200-Mw-Output Battery-Operated Phonograph Amplifier Using RCA-2N109 Junction Transistors

This Note describes a 3-stage, transistor audio amplifier specifically designed for use in battery-operated portable phonographs. The amplifier employs RCA-2N109 alloy-junction transistors and, when driven by a medium-output crystal or ceramic pickup and operated from a 9-volt supply, is capable of delivering 200 milliwatts output at the 10-per cent distortion level. It has low distortion and good frequency response, and is compensated for the "New Orthophonic" recording characteristic developed by RCA and now almost universally employed for 45- and long-play recordings. The operating parameters used for the 2N109 transistors assure satisfactory performance at ambient temperatures up to 50 degrees centigrade.

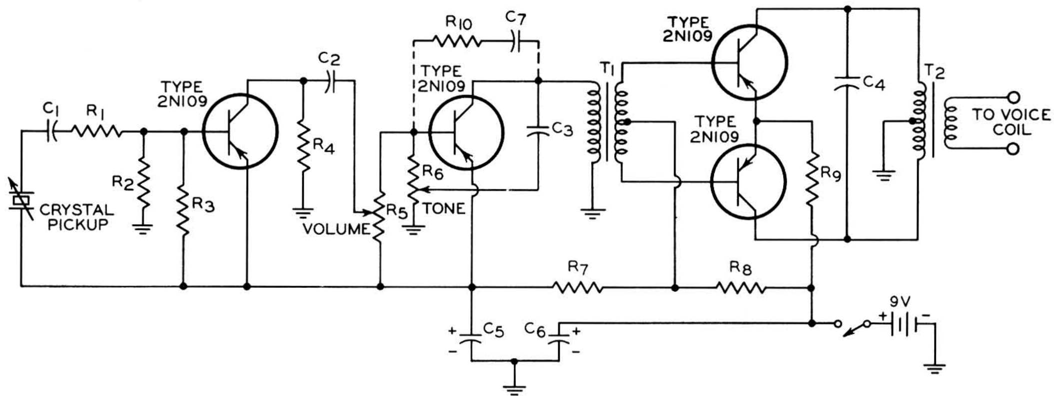
This Note also gives circuit changes which may be made to modify the frequency response, and describes the changes required when special considerations make it necessary that the amplifier operate satisfactorily at ambient temperatures above 50 degrees centigrade.

Circuit Description

The amplifier circuit is shown in Fig.1. The three stages--preamplifier, driver, and class B output stage--provide ample gain for use with crystal or ceramic pickups which deliver open-circuit output voltages of approximately 1 volt at 1000 cycles per second, and have capacitances in the order of 1000 $\mu\mu$f. Commercial pickups of this type usually have high-frequency characteristics which partially compensate for the "New Orthophonic" recording characteristic, and low-frequency characteristics which are easily corrected by the use of high-resistance terminations (see Fig.2).

In this amplifier, substantially flat frequency response from pickups having the characteristics shown in Fig.2 (such as the RCA Crystal Pickup Stock No.75476), is obtained by the use of a 1-megohm resistor (R1) in series with the input to the first transistor.

The volume and tone controls for the amplifier are placed in the second stage and also serve as bias resistors. A log-taper potentiometer is used for the volume control in order to reduce the sensitivity of the control at low-volume settings. The tone-control circuit is designed so that adjustment varies the high-frequency roll-off point as well as the amount of high-frequency attenuation. This control is a linear potentiometer.



C_1: 0.01 μf
C_2: 1.0 μf
C_3: 0.002 μf
C_4: 0.04 μf
C_5 C_6: 50 μf, 12 vdcw, electrolytic
C_7: 0.003 μf
R_1: 1 megohm, 0.5 watt
R_2 R_{10}: 220000 ohms, 0.5 watt
R_3: 4700 ohms, 0.5 watt
R_4: 1500 ohms, 0.5 watt
R_5: Potentiometer, 5000 ohms, logarithmic audio taper
R_6: Potentiometer, 100,000 ohms, linear taper
R_7: 680 ohms, 0.5 watt
R_8: 27 ohms, 0.5 watt
R_9: 33 ohms, 0.5 watt
T_1: Driver Transformer, primary impedance 3000 ohms, secondary impedance (base-to-base) 5000 ohms
T_2: Output Transformer, primary impedance (collector-to-collector) 550 ohms, secondary impedance to match speaker voice coil

Fig. 1 - Circuit of the transistor battery-powered phonograph amplifier.

