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D I V I S I O N

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APPLICATION NOTE
ON
A SELF-BALANCING PHASE-INVERTER CIRCUIT

In the usual two-tube phase-inverter circuit, a portion of the output-signal voltage of a tube (A) is applied to the grid of a second tube (B) in such a manner that the signal voltages between plate and ground of tubes A and B (E_a and E_b , respectively) are equal in magnitude and 180 degrees out of phase. In such a circuit, the proper phase relation between E_a and E_b is obtained automatically; the ratio E_a/E_b , a measure of the amplitude balance of the phase inverter, is made equal to unity by adjusting the portion of E_a that is fed to the grid of tube B. An analysis of Fig. 1, which is representative of two-tube phase-inverter circuits, reveals an important disadvantage of this circuit: possible variations between different tubes of the same type used in position B and variations in the value of R_3 produce corresponding variations in the ratio E_a/E_b .

A self-balancing phase-inverter circuit that does not have this disadvantage is described in this Note. The circuit has been used in other countries for some time with good success, and is shown in Fig. 2. Resistor R_3 is connected between ground and point (a) and is common to the plate circuit of tube A and to plate and grid circuits of tube B. Because of this common connection, the magnitude of the signal voltage across R_3 , which is applied to the grid of tube B, depends on the difference between the values of output-signal currents of tubes A and B. Hence, the effects of variations in the value of R_3 or the effects of possible variations between different tubes of the same type used in position B are very small. The circuit is degenerative, because a portion of the output of tube B is fed back to the input of tube B. Hence, the stability that is characteristic of degenerative amplifiers is obtained. It should be noted that the gain measured from the input (E_1) to tube A to the output (E_o) from the transformer's primary is only a few per cent less than that obtained from the circuit of Fig. 1.

The ratio E_a/E_b cannot be made equal to unity with this self-balancing circuit by any adjustment of the value of R_3 , because of the degenerative action. However, with the values of resistors ordinarily employed in this circuit, E_a/E_b is approximately 1.1; a 10 per cent unbalance in the push-pull output stage of a radio receiver can be tolerated easily. An analysis of the circuit shows that, as the gain of tube B is increased, the ratio E_a/E_b approaches unity.

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A P P L I C A T I O N N O T E S



Values and tolerances of resistors R_1 , R_2 , R_4 , and R_5 that are usually employed in the circuit of Fig. 1 may be used in the self-balancing circuit of Fig. 2. The value of R_3 is not at all critical; its value may be changed by a factor of 5 with small change in overall performance.

Tests were conducted in an amplifier using a 6Q7 (tube A), a 6F5 (tube B), and two 6V6's connected in push-pull in the output stage. The amplifier was connected as shown in Fig. 2. The values of R_1 , R_2 , R_4 , and R_5 were 0.25 megohm each; the value of R_3 was varied and corresponding values of E_1 , E_a , and E_b were determined at a power output of 1 watt. The following table shows the performance of the circuit for two values of R_3 , 0.05 megohm and 0.25 megohm.

R_3 (megohm)	E_1 (millivolts)	E_a (volts)	E_b (volts)	E_a/E_b
0.05	83	3.35	3.17	1.06
0.25	81	3.3	3.3	1*

Note: Tolerance of resistors used throughout the amplifier was $\pm 10\%$.

* The measured value was slightly less than 1.

It will be noted that the change in gain of the amplifier and the change in the ratio E_a/E_b is negligible throughout the 5-to-1 change in the value of R_3 .

