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RCA Application Note

on

A HORIZONTAL DEFLECTION CIRCUIT FOR THE 10BP4 KINESCOPE

This note* deals with the operation of a horizontal deflection circuit for use in television receivers employing magnetically deflected kinescopes. It explains the manner in which the circuit produces a substantially linear saw-tooth current in the horizontal deflection-yoke windings and includes a discussion of a circuit modification which uses a power feed-back principle to increase operating efficiency.

The circuit values shown in Fig. 7 and the values of currents and voltages listed apply to a circuit using a magnetically focused and deflected cathode-ray tube such as the 10BP4, having a 50°-deflection angle and operating at 10-kilovolts anode potential, but with adjustment provided to scan a beam of from 6- to 10-kilovolts anode potential. The values of currents and voltages shown later are based on the particular components listed in the circuit diagram and will be only approximations when other components are used. The circuit uses the developmental-type A-4412 power tube, which is similar to the 807 but which has an octal base and is designed specifically for deflection work. The 6AS7G "booster scanning triode" is also used. This is a low-mu tube capable of handling high currents at low voltage because of its high perveance.

CIRCUIT OPERATION

In the horizontal winding of the deflection yoke a substantially linear saw-tooth current is required, together with a definite time interval during which the current is quickly reversed and the beam returned rapidly to its starting point. The standard television signal as set by the National Television Standards Committee allows 63 microseconds for a complete cycle from the beginning of scanning, through retrace to the beginning of scanning once more. 16 per cent of this cycle is allowed for blanking to take care of synchronizing and retrace. To allow for time delay of synchronizing signals and for non-linearity in the sweep at both ends, the retrace time should not exceed ten per cent of the total cycle. If the retrace time is longer, poor horizontal sweep linearity will result near the picture edges. Fig. 1 illustrates the desired cycle. T_t =

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*Based on a paper by Otto H. Schade on Magnetic Deflection Circuits for Cathode-Ray Tubes which is to be published later.

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total time interval; T_s = scanning time; T_r = retrace time; T_r = 10% of T_t.

The time constant of the horizontal windings of the deflection yoke is approximately 500 microseconds (14 ohms of dc resistance and 8 millihenrys of inductance). Fig. 2 shows the logarithmic build-up of current in the yoke when a dc voltage is applied. It indicates that the 63-microsecond interval is small enough so that current build-up during scanning is essentially linear. Fig. 2 also shows that the current in the deflection yoke reverses in a period of 6 microseconds. Because of this rapid change, a high voltage is generated across the yoke.

Consider the theoretical deflection circuit shown in Fig. 3. L_y represents the yoke inductance; L_t represents the inductance of the transformer secondary which shunts the yoke. Resistor r_y represents the eddy-current, hysteresis, and resistance losses of the yoke circuit. C_s represents the shunt capacitance of the transformer. The yoke capacitance is negligible compared to the transformer capacitance. R_1 is a small, low-inductance resistor inserted to permit examination of the current variations by means of an oscilloscope. Switch S_1 controls the application of a constant dc voltage E_1 to the yoke circuit.

When the switch is closed, a voltage as shown in Fig. 4A appears across AB. Current begins to flow from A to C (with the dc polarity indicated), and a negative deflection appears on the oscilloscope, as in Fig. 4B. At time t_1 switch S_1 is opened. The current falls rapidly to zero and then reverses, because the reactive energy in the circuit is in a state of damped oscillation between the inductance and stray capacitance. Since the inductance of the transformer secondary is large with respect to that of the yoke, its loading effect on the circuit is negligible, and L_t does not, therefore, greatly affect the resonant frequency. Fig. 4A shows the voltage wave, and Fig. 4B shows the current waves as the amplitude of the oscillation diminishes to zero. The rate of current reversal depends upon the Q and natural resonant frequency of the circuit and not upon the value of induced voltage. The resistive losses of the circuit are responsible for damping the oscillation to zero.

Consider the circuit of Fig. 3 when S_1 has been opened and the circuit enters a state of damped oscillation. Switch S_2 connects variable resistor r_L across the yoke. Fig. 5 shows the current as it changes direction. The positive amplitude is smaller than the negative amplitude because of the circuit losses represented by r_y. Suppose that S_2 is closed just as the current reaches its most positive amplitude. An initial value of r_L can be chosen so that the initial rate of current decay is equal to the rate of current build-up from t_0 to t_1. To maintain this rate of decay in the interval from t_1 to t_2, the value of r_L must be increased at such a rate that the product of the instantaneous current and instantaneous resistance is a constant and equal to E_1, the voltage applied during the interval t_0 to t_1. At t_3 switch S_2 is opened. The current reaches zero at this time, and r_L becomes infinite. The current will remain at zero if the circuit is not further disturbed. Thus, by switching in the proper initial value of a variable resistance just as the current reaches its maximum value after reversal, and by increasing this resistance at the proper rate, the oscillations of this circuit are damped and the current returned to zero at a rate equal to its initial rate of increase.

