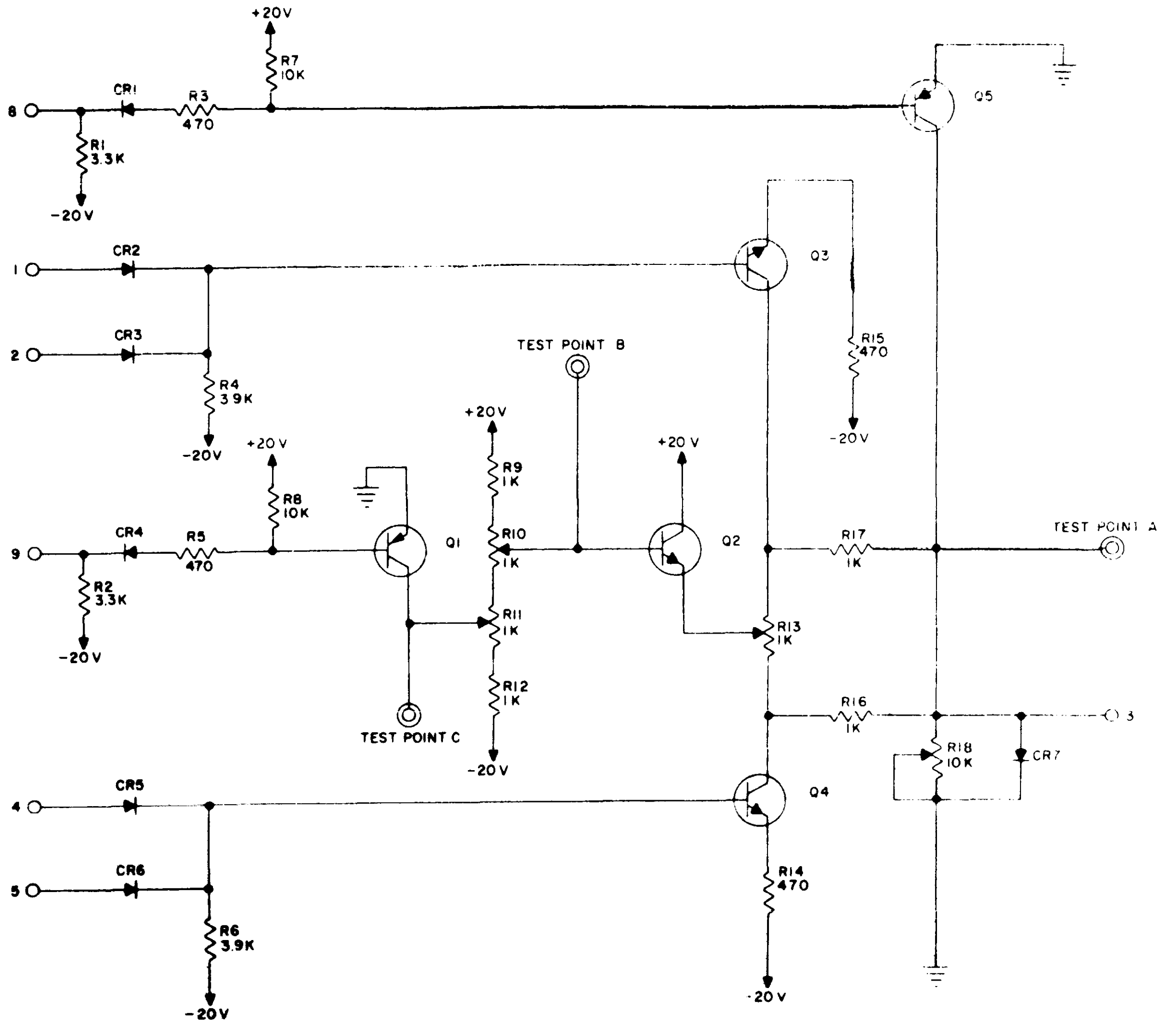



Figure 2-17. 429A Card - Focus and Astigmatism Preamplifier

R18 (pot. 1) of the 429A card increases or decreases the amplitude of the output voltage, controlling the focus level. R13 (pot.2) controls the amount of X, Y mix by applying more or less of the X or Y deflection voltage to output transistor Q4. R10 (pot.3) controls overall gain by varying the bias on Q2. R11 (pot.4) controls the defocus level output, used only if there is a defocus function in the display equipment. A logical 1 at pin 9 enables the defocus network. If the defocus function is not incorporated, pin 9 should be grounded.

## 452A CARD

The 452A line driver is used to amplify the output of the 429A card. Pin 2 is the input and pin 11 is the output. Pins 9 and 10 are not used. Pin 11, the output, goes to the focus and astigmatism correction amplifier. Figure 2-18 is a schematic diagram of the 452A card.

The input signal is applied to the base of Q1 where it is amplified and applied to the base of Q2. Q2 amplifies the signal and applies it to the base of output transistor Q3. Q3 is an emitter-follower. The emitter of Q3 is capacity coupled to the output, pin 11. Pin 11 is connected to the input of the focus and astigmatism correction amplifier.

## FOCUS AND ASTIGMATISM CORRECTION AMPLIFIER

The focus and astigmatism correction amplifier is used to amplify the focus and astigmatism correction voltage. It contains two duotriode tubes, a 12BH7 and a 6BL7. It has one input and two outputs; one output is used for focus correction and the other output is used for astigmatism correction. Both outputs are dc coupled to the high-voltage divider. Figure 2-19 is a schematic diagram of the focus and astigmatism correction amplifier.

The input correction level from the 452A card is coupled to the grid of one-half of a 12BH7. The plate of this half of the 12BH7 is coupled to one-half of a 6BL7 which is used as a cathode follower. This cathode has two outputs, one is the focus correction voltage which is coupled to the focus correction input of the high-voltage divider and one output is from the center arm of the potentiometer in the cathode circuit which provides separate adjustment of the astigmatism correction voltage. The center arm of the potentiometer is coupled to the grid of the second half of the 12BH7 which is used as a cathode follower. This cathode is coupled to the grid of the second half of the 6BL7 which is also used as a cathode follower. This cathode is coupled to the grid of the second half of the 6BL7 which is also used as a cathode follower and provides the astigmatism correction voltage which is coupled to the astigmatism correction input of the high-voltage divider.

## UNIT MONITOR MAINTENANCE CONSIDERATIONS

Five main areas on a display monitor require maintenance adjustments generally. They are character appearance, D/A reference, amplifier tuning, focus and astigmatism, and intensity.

The only normal preventive maintenance requirements involve cleaning the reusable air filters and visual inspections. Cables and wiring should be periodically inspected for connection looseness, insulation breakdown or other damage. The power supplies and monitor components should be checked for leaky capacitors, wire damage, and corrosion. Check all transformers for evidence of bulging, cracking or leaking. Check all mechanical components for looseness, binding and damage.

Normal operator adjustments are common to most display systems and include the intensity control; the setting of which, if too high will display the movements of the electron beam between symbols, or too low will allow some displays to fade. Also included are horizontal and vertical centering and gain. Refer to the controls mentioned in the deflection circuitry. In addition to these we have the focus and astigmatism adjustments. Maintenance adjustment responsibility is to insure that these operator controls are capable of moving the display presentation through the allowable limits afforded by these controls.

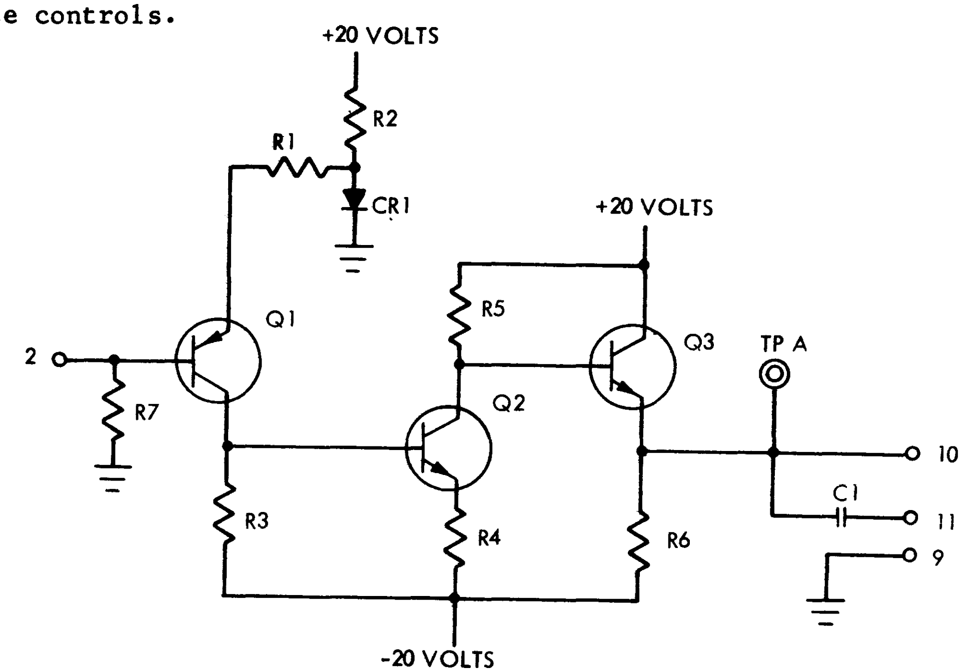



Figure 2-18. Focus and Astigmatism Correction Driver

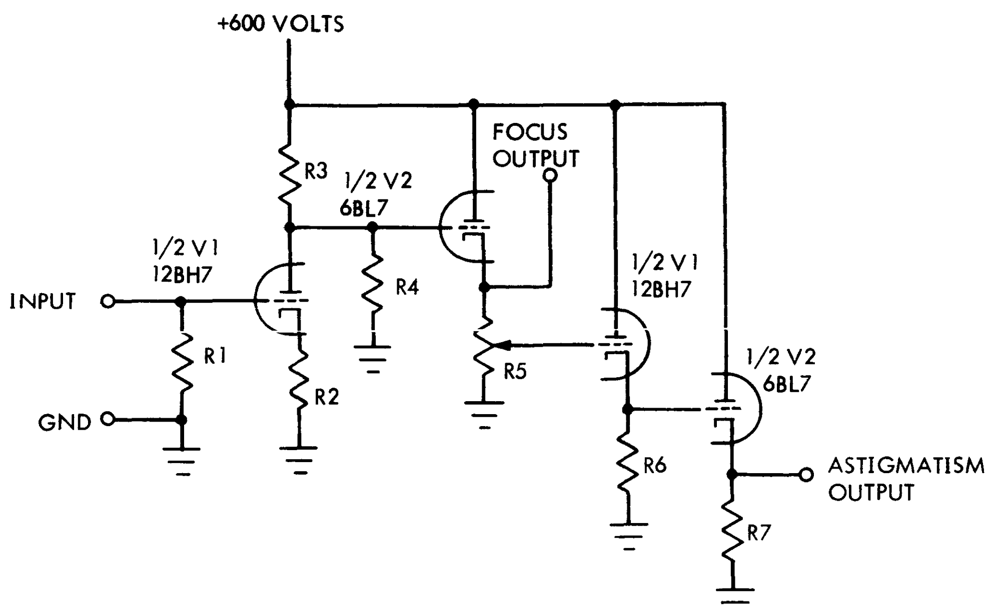



Figure 2-19. Focus and Astigmatism Correction Amplifier

## UNIT MONITOR
## HOMEWORK QUESTIONS

1. Give the meaning of Resolution; Persistency; Astigmatism.

2. What is the need for four (4) rather than two (2) CRT deflection plates?

3. What is the need for astigmatism correction?

4. Give two means by which a curve might be made to appear on the face of a CRT.

5. Intensity of a CRT display is a function of _______ and __________, and is generally variable by ____________________.

6. List six (6) basic parts of a CRT and give their purposes.

7. What is the relationship of opposite beam positioning deflection plates to one another?

8. What voltage is responsible for shaping the electron beam to make it round?

9. What generates the need for focus and astigmatism correction?

10. List the typical CRT controls which would be found on the control panel of a unit monitor.

# SECTION III

SECTION III

## COMPARATIVE DISPLAYS

The application of advancing electronics principles to computer science is a continuing process. The use of the cathode ray tube as a component in peripheral equipment opens new doors; allows more latitude to the imagination of computer equipment users.

The Control Data 200 series of display equipment, the 210, 212, 250, and 280, among others, represents the various types of computer equipment with which a maintenance group will come in contact. Presented here are the basic principles of operation and application of these equipments. In the following sections each of the principles involved in the presentation of a CRT display will be discussed.

The basic intent of all display equipment is production of symbols and/or vectors on a CRT under computer control. The hope of this section is to represent the use of this symbol production in actual application so that these functions may have more meaning.

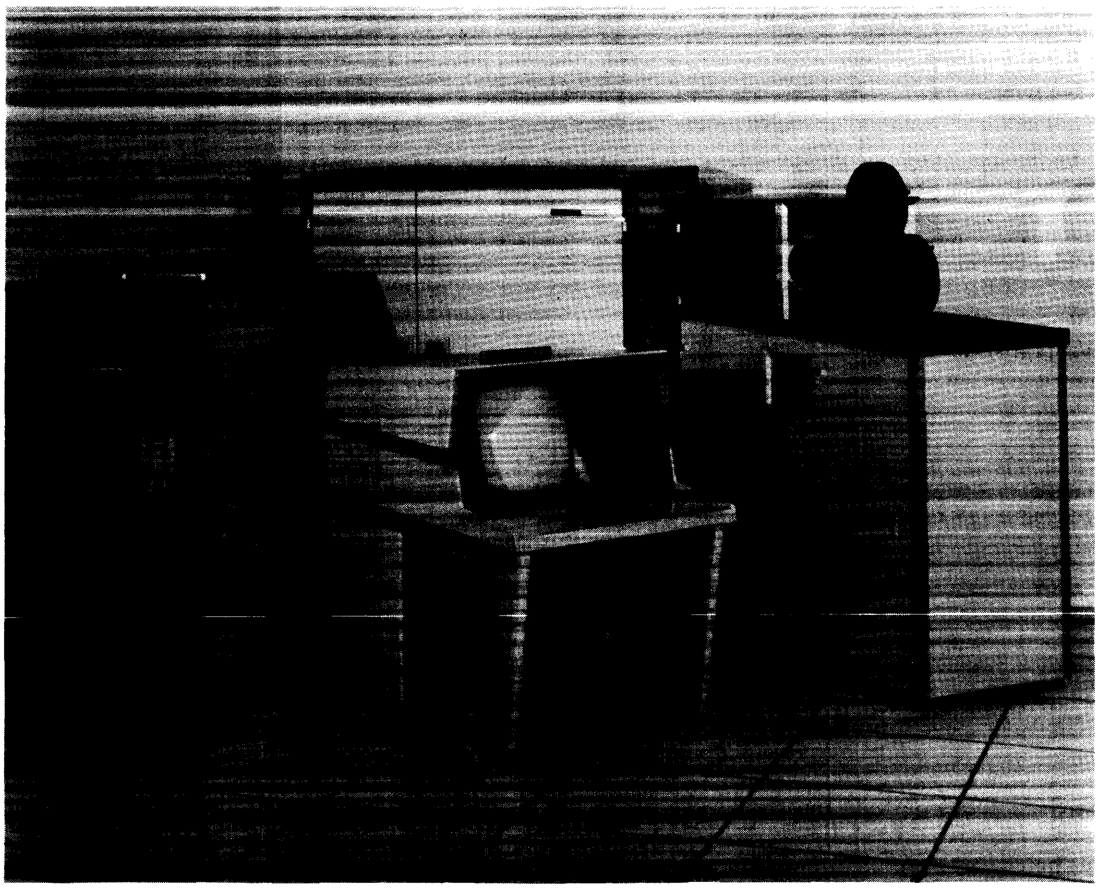


Figure 3-1. Control Data 280 Display System

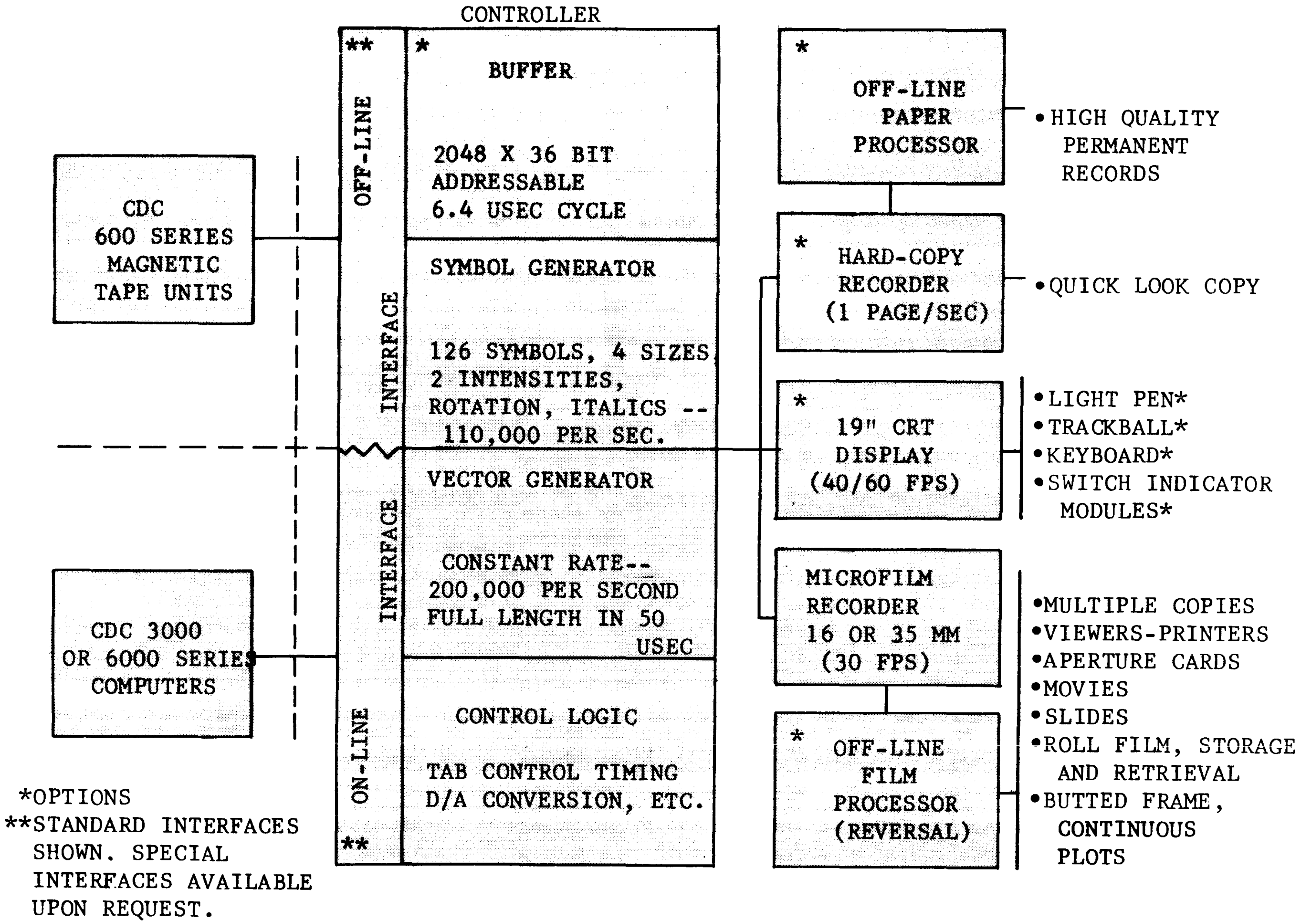



Figure 3-2. Control Data 280 Display System Functional Diagram

The CONTROL DATA® 280 Digital Data Recorder and Display System is a research tool designed for scientists, engineers, mathematicians and, in some cases, commercial users, who must create and have fast access to a great many highly technical graphs, charts, schematics, and maps; three dimensional stereoscopic or mathematical models; and directory listings. Figure 3-1 illustrates the 280 system.

Input to the configuration may be from computer memory or magnetic tape. Output may be in the form of a rapidly variable CRT display, film, or paper. To provide the displays just mentioned, the display unit makes use of a capability to paint characters and symbols, draw vectors and plot points on a CRT under computer command.

The dd80 has a capability of displaying 126 different alphanumeric characters and special symbols. Any symbol may be rotated to provide vertical orientation of a printed, italicized, or specially intensified line. A method known as tabular plotting allows vectors to be painted as continuous lines. There are four standard character sizes selectable with 128, 85, 64 or 43 characters per line, depending upon the size selected. By the same control the number of lines displayed will vary from 64 to 43 to 32 to 21. A grid coordinate addressing capability of ten binary bits for X and ten for Y enables 1024 X 1024 locations or over a million specific addressable locations.

The microfilm recorder is a shutterless camera, operated under computer control, allowing 30 frames per second to be exposed by a high resolution, single sweep five-inch CRT. The film may be either 16mm or 35mm in size.

The hardcopy processor utilizes a seven-inch CRT to expose photosensitive paper to light at a rate of one page per second. The hardcopy is available for a "quick look" use or for final off-line processing.

Regeneration of the display is at a rate of 40 times per second, with the character generation rate of 110,000 characters per second. This rate when compared to line printer operation provides 128 character lines at a rate of 38,400 lines per minute or roughly the capability of 50 high-speed line printers. The means of character generation is the painted beam method, utilizing a timed diode matrix providing movements of the CRT beam every 200-nanoseconds. The diode matrix principle will be discussed at length in a later chapter.

Storage of displayed data is obtained by a standard core memory consisting of 2,048 36-bit words. If the memory is not utilized, regeneration must be obtained by magnetic tape or computer input. The 36-bit word of the display system will contain pertinent information for each display; for example, a character code would allow 20 bits for positioning of the character, six bits for the code itself, and additional code bits for orientation, size selection, italicization, intensity, and unit designation. The single memory of the controller is capable of driving three different display consoles, each with a different presentation.

As illustrated in Figure 3-2, the controller consists of the interface circuitry for computer or magnetic tape input, the buffer memory, the symbol generator, the vector generator, and control logic including the necessary digital to analog conversion. Each of these functions will be discussed at length in subsequent chapters.

The typewriter keyboard is a standard type providing input capabilities for display editing or data entry.

## LIGHT PEN

Another auxilliary device is the light pen. Since a single CRT beam provides the entire display, each symbol or vector displayed will have a point of maximum intensity immediately after the unblanking of the beam for that image. The light pen, or pencil or gun as it might be called, provides a light pen interrupt to be generated at the point of highest intensity when the pen is pointed toward the symbol in question and its interrupt switch is activated. The pulse emitted from the photoelectric cell of the light pen enables a reference to the symbol in question by referring to the display control word that is at that moment held in the controller input register. Depending upon function selections made by the operator at the display console control panel the symbol may be erased or altered and any specially coded function pertaining to that particular symbol may be allowed.

TRACKBALL

The trackball performs a similar function to that of the light pen. It is a small ball inset in the desk top front of the display console. When enabled, the trackball rotational movement controls the position of a cursor on the display screen. A pair of 9-bit position registers maintain a constant X-Y coordinate location of the trackball and the operator needs only to depress a Trackball Interrupt switch in order to call attention to that specific location.

JOY STICK

APPLICATIONS

Some of the applications of the 280 system are: (See Figure 3-3)

A. Curve Plotting
   1. Math functions
      a. Aerodynamics
      b. Hydrodynamics
      c. Structures
   2. Data reduction
      a. Flight
      b. Static testing
      c. Biochemical history
B. Printing
   1. Program debugging
   2. Stock catalog
   3. Account records and listing
C. Tool Path Drawings (Numerical control)
D. Maps
   1. Weather
   2. Radiation
E. Movies
   1. Theoretical events
      a. Shock waves
      b. Explosions
   2. Reactor study
F. Schedule networks
G. Drawings
   1. Electrical
   2. Mechanical
   3. Three dimensional

*APPLICATIONS—Areas of application are limited only to the user's imagination. The following output examples were produced by the 280, and they merely suggest its basic capability.*

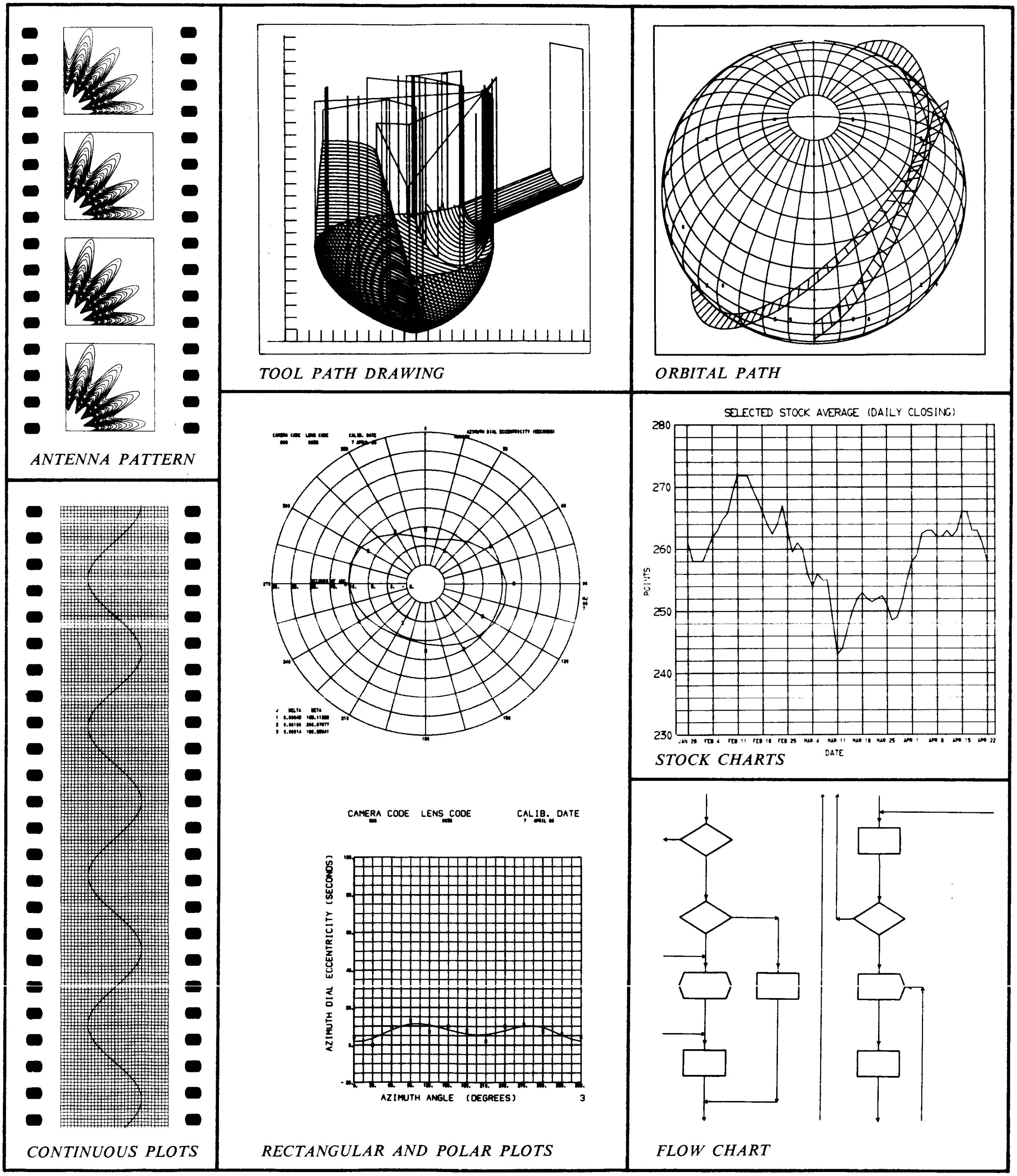



Figure 3-3. Applications of the Control Data 280 DISPLAY SYSTEM

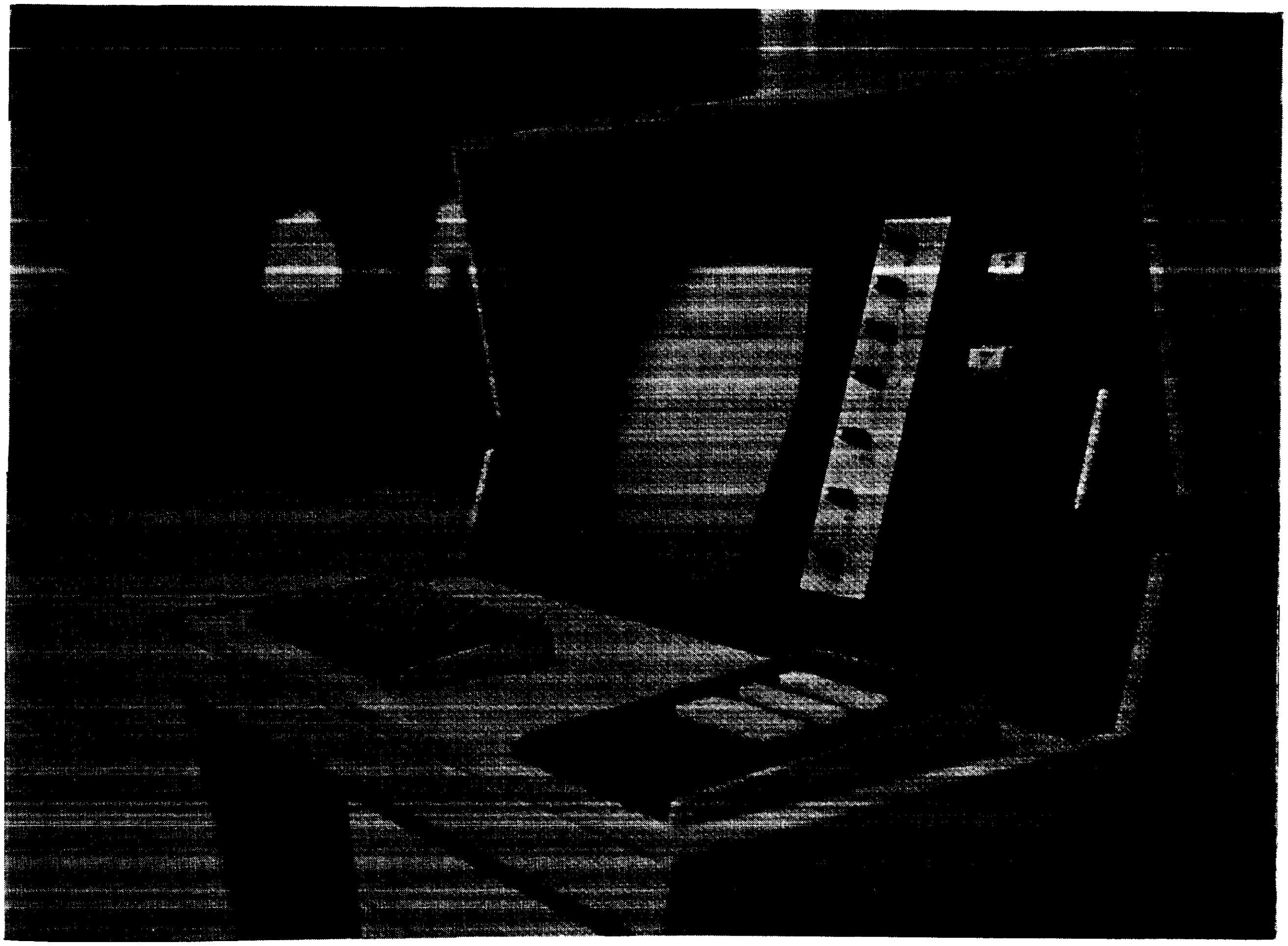


Figure 3-4. Control Data 250 Display Console
(Optional trackball is not illustrated)

The CONTROL DATA® 250 Graphics Display System is a system similar in operation to the 280 system but with innovations making it more attractive commercially than the Control Data 280.

The controller (CDC 3398) is capable of handling 6 display consoles, enabling accommodation of large staffs of research personnel. The display word for the CDC 250 system is a 24-bit word greatly simplifying programming considerations. The memory is an addressable core memory, 4096 24-bit words or 8192 words. 800,000 characters per second may be generated using the buffer memory and character painting time is 3.75 microseconds, using the random plot method, or 2.5 microseconds using the sequential, line printer mode.

As may be seen in Figure 3-4 the basic controls of the unit are the same as the CDC 280, utilizing the light pen and track ball; although function controls have been arranged in three rows on the right side of the console, with numerical push button application of function commands.

