SECTION 3
CIRCUIT DESCRIPTION

BLOCK DIAGRAM

General

The Block Diagram shows interconnections of the functional parts of the instrument, except for the power supplies. Functions of the switches are shown instead of their actual connections.

Step Generator

The Step Generator receives the line frequency waveform, shifts the phase and shapes it to provide a current pulse of a fixed amplitude. The current pulses which are either 120 or 240 pulses per second, depending upon the setting of the STEPS/SEC Control, are fed to a Miller integrator.

The Miller integrator converts the current steps to a series of voltage steps, a staircase waveform.

Step Amplifier

The positive-going waveform from the Step Generator is amplified and inverted by the step amplifier for application to the device under test. Any current drawn from this amplifier by the device under test is measured by the Vertical Amplifier in the GRID position of the PLATE-SCREEN-GRID Control.

+DC Circuit (Floating Power Supply)

The +DC Circuit provides a variable regulated voltage for application to the device under test. Current drawn from this Circuit is measured by the Vertical Amplifier in the SCREEN position of the PLATE-SCREEN-GRID Control.

Plate-Sweep Generator

The Plate-Sweep Generator rectifies the transformer waveform to provide positive-going sweeps of plate voltage. Current drawn from this circuit is measured by the Vertical Amplifier in the PLATE position of the PLATE-SCREEN-GRID Control. The SERIES LOAD Control selects the series resistance for the Plate-Sweep Generator.

Horizontal Amplifier

The PLATE-GRID Control connects the grid or plate of the device under test to the Horizontal Amplifier. The Horizontal Amplifier amplifies the signal and converts it for push-pull application to the deflection plates.

Vertical Amplifier

The Vertical Amplifier amplifies the signal selected by the PLATE-SCREEN-GRID Control and applies it to the vertical deflection plates. For a more complete diagram of the PLATE-SCREEN-GRID Control see the CRT Display Switching diagram.

STEP GENERATOR DIAGRAM

Split-load Phase Inverters

The main power transformer, T401, supplies 35 volts at line frequency to the phase-shifting networks, R6, C6 and R35, C35. PHASE ADJ A has a small range of adjustment to permit this circuit to be adjusted to coincide with the phase of the Plate-Sweep Generator waveform. PHASE ADJ B has additional range to permit its output to be set at 90 degrees with respect to the A circuit. V8A and V38A are Split-Load Phase Inverters with equal resistance in the plate and cathode circuits. The waveform at the plate is 180 degrees out of phase at the cathode. The dc component of the waveform is blocked by coupling capacitors, C8, C10, C38 and C40; and the waveform is rectified by full-wave rectifiers.

Shaper Amplifiers

The output from each pair of rectifiers is applied to a pentode amplifier. The rectifier output is a negative-going rectified sine wave of sufficient amplitude to hold the pentodes cut off except for short pulses as the grids approach ground potential. Since the pen-

todes have a common plate-load resistor, the pulses from both pentodes appear at the grid of the shaper cathode follower.

The STEP/SEC switch biases one of the Shaper Amplifiers below cutoff in each of the 120 positions. This eliminates the corresponding pulses and reduces the stepping rate from 240 to 120 steps per second.

The cathode of the Shaper Cathode Follower, V55A, is held positive by divider R55 and R56. The grid of the cathode follower rests at a point selected by the VOLTS/STEP ADJ Control, R25, and a divider consisting of R26 and R27, when the Shaper Amplifiers are cut off. When the Shaper Amplifiers conduct, the grid of the cathode follower is driven below plate-current cut off. The amplitude of the pulse from the cathode follower can therefore be closely controlled by the VOLTS/STEP ADJ Control.

Clamp and Coupling Diodes

The clamp and coupling diodes, V95A and B, differentiate the pulse from the shaper cathode follower. During the positive portion of the pulse waveform the capacitor, C95, is charged through V95B. When the negative-going pulse occurs, this charge is released through V95A and adds to the charge in C85.

