The New "Isodyne" Phase Splitter

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This recently patented circuit leads to an amplifier that maintains an IM distortion value below 0.1 per cent up beyond the rated output value of the transformer employed—and practically perfect balance from d.c. to Channel 7.

Except for applications of new tubes, the apparent lack of new or refined circuitry in audio amplifiers leads one to believe that there is not much left to be invented. It is indeed fortunate that this is not true. Actually, the action of series-fed direct-coupled or capacitor-coupled amplifiers is pretty well established, but the possibilities of negative feedback are virtually unlimited. The discussion here is principally about a special phase splitter circuit and its application to a complete power amplifier. The results are outstanding. There are better amplifiers built for laboratory purposes, but their bulk and weight and phenomenal cost rule out their use in the home. The amplifier described here has extremely low distortion and very high stability at a realistic cost.

Conventional phase splitters are subject to certain faults. They normally provide low gain—in many cases less than unity—so that a driver stage has commonly been required between the phase splitter and the power output stage of large amplifiers. They are generally incapable of precise balance over a wide range of frequencies, so that unbalance must be compensated within the amplifier system by means of negative feedback. They are easily unbalanced by variation of tube constants or by aging of circuit components, even when initially perfectly balanced, and they are not readily balanced by unskilled personnel.

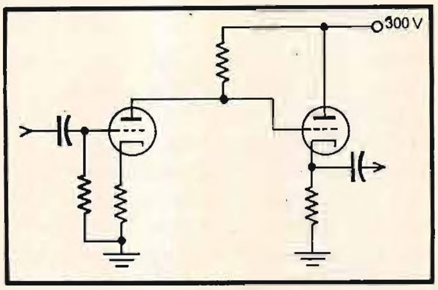

Fig. 1. First step in developing direct-coupled phase splitter was the single-ended two-stage amplifier using a 12AX7.

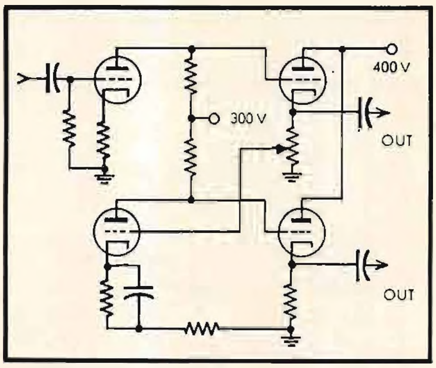

Fig. 2. Two circuits similar to Fig. 1 are combined, with the input signal for the lower section derived from the cathode circuit of the upper.

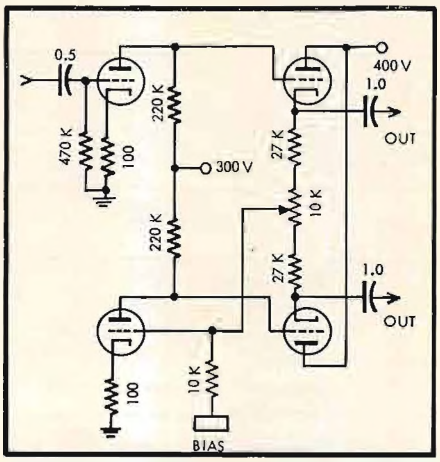

Fig. 3. The third step approaches balance to a.c., but not yet to d.c. bias.

Requirements

A phase splitter should be inherently self balancing, both to input signals and to d.c. bias; it should be direct coupled so as to eliminate any phase shift; it should be fully balanced to ground (capacitively) at all conditions of operation; it should provide an output signal of high amplitude and low output impedance, which should be balanced on both sides; and it should be capable of employing only two tube envelopes. To develop such an inverter was the object of the writer's work.

Figure 1 shows a direct-coupled series-fed circuit using a 12AX7. It has high gain, no capacitors, and its output is from a cathode follower. The problem was to merge two such circuits into a successful phase splitter. Going through intermediate stages, we arrive at *Fig.* 2. However, this circuit is difficult to keep in balance at high signals, when d.c. bias varies so much that distortion is prohibitive. *Figure* 3 is an improvement, but as yet the first half of each side is still not balanced to d.c.

