Back to Class "B" for Home Use

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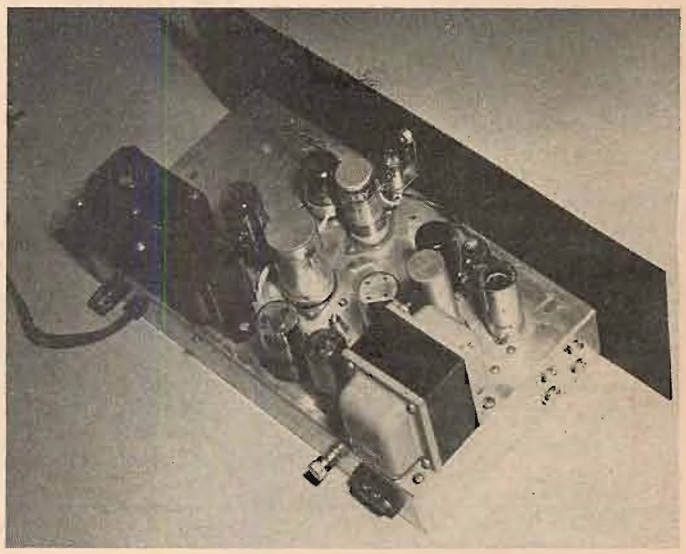
A re-study of the requirements of Class B has yielded an amplifier design which can be compact and efficient, and yet be capable of good quality.

In recent years the interest in high-fidelity sound reproduction has gathered momentum, and the sale of equipment designed for this purpose has assumed all aspects of a major industry. The designers and so-called "hi-fi experts" have constantly come up with "bigger" and "better" amplifiers to supply the ultimate in sound reproduction. Many amplifiers designed for home use are overdesigned, both from the standpoint of power handling capacity and the amount of steel and copper that goes into these amplifiers. Needless to say that the cost, installation and proper ventilation of these monstrous amplifiers has burdened the hi-fi enthusiast unnecessarily. As far as power output requirement is concerned, 10 watts is about as much as the average listener will ever use in a living room.[1] Even if we were to completely disregard the requirement of the listener and design the amplifier for the maximum power that the loudspeaker can handle without too much distortion, we find that even the best 15-in. direct radiator loudspeakers produce about 3 percent distortion with 10 watts input power.[2] To feed these loudspeakers with more than 10 watts would, therefore, be absurd when high-fidelity reproduction is desired.

The amplifier described here is an example of a high-quality amplifier for home use, incorporating all necessary controls for proper sound reproduction and tone control, yet weighing only nine pounds and consuming less than half the power of comparable 10-watt amplifiers.



Compact yet neatly laid out, and with a 10-watt output.

With an amplifier as light and compact as this, there was no need to separate the controls and preamplifier from the main chassis. In order to make the amplifier as light as possible, it was decided to use a class B amplifier in the output stage. Since this was intended to be a high-quality amplifier, a large amount of negative feedback is necessary. This requirement as well as that of light weight excluded the possibility of using transformer couplings. Cathode-follower drivers were used occasionally where economy of the circuit was a prime consideration. Here the cathode follower driver is used in a manner consistent with the requirement for high-quality sound reproduction.

The output stage consists of a single 6N7 operated in class B. In order to obtain the necessary low impedance for the grid circuit of the class B stage, a cathode-follower driver was used. The use of a cathode-follower driver is superior in many respects to the conventional transformer driver. For one thing, it would be virtually impossible to apply an appreciable amount of negative feedback with transformer coupling due to the phase shift in the transformer. Furthermore, a high quality class B coupling transformer costs about 7 to 10 times as much as a tube.

Cathode Follower Driver

Figure 1 shows a simplified schematic diagram of a cathode follower V_1 driving a class B stage V_2. As long as there is no grid current flowing in V_2, the cathode follower presents no problem. The gain of the cathode follower is then:

$$A = \frac{e_k}{e_g} = \frac{\mu}{1 + \mu + \frac{r_p}{R}} = const. \qquad (1)$$

Under zero grid current conditions the only load on the cathode follower is the cathode resistor R. Since μ and r_p remain constant under these conditions, the gain also remains constant.

