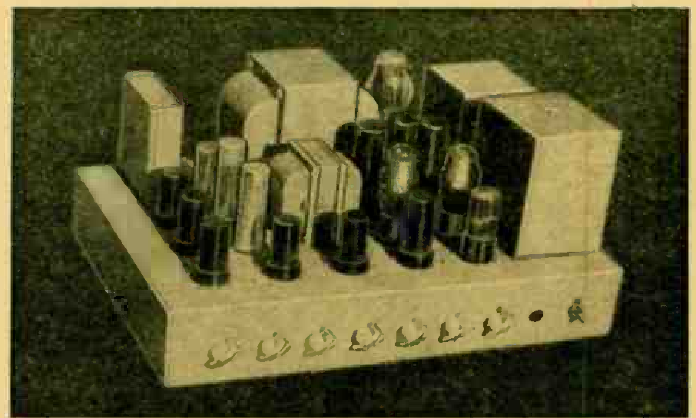
Hi-Fi 35-Watt Amplifie·



Front of the 35-watt high fidelity public address amplifier.

The author describes a good amplifier and tells how he obtained the design figures

By H. R. E. JOHNSTON

THE primary consideration in the design of a PA amplifier for the reproduction of music is frequency response. It is easier to extend the frequency range of an amplifier than it is to eliminate the hum and distortion that an extended frequency range usually reveals. As power is increased the problem becomes increasingly difficult.

Tentative specifications of our proposed new amplifier were:

1. Frequency response flat ±¼db from 50 to 15,000 cycles;
2. Distortion less than 1%;
3. Hum level 62 db down from full output;
4. 18-db negative feedback;
5. Bass boost and attenuation;
6. Treble boost and attenuation.

To be sure of obtaining results approaching these specifications, a great deal of theoretical work was done before construction was started. The design considerations as well as the finished product may be interesting to readers.

For low-power applications, low-mu triodes operating class A give good results and offer no problems in design. As power increases, class-A operation becomes prohibitively inefficient. To keep the power input within reason for power (20 to 40 watts output), class-AB1 operation is necessary. It is also necessary to use pentode or beam-power tubes in the output stage.

The second-harmonic distortion generated in class-AB1 operation is easily eliminated by connecting the tubes in push-pull. Distortion due to imperfect voltage regulation is a different matter and is more difficult to eliminate.

The usual procedure for reducing distortion when beam-power tubes are used, is to apply 10% negative to feedback from the plates to the grids. When 10% negative feedback applied to 6L6's, distortion is reduced by slightly more than half, or 6 db. The tube manuals rate 6L6's operating class AB1 at 2% distortion. Theoretically then, 10% negative feedback should reduce this distortion to less than 1%

However, the figure of 2% distortion is valid only when the tubes are working into a pure resistive load and with perfect regulation of all voltages. But under actual operating conditions, distortion is usually much more than 2%.

In the amplifier illustrated, this problem of distortion was attacked from both ends. First, by increasing the negative feedback factor and, second, by improving the voltage regulation. Ten percent negative feedback over one stage was not considered adequate. It was decided that the feedback factor must be increased either by increasing the gain A in the feedback loop or the percentage of output voltage B fed back. The most practical method was to increase A by applying negative feedback over 2 stages instead of one. The factor A then becomes A1A2 where A1 is the gain of the driver stage and A2 the gain of the output stage.

The gain of the driver stage is 9. The coupling network (explained later) introduces a loss of 1/3 or a gain of 2/3, and the output stage has a gain of 13. The total value of A in AB is 9x2/3x13 or 78. The negative feedback factor is 10% or —0.1, and is obtained from a separate winding on the output transformer. AB is then 78x(—0.1) = —7.8.