By means of proper manipulations of the switches and r_L, the circuit shown in Fig. 5 can be made to produce a substantially linear saw-tooth current in the yoke. Switch S_1 is closed at time t_0 and the current, shown in Fig. 6A, increases at a rate determined by the yoke time constant. By time t_1, when the current reaches its maximum initial value i_1, S_1 is opened. The current then rapidly reverses to its maximum value i_2. The time of reversal is determined by the natural resonant frequency of the yoke circuit. During the interval between t_1 and t_2, the rapid change of current induces across the yoke L_y a negative pulse of voltage whose peak value is e_2 (Fig. 6A). At time t_2, when the current has reached its maximum value i_2, S_2 is closed, and r_L is varied as before to make the current decrease at a rate equal to the build-up rate from time t_0 to t_1. The voltage, which normally would have oscillated to some positive peak as in Fig. 4A, remains at a value equal to E_1. At time t_3 the current reaches zero, S_2 is opened, and, at the same instant, S_1 is closed. The current rises to its initial peak value i_1 by time t_4, when S_1 is again opened, and the switching cycle is repeated. Closing S_2 just as the current reaches its maximum value after reversal produces the maximum peak-to-peak current change. Current i_2 represents a recovery from the circuit of energy stored during time t_0 to t_1. As the Q of the circuit is increased, i_2 more nearly equals i_1. During the complete cycle from time t_2 to t_5, a saw-tooth current which is substantially linear over its working length together with a rapid reversal of direction is produced in the yoke winding.

THE PRACTICAL CIRCUIT.

In the practical circuit shown in Fig. 7 the effects of the switches and r_L ane obtained by the use of two electron tubes and a transformer which, together with suitable circuit elements, control the switch and rheostat action. V_1 (developmental-type A-4412) replaces S_1; V_2 (6AS7G) and its associated circuit replace S_2 and r_L. A transformer is introduced between V_1 and V_2. The yoke furnishes an 8-millihenry load. The transformer windings are connected so that the negative voltage pulse (Fig. 6B) resulting from opening S_1 produces on the primary winding at the same instand a positive surge of voltage of greater amplitude. The negative voltage pulse which is present in the secondary circuit during scanning is applied to the grid of V_2 over a shaping network in which R_3 is adjustable. The network produces a voltage wave on the control grids of V_2 of such a shape that the plate resistance of V_2 and some selected value of R_5 combine to give the required variation of r_L. The circuit of Fig. 7 requires a source of substantially linear saw-tooth voltage of adjustable amplitude, with a maximum of approximately 70 volts peak-to-peak available. A separate high-voltage supply is needed for the kinescope, and a 400-volt dc source or B power supply is required for the scanning circuit.

In the ideal case the plate current of V_1 remains cut off until time t_0 (Fig. 6A). From t_0 to t_1, V_1 conducts, and V_2 is cut off. At t_1, V_1 is cut off, V_2 remains cut off, and the current decreases from i_2 to 0 at t_3. At t_3 the cycle is repeated.

Because of inherent losses in the yoke and transformer, tubes cannot readily be fitted to the circuit to achieve this ideal class B operation. Consequently, from t_0 to t_1 a control current is maintained in V_2.

and from t_2 to t_3 a similar control current is maintained in V_1. Both tubes are essentially cut off from t_1 to t_2 (Fig. 6A). If V_1 is not cut off during retrace time t_1 to t_2, its plate impedance loads the primary of the transformer and dissipates a portion of the energy stored in the transformer and yoke before it can be utilized. This loading amounts to a reduction in the Q of the yoke and transformer. To insure plate-current cutoff in V_1, a fraction of the secondary voltage pulse may be selected by a setting of R_2 (Fig. 7) and fed back to the grid of V_1 to supplement the applied saw-tooth voltage. This voltage supplies additional bias during the retrace time to offset the high surge-voltage appearing on the plate.

Fig. 8 shows the approximate voltage wave across the primary of the transformer. The negative peak is due to inherent leakage-reactance oscillations of the primary winding which are not completely damped by V_2 operating on the secondary. This operation of the tube with negative plate-voltage gives rise to Barkhausen oscillations which may be radiated and picked up in the rf section of the receiver and carried through to appear as bars at the left-hand side of the picture. Thorough shielding of the horizontal circuit should reduce this type of radiation. When full scanning-power is required for deflection of a 10-kilovolt cathode-ray beam, the steady increase of plate-current in V_1 from t_0 to t_1 drops the plate voltage of V_1 below the B supply-voltage by approximately 250 volts. Under this condition the plate voltage of V_1 is 140 volts below the screen voltage, as indicated in Fig. 8.

The wave form of cathode current in V_1 may be examined by connecting an oscilloscope across the unbypassed cathode resistor. This curve (Fig. 9) is flattened by grid current, which prevents the driving voltage from rising. The rate of decay during retrace is faster than can be obtained in the secondary circuit, because during retrace the plate current of V_1 is cut off. Fig. 10 shows the shape of the grid-voltage wave applied to the developmental-type A-4412.

The wave shape of secondary current, as shown in Fig. 11, may be examined by inserting a 0.3-ohm, low-inductance resistor at point X (Fig. 7) and connecting an oscilloscope across it. The wave shape of current through the 6AS7G (shown in Fig. 12) may be examined by inserting a 0.3-ohm resistor at point Y (Fig. 7). A 0.3-ohm resistor inserted at point Z (Fig. 7) permits examination of the wave shape of the yoke current (Fig. 13). In each case the resistance inserted must be low in order to prevent excessive loading of the circuit. The tests on the circuit were made with the aid of a short piece of nichrome wire, the resistance of which was approximately 0.3-ohm.

The negative excursion of the plate of V_1 below the +B voltage by approximately 250 volts appears as a positive voltage of approximately 95 volts on the plate of V_2 with respect to the center tap of R_6. The wave form of the voltage from plate of V_2 to ground is shown in Fig. 14. The dc voltage from plate to cathode is 95 volts minus the drop of 55 volts across R_5, or 40 volts. Because the plate-to-cathode voltage is so low, a high-perveance tube is needed to pass the heavy currents flowing during the damped portion of the scanning cycle.