Step Generator

Because of their interdependence, the multivibrator, disconnect diodes, step generator and associated circuitry will be considered at one time. To provide a starting place, single-family operation will be considered first.

For the single-family type of presentation the STEPS/FAMILY Control, R91, is turned clockwise so that the arm is at the most negative end of its range. In this condition, the voltage on the cathode of the Step-Control Cathode Follower, V55B, is sufficiently negative to hold one half of the Multivibrator, V65A, cut off. The Multivibrator consists of V65A and V65B in a dc-coupled circuit. In the quiescent state the grid of V65A is held at about -100 volts and the grid of V65B is at about -65 volts. V65B is conducting and its plate rests at -10 volts.

When the SINGLE FAMILY button is pushed, C88 is discharged into C90 and the grid of V65A is raised so that V65A begins to conduct. The Multivibrator switches so that V65A is conducting and V65B is cut off. The grid of V65A begins to go negative immediately as C90 loses the charge it received and the Multivibrator returns to its quiescent condition. The result is a short positive pulse at the plate of V65B.

In the quiescent condition, the Step Generator tube, V86, is cut off. Its grid is held negative as a result of current flow through V95, V76B and cathode follower V75B. The grid of V75B is held at -10 volts by the Multivibrator, resulting in -8 volts on the grid of V86. The grid and cathode of V75A rest at about 200 volts as a result of the divider action of R81, B80, and R82. C85 is charged to about 210 volts.

The positive pulse from the Multivibrator passes through the cathode follower, V75B, and diode V76B to raise the grid of V86 to ground potential. V86 conducts and its plate voltage drops cutting off cathode follower, V75A. C85 discharges through R85, R91 and R92 until clamped by V76A. When the Multivibrator reverts, both diodes are cut off and the resistors R85, R91 and R92 tend to pull the capacitor and the grid of V86 negative. At this point the plate of V86 resumes control and any tendency of the grid to go negative is compensated for by a rise in plate voltage. The Step Generator is now ready for its first step. The time required for the preceding operation after the SINGLE FAMILY button is pushed is less than the duration of one step.

The step is formed as follows: C95 has charged through V95B. When the negative pulse is applied to C95 it tends to pull the grid of V86 down with it. The rapid rise in the plate voltage of V86 is coupled back through V75A to C85. This reduces the voltage change on the grid to a very small step. The result is a step in the voltage across C85 as the charge from C95 is transferred to C85. Between pulses no current reaches the grid circuit and the output voltage does not change.

The steps are repeated for 12 or 13 steps at which time the plate of V86 loses control, the grid of V86 goes negative to plate-current cut-off and the quiescent condition is reached.

If the recurrent mode of operation is used, the arm of the STEPS/FAMILY Control is set to a more positive position. The stepping waveform is developed across a divider consisting of R85,

R91 and R92. As the waveform goes positive, a point will be reached where the voltage from the Step-Control Cathode Follower, V55B, is sufficient to switch the Multivibrator. When this happens C85 is discharged and the Step Generator starts over again. R85 labeled MIN NO CURVES is normally adjusted so the Step Generator will have four steps when the STEPS/FAMILY Control is counterclockwise.

STEP AMPLIFIER DIAGRAM

Input Cathode Follower

The incoming step waveform passes through a level-setting voltage divider, R112, R115 and R120, and into cathode follower V115B. V115A serves as a voltage regulator to regulate the voltage from the unregulated +400 volt supplies used for this stage.

Input Amplifiers

V110 and V135 are common-cathode, phase-splitter amplifiers. The VOLTS/STEP ZERO ADJ Control, R105, sets the grid level of V110 to balance the amplifier so the zero bias trace does not shift as the VOLTS/STEP Control is rotated. C125 and C126 reduce the bandwidth of this stage to maintain stability with the large amount of feedback used.