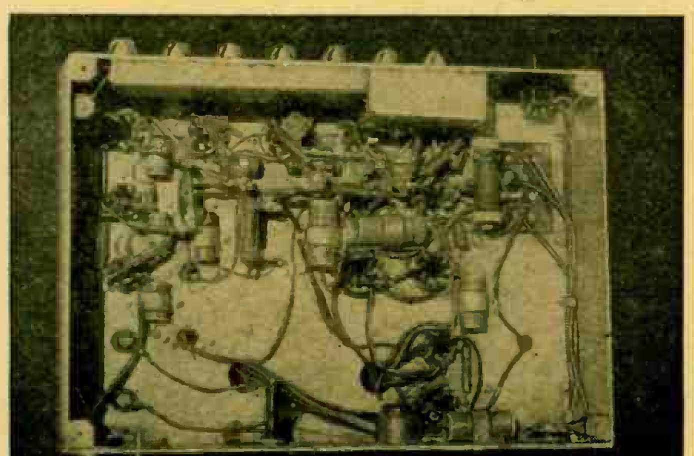
Hum and distortion reduction

1-AB is a factor by which the percentage of distortion without feedback is divided to determine the amount of distortion *with* feedback, and in this case is 1—(—7.8) or 8.8. Assuming that distortion within the tube is 3% and distortion due to reactance in the load is 5%, the total distortion without feedback is 8%. With negative feedback it would then be

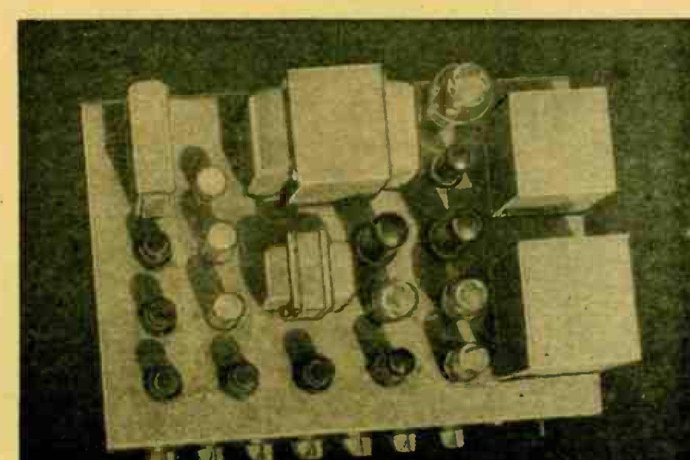
$$\frac{8}{8.8} = 0.91\%.$$

Any hum in the output stage due to inadequate filtering is reduced in the same proportion:

$$\frac{\text{hum without feedback}}{\text{1-AB}} = \text{hum with feedback.}$$



Point-to-point wiring is used between stages of the amplifier.



The heavy transformers and chokes give good voltage regulation.

As a point of interest, the hum level in this amplifier is 38 db down from the standard reference level of .006 watt.

Negative feedback also lowers the effective output impedance of an amplifier as shown in the equation:

$$\text{Effective output impedance} = \frac{Rp}{1-\mu AB}$$

where:

Rp is plate resistance of output tube;

μ is amplification factor of the output tube;

A is the gain between grid of driver and grid of output tube without feedback;

B is the voltage feedback factor.

The lowered effective output impedance greatly assists in damping out transients in the voice coil.

When a large amount of negative feedback is applied over 2 or more stages, oscillation at very low and very high frequencies often results due to phase shift. The coupling network between the driver and output stage was designed to prevent this from occurring.

Another factor to be considered is that change in gain with negative feedback determines the peak voltage required at the grids of the driver tubes for full power output.

The change in gain with negative feedback is given by the equation:

$$\frac{\text{gain without feedback}}{1\text{-AB}} = \text{gain with feedback.}$$

Since the over-all gain of the driver and output stages without feedback is 78 and 1-AB is 8.8, the total gain with feedback is 8.86.

The peak grid-to-grid voltage required by the driver is equal to the peak output voltage divided by 8.86.