To obtain the current wave of Fig. 12 through the yoke, a grid-voltage wave of the form shown in Fig. 15 is necessary. This wave is observed by connecting an oscilloscope from the common grid terminal to the cathode of the tube. The leads to the oscilloscope must have low capacitance, because any appreciable amount of capacitance inserted at this point will shunt the circuit and distort the wave form. The grid-voltage curve is a negatively-sloped saw-tooth which is shaped by the 50,000-ohm resistor in series with R_3 and the 30-uuf capacitor (Fig. 7). The total capacitance in this shaping circuit is made up of the 30-uuf capacitance and the tube interelectrode capacitances shunting this 30-uuf capacitor. The combination of R_4 and the 0.02-uf bypass capacitor sets the bias on the tube as the grid draws current. It was noted previously that V_2 should be cut off during retrace time. Fig. 15 shows the negative pulse of voltage applied to the grid to insure cutoff. The oscillations in the currents through the secondary of the transformer and through V_2 are of considerably magnitude, but these oscillations cancel out in the yoke and give the smooth saw-tooth current needed for linear scanning.

Tube V_2 in the secondary does not require B power directly. All energy fed to V_2 has been previously stored in the magnetic fields of the deflection transformer and yoke. The peak plate current of V_2 occurs at the beginning of scanning at a slightly positive grid voltage. The plate voltage of V_2 is adjusted by means of R_5 with its associated bypass capacitor in the cathode lead. Note that R_5 does not primarily control the grid bias of V_2.

The screen voltage of V_1 is varied by adjusting R_1 to obtain the proper scanning width for the anode voltage employed. The resistance of R_1, however, should not be decreased to the point where the maximum rated screen dissipation of V_1 is exceeded. As R_1 is varied, readjustment of R_5 is necessary to obtain correct operation of V_2 under the new scanning conditions.

A group of 32 developmental-type A-4412 power-tubes was tested in the circuit of Fig. 7; the following table shows the range of currents and voltages measured at several points in the circuit.

Given: Anode voltage (kinescope) = 10,000 volts dc.
Picture Size = 7" by 9" (blanked). 9 1/2" horizontal deflection
R_3 set at 36,000 ohms
R_4 set at 23,000 ohms
R_2 arm at ground. Peaking not utilized. (See explanation following)

R_5 adjusted to 786 ohms
B supply voltage = 400 ohms

Values for developmental-type A-4412:

Plate current = 65 to 75 millamperes
Screen current = 4 to 9 milliamperes.
Screen voltage = 283 volts with respect to ground
Cathode current = 69 to 85 milliamperes

Cathode self-bias voltage = +7 to +9 volts with respect to ground.
Grid current = 20 to 26 microamperes.
Grid voltage due to grid current across 500,000 ohms = -10 to -13 volts with respect to ground.
Total grid bias = -17 to -22 volts with respect to cathode
Negative voltage peak on grid = -70 volts with respect to ground
Positive peak plate-voltage = +4 kilovolts with respect to cathode
Negative peak plate-voltage = -800 volts with respect to cathode
6AS7G negative peak plate-voltage = -1560 volts with respect to cathode.
Voltage across R_5 = 55 volts

In the circuit of Fig. 7 the values of R_3, R_4, and R_5 largely control the linearity of the horizontal sweep. Satisfactory adjustment of linearity requires that each of these resistors be adjustable. With certain 6AS7G booster scanning triodes, R_3 and R_4 may be left fixed and R_5 used to give the required linearity. However, the interelectrode capacitances and cutoff characteristics of the 6AS7G triodes may vary. Since these factors determine the network which shapes the voltage wave applied to the 6AS7G grids, provision must also be made to vary R_3 and R_4 in order to take care of variations encountered when tubes are changed.

Large amplitudes of saw-tooth voltage applied to the grid of the developmental-type A-4412 frequently produce good circuit operation without peaking. Physical arrangement of components and wiring also affects the amount of peaking required for satisfactory operation. The particular circuit used to obtain the data for this Note worked best with no peaking. However, experience with this type of circuit has shown that provision for inserting peaking should be made so that peaking can be used if needed.

POWER FEED-BACK CIRCUIT.

In the normal operation of the horizontal deflection circuit of Fig. 7, it was shown that a voltage drop of approximately 55 volts occurs across the cathode resistor R_5. The power dissipated in this resistor can be utilized to supplement the B power supply of the circuit. The modifications necessary for this utilization are shown in Fig. 16. The horizontal output transformer ratio chosen is such that the current in V_1 is essentially equal to the current in V_2. Resistor R_5 is not used, and the +B lead of the primary of the transformer is connected to the cathode side of the 4-uf bypass capacitor. The +B connection is made to the centering potentiometer R_6 as shown in Fig. 16. The voltage developed across the 4-uf cathode capacitor is now effectively in series with the +B voltage and thus augments the plate-supply voltage applied to V_1.

A simplification of this circuit to clarify the operation of the power feed-back circuit is shown in Fig. 17. V_2 (6AS7G booster scanning triode) is considered as a rectifier without regard to the manner in which the plate current varies in the tube during the portion of the cycle when conduction takes plate. During the cycle of conduction through V_2 the capacitor is positive as in any standard rectifier circuit. Thus, it acts like a filter capacitor in a low-voltage dc power supply. The capacitor is connected so that the voltage developed across it is placed in series with the voltage of the initial B supply. Thus, with approximately 55 volts developed across the capacitor, the voltage applied to V_1 is increased by this amount. An increase in scanning-power is obtained, and this increased power may be used to produce more deflection or to permit a reduction of B supply power as illustrated in Fig. 18.

