Quasi-Complementary Transistor Amplifier

SUMMARY — Transistorized phonograph amplifier uses a quasi-complementary output circuit to provide 6 watts output with less than 1-percent distortion at midfrequencies. Input signal passes through three preamplifiers and a predriver stage before reaching the quasi-complementary output stage. Output feeds directly to loudspeaker voice coil. Operation is satisfactory over temperature range from 0 to 50 C

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OPERATING between a variable-reluctance pickup and a conventional 16-ohm loudspeaker, the amplifier to be described has a frequency response flat within 1½ db from 30 to 15,000 cps and tone controls with boost and cut for bass and treble.

A discussion of some considerations in a transistor phonograph amplifier precedes the description of the circuit.

Distortion

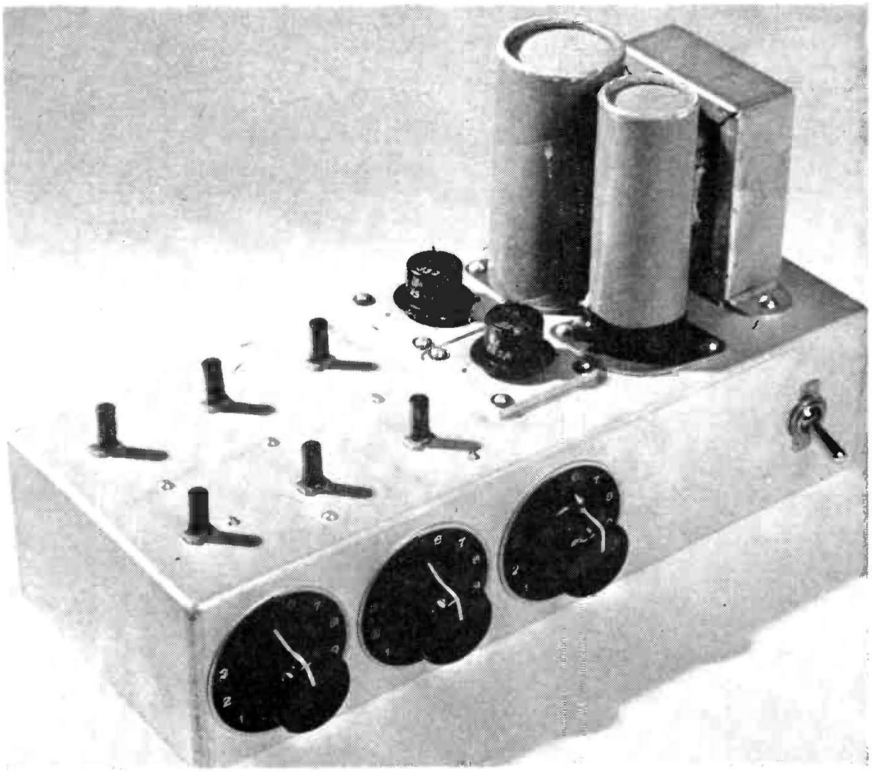
Distortion in a transistor amplifier is usually due to variations with current of either the current-amplification factor, the transconductance or both. When driving a grounded-emitter transistor amplifier stage from a current source (generator Z >> input Z) distortion depends on the variation in collector-to-base current-amplification factor. At high currents, the current-amplification factor usually diminishes.[1]

When a grounded-emitter transistor amplifier stage is driven from a voltage source, (generator Z << input Z), distortion may arise from the dependence of transconductance on base-to-emitter voltage. This nonlinearity in tranconductance may be caused by too low or too high an operating current.[2] Either of these distortions can be reduced by negative feedback.

Frequency Response

A system employing an RCA SPC-1 variable reluctance pickup and the RIAA recording characteristic requires high and low-frequency equalization in the reproducing amplifier. High-frequency equalization can be obtained by making the amplifier input resistance equal to 7,000 ohms. Since the common-emitter transistor input resistance is generally less than 7,000 ohms, the input resistance can be increased by adding resistance to either the base or emitter circuit.

