

Fig. 1. The high-fidelity, high-quality amplifier and its power supply.

# 30-Watt High-Fidelity Audio Amplifier

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A general-purpose medium-power amplifier of broadcast quality.

**T**HE LOW-MU TRIODE AMPLIFIER enthusiasts are at it again, and in view of the impracticability of some of the designs that have been offered within the past few years, the author would like to point out a few fundamental requirements that must be met by a truly high fidelity amplifier which also can furnish sufficient power to "fill" a small auditorium, for loudspeaker testing, or for driving a wax or acetate cutter. These basic requirements are:

1. *Sufficient power output and gain.*<sup>1,2</sup>

2. *Low listening fatigue*, which is primarily insured by low intermodulation distortion.<sup>3,4</sup> The distortion products should result only from second and third harmonics instead of the higher order harmonics usually generated in beam-power tubes. Single-frequency harmonic analysis is useful only in determining some of the operating parameters of the tubes and transformers involved.

3. *Good transient response*, which results in a particularly clean-cut reproduction of speech. Whistling consonants are evidence of parasitic oscillations on peaks. The specific factors responsible for good transient response are (a) good high-frequency response, (b), low phase rotation,<sup>5-8</sup> (c), low internal impedance as seen by the loudspeaker or cutting head, and (d),

low hysteresis distortion, especially at the higher frequencies, in any transformers that may be involved.

It should always be remembered that we are not dealing with sine waves in the reproduction of speech and music. This is important in the matter of phase rotation, for instance; two sine waves out of phase still add up to a sine wave, but two waveforms containing harmonics, and out of phase, add up to a new and different waveform which does not resemble either of the originals. Excessive phase shift in an amplifier sounds like high intermodulation distortion, and produces excessive listening fatigue.

4. *Good input vs. output linearity.* This demands that each voltage amplifier stage be capable of supplying several times the actual voltage required to drive the following stage.

5. *Reliability, ruggedness and ease of servicing*, both with regard to locating the faulty part and replacing it easily. This calls for the use of oil-filled or oil impregnated condensers, hermetically sealed transformers and chokes, resistors which do not get noisy with age and/or temperature variations, and tubes which are of simple design structurally, have their elements well braced, and do not have close grid-to-cathode spacing. Close element spacing offers the probabilities of high microphonism, grid emission and wide variations in electronic para-

eters with small variations in tube geometry. Glass envelope tubes usually have a lower gas content than metal envelope tubes. In addition, glass tubes are an aid to rapid servicing, as a bright spot on a cathode, a gassy rectifier, or an open filament are easily noticed.

## Design

With these elementary considerations in mind, we began the design of an amplifier. After a year of loudspeaker listening and testing with amplifiers rated at 10, 15, 20, 30, and 40 watts output, it was decided that an output of 30 watts with less than 5% total intermodulation distortion was required. We felt that this output should be obtained with triodes rather than beam power tubes: first, because the absence of a feedback loop would result in a simpler and more easily serviced amplifier; second, because the higher order harmonics generated by beam-power tubes (running up through the tenth) were considered undesirable, even though relatively low in amplitude. The value of distortion selected is so low that we felt we could ignore it when the amplifier is used in listening tests.

The output triodes were selected from a list of the following types: 50, 2A3, 6A3, 6B4G, 6A5G, 6AS7G, 3C33, RJ-563 and DRJ-564, and 300A. The first five of these belong to the same generic type, the 6A5G being a heater-

In order to obtain peak output, it is necessary to make the driver and cathode follower circuit slightly more sensitive, as the limitation lies in the phase-inverter output. Approximately 5 per cent regenerative feedback is added from cathode to cathode, increasing peak output and noticeably reducing peak overall distortion. This changes the output impedance imperceptibly because of the large amount of overall degenerative feedback. The regenerative circuit may be omitted if