In the circuit of Fig. 18 there is a small drop (approximately 5 volts) in the centering potentiometer, which is carrying the full equipment load current. (It is desirable to run the full equipment load current through the centering potentiometer to obtain maximum centering.) The plate voltage applied to V_1 remains at 400 volts because of the extra voltage obtained from the secondary side of the transformer. Thus, though the same amount of scanning power is available, the voltage and power requirements of the B supply are reduced, and a saving in the cost of B supply components is effected. The circuit has the further advantage that, once the correct grid voltage has been set for V_2 by means of R_3 and R_4, no further changes in linearity will be noted as the picture width is varied.

Note that the transformer ratio must be chosen so as to equalize the plate currents of V_1 and V_2. Also, the capacitor across which the extra voltage is developed must be large enough so that once charged, it does not discharge appreciably when V_1 draws current. This capacitor charges during the time V_2 conducts and discharges when V_1 conducts. With sufficient capacitance at this point, the conduction cycle of V_1 will not discharge it sufficiently to cause an appreciable loss of boost voltage.

CAUTION.

> The high voltages which appear across the yoke and the primary of the transformer can be dangerous to human life. Care must be exercised when working with this circuit. Therefore, power should be shut off before changes in connections are made. If it becomes absolutely necessary to work on the circuit while it is operating, use extreme care and adjust the methods to the high voltage involved.

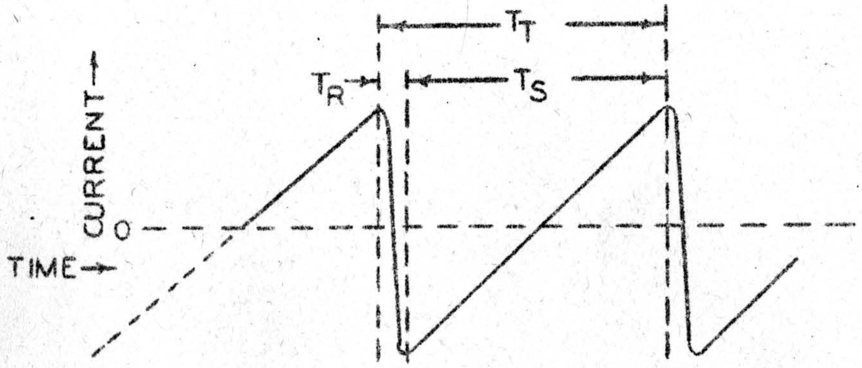


FIG. 1. SWEEP AND RETRACE CYCLE

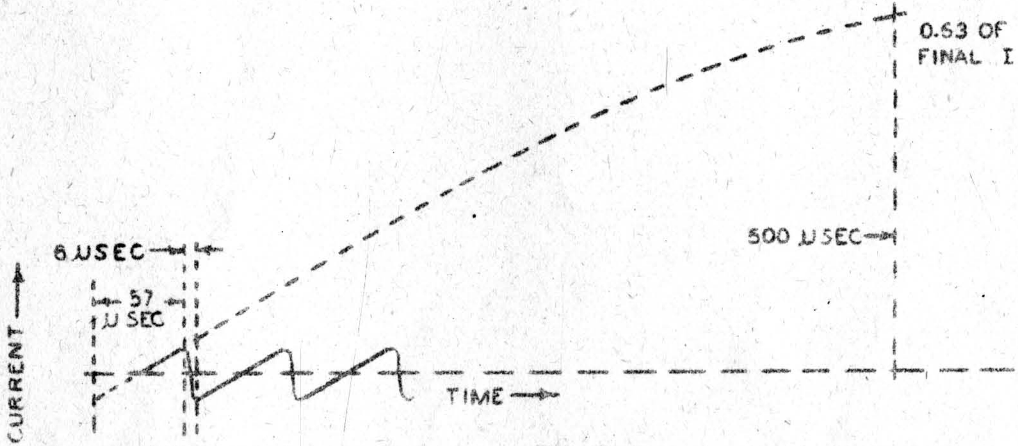


FIG. 2
BUILD-UP AND REVERSAL OF CURRENT IN DEFLECTION YOKE

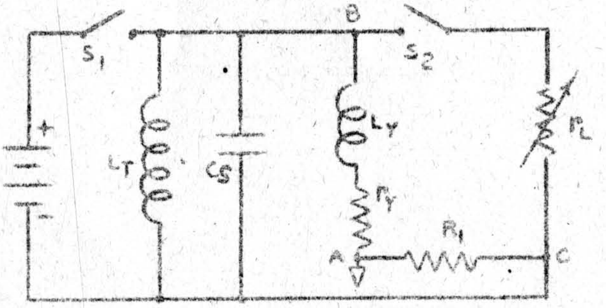


FIG. 3.
THEORETICAL DEFLECTION CIRCUIT

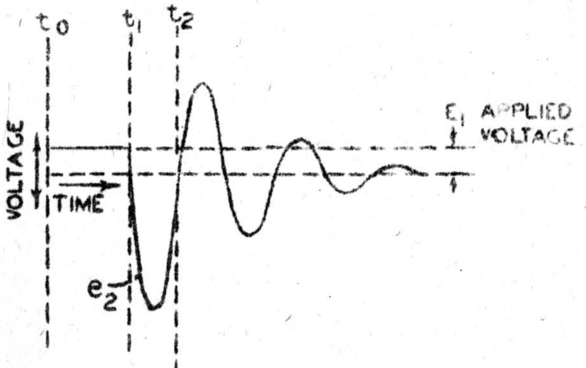


FIG. 4A
WAVEFORM OF VOLTAGE ACROSS AB IN CIRCUIT OF FIG. 3.