As soon as V_2 begins to draw grid current, the cathode follower load changes. This new variable load r consists of the cathode resistor R in parallel with $r_g : r = \frac{R \times r_g}{R + r_g}$, where r_g is the variable grid resistance whose magnitude is a function of the magnitude of the driving voltage under grid current conditions. The gain is no longer constant and is a function of the magnitude of the driving signal. For any particular driving signal amplitude this gain is:

$$a = \frac{\mu}{1 + \mu + \frac{r_p}{r}} \qquad (2)$$

Since r decreases as the driving signal increases, we should expect the gain a to decrease also and introduce nonlinear distortion. This would indeed be so if r_p remained constant under grid current conditions. Fortunately, r_p changes also under these operating conditions in a manner that tends to make the ratio r_p/r nearly constant. Indeed, we can

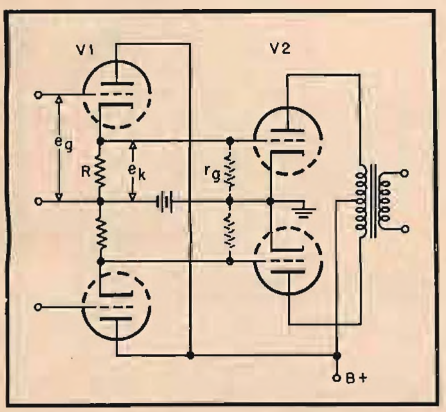


Fig. 1. Simplified schematic of cathode follower driving a Class-B stage.

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create an operating mode of the cathode follower under which the ratio r_p/r remains within reasonable limits.

Figure 2 shows a plot of plate resistance *vs.* grid bias for a triode. It can be seen that the plate resistance decreases as the grid bias becomes less negative. Since the bias resistance under grid current conditions consists of $r = \frac{R \times r_g}{R + r_g}$ and the value of r decreases with driving signal, the plate resistance also decreases which tends to make the ratio r_p/r constant. If we were, therefore, to set the bias of the cathode follower by adjusting R to such a value that the rate of decrease in r_p corresponds to the rate of decrease in r under grid current conditions, we would in effect keep the gain constant. By suitable choice of driver tube and value of R the ratio of r_p/r can be kept within tolerable limits.

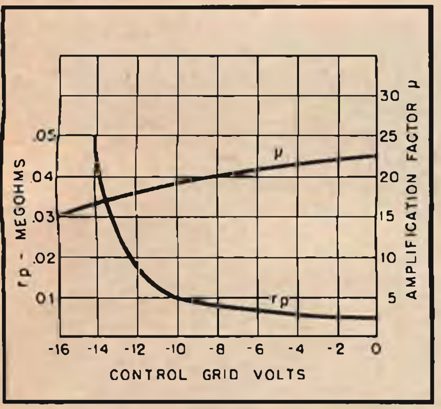
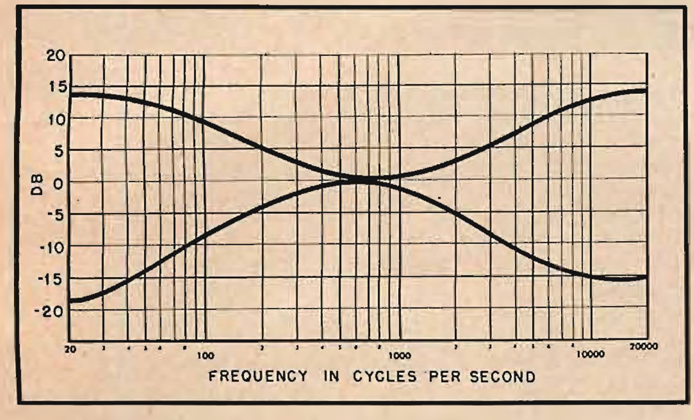


Fig. 2. Graphs of plate resistance vs. grid bias for a triode and of μ with respect to the ratio r_p/r.

Upon examining Eq.(*2*), we see that if we choose a high μ tube, in addition to the above mentioned design procedure, we can effectively nullify whatever discrepancy there remains in the ratio r_p/r. The fact that μ rises with increasing grid current also helps matters considerably (see *Fig. 2*).

It would seem from the foregoing that any of the high μ high-transconductance double triodes, such as the 12AT7 or 6BQ7-A, should be a suitable choice for this type of cathode follower. Investigation showed, however, that it was hard to select such a tube in which both elements of the double triode were properly matched for balanced operation.

It is also desirable that the cathode follower have a gain as near unity as possible so that the stage feeding the cathode follower is not taxed too heavily. From Eq. (*2*) it would seem that a tube with a high μ and low plate resistance would be desirable.



Curves showing tone-control range for the author's amplifier.

In the actual design the 6SN7 was chosen as a reasonable all around compromise.

The output stage bias voltage is applied by way of the driver cathodes. The bias voltage is adjusted to a value which yields a quiescent current for both sections of the 6N7 tube of 12 to 15 ma. With the output stage so adjusted, a power output of 10 watts was obtained with only 1.3 percent distortion and 15 db negative feedback. The plate circuit efficiency was measured to be over 65 percent. As a result the power transformer in this amplifier can be kept very small. A power transformer with a rating of 40 to 50 ma for the plate winding is ample. The output load impedance was chosen at 20,000 ohms. This value yielded maximum plate circuit efficiency and required less grid driving power than the normal recommended plate load.