Early models of this amplifier manifested a variety of motorboating. Because of the low impedance of the output stage, and its consequent control of the power supply voltage, in-phase motorboating is likely to occur due to the push-pull tubes acting as if they were in parallel. The first model using this circuit had the lower ends of the 2400-ohm driver bias resistors connected directly to minus 350. Motorboating occurred even with only the drivers and output tubes plugged in. This can be explained by regarding the minus 350 as the reference point, with ground moving up and down in voltage, depending on the drain by the output stage on the power supply. Ground is coupled to the grids of the drivers through various capacitors and resistors. A negative pulse on the grids of the drivers will cause the grids of the output tubes to become less negative, causing greater drain on the power supply. Ground and the grids of the driver will thus become more negative, and motorboating results. This interesting but undesired phenomenon was eliminated by inserting a 15,000-ohm resistor between the 2400-ohm bias resistors and minus 350, and connecting a 40- $\mu$ f capacitor from the junction to ground. As it is now connected, when ground moves up and down both the grids and cathodes move with it, and the output is practically zero.

#### Speaker Damping

The primary purpose in the design of the amplifier was to achieve unusually good damping. This has been carried to such an extent that the limit-

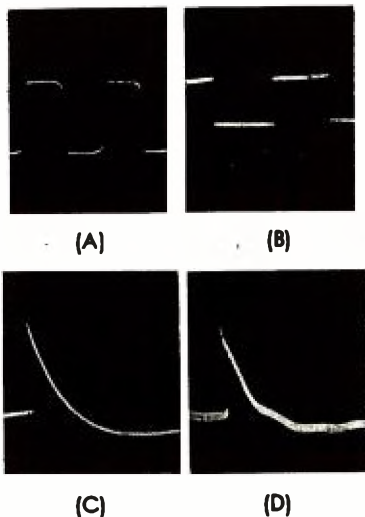


Fig. 6. Oscillograms of output for various input signals: (A) 200-cps square wave; (B) 5000-cps square wave; (C) 0.5-volt d-c pulse at input, speaker connected normally; (D) same signal as at (C), but with 10-ohm resistor in series with voice coil. Last two oscillograms show effect of damping.

ing factor is the d-c resistance of the output winding, less than one ohm. The cleanness of reproduction obtained is definitely noticeable. A good demonstration is side 4 of Columbia's "Young Person's Guide to the Orchestra", which has excellent low notes as well as the crack of a whip near the end of the record. The extreme low frequencies are more naturally reproduced because of the added control of the voice coil. There is no muddiness. Another test of the damping, somewhat analogous to definition in a camera lens, is the separation of rapidly rolled drumbeats.

It is usually suggested that the output of a tweeter be reduced by means of a resistor network, because it is higher in efficiency than a woofer. In listening tests it has been found tentatively that the introduction of a resistance in series with a good compres-

sion type tweeter reduces its sharpness and clarity, making it sound like an ordinary cone type tweeter. It is thus suggested that other methods might be tried, such as multiple tweeters spreading the sound more widely, for example.

The amplifier is used primarily in our "Gilson", a radio-phonograph combination using a Jensen 18-inch theatre speaker with two Jensen tweeters. Passably good reproduction can be obtained, however, even with a 15-inch speaker designed for home use, because of the control of the voice coil.

The frequency response is shown in Fig. 4, the total harmonic distortion in Fig. 5. The deviations shown cannot be detected by the ear.

Figure 6 shows oscillograms taken from the 16-ohm voice coil of a 15-inch speaker. The response to a square wave at 200 cps is shown at (A), at 5000 cps at (B).

The effect of damping is demonstrated at (C) and (D). A 0.5-volt d-c pulse is applied to the input, producing a transient, the shape of which depends on a number of factors. (C) shows the lack of overshoot and smooth exponential return as the coupling capacitors discharge. At (D), a 10-ohm resistor has been connected in series with the 16-ohm voice coil. The potentials produced by the marked overshoot and continued vibration of the voice coil can clearly be seen.

