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TECHNICAL DETAILS
OF
PRINT READER DEMONSTRATOR

by

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and

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U. S. DEPARTMENT OF COMMERCE
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Electronic Instrumentation Section
Electricity and Electronics Division
developed through
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for

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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1. INTRODUCTION

The general method of recognition for identifying typewritten characters used in the Print Reader Demonstrator is an outgrowth of the system developed by J. Rabinow. It is what might be called a scanned-comparison system. The memory is in the form of optical masks, one for each letter to be identified, plus a few control patterns. Each mask is a photographic negative image of an individual letter, i.e., it is transparent in the area where black ink would be on the letter itself. Sequentially the masks are superimposed over the unknown letter, and the mask area is scanned in a regular pattern. During the scanning raster, areas wherein white paper is visible through the transparent portions of the masks are summed up. When the integrated total is below a threshold value upon completion of the raster this mask then must be the correct one. Output indication is then provided to identify the particular mask.

In operation, a telephone-type selector switch moves in phase with the mask changing. Upon recognition, this switch ceases to move farther, leaving one indicator lamp lighted to show the identified character. The time required for recognition is about two seconds per character. The Demonstrator is currently set up to identify all of the alphabetic (upper case only) and numeric characters of Elite type.

2. THEORY OF OPERATION - GENERAL

The important elements of the Print Reader Demonstrator are:

1) Optical System
2) Electronic Circuitry
3) Indicator

The Optical System generates electrical signals from the visual appearance of the letters under study. The Electronic Circuitry provides the necessary sweep current to the Optical System. In addition it carries out the necessary analysis of the output signals from the Optical System. Finally the Indicator provides the identification of the unknown letter of interest.

2.1 Optical System

The important elements in the Optical System in sequence are indicated in the block diagram, Figure 1, and are the following:

1) Illuminator
2) Unknown letter
3) Pick-up Lens
4) Deflector
5) Masks of letters in vocabulary
6) Projection Lens
7) Image Dissector Tube
8) Synchronizing Pulse Generator

The film handling portion of the optical assembly is a modified Revere type 16 mm. motion picture projector. Relatively few modifications were necessary to adapt the unit for this service. The stand and film sprockets were removed directly, while the lamphouse was replaced with a mounting for the Pick-up Lens. The speed control is set to run the motor at 18 to 20 frames per second. Additions to the projector are the Deflector Vanes described below and a bracket for holding the Vocabulary Belt.

Light reflected by the paper and unknown letter is focussed through the Deflector onto the masks by the Pick-up Lens. From here it is focussed on the photo-sensitive surface of the image dissector television pickup tube.

The masks are essentially photographic negative images of each letter in turn, located as successive frames of 16 mm. motion picture film in an endless belt. There are 26 letters, 9 numerals, one opaque and one blank frame. The film-handling assembly is a modified movie projector running at about 20 frames per second. Film motion is of course intermittent; the masks are held stationary for about two thirds of the time.

A synchronizing pulse generator is provided whose function is to generate a pulse each time a new film frame has been brought into position. The pulse is derived through the use of a slotted disk on the projector motor shaft, in conjunction with a lamp and photocell.

The Deflector is a transparent vane which is employed to provide a small, slow horizontal shift from left to right of the unknown with respect to each mask. Thus it allows a certain amount of horizontal misplacement of the unknown letter.

2.2 Electronic Circuitry

A block diagram of the equipment is shown in Figure 1. The major subdivisions of the Electronic Circuitry are:

1) Gating circuits
2) Scanning circuits
3) Recognition circuits

Control of the overall cycling of the scanning and recognition circuitry is the function of the Gating circuits. In the block diagram of Figure 1, this comprises the Master Flip-Flop, Start-Alphabet Pulse Generator and Electronic Switch.

The Scanning circuits generate the various sweep voltages required to scan the mask area on the Image Dissector. In Figure 1 this includes the Frame Flip-Flop, Vertical Scan Oscillator and Deflection Amplifier, the Horizontal Scan Generator and Deflection Amplifier, and lastly the Field Counter.

The Recognition circuits analyze the signals from the Optical System to determine when a mask matches the unknown character. In the diagram this includes the Clipper, the Error Integrator, the Coincidence Circuit, and the Amplifier and Shaper Circuits.

2.3 Indicator

The basic elements of the Indicator are:

1) Stepping Switch
2) Stepping Switch Actuator
3) Indicator Lights

The Stepping Switch is arranged through its Actuator to start from Home position when the first letter mask in the Vocabulary Belt comes into place. The Switch moves one position each time a new mask appears, and is left in position after recognition occurs. It remains in position until returned to the Home position when the operator pushes the Reset Switch.

The Indicator lights are energized through the contacts of the Stepping Switch. When this Switch stops moving, one light is therefore turned on. The Indicator lights are marked with the appropriate characters. For convenience with the recognition method employed, the Indicator Panel contains the lights in the same order as on the Vocabulary Belt.

2.4 Operating Cycle

2.4a Initial Conditions

These are the states of the various portions of the system at the beginning of the operating cycle. See block diagram in Figure 1.

1) Unknown letter in place
2) Vocabulary masks in motion
3) Stepping Switch indicating previous character

4) Vertical Scan Oscillator on continuously
5) Horizontal Scan off, at left edge of mask area

2.4b Operation

When the Reset Switch is actuated, the Stepping Switch is rapidly advanced to its home position. In this position the Start Alphabet Pulse Generator is made operable. Nothing else happens until the Vocabulary Belt passes through the beginning of the alphabet.

In the course of its motion, the Vocabulary Mask Belt comes to the blank or clear frame. At the end of the blank frame which comes at the beginning of the first letter in the alphabet, a clear area pulse is generated in the Start Alphabet Pulse Circuit. This is fed to the Master Flip-Flop, turning it on. Relative timing of these actions is indicated in Figure 2.

At every frame change in the Vocabulary Belt, a synchronizing pulse is generated which occurs after the new mask is in position, phased to come at the left hand position of the Deflector Vane. This pulse starts the Frame Flip-Flop.

The Horizontal Scan Generator is gated on by the output of the Frame Flip-Flop, producing a series of staircase waves of about 5 milliseconds period. Figure 4 shows significant relative timing during the Field period. The discharge at the peak of each wave is called the End of Field pulse. This is counted in the Field Counter, resulting in a pulse to stop the Frame F-F after the sixth pulse. Thus a series of six horizontal scans is produced. As can be seen from Figure 3, showing timing during the Frame period, these six scans or fields occur while the Deflector Vane is moving gradually from left to right extreme horizontal positions. In effect there are "tries" at a match at six positions of the unknown letter with respect to each mask.

Turning off the Frame F-F at the end of the six fields results in a pulse for advancing the Stepping Switch. This pulse must pass through the Electronic Switch however, which is actuated by the Master F-F. Thus the Stepping Switch can only be advanced while the Master F-F is on. The Stepping Switch therefore advances from the Home position at the end of each group of six fields, or at the same time the film is being changed to a new mask. Due to the relative phasing of Master and Frame F-F gates, one extra advancing pulse is generated, so that the first letter of the alphabet can be separate from the Home position.

To sum up the scanning process so far, at each change of trial masks, a series of six complete scanning rasters is made. These rasters or fields are generated while the Deflector Vane shifts the unknown letter with respect to the mask. Since the total amount of horizontal travel is small, the amount during one field is assumed negligible. At the end of this period the Stepping Switch advances to the next position. Approximately simultaneously, the Vocabulary Belt changes to the next mask in alphabet, whereupon the cycle begins again.

During each field the optical signals are analyzed for agreement between mask and letter. First they are passed through a threshold Clipper to decide in effect whether the instantaneous photoelectric current is indicative of black ink or white paper appearing through the transparent areas of the mask under trial. The photoelectric current is very small when the scanning beam is over the opaque areas of the mask. Thus the only opportunity for signals of any magnitude is when the beam is over the transparent portions. The signals from the Clipper emerge as either positive (for black) or negative (for white). The threshold for transition is adjustable depending upon the heaviness of the typewritten character.

The function of the Error Integrator, which is next in line, is to sum up all areas where white paper is visible through the mask. Since the scanning velocity is constant, the actual summation is carried out as the time integral of the white signal from the Clipper. At the end of each field the integrator is sampled to determine whether the integral is above or below the chosen threshold level. If at the end of the field the integral is above the threshold, there is no interference with the overall cycle. The Integrator is reset immediately after the sampling.

However, if the integral is below the threshold, as is the case when the mask matches the letter, a recognition pulse appears at the output of the Coincidence circuit. This is amplified, shaped, and fed to the Master F-F to turn it off. This in turn, disables the Electronic Switch, preventing the Stepping Switch from advacing any farther. Finally, as the output indication in the Demonstrator model, an appropriately labelled lamp is energized through the Stepping Switch contacts.

To take care of the case of non-recognition of an unknown character, the last mask on the belt is entirely opaque; thus recognition is bound to occur on this one if it has not on the other masks. This provides a convenient means for indicating non-recognition of the standard characters.

After recognition on one of the masks, only the Stepping Switch is stopped. There is no interference with the mask changing, scanning, integrating and other functions. Since the Master

F-F can only be reset on the Home position of the Stepping Switch, the Master F-F remains off until the Reset Switch is actuated.

3. THEORY OF OPERATION - DETAILED

3.1 Optical System

3.1a Illuminator

The Illuminator is a standard Eastman Kodak 2X2 slide projector with a 150-watt bulb, arranged with a supplementary lens of 20 diopters located in front of the regular projection lens. The light is focussed to an area of about .2 X .3 inches on the paper. Mounting of the projector is arranged for an angle of illumination of about 35° from the paper. The estimated intensity of the light is about 100,000 to 500,000 foot candles. Uniformity is probably good to about 10% over the scanned area.

3.1b Unkown Letter

In the Demonstrator the characters with recognition to be shown are typed on a roll of white bond paper taped to the typewriter platen. The platen is then turned up until the characters are at the top. Either single or double spacing may be used between letters.

The typewriter itself is a Remington with Elite type face. The dimensions of the letters themselves are about 0.10 inch high by 0.10 inch wide for the letter M. Spacing of characters horizontally is 12 to the inch. Best results with regard to the kind of ribbon seem to be with the heavily-inked variety, or with a paper carbon ribbon.

3.1c Pick-up Lens

This is a movie-camera type lens made by Bell and Howell labelled Lumax f/1.9, focal length 1 inch. It is normally used at f/2.8 for better contrast than is provided at full open.

3.1d Deflector Vane

The Horizontal Deflector Vane is a plate of 1/8 inch thick lucite arranged to oscillate about an axis which is equivalent to the vertical direction on the letter masks. The vane is driven synchronously through a cam on the same shaft which changes the frames on the film. As the vane is tilted, light rays passing through it emerge with a positional shift which is a nearly linear function of tilt. It is moved through a range of about ± 15 degrees, providing a total shift equal to about 15% of the width of the letter M, or about $1\frac{1}{2}$ line widths on the mask.

The Vertical Deflector Vane is a hand-operated means for lining up the letters vertically with the masks.

3.1e Masks

These are photographic (negative) pictures of hand-drawn master figures representing the essential elements of each letter. In the drafting process, the typewritten characters were enlarged on the viewing screen of a microcard reader to about 2 1/4 inches high. The width of the lines was made about 3/4 of the line width in the character when typed with medium inked ribbon. Normal line width in the mask is about 10 mils referred to the typed character, or about 10% of the width of the letter M. Examples of magnified typed characters and the resultant drawn figure are shown in Figure 5.

As photographed on the mask, the dimensions of the letter M are 0.18 inch high by 0.16 inch wide.