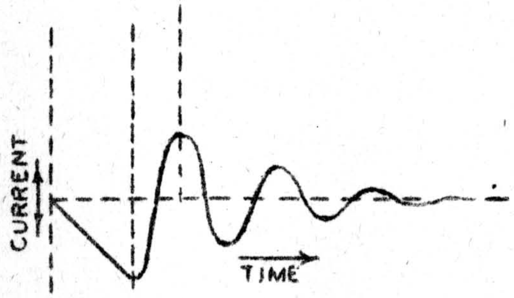


FIG. 4B
WAVEFORM OF YOKE CURRENT, C TO A DIRECTION, IN CIRCUIT OF FIG. 3.

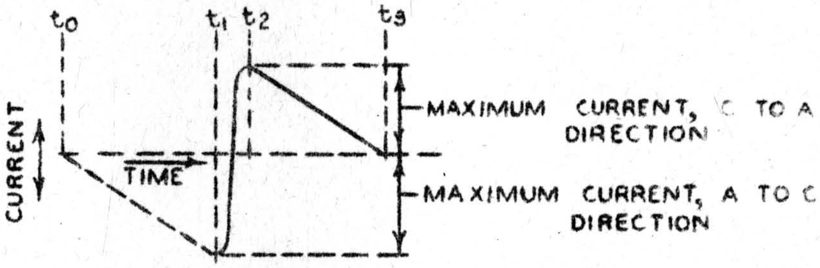


FIG. 5
WAVEFORM OF CURRENT SHOWING EFFECT OF OPENING SWITCH S_1 AT t_1 AND CLOSING OF SWITCH S_2 AT t_2.

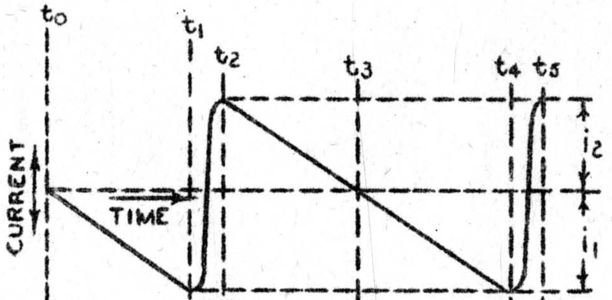


FIG. 6A
WAVEFORM OF YOKE CURRENT.

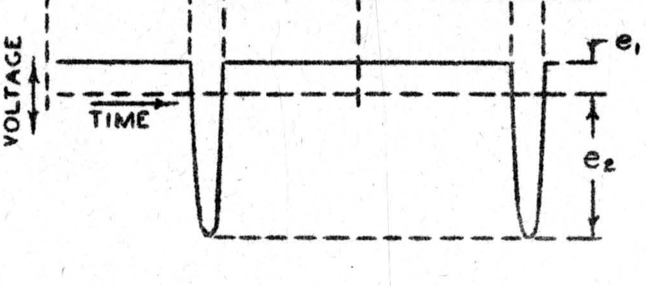
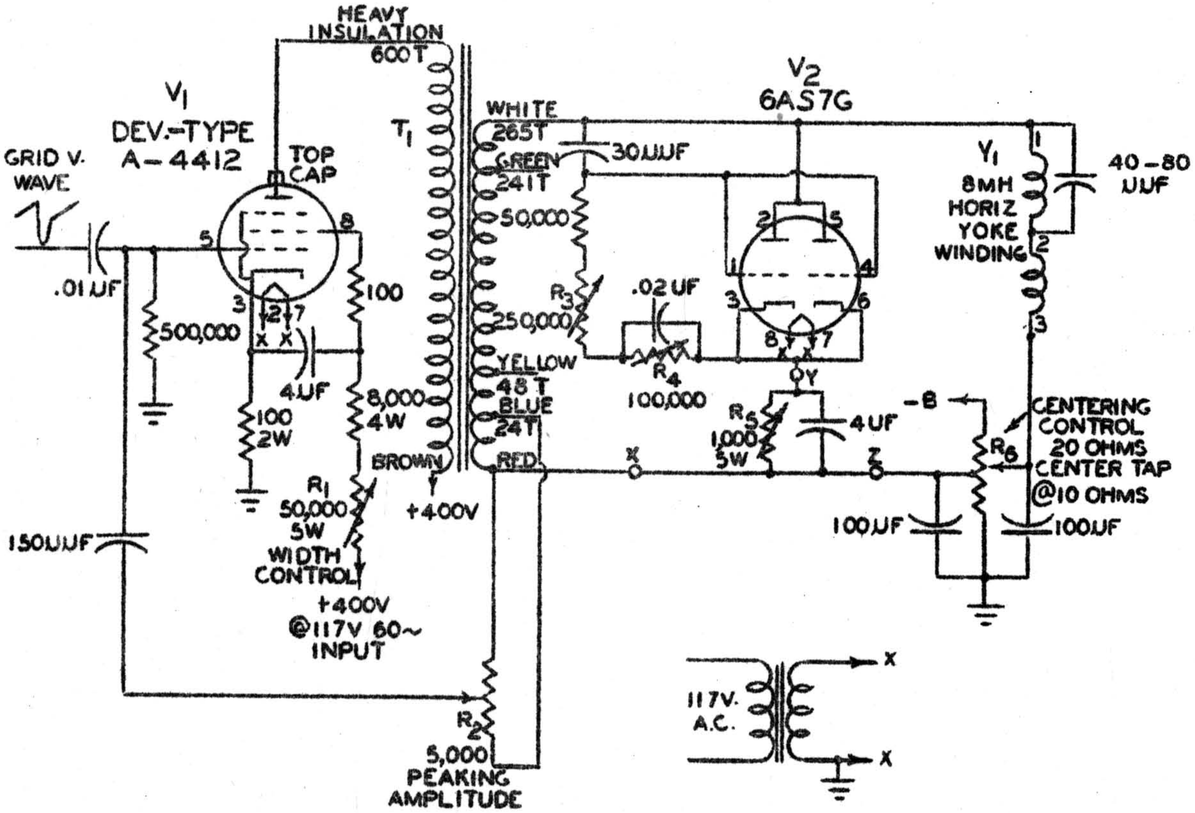