In order to obtain the highest possible efficiency and power output, the output stage is operated under substantially class B conditions. The driver transformer (T_1) has a primary-to-secondary impedance ratio of 3000 to 5000 ohms. Although a transformer having a higher primary impedance would provide more gain, the additional cost of such a transformer was considered unjustified because the available gain is more than adequate for the pickup used. Bias voltage for the output stage is obtained from a tap on the decoupling network for the first two stages. The 33-ohm resistor (R_9) in the common emitter circuit minimizes cross-over distortion and stabilizes the operating point for the output stage sufficiently to prevent thermal runaway at temperatures up to 50 degrees centigrade.

The output transformer (T_2), when connected to the speaker voice coil, provides an effective load resistance (collector-to-collector) of 550 ohms. This transformer should be a high-efficiency type having a dc primary resistance as low as is economically feasible, because the available undistorted power output is reduced in proportion to the square of the dc voltage drop in the primary winding. The capacitor across the output-transformer primary (C_4) is used to minimize the "ringing" which tends to occur in a class B stage when the output current switches from one half of the circuit to the other. The value of this capacitor is not critical and it may be made to serve a double purpose by the choice of a value which will reduce the effects of any high-frequency resonances in the pickup.

Circuit Performance

The over-all frequency response of the system (including the RCA Stock No.75476 Crystal Pickup) to the RCA "New Orthophonic" Frequency-Test Record No.12-5-51 is shown in Fig.3. The drop in high-frequency response in the vicinity of 5000 cps is due partly to the decrease in pick-

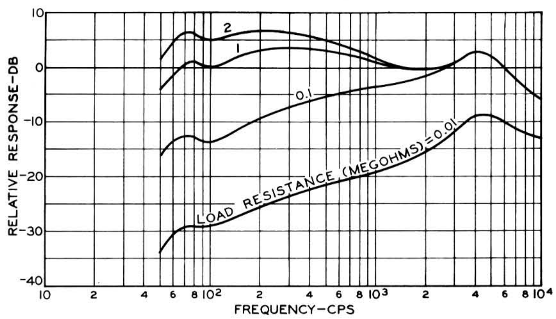


Fig. 2 - Response of medium-output crystal pickup.

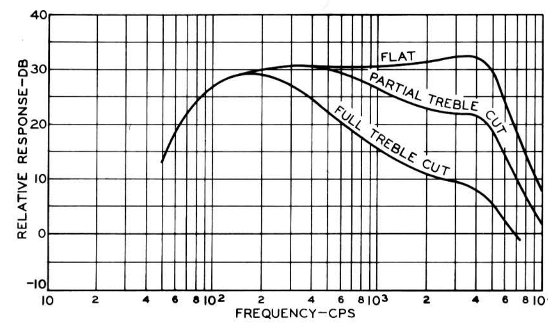


Fig. 3 - Response of amplifier and crystal pickup.

up output in this region and partly to the bypassing effect of the capacitor across the output-transformer primary. The low-frequency response is determined by the time constant of the pickup capacitance and the terminating resistance (R_1), and by the characteristics of the driver and output transformers.

Fig.4 shows the total harmonic distortion contributed by the amplifier versus input-signal frequency at various output-power levels. Fig.5

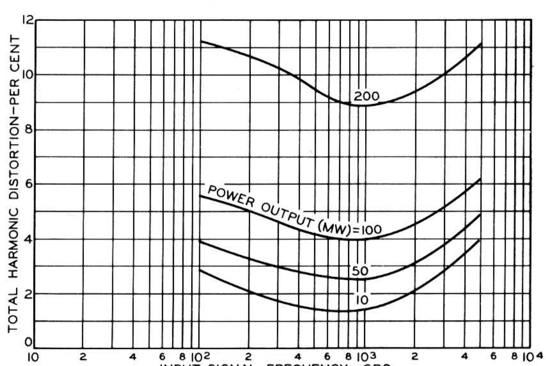


Fig. 4 - Total harmonic distortion produced by the amplifier at various output power levels.