The order of the letters on the Vocabulary Belt is listed in Table I. This order is dictated principally by the ambiguities such as O and Q, where it is necessary to place the Q mask first in order to screen out recognition of the Q as an apparent O.

The Vocabulary Belt was made by photographing the drawn letters sequentially on a motion picture camera arranged for frame-by-frame exposure. The film itself is Recordak Micro-File panchromatic film, 16 mm. width, and perforated on one side. Virtually the only important photographic characteristic is that the unexposed areas be clear after processing. Ordinary 16 mm. negative film has a gray base which absorbs at least 50% of the transmitted light in the unexposed areas, making it unsuitable.

3.1f Projection Lens

This is the regular projection lens for the projector assembly. The focal length is 2 inches; the aperture, f/1.6. In the optical arrangement as set up, this lens focusses an image on the dissector tube which is about one inch high. Thus the overall magnification from typed character to image dissector tube is 10 times. Illumination intensity at the screen is about 2.5 foot candles with white paper and clear mask.

3.1g Image Dissector

This type of pick-up tube was chosen because signals may be extracted on an aperiodic basis. That is, a continuous signal may be obtained if the scanning spot is held motionless. Since there is no storage, as is the case for iconoscopes, orthicons and vidicons, there is no necessity for scanning and discharging the entire screen area. Thus the scan may be limited to any desired area.

At the photosensitive screen of the dissector tube, the boundary of the mask frame is 1.75 inches high and 1.25 inches wide. The reference orientation here is with respect to the projected letters as viewed on the screen.

Orientation and placement of the dissector tube is important in this application. There is an effective rotation of the pattern of about 30° as it is scanned, brought about by the combination of magnetic focussing field and electrostatic accelerating field. Furthermore, this particular style of dissector tube, having its screen internal rather than on the front surface, has the electron multiplier elements blocking the light path from a centrally located lens. To avoid a shadow with the present optical system, the dissector tube is tilted so that the light misses the multiplier structure.

Proper orientation of the tube is furnished by observing a television type presentation wherein a CRO is arranged for identical sweeps, and the CRT grid blanked by optical signals from the dissector. Centering and rotation are easily checked under these conditions. A typical pattern is shown in Figure 6.

From this presentation and a knowledge of size of the projected image, the present sweep amplitudes have been measured as 1.4 inches vertically and 1.0 inch horizontally at the photo-sensitve area. These sweeps are derived from the vertical and horizontal deflection amplifiers, which feed currents through the respective deflection coils of the yoke. While the frequencies are not those for which the yoke was designed, the coils are used in the manufacturer's original intention as regards high and low frequencies. The low frequency coil contains a ferromagnetic structure, and is the relatively thin coil on the yoke. In ordinary television this would of course be the vertical deflection coil.

Scanning current amplitudes are 1.4 ampere peak-to-peak triangular wave for vertical deflection, and 0.6 ampere peak-to-peak staircase wave for the horizontal deflection. Other detailed information on the tube is given in Table 2.

The scanning spot is approximately square, because of the shape of the aperture in the collector structure. As measured to the half signal or 50% response points, the spot width is about 80 mils wide at the tube, or 8 mils referred to the typewritten characters. This size was chosen to provide large signals and at the same time minimizes the effect of typing imperfections. It will be noted that the spot width is somewhat less than the mask opening width, which is about 10 mils. The horizontal rate of travel per vertical sweep is 4 mils.

Thus the horizontal travel per sweep is about one-half the spot width. There are about 20 vertical passes in the width of the letter M. Vertically the measured bandwidth of 60 kilocycles provides a resolution of at least 40 lines in the height of the letters.

Control of the magnitude of the optical signals is provided by means of the potentiometer on the image dissector power supply. This control varies the potential applied to one of the intermediate dynodes, changing its emission efficiency. Maximum gain is secured in the center of its rotation.

3.1h Synchronizing Pulse Generator

This assembly produces a pulse of an amplitude of 0.3 volts and a duration of 1% of one rotation of the film drive motor shaft. The synchronizing pulse originates in the lamp-bulb and photocell assembly arranged around a slotted disc on the film motor shaft. The shaft rotates once for each frame on the Vocabulary Belt. Phasing is such that this pulse occurs at the same time as the film claw retracts at each frame change.

3.2 Electronic Circuitry

Details of the operation of the various portions of the circuitry are given here. Because the circuit is complex, separate diagrams are given for the Gating, Scanning and Recognition circuits, as well as for the deflection amplifiers. Reference is suggested first however to the detailed block diagram Figure 7. Waveforms of significance are included on the diagrams and in the notebook accompanying the equipment.

3.2a Gating and Indicator Circuits - Figure 8a

1) Master Flip-Flop

This is a conventional bistable circuit, pulsed negatively at the two grids whenever transfer is desired. The output of the Master F-F is a gate which is either zero or approximately -50 volts. The latter condition is considered the "on" state of the circuit.

2) Start Alphabet Pulse Generator

The function of this circuit is to generate a pulse whenever the Vocabulary Belt passes through the blank frame coming immediately before the alphabet itself. The circuit begins with a low-pass filter to attenuate the normal scanning signals in proportion to the relatively large one caused by the blank frame. Then a controllable bias is inserted through the 250 K potentiometer to allow adjustment of the threshold. This is followed by a Schmitt trigger of conventional design which flops over whenever the threshold is crossed. Effectively at this point the signals from the blank frame are "squared up". When differentiated, negative and then positive pulses are generated. The pulse inverter V30B is normally biased beyond cut-off at -20 volts, so that only the positive input pulses are amplified. The negative pulse appearing at the plate of V30B is then fed to the Master F-F to turn it on.

An additional condition imposed upon the circuit is that the Master F-F is to be started only when the Stepping Switch is in the Home position, but must not be operable while the Reset Button is pushed. The circuitry for accomplishing this is obvious from the diagram; the basic arrangement is to hold the grid of V30B highly negative whenever the circuit is to be disabled. As part of the arrangement to provide a separate position on the Stepping Switch for the first letter in the alphabet, it is necessary to turn on the Master F-F before the cessation of optical signals. Otherwise the pulse would not come until the "A" mask is nearly in position, leaving too short a pulse for the Stepping Switch. The early start of the Stepping Switch is brought about by coupling the Frame F-F gate to the Schmitt input so that the Schmitt is returned to the "off" state at the End-of-Frame time if it has been previously turned on. The last condition can only be satisfied when the clear frame is in position. Thus the negative pulse at the plate of V30B appears at the time of the End-of-Frame pulse when the clear frame mask is in place.

Therefore the output of this circuit is a negative pulse occurring at the end of the scanning over the clear area of the blank frame. Timewise it comes at the End of Frame pulse, coinciding approximately with the beginning of the film travel which brings the "A" mask into position.

3) Electronic Switch

This circuit is provided to gate the actuating pulses to the Stepping Switch in accordance with the state of the Master F-F. The actuating pulses are really gates which last during the "off" time of the Frame F-F. The input is derived from one plate of the Frame F-F, the one which is positive while the scan is "off". The first actuating pulse comes when the Master F-F is turned on, which coincides with the End of Frame pulse on the clear frame mask. This arrangement provides the initial advance signal which allows a separate Stepping Switch position for the first letter in the alphabet, as distinct from the Home position.

4) Stepping Switch Actuator

The pulses or gates which are allowed to pass by the Electronic Switch are fed to a power amplifier for eventual actuation of a relay. This relay in turn controls the Stepping Switch. Motion of the Stepping Switch occurs when its coil is de-energized, thus the Switch advances to the next light slightly after each synchronizing pulse. The normal advancing action of the Stepping Switch is therefore externally controlled by the relay in the plate of V31.

5) Stepping Switch

The Stepping Switch is of the 20 position telephone type. Alternate rotor contacts are removed, providing through the use of alternate bays of fixed contacts, a 40 position selector switch. The first position is defined as the Home position. Next to this is the commencement of the alphabet.

For rapid self-advance to the Home position when the Reset Switch is actuated, voltage is applied to the Switch coil through its Interruptor contacts. Stopping at the Home position is assured through an additional switch which disables the rapid-advance circuit when the Home position is reached.

6) Indicator Lamps

These are 6-watt, 115 volt bulbs run on approximately half-voltage to avoid over voltage on the Stepping Switch. In the Demonstrator the alphabet as laid out on the Indicator Panel is the same as on the Vocabulary Belt.

3.2b Scanning Circuits - Figure 8b

1) Frame Flip-Flop

This flip-flop is turned "on" by the synchronizing pulse coming after each new mask is in place, and is shut off by the output pulse from the Field Counter at the completion of six fields. It is thus the gate generator for controlling the scanning program.

The "off" state of the Frame Flip-Flop is with the right hand (V26B) tube conducting. In this condition the output gate to the Horizontal Scanning Generator is most positive (zero), disabling the horizontal scan through V27A. In the other condition the gate is at -50 volts.

The synchronizing pulse originates in the lamp-bulb and photocell assembly on the film drive motor shaft. A negative pulse of about .35 volts appears at the anode of the photocell. This pulse is amplified through the two stages of V32, after which it is applied to the Frame F-F to turn it "on".

The output of the Frame F-F is a gate to permit horizontal scan. This gate is zero in the off position and about -50 volts in the "on" position.

2) Vertical Scan Generator

This circuit begins with a free-running multivibrator oscillating continuously at about 3000 cps. In order to generate the desired trigangular wave for vertical scan, the oscillator is fed to a clipper V_{2B} for squaring, then to an integrating circuit. The various time constants including the two low-pass networks at the input of cathode follower V_{14A} and the 2 μf output capacitor, are all tailored to match the characteristics of the Stromberg-Carlson amplifier. With another amplifier, for example one like that used for horizontal deflection, these integrating circuit values would require change.

The output of the Vertical Scan Generator is a triangular wave of about 3000 cps and 25 volts peak to peak amplitude.

3) Horizontal Scan Generator

The horizontal scan is designed to advance the sweep to a new horizontal position each time the vertical scan completes one up or down trace. Therefore the waveform is a staircase wave of about 30 steps. At the conclusion of the 30 steps, the wave is discharged and is repeated. Six rasters or fields are generated, after which the horizontal scan returns to its quiescent value of +8 volts.

The 3000-cycle square wave Vertical Oscillator charges the 2000 mmf capacitor through diodes V_{15} each time the square wave multi-vibrator flops over. The amount of charge is governed by the voltage change applied, and by the ratio of small capacitors (47 and 68 mmf) to the summing capacitor (2000 mf). The accumulation of voltage on the staircase summing capacitor is fed to the cathode follower V_{14B}. To enhance linearity, a bootstrap arrangement from the cathode follower is employed.

Retrace or discharge of the horizontal scan voltage is provided by the thyratron V_{16}. As the output voltage rises, the tap on the voltage divider (130K, 50 K pot, 510 K) reaches the conducting range of the thyratron, bringing about discharge of the staircase summing capacitor. After deionization of the thyratron, the charging process resumes.

In order to gate off the horizontal scan voltage, a gate tube V_{27A} is made conducting during the "off" time of the Frame F-F, thus the horizontal scan can only occur when the Frame F-F is "on".

The major output of the Horizontal Scan Generator is a series of 6 staircase waves of 30 stepseach. After the 6 waves have occurred the voltage remains at the bottom or quiescent level. Amplitude is approximately 60 volts peak to peak. Each step in the staircase is about 167 microseconds in duration, thus each whole staircase has a period of 5 milliseconds.

The other output of this circuit is the End of Field pulse generated by the discharge of the summing capacitor. As its name implies, this pulse coincides with the end of each complete field of scan over the letter area.

