A Ten-Watt All-Triode Amplifier

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Build this simple low-powered amplifier using a pair of relatively new dual-triodes in the output stage and see how good a small amplifier can sound—with efficient speaker systems.

In the early days of electronics the only type of tube used for amplification was the triode. The reason for this was simple; the tetrode and pentode had not yet been developed. With the discovery that higher gain could be achieved by the use of a screen grid, designers jumped on the bandwagon, and the tetrode and later the pentode were thought to render the single-grid tube obsolete.

When the emphasis on faithful sound reproduction came into vogue, audio designers were forced to do some further investigation, for listening tests (as well as refined electronic measurements) revealed some facts which had not previously been noticed. For unkown reasons (some of them still uncertain) some triode amplifiers with low power ratings sounded cleaner than equivalent pentode circuits with more than double the triode audio output.

As high-fidelity grew up, audio fans became convinced of the superiority of one or the other class of tube, and circuits were developed which proved the virtues of either triodes or tetrodes. The Williamson amplifier, which probably gave high-fidelity its biggest boost, showed that a well-designed low-power triode amplifier could reproduce cleaner sound than any of the high-power circuits used at that time.

Triode advocates, however, had a short lived victory, for, in 1953, David Hafler and Herbert I. Keroes showed that an Ultra-Linear connection of the output tubes would more than double the undistorted power output of the triode Williamson. This revived popularity in the Williamson circuit, as well as giving a great deal of publicity to the (then young) third school of output-stage thinking. Partly as a result of the publicity given to the ultra-linear Williamson, this type of connection is now very popular with amplifier designers.

However occasional circuits are still developed which are particularly suited to triode output tubes. This amplifier is one of them. 6BX7's are relatively unknown to audiofans; as far as we know no commercially built amplifier and only one published circuit uses them. In *Radio-Electronics*, February 1957, Norman V. Becker described an amplifier which delivered eight watts at less than ½ per cent total harmonic distortion from two 6BX7's and a $2.95 output transformer. Although Mr. Becker pointed out the great potentialities of the 6BX7 as an audio tube, it has not received the attention it merits.

One of the most notable virtues of the amplifier described here is its efficiency. Remember the power supply of the Williamson? It delivered 450 volts at 120 ma to the output stage. This is more than 50 watts, but the audio output was only rated at 12 watts. Our amplifier, *Fig.* 1, delivers 10 watts with a d.c. input of 25 watts; it is almost twice as efficient! An additional feature of the output stage, which uses two 6BX7's in push-pull (actually, four ½6BX7's in push-pull parallel is more accurate) is its low driving requirement; the grids require only half the signal that the Williamson output stage did.

The early stages of the circuit, *Fig.* 2, bear a close resemblance to the corresponding part of the Mullard 520 amplifier. The change here is the use of a triode voltage amplifier instead of the original pentode. A triode furnishes enough gain so that, with 20 db of feedback, the amplifier requires only 0.5 volt for full output. We did not use an input level control because such controls frequently become noisy even if they are never touched after being initially set. If you want to decrease the sensitivity of the amplifier make up a voltage divider to fit your needs, making sure that the total grid resistance seen by the 6AV6 does not exceed 0.5 megohm.

The plate of the voltage amplifier is connected directly to the first grid of the cathode-coupled phase splitter, thus providing the necessary d.c. potential for the grid. We chose this type of phase splitter mainly because of the fact that the output impedances from its two sides are equal, therefore eliminating problems of unequal high-frequency phase shift that we have encountered with the other-

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Fig. 1. External appearance of the authors' amplifier. Follow this layout for simplest wiring.