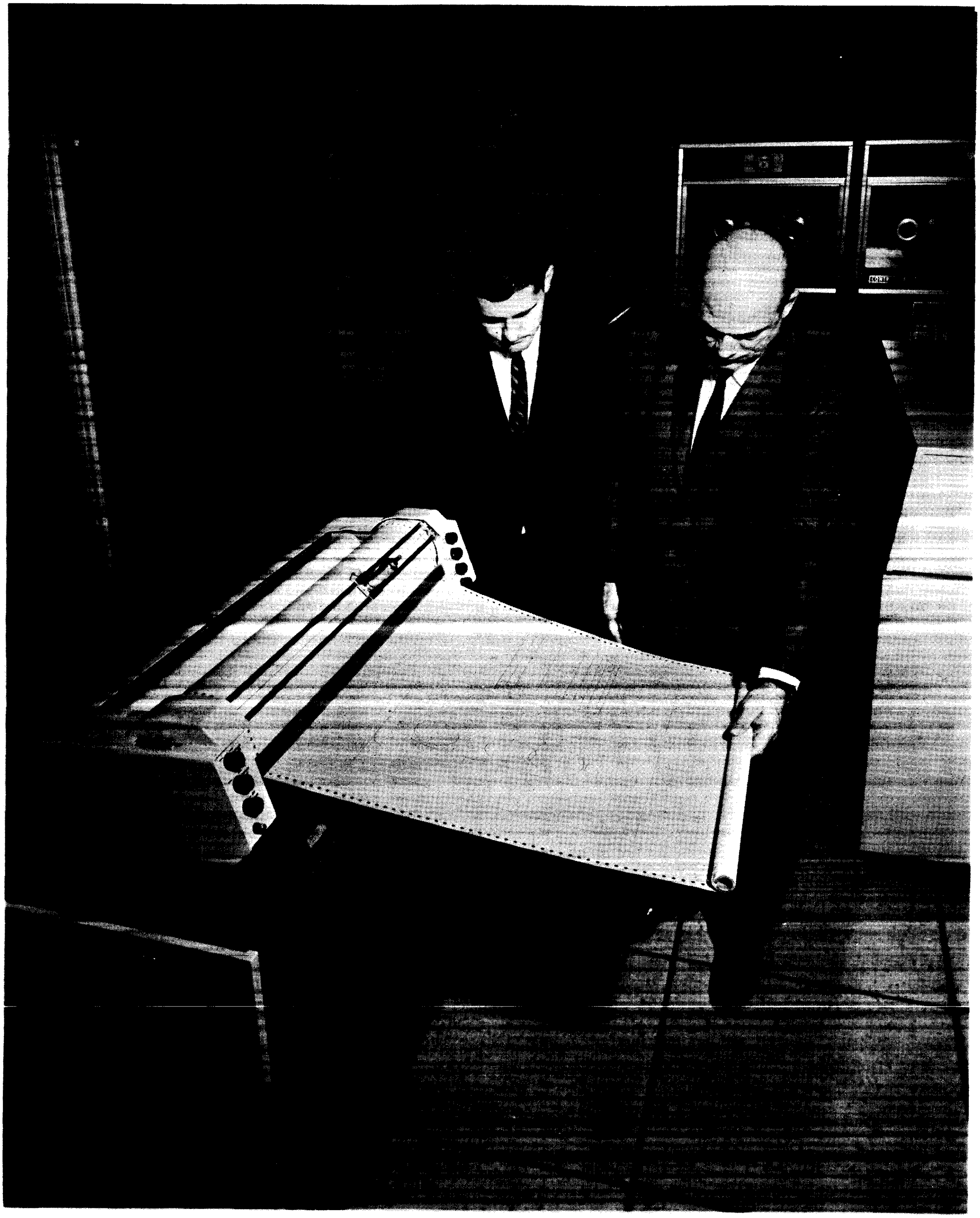


Figure 3-5. Control Data 3293 Incremental Plotter

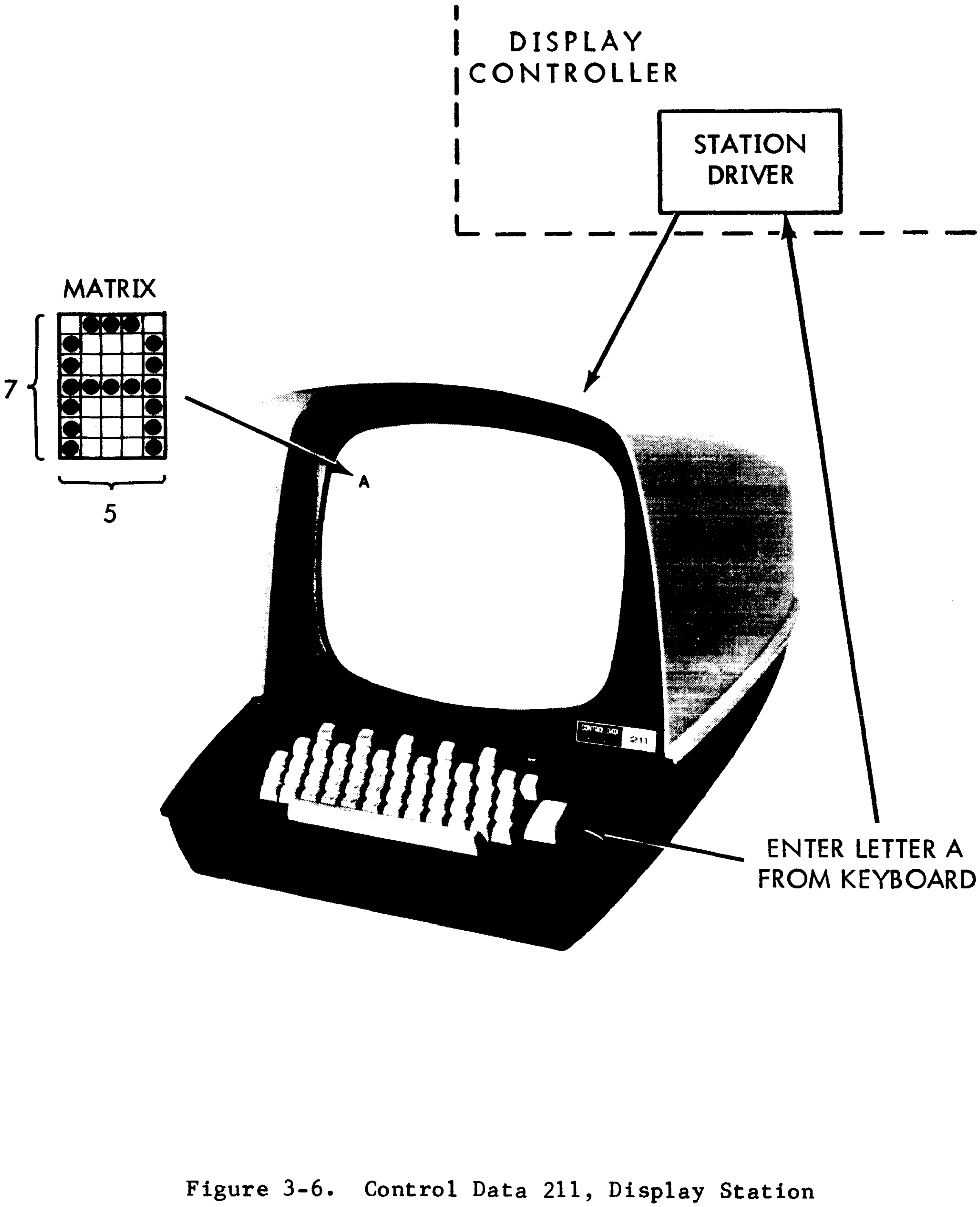
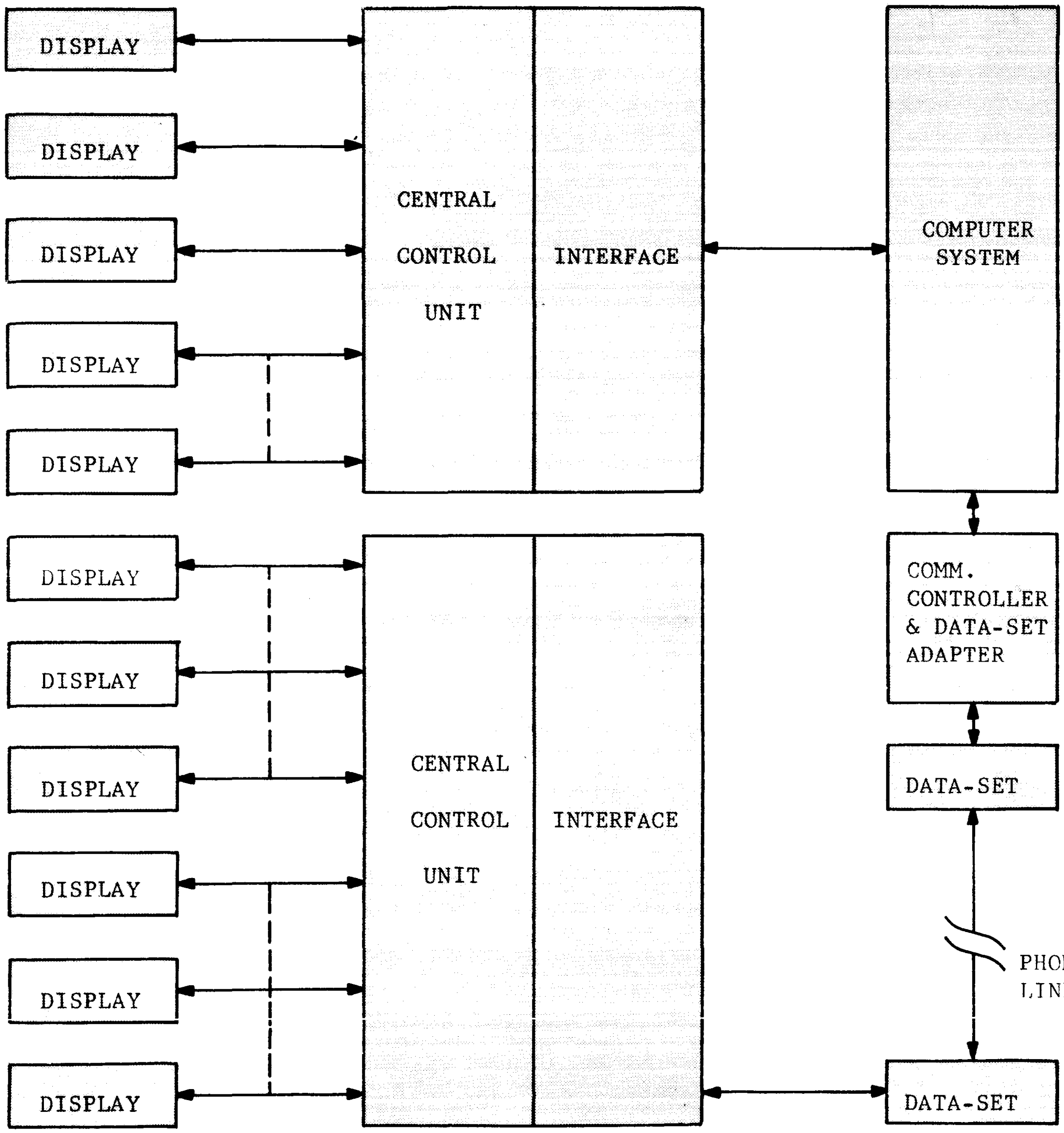



Figure 3-6. Control Data 211, Display Station

CONFIGURATION: The configuration of equipment for a CONTROL DATA 210 Inquiry and Retrieval System must be made upon individual data processing requirements; therefore, each configuration will be different. However, one basic element is characteristic of all of them...the ability to operate groups of 211 Display Stations through one central controller. The following configuration illustrates this ability.




*One Central Control Unit can accommodate any combination of up to 12 Displays or Printers.

Figure 3-7. Control Data 210, System Configuration

## CONTROL DATA® 210 INQUIRY AND RETRIEVAL SYSTEM

### Capabilities

The CDC 210 (Figure 3-6) is an information entry and retrieval system similar in application to the standard typewriter I/O device. The 14" CRT has a raster area of 6 X 8 inches. Twenty lines of 50 characters each may be displayed. An edited page of data may be transferred by console control. The characters used would be arabic numerals, punctuation marks, and normal symbols. The characters are adjustable in size by a maintenance provision around a standard .25". Regeneration occurs at 50 times per second.

Some of the typical applications of the CDC 210 are in transportation; such as airline reservations, seating assignments, weather data, railroad routing, fleet vehicle locations and contents. In banking and finance uses are being discovered in account status checking, deposits, withdrawals, credit checking, and stock transactions. Figure 3-10 illustrates only a few of these applications.

The basic 211 unit within the configuration is controlled by a Station Driver. The effectiveness of display systems of this type is in the fact that the many display stations function through a single central controller. Obviously, buffering must be provided, which affords the necessary storage for an entire page of display to be regenerated 50 times per second.

Each station driver is addressable from the computer and contains logic circutry for controlling operation of one display station and associated printer station (Figure 3-8). Each station driver contains a 10 millisecond magnetostrictive delay line memory for temporarily storing symbol codes.

The display station itself is composed of a CRT of the electromagnetic type and a typewriter keyboard. Across the top of the keyboard are various control switches enabling addressing and control of the display. The arch of display is within a 5 X 7matrix on the face of the CRT for a single symbol. The means is dot unblanking, with the position generation of the "diddle" method. A time diode matrix, controlled by 200-nanosecond pulses from a four-phase clock, provides the display of one symbol in 16.8 microseconds.

The central control unit illustrated in Figure 3-7 can accommodate any variety of 211 entry display stations or printers (specially designed CDC 218 with selective typewriter), up to 12 units. The 211 serves as a control console for manipulation of data and, with the addition of the printer to the configuration, serves as a control unit for information to be printed.

The position entry marker may be positioned in much the same manner as the carriage on a typewriter may make a new area on the paper available. The CLEAR KEY, located at the top of the keyboard, serves to clear the display screen and to reset the entry marker in the upper left hand corner of the screen. The RESET KEY, another control key on the keyboard, positions the marker in the upper left hand corner of the screen, but does not erase data. The LINE SKIP KEY serves as a line indexing mechanism, providing movement from line to line. The SLEW KEY is a repeating space key moving the marker from space to space, left to right. The SKIP KEY is a single space key.

Data Handling

To obtain information for display from computer memory either the CLEAR or RESET key must be depressed. A call code, previously programmed, is then transferred to the computer from the keyboard alphanumeric keys and the SEND key is depressed. By this means (simply utilizing the repertoire of call codes available to the operator) any amount of data may be retrieved, either from computer core storage or magnetic tape or disk storage.

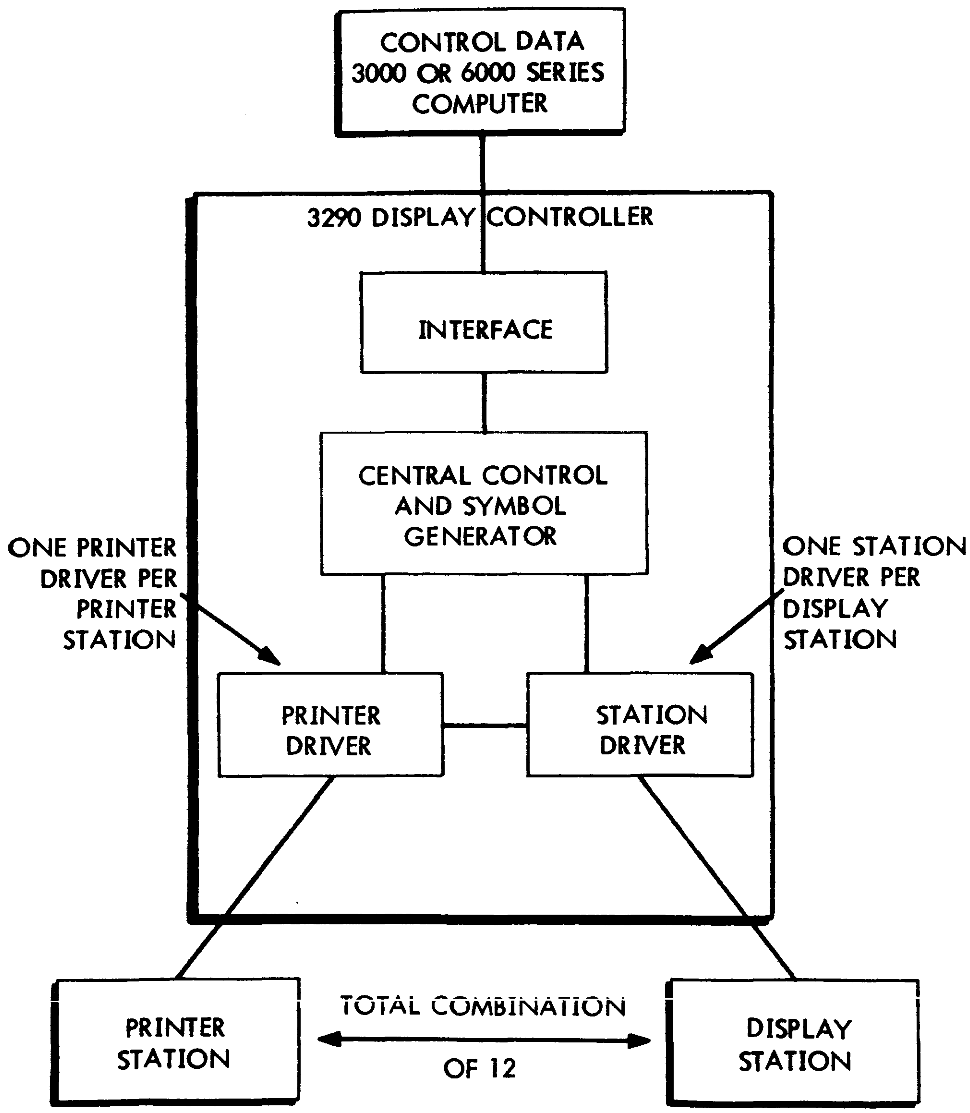
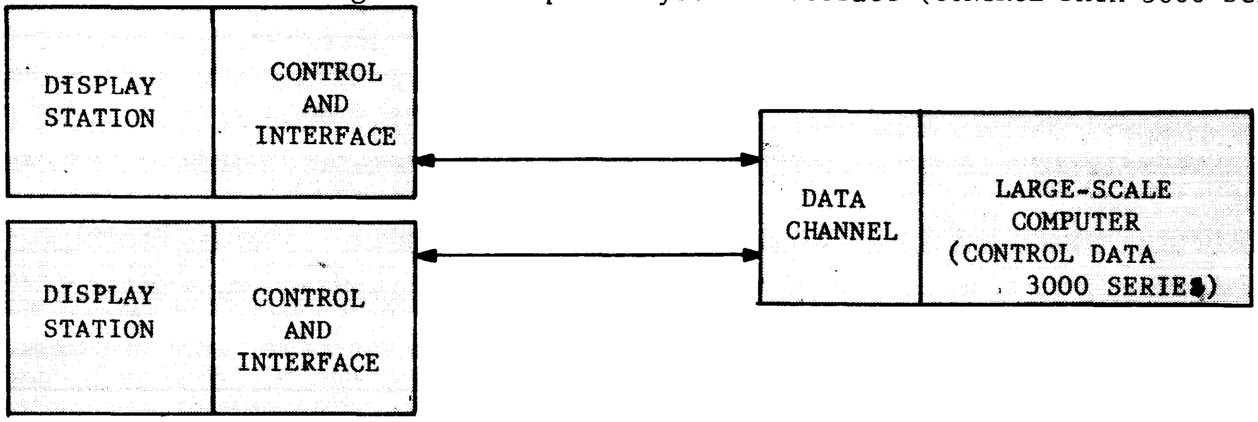
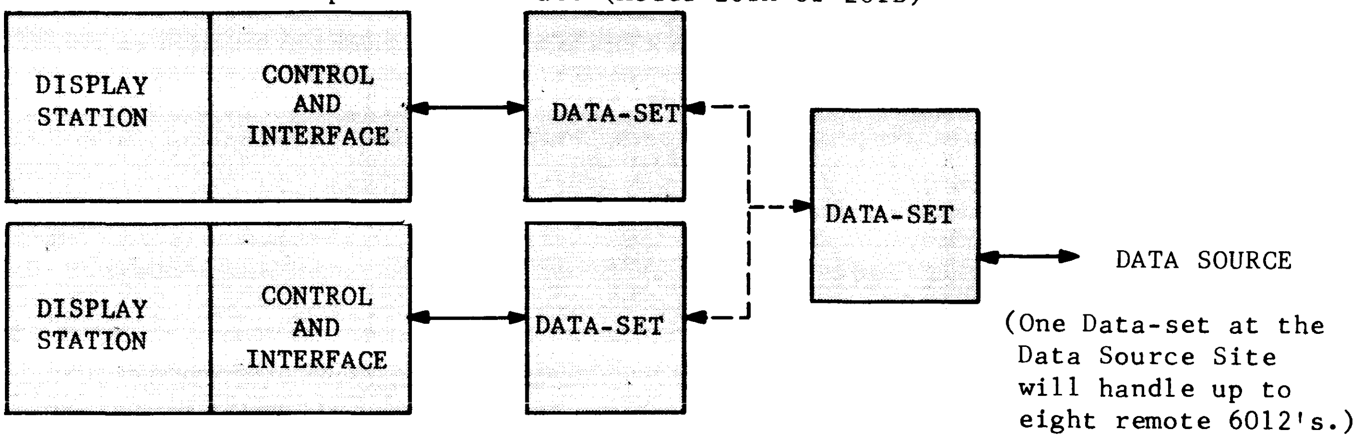



Figure 3-8. Control Data 3290 Display Controller

Model 3291-A: Has large-scale computer system interface (CONTROL DATA 3000 Series)




Model 6012: Has DATAphone® Interface (Model 201A or 201B)




Model 8049: Has small-scale computer system interface (CONTROL DATA 160-A or 8090 System)

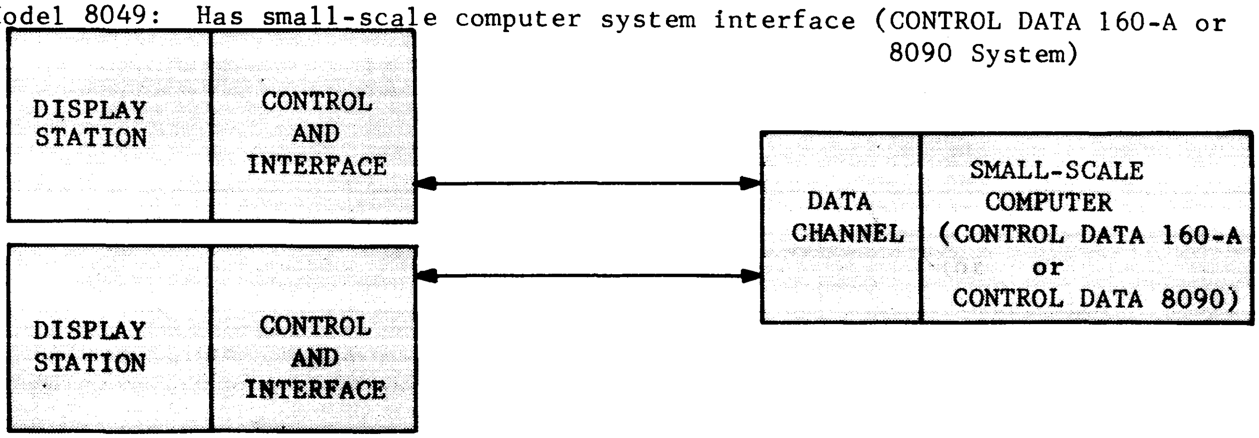



**Figure 3-9. Control Data 212 System Configurations**

To update or edit information in computer memory, the call code is entered, SEND is depressed, and the material is displayed. Mistakes are erased by positioning the entry marker under the information and depressing the space bar. The new information is typed in, using the entry marker to express location, and the newly updated data is ready to be sent to computer storage. RESET is depressed, the call code typed to denote destination, a coded letter (perhaps U) is keyed in and the SEND key provides a return to storage.

By basically the same process information may be transferred from one display station to another simply by typing the necessary codes. For example, CALL 1 and SEND key depression would signify that either data to be typewritten or displayed data should be transferred to display station #1. By the same token, information may be designated to be printed by displaying it on the screen and depressing the PRINT key. Either in the transferring of data or in printing, masking of the data to be transferred may be accomplished by positioning the entry marker one space beyond the last character to be transferred or printed from the display.

All symbol codes sent from the computer or generated by the data entry keys on the display station keyboard are entered into the associated station driver delay line memory. The display remains visible as long as stored data is continually regenerated on the CRT. This is accomplished by continual recycling of the selected display through the memory.

## CONTROL DATA® 212 INQUIRY AND RETRIEVAL SYSTEM

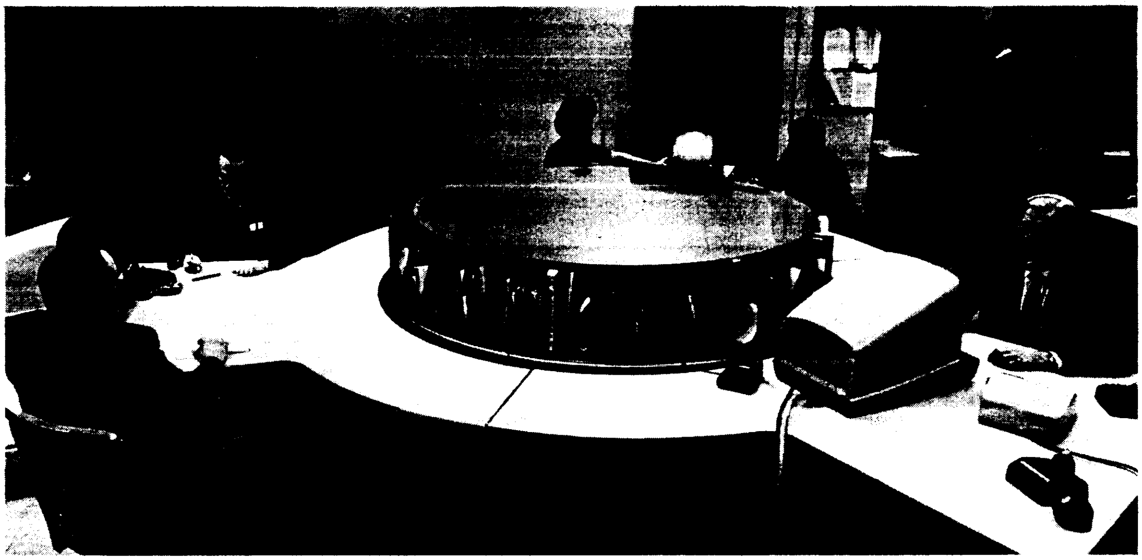
### Capabilities

The Control Data 212 is a remote single station device, having its own buffered memory, controller, and interface built into a base cabinet which is an integral part of the unit itself. The ability of this unit to handle data at computer speeds is extremely important to the achieving of maximum efficiency in overall system operation through savings in computer time, transmission and operator time. Interfacing may be provided either with a large scale computer system such as the CDC 3200 series or with a smaller computer such as the CDC 160A or 8090. In addition to this the display system may also provide interfacing by Dataphone.

The primary advantage of a device of this type is that addressing of certain locations in storage for display is facilitated by allowing coded inputs to call up entire blocks of data. Instead of requiring an entire block of data to be retyped or re-entered, any symbol or group of symbols may be erased and re-typed under an off-line operation. The data is then revised upon restoring it to the storage unit.

The CDC 212 utilizes an entry marker to indicate the next location at which the next symbol is to be placed or the symbol which is to be altered. This entry marker eliminates the necessity of either a light pen or a track ball for these functions.

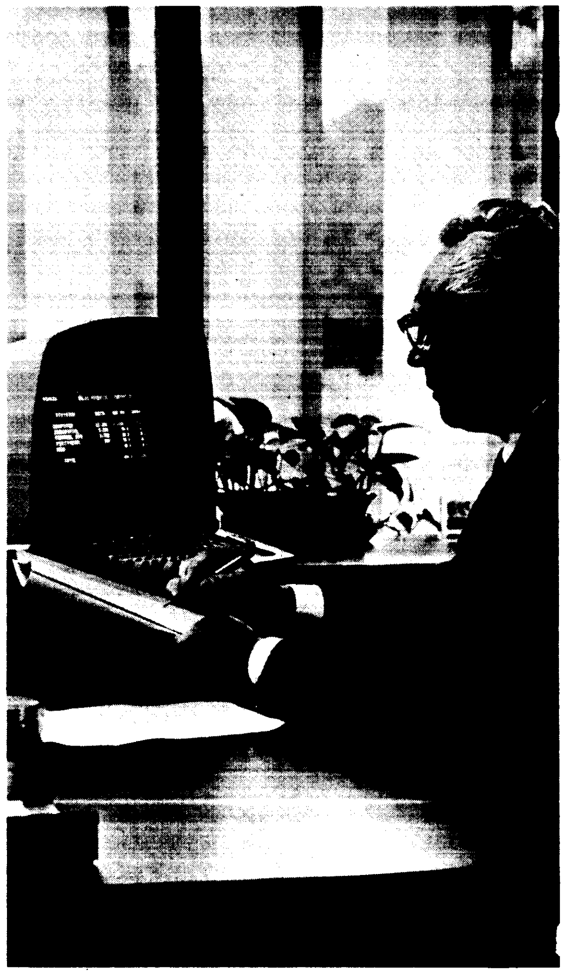
Figure 3-9 illustrates the arrangement of the display station and controller connections normally utilized. Figure 3-10 shows only a few of the applications of the 212.



*TRANSPORTATION: Airline reservations, seating assignments, weather data and other flight information. Railroad car and shipment disposition, fleet vehicle location and contents.*

*INSURANCE: Claim adjustment, policy file maintenance, policy search.*

*BANKING AND FINANCE: Account status checking, deposits, withdrawals, credit checking and stock transactions.*



*INDUSTRIAL MANAGEMENT: Inventory management, order status reports, production control, personnel records, group insurance files, cash flow, scheduling, forecasting and planning.*

Figure 3-10A. Control Data 210, 212 Applications

*INSTANTANEOUS AIR LINE RESERVATION INFORMATION*

*FINANCIAL INQUIRIES Verification of customer credit and account balance.*

*INVENTORY CONTROL Instantaneous information concerning shortages and other supply problems.*

*ENGINEERING Direct Fortran coding without keypunching. (Photo CERN)*

*RAILROAD FREIGHT CAR LOCATION AND DISPOSITION*

Figure 3-10B. Control Data 210, 212 Applications

CONTROL DATA® 200 USER TERMINAL

One of the smaller display systems likely to be seen by customer engineers is the input/output system illustrated in Figure 3-11. It consists of a typical entry/display station, an independent unit, (CDC 217-2); a card reader (CDC 224-1); and a line printer or automatic typewriter. It will provide the user, located at any distance from a central computing station, instant access to the computer over common carrier lines.

Many 200 user terminals may share a single computer, giving users at widespread locations the same computing power that is available to a user at the central computer site.

Two basic modes of operation may be found in the user terminal--line and block. Line mode enables a conversational interaction between the user and the central computer. Through the keyboard of the entry/display unit file control may take place, providing entering, updating, and editing of information. The display presentation is capable of being masked so that given areas may be typed upon and entered without affecting the masked areas. In this mode conversation is established between the display, as a primary device, and the computer, with the printer and card reader serving secondary functions. Block mode provides conventional batch processing with the card reader for input and the line printer as an output, with the display unit serving as an operator console.

The controller for the terminal is contained in the entry display station. It provides a 1000 character buffer for each display, reader, and printer.

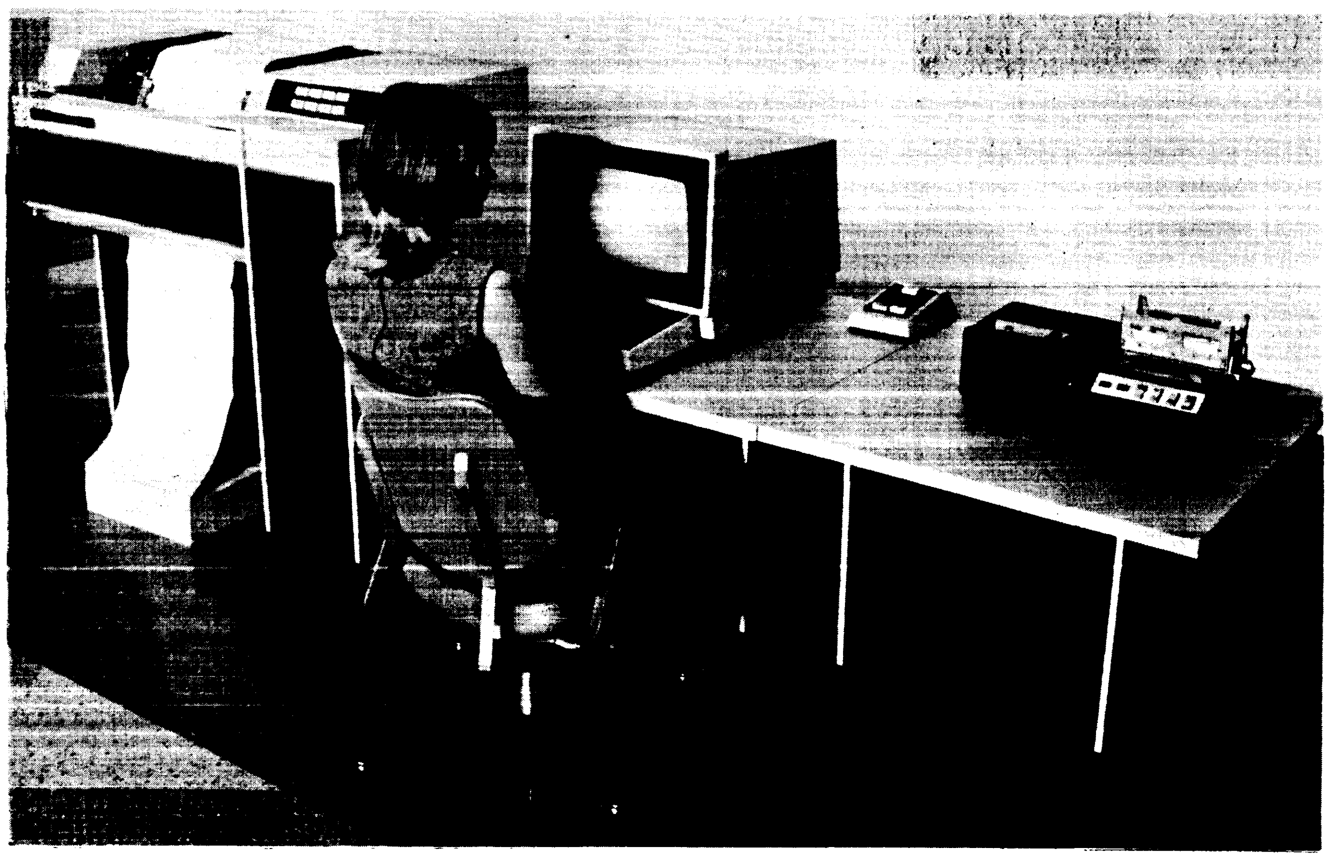


Figure 3-11. Control Data 200 User Terminal

COMPARATIVE DISPLAYS
HOMEWORK QUESTIONS

1. Describe the function of the TRACKBALL.

2. How many display words might be generated for use in the dd80 with two 24-bit words?

3. By what means does the trackball represent a coordinate position?

4. Describe the function of the LIGHT PENCIL.

5. List five (5) auxilliary units of a display peripheral system.

# SECTION IV

SECTION IV

# ANALOG CIRCUITRY

Digital voltages, represesenting logical zeros and ones, regardless of system and actual voltages used will always deal with only two voltage levels. These levels lend themselves well to the digital circuitry utilized in central data processors. Line printers, for instance, obtain mechanical movement of the hammers by the timed application of a digital voltage; the same procedure applies to typewriter equipment and card punches. Occasionally, however, the need arises for the digital voltage to control a mechanical movement precisely over a range of motion, as opposed to the simple tripping of a hammer, or control of a relay. Under these circunstances, equipments such as the Disk File, Incremental Plotter or Display Unit have a need to convert the serial or parallel pattern of varying high and low digital voltage representations to a useful voltage which has many discrete voltages. This new voltage is called an Analog Voltage.

Some computer systems are entirely involved with varying and continuous inputs and outputs and are called analog computers. When a digital computer has a need to observe a varying physical condition such as the reading of a meter, the rate of a pulse, hydraulic pressure, etc., analog voltage inputs are converted to voltage patterns as digital words discernable by the computer. This is known as analog to digital conversion. When the output of the computer has a necessity to be converted to an analog voltage, the process is known as digital to analog conversion.

Analog voltages, upon generation, will be treated not by "on" and "off" electronic circuitry, but by the circuit elements involved in variable voltage circuits: amplifiers, line drivers, servomechanisms, and motors or hydraulic pumps. Figure 4-1 illustrates two typical circuit representations used by Control Data Corporation. Note that circuit designation, card type, location, and pins are designated in the same manner as digital circuitry.

The analog voltage generated by a D/A converter may vary through any range. A very small analog variation may later be simply amplified at a later point in the circuit and the same relationship is maintained. In digital circuits the strength of an incrementing and decrementing count, for example, is directly dependent upon the weight of the bits accomplishing that count. Changing the most significant bit of a counter would have an effect more than double the effect of changing the adjacent lower order bit. To accomplish the same change in an analog circuit, we would simply attenuate or amplify the voltage involved.

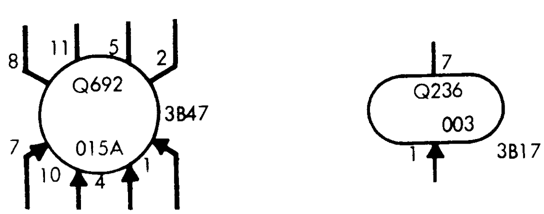



Figure 4-1. Analog Logical Symbols

DIGITAL TO ANALOG CONVERSION

The function of a D/A converter is the changing of one or more binary values into a single current or voltage level. When there are several digital values, such as in a register like we have just seen, we would expect the most significant bit to have an effect on the output voltage equal to the effect of all the lower order bits combined plus one.

Figure 4-2A illustrates a binary count in a register applied to the circuits of a D/A converter. Figure 4-2B is an oscilloscope representation of the counting of the three binary inputs from 000 to 111; eight discrete counts. Figure 4-2C is an oscilloscope representation of the output of a D/A converter for each stage of the count. Notice that for a count of two, the same number of "1" and "0" inputs provides an output roughly double that of the count of one. By the same token, a count of five, using bits one and three, amounts to a 5/3 proportion of the voltage obtained for a count of three, also using two bits. In D/A conversion, the bit weight, not the number of bits, is the prime determinant of output voltage. Bit weight is assigned to a binary number in a converter by allowing each bit to control current flow, on an "on or off" basis, through a resistor of a given size. Since the common usage is to allow the highest digital value the greatest amount of current change, the resistor controlled by the highest bit would be the smallest in size.