If a resistance, R_E is connected in series with the emitter, the input resistance is increased by approximately β R_E where β is the collector-to-base current-amplification factor. Here the input re-



Compact transistorized amplifier uses 12-watt filament transformer, with rewound secondary, as power transformer

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sistance depends directly on the value of β, which may be different for different transistors.

Noise

The noise performance of these two input circuits is not the same. For a low-power transistor operating at an emitter current of about one ma, the s/n ratio of the circuit with added base resistance is generally 10 to 15 db lower than that of the circuit with added emitter resistance. Hence, the configuration for better interchangeability of transistors is not compatible with the configuration for lower noise.

The required low-frequency equalization can be accomplished by an R-C low-pass filter in which the attenuation increases at a rate of 6 db an octave. Above 500 cps, the attenuation stays constant. The location of this filter is dictated by noise and overload. Location at the amplifier input may cause objectionable noise. Location at high-level stages may cause overloading at high frequencies in the early stages. A good compromise is to place the filter immediately after the first stage.

Quasi-Complementary Circuit

The basic quasi-complementary circuit is shown in Fig. 1A. If a sine-wave signal is applied to the input terminals, the two upper transistors conduct during the negative half-cycle and the two lower transistors conduct during the positive half-cycle. During the conduction of the two upper transistors, emitter-following action makes the emitter voltage of Q_7 follow closely the input voltage at the emitter of Q_5 which, in turn, follows the input voltage at the base of Q_5. Since the input current is amplified by Q_5 and Q_7, the output current is equal to $\beta_5\beta_7$ times the input current.

Similarly, during the conduction of the two lower transistors, emitter-following action makes the voltage at the emitter of Q_6 follow closely that at the base and the output current is equal to $\beta_6\beta_8$ times the input current. If $\beta_5\beta_7 = \beta_6\beta_8$, the input resistance during either half of input signal wave is approximately equal to $\beta_5\beta_7R_L$. Therefore, the quasi-complementary circuit is in balanced operation.

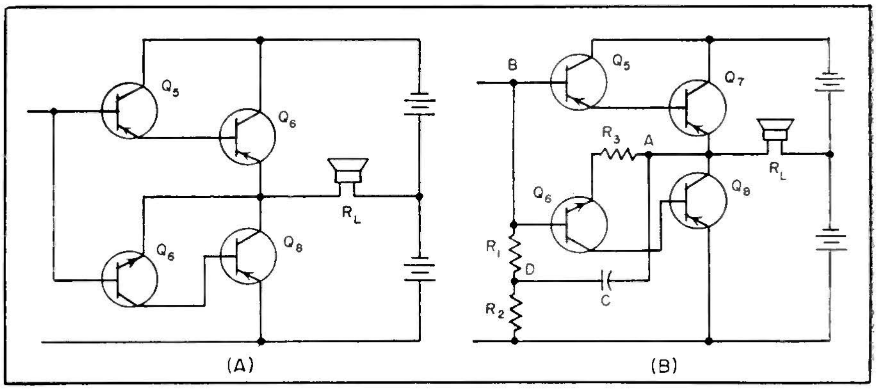

FIG. 1—Basic quasi-complementary circuit (A) and modified circuit to lower input resistance (B)

In practice, the basic configuration presents too high an input resistance so that the d-c coupling resistor of the preceding stage usually tends to shunt a large portion of the input signal current. This high input resistance can be reduced by connecting one or both of the stages in common emitter configuration.[3,4]

Modified Circuit

For the quasi-complementary circuit, a scheme as shown in Fig. 1B may be used. Capacitor C is connected between output junction point A of the series-connected output transistors and tap D on coupling resistors R_1R_2. This returns the input current through C and R_2. So long as R_1 is much greater than the input resistance between the driver base point B and point A during conduction, useful signal