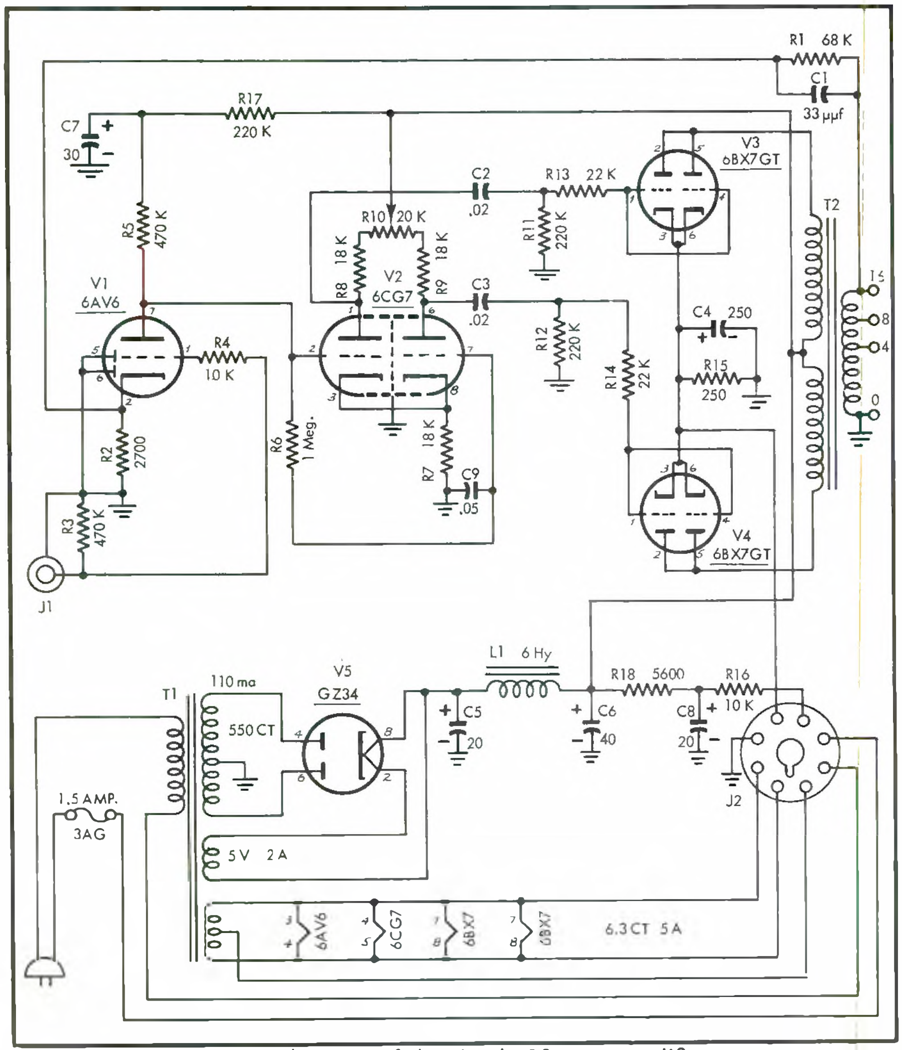

Fig. 2. Schematic of the simple 10-watt amplifier.

wise ideal split-load circuit. The balance control bears special mention. When construction is complete, connect the amplifier to a suitable load, set the control near mid-position, and feed a 1000-cps sine wave into the input. Measure the output and adjust for 3 or 4 volts across the 16-ohm winding. Then adjust the balance control for equal a.c. voltages at the *plates* of the output tubes. Adjusting for equal grid voltages is useless; it assumes that the output tubes have identical transconductance, which is rarely the case even for so called matched pairs. True push-pull operation requires that the output transformer receive equal signals from both sides of the circuit.

Since a d.c. balance control is not incorporated in the output stage, it would be wise to select the closest matched (total current drawn by both sections) of several 6BX7's. We used a choke in the power supply, so that hum will be kept below audibility even with substantially mismatched tubes. Two steps were taken to further guard against hum. First, we used a ground bus to prevent ground loops from forming in the chassis. The bus is connected to the chassis only at the input jack. The filter capacitor must be mounted on an insulating wafer and grounded to the bus. Secondly, separate prongs on the preamp socket are connected to the transformer heater winding center tap and the cathodes of the output tubes. When no auxiliary equipment is being powered from the amplifier, plug a shorting plug (jumpers from pins 6 to 7, and 4 to 8) into the socket. As well as completing the primary circuit of the power transformer, this puts a bias of about 23 volts on the heaters. If a preamp is used, pin 4 can be used as a polarizing source to connect to the slider of a filament hum balance control. Aside from these extra connections, the socket is wired to accept any standard preamp, such as EICO, Heathkit, or Dynakit. It provides 6.3 volts at 1 amp, and 250 volts at 5 ma.

We cannot emphasize too strongly that an amplifier is no better than its output transformer. We selected an Acrosound TO-250 mainly because it will deliver 10 undistorted watts from 20 to 20,000 cycles. Negative feedback can do a great deal to improve frequency response characteristics and lower internal resistance, hum, and noise, but it cannot increase power output. As a matter of fact it can *decrease* useful power output by accentuating undesirable overload characteristics. If you economize by using a less expensive output transformer, don't expect to get as much power at the frequency extremes. This is an honest 10-watt amplifier; try measuring some of the commercial 10-watters around 20 cps and see how many of them will deliver rated power in that vicinity.