4) Field Counter

This circuit begins with a 150 microsecond delay multivibrator to generate a pulse for discharging the Error Integrator after it has been read out. The delayed End of Field pulses are then counted in a staircase counter which is adjusted to provide an output pulse at the sixth input pulse.

The Field Counter is essentially similar to that in the Horizontal Scan Generator. Control of the count is by means of the 500 K potentiometer in the cathode follower V_{25B} output circuit.

The output of the Counter is a series of 6 negative pulses delayed 150 microseconds from the input pulses, plus one counter output pulse for six input pulses.

5) Vertical Deflection Amplifier

This is a commercial Stromberg-Carlson type Model AP 25 audio amplifier. It is rated at 45 watts output. Normally the gain control is set to provide about 1.4 amperes peak to peak output current of triangular waveform through the yoke.

6) Horizontal Deflection Amplifier

This amplifier is of the current-summing type with a high degree of negative feedback. It is arranged for constant-current or high impedance output.

The amplifier is in two nearly-identical portions, one active and the other inactive. The function of the inactive side is to serve as a stable voltage regardless of whether current is drawn from it or fed into it. The active amplifier feeds the reference point through the Horizontal Deflection Yoke and a resistance of 100 ohms. The feedback for the active side is taken from the midtap between yoke and resistance. Thus the voltage across the 100-ohm resistance is made to follow the input signal to the amplifier, hence the output current is proportional to the voltage from the Horizontal Scan Generator.

Centering of the raster horizontally over the masks is accomplished by feeding a controllable bias current into the input terminals.

The output of the Horizontal Deflection Amplifier is a staircase wave of current of 0.6 amperes peak to peak. After the 6 fields for each mask, the current returns to its quiescent value which holds the scanning beam off to the left of the mask.

3.2c Recognition Circuits - Figure 8c

1) Clipper

This is a conventional Schmitt trigger circuit, having two output states which depend upon whether the input is above or below a chosen threshold value. At the input the signal has added to it, by means of current through the 10 K resistor, a controllable bias voltage. With the divider chosen, the effective bias change, for a change in the setting of the 100 K pot, is one-tenth the measured change at the arm of the potentiometer. Thus a voltmeter at this point furnishes a convenient reference for bias changes. The Schmitt circuit is designed for low hysteresis, so that the threshold is substantially the same for increasing (negative-going) or decreasing photoelectric signals.

The relation between actual threshold level and the measured voltage at the potentiometer arm is shown in Figure 9. From the relation, any desired threshold may be chosen, as for example 95 volts at the test point provides a threshold level of about -15 volts.

A discussion of the factors involved in setting the threshold is given in Section 4.

The output of the Clipper is either a signal representing black (0v.) or white (-40v.) at the grid of V_{18}.

2) Error Integrator

The chief action of this circuit is to accumulate charge on the 320 micro-microfarad integrator capacitor whenever the Clipper signal represents "white". Then at the end of the field the accumulated voltage is fed to the Coincidence circuit. Finally the integrator capacitor is discharged by the Delayed End of Read pulse.

Charging of the integrator capacitor is accomplished through the series combination of 330 K and diode V_{19A}, whenever V_{18} is cut off. When V_{18} is conducting there can be no accumulation of charge. Effectively the final voltage on the capacitor is proportional to the total area that white paper is seen through the letter mask. An output cathode follower V_{19B} is added to permit current to be drawn from the integrator voltage.

The integrator charging function is gated by V_{27B} to permit the acquisition of charge only while the horizontal scan is on. A discharge tube V_{22B} resets the capacitor voltage when its grid is pulsed positively by the inverted (through V_{22A}) Delayed End of Field pulse.

3) Coincidence

This circuit receives the final integrator voltage, using it to enable or suppress the passage of the End of Field pulse. If the integrator output is below a chosen threshold, as set by the 100 K potentiometer, the End of Field pulse appears at the plate of V_{21A} as a large positive spike of short time constant. If the integrator output is too large (positive), V_{21B} is conducting at the time the End of Field pulse occurs. Under this condition, no appreciable positive spike can appear at the common plates of V_{21A} and V_{21B}. The actual transition between pulse and no-pulse is not an abrupt one; there is a narrow band of proportionality for a small range of integrator voltage.

4) Recognition Pulse Shaper

In order to trigger the thyratron V_{28} reliably, the sharp spike at the plates of V_{21} is lengthened by the rectifier time constant circuit of V_{8B}. The lengthened pulse is then fed to the normally cut-off thyratron. The thyratron fires when it receives a pulse from the Coincidence circuit, creating a rapid, negative Recognition pulse at its plate. This is the pulse which shuts off the Master Flip-Flop upon recognition of a character.

As part of the Demonstrator, firing of the thyratron is rendered audible on a small loudspeaker through which the tube discharges.

5) Meter Circuit

This circuit is added to furnish an indication of optical signal magnitudes. In general the optical gain seems to disply some instability, necessitating occasional adjustment of the image dissector gain control or the Illuminator lamp voltage.

The circuit is essentially a negative peak rectifier with a very long time constant to retain the peak reading. Primarily the meter circuit derives its reading from the peak signal voltage during the clear frame. The meter indication is characterized by a pulse whenever the clear frame passes, followed by a slow decay until the next pulse. In operation the magnitude of the optical signals should be adjusted until the meter reads 100 at the beginning of the slow decay.

The circuit itself is a negative peak rectifier V_{23A} followed by a cathode follower V_{23B}. The zero control is set with the Illuminator off but with the ambient light at its prevailing valve. In general dim ambient light is preferable, since there will be less variation with movement of the operator.

4. CONCLUSIONS

Threshold and Error Level Adjustments

There are two important controllable variants involved in the discrimination between wanted and unwanted characters. These are 1), the setting of the level of transition for black to white signals, and 2), the threshold for maximum area of disagreement allowing recognition. These two functions are somewhat interrelated, however an optimum balance between the two will result in the greatest degree of discrimination. This means proper recognition over the greatest range of practical input conditions.

An examination of actual typewritten characters shows two general forms of degradation which are always present in varying degrees. These are 1) the inked portions are effectively gray rather than black, and 2) the inked areas differ in geometry from the idealized shapes drawn for the masks. The former produces an obvious increase in the reflectance of the inked areas, lessening the range between it and the reflectance of white paper. It is in this range that the Clipper Threshold must be placed. The latter condition however has been found to be the more bothersome. In this category are included characters in which the lines are too thin as from light typing, characters in which the lines are so wide as to spread into the areas of unwanted masks from heavy typing, and finally characters with defects in the type face itself. Factors in this category are the ones which principally influence the setting of Error Threshold.

All of these conditions make recognition more difficult. If one of these is very pronounced, for example, if the lines are gray rather than black, the permissible range of other factors is in general reduced. To provide as large a range of these factors as possible is the object of optimizing the controllable factors of clipper level and error level.

Measurements of the effective reflectance of the inked areas of typewritten characters vary from 30 to 50 percent of that of white paper alone.

These are figures derived when the letter is stationary with respect to the mask. However in actual operation, the letter is moving slowly horizontally because of the motion of the Deflector Vane. During the time of one field, for example, the total horizontal travel is about 2% of the width of the letter M or about 20% of the width of the lines of the letter. This means that if a letter and mask match at the left side at the instant of scan, they will not coincide exactly at the right side by the time the scan reaches the right side. Instead some white will be visible, raising the effective reflectance of this part of the letter. The net effect of this motion is therefore to narrow the range between the reflectances of inked areas and white paper.

This effect could be compensated by shrinking the horizontal dimension of the letters as the master patterns are drawn. In the Demonstrator however, the compensation was not included. Undoubtedly the measured range of Clipper Threshold could be extended if the horizontal distortion had been introduced.

Experience with the present equipment shows an optimum setting for Clipper Threshold at about 75% equivalent reflectance, for an ink reflectance of about 40-45 percent. Thus the clipping level is approximately half way between black and white signals.

These reflectance figures may be converted to electrical voltages with the assignment of a standard reference level for signals from white paper. It has been arbitrarily set at 30 volts peak-to-peak for signals during the scan over the clear mask. When scanning over a letter mask, these signals are slightly reduced, because of bandwidth limitations, to about 25 volts average peak-to-peak.

The optical signals are least (most positive) when the scan is over the opaque areas of these masks. These signals begin a +4 volts, going to -21 volts on white paper, and to -26 volts on the clear frame. Over the inked portions on the paper, the signals average perhaps 10 volts from the origin, or about -6 volts from ground. Thus the Clipper Threshold extremes can be from -6 to -21 volts. Under typical type conditions, correct recognition has been observed for the threshold set between -13 to -17 volts. Mid-range is therefore about -15 volts.

The relation between the Clipper Threshold bias and the voltage read at the arm of the potentiometer is plotted in Figure 9. The optimum point appears to be at about +95 volts, giving the clipper level mentioned above.

Conditions surrounding the threshold of error level are that it must provide for discrimination of unwanted characters without setting unreasonably high standards for the quality of the matching letter. With the particular type face (Elite) used in the Demonstrator, the optimum level appears to be about 0.75% of the maximum letter area (product and height and width of letter M). At this level recognition of all alphabetic and numeric characters has been demonstrated. Presumably there is a range of tolerance for this value, however the time available did not permit a detailed study of this item.

REFERENCES

1. Fournier D'Albe, "On a Type-Reading Optophone", Proc. of the Royal Society, 90, 1914.

2. V. K. Zworykin and L. E. Flory, "Reading Aid for the Blind" Electronics, August 1946.

3. Zworykin, Flory and Pike, "Letter Reading Machine", Electronics, June 1949.

4. D. H. Shepard, "Apparatus for Reading", U. S. Patent No. 2,663,758, December 22, 1953.

5. C. Hillyer, "Method of an Apparatus for Comparing Information" U. S. Patent No. 2,679,636, May 25, 1954.

TABLE I

Order of Alphabet on Vocabulary Belt

	A	K	M	N	V	W	X	Y	Z	B	8	S	H	R	
P	E	D	F	U	J	Q	O	G	C	L	T	I	1	2	3
		4	5	6	7	9	Opaque Frame				Clear Frame				

TABLE II

IMAGE DISSECTOR DATA

Type	D-40-SE Dissector
Mfgr.	Farnsworth Radio and Television

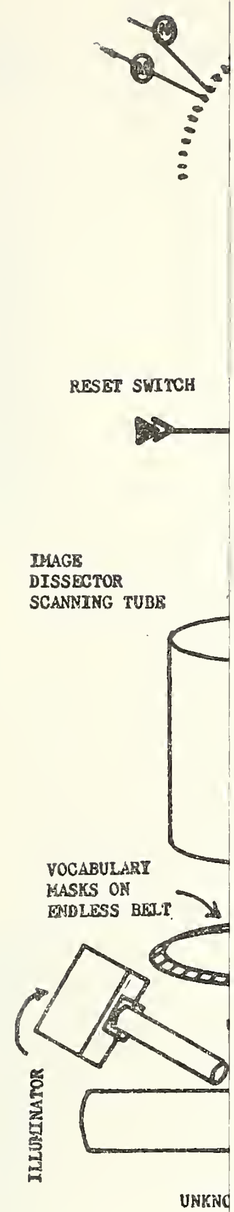
Yoke Data

Vertical deflection winding	1.3 mh., 8 ohms
Horizontal deflection winding	2.7 mh., 2 ohms
Focus winding	1.27 h, 240 ohms
Rotation	70 degrees approx.

Signal Data

Peak signal current	150 μA approx.

