Amplifier Uses Cheap Output Transformer

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Pleasant sound does not necessarily mean highest fidelity. It can be obtained with inexpensive output transformers and by using feedback. The authors show designs for single-ended and push-pull jobs.

THE AUTHORS SET OUT to explore the possibilities of obtaining high fidelity from the average service-replacement output transformer produced by leading transformer manufacturers. These generally sell for about $3.00, with those intended for higher outputs running up to about $6.00. They generally have a primary inductance of 7 to 10 henries depending upon whether they are intended for single-ended or push-pull operation.

It is the low load presented by the primaries of these transformers which would ordinarily prevent their use in connection with quality amplifiers. The gain of the output stage depends upon the matching of the plate impedance of the tube used and the impedance produced by the inductance of the primary of the output transformer. Thus, a tube with a high plate impedance requires greater impedance from the primary inductance for good results. Moreover, to obtain the same response in the bass frequencies as in the middle frequencies also necessitates a high inductance, because the impedance of the inductance falls off proportionately to the decline in frequency.

To get the best results from these transformers then requires that they be used in conjunction with output tubes which require relatively low-impedance loads such as the 6B4 and the 6L6, which operate satisfactorily with loads of 2500 ohms, and the 6Y6 and 50L6, which will do likewise with loads of 1500 to 2000 ohms.

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Uniformity of response can be obtained by using inverse feedback in a proper circuit. For example, 6 db of feedback in the circuit of *Fig.* 1 will flatten out the response of such a transformer, when used with a 6L6 in the output stage, down to 100 cps. Twenty db feedback will flatten out the response down to 20 cps (see *Fig.* 2). These results are much like those obtainable from increasing the primary inductance by like factors.

Such a transformer when used in the circuit of *Fig.* 1 without R_5 and fed into a resistive load produced the following harmonics: at 100 cps:

Watts	2nd	3rd	4th	5th
1	8.5%	0.49%	0.28%	0.12%
2	12.0	0.68	0.50	0.10
6.5	20.0	2.00	2.80	1.60

At the same frequency but with the application of a factor of about 20 db of inverse feedback through R_5 from the secondary of the output transformer the following harmonics were produced:

Watts	2nd	3rd	4th	5th
1	0.80%	0.13%	0.01%	.03%
2	1.20	0.30	.065	.04
4	2.20	0.90	0.32	0.16

Under the same conditions but with an input frequency of 1000 cps the following harmonics were produced:

Watts	2nd	3rd	4th	5th
1	0.34	0.14	.02	
2	0.66	0.24	.05	
4	1.20	0.52	0.15	.04
6.5	1.6	0.90	0.32	0.14

From these tabulations several conclusions can be drawn. First, for the reproduction of speech and treble instruments this is a very fine amplifier. Second, that the harmonic distortion is reduced roughly by the factor of inverse feedback. Third, that the difference in the amount of distortion resulting at the two frequencies at which the measurements were made corresponds roughly to the factor of difference in gain response without inverse feedback at the two frequencies.

In an effort to follow up these conclusions and obtain further improvement a 6SJ7 was substituted for the 6SF5 in the driver stage of *Fig.* 1. The higher gain of the 6SJ7 would permit more inverse feedback. As the cathode was not bypassed a further improvement of 25 per cent in gain, and so also in the amount of inverse feedback, was obtained by connecting the return lead of the screen bypass capacitor directly to the cathode instead of the usual connection to ground. Since the screen is

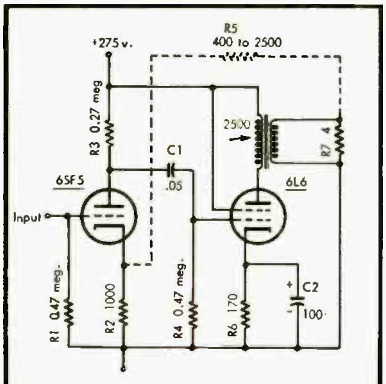
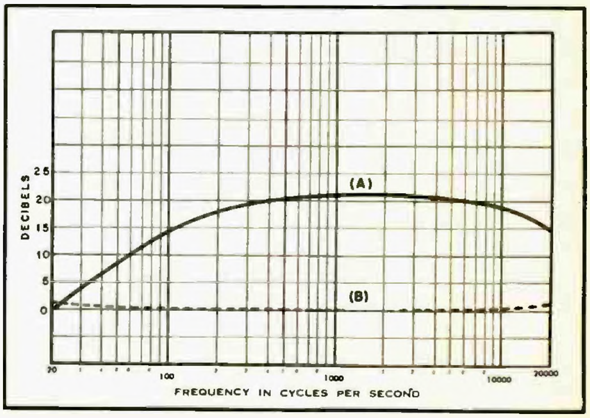


Fig. 1. The basic circuit employs feedback from the transformer secondary. Value of R determines feedback.

