ELECTRON TUBES

RCA Application Note

AN-182

Use of the 6EM5 in Vertical-Deflection Circuits of 110° Systems

This Note discusses the application of the new RCA-6EM5 beam power tube in vertical-deflection circuits of television receivers utilizing picture tubes having diagonal deflection angles of 110 degrees and operating at ultor voltages up to 20000 volts (zero beam). A vertical-deflection amplifier circuit utilizing a 6EM5 is presented and analyzed together with a discussion of the causes of top-picture stretch and compression, the relation between lock-in range and discharge-tube-grid time constant, and a method of obtaining linear drive in a given circuit using the 6EM5. Formulas and sample calculations are given for the determination of plate power output, plate efficiency, and plate dissipation.

Features of the 6EM5

The 6EM5 is designed to have a high triode mu and a high plate-current capability. When the grid No. 2 is connected directly to a B+ voltage supply in the order of 260 volts, a current peak of over 180 milliamperes can be obtained. The 6EM5, therefore, does not require a grid-No. 2 dropping resistor and bypass capacitor. The transfer characteristic of the tube is such that linear deflection can be obtained with a linear drive of only about 44 volts peak-to-peak.

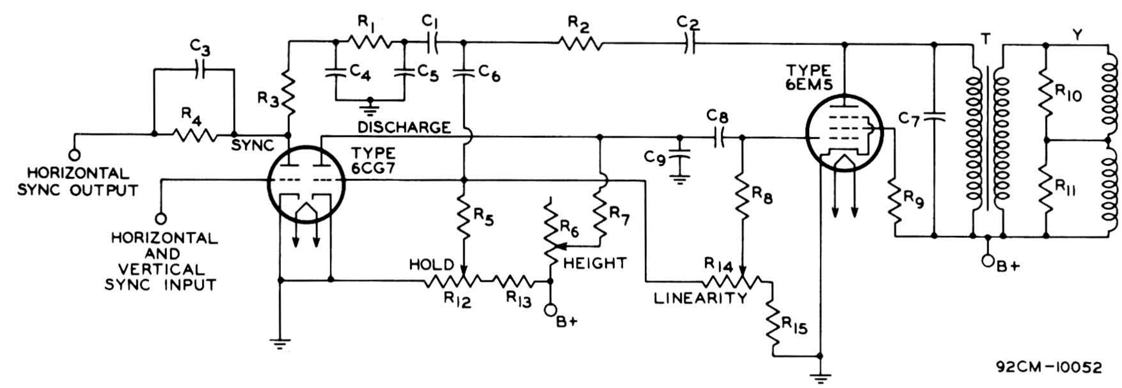
Other special features of the 6EM5 include manufacturing controls for "knee", plate, and grid-No. 2 current, and two cutoff tests--one for the maximum cutoff limit and the other for the average cutoff value. Grid emission, gas, leakage, and microphonics are also held to tight controls. Protection against breakdown due to high plate pulses is provided by wide element spacing and plate-lead isolation.

General Circuit Description

The circuit shown in Fig. 1 employs a minimum number of components and provides good performance over the range of tube characteristics that are normally encountered during life and under conditions of high and low line voltage. Other features of this circuit are the low impedance in the grid-No. 1 circuit of the output tube (to minimize the effects of grid emission, gas, or leakage currents), low plate pulse, good interlace, wide lock-in range, low control interaction, and self-regulating bias (to prevent runaway caused by grid current and to give good linearity over a wide range of line-voltage conditions). Table I gives typical operating values for the 6EM5 in this circuit; and Tables II and III give the specifications for the vertical-output transformer and the yoke, respectively.

Circuit Analysis

The circuit shown in Fig.1 is of the "feedback-oscillator" type. In principle, it is a blocking oscillator which utilizes the vertical flyback pulse rather than a separate blocking-oscillator transformer



C_1: 0.01 μf, paper, 600 volts
C_2: 0.03 μf, paper, 200 volts
C_3: 220 $\mu\mu$f, ceramic, 600 volts
C_4 C_5: 0.01 μf, paper, 600 volts
C_6: 0.006 μf, paper, 600 volts
C_7: 0.001 μf, paper, 200 volts
C_8: 0.05 μf, paper, 600 volts
C_9: 0.01 μf, paper, 600 volts
R_1 R_3: 150,000 ohms, 0.5 watt
R_2: 33,000 ohms, 0.5 watt
R_4: 10,000 ohms, 0.5 watt
R_5: 1 megohm, 0.5 watt
R_6: Height control, potentiometer, 1 megohm, 0.5 watt
R_7: 470,000 ohms, 0.5 watt
R_8: 1 megohm, 0.5 watt
R_9: 150 ohms, 0.5 watt
R_{10} R_{11}: 200 ohms, 0.5 watt
R_{12}: Hold control, potentiometer, 150,000 ohms, 0.5 watt
R_{13}: 330,000 ohms, 0.5 watt
R_{14}: Linearity control, potentiometer, 250,000 ohms, 0.5 watt
R_{15}: 150,000 ohms, 0.5 watt
T: Transformer (See Table II for specifications)
Y: Yoke such as RCA Stock No.104408 (See Table III)