Circuit Diagram - Fig. 8d



RESET SWITCH
IMAGE
DISSECTOR
SCANNING TUBE
VOCABULARY
MASKS ON
ENDLESS BELT
ILLUMINATOR

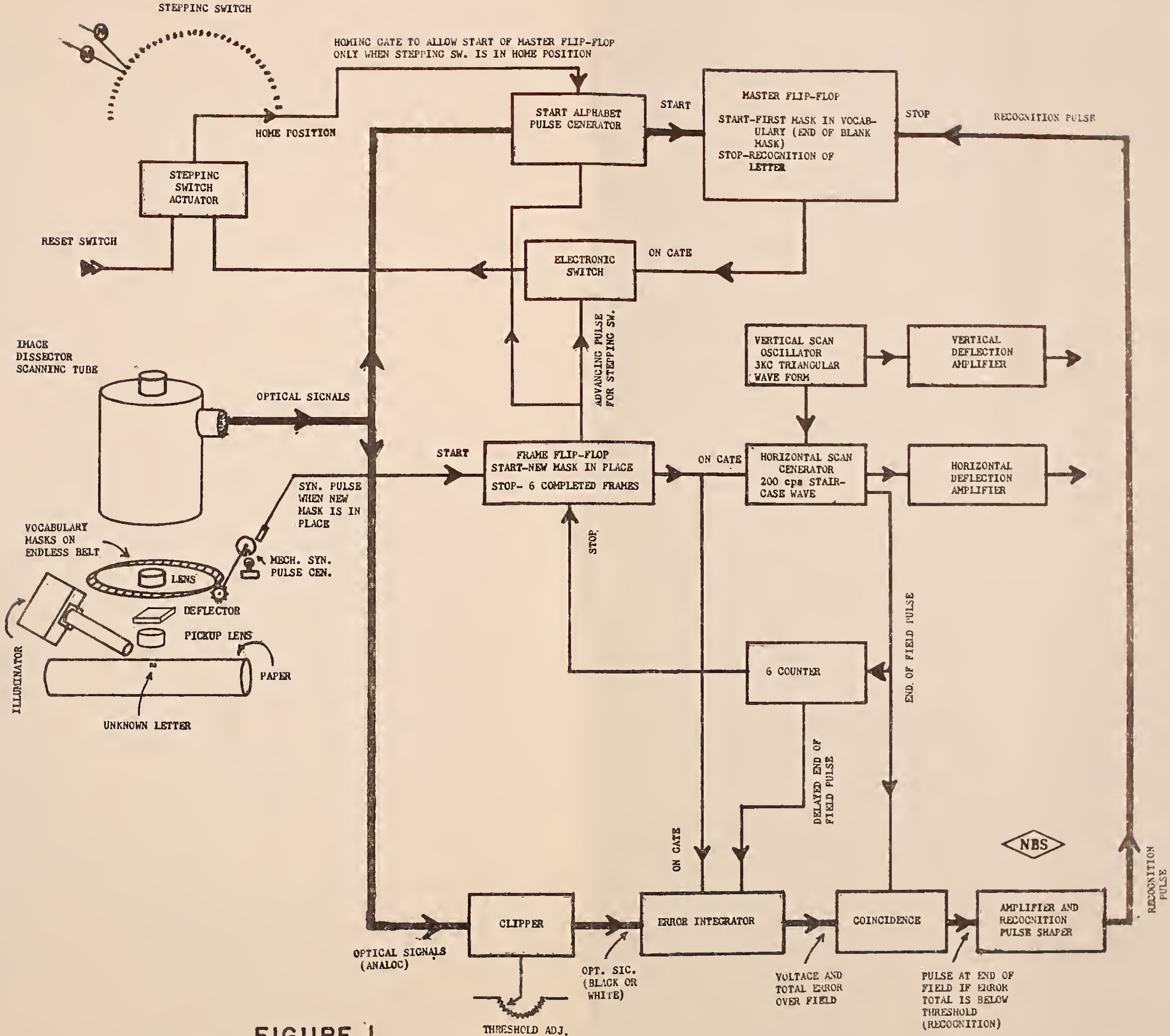


FIGURE 1

BLOCK DIAGRAM OF PRINT READER DEMONSTRATOR

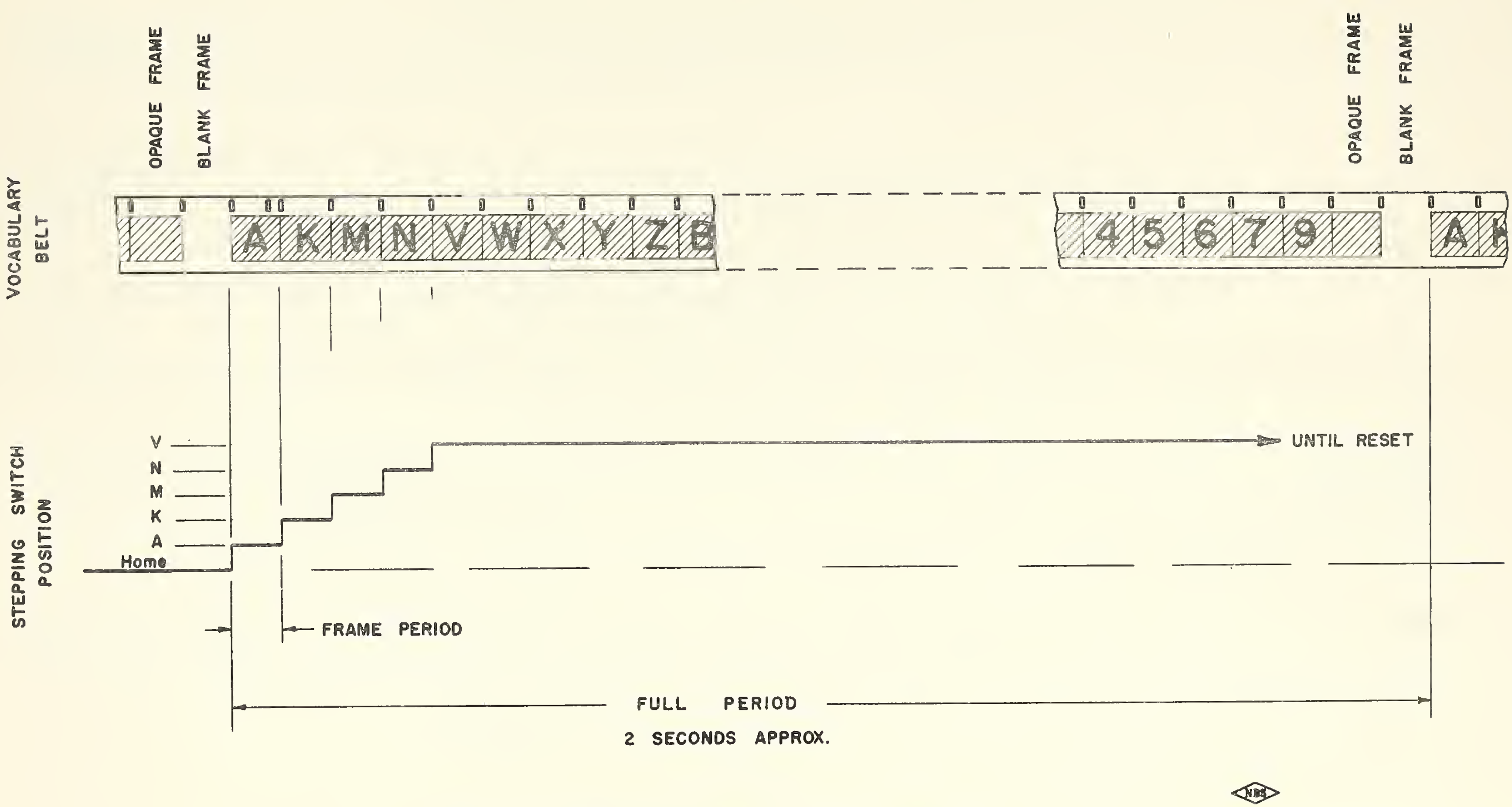


FIG. 2 RELATIVE TIMING, FULL PERIOD

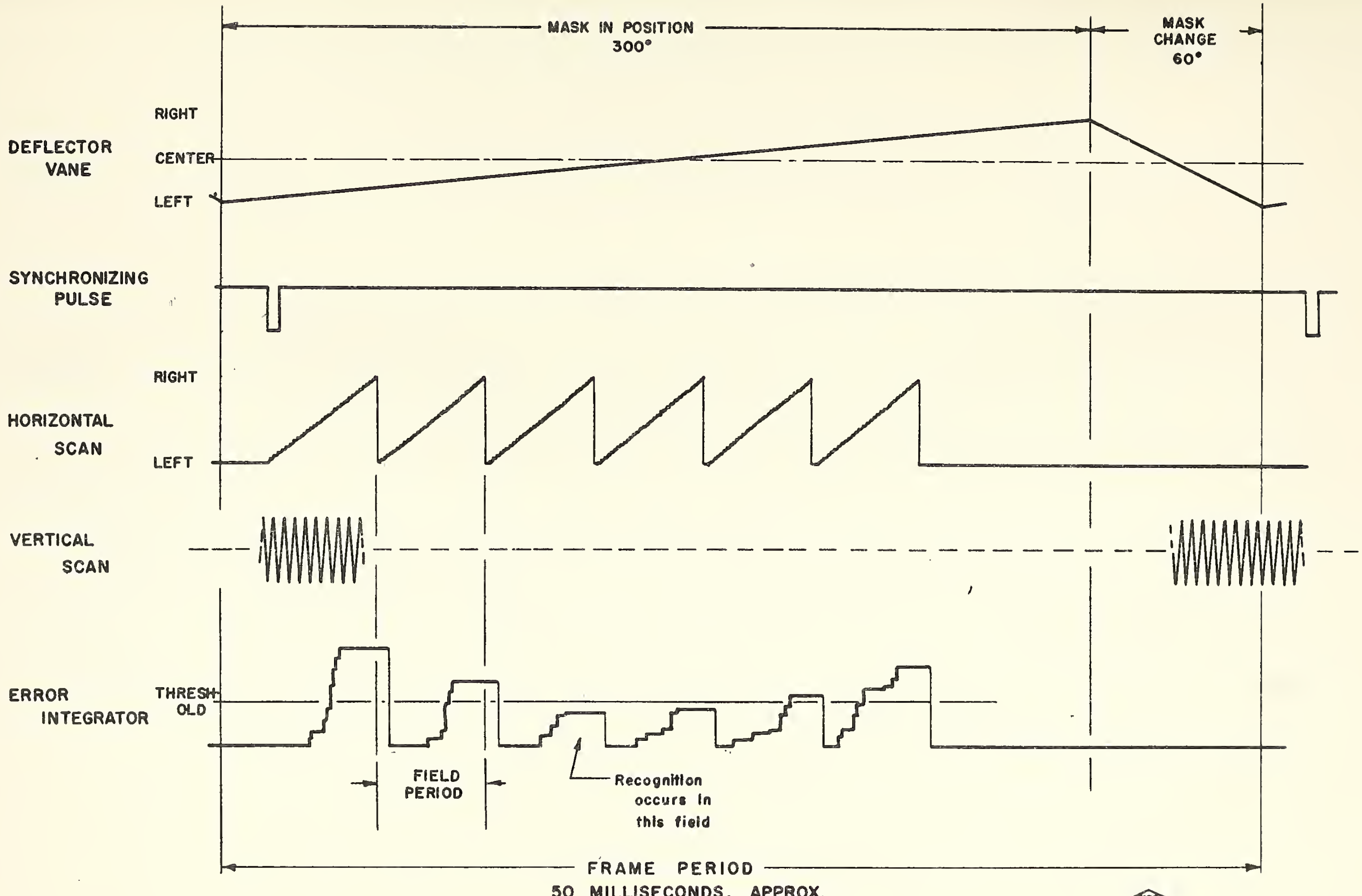


FIG. 3 RELATIVE TIMING, FRAME PERIOD

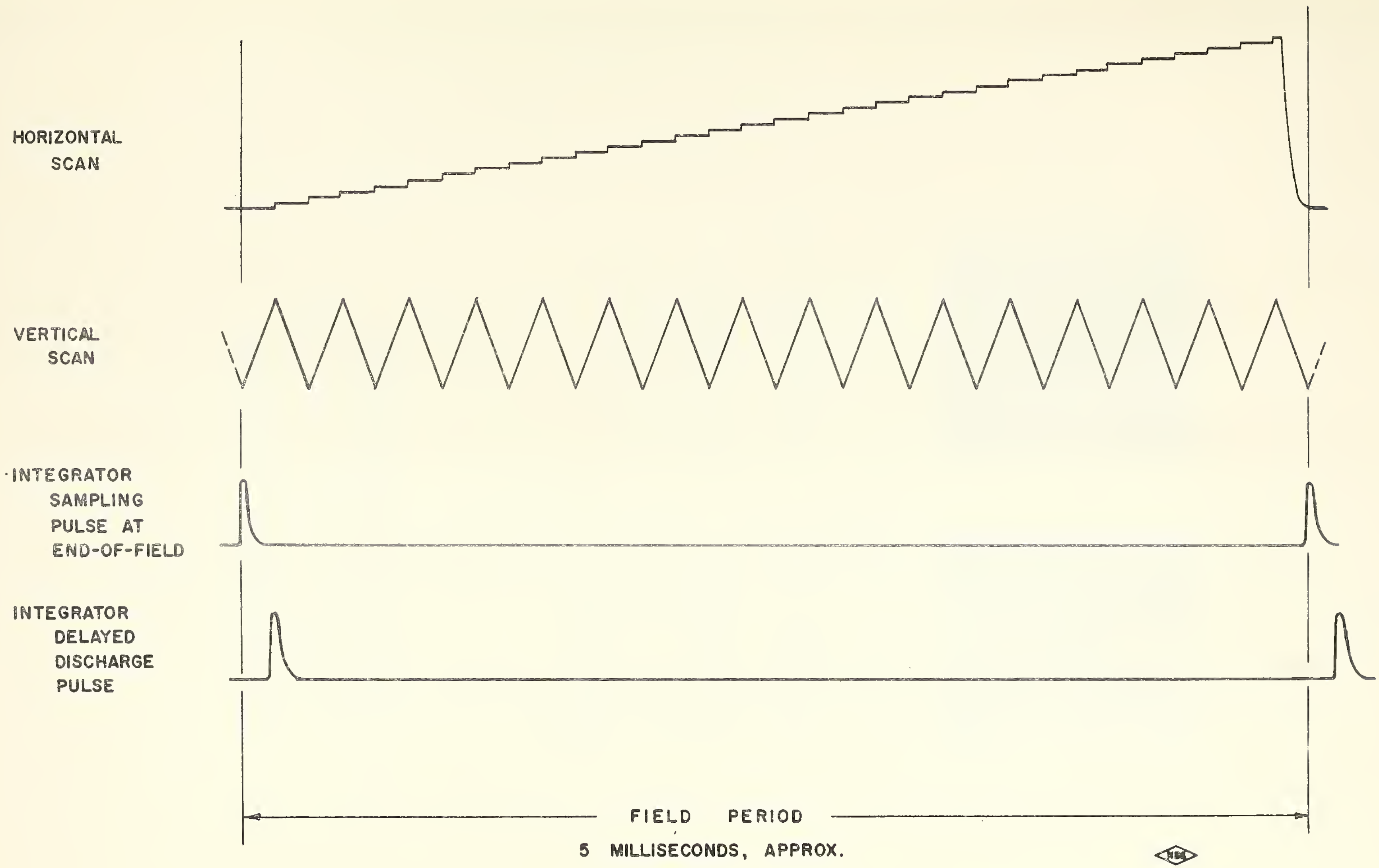


FIG. 4 RELATIVE TIMING, FIELD PERIOD

PHOTO
OF MAGNIFIED
TYPEWRITTEN
CHARACTER