Reference to the photograph of the underside of the chassis may occasion some question as to the reason for the small channel-frame transformer. It supplies filament current to a tuner used with this amplifier, but is not shown on the schematic.

The output transformer specified in the original circuit is a UTC LS-6LA, but equivalent results should be expected from ADC type 315G, Freed F-1967, Langevin, 316A, Peerless S-245-Q, or Triad HS-94. With respect to the power transformers, it is obvious that the least costly arrangement is that shown, employing two transformers in parallel. It must be remembered, however, that the two transformers used must be identical, or a certain amount of circulating current will flow in the secondaries. If it should be desired to employ only one power transformer, any of those listed below should be adequate. Some of these substitute transformers may be capable of furnishing a reasonable amount of heater current for an additional tuner or a control amplifier. The suggested substitutes are: UTC CG-431, Langevin 100B, Peerless R-800-A, or Triad R-24A.

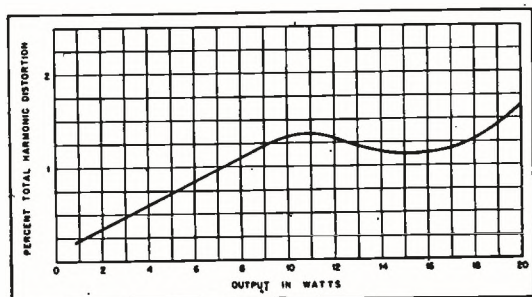


Fig. 5. Total harmonic distortion vs output at 50 cps.

