RCA MANUFACTURING COMPANY, INC.

A RADIO CORPORATION OF AMERICA SUBSIDIARY

Harrison, New Jersey

RCA RADIOTRON
DIVISION

APPLICATION NOTE No. 71
March 3, 1937

APPLICATION NOTE
ON
LOW-CURRENT, HIGH-POWER OPERATION OF TWO 6L6'S CONNECTED IN PUSH-PULL

It is often economical to increase the power output of a tube by increasing the voltages applied to its electrodes. When all the electrode voltages of a tube are increased by a factor of n, the power output of the tube increases by a factor of $n^{5/2}$ approximately. For example, 15 watts can be obtained from two 6L6's connected in push-pull when 250 volts are applied to plates and screens from an ideal power-supply source. The power output of these tubes can be increased to approximately 24 watts by increasing plate and screen voltage to 300 volts. Hence, a 20 per cent increase in voltage results in a 60 per cent increase in power.

The voltages applied to the electrodes of a tube can be increased until either the maximum voltage or the dissipation rating of the tube type is reached. In the case of the 6L6, the plate plus the screen dissipation should not exceed 24 watts and the screen dissipation should not exceed 3.5 watts. Plate dissipation decreases and screen dissipation increases as power output increases. For this reason, the recommended maximum plate dissipation value should not be exceeded for the zero-signal condition and the recommended maximum screen dissipation value should not be exceeded for the full-signal condition. Screen dissipation also increases with load resistance, because rectification in the screen circuit increases with load resistance. This action limits the possible power output to a greater extent in a single-tube amplifier than in a push-pull amplifier, because the load per tube is usually low in a push-pull amplifier. It is possible to use a low value of load resistance in a single-tube amplifier in order to reduce screen dissipation at high plate and screen voltages; however, power output is low and distortion is high under these conditions.

The high power sensitivity and high plate-circuit efficiency of a single 6L6 can be realized when the tube is overbiased to produce comparatively small zero-signal cathode current, although high second-harmonic distortion may be generated. High second-harmonic distortion can be balanced out by connecting two 6L6's in push-pull. This Note describes the characteristics of two 6L6's connected in push-pull under the following

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conditions: Plate voltage, 300 volts; screen voltage, 300 volts; zero-signal cathode current, 80 milliamperes (two tubes). This condition is discussed for ideal and for practical power-supply systems. Equal plate-and screen-voltage operation is desirable because: (1) the plate currents of the output tubes can be used to obtain proper excitation of the field coil of a loudspeaker, (2) some simplification in wiring can be effected, and (3) inverse-feedback circuits can be employed to reduce distortion and the effects of variable speaker impedance. Equal plate- and screen-voltage operation is desirable with inverse feedback, because adequate filtering is required in both plate- and screen-supply leads. The input signal is increased only to the grid-current point of the 6L6's; operation in the grid-current region is undesirable, because high-order distortion increases rapidly as the input signal is increased beyond the grid-current point.

The circuit of the amplifier is shown in Fig. 1. With switches S_1, S_2, and S_3 in position (1), electrode voltages are applied to the 6L6's from a power supply having zero internal resistance; control-grid bias is obtained from a battery. This is not a practical operating condition; however, the results of this test show what can be obtained from the 6L6's when they are operated from an ideal power-supply unit. With S_1, S_2, and S_3 in position (2), the no-signal electrode voltages remain unchanged, although the internal resistance of the power-supply unit is 1000 ohms. The bias is obtained from a cathode resistor, as shown.

The curves of Fig. 2 show the variations in power output and distortion vs plate-to-plate load for the ideal and practical power-supply units. These curves indicate that an 8000-ohm plate-to-plate load is suitable for use when the d-c electrode voltages vary with power output; a 5000-ohm load is suitable for use under the ideal conditions described previously. Approximately 16 watts at 7 per cent distortion is obtained from the amplifier when a practical power-supply unit and self-bias are used; approximately 25 watts at 2 per cent distortion is obtained when an ideal power-supply unit and fixed bias are used. The manner in which distortion varies with power output for the two conditions of operation is shown in Fig. 3. The distortion characteristic corresponding to the practical operating condition rises with power output to a maximum of nearly 7 per cent; the distortion corresponding to the ideal operating condition is nearly independent of power output.