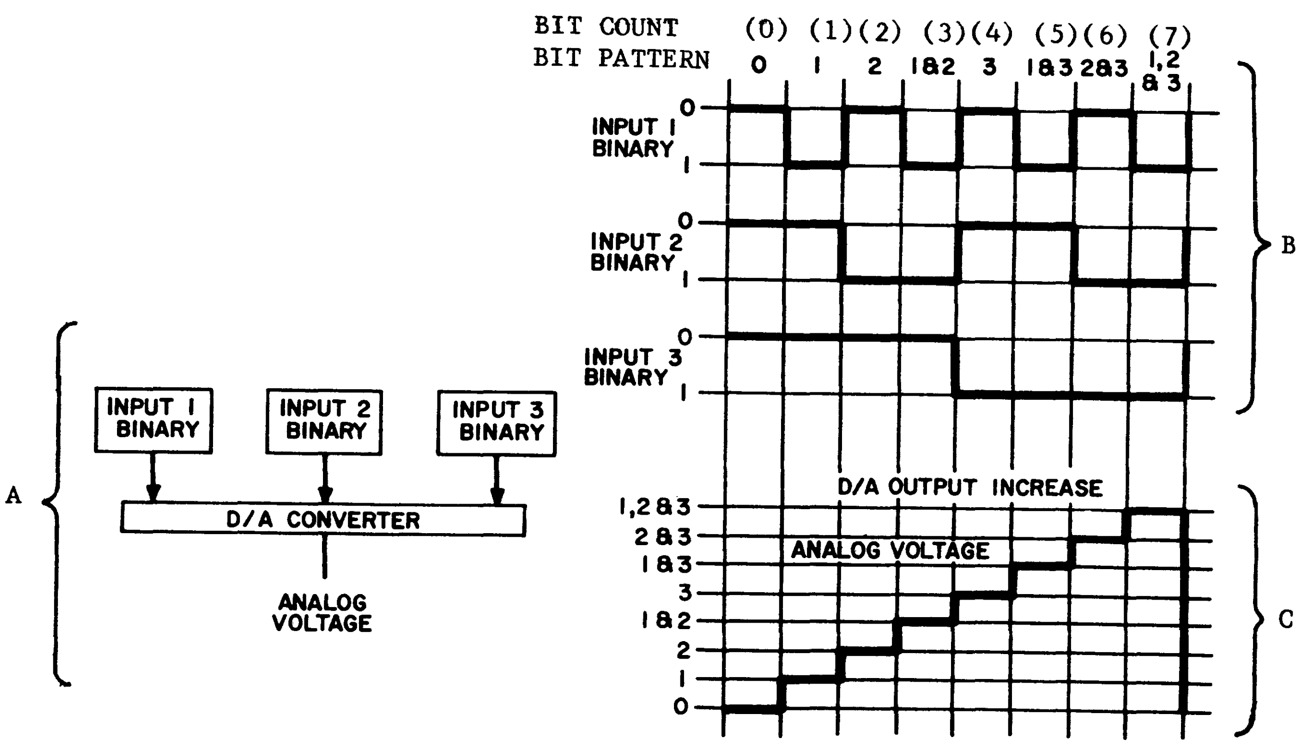



Figure 4-2. Simplified D/A Conversion Waveforms

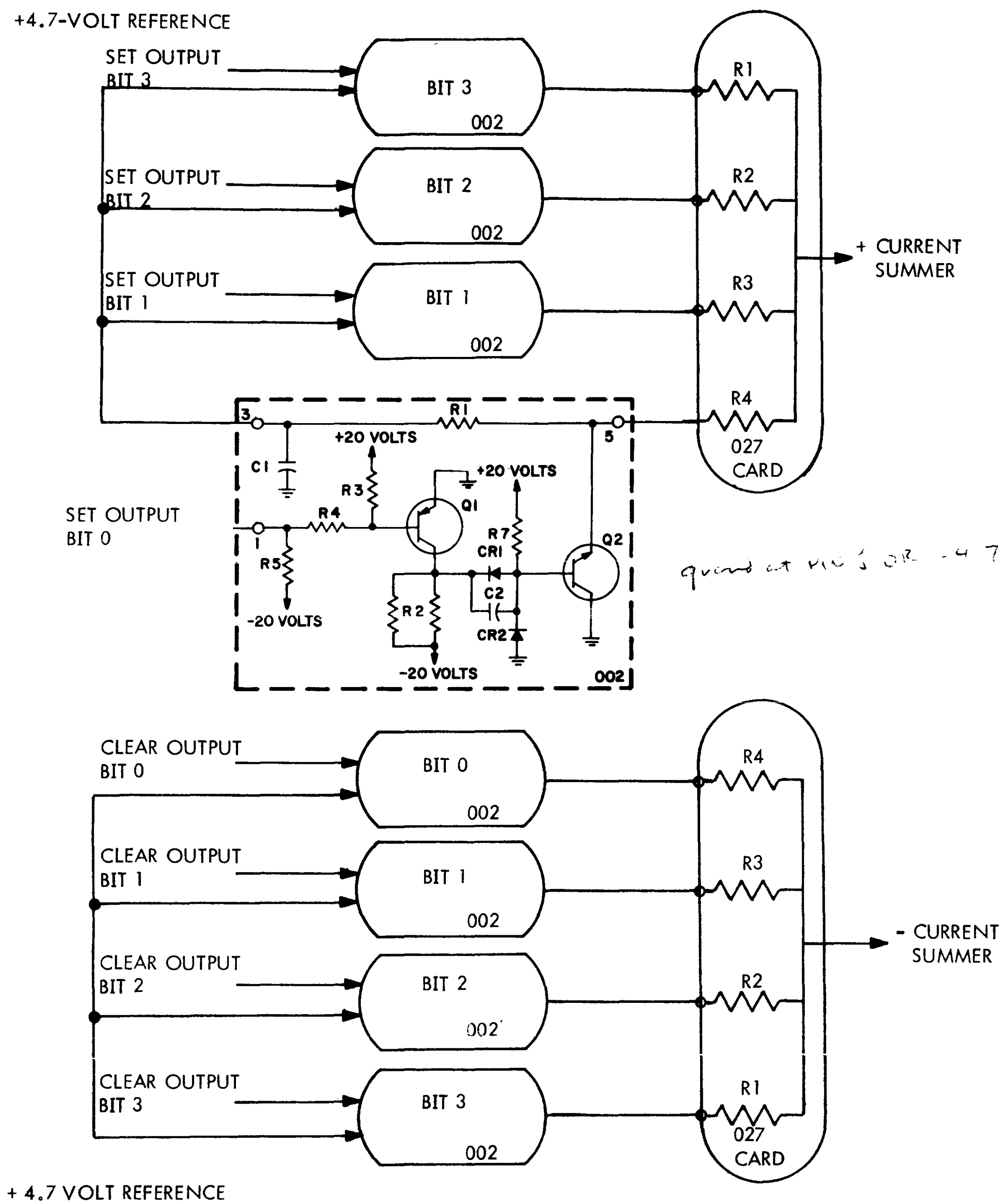



Figure 4-3. Simplified D/A Network

Figure 4-3 illustrates a simplified D/A converter network. The basic elements are an input binary register, a reference current source (in this case an 002 card), and a group of high-precision resistors, an 027 resistor card. In display applications it is necessary to have both a positive X or Y voltage and a negative X or Y in order to provide linear control and movement of the electron beam of the CRT. For this reason each 002 card generates both a set count representation and a complement representation in order to provide two voltages opposite in polarity. The figure represents a simplified D/A network having just four digital inputs, (four F/F's). The set and clear outputs of each F/F feed an 002 circuit. A detailed schematic of one of the 002 circuits is shown within the dotted area. A logical 0 in results in a positive voltage output. A logical "1" in holds the output at near ground potential. Current output of each 002 circuit is determined by the bit position weight. Lower bits have less significance so they require the largest terminating resistors to provide for a lower current value. This output current will actually be determined by the size of the 027 card resistor.

## D/A CONVERTER (002 CARD)

The 002 card contains two identical circuits; one normally is fed by the set output from a F/F and the other by the clear output. Pins 3 and 9 are D/A reference voltage inputs, pins 1 and 7 are digital inputs, and pins 5 and 11 are outputs. The D/A reference level is approximately 5 volts. Figure 4-4 is a schematic diagram of an 002 card. Note that the tolerance of R1 varies according to the bit position fed into the circuit.

Assuming there is a logical 1 input on pin 1 and a logical 0 input on pin 7 of the 002 card, Q1A conducts and Q1C is cut off. The conduction of Q1A causes Q2A to conduct and a near ground potential is felt at output pin 5. With Q1C cut off, Q2C is unable to conduct and a positive voltage approximately equal to the reference voltage results on output pin 11.

## RESISTOR NETWORK (027 CARD)

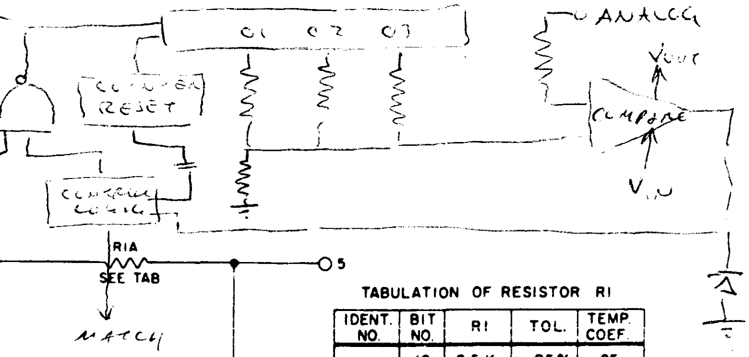
Figure 4-5 shows the resistors contained on an 027 card. Pins 12 through 3 are fed by bits 0 through 9, respectively, pin 2 is usually grounded, and pin 1 outputs to the current summing network. Note that the lower order bits need the highest resistive values as was pointed out previously.

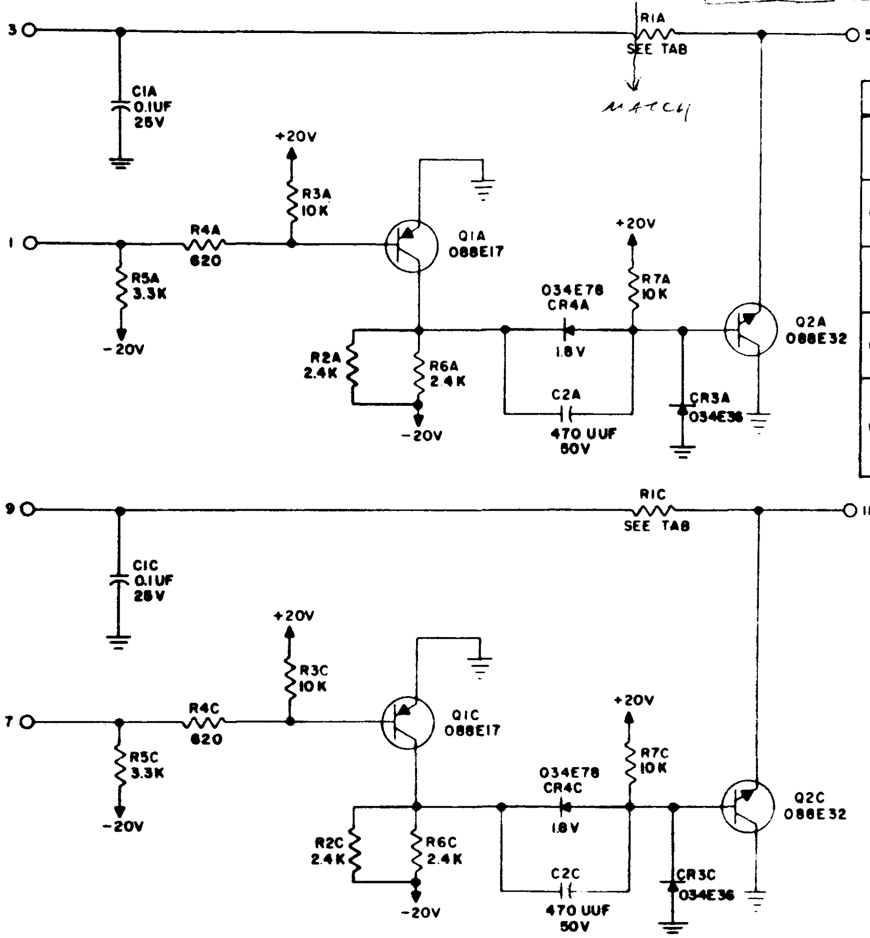
A/D

OUTPUTS VALUE IN INCREMENT REGISTER UNTIL EQUAL . . .

TIME ENCODE OUTPUTS TIME IN COUNTER CLOCK WHEN MATCH

LINEAR AMPLIFIER AS COMPARE VOLTAGE AND INCREMENTING CLOCK . .




TABULATION OF RESISTOR R1

| IDENT. NO. | BIT NO. | R1 | TOL. | TEMP. COEF. |
|---|---|---|---|---|
| 002-9 | 10 | 2.5 K | .05% | 25 |
| | 9 | 2.5 K | .05% | 25 |
| 002-7 | 8 | 2.5 K | .1% | 25 |
| | 7 | 2.5 K | .1% | 25 |
| 002-5 | 6 | 2.5 K | .5% | 50 |
| | 5 | 2.5 K | .5% | 50 |
| 002-3 | 4 | 2.5 K | 1% | 150 |
| | 3 | 2.5 K | 1% | 150 |
| 002-1 | 2 | 2.7 K | 5% | |
| | 1 | 2.7 K | 5% | |
| | 0 | 2.7 K | 5% | |

Figure 4-4. 002 Card - D/A Converter

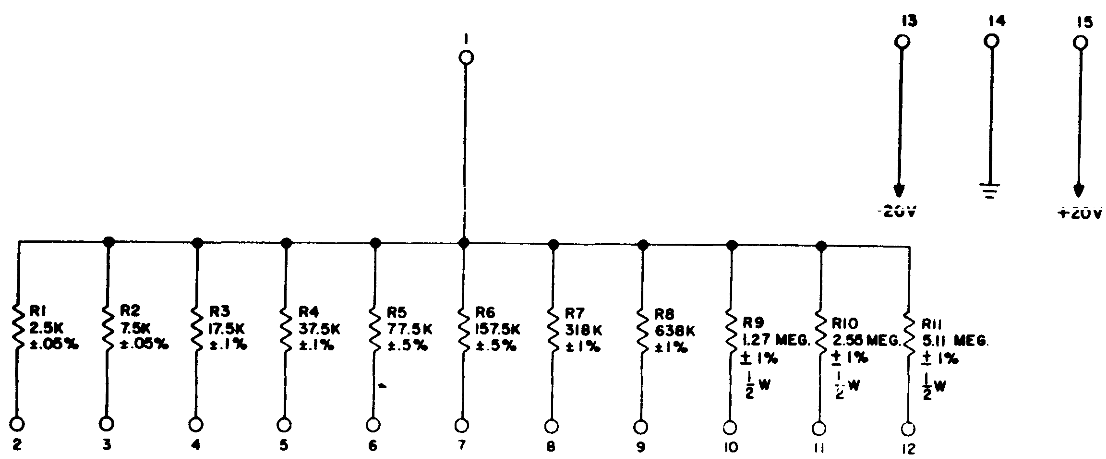



Figure 4-5. 027 Card - Resistor Network

D/A REFERENCE VOLTAGE

The 401 and 443 regulator cards shown in Figures 4-6 and 4-7 control the analog reference voltage source for the positioning D/A converters.

Output of the 401 supplies the input to the 443 and output of the 443, which supplies the analog reference voltage, is also connected back to the input of 401. The circuit is, thus, a closed loop voltage regulator.

Output voltage is adjustable by setting R2 on the 401 card for the desired value. Once the value is set, it is held essentially constant by the closed loop circuit. For instance, suppose the load on the output of the 443 card is suddenly reduced, tending to allow the output voltage to increase. Increasing the voltage to Ql of the 401 card, increases the current through R6, which decreases the current through Q2 causing the voltage on the base of Q3 to increase. Resulting increase in Q3 current causes a reduction in the voltage output at pin 12. This voltage is then applied to the input of the 443 card which is a double emitter-follower having a low output impedance. There is no phase inversion through an emitter-follower having a low output impedance. There is no phase inversion through an emitter-follower; therefore, the output reduces as does the input. The opposite voltage change occurs when the reference voltage drops due to loading. Output voltage tends to be essentially constant at the value set with potentiometer R2.

Normal output is considered to be 4.7 volts $\pm$ 0.3 volt. This voltage is set to provide the amount of total deflection necessary from the D/A converters.

CURRENT SUMMING

The output of the D/A converter network goes to a type 003 current summing card. Four current summing cards are used, two for each of the horizontal (X) and vertical (Y) deflection signals. Figure 4-8 shows a simplified block diagram display controller.

The summing takes the algebraic sum of the symbol generator or vector or line generator currents and base positioning currents and combines them into one single variable current. Output of the current summing card is approximately 4.7 volts. Output variations are caused by increasing or decreasing current flow. Figure 4-9 is a schematic diagram of the 003 card.

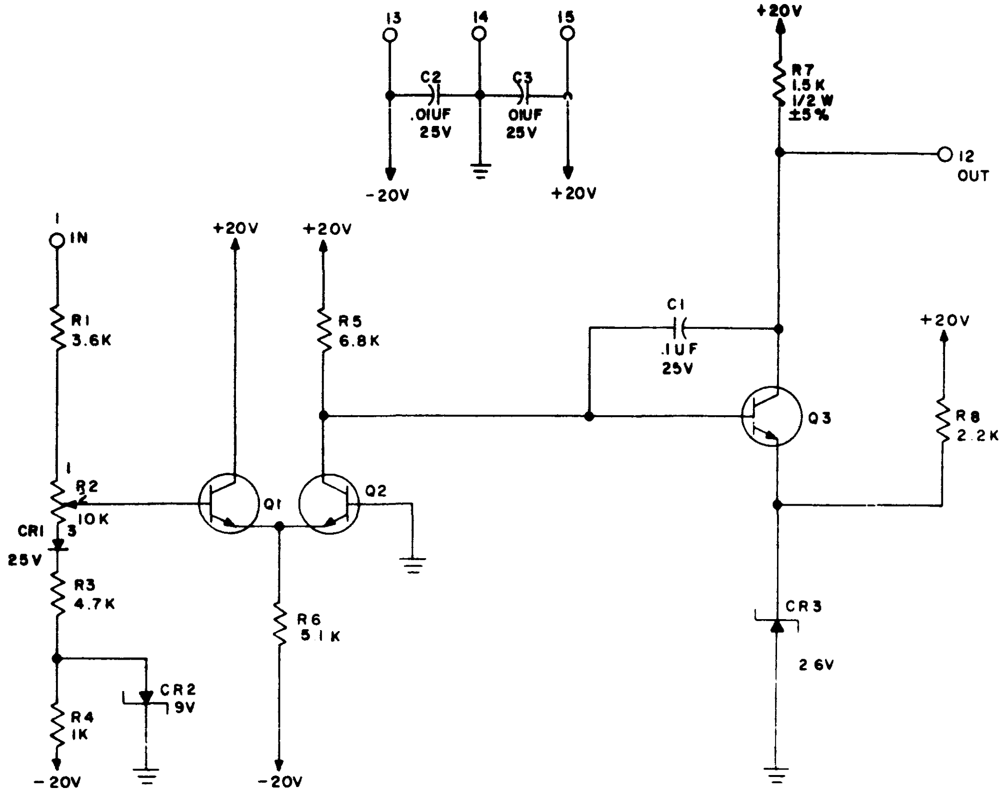



Figure 4-6. 401 Card - DC Regulator Amplifier

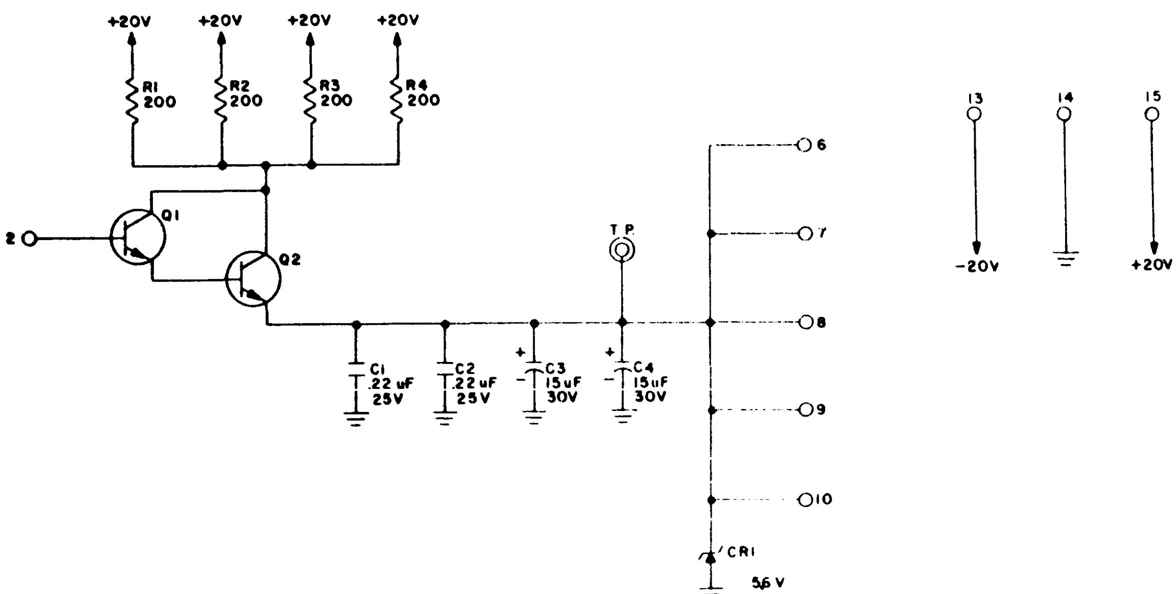



Figure 4-7. 443 Card - 5 Volt Series Regulator

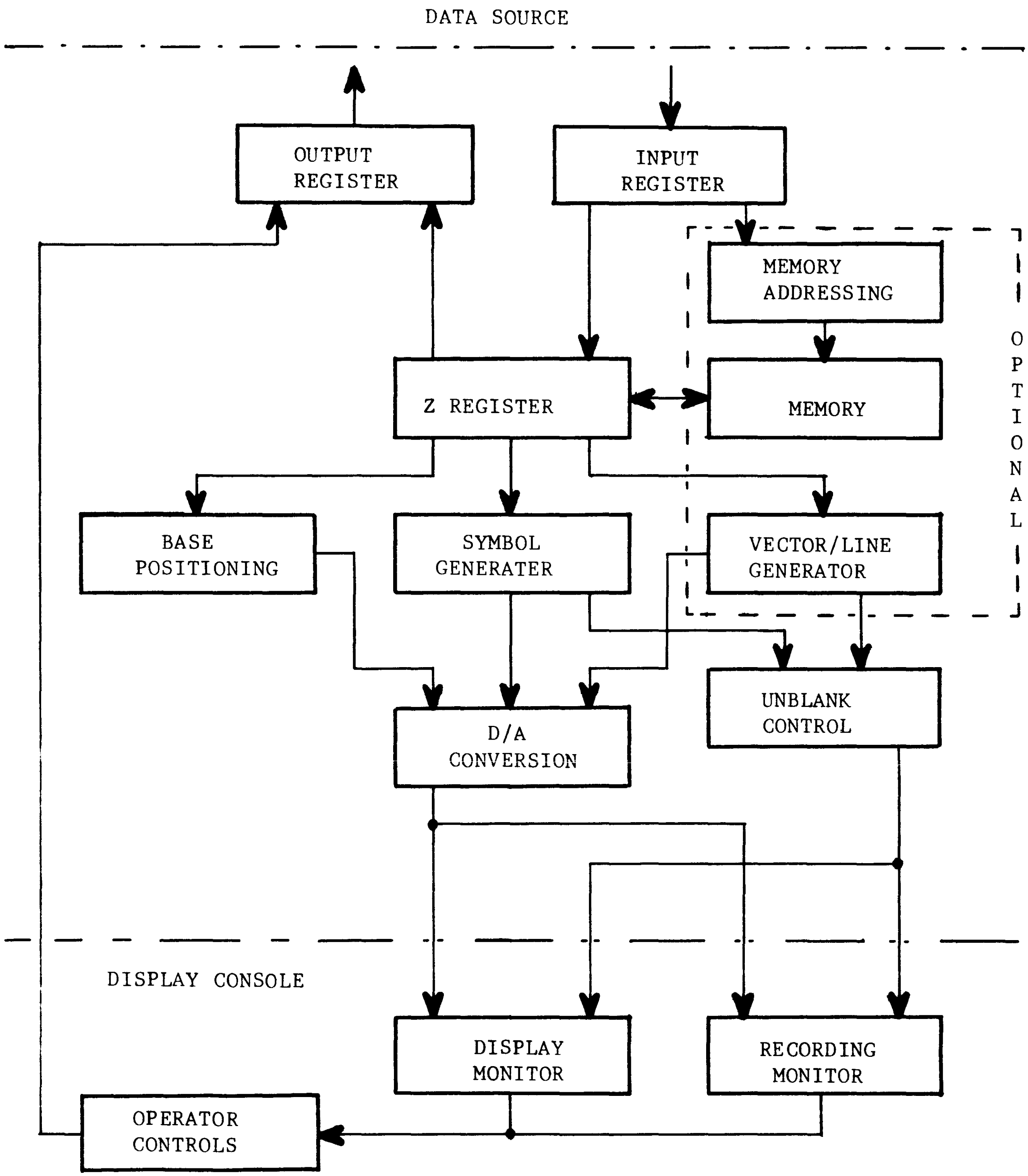



Figure 4-8. Simplified Block Diagram Display Controller

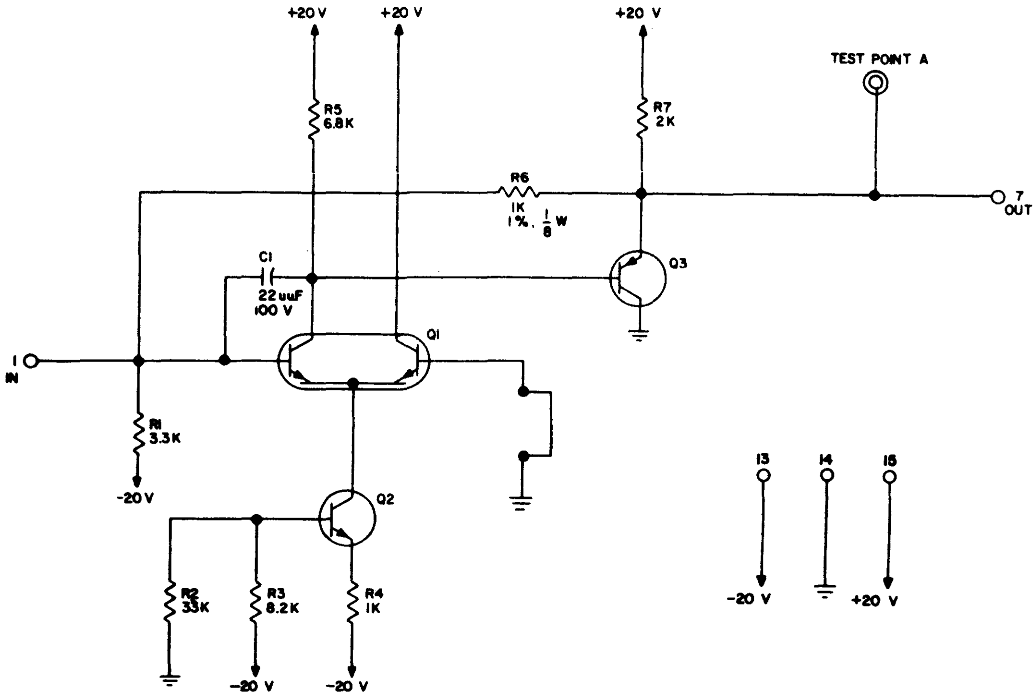



Figure 4-9. 003 Card - D/A Current Summing Amplifier

ANALOG TRANSMISSION

Each current summing card output feeds a level-shift amplifier contained on the 031 card. Each level-shift output then feeds a current amplifier (015 card) which, in turn, feeds another current amplifier (015A card). Figure 4-10 shows the analog transmission circuitry.

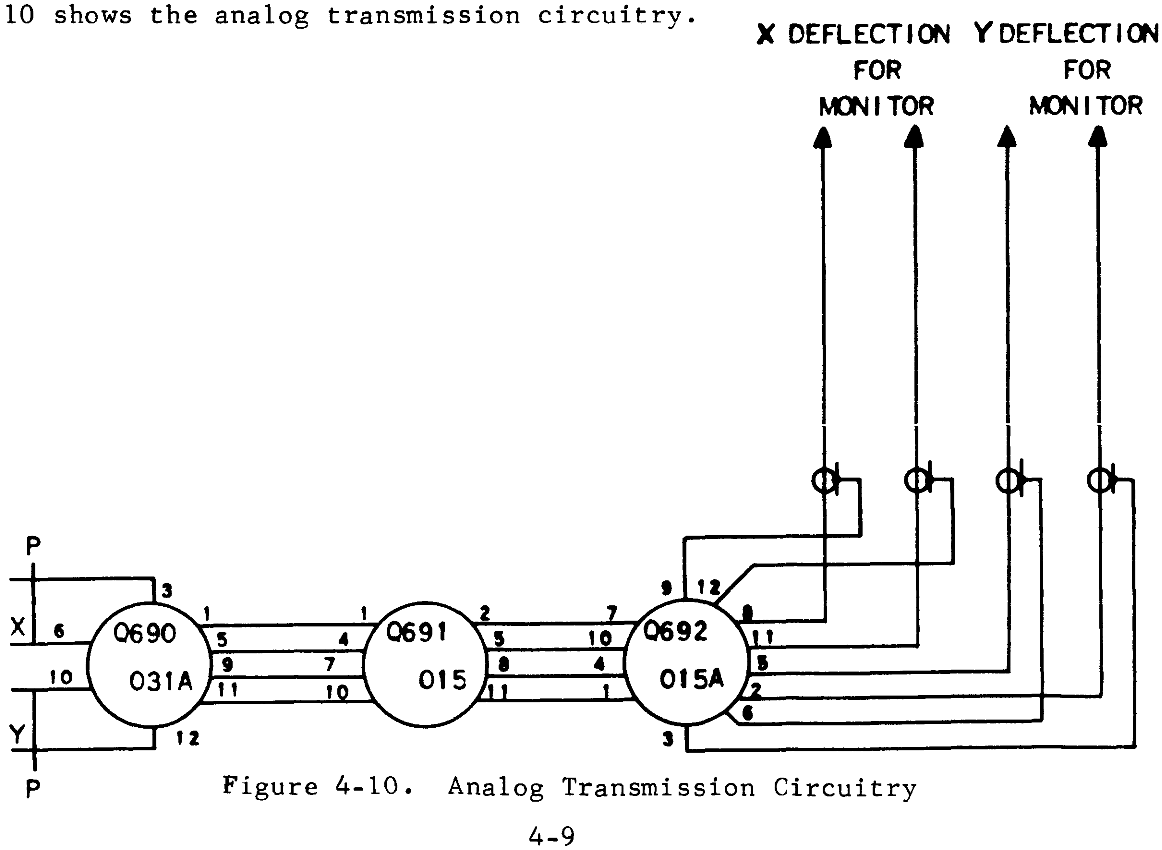



Figure 4-10. Analog Transmission Circuitry

LEVEL-SHIFT AMPLIFIER (031 CARD)

The 031 card (Figure 4-11) provides differential amplification of push-pull current summing amplifier outputs. Pins 3, 6, 10, and 12 are the four deflection signal inputs. Zener diodes CR1, CR2, CR3, and CR4 maintain a constant level-shift voltage of approximately -15 volts. Q3 and Q4 provide the differential balance; an increase in magnitude of +X signal also results in an increase in magnitude of -X. This is controlled through conduction of Q1, Q2, Q5, and Q6.

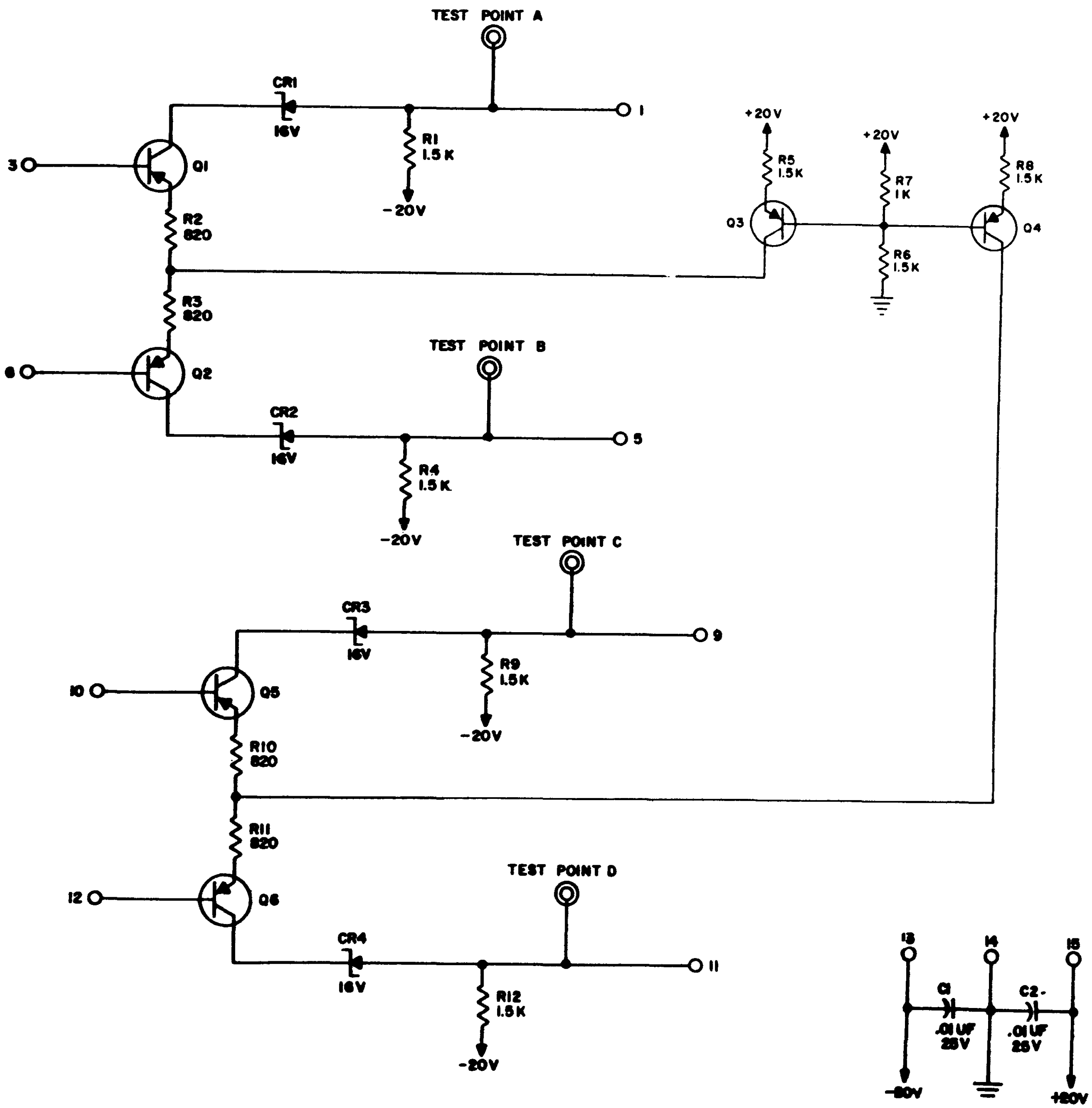



Figure 4-11. 031A Card - Level-Shift Differential Amplifier

LINE DRIVERS (015 AND 015A CARDS)

The 015 and 015A cards (Figures 4-12 and 4-13) each contain four emitter-follower circuits. The four outputs from the 031 level-shift amplifier each feed one of the circuits on the 015 card. Each 015 card circuit can handle 100 milliwatts. The four outputs from the 015 card then feed the 015A card which handles 400 milliwatts and acts as a line driver for the two X, Y deflection signals.