PHOTO
OF MASTER
CHARACTER
AS DRAWN
FOR MASK

FIG. 5 MAGNIFIED TYPEWRITTEN LETTER AND ASSOCIATED MASTER CHARACTER

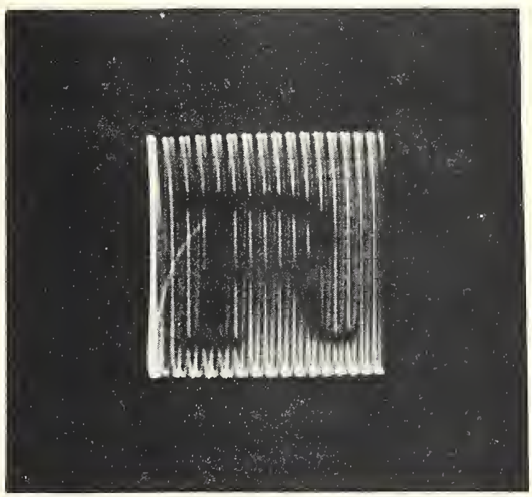


FIG. 6 EXAMPLE OF TELEVISION - TYPE PRESENTATION FOR CHECKING ORIENTATION OF IMAGE DISSECTOR

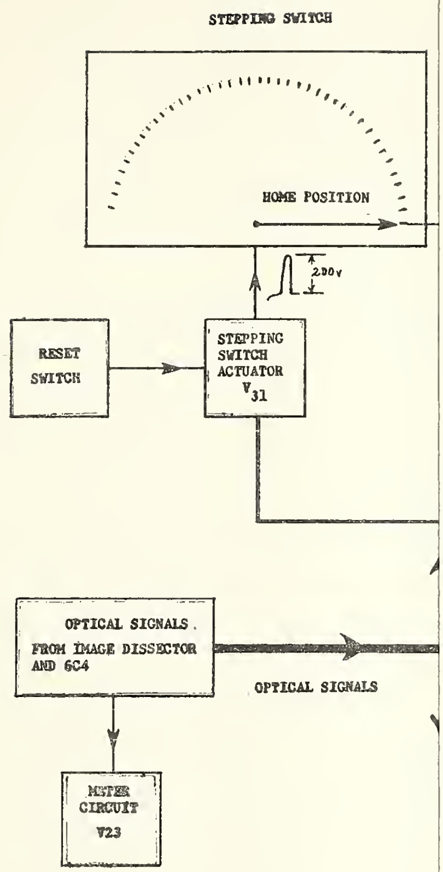
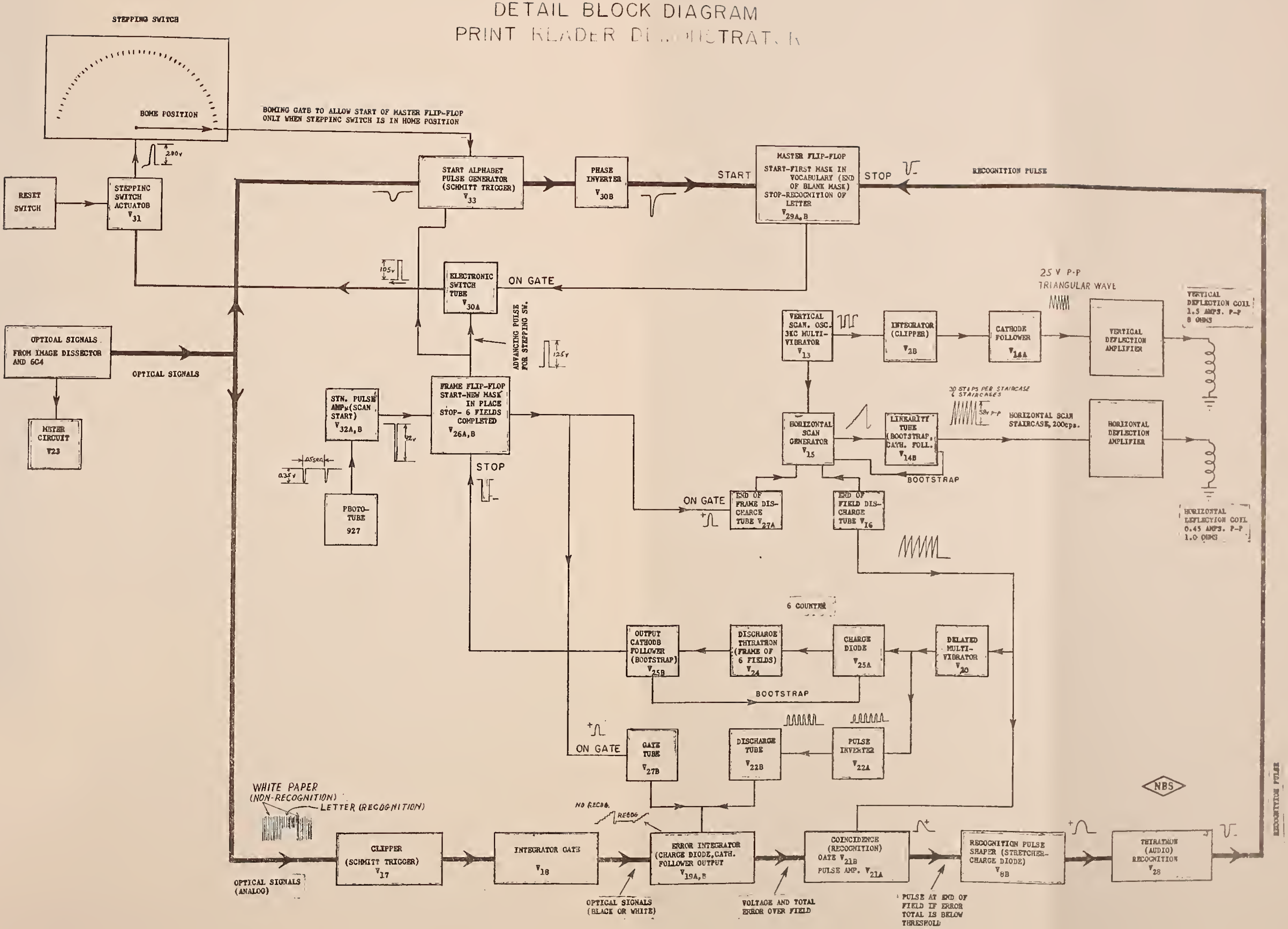

STEPPING SWITCH
HOME POSITION
200v
RESET SWITCH
STEPPING SWITCH ACTUATOR V31
OPTICAL SIGNALS FROM IMAGE DISSECTOR AND 6C4
OPTICAL SIGNALS
METER CIRCUIT V23