FIG. 6B
WAVEFORM OF VOLTAGE ACROSS YOKE



ALL RESISTANCE VALUES IN OHMS

T_1 = R.C.A. TYPE NO.204T1

Y_1 = R.C.A. TYPE NO.201 D1

FIG. 7

PRACTICAL
HORIZONTAL-DEFLECTION
CIRCUIT

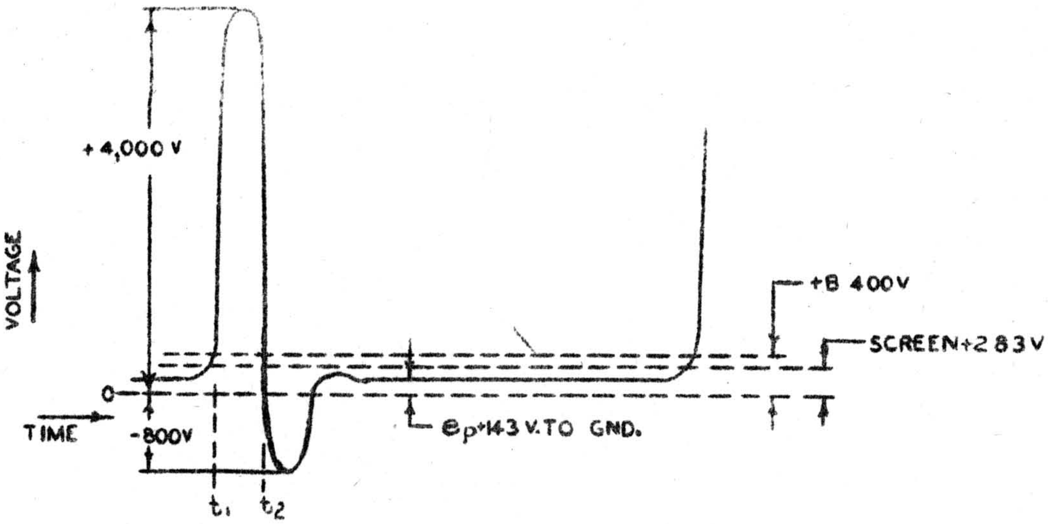


FIG. 8.
WAVEFORM OF DEV.-TYPE A-4412 PLATE VOLTAGE

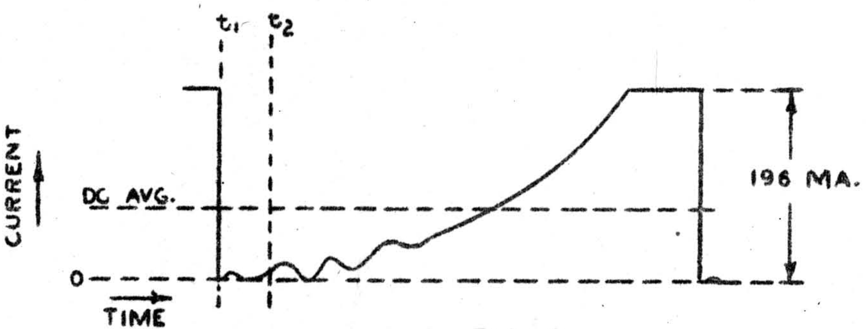


FIG. 9.
WAVEFORM OF DEV.-TYPE A-4412 CATHODE CURRENT

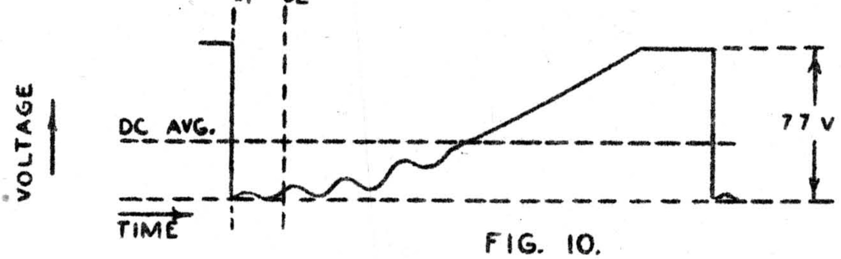


FIG. 10.
WAVEFORM OF DEV.-TYPE A-4412 GRID VOLTAGE