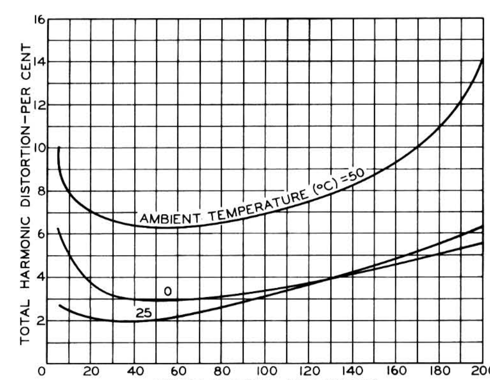


Fig. 5 - Total harmonic distortion produced by the amplifier as a function of power output.

shows total harmonic distortion versus power output for different ambient temperatures.

The signal-to-noise ratio of the system is in the order of 55 to 60 db.

Fig.6 shows the total current drawn by the amplifier from a 9-volt battery versus power output at an ambient temperature of 25 degrees centigrade. At the maximum rated output of 200 milliwatts the current drain for sinusoidal signal waveforms is approximately 41 milliamperes, representing a power consumption of 0.369 watt. At normal listening levels for speech and music (approximately 50 milliwatts) the amplifier draws only about 22 milliamperes, representing a power consumption of 0.198 watt. The amplifier will operate satisfactorily, although with reduced output, at reduced battery voltage. The total battery drain will, of course, depend upon the current drawn by the turntable motor. A typical 45-rpm, 6-volt motor draws 30 milliamperes.

Circuit Modifications

If the amplifier is to be used with a pickup which faithfully follows the recording characteristic, correction for the "New Orthophonic" recording characteristic may be obtained without an appreciable reduction in over-all gain by the use of the alternative input circuit shown in Fig.7. The

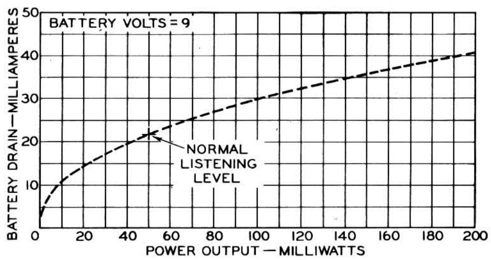


Fig.6 - Total current drawn by the amplifier as a function of power output.

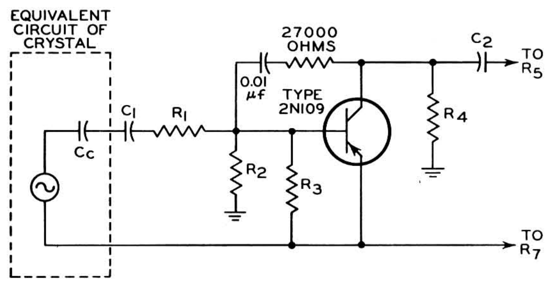


Fig.7 - Alternative input circuit for use with pickups having flat frequency-response characteristics.

value of R_1 will depend on the pickup capacitance and should be selected so that the time constant $R_1 C_c$ is 75 microseconds. When this alternative input circuit is used, the functions of the volume and tone controls in Fig.1 should be reversed in order to minimize changes in over-all frequency response with changes in the setting of the volume control. In this case the 100,000-ohm potentiometer (now the volume control) should have a logarithmic audio taper.

The low-frequency response of the amplifier may be improved by the addition of the 220,000-ohm resistor (R_{10}) and 0.003-microfarad capacitor (C_7) shown connected by dashed lines across the second transistor in Fig.1.

The amplifier can readily be modified for operation at ambient temperatures above 50 degrees centigrade by a reduction in the base-to-emitter forward bias of each stage. The reduction should be at the rate of 0.002 volt for each degree by which the desired operating temperature exceeds 50 degrees centigrade, and may be obtained by (1) insertion of suitably bypassed resistors in the emitter leads of the first two stages; (2) a change in the bias circuit for the output stage so that the driver transformer center tap is connected to a suitable point on a voltage divider directly across the 9-volt supply, instead of to a tap on the decoupling network.