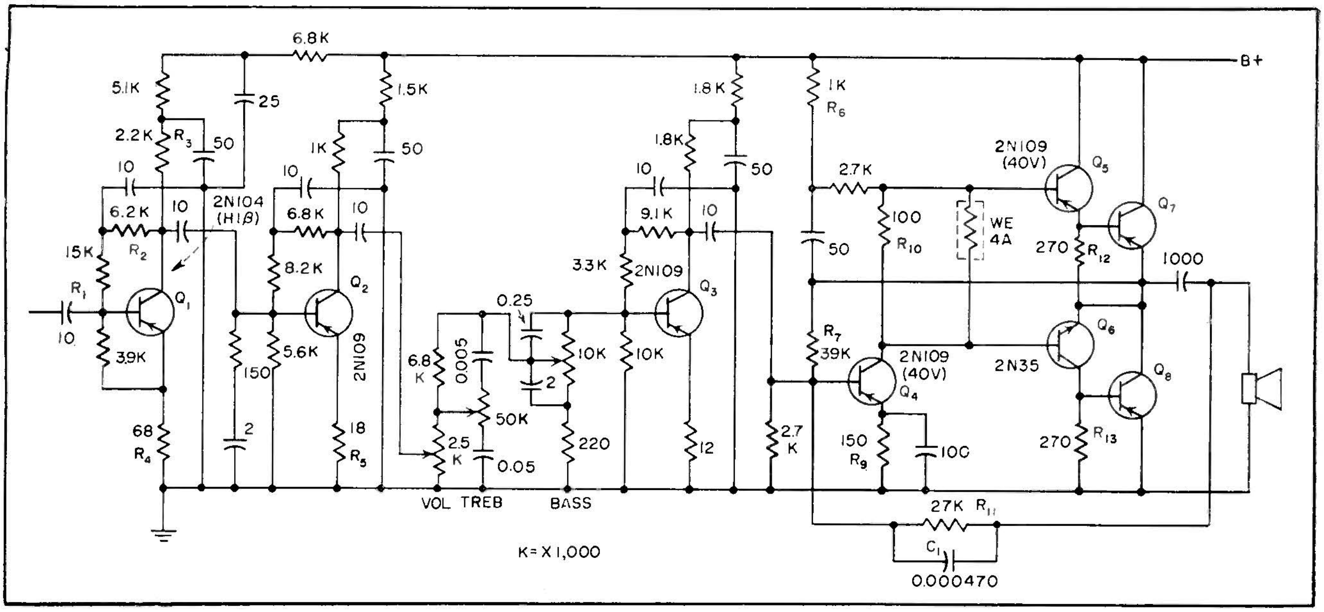

FIG. 2—Complete amplifier schematic. Tone controls provide either boost or cut

will not be diverted into R_1.

For the negative half cycle the input resistance between B and A is approximately $r_5 + \beta_5 r_7$, where r_5 and r_7 are the base lead resistances of Q_5 and Q_7. For the positive half-cycle, the input resistance is approximately r_6, the base lead resistance of Q_6. For perfect balance, these input resistances could be made equal by connecting R_8 in series with the emitter of Q_6, as shown. However, R_3 can usually be dispensed with if R_1 is large. R_2 should be much greater than R_L since the former is in shunt with the latter.

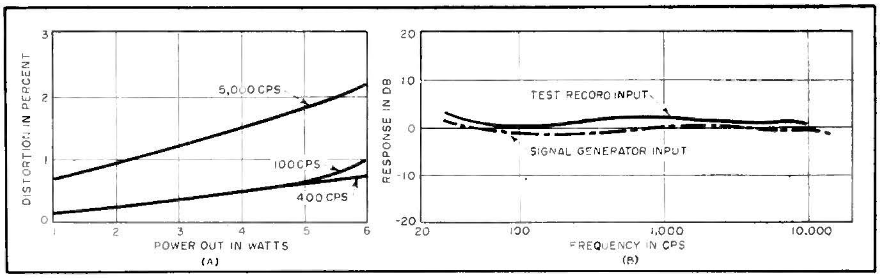

FIG. 3—Curves show distortion with change in power out (A) and frequency response for two input conditions (B)