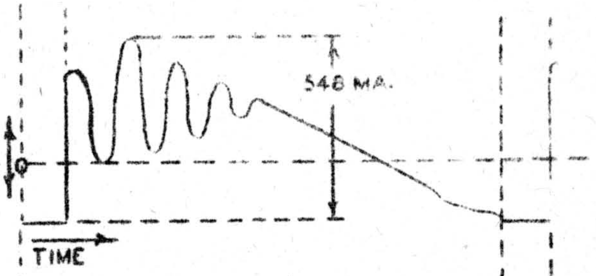


FIG. 11.
WAVEFORM OF CURRENT IN TRANSFORMER SECONDARY

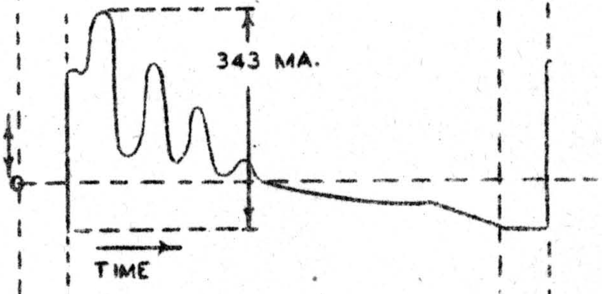


FIG. 12.
WAVEFORM OF 6AS7G PLATE CURRENT

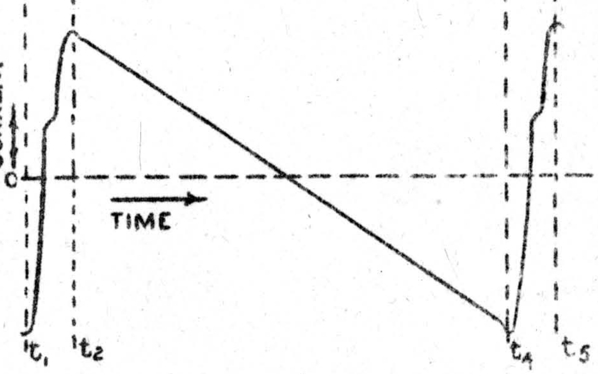


FIG. 13.
WAVEFORM OF YOKE CURRENT

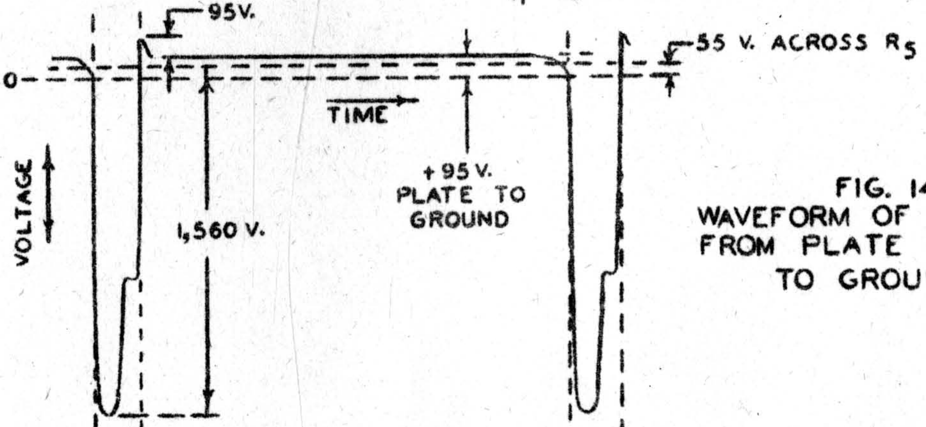


FIG. 14.
WAVEFORM OF VOLTAGE FROM PLATE OF 6AS7G TO GROUND

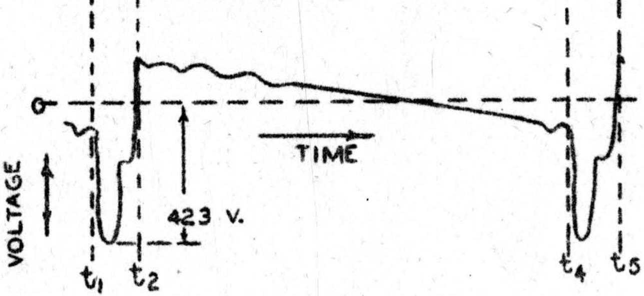
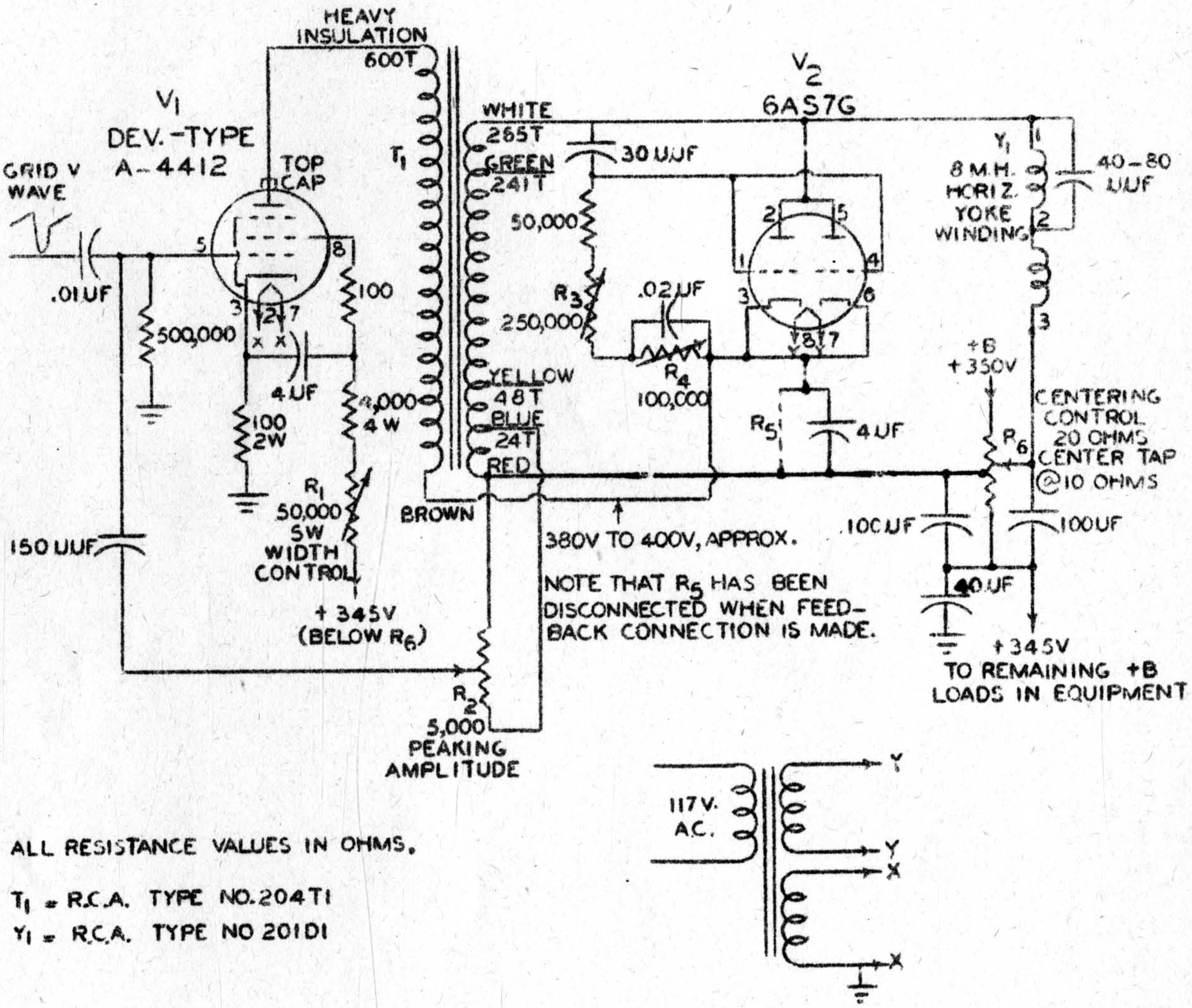