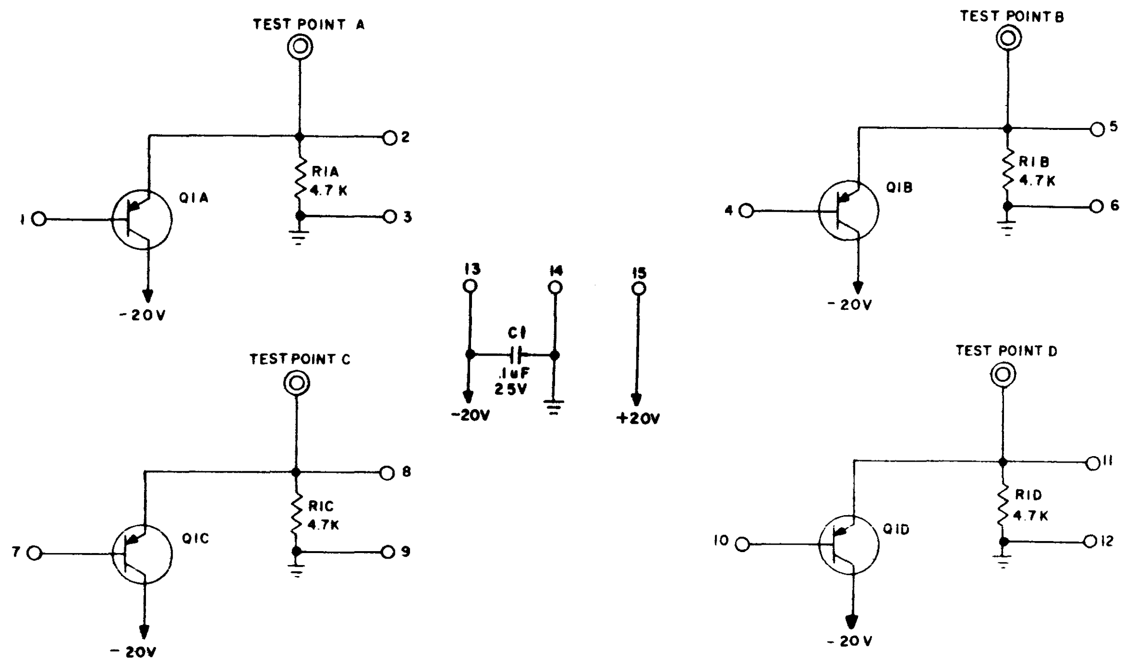



Figure 4-12. 015A Card - Line Driver (400 Milliwatts)

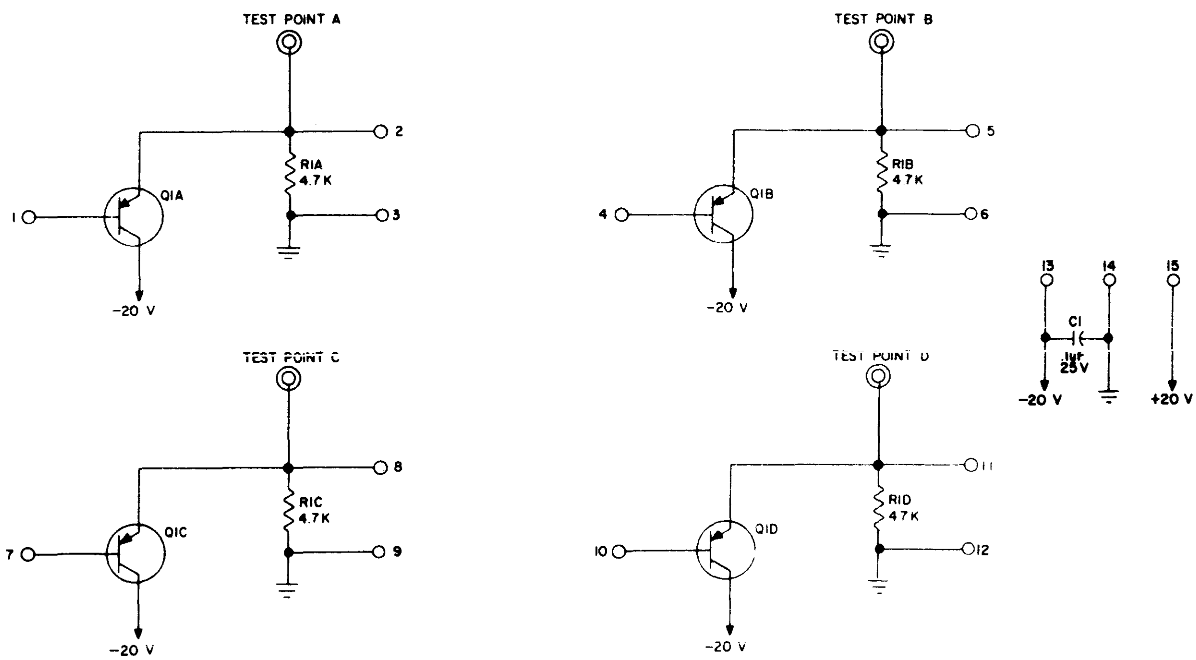



Figure 4-13. 015 Card - Line Driver (100 Milliwatts)

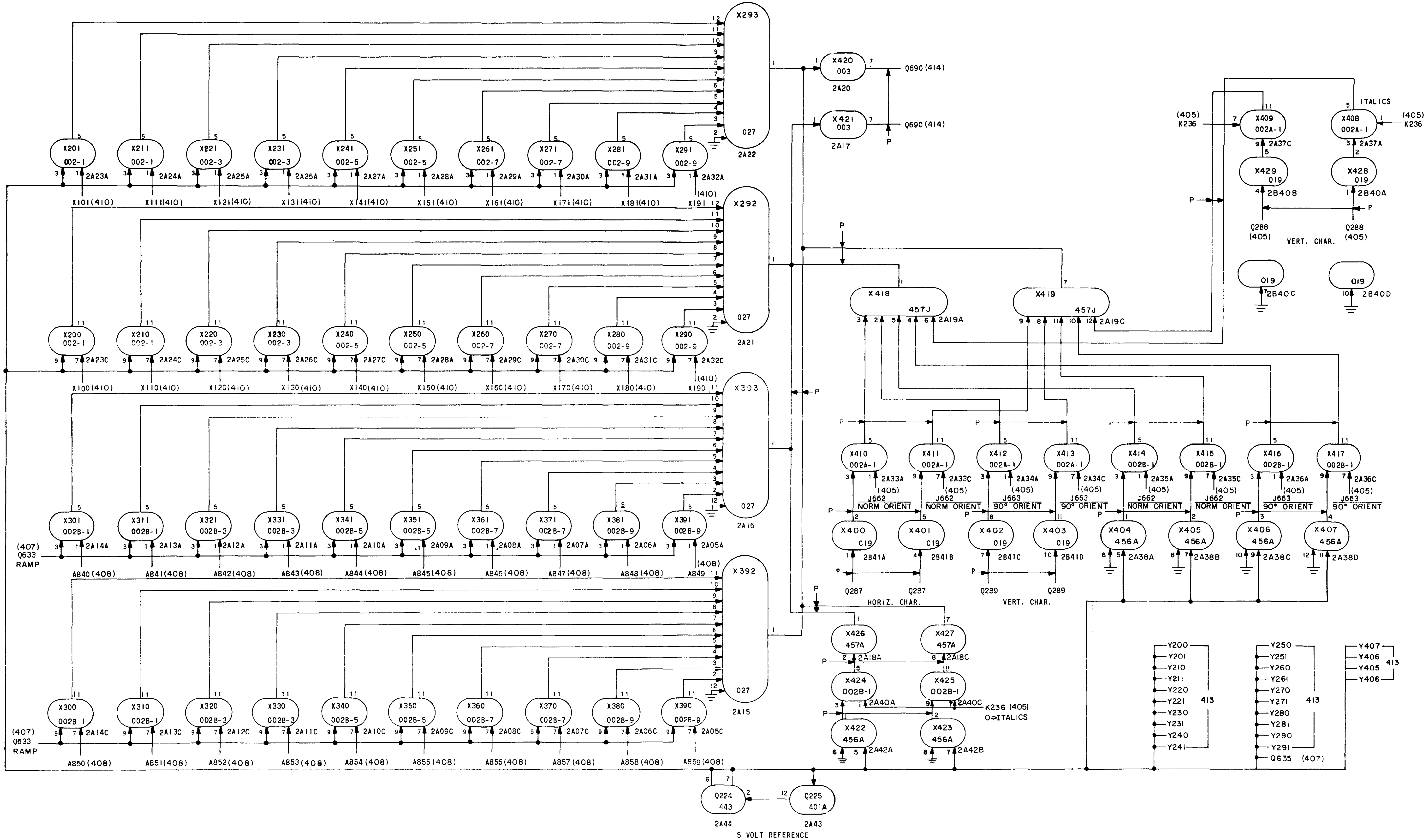


Figure 4-14. Digital-to-Analog Conversion

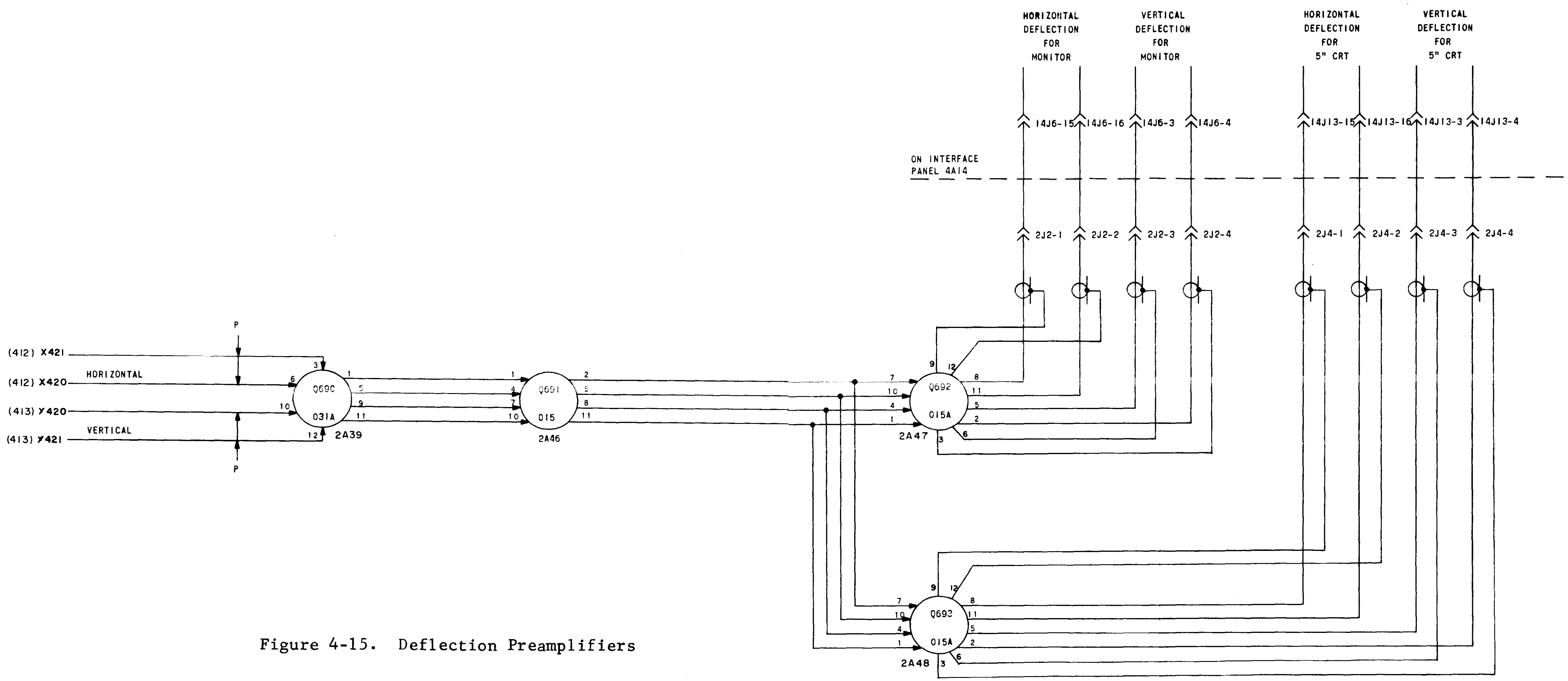



Figure 4-15. Deflection Preamplifiers

ANALOG CIRCUITRY
HOMEWORK QUESTIONS

1. Give a definition of ANALOG.

AN INCREMENTING VOLTAGE OF INFINITE POINTS

2. Give the basic purpose of the 027 card and how it works.

D/A CONVERTER RESISTORS
CURRENT SUMMING
(IT WEIGHTS THE DIGITAL ~~OUTPUT~~ INPUT SIGNAL)

3. Provide the purpose of the 002 card and explain how it works.

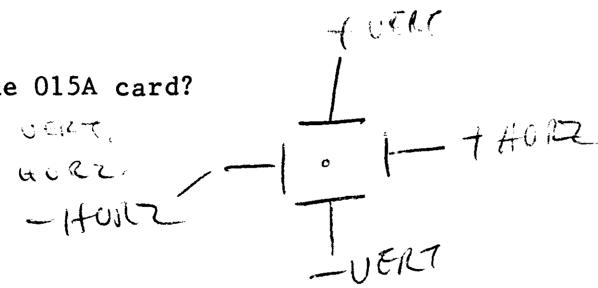
COMPARE CIRCUIT

{D/A [illegible]} PROVIDES REFERENCE VOLTAGE [illegible]
FOR CURRENT SUMMER

4. Vectors symbols and base positioning are all summed VOLTAGES ALGEBRAICALLY.

5. Why do we need four outputs from the 015A card?

2 FOR VERT,
2 FOR HORZ.



# SECTION V

SECTION V

# BASE POSITIONING

## CRT ADDRESSING

In most display systems the selection of a point on the face of the CRT at which a symbol or vector is to be placed is a function either of an input address representing X and Y coordinates which accompanies the symbol code or of the natural spacing mechanism of the display station itself. The "address" of a location on the face of any CRT is simply a balance of analog voltages sufficient to place the electron beam on that point by means of the deflection circuits. This is known as the base position.

Base positioning may be accomplished in random fashion, such as in the plot symbol mode of the CDC 280, or it may follow a fixed pattern such as the intensity modulated sweep pattern of the CDC 211 display station. In both of these devices, however, a given location on the face of the CRT is marked by two registers; X and Y. The size of these registers will vary from system to system, depending upon application. A character-only type of display would possibly require only two 9-bit registers, affording 512 increments on a side; whereas a point plot design console might require a 10 or 11-bit register.

Point plot or symbol plot operations will involve selection of CRT location with each new symbol or dot to be displayed. The line printer mode of operation, however, used with all small display stations and available with larger units, allows a specific pattern of symbol positioning to be followed. The Y register begins with a high value and the X with zero in order to position the electron beam at the upper left corner of the page. Upon the display of each symbol, the X register is incremented by a specific count, usually in powers of two, in order to reposition the electron beam far enough to the right to display the next character. At the end of the line a carriage return is effected, the X register is cleared out, and the Y register is decremented by an amount sufficient to give room for the next character. Machines with variable character size will have fewer characters per line and fewer lines as character size is increased. The increment and decrement inputs to both the X and Y registers will be varied according to the character size selected.

## BEAM POSITIONING

The fact that a push-pull type of signal is required for CRT positioning is of no consequence to the X and Y registers since the positive and negative X and Y voltages are generated in the D/A conversion process. A single X position word would allow the generation of both positive and negative X for positioning.

Representation of location on the face of the CRT with a binary word may differ in coding from one device to another according to application. Figure 5-1 illustrates one position selection arrangement. If a 10-bit word is used for all Y deflection, then the most significant bit should provide for one-half of total

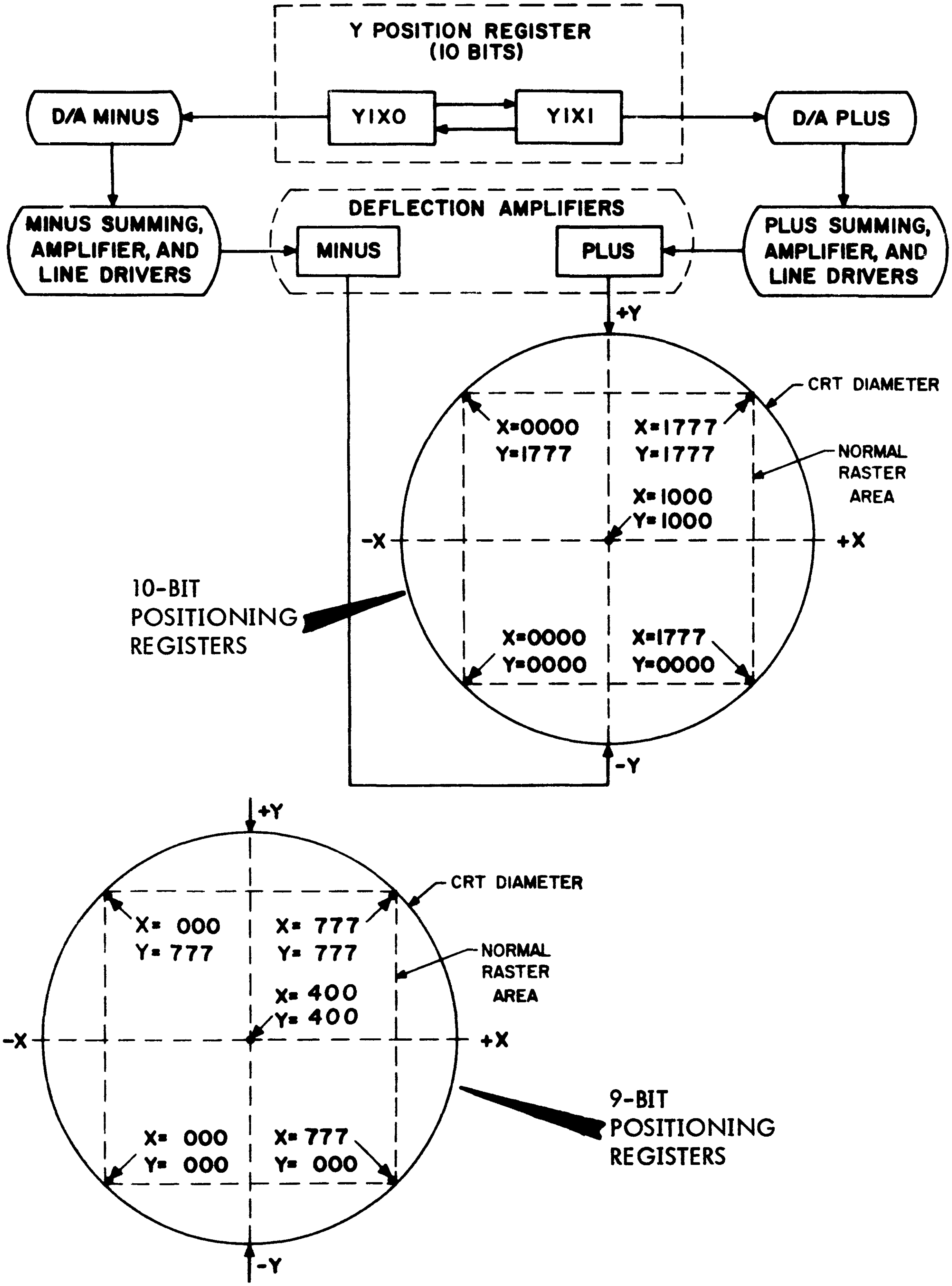



Figure 5-1. Base Positioning Network

deflection. Following this line of thought, a $Y=0000_8$ should place the electron beam at the bottom of the raster. $Y=1000_8$ should be midpoint and $Y=1777_8$ should be the top. Positioning is incremental by count and will provide a total of 1024 points on the CRT for a 10-bit positioning code. This same consideration may be made on a digital positioning word of any size, and on a CRT raster of any size or shape. Accuracy is, of course, a matter of the number of points addressable as well as the resolution of the CRT.

EXPANSION

It is the matter of weight which allows design display devices of certain types to employ the concept of expansion. If a 10-bit X and 10-bit Y code are representative of an entire raster and it is desired to have a given area, for instance, one quarter of the display, cover the entire raster area. The expansion is accomplished by, first of all, allowing only those symbols which would normally be placed within the specified area to be unblanked; and secondly, by altering the circuit recognition of bit weight so that bit $2^9$, in a 10-bit word, would not be converted and bit $2^8$ would be assigned the analog weight formerly assigned to $2^9$.

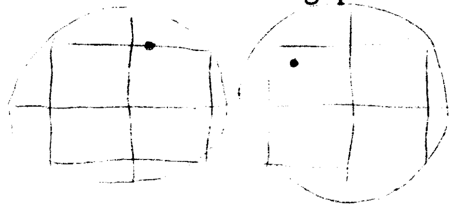
The contents of the base position registers will at all times be a factor in the final analog voltage found at the current summing device. Vectors or symbols will simply be varying analog voltages riding the base position reference.

BASE POSITIONING
HOMEWORK QUESTIONS

1. Show actual position on a CRT for the following positioning words:

   a. X, 1111; Y, 1777

   b. X, 0077; Y, 1700



2. What are the normal lengths of base positioning registers used to furnish base values necessary for base positioning?

   9 OR 10 BITS

3. The tabular mode of printing is an alternate to what system?

   LINE PRINTER MODE

Expansion of a CRT display may be accomplished by what means?

   REASIGN BIT WEIGHTS [illegible] ONLY RASTER AREA TO BE USED. . .

# SECTION VI

# SECTION VI

# SYMBOL GENERATION

## THE DIODE MATRIX

As has been stated, symbol generation may be accomplished by several methods: stencil painting, involving selection of a character by allowing the electron beam to be positioned on a stencil for character selection and further positioned on the face of the CRT to accomplish a display; the plot point system, creating symbols or vectors or curves by dot painting; the diddle system, utilizing an intensity modulating principle and a variation of the television principle; and the symbol painting method. In each of the considerations above, with the exception of stencil painting, production of a character is a matter of selection of a base position at which the character is to be painted and then providing extremely rapid movement of the electron beam with well coordinated blanking and unblanking in order to produce the character desired. In looking at the speed of production of characters in the previous sections, it becomes obvious that the motion in the production of characters involves movement and intensity control of the segments of characters being produced which takes place in the nanosecond range. To accomplish the production of many different characters without undue use of logic circuitry, a device known as the diode matrix is incorporated.

The principle of the diode matrix is that any routine processing procedure may be precoded in a circuit in such a way that selection of that procedure will immediately result in an automatic sequence of events. This wired program theory may be applied to the production of characters, whether the process involves a timed unblanking of the CRT for the purpose of intensity modulation of a sweep, or timed movement of the electron beam coupled with unblanking signals.

## SYMBOL PLACEMENT

It has already been seen that the coordinate locations on the face of the CRT may be identified by combinations of X and Y binary position words. Obviously, with a million coordinates it would not be feasable to attempt to paint one character per coordinate; but rather, to assign a group of coordinates for each character. This group selection would be dependent upon the actual size of the character being painted, bearing in mind the physical size of the coordinates involved (factors of the size of the raster area and the positioning words). See Figure 6-1. The area then allotted to painting of the character would be assigned as a working area, and the circuitry involved in the painting of the character would make symbol "moves" within the working area. The "moves" would be of a precalculated length based upon the division of the working area into a grid coordinate known as a matrix. The number of coordinate locations referred to are elements of the character generation circuitry, independent of position, and need not necessarily correspond to the number of address coordin-

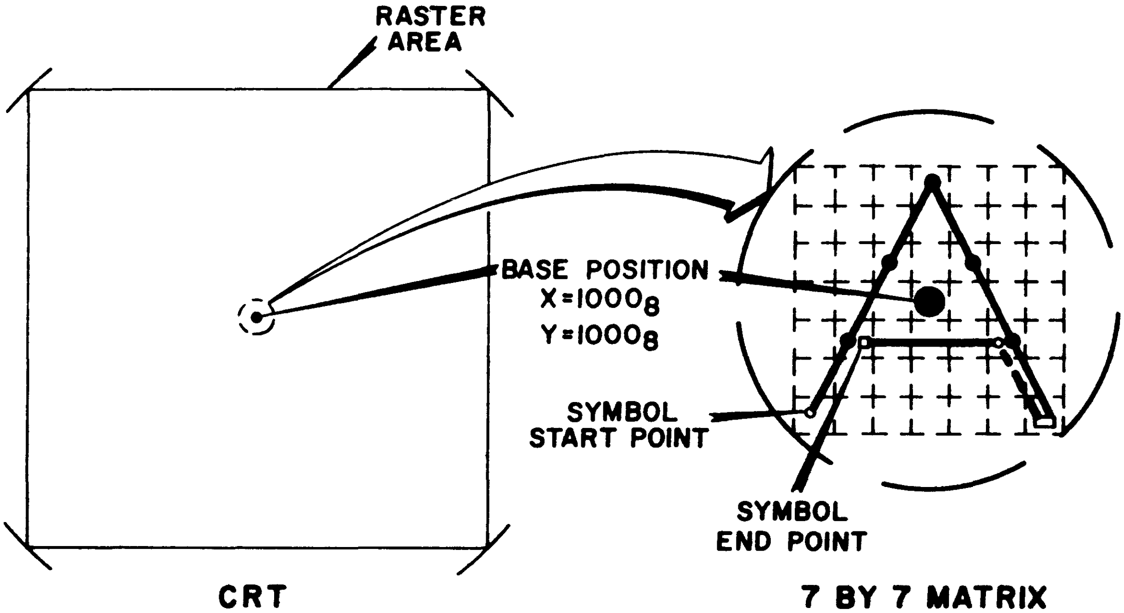



Figure 6-1. CRT Raster Area And Symbol Matrix

ates previously assigned. They are also, in terms of analog position selection, therefore capable of being varied in size, still maintaining the same number of "moves" per symbol.

The term "character moves" is applicable to the symbol painting method. Most of the discussion of symbol generation will be the treatment of this method. The "diddle" character generation system, though, will still use a timed diode matrix to generate a character of a specific size within a specific working area. Here the diode matrix outputs will not provide symbol moves but unblanking pulses which will intensify the electron beam at specific points along the sweep of the CRT in order to produce a character.

The matrix of coordinates utilized by the character generation circuitry will be sized according to application from a 5 X 7 matrix used by the CDC 211, to the 9 X 9 matrix of the CDC 280, to even larger matrices of other equipments. The size of the matrix will depend upon the number of symbol moves which may be required; and, of course, the larger the matrix the more the circuitry which will be required to provide these moves.

The following discussions will involve the painting of a symbol on a 7 X 7 matrix.

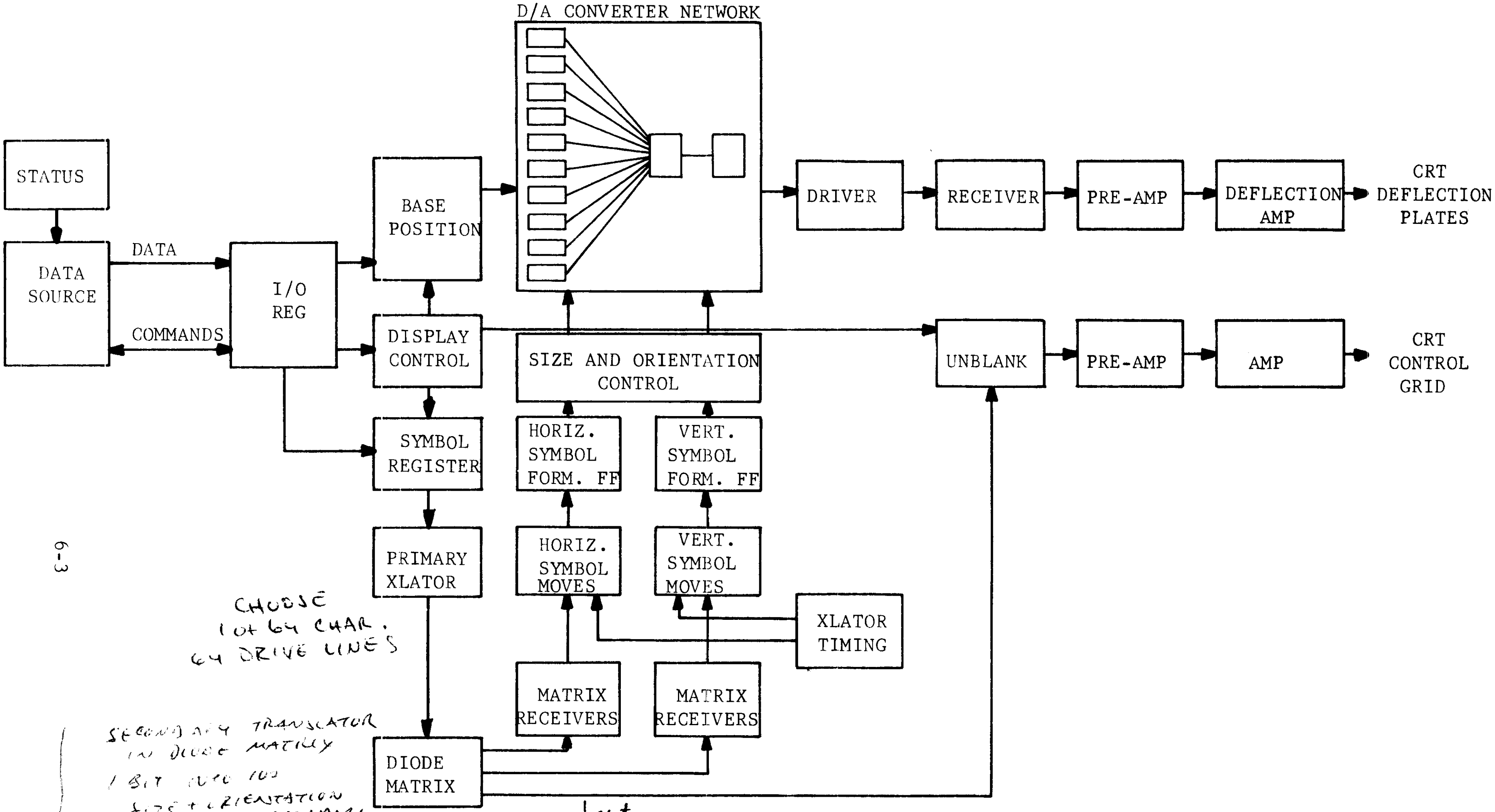



Figure 6-2. Symbol Formation and Timing Control Block Diagram

SECONDARY TRANSLATOR IN DIODE MATRIX
1 BIT OUT OF 100
SIZE + ORIENTATION CONTROL. SECONDARY
BLANK + UNBLANK

CONTROLS PROPORTIONATE X-Y DEFLECTION VOLTAGES IN ROTATION AND INTENSITY
ADDS TO BASE DISPLACEMENT

45° 90° ANGLE OR 30° 60°

GROUPS OF 5 FROM DIODE MATRIX
VERT 1
VERT 2
HOR 1
HOR 2
UNBLANK

20 TIMING PULSES PER CHAR.
400 NS / STROKE
8 μS / CHARACTER

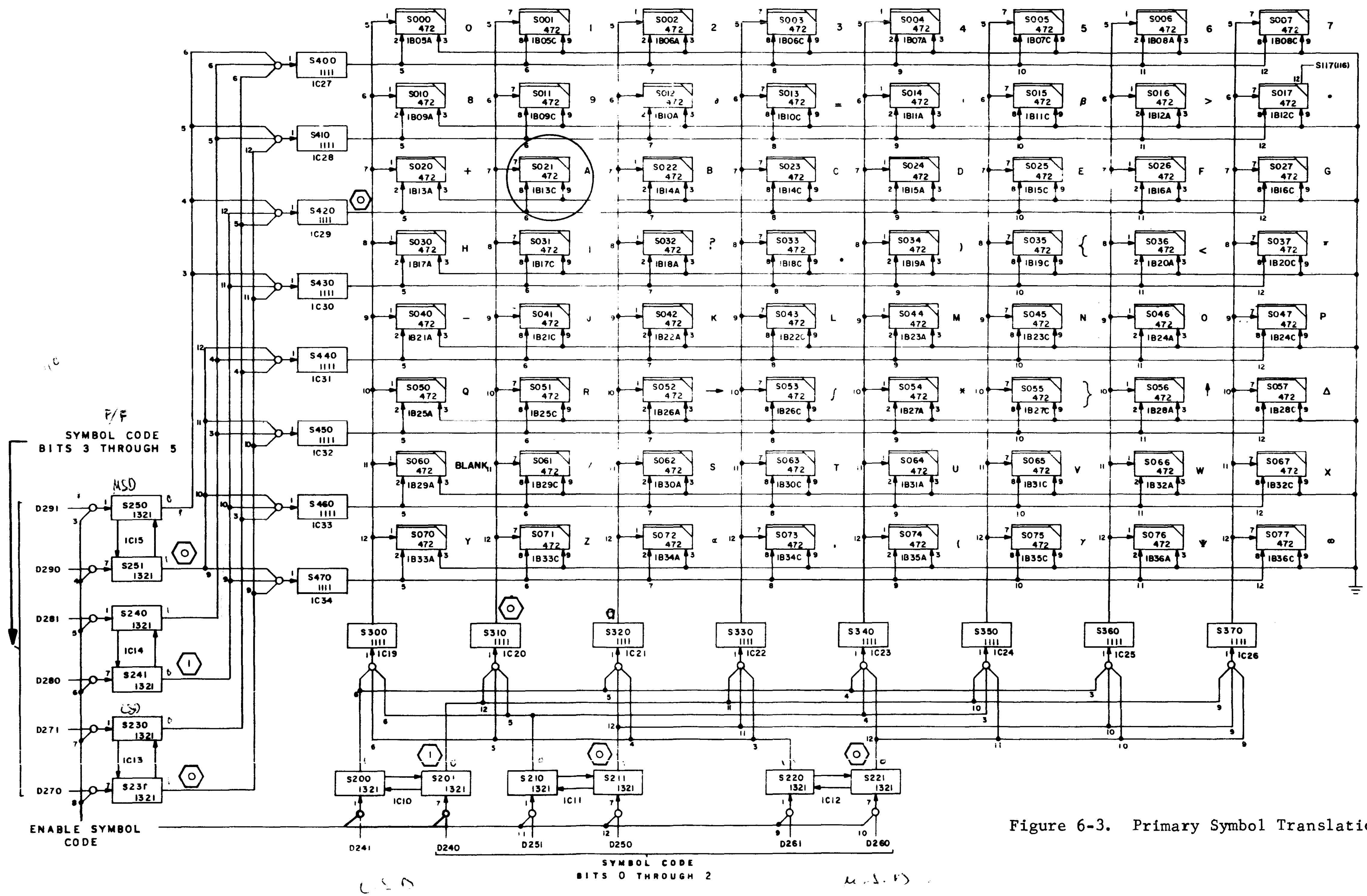



Figure 6-3. Primary Symbol Translation Logic

Figure 6-2 is a block diagram of the 7 X 7 symbol formation and timing control circuitry. Initially, the display register transfers a symbol code to the primary symbol translator. The primary symbol translator selects the respective diodes in the diode matrix used to form the symbol and enables unblank. Display control enables the primary symbol translator, symbol timing, and symbol preset positioning. Matrix receivers and symbol timing enable the horizontal and vertical formation F/F's. Outputs from these F/F's go to the position digital-to-analog converters where they increase or decrease deflection levels; thereby, moving the CRT beam around the base position, forming the symbol. For purpose of explanation, a symbol code of 21 octal is selected. This code portrays symbol A for this example.