The difference between the two distortion characteristics of Fig. 3 is due to the effects of plate, screen, and control-grid regulation. The effect of plate regulation is to decrease power output and increase distortion; the load resistance should be decreased in order to reduce distortion due to plate-supply regulation. The effect of screen regulation is to decrease power output and increase distortion; the load resistance should be increased in order to reduce distortion due to screen-supply regulation. The effect of bias regulation is to increase distortion; the zero-signal bias should be adjusted so that the bias is optimum at full output. Because these effects cannot be calculated readily, it is best to determine the proper load resistance and bias voltage from measured data. However, the data represented by the solid-line curves of Figs. 2 and 3 obtain for many receivers designed for Class AB_1 operation.

The results of these tests were checked by measurements made on a commercial receiver of representative design. The audio amplifier in this receiver consisted of a 6Q7-6C5 resistance-coupled phase inverter feeding two 6L6's connected in push-pull; the power-supply unit had an internal resistance of approximately 1500 ohms; the 6L6's were self-biased; the cathode resistor was by-passed with a 10 μf condenser. The signal was fed to the input of the phase inverter (the 6Q7) in order to obtain the distortion characteristic of the audio amplifier when the 6L6's operated in the grid-current region.

Curves of power output and distortion at the grid-current point of the 6L6's vs plate-to-plate load resistance are shown in Fig 4. These curves indicate that a 7000-ohm load produces maximum output at minimum total distortion. However, the solid-line curves of Fig. 2 indicate that an 8000-ohm load produces nearly maximum output at minimum distortion. This discrepancy is due to the higher-than-average regulation of this receiver. However, when operated with an 8000-ohm load on the 6L6's, the receiver can furnish 14.8 watts at 6.7 per cent distortion at the grid-current point; the output with a 7000-ohm load is 15.8 watts at 6 per cent distortion at the grid-current point. The distortion characteristic of the audio amplifier with a 7000-ohm load is shown by the solid-line curve of Fig. 5; the dashed-line curve is the solid-line curve of Fig. 3 redrawn to facilitate comparison.

A tabulation of the operating conditions which are suggested for an average receiver is given below:

Heater Voltage	6.3	Volts
Zero-Signal Plate Voltage	300	Volts
Zero-Signal Screen Voltage	300	Volts
Zero-Signal Cathode Current (Two Tubes)	80	Milliamperes
Max.-Signal Cathode Current (Two Tubes)	108	Milliamperes
Load Resistance (Plate-to-Plate)*	8000	Ohms
Self-Bias Resistance	335	Ohms
Power Output (Approximate)*	16	Watts
Total Distortion (Approximate)*	7	Per cent

*For a power supply having an internal resistance of approximately 1000 ohms.