FIG. 15.
WAVEFORM OF 6AS7G GRID VOLTAGE



ALL RESISTANCE VALUES IN OHMS.

T_1 = R.C.A. TYPE NO. 204T1

Y_1 = R.C.A. TYPE NO 201D1

FIG. 16

POWER FEED-BACK CIRCUIT

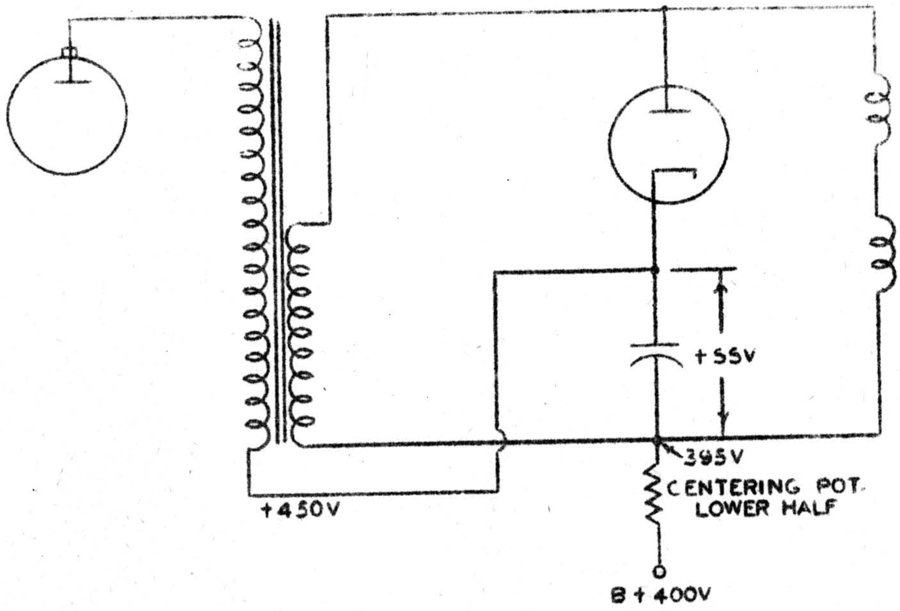


FIG. 17
SIMPLIFIED POWER FEED-BACK CIRCUIT

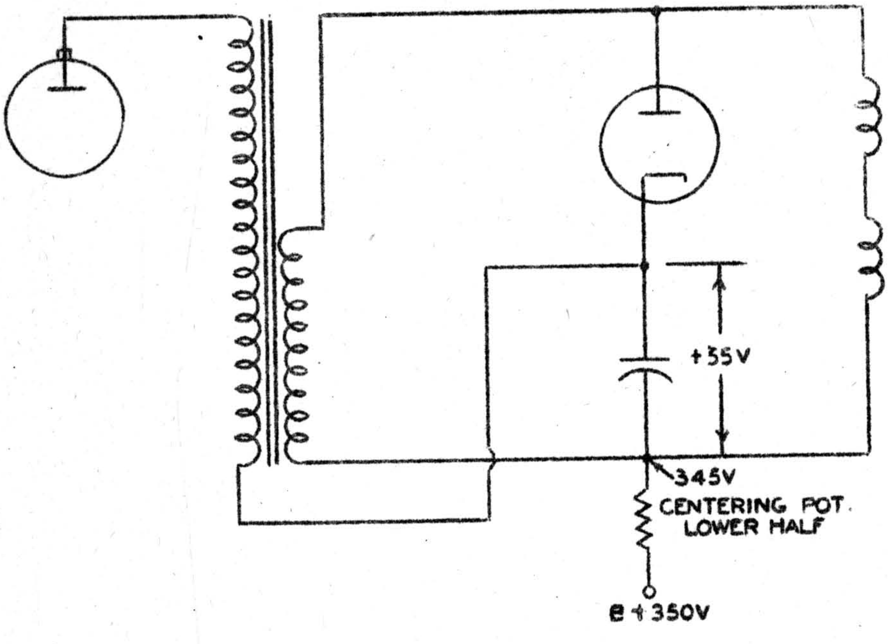


FIG. 18
SIMPLIFIED POWER FEED-BACK CIRCUIT
SHOWING LOWER B VOLTAGE REQUIREMENTS