PRIMARY SYMBOL TRANSLATION

The purpose of the primary symbol translation circuitry is to decode 6-bit binary codes (symbol) and a seventh-bit (case), if included. The case bit allows selection of upper and lower cases of letters or two different symbols similar to a shift key on a typewriter.

Each code selects one primary symbol translator driver. This driver activates one drive line of the diode matrix (D88) cards. Diodes, connected to the drive lines, ANDed with symbol timing, enable symbol formation F/F's. Symbol formation F/F's control movement of the CRT beam.

Figure 6-3 is the logical diagram of the primary symbol translator. The hexagon enclosed ones and zeros represent the selection of the primary symbol translator driver for a symbol code of 21 octal in respective bit positions 24 through 29.

SECONDARY SYMBOL TRANSLATION

D88 cards with their bus lines connected in series, form the secondary translation circuitry. Figure 6-4 is a drawing of four diode matrix cards in series, the times the beam movements are enabled, and the diode connections used to form the symbol A.

Four D88 cards are connected in series for each symbol group; drive lines 6, 7, 14, etc. on the four cards are common. The 20 groups of four advance lines and one unblank line correspond to t1 and t20 of the main timing chain. Advance and unblank lines set and clear position and unblank F/F's, respectively.

A diode (represented by dots in Figure 6-4) connected between the symbol drive line and the advance line enables the beam position in horizontal/vertical direction, or controls beam unblank. A diode connected between a drive line and the first advance line (pins 5, 12, 20, etc.) repositions the beam one horizontal increment, and a diode connected between a drive line and the second advance line (pins 4, 11, 19, etc.) repositions the beam two horizontal increments. Vertical repositioning functions the same, using the third advance line (pins 3, 10, 18, etc.) for one increment and the fourth advance line (pins 2, 9, 17, etc.) for two increments. Diodes connected between the first and second advance lines in the same time group reverse horizontal direction of subsequent beam positioning incre-

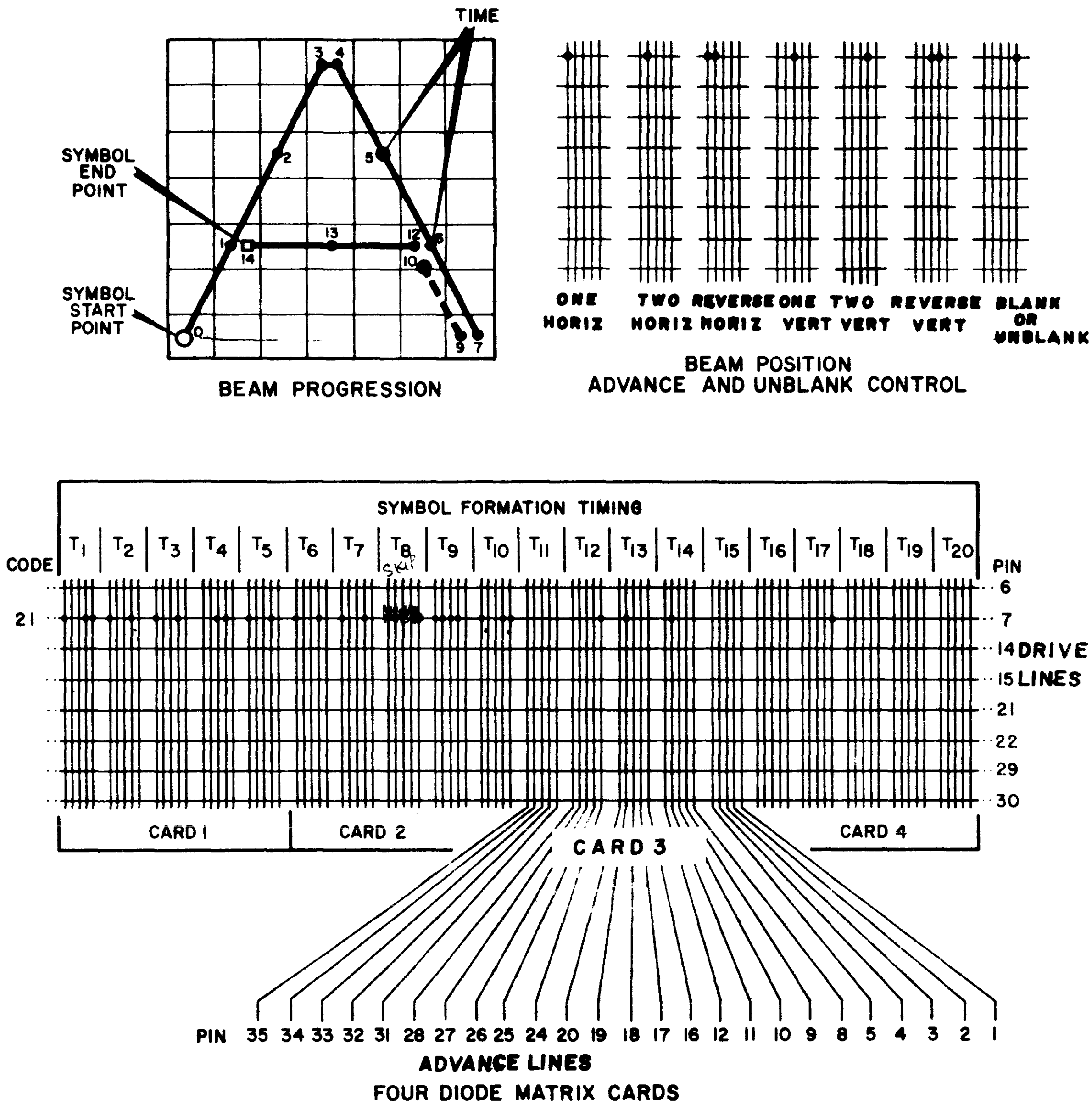
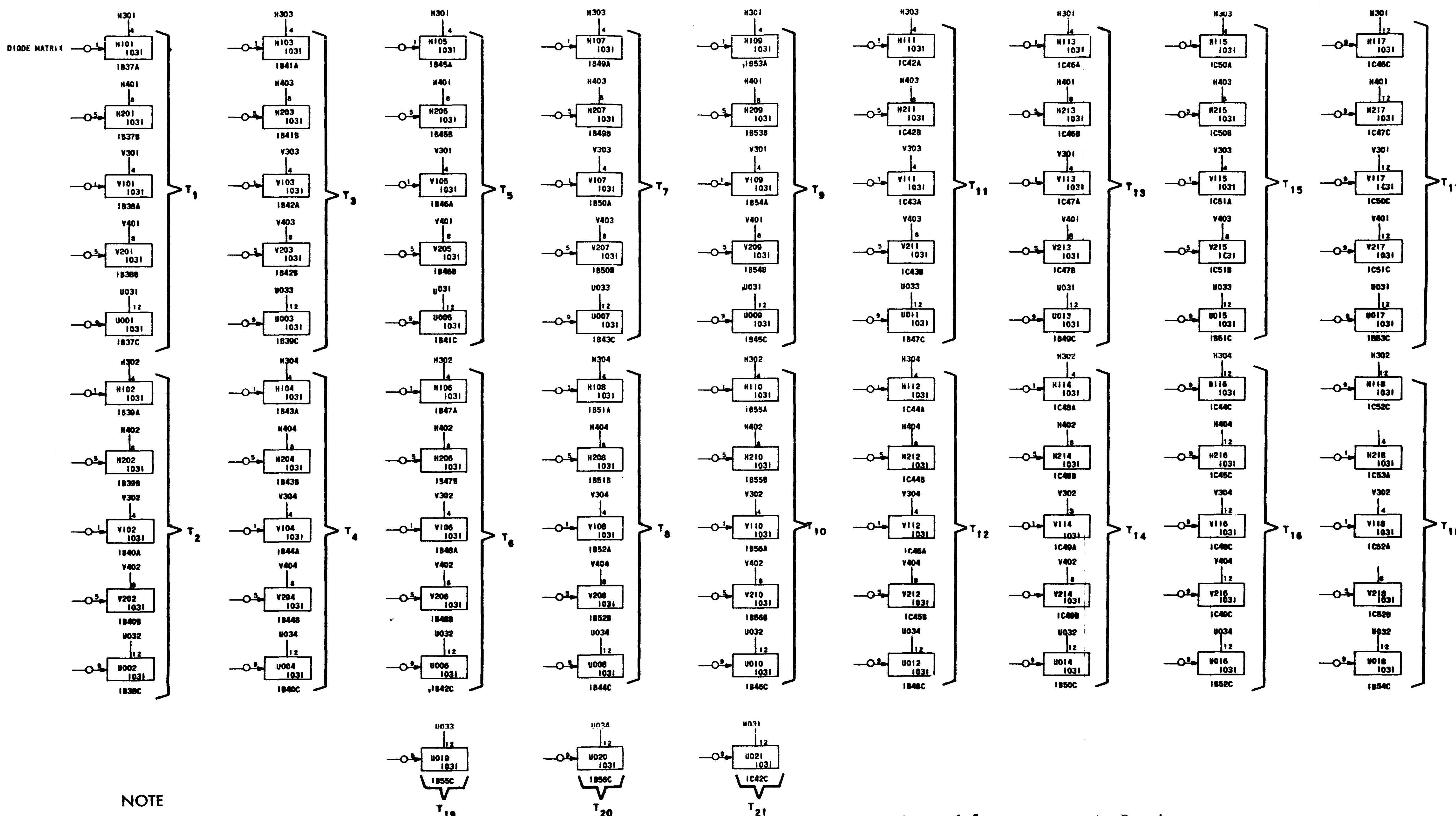



Figure 6-4. Typical Symbol Formation

ments, and diodes connected between the third and fourth advance lines in the same time group reverse vertical direction of subsequent beam positioning increments. The fifth advance line enables the unblank. The first time a diode is connected on the fifth line the beam is unblanked, and the second time a diode is connected on the fifth line the beam is blanked.




NOTE

DIODE MATRIX INPUTS NOT SHOWN IN THIS FIGURE. REFER TO FIGURE 6-6 FOR INPUT EXAMPLE.

Figure 6-5. Diode Matrix Receiver

Symbol formation for the letter A begins in the lower left corner of the 7 X 7 symbol matrix (Figure 6-4). T1 moves the beam from the lower left of the 7 X 7 matrix, two vertical increments and one horizontal increment in a positive direction, and unblanks the beam. T2 moves the beam two more vertical increments and one more horizontal increments. T3 continues moving the beam in the same direction. T4 reverses the vertical direction. T5 moves the beam two reverse vertical increments and one horizontal increment as does the T6 and T7. T8 is not used. T9 reverses both horizontal and vertical direction. T10 moves the beam two vertical increments, one reverse horizontal increment, and blanks the beam. Blanking of the beam is enabled 400-nanoseconds after the beam movement because of the deflection circuitry delay. T11 is not used. T12 unblanks the beam again. Beam positioning and unblanking continues until the letter A is formed on the face of the CRT.

DIODE MATRIX RECEIVERS

Matrix receivers are standard inverters enabling symbol moves, reversing, and unblanking. Their input is from advance lines of the diode matrix D88 cards. Figure 6-5 is a logical diagram of the matrix receivers. To enhance clarity of the figure, inputs to matrix receivers are not shown. The following paragraphs explain input connections.

There are eight sets of symbol formation diode cards. Each set contains four D88 cards, numbered one through four. Figure 6-4 shows one set. Each matrix receiver card has eight inputs. Pins 35 of the eight number one D88 cards connect to matrix receiver H101. Therefore, H101 has eight inputs. Pins 34 of the eight number one D88 cards connect to H201, pins 33 connect to V101, etc. Pins 35 of the eight D88 cards numbered two connect to matrix receiver H106, pins 34 connect to H206, pins 33 connect to V106, etc. D88 cards numbered three feed inverters H111 through U015. D88 cards numbered four feed inverters H116 through U021. T18 are the last advance lines used to position the beam. Advance lines T19 and T20 are for blanking and special purposes such as pre-positioning.

Figure 6-6 shows pin numbers and connections between eight number one D88 cards and matrix receivers.

The first number of the Hxxx and Vxxx terms represents moves. H1xx and V1xx represent one horizontal or one vertical move and H2xx and V2xx represent two horizontal or two vertical moves. The last two numbers of the Hxxx, Vxxx, and Uxxx terms represent the time of beam movement or unblank. Hx01, Vx01, and Ux01 represent T1, Hx02, and Ux02, T2, etc.

A symbol code grounds a bus line of the D88 cards. Code 21 octal grounds the D88 bus line used to form the symbol A. A diode between an advance line and a selected bus line places a ground on the advance line. Advance lines are connected to matrix receivers; therefore, matrix receivers H101, V201, U001, H102, V202, H103, V203, V104, V204, H105, V205, H106, V206, H107, V207, H109, H209, V109, V209, H110, V210, U010, U012, H213, H214, and U017 have grounded inputs. A grounded input to a matrix receiver switches its output to logical 1. These logical 1, ANDed with the main timing chain, enable unblank and horizontal and vertical symbol moves.

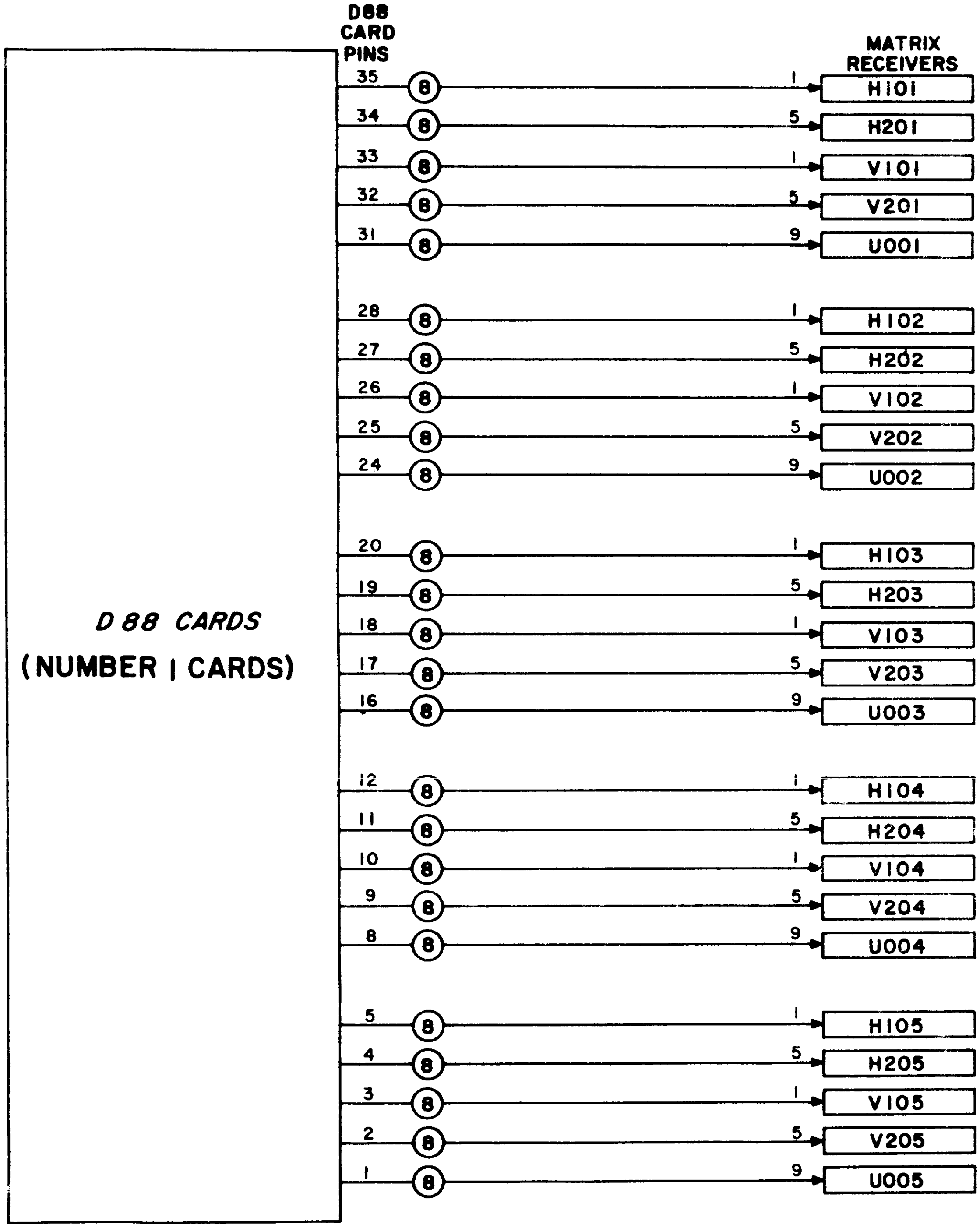



Figure 6-6. D88 Card And Matrix Receiver Connections

## SYMBOL MOVES

Horizontal and vertical symbol moves, ANDed with the main timing chain, set and clear horizontal and vertical formation F/F's. Only vertical beam movements are explained since both the horizontal and vertical symbol moves function the same, with the exception of beam movement direction. Figure 6-7 is the logical diagram for symbol moves.

V201 from the matrix receivers has a logical 1 output as previously explained. This 1, ANDed with the first symbol formation time (T1), applies a logical 1 to symbol move inverter V401. V401 applies a logical 0 to V407 and V501. V501 has a logical 1 applied from V301; therefore, V501 outputs a logical 0. Two logical 0 to V407, one from V501 and one from V401, switch the output of V407 to a logical 1. V407, ANDed with a clock pulse, sets K270/271 (even vertical 2 F/F). K270 applies a logical 0 to V904 and V906. Assuming that the even direction F/F K252/253 is set, V904 outputs a logical 1 and V906 a logical 0. V904 sets two vertical formation F/F's which advance the CRT beam two vertical increments. Corresponding to the position of the diode at T1 on the diode matrix, the logical 1 output from V409, ANDed with a clock pulse, clears the even vertical 2 F/F, K270/271.

T4 on the diode matrix is a vertical reverse. Matrix receivers V104 and V204 apply logical 1 to the input ANDs at V304 and V404, respectively. V304 and V404, ANDed with the main timing chain, output logical 0. The logical 0, when applied to V502, switch its output to a logical 1. The output is ANDed with a clock pulse and the set output of the even direction F/F (K252/253) which clears the vertical reverse F/F k250/251. K250, ANDed with a clock pulse, clears the even direction F/F K252/253. K252 prevents the output of V904 from going to a logical 1 the next time V401 is enabled. K253 enables a logical 1 output of V906. The next vertical 2 movement to V401 decreases the symbol formation FF count by two vertical increments. This system of setting and clearing FFs and switching inverter outputs controls the symbol formation FFs.

## SYMBOL FORMATION FLIP-FLOPS

Horizontal and vertical symbol formation F/F's advance or retard the beam position one or two increments horizontally or vertically on the symbol matrix and preset the beam to one of three positions on the symbol matrix. Preset positions are lower left corner or normal, center, and upper right corner. Since horizontal and vertical symbol formation is identical, with the exception of direction, only the vertical is explained. Figure 6-8 is the logical diagram for vertical symbol formation F/F's.

A logical 1 from vertical symbol move V900 sets V600/601. V600 increases the negative deflection level and V601 increases the positive deflection level through D/A conversion circuitry Q002. This change moves the CRT beam one symbol matrix increment in the positive or upward direction. V601 also applies a logical 1 to V604 which, ANDed with a clock pulse, sets V604/605. The next V900 enable, ANDed with V605, sets V610/611. V610/611 moves the beam one more vertical increment. V620/621, V630/631, V640/641, and V650/651 are success-

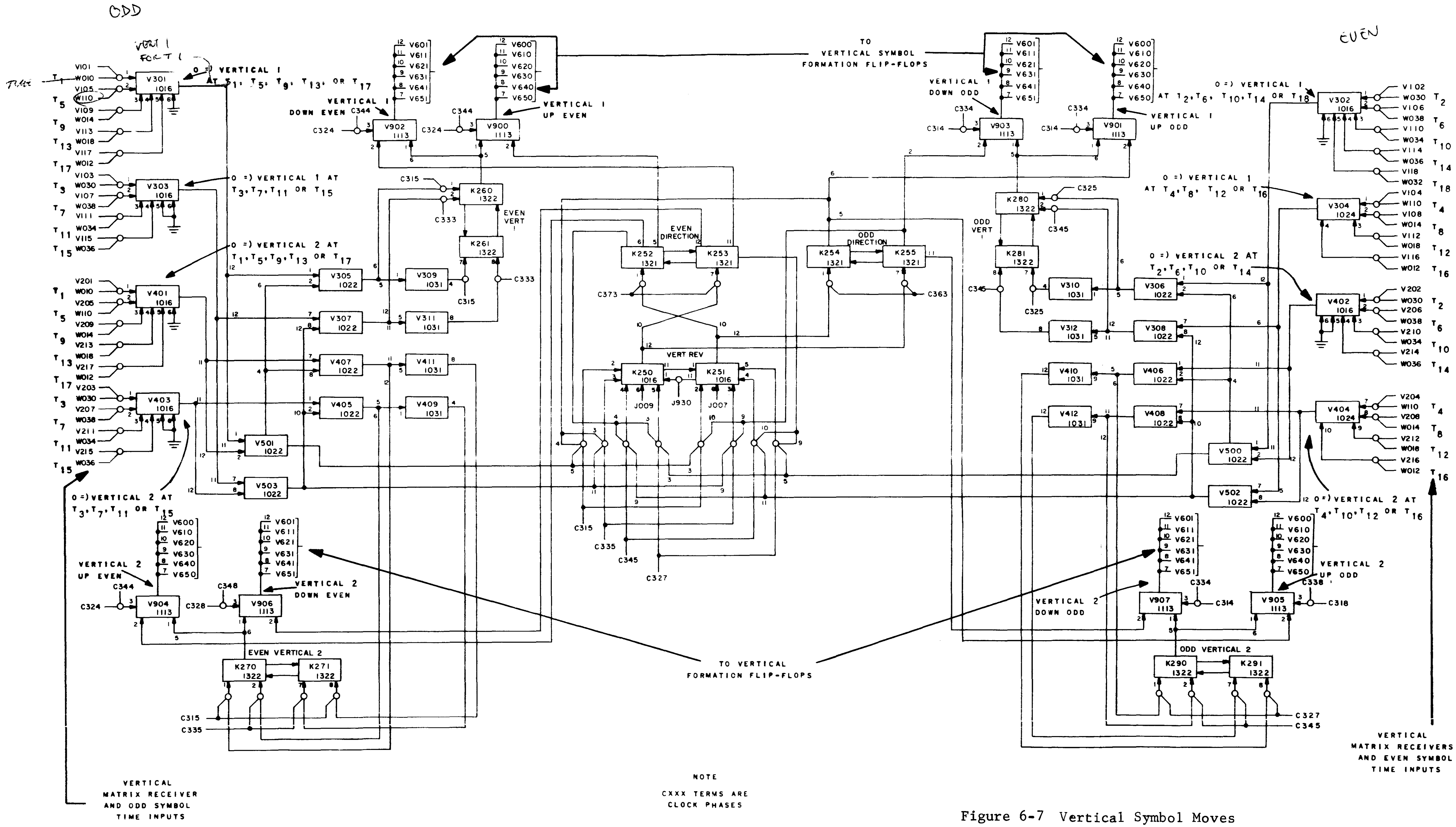


Figure 6-7 Vertical Symbol Moves

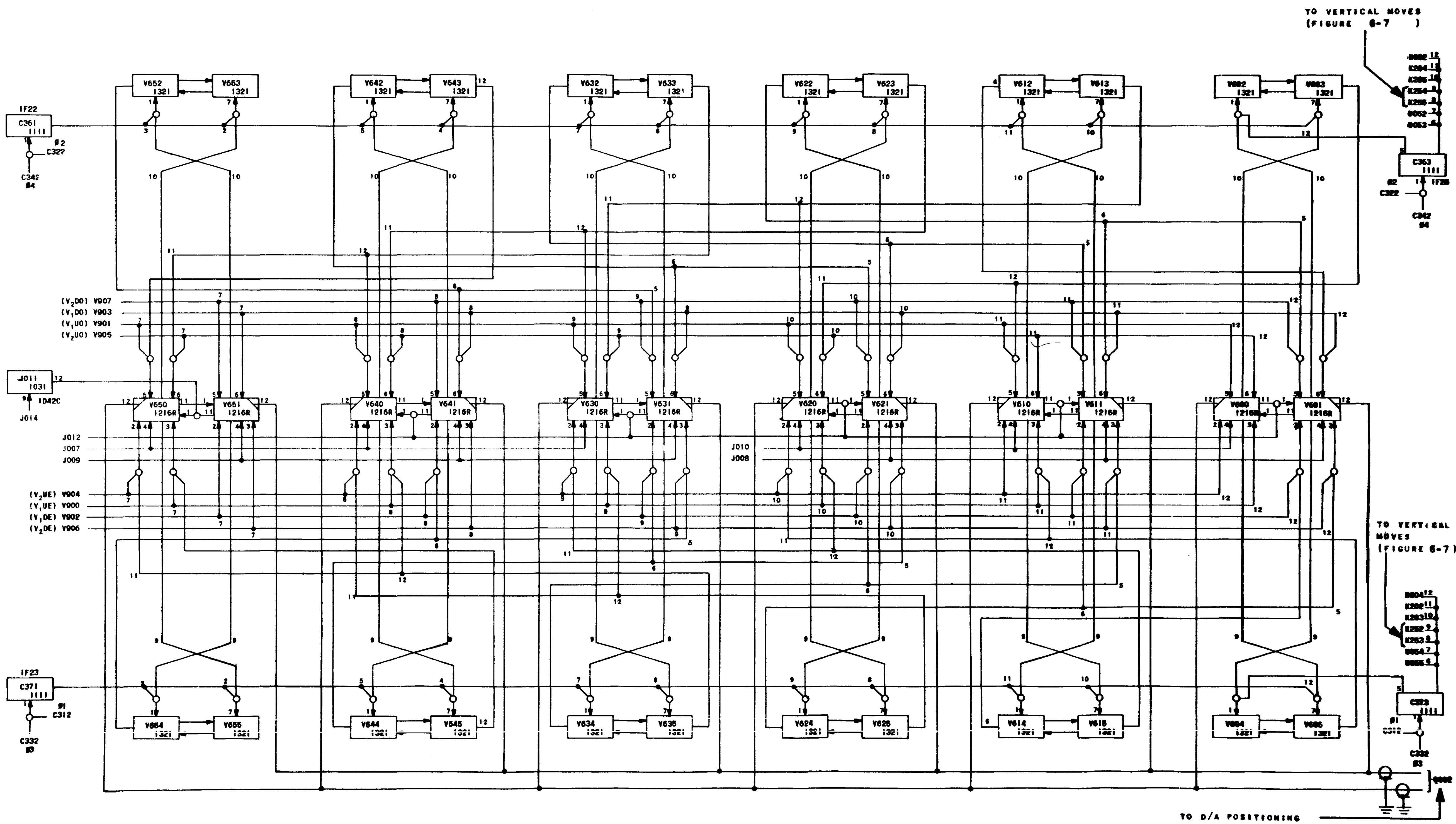
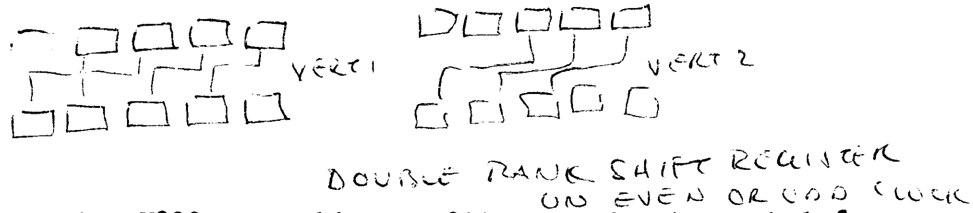



Figure 6-8 Vertical Symbol Formation Flip-Flops




ively set each succeeding time V900 is enabled. V901 controls the symbol formation F/F's the same as V900. V900 is enabled at even times and V901 at odd. V904 and V905 function the same as V900 and V901 except either being enabled sets two symbol formation F/F's, moving the beam two increments. V902, V903, V906, and V907 function the same except that they are connected to the clear inputs of the symbol formation F/F's. They decrement symbol formation F/F's, moving the beam in a downward or negative direction.

J007, J008, J009, and J010 preset the beam. Enabling J008 and J009 clears all symbol formation F/F's, positioning the beam at the bottom of the symbol matrix. Enabling either J007 or J010 sets half the symbol formation F/F's, positioning the beam in the center of the matrix. Enabling both J007 and J010 sets all symbol formation F/F's, positioning the beam at the top of the symbol matrix.

## SYMBOL TIMING AND PRESET POSITIONING

Symbol timing enables the inputs to horizontal and vertical moves. Symbol times are identified by tx in Figures 6-7 and 6-9. Timing pulses are generated by using a standard timing chain with or without a pass counter.

Preset positioning involves moving the beam to a predetermined position within the symbol matrix or shifting the matrix. An example of moving the beam to a predetermined position within the matrix would be a preset pulse which sets all the symbol formation F/F's and positions the beam in the upper right corner of the matrix. Setting one-half of the symbol formation F/F's with one preset pulse positions the beam in the center of the matrix.

Some equipments shift the matrix two increments down or up to write superscripts, subscripts, and letters with parts below the line. The shift is accomplished by preset positioning.

## SYMBOL UNBLANK TRANSLATOR

The unblank translator sets unblank F/F U110/111 which, in turn, unblanks the CRT beam. This translator is used for symbol unblank only. Its circuitry consists of standard inverters and three F/F's. One unblank enable F/F, U050/051, sets unblank F/F U110/111. The other two F/F's, odd and even unblank U052/053 and U054/055, set and clear the unblank enable F/F. Figure 6-9 is the logical diagram of the unblank translator.

Enabled U0xx matrix receivers apply logical 1 to the input ANDs of unblank translator inverters U031, U032, U033, and U034. The main timing chain furnishes the second enable. Switching the output of U031 applies a logical 0 to U041. U041 applies a logical 1 to an ANDed input to U050. A second enable is from C313 (clock pulse) and the third and final enable is from U052. U050/051 is set. U050 enables the setting of the unblank F/F. U051 sets the unblank F/F through Q015.

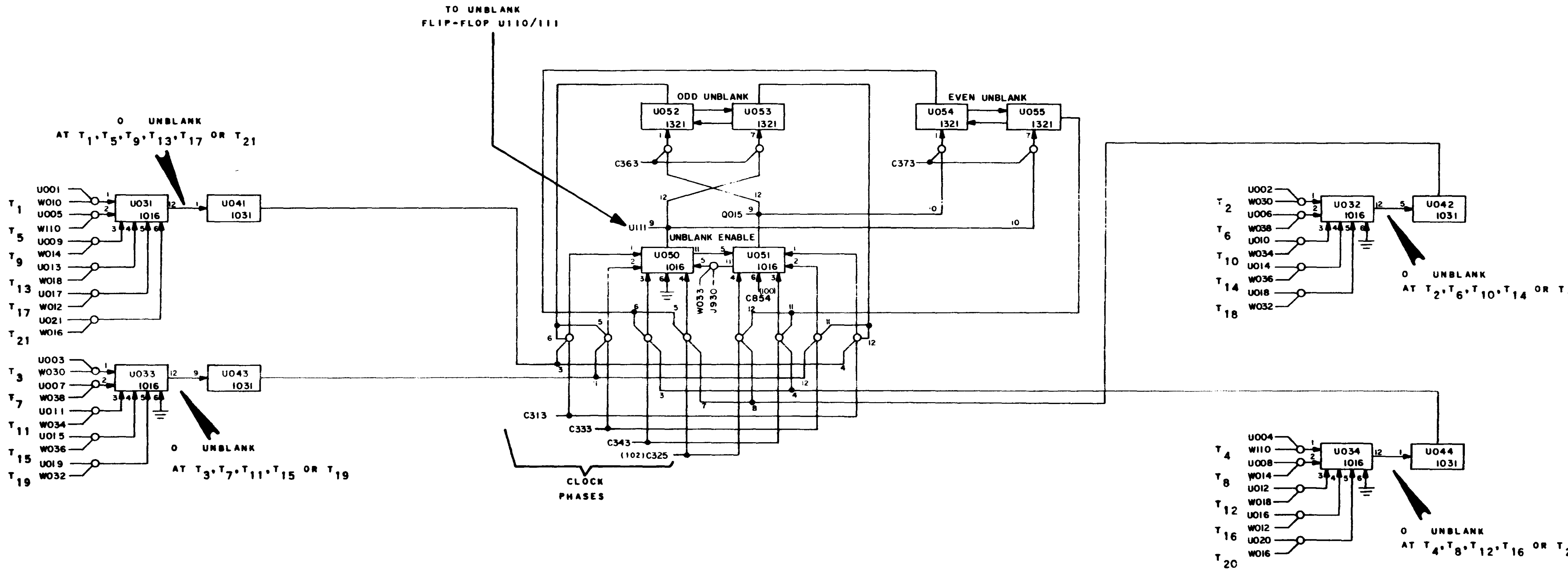
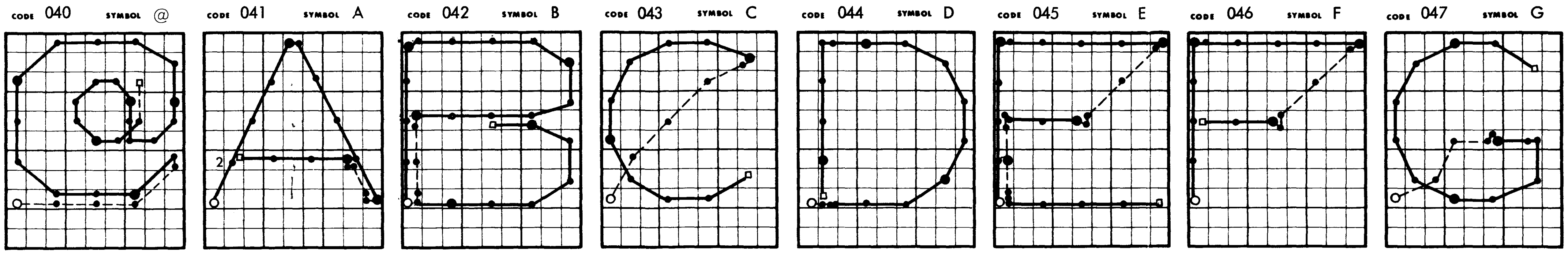


Figure 6-9. Unblank Translator

U051, ANDed with a clock pulse, also sets the odd and even unblank F/F's U052/053 and U054/055. Setting both these F/F's disables all four ANDed inputs to U050 and enables all ANDed inputs to U051. The unblank enable F/F remains set until a second unblank enable is applied to an unblank translator inverter. Assume that the unblank (blank) enable is through U034. U034 through U044 furnishes the final enable to one of the ANDed inputs to U051. U051/052 is cleared. This clears the odd, even, and unblank F/F's. Clearing the unblank F/F blanks the CRT beam and clearing the odd and even unblank F/F's re-enables the ANDed inputs to the set input of U050/051.