Figure 3 shows the frequency response of the amplifier. The smooth, extended high-frequency range is apparent in high-frequency transients. The undistorted power output is shown in *Fig.* 4.

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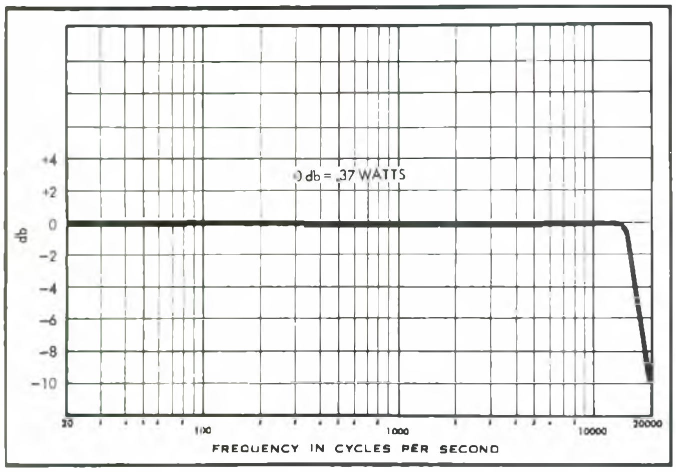

Fig. 3. Frequency response of the amplifier.

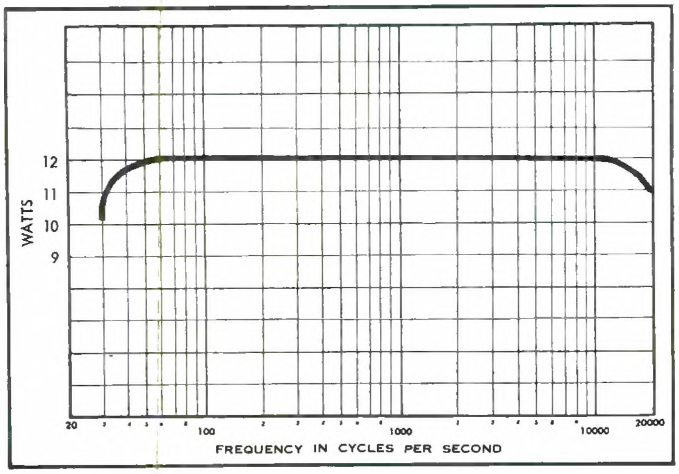

Fig. 4. Curve of power output vs. frequency.

The low-frequency power handling capacity shows up when sharp drum beats or bass violin pizzicati are passed without amplifier breakup. The high damping factor, *Fig.* 5, controls any unwanted cone movement. Some modern speakers, however, require lower damping factors for optimum results. If you are interested in lowering the damping factor of the amplifier, remove the connection from the "O" output terminal (see *Fig.* 7) to the common secondary lead (which is left connected to the ground bus) and ground it through a resistor of no more than 1 ohm. The voltage feedback should now be decreased, by increasing the value of R_1 and decreasing the value of C_1, keeping the product of the two constant. You will have to experiment with different ratios of current and voltage feedback to get the required value of internal resistance. In any case, don't use more than 1 ohm for the current feedback resistor, or too much power will be dissipated in it. Use a two-watt or larger resistor.

Figure 6 shows the underside of the amplifier. We used an 8″ × 12″ × 3″

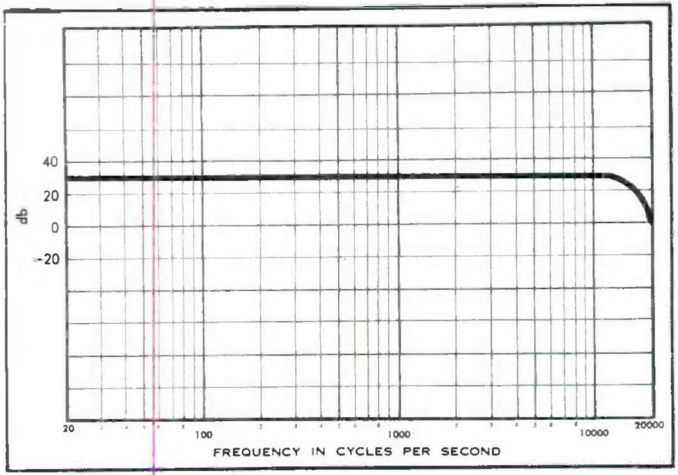

Fig. 5. Curve of damping factor vs. frequency.