Fig. 2. Curve (A) shows original frequency response of Fig. 1 amplifier without feedback. Adding 20 db of feedback gives response of curve (B).



really acting as the plate of a triode this change in circuitry avoids degeneration caused by permitting a.c. from the screen to pass through the cathode resistor.

It was further observed that to get the same amount of inverse feedback at 60 cps as at 400 cps it was necessary to increase the screen bypass capacitor from 0.5 to 8 µf.

By connecting the plate of the output stage through a resistor and capacitor to the cathode of the driver stage as shown in *Fig.* 3, a further increase in inverse feedback can be obtained. However, on checking the over-all response of this arrangement it was found that with a feedback of only 16 db in the middle frequencies there was no response at 20 cps and that above 800 cps there was a gradual loss which amounted to 10 db at 12,000 cps. This meant that there was positive feedback present and more of it at the treble frequencies. The squeals which emanated from the loudspeaker when rotating the dial of the FM tuner showed that there was oscillation. This approach was, therefore, abandoned.

A 6SH7, which has a higher gain than a 6SJ7, was then substituted, and two loops of inverse feedback were employed. The loop through R_7 in *Fig.* 4 served to flatten out the response from the output transformer and to reduce any tendency to oscillate. It also produced a sweeter "feel," much like that of a triode, which the 6L6 resembled after this reduction in its gain. A 6AU6 may be substituted for the 6SH7, but a 6BC5, 6CB6, or 6AG5 cannot be used as these radiate badly.

The following factors of inverse feedback were obtained from the amplifier

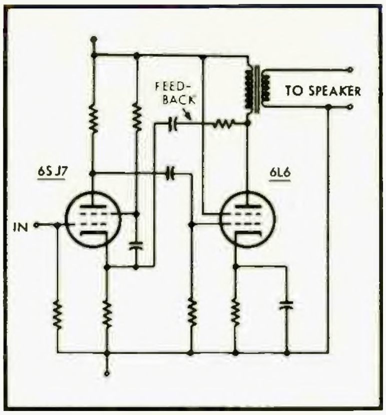


Fig. 3. Obtaining the feedback path from the plate of the output tube gave higher feedback but poorer response.

shown in *Fig.* 4 while using a Stancor A-3830 output transformer:

Frequency	1st Loop	2nd Loop	Total
60	2.8 times	6.5 times	18.2 times
400	4.2 times	6.5 times	27.3 times

With this amplifier signals were heard below 20 cps and a slight loss of amplification was measured at 300 kc. The break-up of the sine wave on the oscilloscope (generally at 3 per cent total harmonic distortion) at 60 cps occurred at 3 watts, and at 400 cps at about 4 watts. Amplifiers which employ large amounts of inverse feedback show low distortion up to a point which is considerably below the ratings published in the tube manuals and beyond which there is a sharp and very great increase in harmonic distortion. Based upon the above tables and compensating for the increase in feedback, it is estimated that at the 400–1000-cps point at just below 3 watts there should be less than 1/3 of 1 per cent harmonic distortion, and at the 60-cps point, after allowance for the lower frequency, 1.5 per cent harmonic distortion.

Where a tone-compensator stage is desired and where a variable-reluctance cartridge is to be used, the circuit shown in *Fig.* 5 is suggested. It may be necessary to increase the values of either the capacitor or the resistor, or of both, in the decoupling circuits at points A or B in order to overcome motor-boating, which can occur in this amplifier at a frequency as low as one half cycle per second.

A pair of 50L6's connected in push-pull were tried in the circuit shown in *Fig.* 5. An inverse feedback factor of about 7 and an undistorted output of about 3 watts was obtained at 60 cps. Less inverse feedback was needed for this result because the push-pull operation cancelled nearly all the 2nd and 4th harmonics and also the magnetizing effect of the d.c. in the windings of the primary of the output transformer. This latter raised effective input inductance. The 3-megohm volume control R_1 permitted the use of a broad-range crystal cartridge. Capacitor C_1 and resistor R_2 furnished some Fletcher-Munson compensation. Capacitor C_2 served to overcome losses in the shielded cable from the pick-up to the amplifier and also to afford some Fletcher-Munson compensation in the treble frequencies. Various values of C_2 should be tried until the most pleasing result is obtained. An FM tuner with a 1-volt output could be used to drive this amplifier to nearly