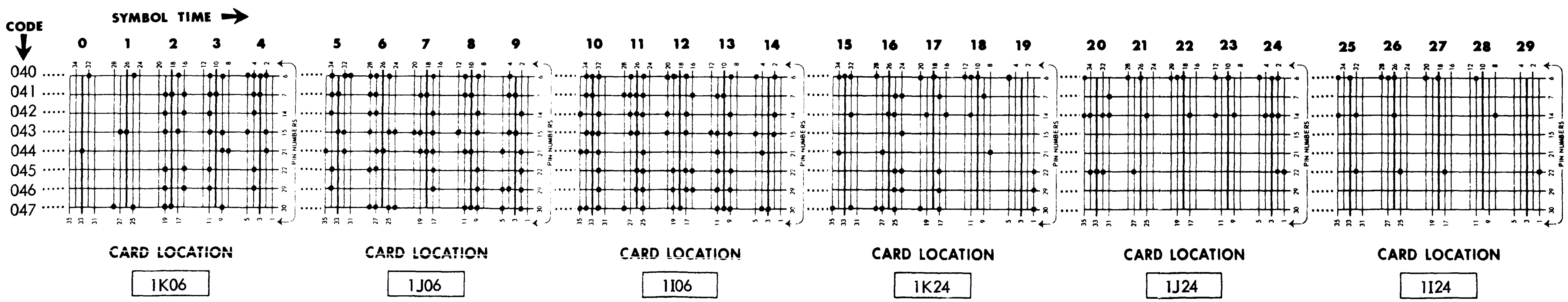
# SYMBOL TIMING dd 80 C

## Individual Symbol Timing Charts




Each dot in the above timing diagrams corresponds to the beam position during one symbol time interval. The larger dots represent times 5, 10, 15, 20, and 25. Starting at the small circle, the trace connecting the dots indicates the sequence of beam movements. Where the beam remains stationary for several successive intervals, dots are sometimes omitted to enhance the clarity of the diagram. When this is the case, a number in the appropriate square indicates the time interval during which beam movement resumes. The solid portion of the trace represents time intervals during which the beam is unblanked. The small square that terminates the trace represents the final blanking signal in the given sequence.

## Diode Matrix (type D88) Card Layouts




The layout diagram approximates the physical configuration of the set of six D88 cards that control the formation of the eight symbols shown in the individual symbol timing charts. The horizontal lines in the diagram represent bus bars. The bus bars run serially through the set of six cards, and as the code numbers indicate, each bus bar corresponds to one of the eight symbols. The vertical lines represent printed conductors on the card. Each group of five corresponds to one interval of the symbol timing chain, and each group of five implements the same five beam controls, viz., move one or two spaces vertically, and/or one or two spaces horizontally, and/or unblank. A dot connecting two lines indicates that the lines interact. Physically the dot represents a diode connected between the two lines, anode lead to the bus bar.

Figure 6-10. Symbol Formation Chart

SYMBOL GENERATION
HOMEWORK QUESTIONS

1. How do we accomplish a direction reversal during the painting of a symbol?

   TWO DOTS ON LINES

2. What is the relationship of translator timing pulses to the moves involved in the painting of a character?

   DIRECTLY PROPORTIONAL (EACH
   CHAR RESOLUTION 26/29

3. Symbols formed on a 9 X 9 matrix should require (more, fewer) beam positions than on a 7 X 7 matrix. Under what circumstances, if any, would a 9 X 9 symbol be smaller than a 7 X 7 ~~signal~~? symbol.

   SIZE CONTROLS DETERMINE
   PHYSICAL LENGTH AND WIDTH
   CAN VARY

4. Differentiate between primary and secondary translation, giving the function of each.

   PRI. PICK PROPER CHAR. SELECTION 1 OF 64 6BIT TO 1 BIT
   SEC- CHANGE 1 BIT CODE TO 100 BIT CODE
   BY DIODE MATRIX CONTROL DIODES
   USED TO CONTROL SWEEP OF BEAM

5. A seventh bit in the symbol binary code would serve what purpose?

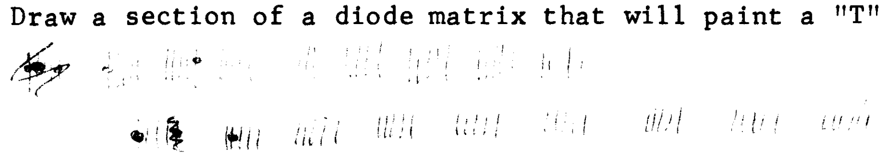
   PARITY CHECK BIT

   UPPER OR LOWER CASE SHIFT

6. Define the basic principle of a diode matrix.

   INDICATES A FUNCTION TO BE PERFORMED
   AT EACH TIME PERIOD.

7. Draw a section of a diode matrix that will paint a "T".



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HOMEWORK QUESTIONS (Continued)

8. Where is timing controlled during primary and secondary translation?

VIA CLOCK COUNTER

9. What would result if the unblanking F/F were always set?

RETRACE AND RASTER WOULD BE SEEN

10. Trace the operation of the display of a symbol starting with primary translation.

PRI X LATOR SELECT DRIVE LINES
SEC X ? DRIVE LINES
X Y
X
Y ORIENTATION & CONTROL
DEFLECTION PLATES
UN BLANK CONTROL

DSS 64 X 4

# SECTION VII

## SECTION VII

## VECTOR AND LINE GENERATION

One of two methods are employed to construct graphics on the display equipment cathode ray tube CRT) presentation. The vector generator is used with a vector word format to draw vectors from the last digitally specified point to the point in the direction specified by delta X (ΔX) and delta Y (ΔY) (change-in X and change-in Y). Each line segment requires two display words; one to specify the starting location and another to specify ΔX and ΔY (vector word). The second method is a line generator. This involves drawing straight lines (vectors) between points specified as X and Y coordinates in a line word format. With either the vector generator or line generator, lines on the CRT are drawn to present a constant intensity irrespective of line length.

### VECTOR GENERATOR

Vectors are drawn by a sequence of two words as mentioned; position or normal word followed by one or more vector words. A series of vectors, all emanating from a common location, may be drawn by one position word and a series of vector words.

With the beam at a specified base position, a vector can be directed from the base position having the direction and magnitude as specified by ΔX and ΔY in a given vector format. A typical vector word format is shown in Figure 7-1; the identifying bit positions and word length may vary with different equipment, but word content is essentially the same. Length of vectors may range up to plus and minus the full display size in either ΔX or ΔY or both.

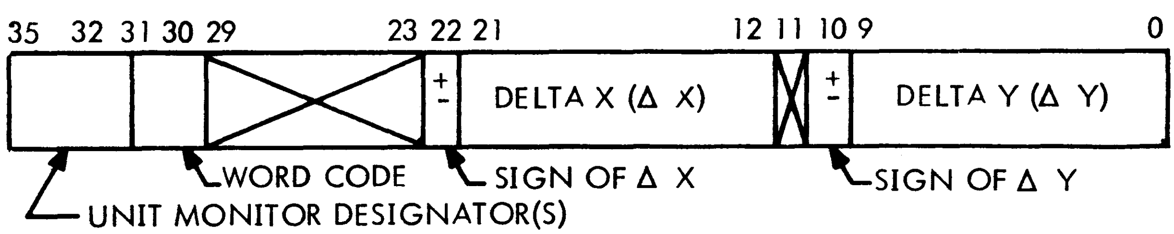


Figure 7-1. Typical Vector Word Format

### LINE GENERATOR

The line generator allows construction of figures and connected line segments by the specification of each end point only once. For a sequence of connected line segments, the starting location of the first line segment is given in a position word. This positions the CRT beam to that location. This is followed by a line word, which contains the terminating point of the first line segment.

Following formation of a line, the terminating point becomes the new base position and another line segment can be drawn from the end of the first, second, third, etc. by simply executing additional line words.

A typical line word format is shown in Figure 7-2. As was true of the vector word, the identifying bit position and word lengths may vary from one equipment to another.

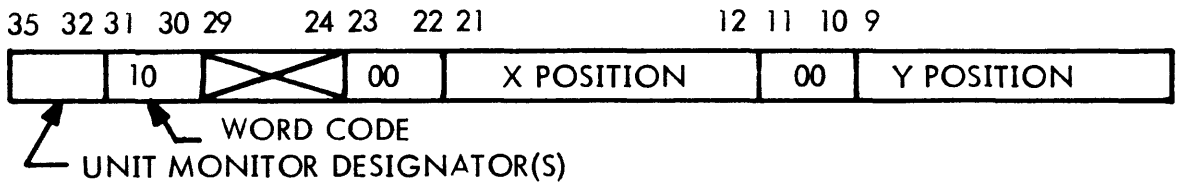


Figure 7-2. Typical Line Word Format

OPERATIONAL ANALYSIS

Line generation requires exercise of five main functions: control, ramp generation, adder, deflection, and unblank; whereas, vector generation requires four functions: control, ramp generation, deflection, and unblank. Vector generation does not require an adder since $\Delta X$ and $\Delta Y$ are programmed in the vector word format.

Since the line generator and vector generator are similar in all other respects, the following explanation applies to both methods with the exception of the adder.

General

The control area, enabled by the ramp generator, starts and stops the beam deflection and unblanking. Line or vector generation consists of unblanking and moving the beam from the base X, Y raster position to a new position determined by the end points. The line generator uses an adder to subtract the end point values from the base X, Y values, thus forming $\Delta X$ and $\Delta Y$. The $\Delta X$ and $\Delta Y$ values feed the $\Delta X$ and $\Delta Y$ digital-to-analog (D/A) converters, which the ramp generator controls.

Ramp generation involves the gradual addition of positive or negative $\Delta X$ and $\Delta Y$ values to the base X, Y values. This results in generation of a line from a point defined by the base position to a point defined by the base position plus the $\Delta X$, $\Delta Y$ values.

Figure 7-3 shows a vector or line generator network and the effect of summing $\Delta X$ and $\Delta Y$ with the base positioning level. Only three bits are used for simplification.

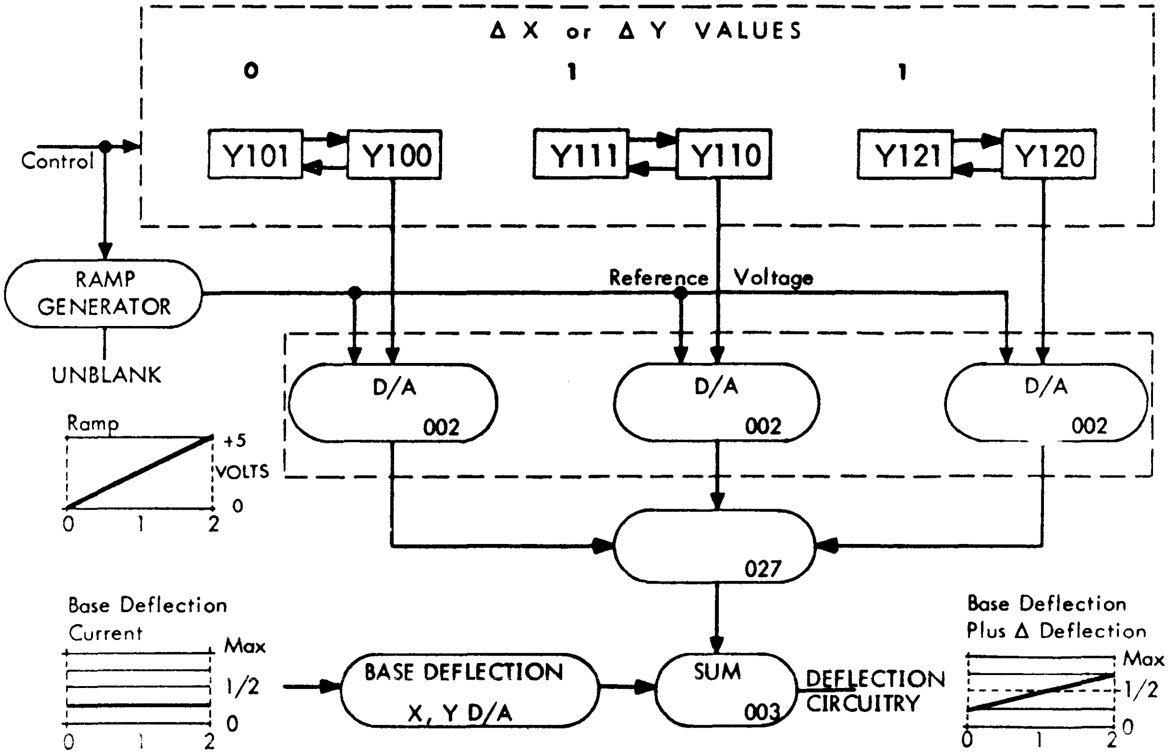


Figure 7-3 Vector or Line Generator Network

Control Network

The control network starts vector or line generation by enabling the adder for line generation, the ramp generator, and partially enabling unblank logic. Following completion of the vector or line, these same terms are cleared by the control network. Figure 7-4 is a simplified block diagram of a typical control network.

Initially, the display reference FF sets the vector or line enable FF shown in Figure 7-4. The main timing and vector or line enable FF sets ramp enable FF, K610/611. K611 enables ramp generator Q605. When the ramp generator output reaches 0.5 volt, Q607 (0.5-volt detector), Q608 (5-volt detector), and K611 enable the ANDed input to delay line Q617. Q617 sets unblank FF U110/111 and the start vector or line FF. When output of the ramp generator reaches 5 volts, the ANDed input to the delay line is disabled. The unblank FF is cleared through inverter U603 and the end vector or line FF sets. The end vector or line FF clears the ramp enable FF. The ramp enable FF disables the ramp generator and clears the end vector or line FF. Until the ramp enable FF is set again, the ramp generator remains disabled.

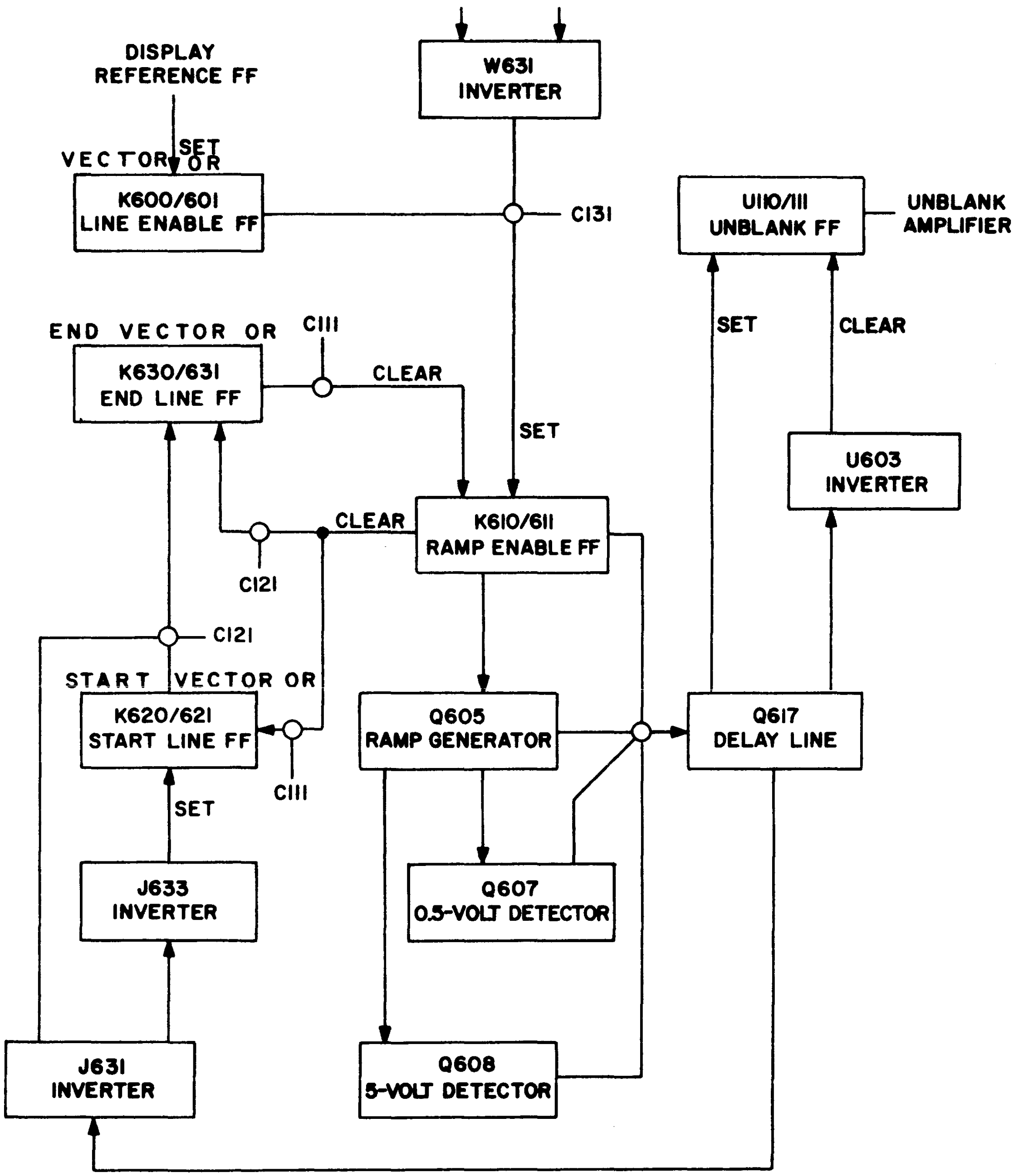


Figure 7-4. Vector or Line Control Network

Ramp Generation

The ramp generator system (Figure 7-5) enables a constant CRT beam sweep rate when painting vectors. Because of this constant sweep rate, the intensity at any point along the vector is constant. A ramp linearly adds the ΔX, ΔY digital value to the base X, Y register digital value in an analog manner. Ramp generation is the result of the charging of one or more capacitors in parallel by a constant current generator. The smaller the capacitance, the less the charge time; conversely, the larger the capacitance, the longer the charge time.

There are seven cards used in the ramp generator. They are: the 461 switching circuit, the 462 capacitor D/A converter, 463 ramp generator, 464 ramp driver, 456D charging current selection card, 455 level detector, and the 466 delay line. (Schematics for these card types are shown at the end of this section.)

The 463 ramp generator card is the central circuit of the ramp system. It consists of two identical ramp generators and a comparitor which selects the ramp with the smallest slope. Pins 1 and 7, which are internally jumpered, are connected to a common reference input voltage to establish two identical constant current drivers. Current flow from pins 1 or 7 to the ground, furnished by the 461 switching circuit cards through the 456D card, determines the amount of constant current generated. Pin 8 of the 463 card is the ramp enable input. A logical 1 to pin 8 enables the ramp generation circuitry and allows the selected capacitors determines the slope of the ramp. A logical 0 to pin 8 disables the ramp, allowing the selected capacitors to discharge and return the ramp to a zero level.

Pin 5 of the 463 card is connected to ground to minimize noise generation during discharging of the capacitors. Charging of the selected capacitors imparts a proportional level change on the base of the two emitter-follower transistors in the comparitor circuit. At any one time, only one of the two transistors is conducting, the other is at cutoff, depending upon which has more positive vol-

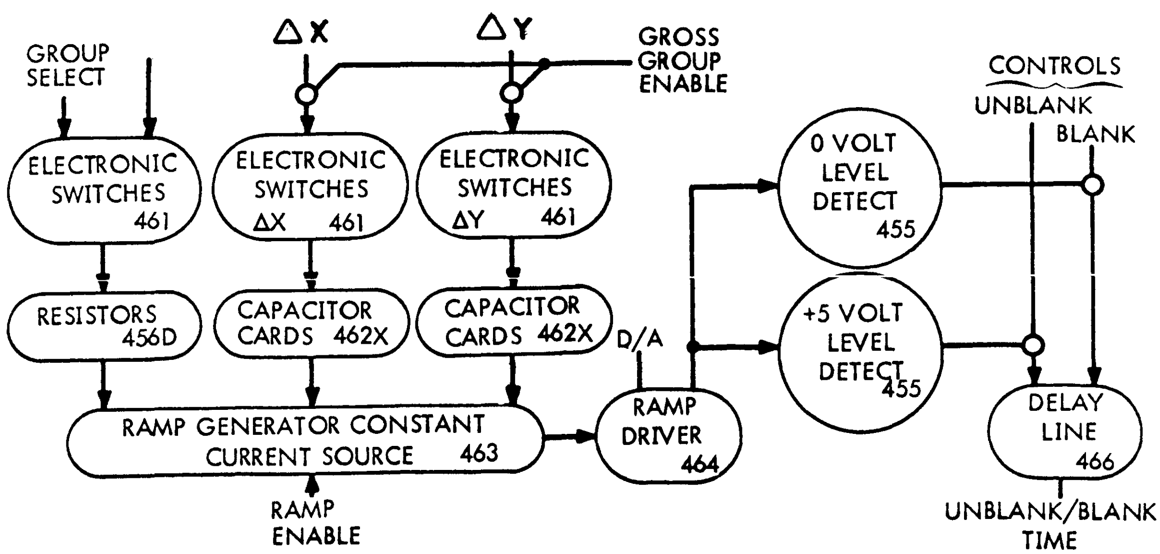


Figure 7-5. Ramp Generator Block Diagram

tage on the base with respect to the emitter. The common emitter output thereby compares the two ramps and selects the ramp with the smallest slope. The output (pin 12) of the 463 card goes to pin 1 of the 464 ramp driver card which is a noninverting power amplifier. Its output varies between -0.6 volt and +6 volts. The four potentiometers on the 456D card vary the intensity of each of the four vector length groups.

Initially (just prior to setting the ramp enable FF) the logic gates X and Y data into the adder for line generation. The ΔX and ΔY outputs from the adder or vector word format (vector generation) go to the positive ANDs (461 card circuit) for determining ramp length. Gross group enables complete the ANDs thereby selecting the capacitors.

The 461 switching circuit cards use positive logic, ie, the negative OR is used as a positive AND and the negative AND is used as a positive OR. Therefore, to enable the 461, logical 0 must appear at both of the two AND inputs. Note that where only one input is to be used, the other must be grounded. (See Q600 through Q603, Figure 7-6.)

## Gross Group Selection

A special circuit consisting of inverters J600 through J609 (Figure 7-6) provides a means of selecting the four categories of ramps. The ΔX and ΔY outputs are categorized into four groups: bits 0 through 3; 4 - 5; 6 - 7; and 8 - 9. Each of the four groups drives a 461 circuit (Q600 through Q603) which enables one of the four charging current circuits of the 456D card, Q604. Figure 7-6 portrays the overall function of the group selection. Any time bits 9 or 8 are selected, J606 outputs a logical 0 which selects Q600 and the long ramp time. J607, J608, and J609 operate in a similar manner.

Inverters J610 through J613 enable the ANDs of the 461 cards which select the 462 capacitor cards. They form two groups with bits 9, 8, 7, and 6 forming group one; and bits 5, 4, 3, 2, 1, and 0 (NOT bits 9, 8, 7, 6) forming group two. Selection of one group or the other essentially shifts the gating of the ΔX and ΔY data into the 461 cards by three positions.

Ramp selection is the next step in the generation of a ramp. Setting the ramp enable FF places a logical 1 on pin 8 of the 463 card. This causes a current flow through the 462 card capacitors to the ground furnished by the selected 461 switching circuits. The time that it takes the capacitors to charge determines the slope of the ramp.

After the ramp is complete the ramp enable FF clears, which disables the 463 card. The 463 card now removes the current charging the capacitors allowing them to discharge and return the ramp to a zero level.

The ramp generator must determine the vector or line sum of the ΔX and ΔY values. This vector or line sum is then used to obtain the correct slope of the ramp. The ramp generator uses an approximation method to determine the square root of the sum of the squares of ΔX and ΔY $\sqrt{(\Delta X)^2 + (\Delta Y)^2}$ . This algebraic expression can be approximated by (ΔX) + .4(ΔY) if ΔX is the larger or by (ΔY) + .4(ΔX) if ΔY is the larger. Capacitors of the 462 cards are se-

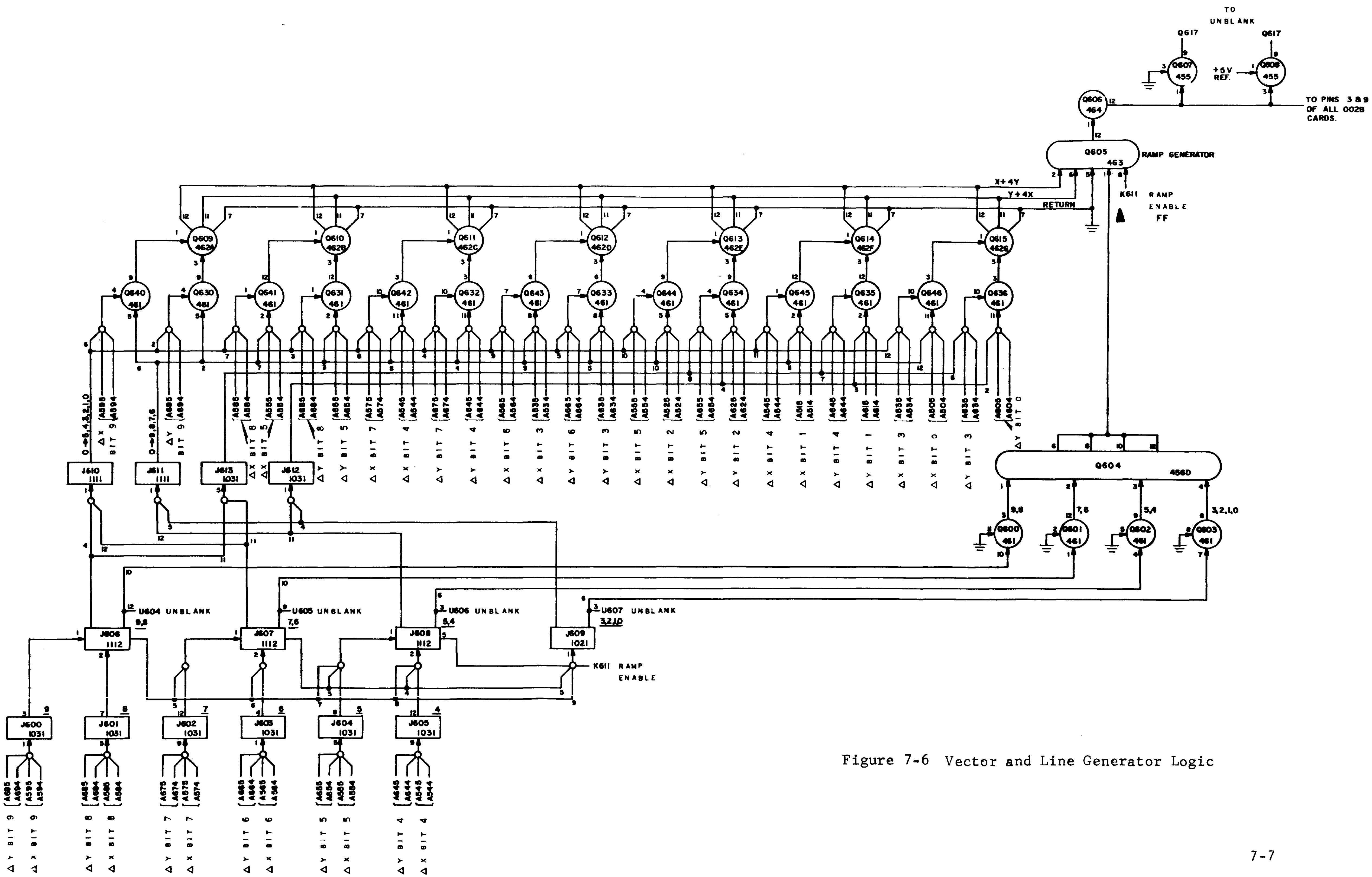

Figure 7-6 Vector and Line Generator Logic

lected by the 461 cards to determine both $(\Delta X) + .4(\Delta Y)$ and $(\Delta Y) + .4(\Delta X)$ equivalent capacitor values. When the constant current generator of the 463 card is enabled, both capacitor summations start to charge. But because of the comparitor circuit of the 463 card, only the capacitor summation line with the smallest capacitance (shortest ramp slope) is selected. Thus, the approximation of the formula $\sqrt{(\Delta X)^2 + (\Delta Y)^2}$ is accomplished.

Figure 7-7 is a graph showing the time necessary to draw various length lines or vectors. Four groups or categories of ramps shown correspond to the four groups shown in Figure 7-6. If bits 9 or 8 of either $\Delta X$ or $\Delta Y$ are a logical 1, a vector length of 400 or greater is selected, enabling group 4. If bits 7 or 6 are a logical 1, group 3 would be selected. Group 2 is selected by bits 5 or 4, and group 1 by bits 3, 2, 1, and 0. The groups overlap. For example, if neither $\Delta X$ or $\Delta Y$ had bits 9 or 8 selected, but both $\Delta X$ and $\Delta Y$ contain a number close to 400, the vector length is greater than 400 and group 3 is selected.

A zero length vector is a special case. None of the 461 switching circuit cards select any 462 capacitor cards. Therefore, fixed capacitors are added to the $(\Delta X) + .4(\Delta Y)$ and $(\Delta Y) + .4(\Delta X)$ outputs of the 462 card to ensure that the constant current source has some capacitance to charge.

## Unblanking

The type 455 level detector cards, Q607 and Q608 (Figure 7-6) control the turn-on and turn-off times of the unblank circuits. Q607 signals the starting of the unblank period (when the ramp crosses 0 volt) and Q608 signals the completion of the ramp (when the ramp reaches +5 volts).

Setting the vector or line enable FF starts the ramp and places one enable on the vector unblank delay line (Figure 7-4). Ramp voltage starts out slightly negative. When the ramp output reaches 0 volt, Q607 output goes to logical 1. Q608 then outputs a logical 1 to Q617, which, when combined with the output of Q607, starts a pulse down the delay line. Delay line outputs set the unblank control FF's for the various selected CRT which in turn feed into the intensity control circuits. The unblank signal from the FF's is combined with vector group length intensity selection and an address translation causing the proper CRT to unblank at the correct time and level.