RCA Cunningham Radiotron RADIO TUBES

DIAGRAM OF TEST CIRCUIT

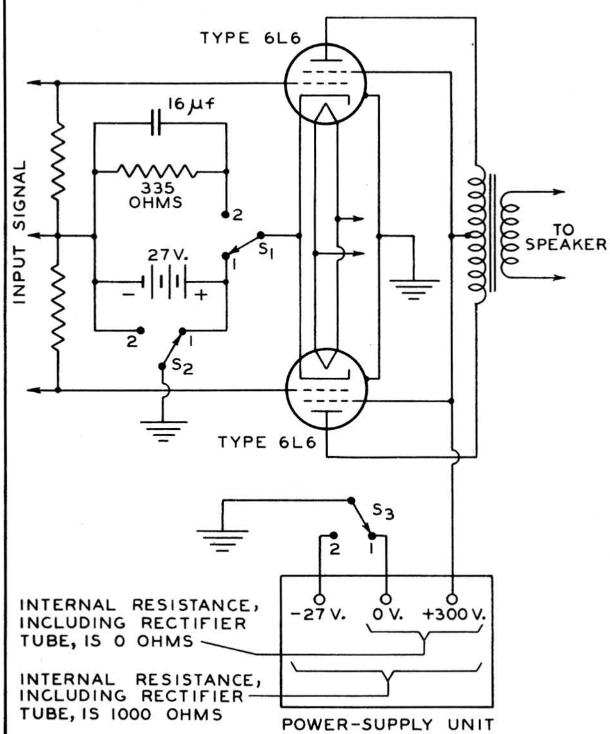

FIG. 1

RCA Cunningham Radiotron RADIO TUBES

RCA-6L6

PUSH-PULL OPERATION CHARACTERISTICS AT GRID-CURRENT POINT

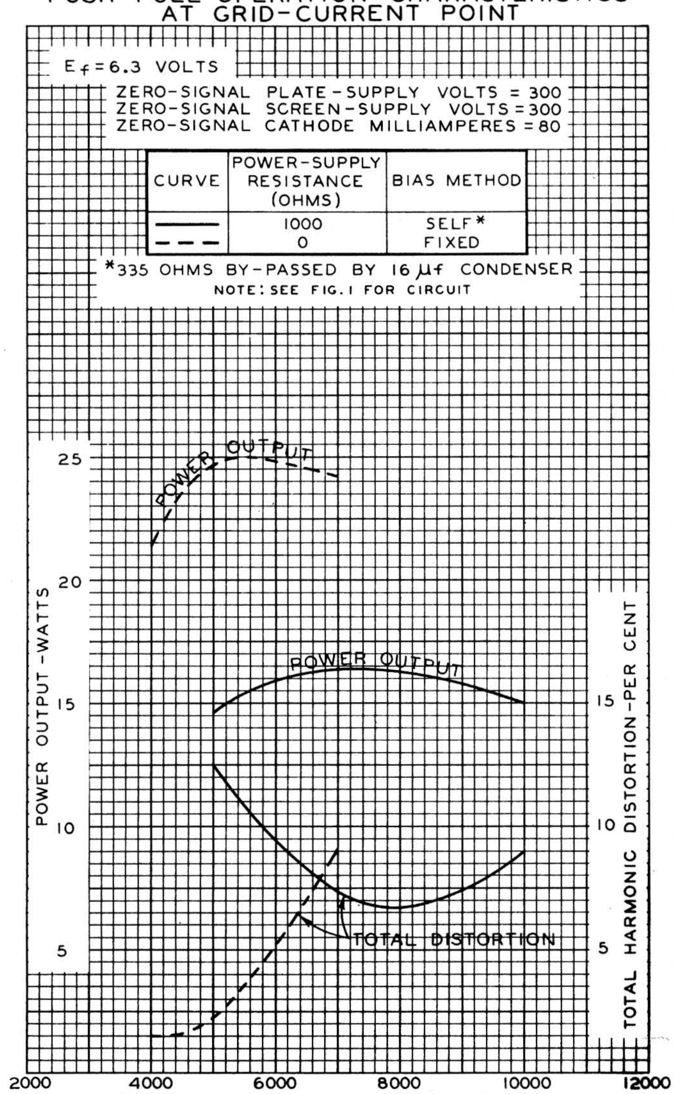

FIG. 2

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RCA-6L6

PUSH-PULL OPERATION CHARACTERISTICS

