Both of the above-mentioned circuits require well balanced push-pull drive for proper operation. Since many input signals occur as single-ended signals, some form of single-ended to push-pull converter is usually required. Such a converter circuit is often difficult to design and expensive to produce. In addition, the above circuits often require two balancing adjustments, a dc adjustment to equalize the g_m's of the two tubes and a drive amplitude or phasing adjustment.

A circuit without these disadvantages is shown in Fig. 3. In this circuit a single-ended input signal is applied to both the grid of one tube and the cathode of the other, and a single-ended local oscillator signal is applied to the other grid-cathode pair. The two plates are connected in parallel. The circuit may be thought of as a pair of grounded-cathode amplifier stages driven in parallel with a pair of grounded-grid amplifier stages and with a common plate load. Since the gain of the grounded-grid stages is equal and opposite to that of the grounded-cathode stages, the net gain is zero at the input frequencies. In the appendix we show that the output contains only the beat signal and even-order harmonics of the inputs. This analysis also applies to the circuits of Figs. 1 and 2. The only balancing adjustment necessary is a dc g_m balance. This is accomplished in the circuit of Fig. 4 by the potentiometer in the cathode circuit. Because of the low input impedance of the grounded-grid stages, the circuit is inherently broadband and will operate over a wide range of frequencies without tuning. The circuit shown in Fig. 4 exhibits a conversion transconductance of about 1500 μmhos with a local oscillator drive of 0.5 volt.

Several variations of the basic circuit are shown in Fig. 5. The triode circuit of Fig. 5A does not balance as well as the pentode circuit because of direct feed-through from input to output through the plate-to-grid capacities. For operation over a very narrow band, however, the grid-plate capacities can be neutralized by shunt inductors. The transistor circuit of Fig. 5B is a direct counterpart of the triode circuit of Fig. 5A.

References

1. F. E. Terman, "Radio Engineers' Handbook," *McGraw-Hill Book Company, Inc.*, New York, 1943, page 551.
2. J. P. Costas, "Synchronous Communications," *Proceedings of the IRE,* December 1956, page 1715.

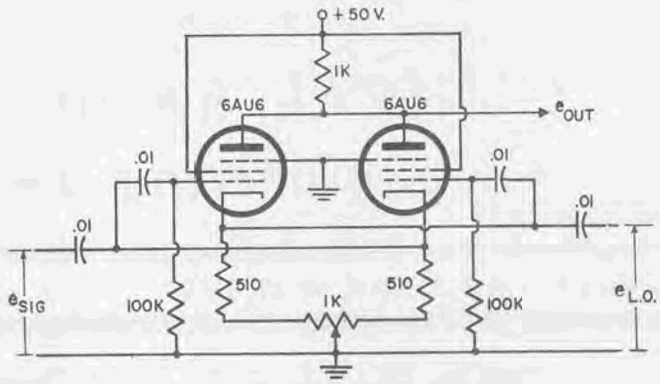

Fig. 4: Potentiometer in the cathode circuit provides dc g_m balance. Circuit is inherently broadband.

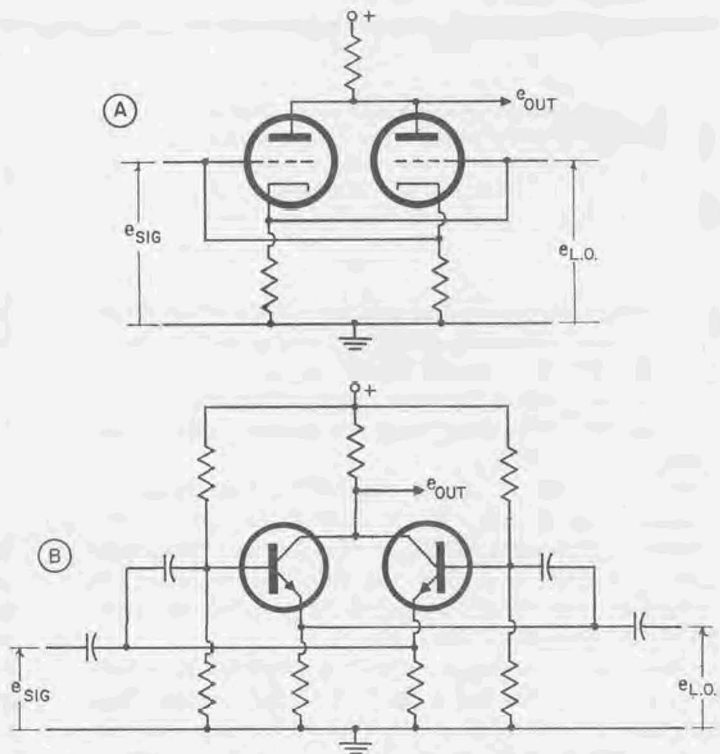

Fig. 5: Variations of the basic circuit. 5A does not balance as well as the pentode circuit because of direct feed-through from input to output through the plate-to-grid capacities.