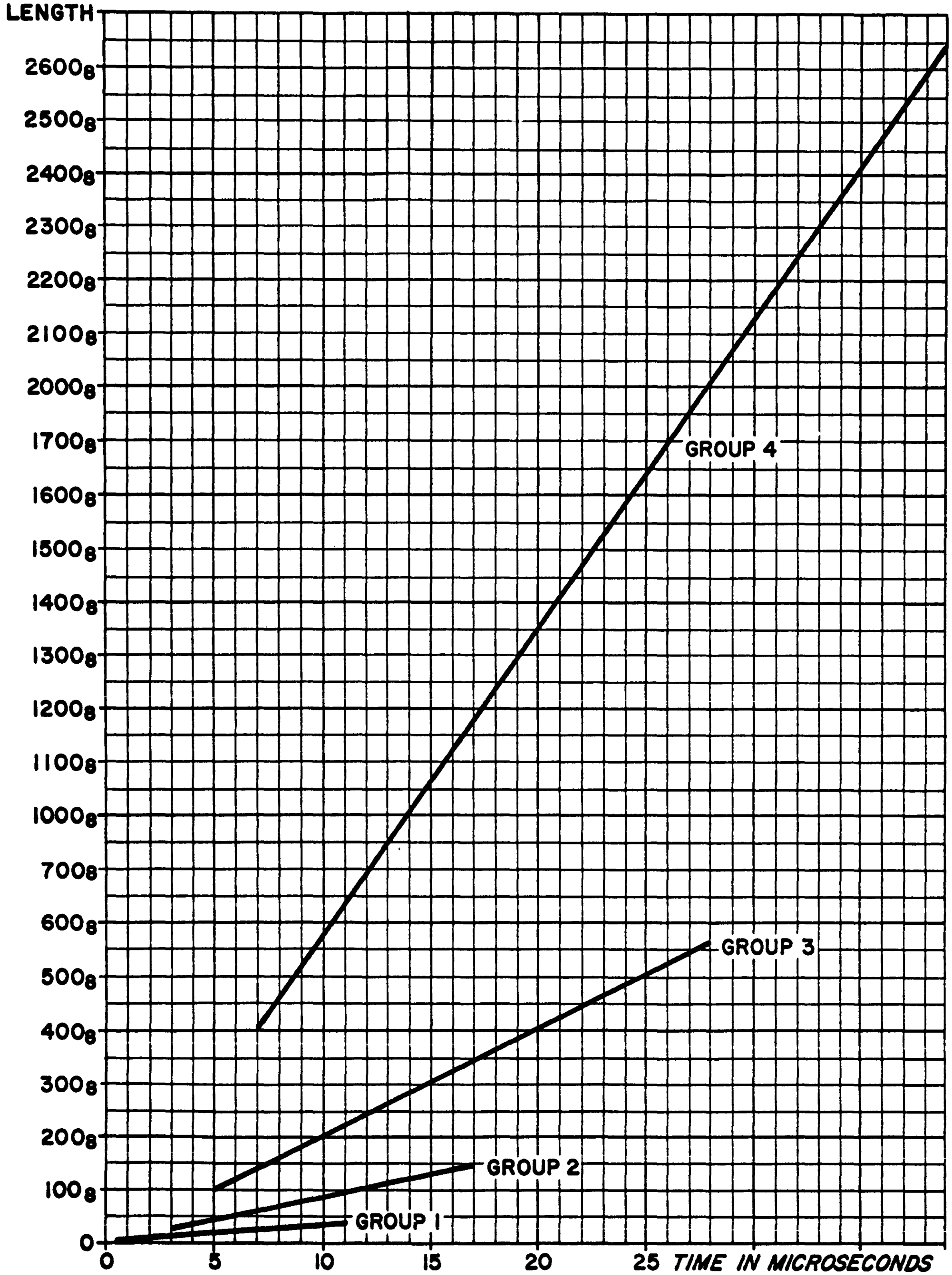


Figure 7-7. Vector or Line Time/Length Graph

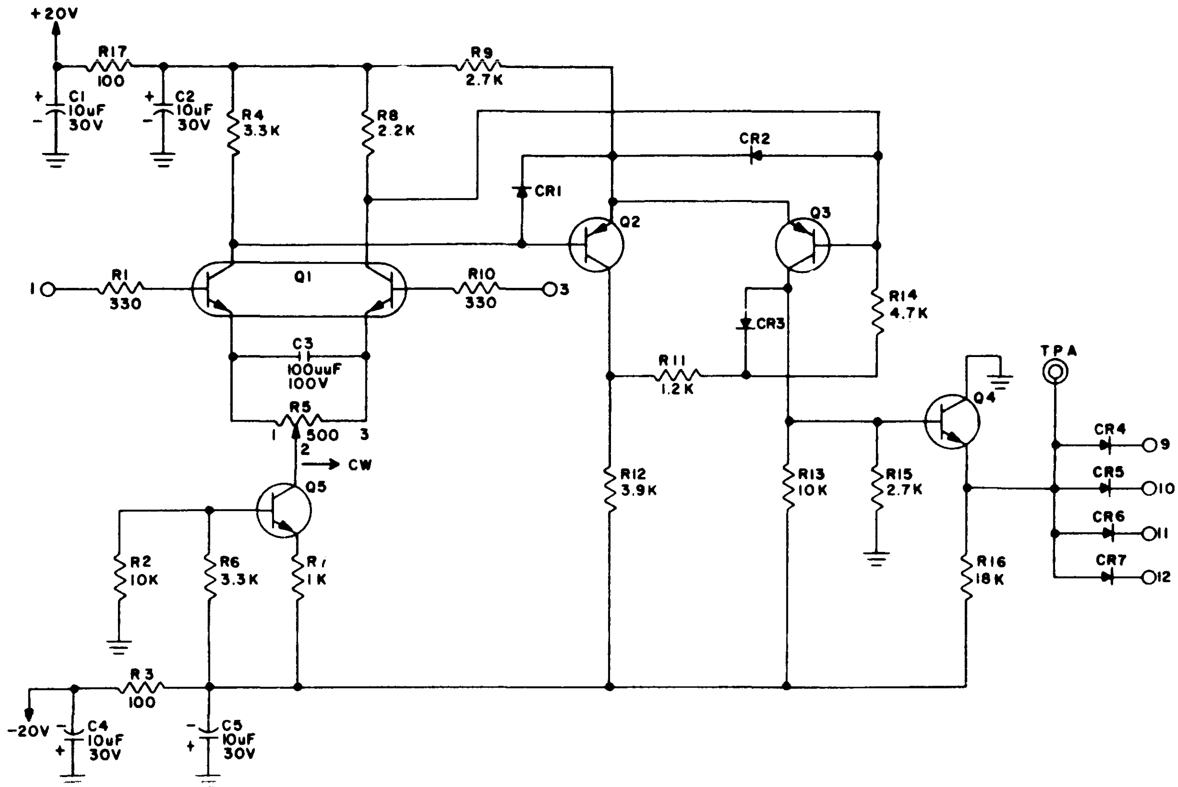


Figure 7-8. 455 Card-Level Detector

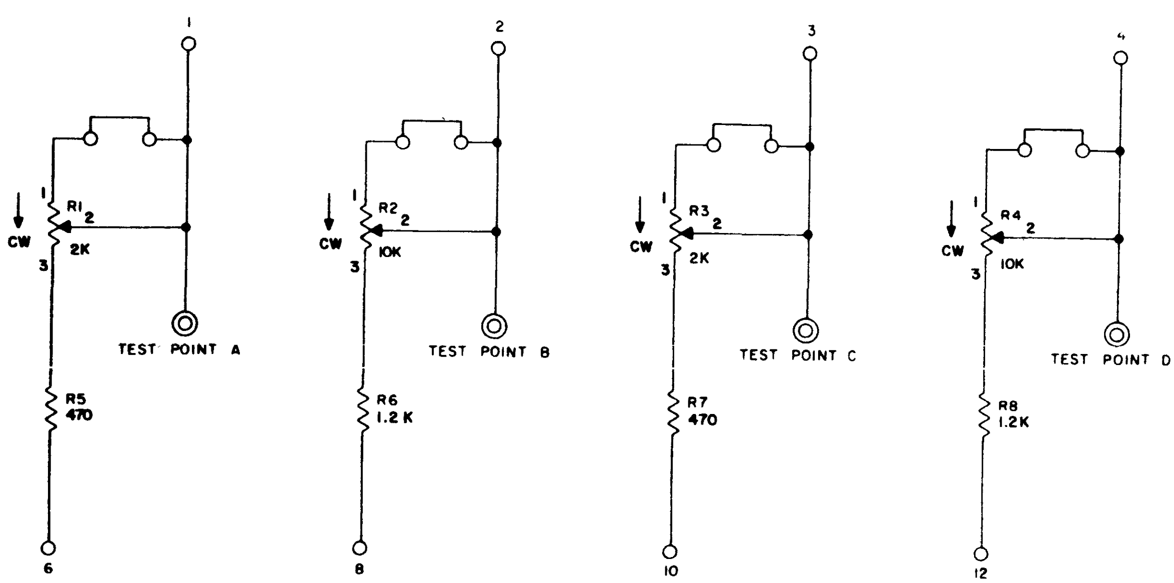


Figure 7-9. 456D Card-Charging Current Selection

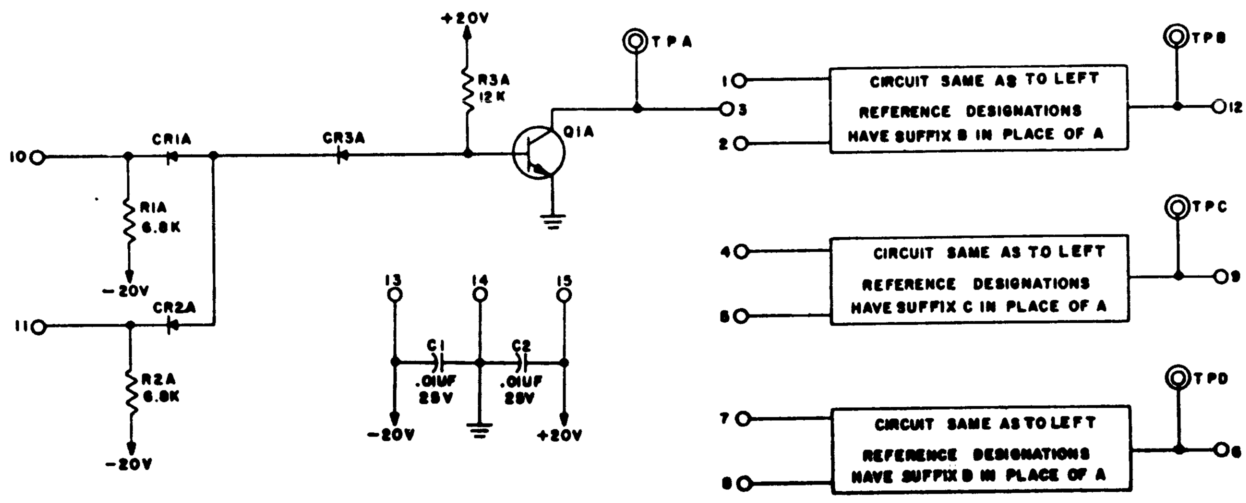


Figure 7-10. 461 Card - - - Saturating Switch

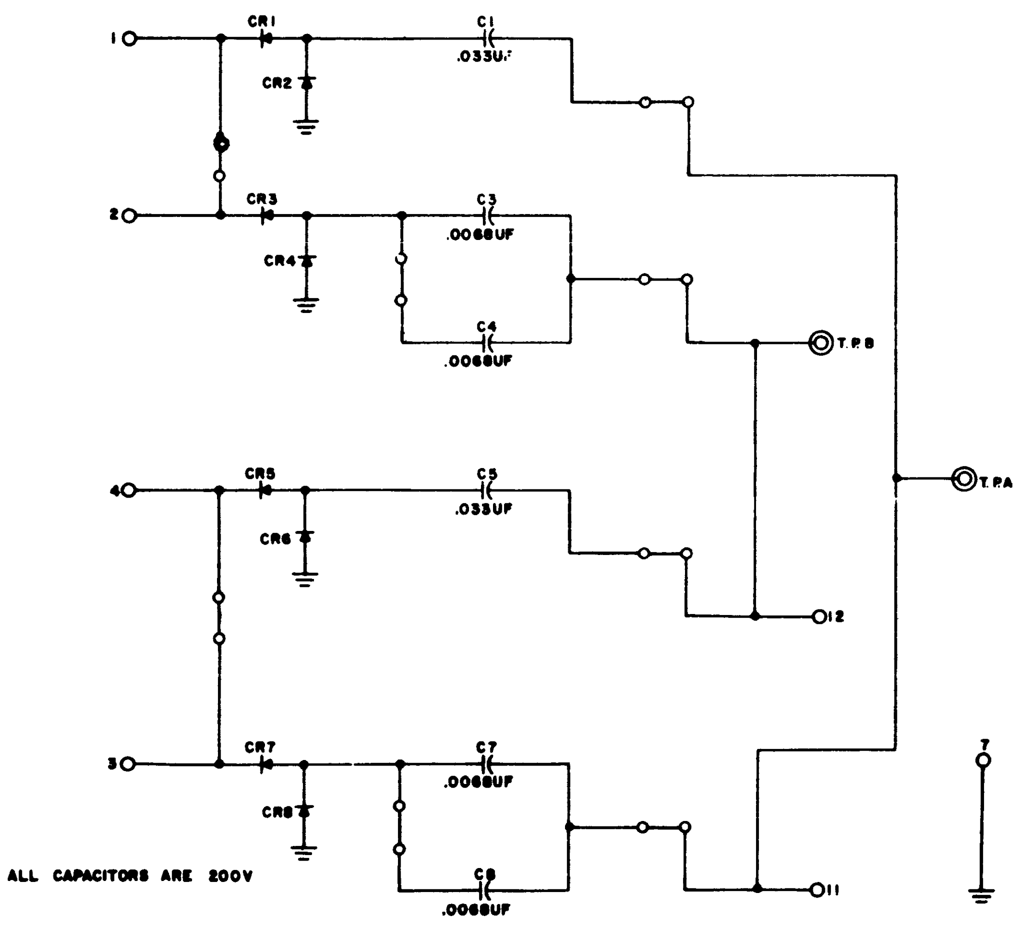


Figure 7-11. 462A Card -- Capacitor D/A Network

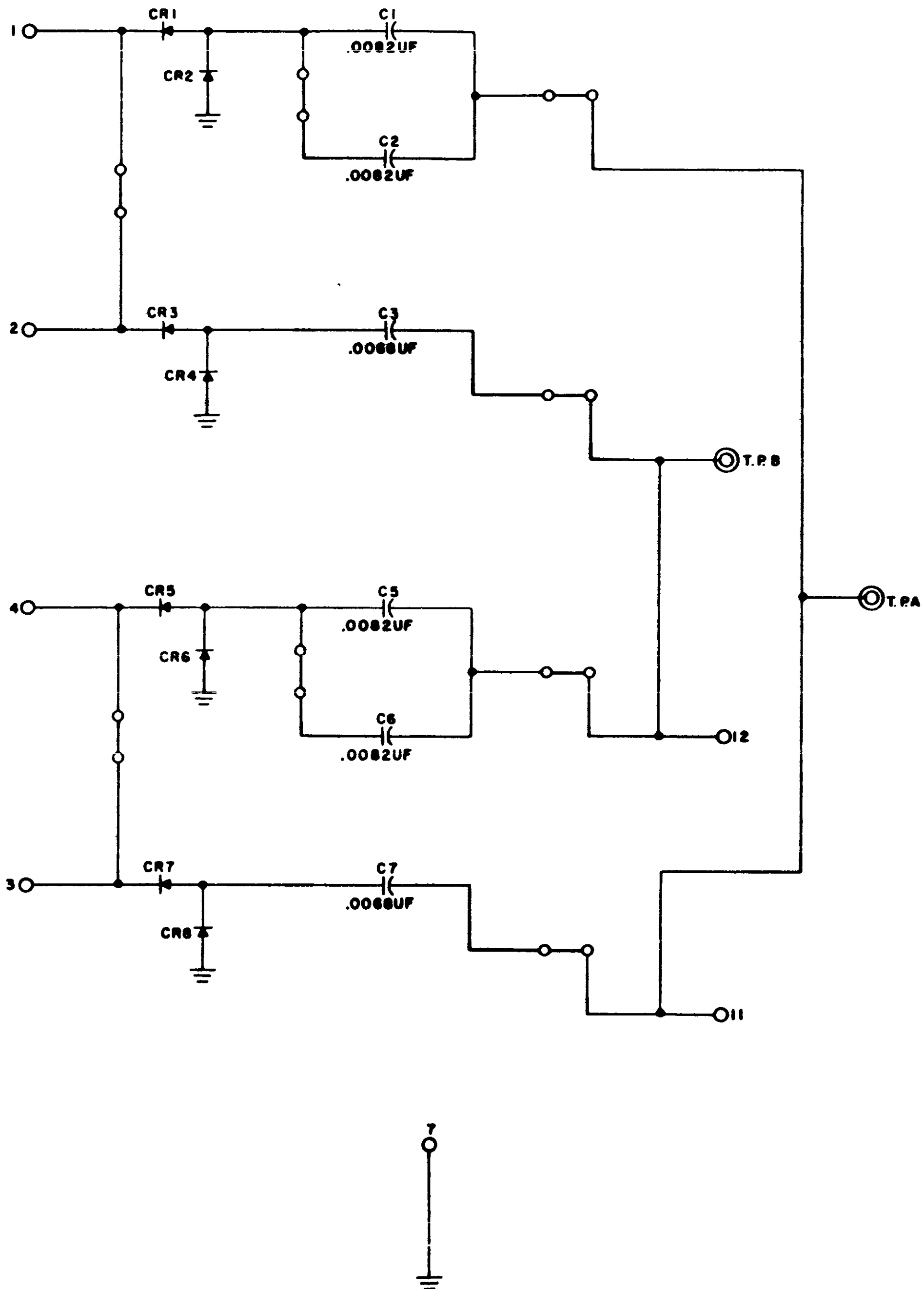


Figure 7-12. 462B Card - Capacitor D/A Network

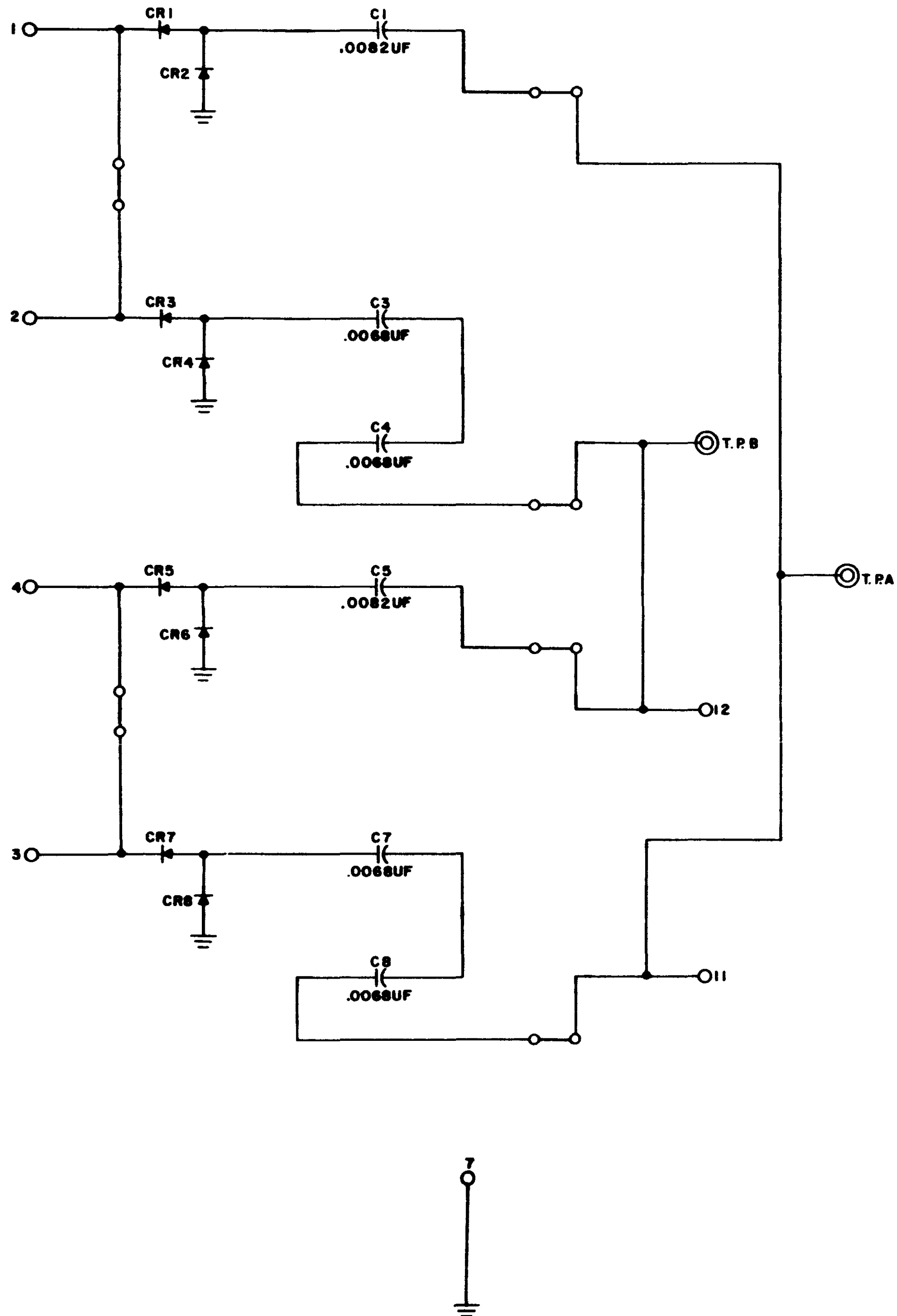


Figure 7-13. 462C Card - Capacitor D/A Network

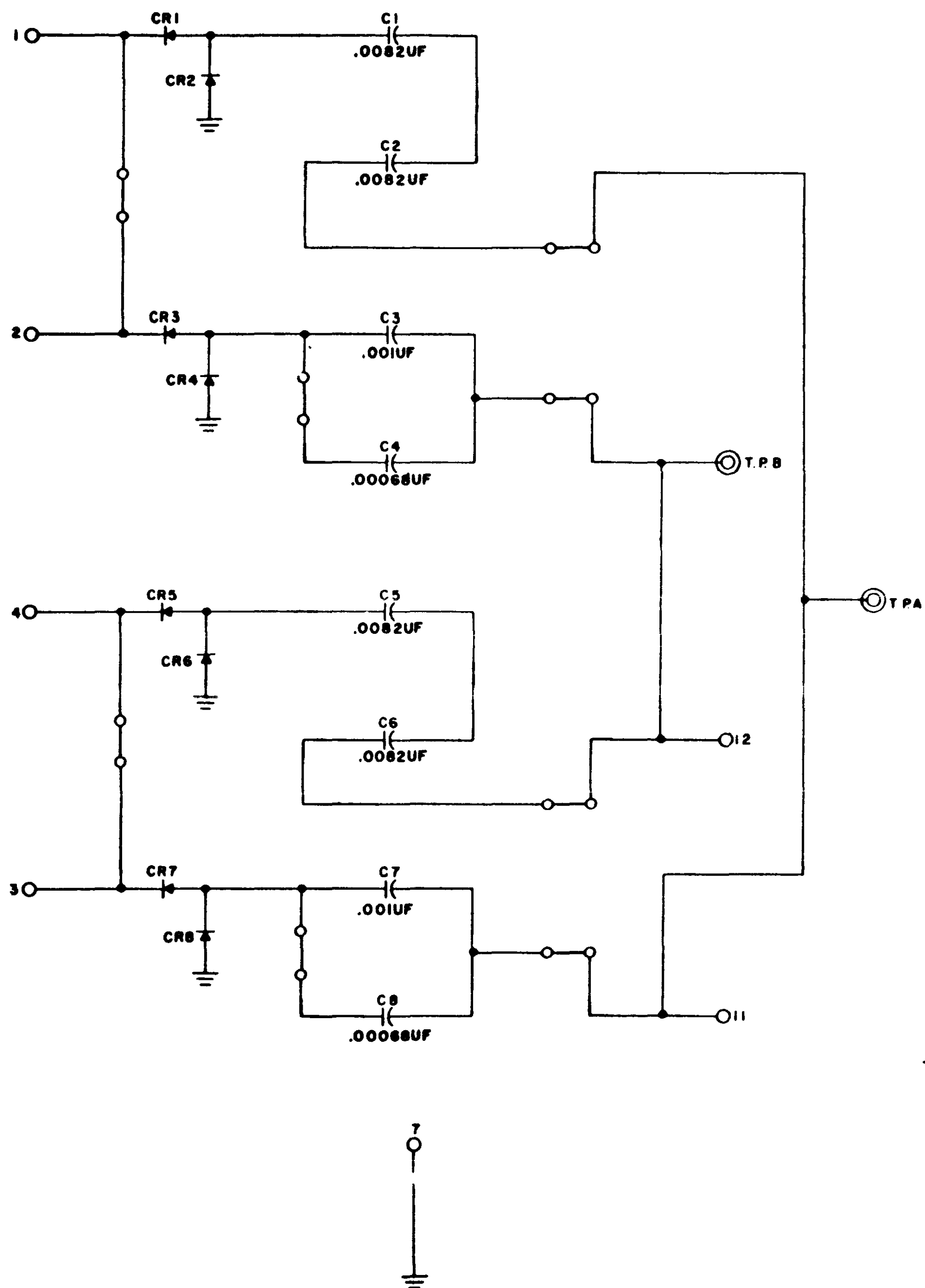


Figure 7-14. 462D Card - Capacitor D/A Network

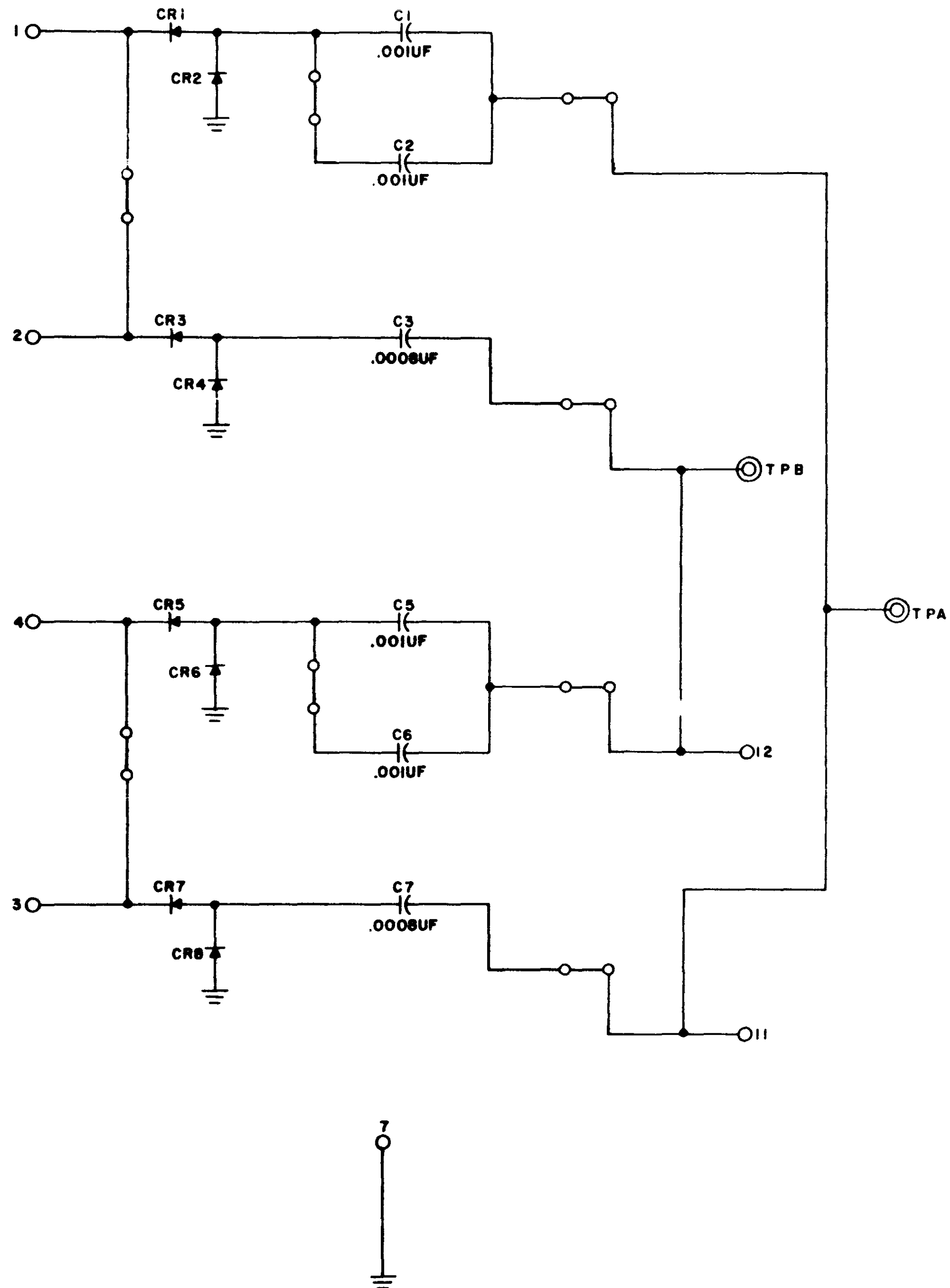


Figure 7-15. 462E Card - Capacitor D/A Network

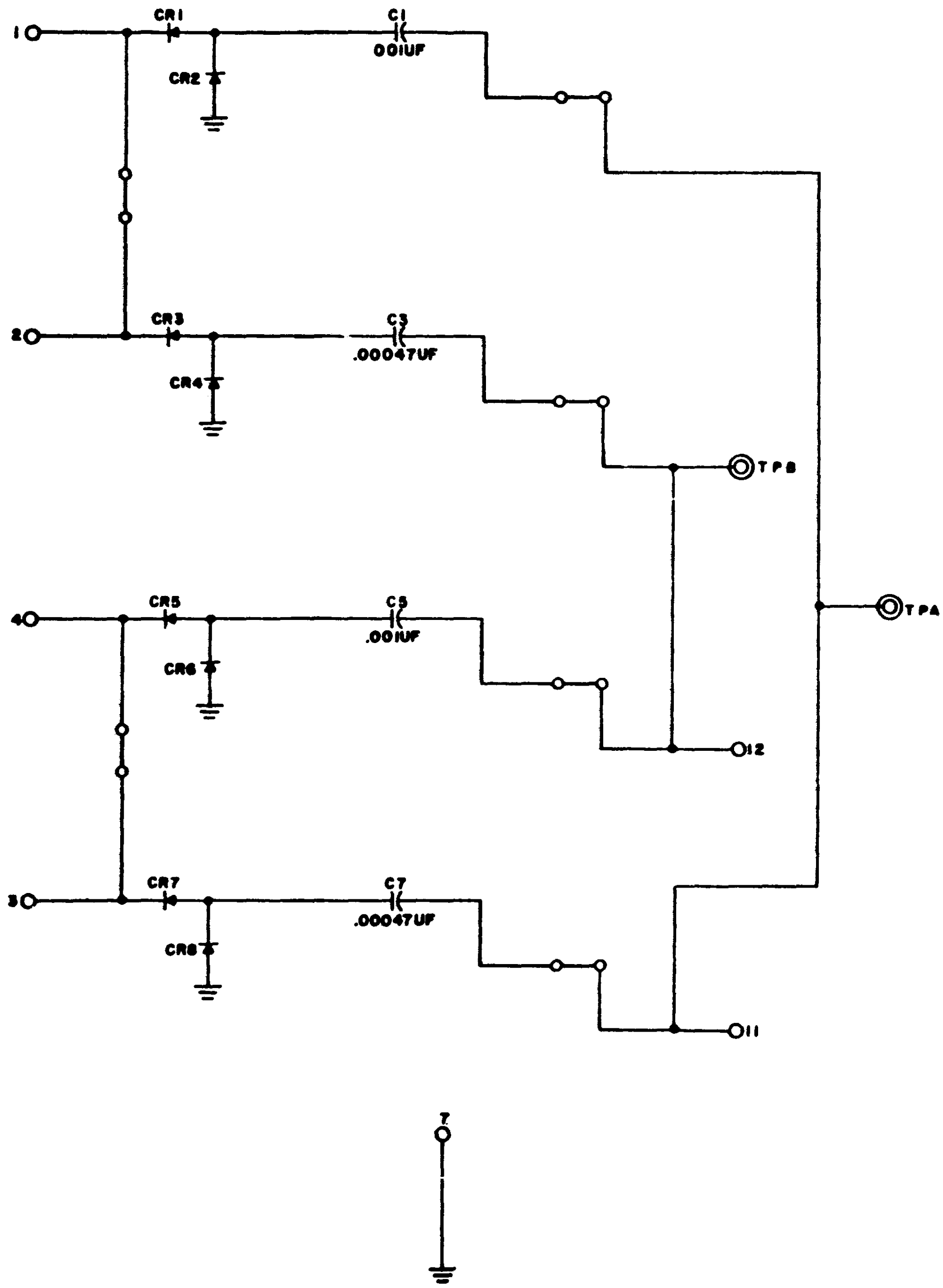


Figure 7-16. 462F Card - Capacitor D/A Network

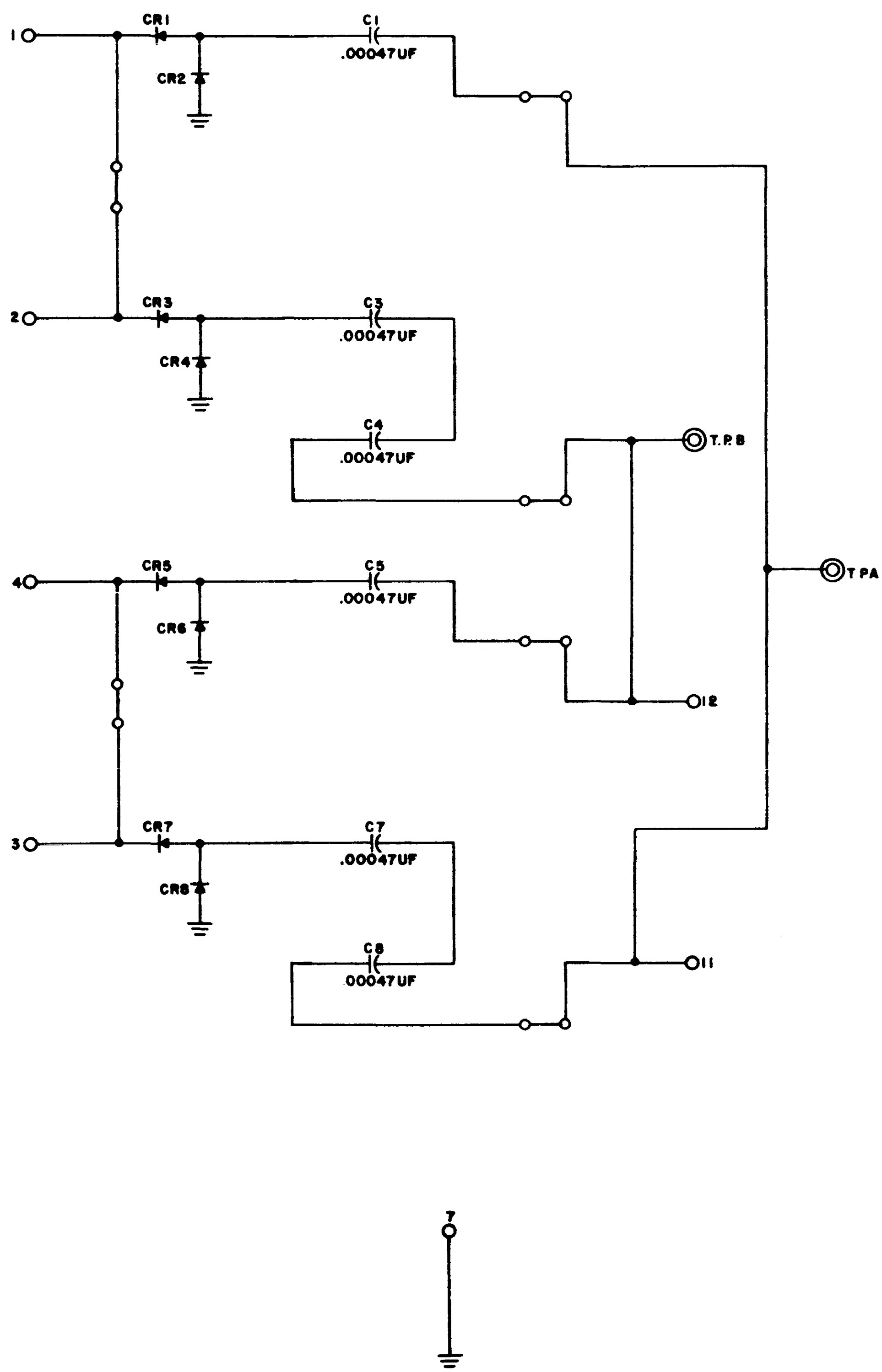


Figure 7-17. 462G Card - Capacitor D/A Network

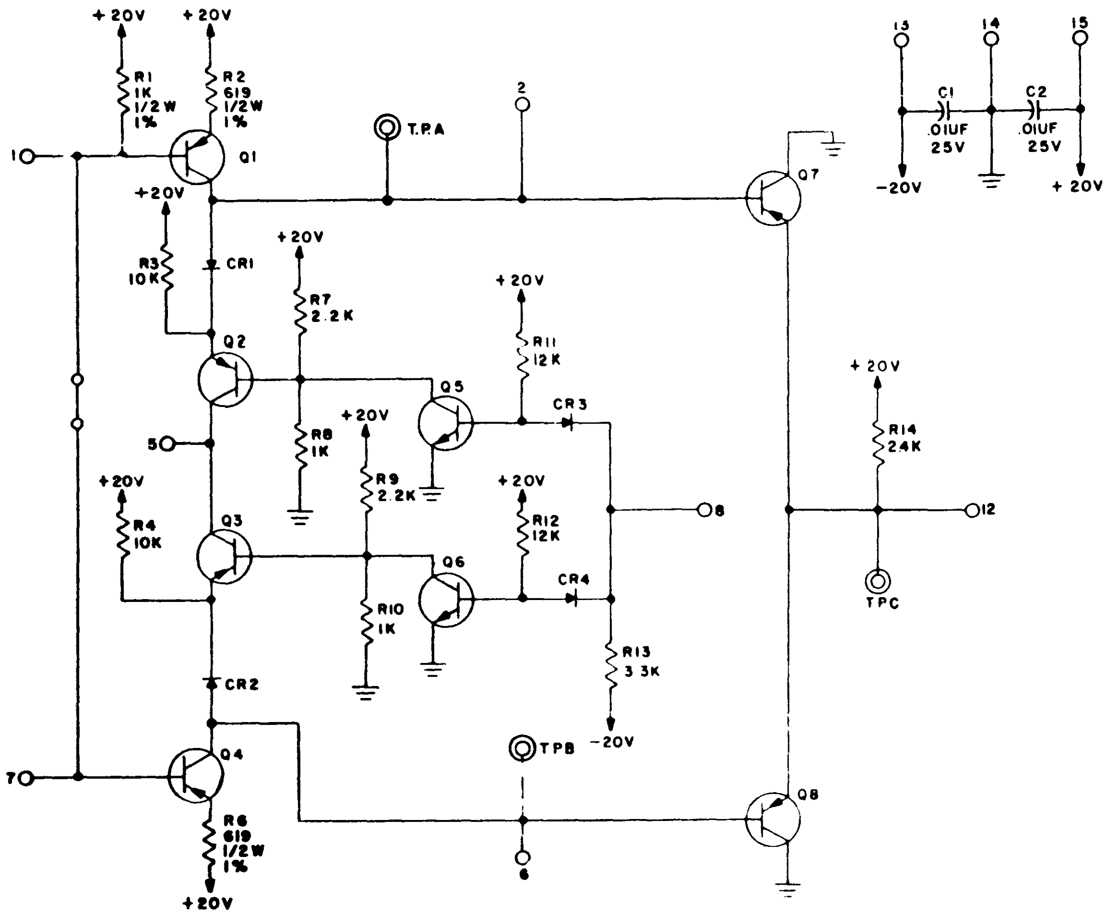


Figure 7-18. 463 Card - Ramp Generator

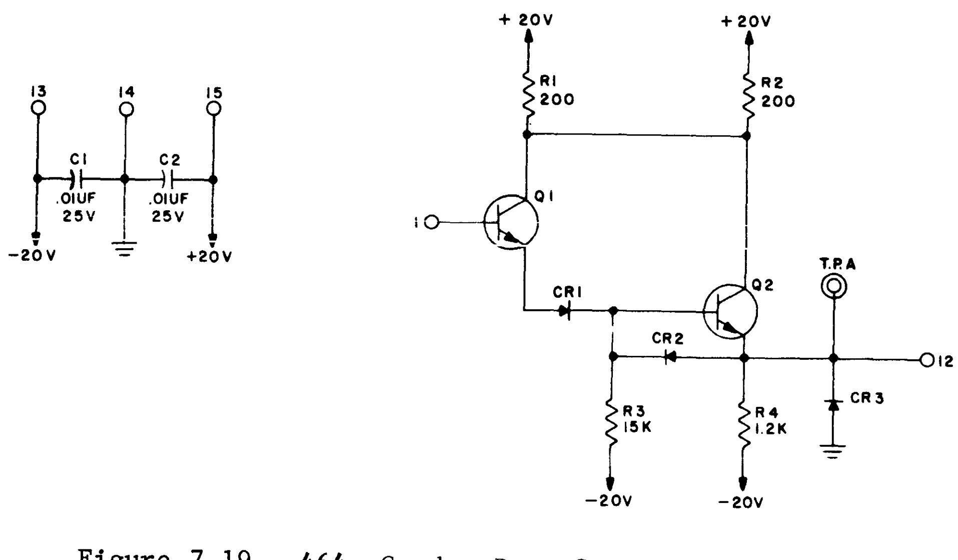


Figure 7-19. 464 Card - Ramp Current Amplifier

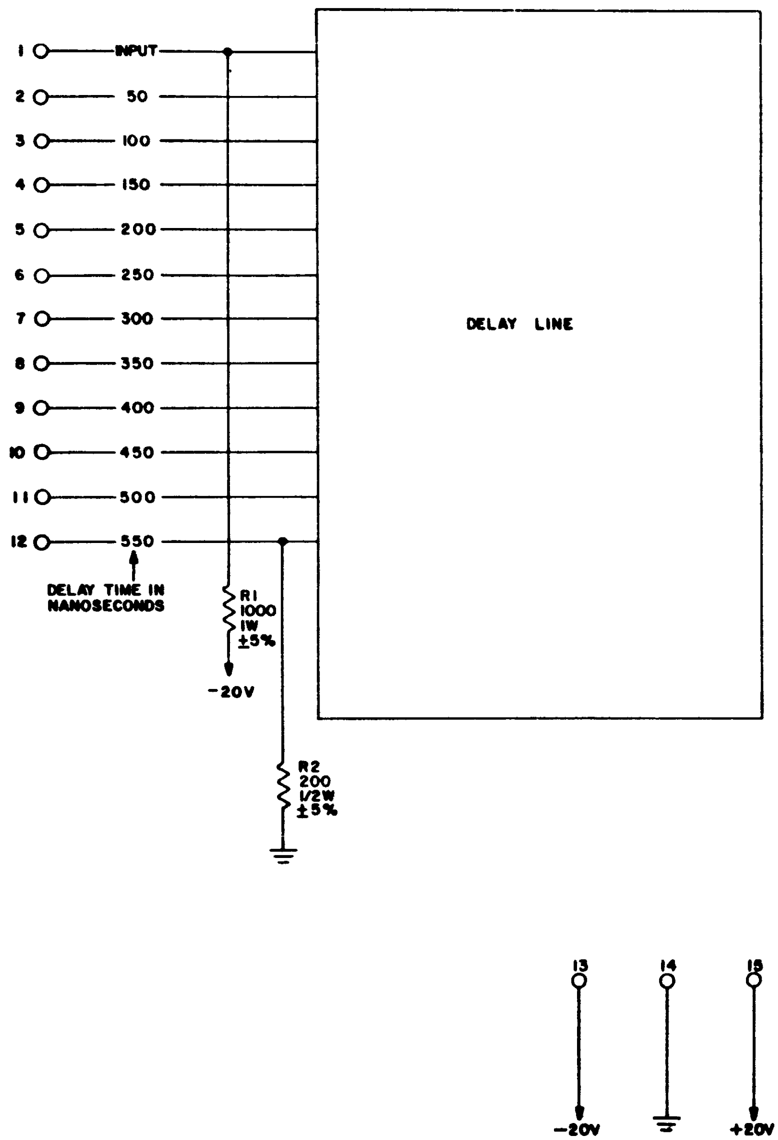


Figure 7-20. 466A Card - 550-Microsecond Delay Line

## VECTOR AND LINE GENERATION
## HOMEWORK QUESTIONS

1. Give the purpose of the Ramp Generator.

2. Define $\Delta X$, and $\Delta Y$.

3. In determining ramp scope selection we are interested in:

   a. Capacitor discharge time.
   b. Capacitor-resistor charge time.
   c. The timing chain.