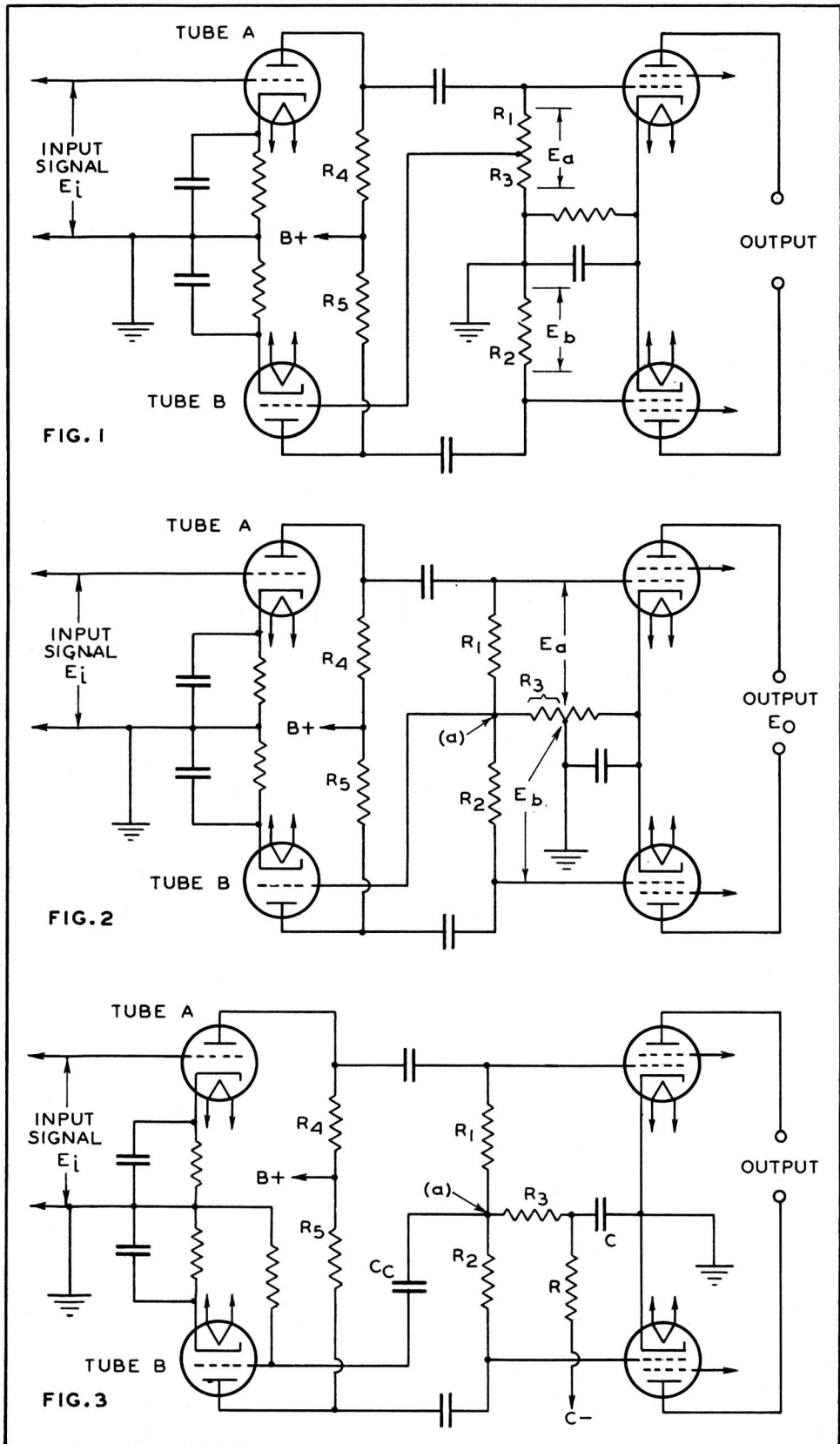
Another test using a 6C5 in place of the 6F5 was conducted. The results of this test were similar to those shown in the table, except that the gain and balance of the amplifier were somewhat more critical to changes in the value of R_3 . Other tests of this circuit in typical radio receivers indicate that a good value of R_3 is 0.25 megohm for any of the tubes ordinarily used in phase-inverter circuits. It should be noted, however, that it may be necessary to use a lower value of R_3 in order to satisfy recommendations for the maximum value of grid resistor for the output tubes.

The output tubes in the self-balancing phase-inverter circuit of Fig. 2 are self-biased. When the bias for these tubes is obtained from a fixed-or partial-fixed-bias source, it is necessary to couple the grid of tube B to point (a) through a suitable condenser (C_c), as shown in Fig. 3. In addition, a hum filter (R and C in Fig. 3) may be required, because most partial-fixed-bias sources contain appreciable hum voltage; any hum voltage appearing across the grid resistor of tube B is amplified by tube B and by one of the output tubes.

Under many operating conditions, this circuit requires no more components than conventional circuits, and at the same time offers advantages of high stability and freedom from balance adjustments.



PHASE-INVERTER CIRCUITS



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