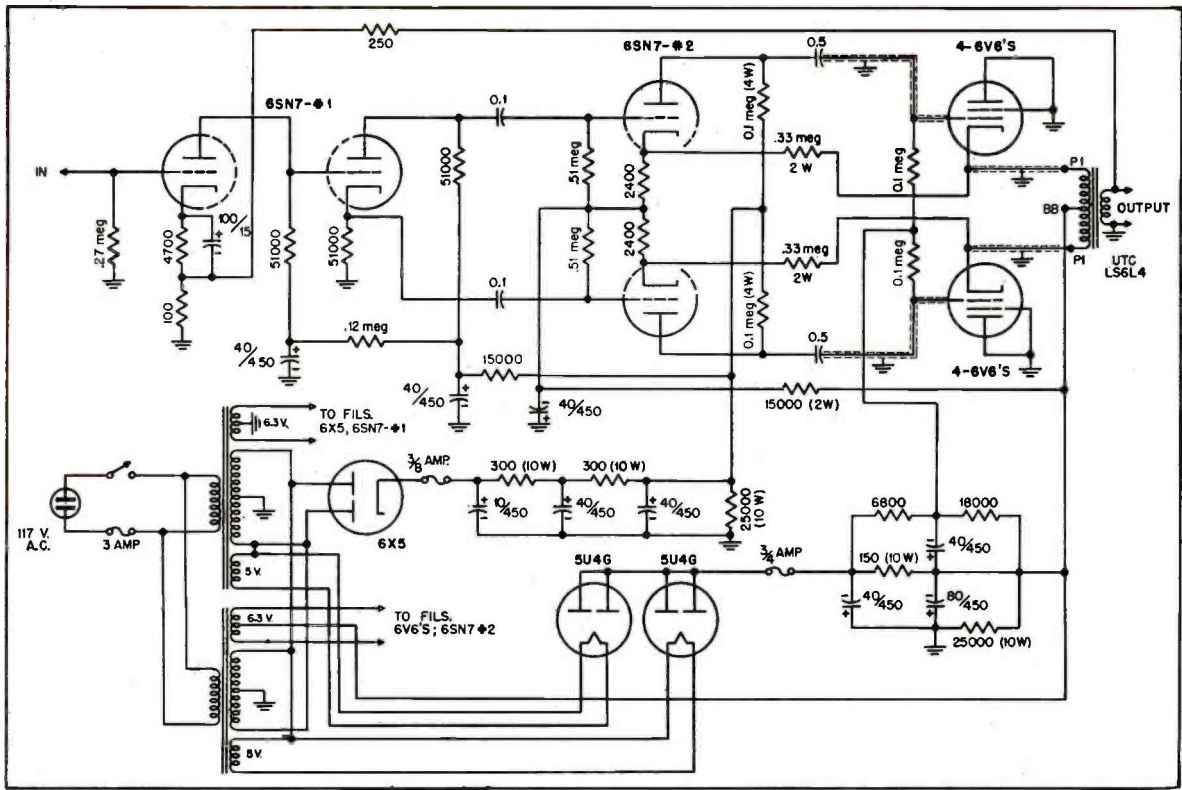


Fig. 3. Overall schematic of complete amplifier and power supply.

Considerably better damping can be obtained with a cathode follower amplifier. This type of audio output circuit has seldom been used, probably because of the high driving voltage required. The present circuit has been developed to provide adequate output with an economical source of distortion-free high driving voltage. The circuit appears slightly unconventional, but there is a definite reason for all of the departures from the usual. The amplifier is shown in Figs. 1 and 2.

**Driving Voltage**

The driving voltage is obtained by using a resistance coupled 6S7 with a plate supply voltage of 700, and a plate voltage of 300. The cathode follower output requires high current at low voltage, and the preamplifier stages require low current at low voltage. To fulfill these requirements, two SNC transformers are used with their high-voltage secondaries in parallel. The combination is then rated at 350 volts each side of the center tap, at 300 ma. Two 5-volt and two 6.3-volt windings are also available. One of the 6.3-volt windings, with its center tap connected to ground, is used for the heaters of the early amplifier stages and for the 6X5GT rectifier, which supplies 350 volts above ground at low power for

these stages. The two 5-volt windings are used for the two 5U4G rectifiers, which are connected in the reverse of the usual manner to provide 350 volts below ground at high power, for the output stage. There is a total difference of 700 volts, across which the driver stage is operated. The remaining 6.3-volt winding, which has its center tap connected to minus 350, supplies

the heaters of the driver and output stages.

The bias for the final stage is obtained from the pulsating d-c voltage drop across the 150-ohm filter resistor, which voltage would otherwise be wasted. This is voltage-divided and filtered and gives a 25-volt negative bias which is highly stable.

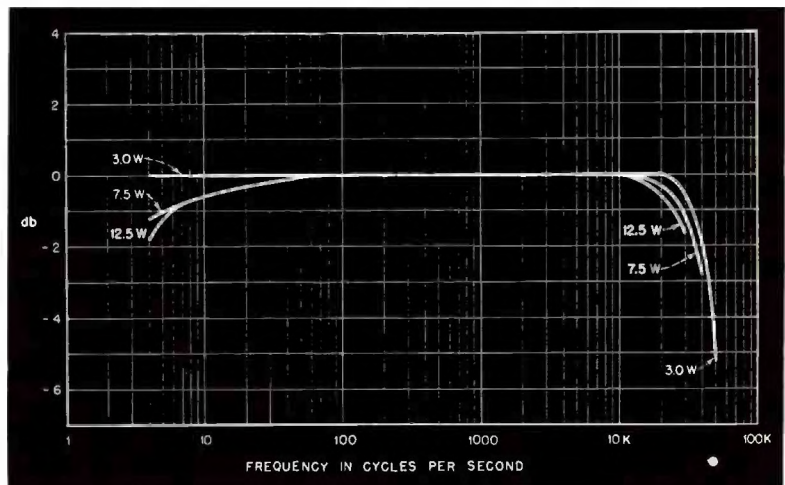


Fig. 4. Frequency response curves at different output levels. Note that range extends from 4 cps to well over 30 kc.