Fig.1 - Vertical-Deflection Amplifier Circuit for 110° System Utilizing RCA-6EM5.

to control the grid-No.1 circuit of the discharge tube. No special linearizing feedback networks are needed because the sawtooth component in the bias voltage (from the grid of the discharge tube) is integrated to give the required negative-going parabolic pulse shape as shown in Fig.2. No peaking is used because circuits which use peaking are more sensitive to variations in the tube cutoff range and can give rise to distortions such as extreme top-picture stretch (known variously as "Egg Head" or "Denny Dimwit") and extreme top-picture compression ("Flat Top").

Cathode bias is not used in this circuit primarily because it would necessitate more supply voltage (and power) for a given power output and the use of an additional potentiometer and bypass capacitor. Moreover, when cathode bias is used, linearity tends to be poor (center-

Table I - *Typical Operating Values for RCA-6EM5 in Vertical-Deflection Amplifier Circuit for 110° System (ultor voltage of 20,000 volts) shown in Fig.1*

Plate Supply Voltage	260	volts
Grid-No.2 Supply Voltage	260	volts
Grid-No.1 Voltage	-22	volts
Peak-To-Peak AF Grid-No.1 Voltage	44	volts
Average Cathode Current	50	ma
Average Grid-No.2 Current	4	ma
Effective Load Resistance	3100	ohms
Peak Plate Pulse Voltage	1500	volts

Table II - *Vertical Output Transformer Specifications*

Ratings:			
DC primary current (limited by iron saturation)	0.05	max.	ampere
Ambient Temperature	60		°C
Electrical Characteristics:			
Turns Ratio (Primary to Secondary)	11.8:1		
Primary Impedance (30 Volts, 60 cps superimposed) at:			
50 ma DC	5000	min.	ohms
30 ma DC	11000	± 15%	ohms
0 ma DC	13000	± 15%	ohms
DC Resistance at 25° C:			
Primary	311	± 10%	ohms
Secondary	2.4	± 10%	ohms
High Potential Test (winding to core) 60 cps	1700		volts
Leakage Inductance (Inductance in Primary with Secondary shorted, 1 volt AC, 1000 cps)	135	max.	mH

Table III - *Yoke Specifications (RCA Yoke Stock No.104408)*

Vertical Winding and Negative Temperature Coefficient	17.9	ohms
Vertical Winding Inductance	14.8	henries
Vertical Yoke Current (Peak-To-Peak) Required for Full Deflection at 20000 Volts Ultor Voltage	1.6	amperes

picture stretch) at the end of tube life or when low-current-level tubes are used at low line voltage. Cathode-bias nonlinearity arises from the normal exponential curvature of the uncorrected sawtooth-generator voltage. The large grid-No.1 resistor which must be used to keep this curvature to a minimum increases the effects of grid currents and may hasten tube failure.

The type of bias used in this circuit gives ac as well as dc regulation and requires about 20 volts less B+ than would be required with cathode bias. The advantages of good linearity under limiting conditions and low grid-No.1 impedance can be obtained only with this type of biasing. If desired, some cathode bias can be used for protection of the tube in the absence of drive, provided more parabolic compensation is used (Fig.2) by increasing the time constant of the discharge-tube grid circuit or by increasing the pulse voltage on the grid of the discharge tube. Additional B+ must be used, however, and a bypass capacitor may be needed.

The grid impedance of the discharge tube is kept low to provide a short time constant so that the horizontal portion of the grid waveform is long, as shown in Fig.3. Such a waveform gives a wide lock-in range. The low grid impedance also attenuates any stray coupling of horizontal-deflection pulses and reduces the possibility of poor interlace by minimizing the possibility of changes in conduction time due to the slightly different effect of the pulses on alternate fields.

