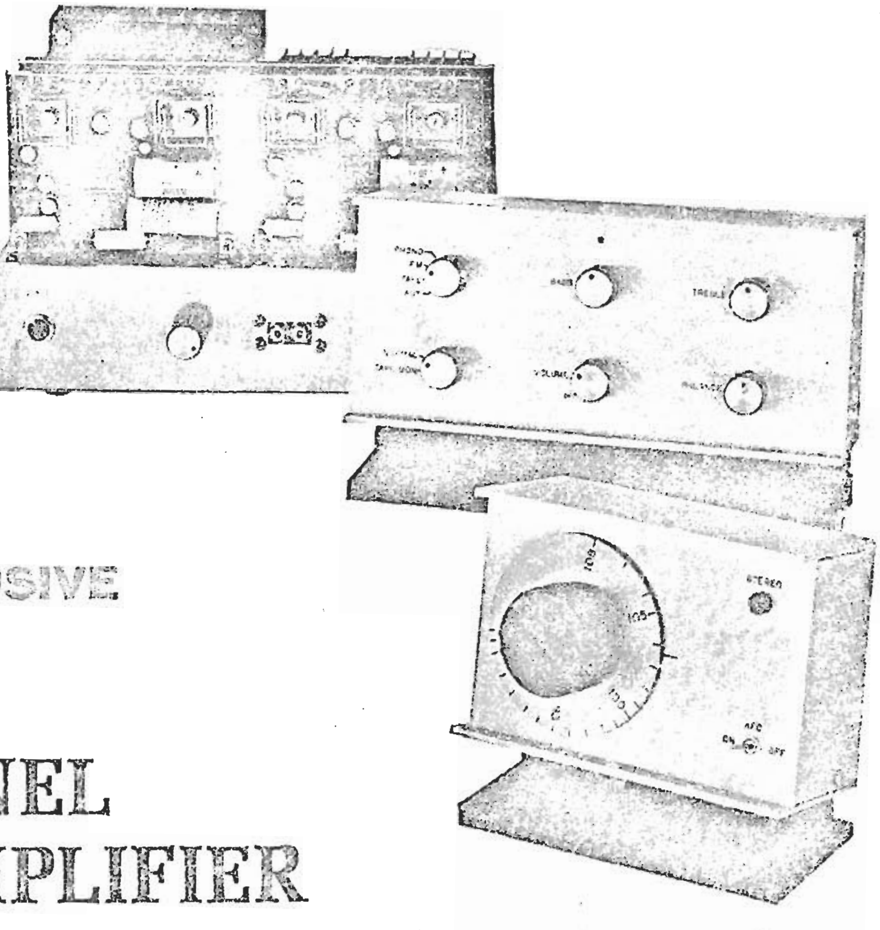


COVER STORY

BUILD—R-E EXCLUSIVE

125 WATTS PER CHANNEL STEREO AMPLIFIER

By KENNETH F. BUEGEL

[illegible] ARTICLE IS THE FIRST OF THREE that will give details on how to build a [illegible] state-of-the-art stereophonic [illegible] fidelity system that is the ultimate [illegible] quality and performance.

The three parts are the power [illegible]amplifier—it delivers 125-watts-per [illegible] into a 4-ohm load and is burn-[illegible] proof, the stereo preamplifier—[illegible] around three IC's to reduce its [illegible] and improve its perform-[illegible] and a most unusual FM stereo [illegible]—it uses variable-voltage-diode [illegible] and enables you to mount the [illegible] end up at the antenna for maxi-[illegible] sensitivity and selectivity.

This article will describe the pow-[illegible] amplifier and it's power supply. [illegible] you build the preamp (next [illegible]) it draws operating power [illegible] this amplifier. So here we go. [illegible] new dimension in high-fidelity [illegible] sound.

[illegible] an earlier era of high fidelity [illegible] all speakers were highly effi-[illegible] devices for transforming elec-[illegible] signals into audible sound, and [illegible] powers seldom exceeded to [illegible]

[illegible] pace with the recording [illegible] speaker manufacturers ex-[illegible] the range of frequencies line-[illegible] reproduced. At first the trend was [illegible] larger cabinet volumes to in-crease the usable bass range. But it soon became evident that few people wanted the huge speaker cabinet volumes associated with high-fidelity sound.

Speaker manufacturers were aware of the trade-offs in making a small cabinet volume adequately reproduce the lower frequency sounds—simply reduce the efficiency of the speaker in the middle and upper ranges. This was in direct contrast to boosting the low-range efficiency by tuning a larger cabinet volume.

The advent of stereo accelerated the advance of low efficiency speakers until today relatively few new installations are the larger cabinet volumes. Of course this lowered efficiency has forced an increase in amplifier power to maintain realistic levels of room volume. Fortunately, transistor amplifiers came along to replace the tube designs.

Early designs became notorious for their sudden death if a speaker output was shorted for even an instant. Manufacturers responded with a rash of protection circuits, almost all of which depended on limiting input current to the output transistor stages. One method of protection limits driving current to the output stages.

Examining Fig. 1, we see that increasing current flow through R4 will cause a larger voltage drop across R4. At some current flow, the base-emitter voltage of Q1 and Q2 plus the forward voltage of D4 and the voltage across R4 will exceed the Zener voltage of D5. Increases in drive current only increase the Zener current.