Appendix

In Fig. 3 let:

e_1 = the input signal applied to one grid-cathode pair

e_2 = the local oscillator signal applied to the other grid-cathode pair

i_1, i_2 = the variational plate current of each tube

$e_{g1} = e_1 - e_2$ = the grid-to-cathode voltage of one tube

$e_{g2} = e_2 - e_1$ = the grid-to-cathode voltage of the other tube

The transfer characteristic of each tube can be represented by a power series as follows:

$$i = a_1 e_g + a_2 e_g^2 + a_3 e_g^3 + \cdots$$

The total variational load current is:

$$i_L = i_1 + i_2 = a_1 e_{g1} + a_2 e_{g1}^2 + a_3 e_{g1}^3 + \cdots$$
$$+ a_1 e_{g2} + a_2 e_{g2}^2 + a_3 e_{g2}^3 + \cdots$$

$$i_L = a_1 (e_1 - e_2) + a_2 (e_1^2 - 2e_1 e_2 + e_2^2)$$
$$+ a_3 (e_1^3 - 3e_1^2 e_2 + 3e_1 e_2^2 - e_2^3) + \cdots$$
$$+ a_1 (e_2 - e_1) + a_2 (e_2^2 - 2e_2 e_1 + e_1^2)$$
$$+ a_3 (e_2^3 - 3e_2^2 e_1 + 3e_2 e_1^2 - e_1^3) + \cdots$$
$$i_L = 2a_2 (e_1^2 - 2e_1 e_2 + e_2^2) + \cdots$$

It can be seen that i_L contains only even-order terms indicating that the mixer output contains only sidebands and even-order harmonics of the input signals.

The above analysis was carried out with the assumption of zero source impedance for both the input signal and local oscillator signal. The results are true, however, for any source impedance, the only assumption being that $1 + \mu \approx \mu$. The degree to which this assumption is in error determines the residual unbalance of the circuit.

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS

Printed in U.S.A.

GENERAL RADIO COMPANY
engineering department
REPRINT No. A87 1960

Reprinted from ELECTRONIC INDUSTRIES October, 1960

With Double-Balanced Design the

Mixer Circuit Has Clean Output

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A double-balanced mixer circuit is desirable for many communication and measurement systems. The balance system, when properly designed, will eliminate the appearance of the input signal and local oscillator from the output.

IN many communication and measurement systems, the use of balanced mixer circuits is highly desirable. A balanced mixer circuit is one which is so designed that either the input signal frequency or the local oscillator frequency does not appear in the mixer output.

In one form of single sideband generation, for example,[1] a balanced mixer circuit is used which eliminates the local oscillator (or carrier) frequency from the output, leaving the input signal and the two sidebands. One sideband is then extracted from the mixer output by filtering.

Occasionally, a mixer circuit is required in which both the local oscillator and the input signal frequencies are cancelled in the output, leaving only the beat signals or sidebands. Such a circuit is called a double-balanced mixer.

As an example of the use of a double-balanced mixer, consider the problem of measuring the frequency of a signal of approximately 11 MC with a 10 MC frequency counter. One method involves mixing the 11 MC signal with a 10 MC local oscillator signal and applying the 1 MC difference frequency to the counter. However, since the counter may be sensitive to both the 11 MC signal and the 10 MC reference, as well as the 1 MC beat, a mixer is required which does not pass the signal or local oscillator frequencies, i. e., a double-balanced mixer.

A common double-balanced mixer circuit is shown in Fig. 1.[2] In this circuit two tubes are used, each having two control grids. The local oscillator signal is applied as a balanced push-pull signal to one pair of grids and the input signal is similarly applied to the other pair of grids. The two plates are connected in parallel. Since both the input signal and local oscillator signal are applied in opposite phase to each tube, their effect is cancelled in the combined plate current, leaving only the beat signal and harmonics of the inputs.

A variation of this circuit employing a double triode is shown in Fig. 2. In this circuit the local oscillator signal is applied to a pair of cathodes rather than a pair of grids.

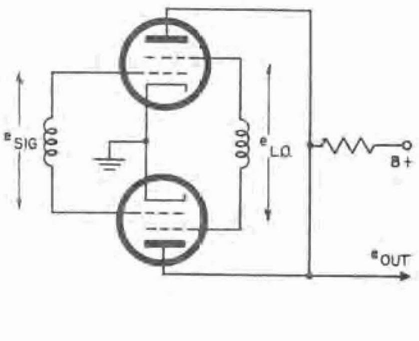

Fig. 1: Common double-balanced mixer circuit. Input signal and local oscillator signal are cancelled in combined plate current.

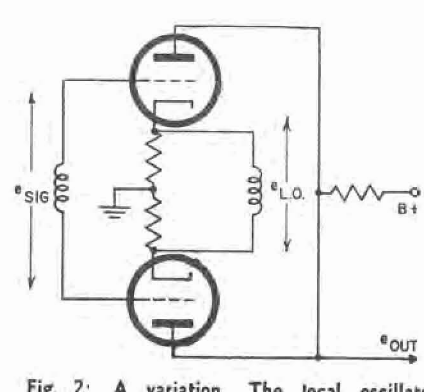

Fig. 2: A variation. The local oscillator signal is applied to a pair of cathodes rather than to a pair of grids.

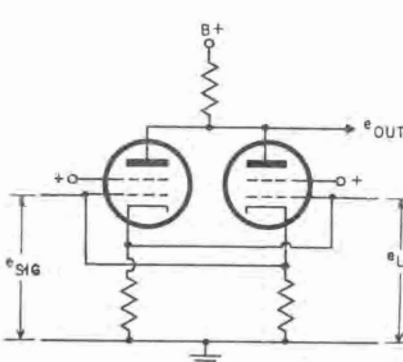

Fig. 3: Circuit has none of the disadvantages of figs. 1 and 2. Output contains only the beat signal and even-order harmonics of input.