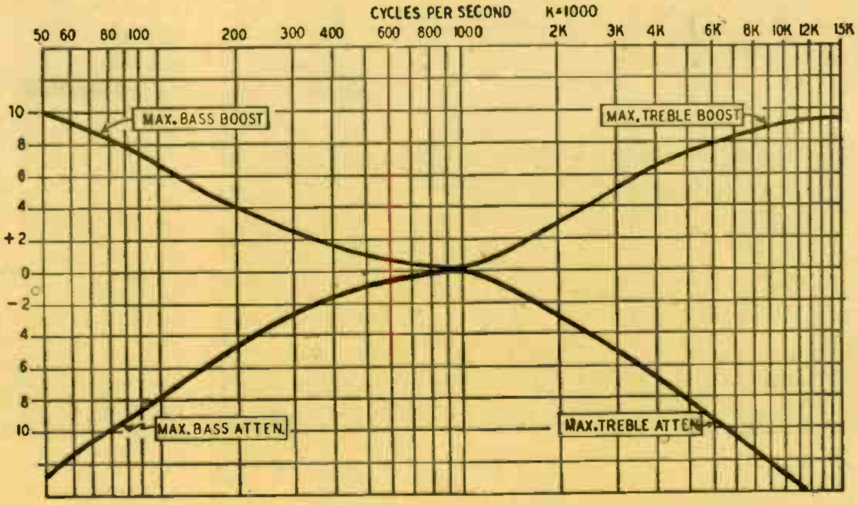


Fig. 1—Amplifier response under maximum tone control settings.

The r.m.s. plate voltage of *each* 6L6 at full output is the square root of ½ power output times ½ plate-to-plate load impedance, or:

$17.5 \times 3{,}300 = 240$ volts r.m.s. The peak-to-peak output voltage is $240 \times 1.414 \times 2$ or 679 volts. The voltage required by the driver is 76.5 volts peak.

The amplifier circuit

The front end of the amplifier is conventional. There are 4 inputs; 2 high-impedance microphone inputs, 1 phono input, and 1 radio input. There is a gain control for each input and a master gain control. The treble boost and attenuation circuit is located between the third and fourth stages. All single-ended stages are isolated from one another and the filtering in the decoupling network reduces hum to a very low level.

The frequency response is flat within ¼ db from 50 to 15,000 cycles. Distortion is less than 1%, and the hum level is 62 db down from full output. Total negative feedback is 18 db.

The power transformer has 2 high-voltage windings. One winding supplies plate and screen voltages for the output tubes; the other furnishes the plate voltage for the voltage amplifiers. Good voltage regulation is obtained by using a single-section choke-input filter, with a low-resistance choke and a transformer with good regulation. Good screen voltage regulation is provided by using 2 regulator tubes in series across the screen lead. Note well the size of the components in the illustrations. Plenty of iron and copper are necessary for the best audio quality.