Output Amplifiers

The Output Amplifiers, V150A and V150B, amplify the waveform and reconvert it to single-ended output. The network including the neon diode B170 reduces the dc level of the signal at the grid of V180 without attenuation of the signal.

Output Cathode Follower

The Output Cathode Follower, V180, provides the necessary low impedance to drive the grid of the device being tested. The ZERO BIAS switch, SW180, grounds the GRID A or GRID B connector on the test panel to provide a zero-bias reference curve. The TEST POSITION switch connects the output of the Step Amplifier to either the GRID A or GRID B connector on the test panel.

VOLTS/STEP Control

The VOLTS/STEP Control varies the amount of feedback and thus, the gain of the Step Amplifier is seven fixed steps. This determines the grid-voltage change between the curves in the display.

Grid-Current Measurement

In order to measure grid current in the device being tested, the grid current must flow through the current measuring circuits. Any current used to operate the Step Amplifier must be kept separate. To do this the Output Cathode Follower is supplied with plate and cathode voltage from an ungrounded or Floating Power Supply. The only path though which current will flow from ground into this power supply is from grid to cathode in the device being tested and through the current-measuring resistors.

Since the Input Cathode Follower is connected to the Output Cathode Follower by the feedback resistors, it is also connected to the Floating Power Supply.

HORIZONTAL AMPLIFIER

VOLTS/DIV. Switch

The Input Cathode Follower, V215, presents a high impedance to the circuits being measured and a low impedance to the part of the VOLTS/DIV switch in its cathode circuit. Part of the attenuation of the VOLTS/DIV switch is placed in the grid circuit so that the input voltage will not exceed the capabilities of the Input Cathode Follower. This attenuator in the grid circuit is switched so that the current it draws will not be measured by the current measuring circuits in any position of the PLATE-SCREEN-GRID switch.

The VOLTS/DIV BAL Control R214, adjusts the dc level on the grid of cathode follower V210. This control is set so there is no shift of the zero-voltage line as the VOLTS/DIV Control is rotated. The VOLTS/DIV CAL Control compensates for the loading effect of the attenuator on the cathode follower.

Amplifiers

The first amplifiers, V240 and V241, are common-cathode, phase-splitter amplifiers The bandwidth of this stage is limited by C242 for stability with feedback. The second stage, V245A and V245B, provides additional gain to drive the crt deflection plates. The HORIZ

GAIN ADJ Control adjusts the overall gain by varying the amount of feedback. The HORIZONTAL POSITIONING Control positions the trace by varying the voltage on the grid at V241. Wafer 3R of the PLATE-GRID selector, SW205, positions the beam to the right in the GRID position.

CRT-DISPLAY SWITCHING DIAGRAM

The CRT-Display Switching diagram shows the PLATE-SCREEN-GRID Control in detail with the associated circuitry shown in block form. The PLATE-GRID Control and the VOLTS/DIV attenuator resistor are shown in the horizontal-amplifier block to show the path of the load current drawn by this resistor.

The Floating, unregulated, Power Supply shown at the left of the diagram is an auxiliary power supply. Its only return to ground is through SW510-5R which connects it to the current measuring resistors in the GRID and SCREEN positions of this switch.

In the GRID position of the PLATE-SCREEN-GRID selector, the Floating Power Supply is connected to circuits in the Step Amplifier which supply current to the grid of the device under test. In the SCREEN position of the PLATE-SCREEN-GRID selector, the Floating Power Supply is connected to the +DC-circuit series regulator and the current which flows through the current measuring resistors is screen current. In the PLATE position of the PLATE-SCREEN-GRID selector, the Floating Power Supply remains connected to the series regulator, but it is now disconnected from the current measuring resistors and grounded by SW510.

The Plate-Sweep Generator is also an ungrounded supply. It is connected to the current measuring resistors in the PLATE position of the PLATE-SCREEN-GRID selector by SW510-5R. In the other two positions of this switch the Plate-Sweep Generator is grounded.