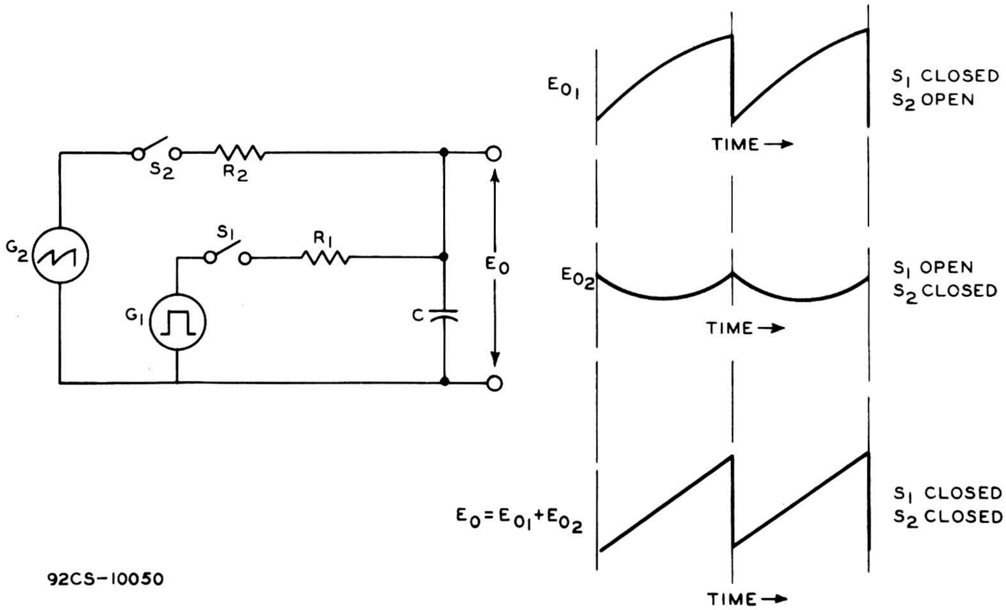


Fig.2 - Equivalent Circuit Showing Method of Adding Plate Voltage (G_1) and Grid Voltage (G_2) of Discharge Tube to Provide Linear Drive Voltage (E_o) for the Vertical Output Tube in Fig.1.

Circuit Layout

No special wiring or layout need be used provided the grid-No.2 circuit is slightly regenerative (obtained by the 150-ohm resistor in series with grid No.2) so that spurious oscillations are prevented.

Temperature Compensation

The effect of the change in resistance of the vertical-deflection winding of the yoke during the initial warm-up period is more severe in 110-degree-deflection systems than in 90-degree-deflection systems because of the relatively high final operating temperature of the yoke. The yoke temperature may rise to as high as 85 degrees Centigrade over a two-hour period. This rise in temperature will increase the winding resistance from 13.5 ohms to about 17.5 ohms. The output current will decrease proportionally due to the change in slope of the load line, and reduced scan will result.

This variation in the resistance of the yoke winding can be compensated by placing a resistor having a suitable temperature coefficient in series with the yoke-winding output transformer, height control, or grid-No.2 circuit. Probably the most direct compensation is effected when the compensating resistor is in series with the yoke windings within the yoke structure where it can respond quickly to changes in the yoke temperature. The RCA Yoke Stock No.104408 keeps the yoke resistance constant at about 17.9 ohms and is, therefore, recommended for use in all 110-degree-deflection circuits.

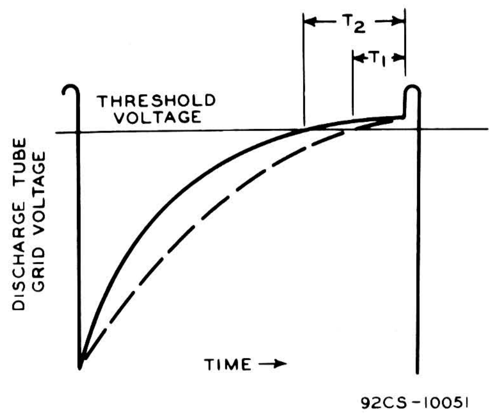


Fig.3 - Effect of time constant of discharge-tube grid circuit on lock-in range. With long time-constant (dashed curve), the lock-in range (T_1) is short; with short time-constant (solid curve) the lock-in range (T_2) is long.

Sample Calculations

Sample calculations are given for determination of power output, plate dissipation, and plate efficiency of a 6EM5 operating in a vertical-deflection circuit such as that shown in Fig.1. The values given below are taken from Tables I, II, and III:

Average Cathode Current ($\bar{I}_K$)	0.05	ampere
Average Grid-No.2 Current ($\bar{I}_{c_2}$)	0.005	ampere
Plate Supply Voltage (E_{bb})	260	volts
Transformer Turns Ratio (N)	11.8	
Resistance of Yoke and Transformer Secondary Winding (R_{ys}) . . .	17.9 + 2.4 or 20.3	ohms
Resistance of Transformer Primary Winding (R_p)	311	ohms

The approximate plate power output, P_o, can be found from the equation:

$$P_o = 3/4\ (\bar{I}_k - \bar{I}_{c2})^2\ (R_{ys} N^2 + R_p)$$

$$P_o = 3/4\ (0.05 - 0.005)^2 \left[(20.3)\ (11.8)^2 + 311\right]$$

$$P_o = 4.77 \text{ watts}$$

The plate power input can be found from the equation:

$$P_i = (\bar{I}_k - \bar{I}_{c2}) \left[E_{bb} - R_p\ (\bar{I}_k - \bar{I}_{c2})\right]$$

$$P_i = (0.05 - 0.005) \left[260 - 311\ (0.05 - 0.005)\right]$$

$$P_i = 11.1 \text{ watts}$$

The plate dissipation, P_b, therefore, is $P_i - P_o$ or 6.33 watts, and the plate efficiency is P_o/P_i or 43 per cent.