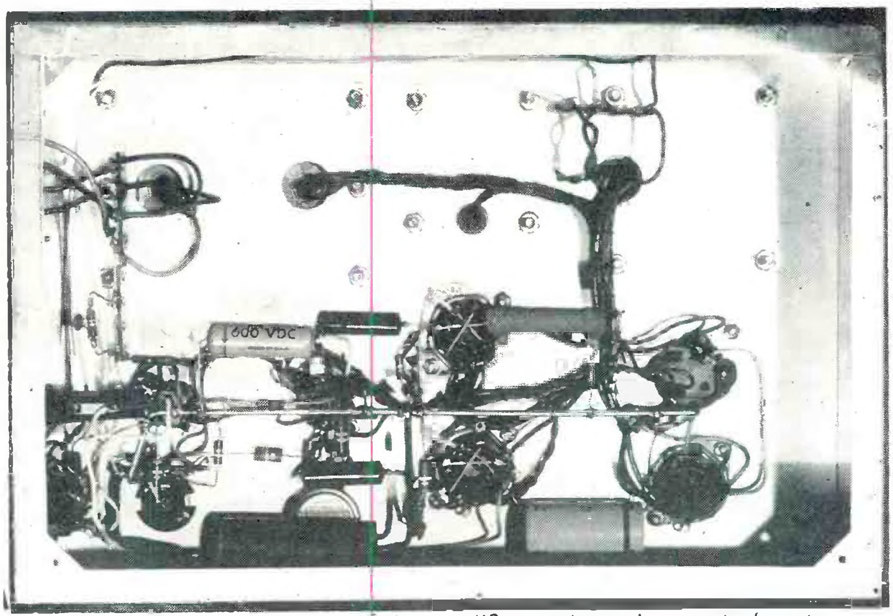

Fig. 6. Under-chassis view of the amplifier to show placement of parts.

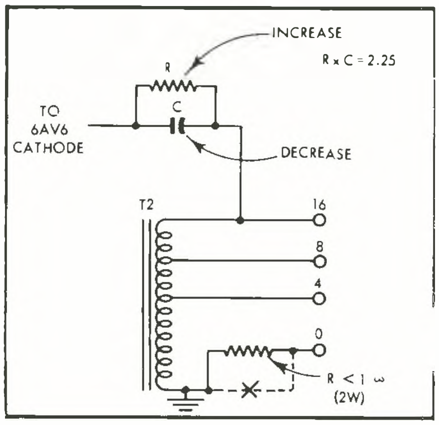

Fig. 7. Detail of changes to output circuit to lower damping factor.

chassis, and there is plenty of room underneath it. The balance control is a locking type, to eliminate tampering after it has been set. The only precatuion to observe in wiring is to keep heater leads twisted away from low level audio circuits to eliminate hum. Use direct point-to-point wiring throughout, and follow our layout (*Fig.* 1) for easiest construction as well as nice overall appearance. The output tubes are being operated at very near maximum ratings, so give the amplifier plenty of room to breathe.

Remember when you use it that this is a 10-watt amplifier, and, although it will outperform many higher powered amplifiers, it won't drive low-efficiency loudspeakers in a 20′ × 30′ living room. For efficient speakers, however, it can't be beat. Æ

Parts List

C_1	33 μμf, ceramic
C_2, C_3	.02 μf, 600 v, paper
C_4	250 μf, 50 v, electrolytic
C_5, C_6, C_7	20–40–30 μf, 450 v, electrolytic
C_8	20 μf, 450 v, electrolytic
C_9	.05 μf, 400 v, paper
J_1	Phono jack
J_2	Octal socket
L_1	6-H, 160-ma filter choke (Triad C-12A)
R_1	68,000 ohms, ½ watt, 5%
R_2	2700 ohms, ½ watt, 5%
R_3	470k ohms, ½ watt, 5%
R_4	10,000 ohms, ½ watt, 5%
R_5	470k ohms, 1 w, deposited carbon
R_6	1.0 meg, ½ watt, 5%
R_7, R_8, R_9	18,000 ohms, 1 watt, 5%
R_{10}	20,00-ohm linear potentiometer, (locking, see text)
R_{11}, R_{12}, R_{17}	220k ohms, ½ watt, 5%
R_{13}, R_{14}	22,000 ohms, ½ watt, 5%
R_{15}	250 ohms, 5 w, wirewound
R_{16}	10,000 ohms, 1 w, 5%
R_{18}	5600 ohms, 1 watt, 5%
T_1	Power transformer, 550 v, c.t., 110 ma; 5 v at 2 a; 6.13 v, c.t., 5 a. (Triad R-12A)
T_2	Output transformer. Acrosound TO-250
V_1	6AV6
V_2	6CG7
V_3, V_4	6BX7GT
V_5	GZ34