Figure 4 approaches a solution. Amp. #2 seems satisfactory, but Amp. #1 is not sufficiently identical to provide reliable balance throughout its operation. However, if resistor X—the grid resistor for the first half of the phase splitter—is returned to signal ground through the bias control, both halves of the circuit are operating with the same d.c. conditions. Results were beyond expectations. It is now only necessary to adapt this circuit to a complete amplifier, as it is in *Fig.* 5. In the meantime, the advantages of the phase splitter by itself were sufficiently important to warrant filing a patent application. After due course, U. S. Patent 2,833,871 issued to the writer.

R_7 in *Fig.* 5 serves as an a.c. balance control, while the bias is controlled independently. Referring to a typical amplifier using this phase splitter, R_7 is the signal or a.c. balance control, while R_{26} adjusts the d.c. bias on the input stage. It can be seen that resistor R_{24} is floating between the grids of the opposite amplifiers, the junction point (the arm of R_7) is free to appear at the point which represents balance for the particular signal at which the circuit is operating. This freedom is an important factor in the over-all stability of the phase splitter.

The phase splitter alone is capable of driving directly a Class AB or Class B push-pull output stage, and since the output from the phase splitter is derived from a cathode follower its impedance is low. All elements are direct coupled up to the input of the output stage so there is an absolute minimum of phase shift. Balanced operation up to a frequency of 1000 kc can be achieved easily.

The Amplifier

Figure 5 is the complete circuit of an amplifier employing the phase splitter de-

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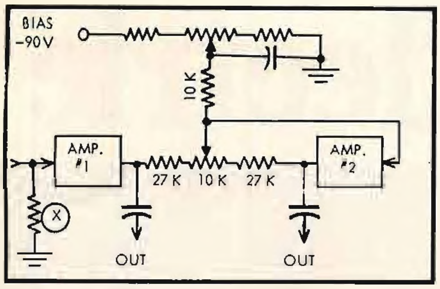

Fig. 4. Circuit of Fig. 3 in block schematic form.

scribed. The pentode section used for the first stage provides considerably higher gain than the triode used as an example in describing the operation of the circuit. R_{26} adjusts operating bias for the first stage, and should be set at approximately 2 volts. R_7 adjusts for a.c. balance of the phase splitter, and once R_{26} and R_7 have been adjusted, they usually retain the adjustment indefinitely. C_4 should have a value of 1500 μμf, and C_8 should be 82 μμf; there is no C_7 or C_9. R_{20} has a value of 750 ohms for the transformer specified when working at 16 ohms. The transformer may not be critical to the circuit, but as with any tetrode or pentode power amplifier using feedback, the components in the feedback circuit may require adjustment with a square-wave generator and an oscilloscope. The screens of the two 6AN8's should be operated at 60 to 62 volts, while the plates should measure around 95 volts. At the power supply, the output-stage tap is 470 volts; the plates of the triode sections of the 6AN8's should be 410 volts, and the voltage at the junction of R_4 and R_5 should be 300 to 310 volts. Bias on the output stage measures at 37 volts on the grids, and is adjusted by R_{22}; R_{12} balances the plate current in the two output tubes. It may be necessary to select two 6AN8's to get a good balance between them, but once balanced they should remain so.

There is no reason why this amplifier could not be constructed with output transformers other than the one specified, but the characteristics of transformers vary appreciably, and some of the circuit constants would have to be readjusted.

In layout, it is important that leads should be as short as possible. The coupling capacitors leading from the cathode followers should go direct to the output stages without crowding to ensure a good capacitive balance. It is desirable that the a.c. balance control, R_7, be located between the phase splitter tubes, and R_{26} should be close enough so that R_{24} runs directly between the arms of the two pots.

Performance

Measured IM distortion on the amplifier was below 0.2 per cent up to 30 watts, reaching 0.6 per cent at 45 watts, and 2 per cent at 51 watts. Frequency response is within ± 0.5 db from 10 to 10,000 cps (for the phase splitter alone it remained balanced and "flat" to over 1 mc). An input signal of 2 volts is necessary to overcome the very heavy feedback and drive the amplier to a 50-watt output.