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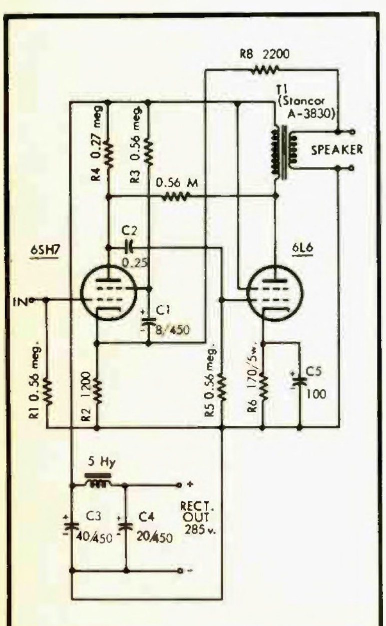

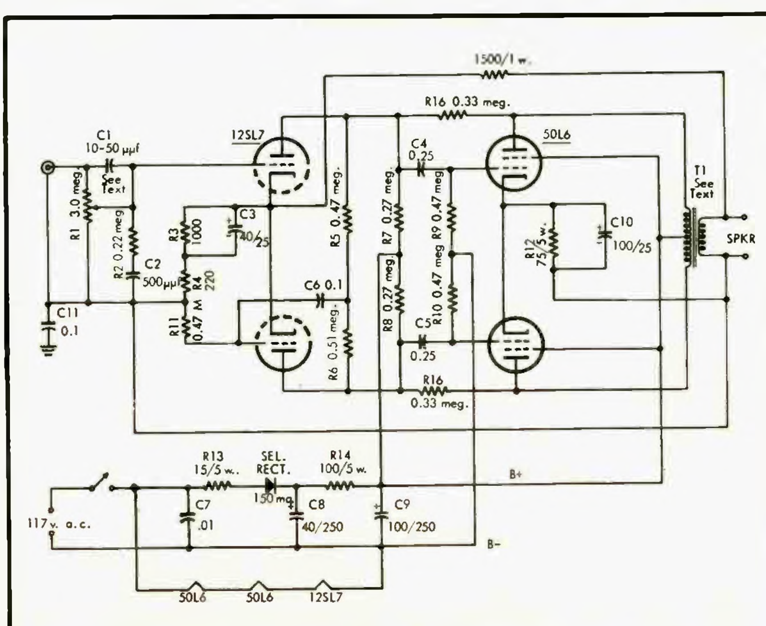

Fig. 4. (left) The final single-ended amplifier, with two feedback connections, one from the plate of the output tube to the plate of the 6SH7 and the other from the secondary of the transformer to the 6SH7 cathode. Fig. 5. (right) The push-pull version of the amplifier.

full output. It may be necesary to change the polarity of the power line to reduce hum.

These amplifiers are suitable for home use where all that is needed is an amplifier capable of delivering 2 watts undistorted at 60 cps with a flat response from 20 to 20.000 cps. (Below 60 cps there is very little program material and most loudspeakers produce a great deal of harmonic distortion.) As a matter of fact, with the present higher-efficiency loudspeakers and loudspeaker housings an input to the loudspeaker of 2 watts bass is more than enough to reproduce symphony music in the average living room; and continuous operation at this level is sure to make the neighbors complain.

Although it was not tried, it is very probable that by raising the plate voltage in the circuit of *Fig*. 5 to 135, better than 5 watts undistorted power output can be obtained at 60 cps. If a transformer supplying 6.3 volts is available for the filaments, 6Y6's can be substituted for the 50L6's. The cathode-bias resistor of the output stage R_{11} should then be increased to 120 ohms. A B supply of 135 volts is shown in *Fig*. 6.

Several amplifiers were constructed in accordance with the circuits in *Fig* 4, in which the following transformers were used with excellent results: Stancor A-3825; Thordarson T22S60. A Thordarson 22S74 (costing about $5.00) was used in the circuit of *Fig*. 5 with 6L6's and the following changes: B+, 285 volts; primary impedance, 5000 ohms; R_{11}, 125 ohms; R_{11}, R_{11}, 400.000 ohms. With these changes the undistorted power output at 60 cps on the oscilloscope was 11 watts. A Stancor A-3830 was also used in a similar amplifier with the additional change of substituting a 12AX7 for the 12SL7. With the 12AX7 it was found necessary to remove the output transformer, which was not shielded, from the chassis and mount it on the loudspeaker frame, and also to connect a 100-μμf capacitor from the plate of the input half of the 12AX7 to ground to cut out high-frequency oscillation. Despite this, there was a subtle difference in "feel" between the 12AX7 and the 12SL7 in favor of the former.

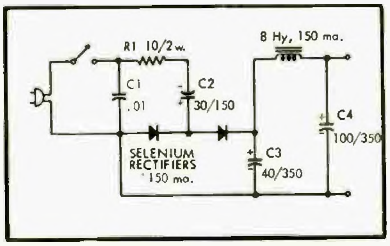

Fig. 6. A 135-volt power supply for the push-pull amplifier.