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 permeance.

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.

*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; \( T_s = \text{scanning time} \); \( T_r = \text{retrace time} \); \( T_v = 10\% \) of \( T_s \).

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. \( C_g \) 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 \( t_2 \) 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.
The circuit shown in Fig. 5 can be made to produce a substantially linear saw-tooth current in the yoke. Switch S2 is closed at time t0 and the current shown in Fig. 6A. Increases at a rate determined by the yoke time constant. By time t1, when the current reaches its maximum initial value i1, S1 is opened. The current then rapidly reverses to its maximum value i2. The time of reversal is determined by the natural resonant frequency of the yoke circuit. During the interval between t1 and t2, the rapid change of current induces across the yoke a negative pulse of voltage whose peak value is i2 (Fig. 6A). At time t2, when the current has reached its maximum value i2, S2 is closed, and r1 is varied as before to make the current decrease at a rate equal to the build-up rate from time t0 to t1. The voltage, which normally would have oscillated to some positive peak as in Fig. 4A, remains at a value equal to E1. At time t3 the current reaches zero, S2 is opened, and, at the same instant, S1 is closed. The current rises to its initial peak value i1 by time t4, when S1 is again opened, and the switching cycle is repeated. Closing S2 just as the current reaches its maximum value after reversal produces the maximum peak-to-peak current change. Current i2 represents a recovery from the circuit of energy stored during time t0 to t1. As the Q of the circuit is increased, i2 more nearly equals i1. During the complete cycle from time t2 to t5, 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 r1 are obtained by the use of two electron tubes and a transformer which, together with suitable circuit elements, control the switch and rheostat action. V1 (developmental-type A-3412) replaces S1; V2 (6AS7G) and its associated circuit replace S2 and r1. A transformer is introduced between V1 and V2. The yoke furnishes an 8-milliampere load. The transformer windings are connected so that the negative voltage pulse (Fig. 6B) resulting from opening S1 produces on the primary winding at the same instant 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 V2 over a shaping network in which R3 is adjustable. The network produces a voltage wave on the control grids of V2 of such a shape that the plate resistance of V2 and some selected value of R3 combine to give the required variation of r1. 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 V1 remains cut off until time t0 (Fig. 6A). From t0 to t1, V1 conducts, and V2 is cut off. At t1, V1 is cut off, V2 remains cut off, and the current decreases from i2 to 0 at t5. At t3 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 t0 to t1 a control current is maintained in V2.
and from t₂ to t₃ a similar control current is maintained in V₁. Both tubes are essentially cut off from t₂ to t₃ (Fig. 6A). If V₁ is not cut off during retrace time t₁ to t₂, its plate impedance leads 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 V₁, a fraction of the secondary voltage pulse may be selected by a setting of R₅ (Fig. 7) and fed back to the grid of V₁ 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-resistance oscillations of the primary winding which are not completely damped by V₂ operating on the secondary. This operation of the tube with negative plate-voltage gives rise to Faraday 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-kilocycle cathode-ray beam, the steady increase of plate-current in V₁ from t₃ to t₄ drops the plate voltage of V₁ below the B supply voltage by approximately 250 volts. Under this condition the plate voltage of V₁ is 140 volts below the screen voltage, as indicated in Fig. 8.

The wave form of cathode current in V₁ 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 V₁ 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 X (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 V₁ below the +B voltage by approximately 250 volts appears as a positive voltage of approximately 95 volts on the plate of V₂ with respect to the center tap of R₅. The wave form of the voltage from plate of V₂ to ground is shown in Fig. 14. The dc voltage from plate to cathode is 95 volts minus the drop of 65 volts across R₅, or 40 volts. Because the plate-to-cathode voltage is so low, a high-pervance 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 6AG7 or grid-voltage wave of the form shown in Fig. 16 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 Rg and the 30-muf capacitor (Fig. 7). The total capacitance in this shaping circuit is made up of the 30-muf capacitance and the tube interelectrode capacitances shunting this 30-muf capacitor. The combination of R4 and the 0.02-muf bypass capacitor sets the bias on the tube as the grid draws current. It was noted previously that Vg should be cut off during retrace time. Fig. 16 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 Vg are of considerably magnitude, but these oscillations cancel out in the yoke and give the smooth saw-tooth current needed for linear scanning.