FIGURE 7
DETAIL BLOCK DIAGRAM
PRINT READER DEMONSTRATOR




FROM
FRAME F-F
OPTICAL
SIGNALS
220 K
.05
MF
FRAME GATE
FROM FRAME F-F

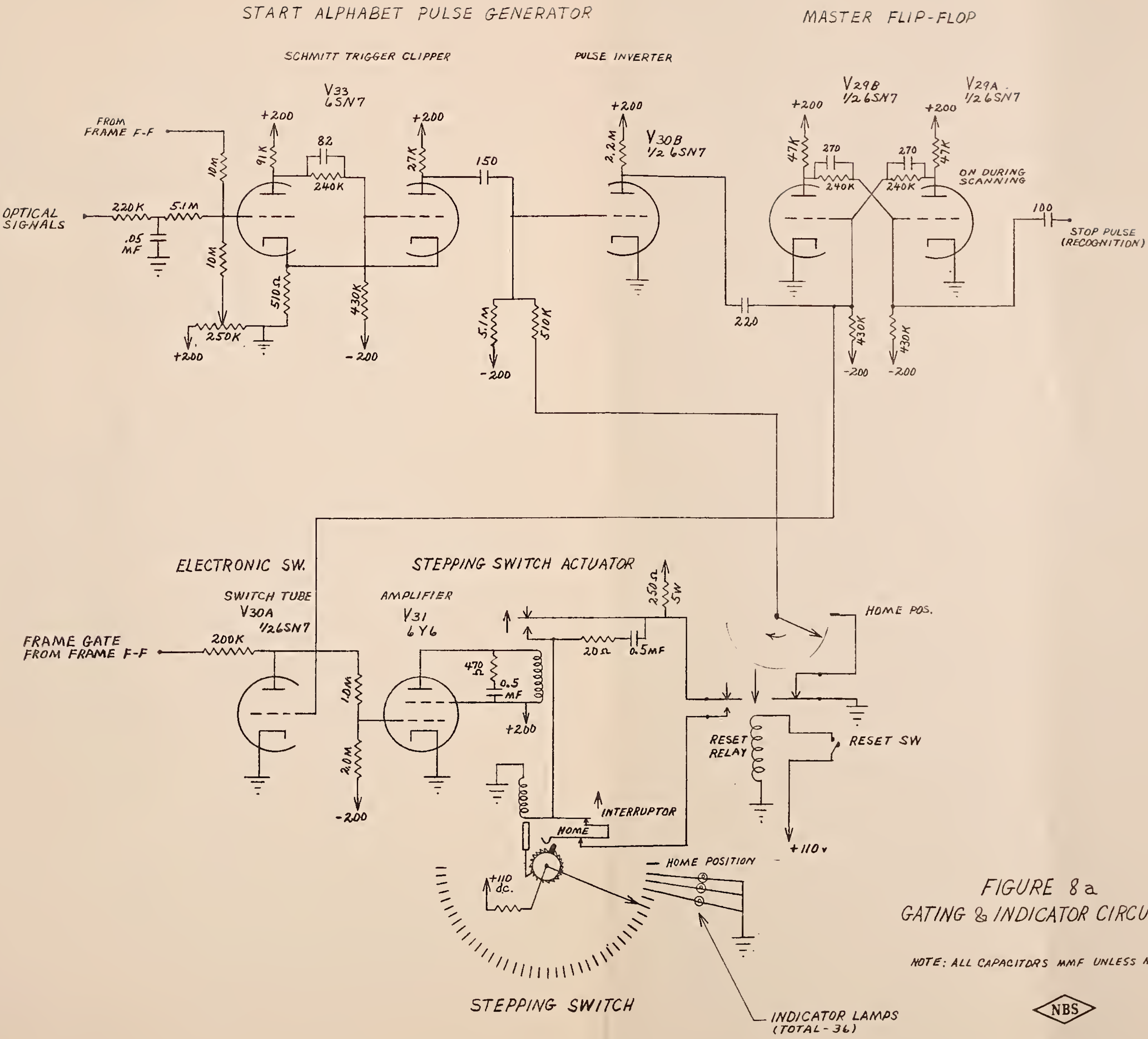
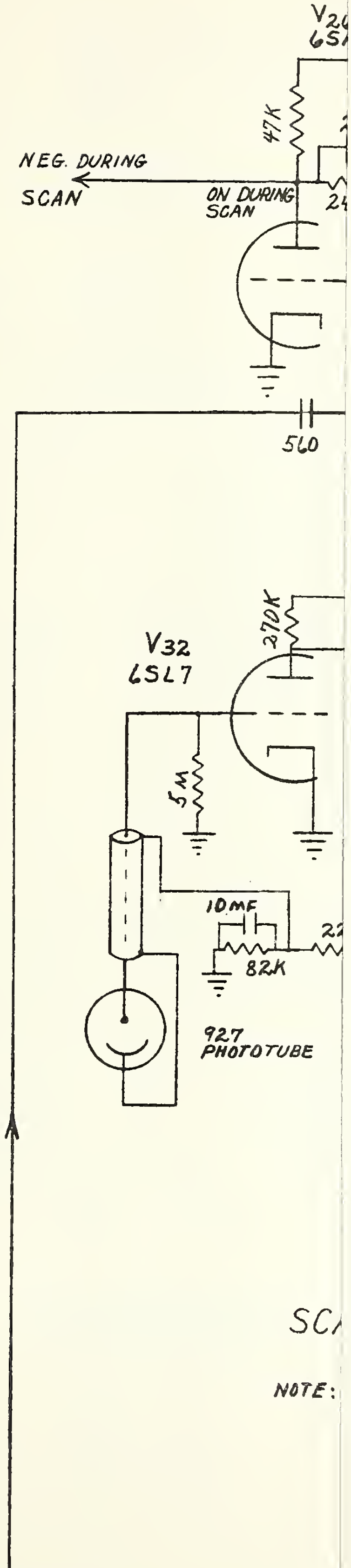


FIGURE 8a
GATING & INDICATOR CIRCUITS

NOTE: ALL CAPACITORS MMF UNLESS MARKED

FRAM


V2
6S
47K
NEG. DURING
SCAN
ON DURING
SCAN
24
560
270K
V32
6SL7
5M
10MF
82K
22
927
PHOTOTUBE
SC
NOTE:

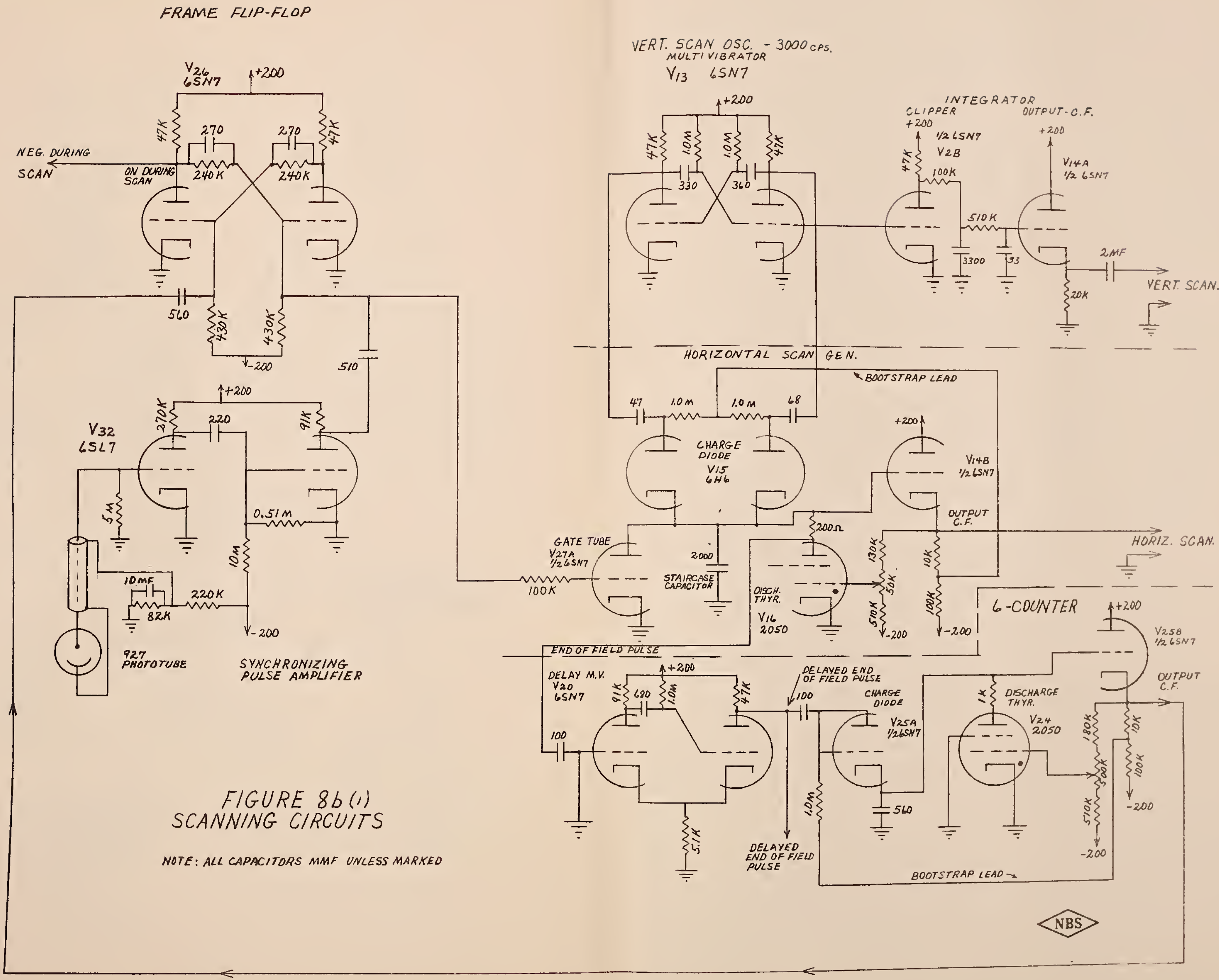


FIGURE 8b(1)
SCANNING CIRCUITS

NOTE: ALL CAPACITORS MMF UNLESS MARKED

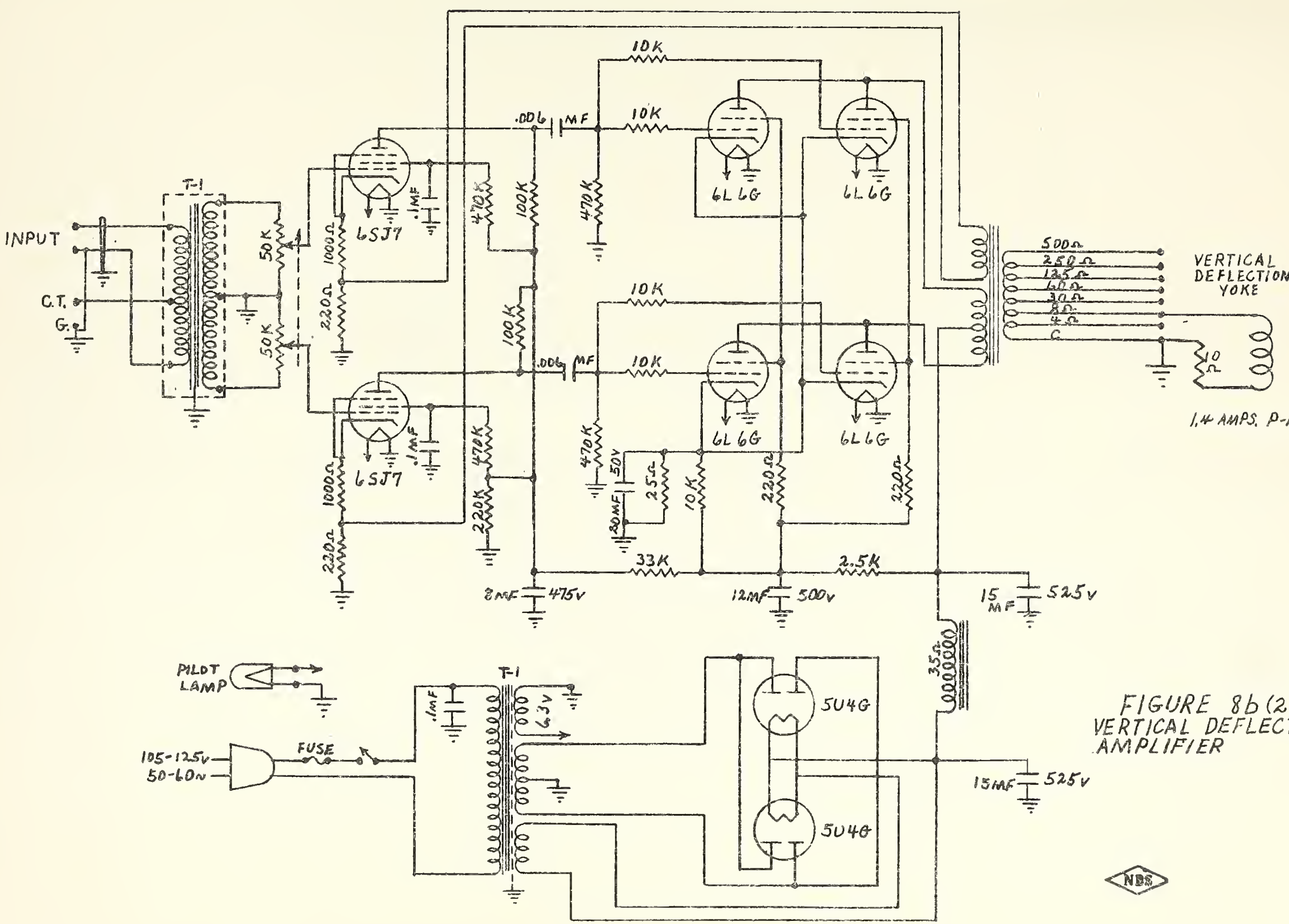
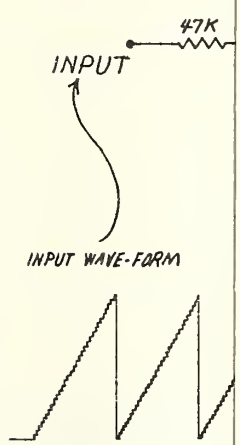


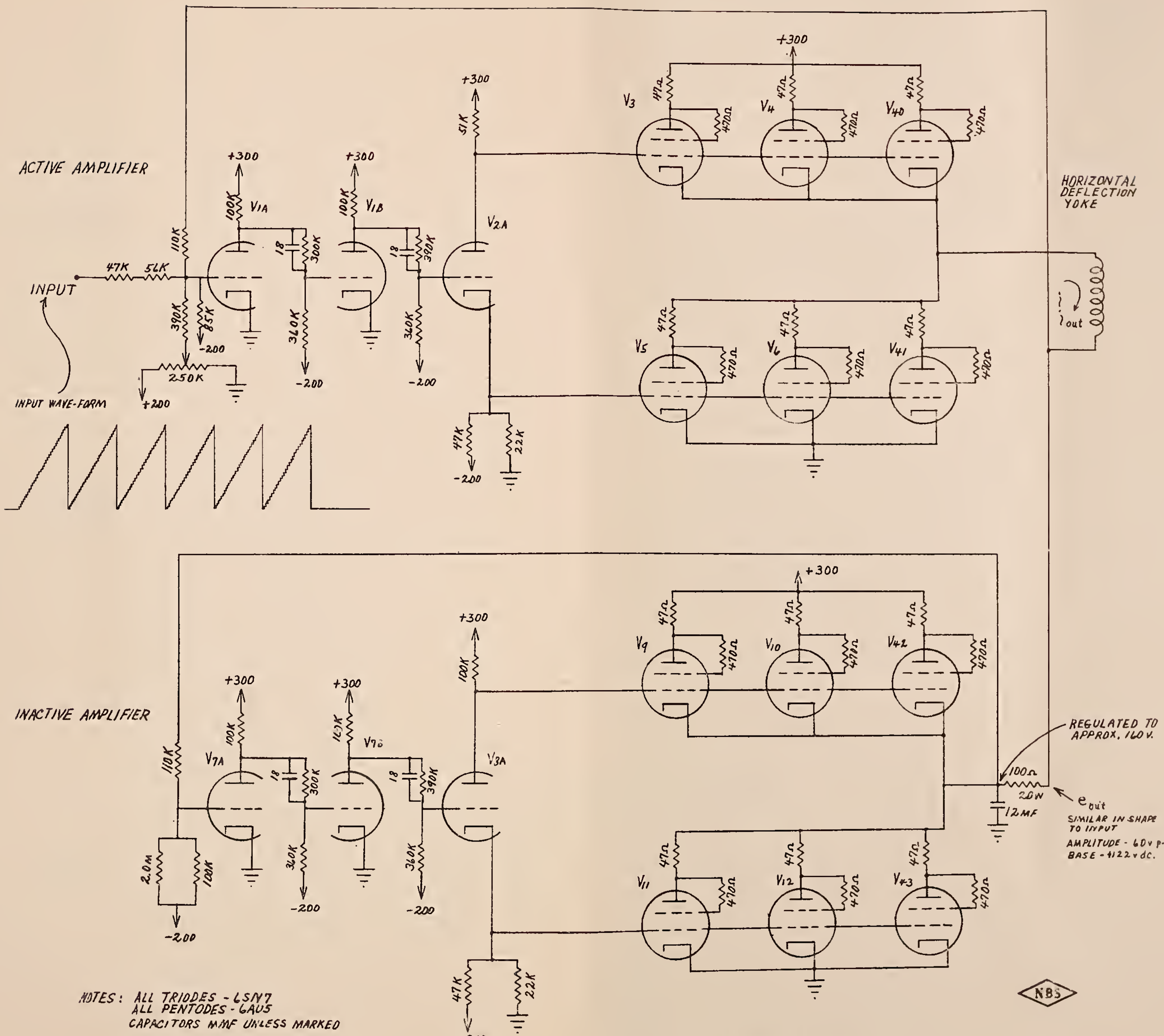
FIGURE 8b (2)
VERTICAL DEFLECTION AMPLIFIER

ACTIVE AMPLIFIE



INACTIVE AMPLIFI

NOTES:



NOTES: ALL TRIODES - 6SN7
ALL PENTODES - 6AU5
CAPACITORS MMF UNLESS MARKED

FIGURE 8b (3)
HORIZONTAL DEFLECTION CIRCUITS

INPUT
OPTICAL SIGNALS

TE

DELAYED END
OF FIELD PULSE

INTEGRATED
OUTPUT

NOTE:

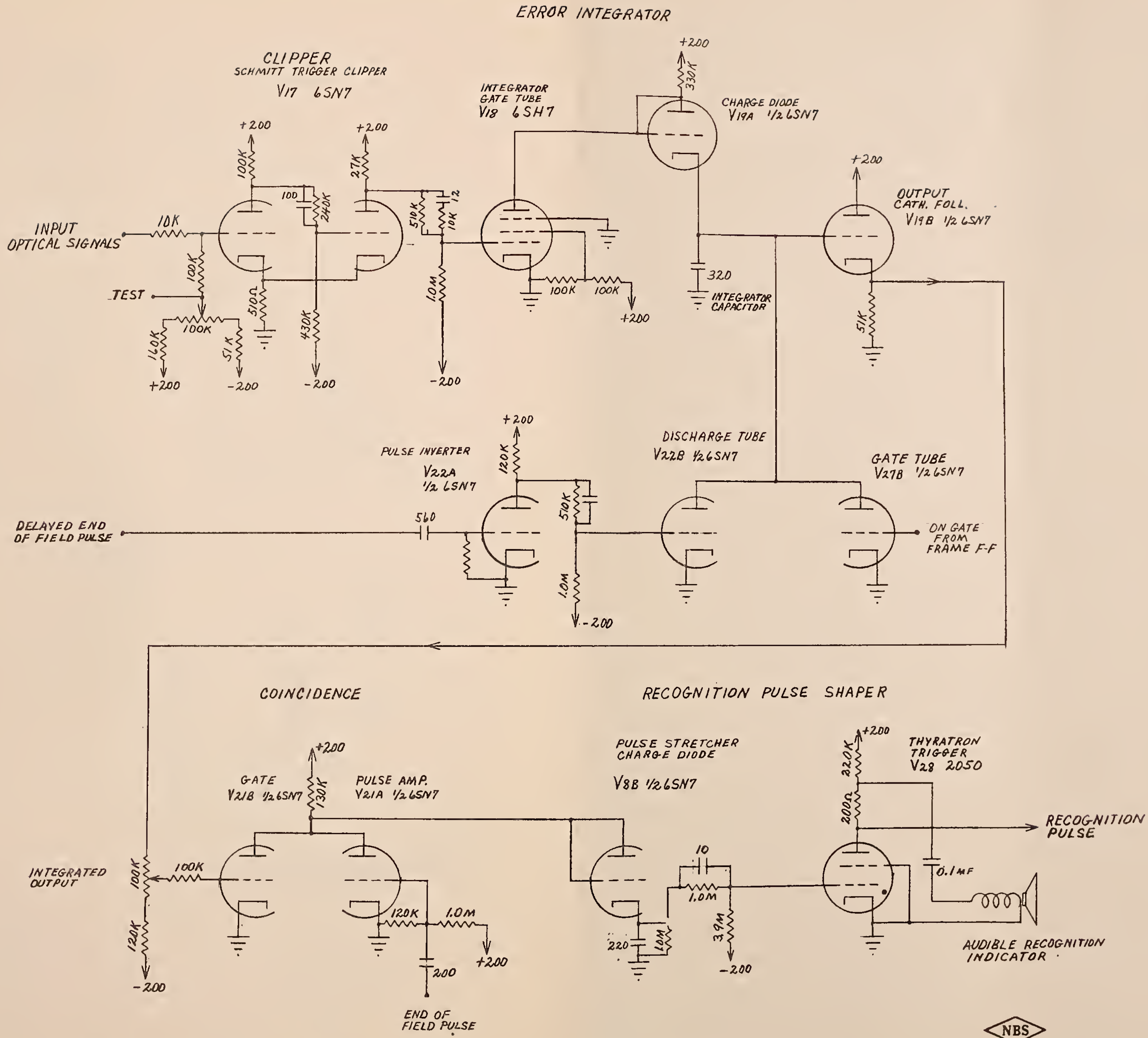


FIGURE 8c
RECOGNITION CIRCUITS

NOTE: ALL CAPACITORS MMF UNLESS MARKED

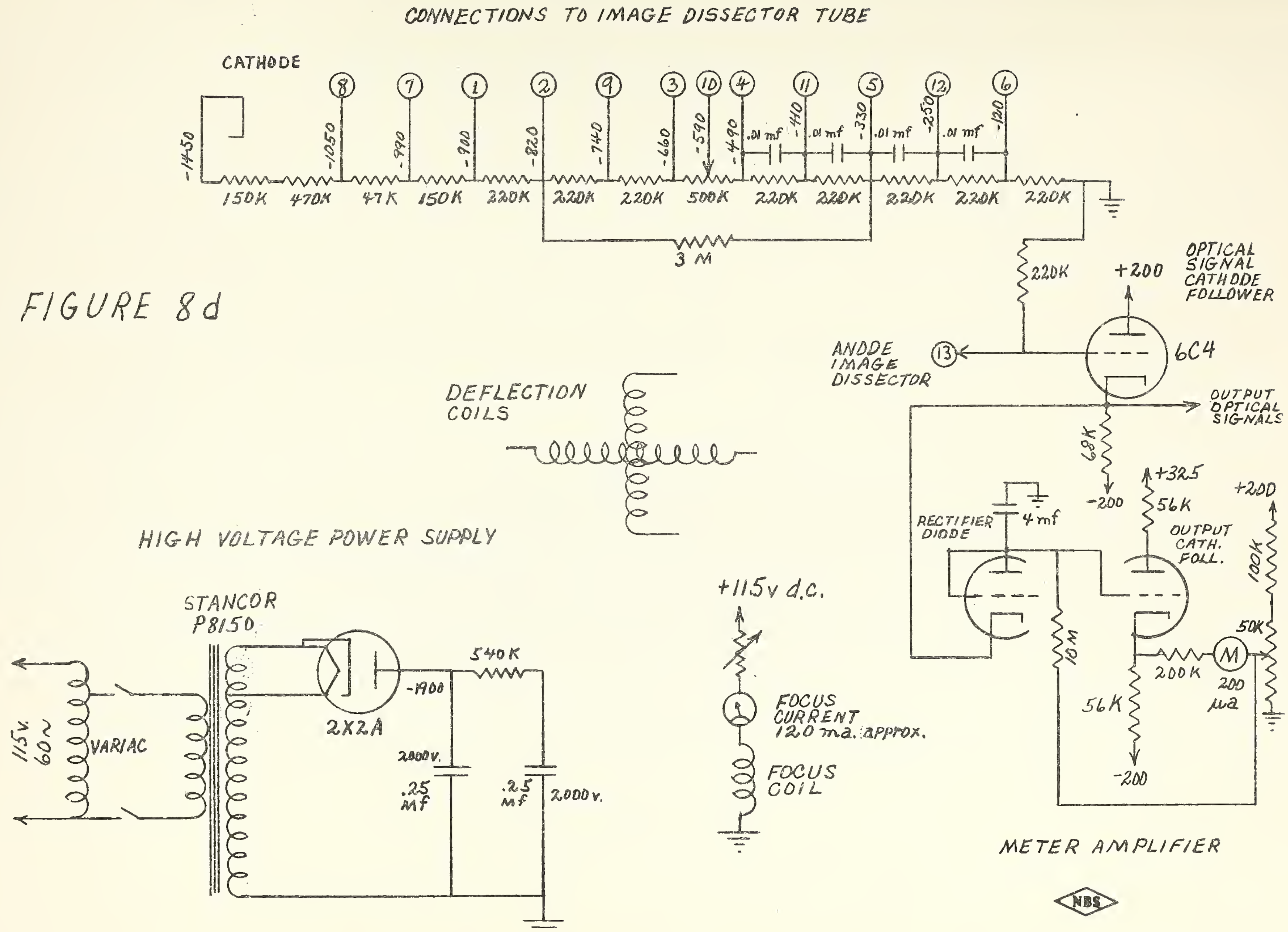

CONNECTIONS TO IMAGE DISSECTOR TUBE
CATHODE
-1450
-1050
-990
-900
-820
-740
-660
-590
-490
-410
-330
-250
-120
.01 mf
150K
470K
47K
150K
220K
500K
3 M
220K
+200
OPTICAL SIGNAL CATHODE FOLLOWER
6C4
ANODE IMAGE DISSECTOR
OUTPUT OPTICAL SIGNALS
68K
-200
+32.5
56K
+200
RECTIFIER DIODE
4 mf
OUTPUT CATH. FOLL.
100K
50K
10M
200K
M
200 μa
56K
-200
METER AMPLIFIER
DEFLECTION COILS
HIGH VOLTAGE POWER SUPPLY
STANCOR P8150
115v. 60~
VARIAC
2X2A
-1900
540K
2000V.
.25 Mf
2000V.
+115v d.c.
FOCUS CURRENT 120 ma. approx.
FOCUS COIL
NBS

FIGURE 8d

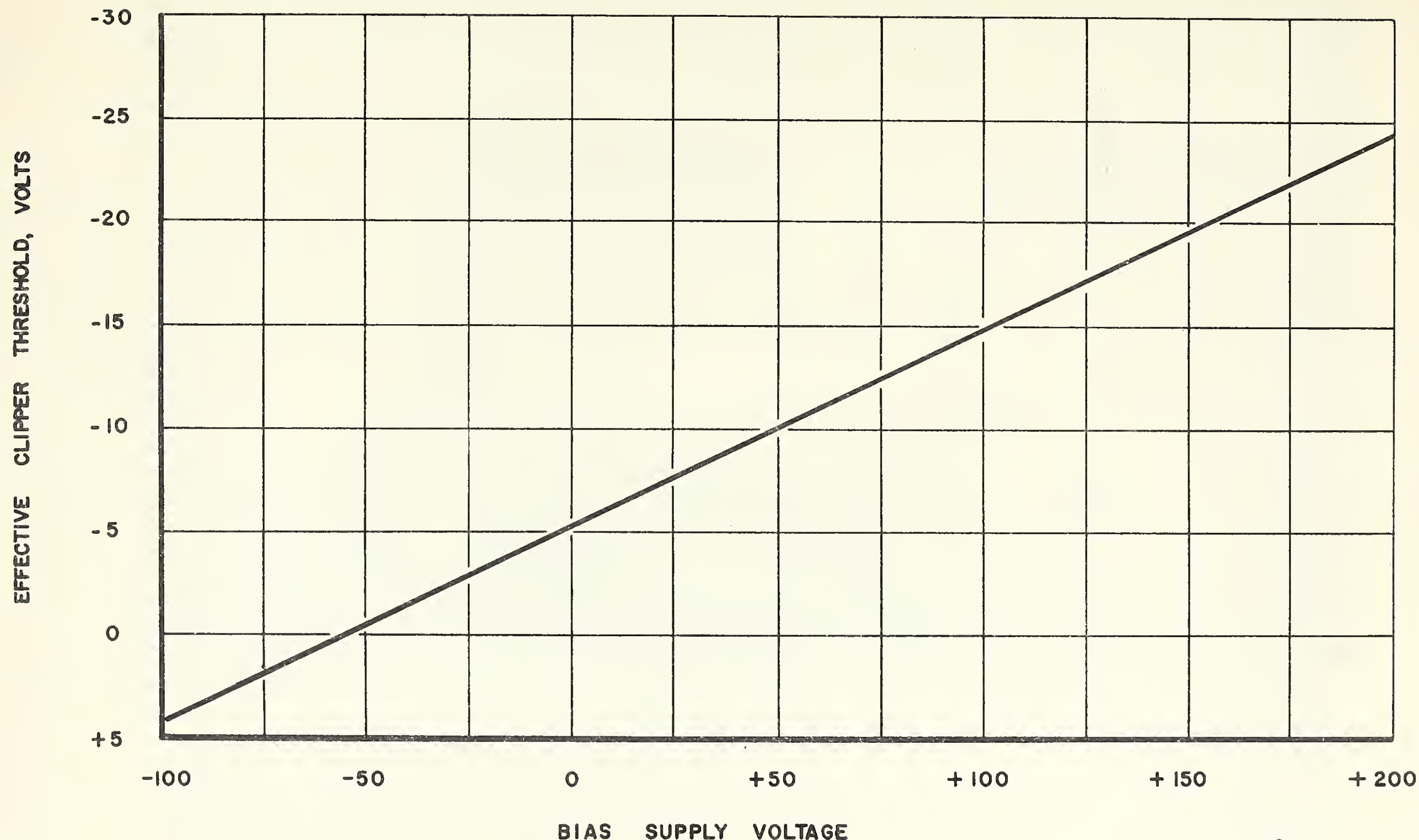


FIG. 9 CLIPPER THRESHOLD LEVEL VS. BIAS SUPPLY VOLTAGE

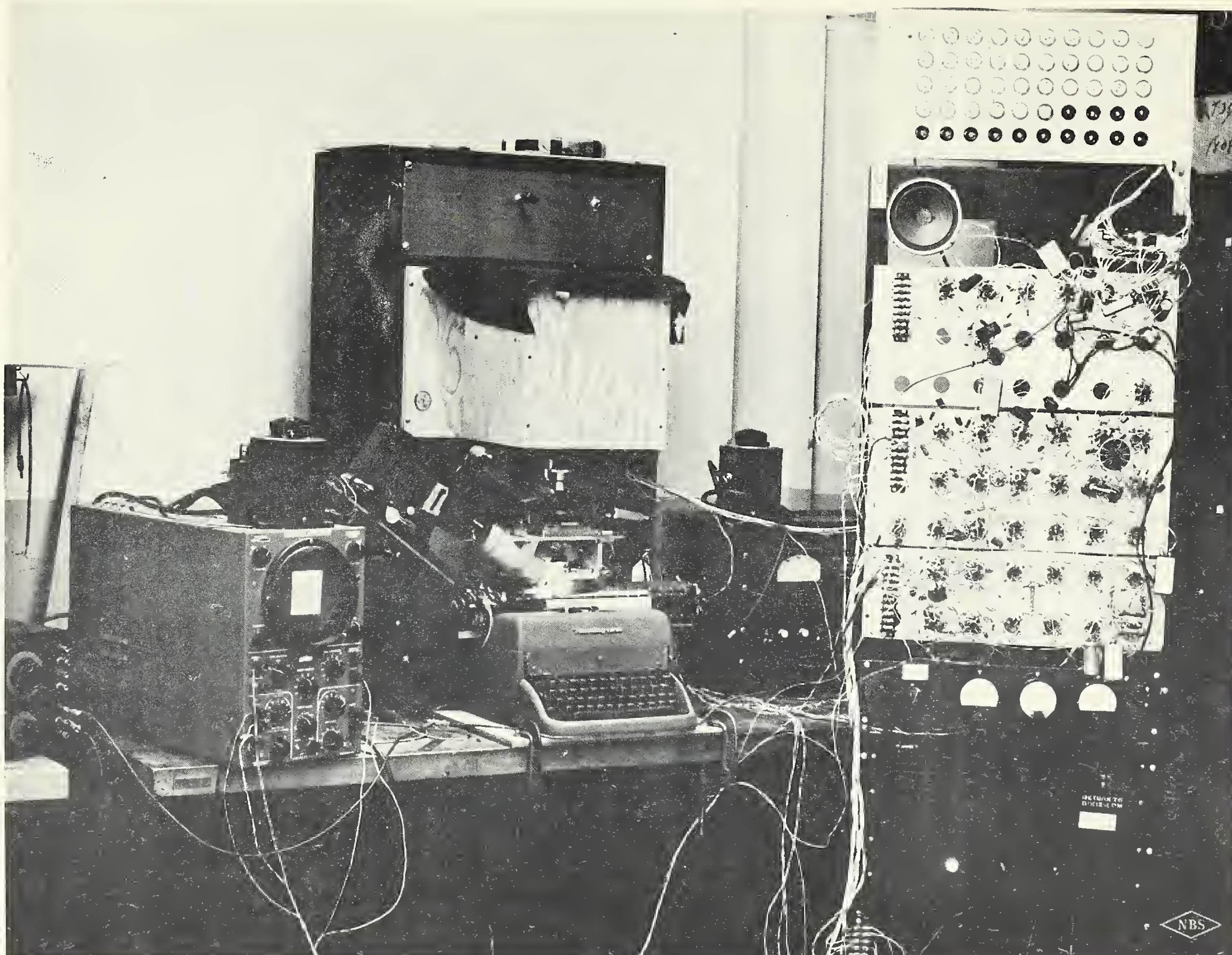


FIG. 10 PHOTOGRAPH OF PRINT READER DEMONSTRATOR

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