

former merely employs a bridge type rectifier ( $V_1, V_2, V_3$ ) so arranged that the center tap of the winding is +400 volts. This type of power supply is sometimes referred to as a "duplex" power supply.

The thermostatic delay relay is included to prevent the application of plate voltage to the output tubes before the indirectly heated cathodes of the voltage amplifiers have warmed up sufficiently to provide correct bias.

The 6.3 volt a.c. heater winding is baised at +400 volts. The cathodes of  $V_1$  and  $V_2$  are biased at +400 volts, so the same heater winding that supplies the output tubes can be used for the 6X5 heaters. Also, it will be noted that the cathode of  $V_3$  operates at approximately +327 volts which permits this same source of 6.3-volt a.c. to be used for the heater of  $V_3$ .

A full-wave selenium rectifier and associated transformer are used to provide d.c. heater current for  $V_4$  to  $V_7$ , inclusive. The use of d.c. heaters in these tubes reduces hum disturbances.

### Construction

The entire amplifier can be mounted on a 15×19 chassis, but it is recommended that the power supply be mounted on a separate chassis. If only one chassis is used, the parts must be arranged so compactly that a cooling fan is almost a necessity, especially if the amplifier is to be placed in a confined box. If a single chassis is used, the parts should be laid out so that the power supply is at the opposite end of the chassis from the low level stages. Since the circuit is completely push-pull (except for the preamplifier), hum is minimized and shielded wire need not be used. However, the preamplifier must be carefully shielded.

The use of a single ground and grounding bus is recommended to avoid hum which sometimes results from multiple grounds. In this case of the preamplifier, an insulated input jack should be used. The grounded side of this jack should be attached to the grounded end of  $R_1$ . If this precaution is not observed, a high hum level will almost invariably result.

In the interest of good construction, filter capacitors  $C_1$  and  $C_2$  should be oil filled. Because of the push-pull arrangement with its inherent hum cancellation characteristics, no large capacitance electrolytic capacitors are required except in the case of the preamplifier and d.c. heater supply.

It is not absolutely essential to match resistors, capacitors, tubes, etc., of the two halves of the push-pull circuit, because cross-coupling, cathode degeneration, inverse feedback, and balancing potentiometers provide for a reasonably well balanced output, even if exact push-pull symmetry is not maintained. Nevertheless, accurate balance and superior performance of the amplifier can be attained only by electrical and mechanical symmetry. Furthermore, changing line voltage will result in unbalanced opera-

tion if parts are not fairly carefully matched. Therefore, matching of corresponding parts is recommended insofar as possible.

Wiring of those portions of the circuit operating at +400 volts or less should follow conventional procedure. For the higher voltages, wire with fibre glass insulation is recommended.

Potentiometers  $R_{11}$  and  $R_{12}$  should be so located that they can be reached easily with a screwdriver while the amplifier is in operation.

Transformers and chokes should be of good quality. The output transformer is especially important. The quality of the entire amplifier will depend largely on this item. This circuit was designed, among other things, to eliminate expensive interstage audio transformers, and the money so saved can be invested in the output transformer. A number of excellent makes are available. The author used a UTC linear standard LS55, and found it very satisfactory.

Tubes  $V_1, V_2$ , and  $V_3$  should be

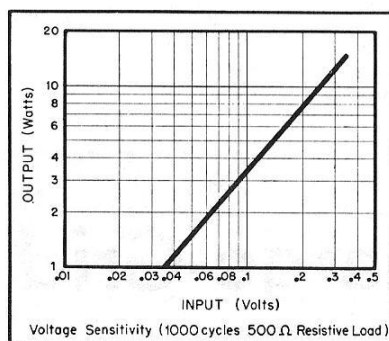


Fig. 3. Curve showing voltage sensitivity of the amplifier when feeding a 500-ohm resistive load.

mounted in non-microphonic tube sockets. Switches  $S_1$  and  $S_2$  should be the shorting type to prevent noisy switching. The feedback loop attached to the secondary of the output transformer should not be finally soldered in place until adjustments of the amplifier are completed.

### Adjustment

After completing the construction, insert all tubes heated by d.c. Turn on the amplifier and check the heater voltage to make sure it is 6.0 to 6.3 volts.

Next, insert all tubes heated by a.c. The thermostatic switch should not be inserted until later. Turn on set and measure a.c. heater voltage.

If everything is operating normally, place the thermostatic switch in its socket and turn on the amplifier. Adjust  $R_{11}$  and  $R_{12}$  to produce correct operating current and voltages for the output tubes. If parts have been well balanced, minimum hum will be obtained when plate currents are balanced. If parts have not been carefully selected, minimum hum may occur when plate currents are slightly unbalanced. Adjust  $R_{11}$  for minimum hum.

Finally, attach feedback loop from

output transformer secondary to one of the cathodes of  $V_1$ . If noise increases when feedback loop is attached, the loop has been reversed and should be attached to the other cathode.

A final check of voltages should be made; Table I shows typical values for plate, grid, and cathode potentials referred to ground. If everything is in correct working order, hum and noise will be inaudible when the ear is held more than three or four inches from the speaker. When the preamplifier is switched into the circuit, a small amount of noise will become apparent, though this noise should be so slight as to cause no objection.

In order to maintain balance of the amplifier, potentiometers  $R_{11}$  and  $R_{12}$  will have to be adjusted periodically as the tubes age. The frequency of these adjustments will decrease after the first few weeks of operation, during which time the tubes' characteristics are changing quite rapidly. Since line voltages will vary throughout the day, it is suggested that balancing be done when the line voltage is at its average value. The amplifier should be adjusted only after it has warmed up at least half an hour.

### Performance

Full output of 15 watts is attained with an input voltage of 0.35 volts rms. An output of over 20 watts can be attained, though the amplifier begins to produce appreciable distortion over 15 watts.

Frequency response is flat to approximately 20,000 cps, with a gradual droop above that point. Voltage sensitivity is shown in Fig 3. Hum and noise voltages were so low that they could not be measured with equipment available.

### Conclusions

In the past, direct-coupled amplifiers have proved unpopular probably because of several problems associated with this type of design. The circuit described herein overcomes all these difficulties by unconventional arrangements, except that periodic adjustment of the current of output tubes will be required.

However, for those who require unusually good performance, and enjoy the work of achieving it, it is believed that this circuit will provide satisfactory results. Its superiority to most typical designs can be shown either by instruments or by listener tests.

TABLE I

Tube	Plate	Grid	Cathode
V5	170	0	6.5
V6	120	6.5	8
V7	309	120	122.7
V8	750	309	327
V9	745 @ 42 ma	327	400
V10	745 @ 42 ma	327	400

NOTE 1. Actual voltages may vary as much as 15 per cent from figures shown without detrimental effect. However, output tube plate current and voltage should be adjusted as accurately as possible. The exact voltage of output tube grids is unimportant, provided plate current and voltage are correct.

NOTE 2. Voltage measurements should be made with a vacuum tube voltmeter.