Tube Vg in the secondary does not require B power directly. All energy fed to Vg has been previously stored in the magnetic fields of the deflection transformer and yoke. The peak plate current of Vg occurs at the beginning of scanning at a slightly positive grid voltage. The plate voltage of Vg is adjusted by means of R5 with its associated bypass capacitor in the cathode lead. Note that R5 does not primarily control the grid bias of Vg.

The screen voltage of V1 is varied by adjusting R1 to obtain the proper scanning width for the anode voltage employed. The resistance of R1, however, should not be decreased to the point where the maximum rated screen dissipation of V1 is exceeded. As R1 is varied, readjustment of R5 is necessary to obtain correct operation of Vg 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
- 3 set at 35,000 ohms
- R4 set at 25,000 ohms
- R2 arm at ground. Peaking not utilized. (See explanation following)
- R5 adjusted to 786 ohms
- B supply voltage = 400 ohms

**Values for developmental-type A-4412:**
- Plate current = 65 to 75 milliamperes
- 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 -15 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 ground.
Negative peak plate-voltage = -600 volts with respect to cathode.

6AS7G negative peak plate-voltage = -1560 volts with respect to cathode.
Voltage across R5 = 65 volts

In the circuit of Fig. 7 the values of R3, R4, and R5 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, R3 and R4 may be left fixed and R5 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 R3 and R4 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 R5. 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 V1 is essentially equal to the current in V2. Resistor R5 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 R8 as shown in Fig. 16. The voltage developed across the 4-uf cathode capacitor is now effective in series with the +B voltage and thus augments the plate-supply voltage applied to V1.

A simplification of this circuit to clarify the operation of the power feed-back circuit is shown in Fig. 17. V2 (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 place. During the cycle of conduction through V2 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 cap-
actor is connected so that the voltage developed across it is placed in series with the voltage of the initial B supply. Thus, with approximately 65 volts developed across the capacitor, the voltage applied to V1 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 V1 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 V2 by means of R3 and R4, 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 V1 and V2. Also, the capacitor across which the extra voltage is developed must be large enough so that once charged, it does not discharge appreciably when V1 draws current. This capacitor charges during the time V2 conducts and discharges when V1 conducts. With sufficient capacitance at this point, the conduction cycle of V1 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.

The license extended to the purchasers of tubes appears in the license notice accompanying them. Information contained herein is furnished without assuming any obligation.
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 S₁ AT t₁ AND CLOSING OF SWITCH S₂ AT t₂.

FIG. 6A
WAVEFORM OF YOKE CURRENT.

FIG. 6B
WAVEFORM OF VOLTAGE ACROSS YOKE.
ALL RESISTANCE VALUES IN OHMS

T₁ = R.C.A. TYPE NO.204 T₁
V₁ = 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 6A57G
PLATE CURRENT

FIG. 13.
WAVEFORM OF YOKE CURRENT

FIG. 14.
WAVEFORM OF VOLTAGE
FROM PLATE OF 6A57G
TO GROUND

FIG. 15.
WAVEFORM OF 6A57G
GRID VOLTAGE
ALL RESISTANCE VALUES IN OHMS.

T1 = R.C.A. TYPE NO. 204 TI
Y1 = R.C.A. TYPE NO 201 D1

FIG. 16
POWER FEEDBACK CIRCUIT
FIG. 17
Simplified Power Feed-Back Circuit

FIG. 18
Simplified Power Feed-Back Circuit Showing Lower B Voltage Requirements