4. Vector unblanking is controlled by ____________________________________.

5. Give the difference between a line and a vector.

6. The control portion of vector and line generation involves _________________.

# APPENDIX A

APPENDIX A

BUILDING BLOCKS OF LOGICAL CIRCUITRY

This section begins with a general description of the four basic circuits used to create a logical network: inverts, non-inverter, flip-flop (FF), and control delay. The last portion of this section covers circuit cards on which the basic circuits are arranged.

STANDARD INVERTER

The inverter circuit outputs a logical 0 for a logical 1 input and outputs a logical 1 for a logical 0 input. Switching time between states ranges from 30 to 60 nanoseconds (one nanosecond is equal to one one-billionth of a second). Figure A-1 shows a 2-microsecond input pulse and the resulting 2-microsecond output pulse.

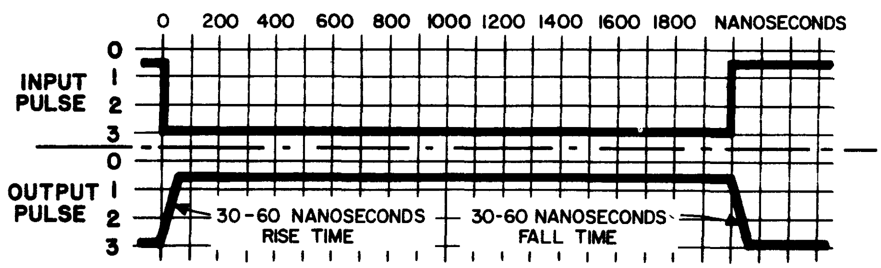


Figure A-1. Inverter Pulse

ELECTRICAL DESCRIPTION

Figure A-2 is a schematic diagram of an inverter circuit. Dotted areas show additional OR inputs and diode outputs that may be added.

An input signal of -0.5-volt (point A) results in -1.5-volts (point B) and -0.8-volt at the base of the transistor (point C). The -0.8-volt drives Q1 towards cutoff. This develops a higher voltage drop across the transistor (because of the higher impedance) and less of a drop across R7, resulting in a 3-volt level on the output line. A -3-volt input results in a reverse operation which forces Q1 away from cutoff. This produces a greater voltage drop across R7, resulting in a -0.5-volt level on the output line.

Output diodes, CR9 through CRxx, isolate the output lines from each other, and prevent feedback into the inverter circuit from the AND and OR gates fed by the output lines.

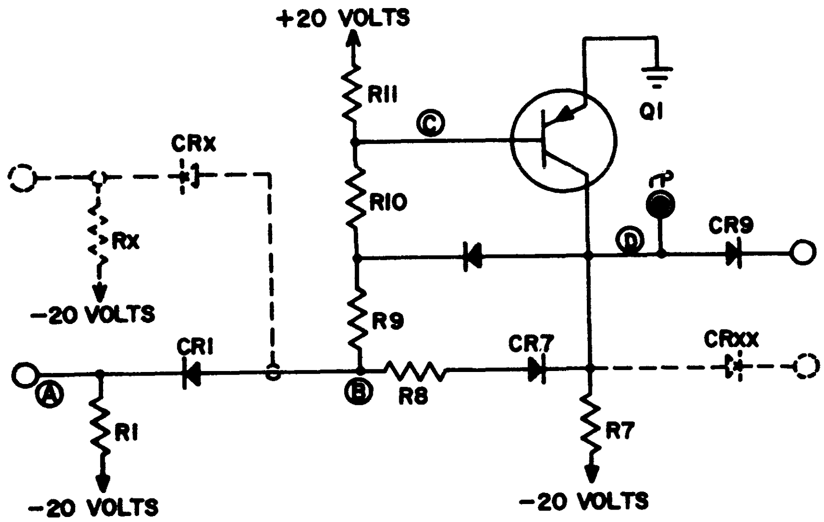


Figure A-2. Inverter Circuit Schematic Diagram

An unconnected input appears the same as a logical 1 in that the input is left floating. This 1 causes the voltage level to remain sufficiently negative to satisfy the logical 1 (-3-volt) condition. Clamping the input line to -0.5-volt or ground is the only means of satisfying the logical 0 (-0.5-volt) condition.

In special cases, an output diode is eliminated completely or replaced with a resistor. This is necessary for tying the output of a standard logical circuit to an analog network, or to a digital-to-analog (D/A) converter. In other cases where the output diode is not desired, it is replaced by a shorted output, ie, the output is connected directly to the collector of the transistor.

LOGICAL REPRESENTATION

A single inverter circuit is represented on a logical diagram by a rectangle as shown in Figure A-3. In this example, input pins 1 and 2 are OR inputs with pin 1 being a 3-way AND. The alphanumeric designations are pointed out in the figure.

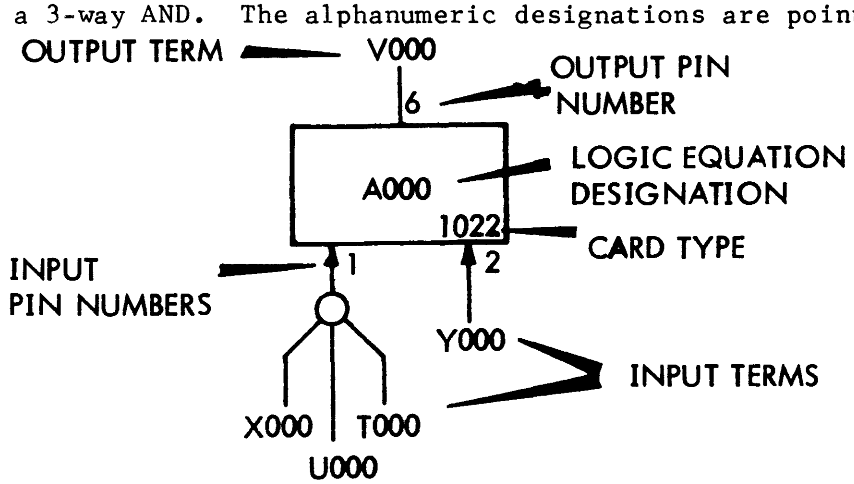


Figure A-3. Standard Inverter Logical Symbol

Figure A-4 shows how the special inverters are represented on a logical diagram. These are cases where the output diode is not desired, as previously explained in the electrical analysis.

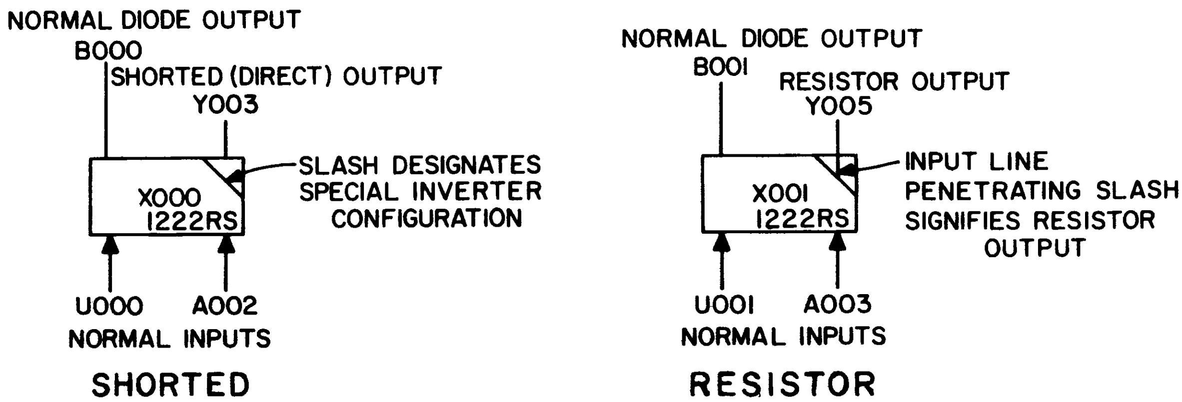


Figure A-4. Special Inverter Logical Symbols

STANDARD NONINVERTER

The noninverting circuit outputs a logical 0 for a logical 0 input and a logical 1 for a logical 1 input. The noninverting circuit used in display equipment consists of two emitter-followers connected in series.

ELECTRICAL DESCRIPTION

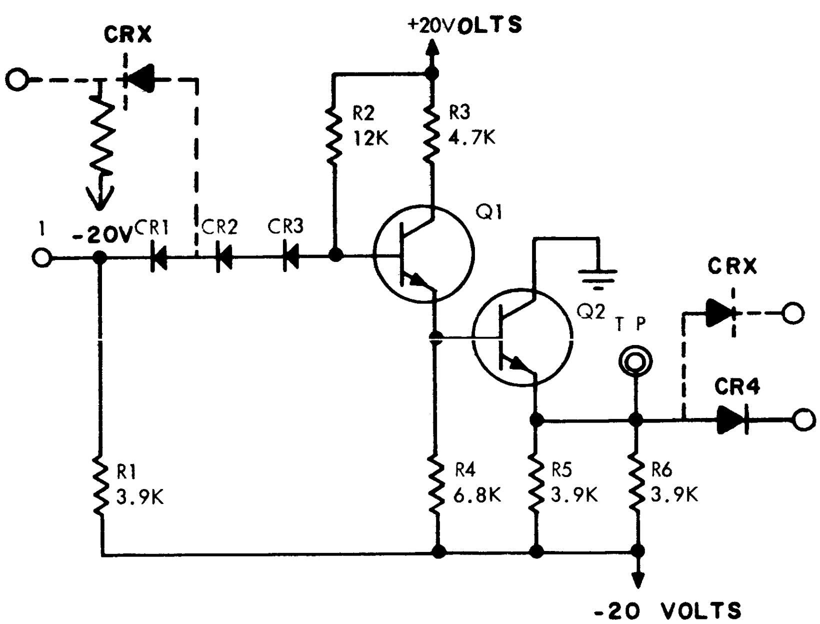


Figure A-5. Noninverter Circuit Schematic Diagram

Figure A-5 is a schematic diagram of a noninverting circuit. Dotted areas show additional OR inputs and diode outputs that may be added. Capacitors CR2 and CR3 are added to the base input of Q1 to provide a faster transistor switching time.

With a 0.5-volt input at pin 1, the base of Q1 is placed at approximately +1.8-volts causing Q1 to conduct. With Q1 conducting, the base of Q2 is also slightly positive due to the current flow through R4, Q1, and R3. Q2 is allowed to reach saturation, resulting in a near ground potential at the output diodes. A -3-volts at the input causes Q1 and Q2 to approach cutoff placing -3-volts at the output diodes. Q1 and Q2 do not reach complete cutoff.

## LOGICAL DESCRIPTION

The only difference between the standard inverter symbol and the noninverting symbol is a bar across the top of the rectangle. Figure A-6 shows the symbolic representation of a noninverting circuit and noninverters with special outputs. Reference Figure A-3 for alphanumeric designations.

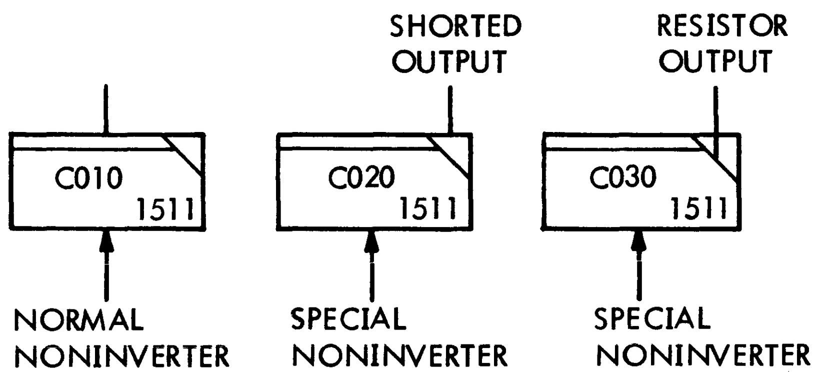


Figure A-6. Noninverter Logical Symbols

## FLIP-FLOP

Display logic uses the FF for short-term storage and switching purposes. Two interconnected, single-inverter circuits comprise the FF. The inverters may be externally interconnected on the same or different circuit cards, or they may be on the same card and internally interconnected.

## LOGICAL ANALYSIS

One inverter constitutes the set side of the FF, the other the clear side (Figure A-7). The FF is placed in the logical 1 (set) state by a set input that is a logical 1. Conversely, it is placed in the logical 0 (clear) state by a clear input that is a logical 1. The storage ability means that the FF remains in the state indicative of the last logical 1 input received. If a logical 1 pulse is present at the set input (Figure A-7) the output of B000 is a logical 0, which in turn feeds B001 giving it a logical 1 output. The output from B001 feeds B000 which causes the output of B000 to remain a logical 0 until a logical 1 is present on the clear input. After the logical 1 on the set input line returns to a logical 0 the FF remains in the logical 1 (set) state. The operation is similar when a logical 1 appears on the clear input line. A logical 0 impressed on either input has no effect.

In summary to the preceding analysis, when the FF is set, B001 has a logical 1 output and B000 has a logical 0 output. When the FF is cleared, B001 has a logical 0 output, and B000 has a logical 1 output.

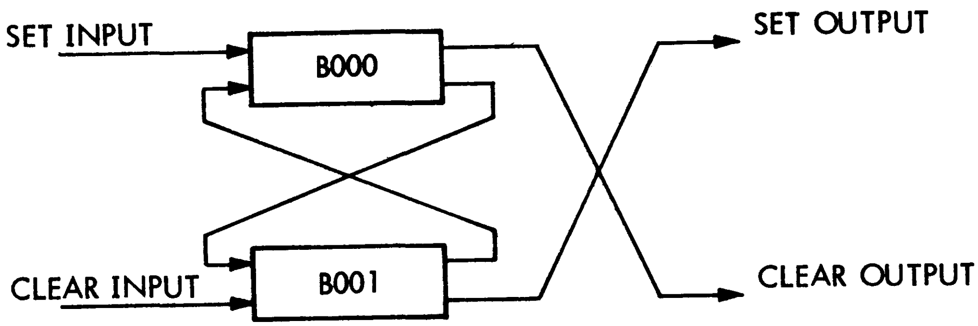


Figure A-7. Flip-Flop Operation

LOGICAL REPRESENTATION

Display logic uses the symbols shown in configuration 1 and 2 of Figure A-8 to represent a FF. Configuration 1 shows the symbol used for both an internally and an externally interconnected FF, while configuration 2 shows the symbol used only for an externally interconnected FF. The logical designation of the set output of the FF has an odd last digit, while the clear output side of the same FF has an even last digit; eg, B000 (clear output) and B001 (set output).

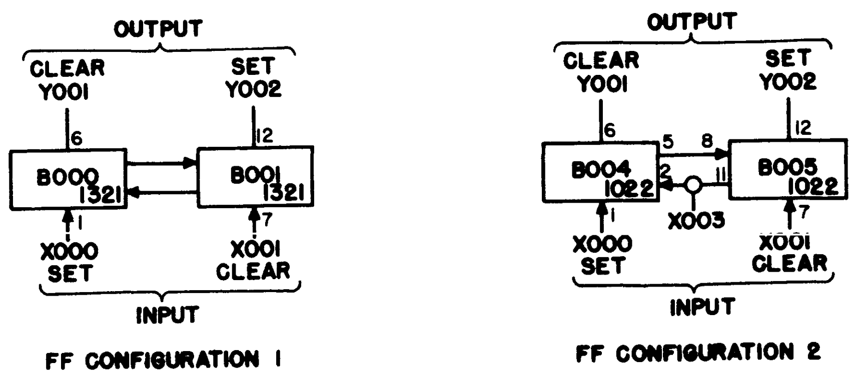


Figure A-8. Flip-Flop Logical Symbols

# APPENDIX B

# APPENDIX B

## GLOSSARY OF TERMS AND DEFINITIONS

ALPHANUMERIC - Numbers and/or letters.

ANALOG - A means of representing movement or position, as in a CRT, in terms of definable increments, each unique in itself as opposed to digital, in which only two increments or states are represented.

ASTIGMATISM - Variations in the shape of the electron beam of the CRT usually caused by movement of the beam across the face of the CRT, thus causing variations in the distance traveled.

ASTIGMATISM CORRECTION - A feedback voltage fed to the accelerating anode of the CRT, representative of the actual deviation from center of the display, for the purpose of maintaining beam shape.

BASE POSITIONING - The fundament address on a CRT at which the painting of a character or vector is to begin.

BLANKING - Deintensifying the electron beam in a CRT to a point below the sensitivity of the human eye.

CHARACTER REPERTOIRE - The specific symbols which a display system may generate, usually 64, using a six-bit character code, or 128, using a seven-bit code.

CRT - Cathode ray tube.

D/A - The process of converting digital information to an analog value within a definable scale.

DELAY LINE MEMORY - A magnetostrictive temporary storage device used in displays to maintain an image on the face of the CRT.

$\Delta$ - Delta, meaning change.

DIODE MATRIX - An arrangement by input and output lines in matrix form so that diodes placed at given points between the input and output lines may allow a sequence of control outputs at a very rapid rate for the activation of a single input line.

ENTRY MARKER - An underline symbol utilized in some line printer mode displays to make the position at which the next character to be entered or outputted will be displayed.

GLITCH - Distortion of base positioning of the CRT.

HARDCOPY RECORDER - A display equipment optional auxilliary device used to permanently record an image displayed on a CRT.

JITTER - Distortion or degradation of a display image, usually a result of CRT circuitry unbalance or noise.

LIGHT PEN, PENCIL, OR GUN - Photoelectric devices used in display equipment to identify a given symbol on the face of the CRT at the moment it becomes intensified in the display regeneration sequence for the purpose of adding or editing information.

LINE - A connection by CRT trace of two sets of definable coordinates.

LINE PRINTER MODE - An arrangement in certain display systems in which each symbol to be painted is positioned automatically one space to the right of the previous character and in which coordinates for each symbol are unnecessary.

MAGNETOSTRICTION - A physical principle stating that a wire or rod within a varying magnetic field will vary slightly in length in accordance with the field.

MATRIX - A mathematical or electrical arrangement of any definable units so that any given unit may be defined in terms of coordinates or rows-to-columns.

PAINTING - The movement of the electron beam of a CRT in forming a character, line, or symbol on the CRT.

PLOTTER - A mechanical device usually operating under analog control which is capable of printing or scribing curves or symbols at given coordinate locations on a graph or map under computer control.

PLOTTER MODE - An arrangement in certain display systems in which each symbol or line to be painted must be accompanied by a coordinate address.

RAMP - A gradually changing voltage level used in vector and line generation to delay changes in coordinate position of the CRT in order to allow an even intensification of a trace.

RASTER - The name given to the useful area of display on the face of the CRT.

STEPPING - Increasing or decreasing by increments.

SYMBOL - Numbers, letters, punctuation marks, etc.

TRACKBALL - An optional auxilliary display device used to control the position of a cursor in order to identify locations on the face of the CRT for entry, deletion, or alteration of data.

UNBLANKING - Intensifying the CRT beam to a level visible to the human eye.

UNBLANKING LEVEL - The amplitude of the unblanking gate to the control grid of a CRT determined by character or vector size and by special function of intensity.

VECTOR - (1) A trace drawn on a CRT from a definable set of coordinates in an angular direction representing a given magnitude. (2) Any line drawn on a CRT.

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# Visual Displays

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# FOREWORD

This manual is intended to supplement the course material. No one can learn this material for you, but you can help yourself by paying attention to the way you learn.

Every session is structured to give you the ability to meet the objectives that are expected of you. These objectives are the basic elements on which you are tested and the information that you need to be successful when you graduate. Every subject contains explicit objectives. Read them, use them to study, and review them to ask yourself if you have completely learned the material.

At times you may be inclined to question whether or not some material is necessary. Keep in mind that there are succeeding subjects which you must learn and that the material may provide the foundation required to master these more advanced concepts.

Everyone wants to succeed. You would like to consider yourself a success in a few months. The following suggestions should help you:

1. Read the objectives before class. These are goals, and it is your responsibility to attain them.
2. Start now, and be prepared for every class. It is much more difficult to catch up than it is to prepare adequately.
3. See your instructor immediately if you become confused; do not wait until it is too late. You may see him by appointment, during a break, or before or after class.
4. Do not hesitate to ask questions in or out of class. You may feel that everyone else knows the answers, but the objectives are your personal objectives. If you knew all the answers, you would not be here.
5. Take careful notes, but do not try to record so much of the lecture that you fall behind.
6. Laboratories are extremely important. Participate actively, and rely on your work. Do not accept someone else's demonstration of his abilities; achieve your own objectives.
7. Assignments are designed to prepare you for the material in each subject. Check ahead for long reading assignments so you can complete all assignments on time. All review questions in assigned reading material are part of the assignment.

# CONTENTS

# CHAPTER 1
# OBJECTIVES AND ASSIGNMENTS BY SUBJECT

Reading assignments may be done in advance, but all assignments are due on the day after the subject is presented.

The textbooks for this course are the Visual Displays Training Manual, Control Data publication 60355300, and Visual Displays Student Manual, Control Data publication 60354200.

## 1. INTRODUCTION TO VISUAL DISPLAYS – HISTORY AND APPLICATIONS

OBJECTIVES

Upon completion of this subject you should be able to:

1. Describe the history of visual displays.
2. List the common display devices.
3. List five display applications.

ASSIGNMENT

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|---|---|
| Training Manual: | Chapter 1; Chapter 2, pages 2-1 through 2-3 |
| Student Manual: | Exercise 1 |

## 2. DISPLAY SYSTEMS, CATHODE-RAY TUBES, CONTROLS AND ADDRESSING

OBJECTIVES

Upon completion of this subject you should be able to:

1. Recognize various types of visual display systems.
2. Describe the types of CRT's used in visual displays.
3. Explain CRT addressing.
4. Describe the use of the various visual display operator controls.

ASSIGNMENT

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| Training Manual: | Chapter 2, pages 2-4 through 2-15; Chapter 3 |
| Student Manual: | Exercises 2 and 3 |

## 3. DIGITAL-TO-ANALOG AND ANALOG-TO-DIGITAL CONVERSION AND INTRODUCTION TO DISPLAY GENERATION

OBJECTIVES

Upon completion of this subject you should be able to:

1. Define analog.
2. Explain basic D/A conversion.
3. Explain basic A/D conversion.
4. Describe how D/A and A/D converters are used in display equipment.

5. Describe the point plot method of display generation.

ASSIGNMENT

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| Training Manual: | Chapter 4; Chapter 5, page 5-1 |
| Student Manual: | Exercise 4 |

4. CHARACTER GENERATION, VECTOR GENERATION, AND DISPLAY SYSTEM BLOCK DIAGRAMS

OBJECTIVES

Upon completion of this subject you should be able to:

1. Describe the various methods of character generation.
2. Describe the differences between line generation and vector generation.
3. Explain the function of each block of the display system block diagrams.

ASSIGNMENT

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| Training Manual: | Chapter 5, pages 5-2 through 5-16; Chapter 6 |
| Student Manual: | Exercises 5 and 6 |

5. INTRODUCTION TO REMOTE PROCESSING

OBJECTIVES

Upon completion of this subject you should be able to:

1. Describe methods of long-distance data communication.
2. Discuss time sharing and the use of remote terminals.

ASSIGNMENT

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| Student Manual: | Exercise 7 |

# CHAPTER 2
# EXERCISES

## 1. FUNDAMENTAL CONCEPTS

1. Describe an interactive display system.
2. What is the difference between small-scale and large-scale displays?
3. Give an example of an early use of CRT's.

## 2. DISPLAY SYSTEMS AND APPLICATIONS

1. Describe the function of an entry marker and a cursor. How are they different?
2. List five optional features available on a peripheral display system.
3. Describe the function of a light pen. How does it differ from a trackball?
4. List five applications of small-scale displays.
5. List five applications of large-scale displays.

## 3. CATHODE-RAY TUBE OPERATION

1. List the components of a conventional CRT.
2. Define resolution and persistency.
3. Describe the function of the high-voltage divider.
4. List the standard CRT operator controls. Describe the function of each control.
5. Describe the process of beam deflection. Why are two sets of deflection elements used?
6. Illustrate the location on a CRT screen addressed by the following positioning words:
   1. X = 1111, Y = 1777
   2. X = 0077, Y = 1700
7. How is a portion of the displayed image expanded to cover the whole screen?
8. Describe the construction of a shaped-beam tube. How is a character formed in a shaped-beam tube?
9. What is a storage cathode-ray tube?
10. What is a normal refresh-rate?
11. List the various modes of display equipment operation, and describe any differences.
12. List four types of displays which do not use a CRT.

## 4. BASE POSITIONING, DIGITAL-TO-ANALOG CONVERSION, AND ANALOG-TO-DIGITAL CONVERSION

1. Define the term base position.
2. Which two modes of operation affect base position? Describe each one.
3. What is the difference between analog and digital?
4. Why are D/A and A/D conversion needed by display systems?
5. Describe D/A conversion.
6. What is the current summer?
7. Describe A/D conversion.
8. List the three principles on which A/D conversion is based. Describe any differences.
9. How is signal conversion used in beam positioning?

## 5. METHODS OF DISPLAY GENERATION

1. List three means of generating graphic displays. Describe each one, including advantages and disadvantages.
2. List three means of generating characters. Describe each one, including advantages and disadvantages.
3. Which method of character generation can be used to construct either graphics or symbols?
4. Describe the function of the diode matrix.
5. What are the two most common methods of character generation? How are they alike, and how are they different?
6. What are the differences between lines and vectors? How would these differences affect their use?
7. Describe the function of the ramp generator. How is this accomplished?
8. Symbols formed on a 9 x 9 matrix should require (more, fewer) beam positions than on a 7 x 7 matrix. Under what circumstances, if any, would be 9 x 9 symbol be smaller than a 7 x 7 signal?
9. Differentiate between primary and secondary translation, giving the function of each.
10. A seventh bit in the symbol binary code would serve what purpose?
11. Draw a section of a diode matrix that will paint a "T".
12. Where is timing controlled during primary and secondary translation?
13. Define $\Delta X$, and $\Delta Y$.
14. In determining ramp slope selection we are interested in:
    a. Capacitor discharge time.
    b. Capacitor-resistor charge time.
    c. The timing chain.

## 6. BLOCK DIAGRAM ANALYSIS

1. List the basic elements of a display system. Explain how they are linked.
2. Describe the deflection network. How does it function?
3. Describe the function of the unblank circuitry.
4. Why are focus and astigmatism correction needed?
5. How does a remotely connected small-scale display system differ from one located on-site?

## 7. INTRODUCTION TO REMOTE PROCESSING

1. Why are telephone lines used for long-distance data communications?
2. Describe the functional difference between parallel and serial modes of data transmission.
3. Describe the function of the monitor buffer.
4. Define the following terms:
   a. Off-line
   b. On-line
   c. Batch processing
   d. Real time
   e. Multiprocessing
5. Describe the functional differences between multiprogramming and time sharing.
6. List three applications of multiprogramming.
7. List three applications of time sharing.
8. What is interactive processing? How would it be implemented from a CDC® 200 User Terminal?
9. What are conversational languages, and who would be the most logical user?

# APPENDIX

## APPENDIX A

## GLOSSARY

| | |
|---|---|
| ac | alternating current |
| A/D | analog-to-digital |
| adder | a circuit capable of accumulating electrical quantities — may be used to add or subtract |
| alphanumeric | pertaining to a character set containing alphabetic letters, numerical digits, and special symbols which are machine processable |
| analog | the representation of data in the form of continuously variable physical quantities |
| aquadag coating | a form of phosphor coating |
| ASCII | American Standards Council for Information Interchange |
| astigmatism | a distortion in the shape of the electron beam caused by an inbalance in the push-pull deflection voltages |
| base position | the fundamental address at which the generation of a character or a vector is to begin |
| BCD | binary coded decimal |
| blanking | the deintensifying of the electron beam below visibility. |
| byte | a portion of a computer word |
| cartesian coordinates | the two values that specify the position of a point on a graph with respect to two reference lines at right angles to each other |
| conversational languages | a problem-oriented computer programming language for use by non-professionals |
| CPU | central processing unit |
| CRT | cathode-ray tube |
| current summer | a circuit within a D/A converter network that algebraically adds current from all bit positions |
| cursor | a position indicator on the CRT screen under operator control which may be positioned anywhere on the display |
| D/A | digital-to-analog |
| dc | direct current |
| delay-line memory | a temporary storage device used on alphanumeric displays to store one page of data with which to regenerate the display |
| Δ | delta, meaning change |

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| digital | pertaining to the use of discrete integral numbers in a given base to represent all the quantities that occur in a problem or calculation |
| diode matrix | an array of coupled diodes capable of converting one input signal into a rapid sequence of control outputs |
| entry marker | an underline symbol used in the line printer mode to mark the location of the next character to be entered or displayed |
| flicker | the wavering or fluttering visual sensation produced by intermittent light when the rate of intermittence (refresh rate) is not rapid enough to produce complete fusion of the individual impressions. |
| flip-flop | a bistable storage device capable of assuming two states (one and zero); it remains in either state until reversed |
| gate | a circuit having one output and multiple inputs so designed that the output is activated only when a specified combination of pulses is input. |
| graphic | displayed images which are not alphanumeric (in the context of this course) |
| hard copy | a copy of a displayed image which is printed on paper or film. |
| input/output<br>I/O | the bidirectional transmission of information between computer memory and peripheral devices |
| interactive system | a display system in which the operator interacts with the control program directly, such as by means of the light pen |
| interrupt | a computer-generated signal which breaks the normal flow of processing in such a way that the flow can be resumed from precisely that point at a later time |
| light pen | a stylus imbedded with a photosensitive cell which, when pointed at a CRT screen, detects light from a beam unblanked at the target point; the pen's response is sent to the computer which acts upon the display in accordance with previously programmed instructions |
| line | the path of the electron beam trace from one specified set of coordinates to a second set of coordinates. |
| line printer mode | a method of displaying alphanumeric data in which each symbol to be generated is automatically positioned one space to the right of the previous symbol, thereby eliminating the need for specifically defined coordinates for each symbol |
| Lissajous pattern | a symmetrical pattern of curves formed by combining two mutually perpendicular harmonic frequencies which are in a ratio of whole numbers to one another |

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| location | a position in computer storage for one computer word, identified by its address |
| logical digit | in a binary computer, either of two possible states for one bit; "1" or "0" |
| magnetostrictive | changing in dimensions when placed in a magnetic field |
| matrix | an arrangement of definable units in such a manner that any given unit can be addressed by coordinates of row and column |
| MODEM | modulator-demodulator; a signal conversion device used in remote data transmission |
| painting | the movement of the electron beam in the process of forming a displayed image |
| parallax | the apparent displacement of the position of an object caused by a shift in the point of observation |
| passive system | a display system which does not allow two-way data transmission |
| peripheral device | a piece of computer equipment which performs some part of its operations independent of CPU control |
| priority interrupt | a scheme for ordering real-time inputs to a multiprogramming system |
| processor | a device capable of receiving data, manipulating it, and supplying results from it |
| program | a precise set of computer instructions to be used to solve a problem |
| queue | a list of inputs, usually ordered by priority, maintained internally by a computer |
| ramp | a variable voltage level used to maintain an even trace intensification in line and vector generation |
| raster | the area of the CRT face within which the electron beam may be aimed; the usable display area |
| real time | a mode of computing which produces the answer to a problem within the actual elapsed time of solving the problem |
| refresh, regenerate | the process of periodically restoring a CRT image to compensate for the decay of the display medium; generally within a range of 30-60 times per second for flicker-free visibility. |
| remote terminal | a peripheral input/output device located more than 500 feet from the CPU, therefore, connected by telephone lines |
| scaling | the increase or decrease of the size of the displayed image according to a fixed ratio |

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| software | the programs stored by the computer to accomplish the requested operations; as contrasted to hardware which is the machinery |
| stepping | movement in discrete increments or decrements |
| storage tube | a CRT whose screen is coated with a compound which switches to a display state and remains there; does not need to be refreshed |
| trackball | a device used by the operator to control the cursor; within itself it constitutes an A/D converter utilizing shaft encoding |
| unblanking | the process of intensifying the electron beam to a visible level |
| vector | an electron beam trace of a given magnitude drawn from a set of specifically defined coordinates in a specified angular direction |
| weighting | the principle of assigning voltage levels in accordance with the significance of the bit position in D/A conversion |

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