Choice of an output transformer is important, but is limited to those having

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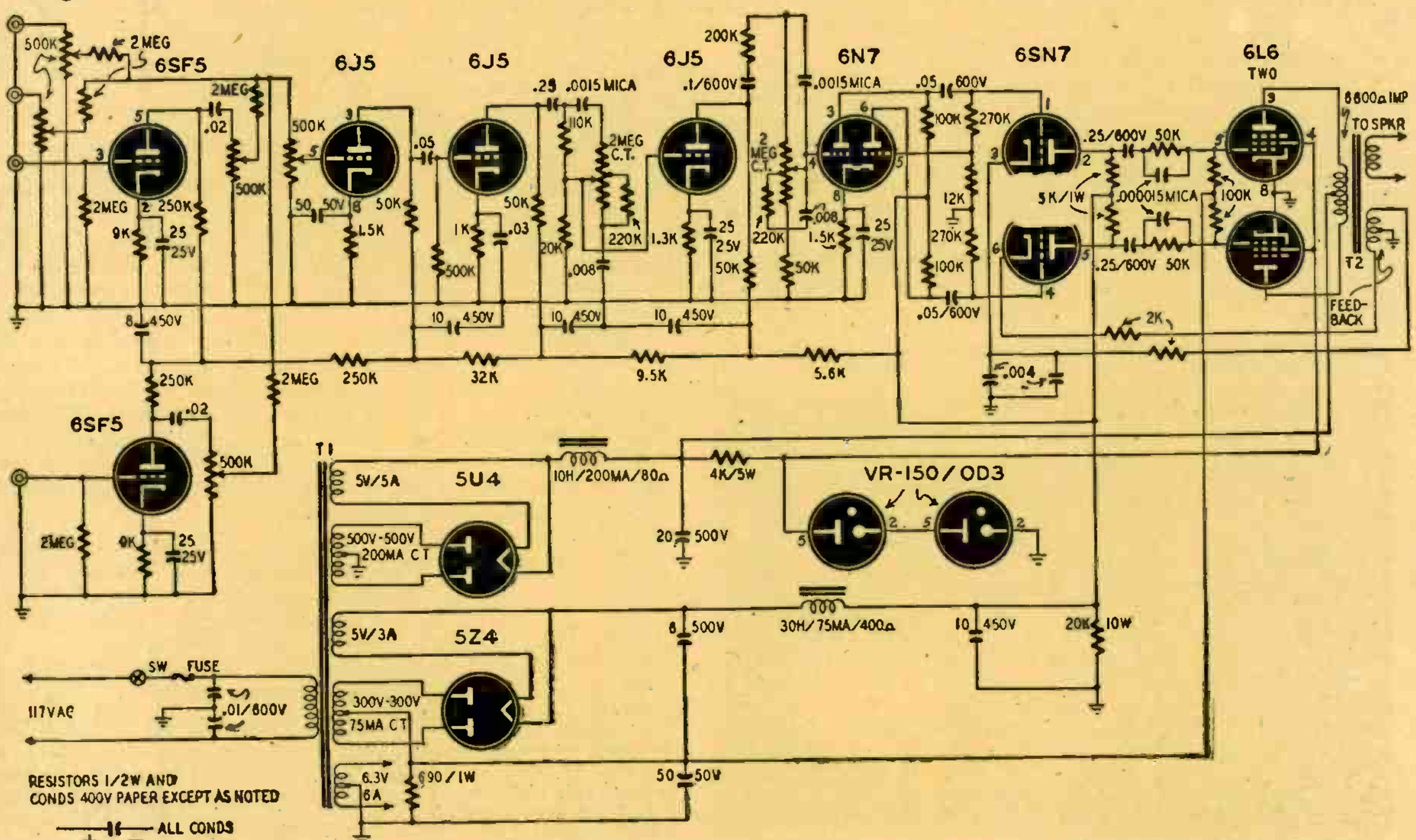

Fig. 2—The circuit of the amplifier. The bass and treble tone controls are located between the third and fifth amplifier stages.

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the special feedback winding. (The Stancor A-3851 and Thordarson T-17S13 are examples.) It should be rated at 35 watts at least. Plate-to-plate impedance should be 6,600 ohms.

The amplifier is built on a 12 x 17 x 3-inch chassis. Controls from left to right are: master gain, No. 1 microphone gain, No. 2 microphone gain, phono gain, radio gain, treble control, and bass control.

Point-to-point wiring is used throughout, with all components securely fastened to the chassis. All controls and input leads are shielded to keep hum pickup at a minimum. All circuit values were carefully calculated and should be adhered to if duplicate results are to be expected.

In actual operation, music and speech are reproduced with a clarity seldom heard in an ordinary public address system.

Readers will note that manufacturers do not recommend the use of 6L6's at the ratings given in this article, though such ratings have been deemed permissible in the past. Cautious constructors might reduce voltages to bring power output down to about 25 watts or—possibly even better—use 807's in place of the 6L6's.