Complete Circuit

The complete schematic diagram of the amplifier is shown in Fig. 2. There are six stages, consisting of the quasi-complementary driver-output circuit, a predriver and three preamplifiers. Transistor Q_1 is an experimental transistor similar to the 2N104 but with somewhat higher collector-to-base current-amplification factor $\beta \cong 85$. Transistors Q_4 and Q_5 are experimental *pnp* transistors with characteristics similar to those of the 2N109 but with a collector breakdown voltage of over 40 v. Experimental *npn* transistor Q_6 has characteristics complementary to that of Q_5. Both Q_7 and Q_8 are *pnp* power transistors.

In the first stage, an unbypassed resistor R_4, connected in series with the emitter reflects an input resistance of 7,000 ohms at the base. The base-to-emitter bias is furnished by R_1 and R_2 connected between collector and base. These resistors with collector resistor R_3 constitute a d-c feedback circuit for stabilizing the operating point against ambient temperature variations.[5] Similar biasing arrangements are used in the next two stages. Bypassing capacitor C_1, connected to the junction of R_1 and R_2 presents degeneration. Resistor R_5 linearizes the transconductance of Q_2 and reflects an input resistance of approximately 800 ohms.

Predriver

The predriver Q_4, operates class A. The output is directly coupled to the input of the driver. Resistors R_6, R_8 and R_{10} form the return path for the d-c collector current of Q_4. The flow of d-c through R_{10} creates a forward base-to-emitter bias for drivers Q_5 and Q_6 which eliminates crossover distortion. The required bias voltage to maintain class B operation of the driver decreases with increase in temperature. The thermistor, in parallel with R_{10}, provides this bias.

Since the voltages at the emitters of Q_5 and Q_7 follow closely the voltage at the collector of Q_4, any change in collector current will upset the balance of the subsequent stages. To hold Q_4 collector current constant, emitter resistance R_9 and negative d-c feedback through R_7 are used.

Feedback

Since the output is capacitively coupled to the 16-ohm load, the d-c power supply need not have a center tap. Negative feedback is applied from the hot side of the loudspeaker voice coil to the base of Q_4 through R_{11} and R_7. C_2 is connected in parallel with R_{11} to give a step-response in the feedback loop for stability. The use of R_{12} between emitters of the drivers helps to temperature stabilize the driver stage. Resistor R_{13} also serves this purpose by reducing the external d-c resistance between base and emitter to a low value.

The peak a-c voltage swing at the collectors of the transistors Q_4 through Q_8 is nearly equal to the supply voltage. Since the no-signal supply voltage is 40 v, the transistor breakdown-voltage must be in excess of this.

Output

The envelope of the power-output transistor is electrically connected to the collector and must be insulated from the main chassis. The envelope should also have good thermal contact with the main chassis to remove the heat generated in the transistor. For these purposes, an anodized aluminum plate which insulates electrically but conducts thermally, is sandwiched between the power transistor and the main chassis.

Performance

Amplifier distortion is shown in Fig. 3A. Note that the distortion for 100 cps and 400 cps is below 1 percent at six watts, whereas the distortion for 5,000 cps is somewhat higher because of the reduction in current gain and negative feedback.

The frequency response is shown in Fig. 3B. Measurements were made with the tone controls at mid-position and the volume control at maximum. The upper curve shows the response to an RIAA test tone record using the SPC-1 variable reluctance pickup. The lower curve was taken with a signal generator whose output voltage was adjusted to conform with RIAA characteristics and connected in series with a variable reluctance pickup head. At other volume control settings, the frequency response does not vary appreciably.

References

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