



Fig. 2. Over-all schematic of the direct-coupled amplifier.

Such distortions are cancelled by inverse feedback from the output transformer secondary tap to which the loud-speaker voice coil is attached. This arrangement effectively feeds back an accurate sampling of the voltage supplied to the loud-speaker. The feedback resistor used in this circuit should have a resistance equal to 7800 times the square root of the voice coil impedance.

The values of the feedback resistors were selected after considerable investigation of the effect of feedback on signal waveform. Both sine and square wave inputs were used and the resultant oscilloscope patterns were carefully studied. Because of the small phase shift inherent in this direct-coupled circuit, unusually large amounts of feedback can be used. However, feedback in excess of that recommended will result in reduced amplification and may cause high-frequency oscillation.

Signal input can be either single ended or push-pull. Referring to Fig. 2, phase inversion is accomplished by  $V_5$  and  $V_6$  in case a single-ended signal is used. This type of phase inverter has no frequency discrimination and produces a perfectly balanced push-pull signal, provided the corresponding parts of the circuit are matched. The design was adapted from similar circuits which have been published recently. A unique form of loudness control is shown as the three-section ganged potentiometer  $R_{20}$ , capacitor  $C_{11}$  and resistor  $R_{21}$ . It will be observed that the high frequencies fed to the grid

of  $V_5$  are automatically attenuated as volume is decreased, thus giving an increased proportion of lower frequencies at reduced volume levels. The values of  $R_{21}$  and  $C_{11}$  can be varied to suit the individual. The author used a value of .04  $\mu$ f for  $C_{11}$  and a value of 0 ohms for  $R_{21}$ . After values have been established for the elements of this loudness control, it will work with greatest effectiveness for input signals which have the same average strength as the signal for which the loudness control was originally designed. Therefore, individual semi-adjustable volume controls ( $R_{17}$ ,  $R_{18}$ ,  $R_{19}$ ) have been provided for each signal device.

In case a balanced signal is to be used instead of a single ended signal, the signal should be fed to the ungrounded ends of  $R_{20A}$  and  $R_{20B}$ .  $C_{10}$  is then attached to  $R_{20B}$  in the same way as  $C_{12}$  is attached to  $R_{20A}$ . A fourth potentiometer should be ganged to the loudness control and wired similarly to  $R_{20A}$  and  $R_{20B}$ .

The slightest trace of d.c. appearing on the grid of  $V_5$  will upset the balance of the entire amplifier. Therefore,  $C_{12}$  is used to insure that d.c. from the signal sources is eliminated.

It will be noted that  $V_5$  is a cathode follower and hence produces no amplification.  $V_6$  and  $V_7$  amplify in the normal manner. The common cathode resistor of  $V_7$  tends to correct for any signal unbalance which may occur. Finally, the balanced feedback from  $V_8$  to  $V_5$  corrects

for any small residual signal unbalance. Oscilloscope tests show that the signals supplied to the output tubes are balanced under all conditions. This is an important requirement in push-pull circuits.

It will be noted that  $V_8$  has an unbypassed cathode resistor. The resultant degeneration improves frequency response and stability.

$V_8$  is a cathode-follower driver. Since the 6A5G's are to be operated Class AB<sub>1</sub>, and presumably draw no grid current, it may be wondered why  $V_8$  is used. The principal reason for the presence of this tube is that the grids of the 6A5G's do draw current, even though they are not driven positive. This characteristic is typical of many triode-output tubes.  $V_7$  cannot supply current from its plate to the grid of the following tube without suffering serious distortion in its output. However, a cathode follower can supply the small amounts of power required without ill effects, and so this arrangement is used for the driver. An inspection of the circuit diagram will show that  $R_{38}$  controls the total plate current of the output tubes and that  $R_{38}$  balances the plate current.

A number of excellent preamplifier designs are available. The one shown has been described previously.

#### Power Supply

At first glance, the power supply may appear to be unusual. Actually, the high voltage secondary of the power trans-