The Horizontal Amplifier is connected to the plate or the grid of the device under test by the PLATE-GRID selector. If the VOLTS/DIV attenuator resistors were grounded, current drawn by this resistor would pass through the current measuring resistors of the Vertical Amplifier. To avoid this, a section of the PLATE-GRID selector connects the ground return back to appropriate places on the PLATE-SCREEN-GRID selector.

VERTICAL AMPLIFIER DIAGRAM

MA/DIV Switch

The MA/DIV switch selects the resistance to ground in the current measuring circuit and thus selects the sensitivity of the measurement. The grid of the Input Amplifier, V281, is connected to R255 instead of the arm of the switch to prevent any error that might be caused by contact resistance. R254 maintains a current path at all times as the switch is rotated between positions. Fuse F255 added at serial number 5001-up protects the high value resistors in the attenuator but is shorted out in the high-current positions of the switch.

Amplifiers

The Input Amplifiers, V281 and V280, are common cathode, phase-splitter amplifiers. R270 positions the crt display vertically by varying the voltage on the grid of V280. C280 limits the bandwidth of the input stage to maintain stability with the feedback used. The VERT GAIN ADJ Control varies the gain by changing the amount of negative feedback. The Output Amplifiers provide the additional gain necessary to drive the crt deflection plates.

Plate-Sweep and Meter Circuit Diagram

Transformer

The plate-sweep transformer, T310, is supplied from taps on the primary of the main power transformer, T401. Both primary and secondary windings are shielded to provide maximum control over capacitive currents. The PLATE TRANS CURRENT BALANCE Control, C315, balances the stray capacitances to ground which are associated with this winding. These currents would otherwise flow in the current measuring circuits.

SERIES LOAD Control

Full-wave rectification of the incoming sinusoidal waveform occurs in V315 and V316. The resulting waveform is applied to the plate of the tube under test by way of the SERIES LOAD switch. In the 300 ohm position of this

switch, the transformer and rectifiers provide the resistance. Since the rectifiers are nonlinear, this resistance varies from more than 30 ohms at low current to less than 200 ohms at maximum current.

Capacitive Current Balance

The Current-Balance Cathode Follower compensates for capacitive current to ground in the SERIES LOAD switch and associated wiring. The plate sweep waveform is applied to the grid of the cathode follower by divider R316 and R317. Current is then added to the negative return lead by C310 and C311 which is opposite in phase to that drawn by the stray capacitance. C311 can be adjusted so no capacitive current flows in the current measuring resistors.

Meter Circuit

The Meter Circuit consists of a 200 μa meter from serial number 101 to 5120 and a 1 ma meter from serial number 5121 and up. The Meter Circuit also has associated multiplying resistors along with the meter. The INDICATION switch selects either the +DC, -DC or HEATER supplies for application to the meter. The heater voltage is taken from fixed taps on the heater transformer and rectified in D350 and D351. The meter indicates heater voltage as a percentage of the voltage selected by the HEATER switch.

"MAIN" POWER SUPPLY DIAGRAM

Transformer

The "main" power transformer, T401, supplies plate and heater power to all circuitry in the instrument except the floating supply tubes and circuitry. The two primary windings can be connected in series for 234-volt operation or in parallel for 117-volt operation. One primary winding is tapped to supply the voltage required by the plate-sweep transformer.

Negative Supplies

Terminals 7 and 9 connect to V405 in a full-wave circuit to supply voltage to the negative 150 volt supply. A gas-diode Voltage-Reference Tube, V407, establishes the reference voltage for the -150 volt supply. This reference voltage is applied to the cathode of a Comparator Tube, V410, and is compared with the voltage on a divider connected between the -150-volt bus and ground. R413, labeled -150 ADJ, determines the percentage of voltage that appears at the grid of V410 and thereby determines the total voltage across the divider.