The amplifier described—as well as the phase splitter itself—is not commercially available, but its performance makes it well worthy of investigation by the advanced experimenter. Æ

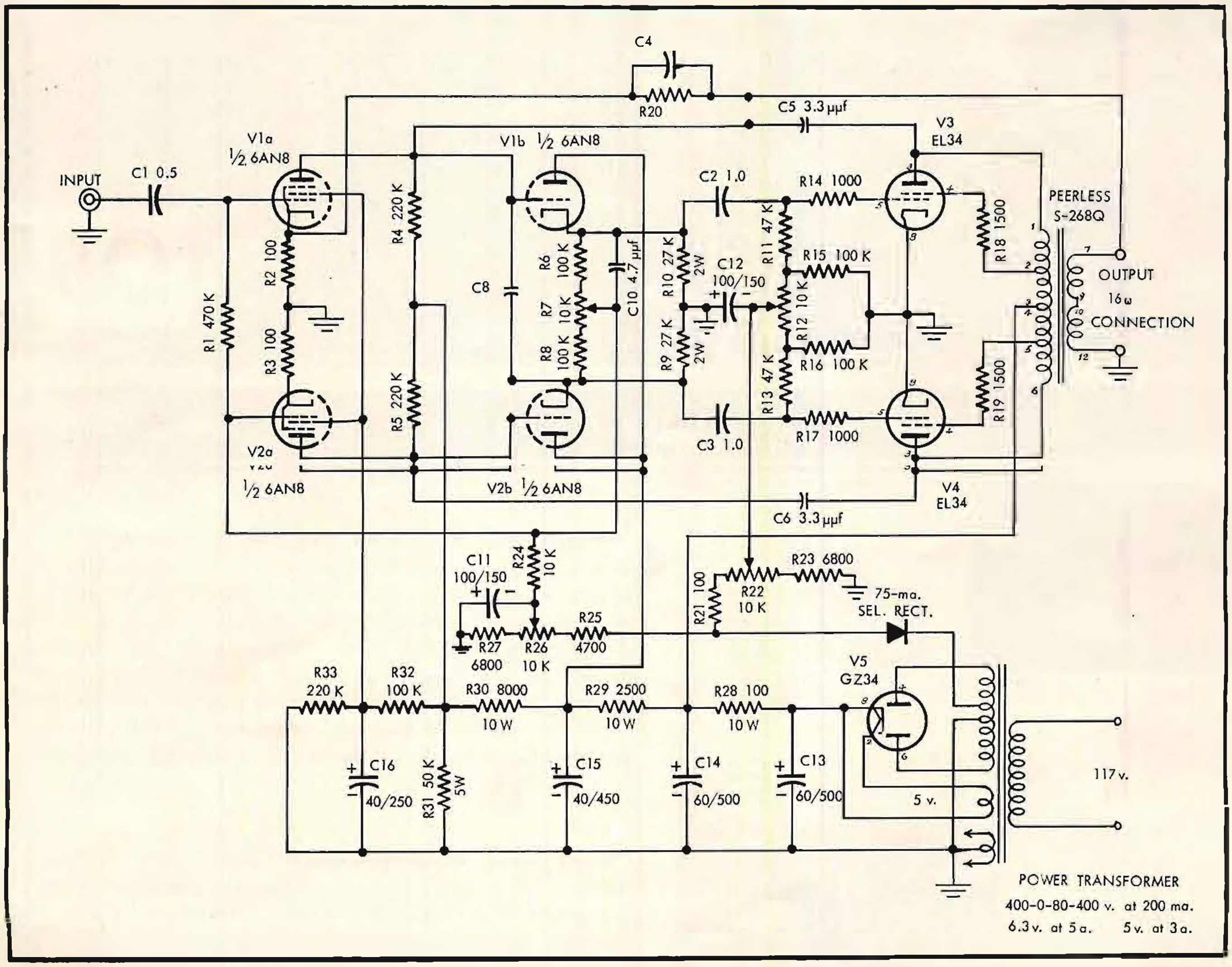

Fig. 5. The complete amplifier using a pair of EL34's in the output stage reaches a new low in distortion and unbalance.