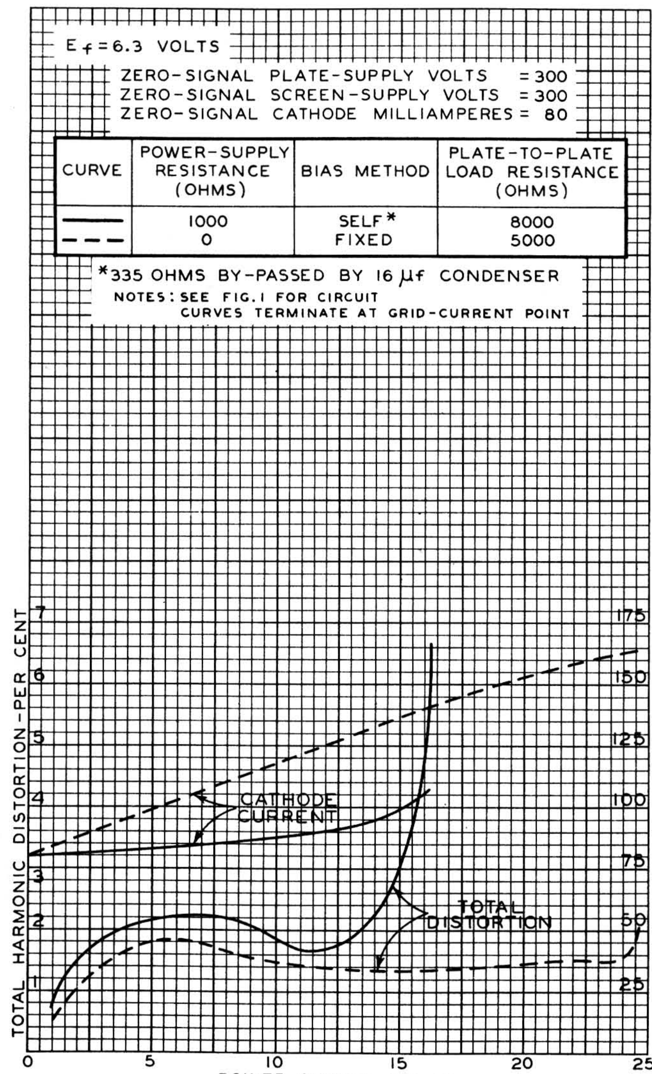

FIG. 3

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RCA-6L6

PUSH-PULL OPERATION CHARACTERISTICS AT GRID-CURRENT POINT IN A TYPICAL RECEIVER

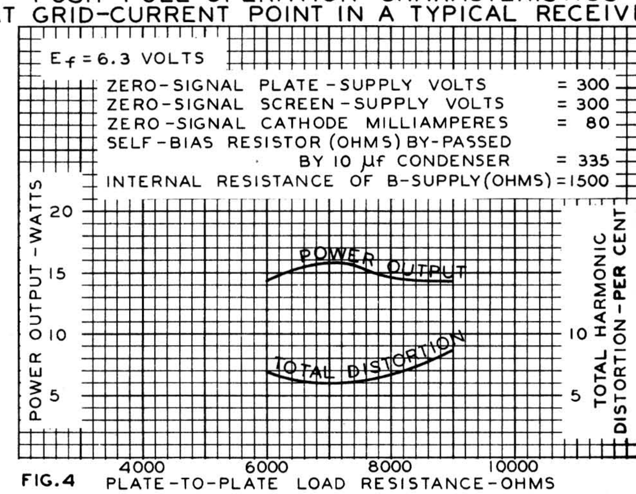

FIG. 4

PUSH-PULL OPERATION CHARACTERISTICS IN A TYPICAL RECEIVER

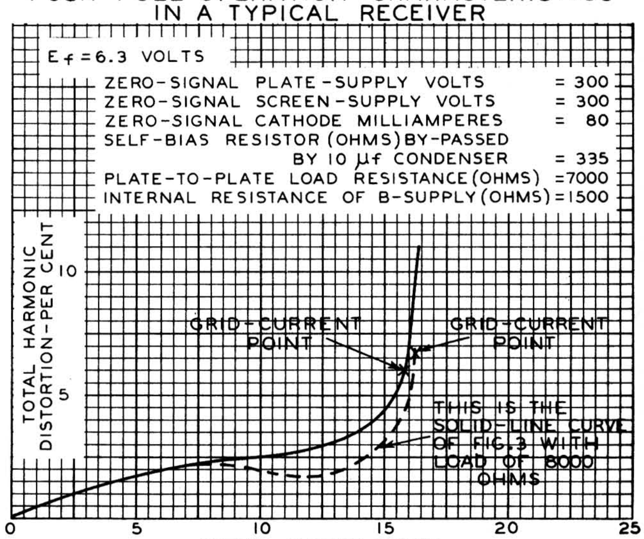

FIG. 5

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