Any variation from the normal grid to cathode voltage on V410 appears as an amplified error signal at the plate. This error signal is applied to the grid of the Series Regulator Tube, V412. This dc-coupled error signal controls the plate resistance of the series regulator tube, changing it in the proper direction to compensate for any change in output voltage. C412 increases the ac gain of the feedback loop to reduce the ripple.

V403 is connected in a full wave circuit with its output added to the -150-volt supply to provide a -300-volt unregulated supply. This supply is used to supply other circuits which are insensitive to voltage variations.

Positive Supplies

V483 and V484 supply +400 volts, unregulated, to the positive-voltage supplies and other circuits which are insensitive to voltage variations.

The -150 volt supply is used as the reference voltage for the positive voltage supplies. In the +300 volt supply, the voltage at the junction of R492 and R493, which is located between +300 volts and -150 volts, is compared with ground potential in the Comparator Tube, V489. The amplified error signal is applied to the Series Regulator Tube, V495. R496 reduces the current through the series tube. C492 increases the ac gain of the feedback loop.

The +100 volt supply is similar to the +300 volt supply with V470B as the Comparator Tube and V470A as the Series Regulator.

FLOATING POWER SUPPLY DIAGRAM

Transformer

Transformer T501 supplies plate and heater voltage for the Floating Power Supply. Shields are used around the windings to minimize the effects of capacitive currents.

Non-Regulated Supplies

V505 and V506 supply +400 volts and -300 volts with respect to the common lead. This supply is sometimes grounded directly and at other times connected to the current-measuring resistors as shown on the CRT-Display Switching Diagram. C502 balances the stray capacitive current to ground so that this current does not flow through the current measuring resistors.

+DC Circuit

The +DC Circuit receives +400 volts and -300 volts, unregulated, from either the Main Power Supply or the Floating Power Supply. This is determined by the setting of the PLATE-GRID switch shown in the CRT-Display Switching Diagram. The output of the +DC circuit is variable from approximately +10 volts to +300 volts.

Screen voltage for the Series Regulator Tube, V515, is obtained from the full-wave rectifier, V510. C510A and C510B with R510 reduce the ac ripple on the screen. The negative side of the supply is tied to the cathode of V515 so that the screen to cathode voltage remains the same as the output voltage is changed. C509 balances the capacitive current to ground in the circuit which supplies screen voltage for V515.

Reference voltage for V525B is obtained from the +DC VARIABLE Control which is connected between -150 volt supply and +100V. V540B isolates the reference voltage supply from the Series Regulator so that no current will flow between the two circuits. V525A and V525B are Comparator Tubes. The voltage at a tap on the divider between the output of the Series Regulator and the reference voltage are compared with ground potential. The amplified error signal at the plate of V525B is applied to the grid of the Series Regulator Tube, V515. B515 and B516 reduces the dc level of signal at this grid without attenuation of the signal.

The +DC switch changes the divider ratio in the divider at the grid of the comparator tube, V525B. The +DC VARIABLE Control changes the reference voltage at the bottom of this divider through V540B. These two controls provide continuous variation of the output of the regulator from approximately +10 volts to +300 volts.

CRT CIRCUIT DIAGRAM

Accelerating voltage for the cathode-ray tube is obtained by rectifying a 60-kc voltage produced by a vacuum tube oscillator. V610 is the oscillator tube with the primary of T620 serving as a tapped inductor. Rectifiers V630 and V631 supply -1700 volts to the crt cathode and +2300 volts to the post acceleration anode for a total of 4 kv accelerating voltage.

The high voltage is adjusted by means of R626 in the regulator circuit. The voltage at this point is compared with -150 volts in V605A. The amplified error signal is applied to the grid of the Shunt Regulator Tube, V605B, which varies the screen voltage of the oscillator tube.

The INTENSITY, FOCUS, and ASTIGMATISM Controls adjust the crt operating voltages for the desired intensity and focus the beam. The GEOM ADJ Control adjusts the voltage on the second anode of the crt for best linearity at the extremes of deflection.