In order to obtain a low impedance bias supply for the output stage, the positive terminal of the d.c. filament supply for the preamplifiers was grounded, leaving the negative terminal available for bias purposes.

Other features of the amplifier include a two-stage preamplifier for magnetic cartridges with a choice of equalization having turnover points at 250, 500, and 800 cps; a five position program selector for tape, phono, AM, FM and TV; continuous bass and treble controls (see *Fig.* 3) and a high-frequency cutoff filter to limit the response of the amplifier when playing noisy or distorted records. The power amplifier is shown in *Fig.* 4.

The Cutoff Filter

In order to provide a high rate of attenuation, the cutoff filter was designed as a three-section filter using a constant-*k* middle section and two *m*-derived terminating sections; and to prevent ringing, the corner at the cutoff

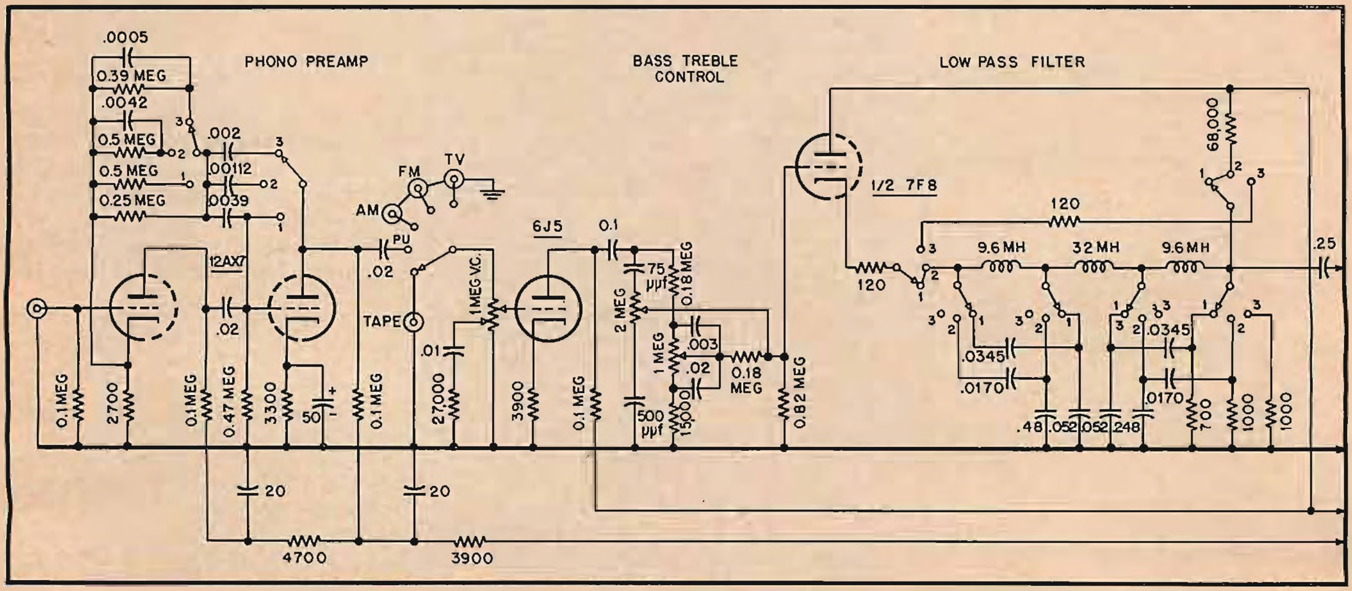
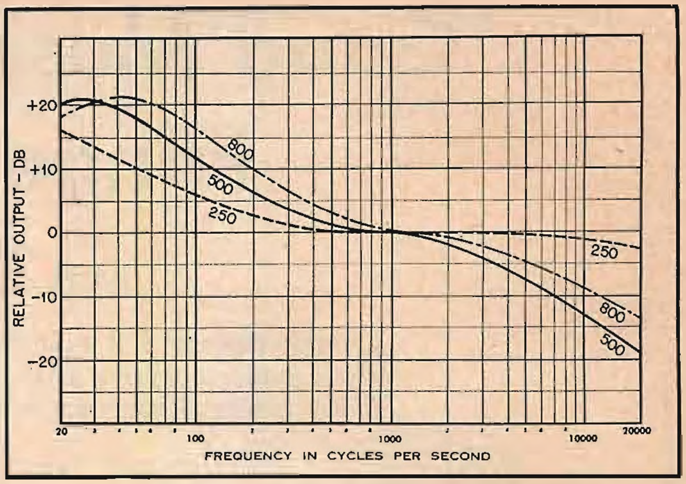


Fig. 3. Input section of the amplifier. This is built together with the output section, Fig. 4.

point was well rounded by controlling the Q of the coils. The inductances are fixed and the variable cutoff is obtained by changing the capacitors as well as the termination impedances. The characteristic impedance of the filter was chosen to be quite low to minimize hum problems. The required low input impedance is determined by the impedance of the cathode follower, which, in turn, is controlled by the bias of that tube. In the 7,000-cps cutoff position the output impedance of the cathode follower is 570 ohms. This value of cathode follower impedance was obtained by adjusting the bleeder current through the terminating resistor. A 130-ohm series resistor with the cathode raises the source impedance to the desired 700 ohms. In the 10-kc cutoff position the characteristic impedance is 1,000 ohms. The operating mode of the 7F8 cathode follower was so chosen that a fixed bleeder current of 2.85 ma through the termination resistors will yield the image of that impedance at the input of the filter. Thus, if 5,000 or 13,000 cps cutoffs were desired, it would only be necessary to change the terminating resistor to 500 and 1,300 ohms respectively. Of course, additional switch positions and tuning capacitors would be required in that case. This bleeder current also helps to decrease the cathode follower plate voltage variations when the power supply impedance is large. A switch position is also included in which the filter circuit is bypassed to provide a flat response position.

A balancing control is incorporated in the driver stage to balance the bias for the 6N7 tube.

It should be pointed out that although



Response curves from the preamplifier section—tone controls flat.

this amplifier was designed to deliver only 10 watts, there is no limitation on cathode follower drive for class B operation. The circuit used here can very well be adopted to amplifiers of multikilowatt size, such as would be required for transmitter modulators. The saving in cost and improvement in performance become more pronounced as more power handling capacity is required.

Appendix

The class-B stage driven by a cathode follower can be made practically immune to "notch" response caused by plate current cut-off in the presence of output transformer leakage inductance. This is accomplished by operating the output tubes at a slightly higher current than would be dictated by maximum efficiency requirement and deliberately choosing a slightly higher output impedance than called for by other considerations. When these precautions are taken and the cathode-follower load resistors are so adjusted as to cause the cathode follower to cut off before the output tubes cut off, "notch-free" operation will result. In this respect, the cathode follower is superior to the conventional input transformer.

It should be apparent that a cathode-follower driver used in conjunction with the precautions mentioned above should also make an ideal driver for class AB stages for "notch-free" operation. Under these conditions, a cathode-follower driver is vastly superior to a distortion free class A, R-C driver.

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[1] Harry F. Olson, "Matched line of hi-fi equipment." Audio Engineering, August, 1953.

[2] H. F. Oson and A. R. Morgan, "A high-quality sound system for the home." Radio & Television News, November, 1953.

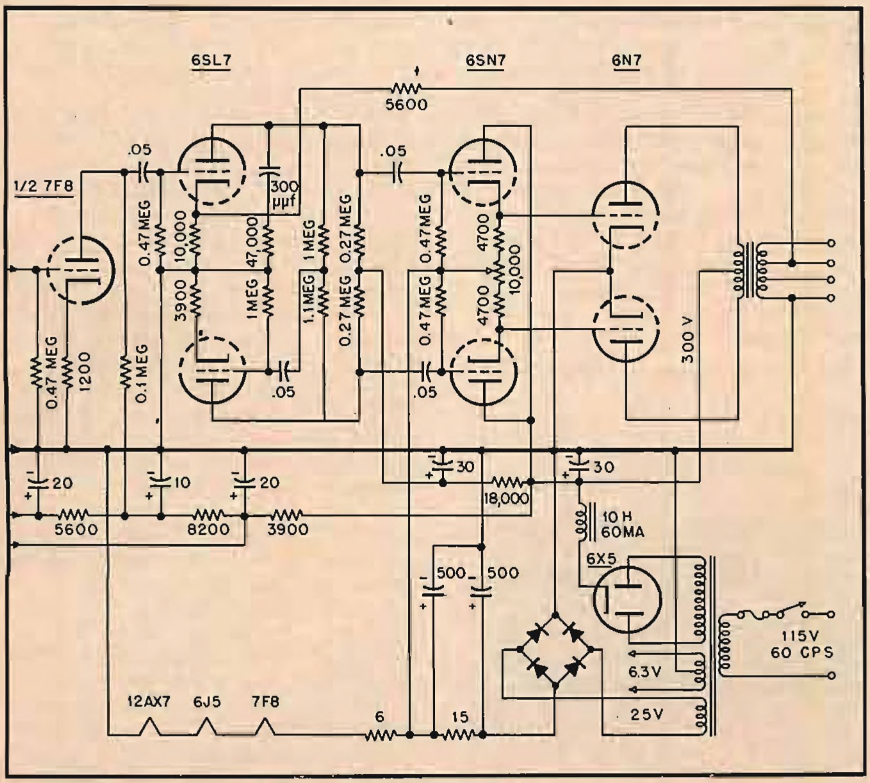

Fig. 4. Output section of the amplifier.