Unfortunately, this theory is not too practical. Variations in the base-emitter voltages of Q1 and Q2 and the Zener voltage of D5 combine to allow substantially higher current flow at increasing temperatures. Most designs of this type require a thermal

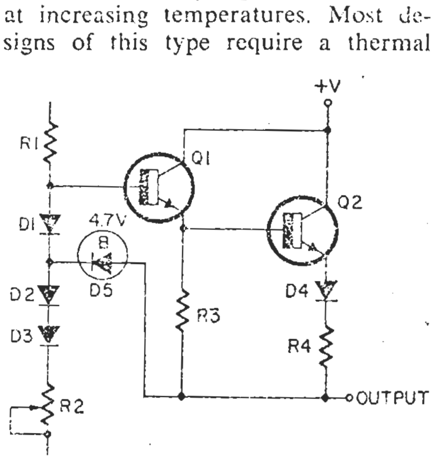


Fig. 1—Increasing current flow through R4 will cause a larger voltage drop across R4 to protect the amplifier.

cutout switch to eventually remove all input power.

An ideal protective circuit should sense only the current flow and must not be affected by heat sensitive parameters. This amplifier incorporates such a circuit. The schematic of Fig. 4 illustrates its operation.

Let's assume that the driving voltage at Q5's base becomes more positive. Q5 and Q6, connected as a Darlington pair, transmit this drive signal to the output terminals. Note that the same output voltage appears at the bottom end of R15 and at the emitter of Q4.

Transistor Q4 will not conduct and remove drive current until its base is about 0.55 volt more positive than its emitter. Let's calculate the output required to reach this state.

For a 125 watt output into a 4 ohm load:

$$P_o = \frac{E^2_{RMS}}{R_L},\ E_{RMS} = \sqrt{P_o \times R_L}$$

$$= \sqrt{500} = 22.3V$$

$$E_{PK} = E_{RMS} \times 1.41,\ E_{PK} = 22.3 \times 1.41 = 32.6V_{PK} \left(\begin{matrix}\text{Base voltage}\\ \text{of Q4}\end{matrix}\right)$$

$$I_{PK} = \frac{E_{PK}}{R_L} = \frac{32.6}{4} = 8.15A_{PK}$$

$I_{PK} \times R18 = 8.15 \times 0.33 = 2.72V$ drop across R18

Q4 ~~emitter~~ b voltage $= (2.72 + 32.6) \frac{1000}{1000 + 68} = 33.1V$

Note that the base of Q4 is 0.5 volt more positive than its emitter and Q4 is *near* conduction. The same voltage, minus the voltage drop across R18, is applied to the emitter of Q 4. For negative signals Q7 limits drive current to Q8 and Q9.

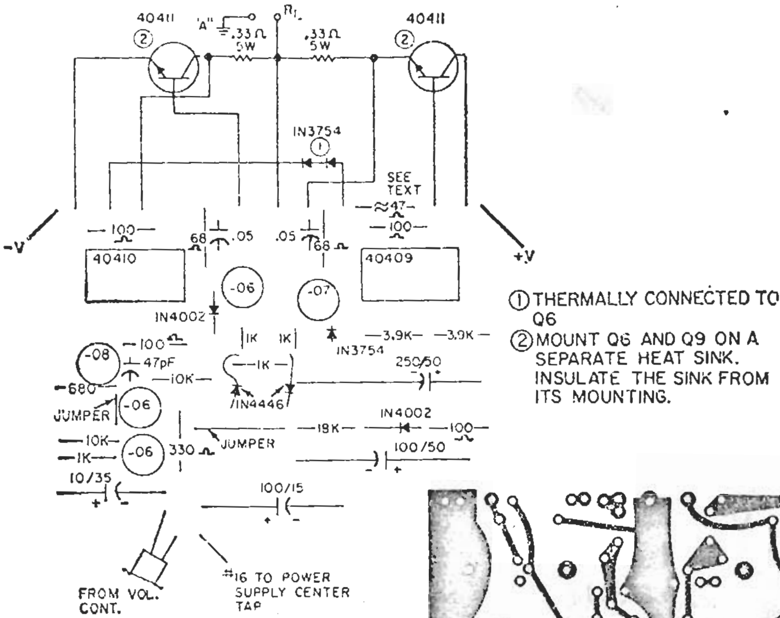
Now let's see what happens with shorted output terminals. First of all, Q4's emitter will be held at ground potential. Also, no current can flow through D6 and all voltage drop across R18 is applied to the base of Q4.

With a voltage drop of 0.55 volt across R18, the current flow is 0.55V ÷ 0.33 or 1.67 amp. The output current available is far less during shorted conditions than normal operation. The measured heat sink temperature actually drops when a short is applied to the output.

Of course, R18 may be changed to limit the output power to any lower level desired. Use the following formulas to calculate R18.

$$E_{PK} = \sqrt{2P_oR_L},\quad I_{PK} = \sqrt{\frac{2P_o}{R_L}}$$

$$R18 = \frac{E_{PK} + 0.55}{0.934\, I_{PK}} - R_L$$



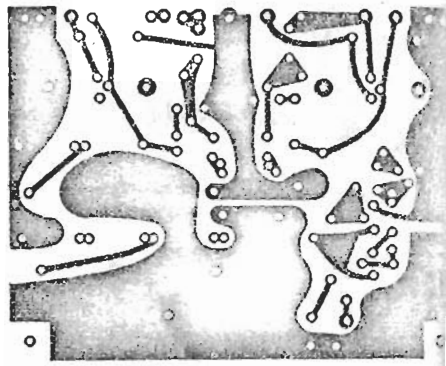


Fig. 2—Parts layout on the printed circuit board is detailed above. It also shows how the circuit board connects to the rest of the circuit. The foil side of the board (right) is half actual size.

No matter what output level is chosen, the short circuit output current will always be less than full power output current. No adjustments are required to set the current and circuit operation is entirely automatic.

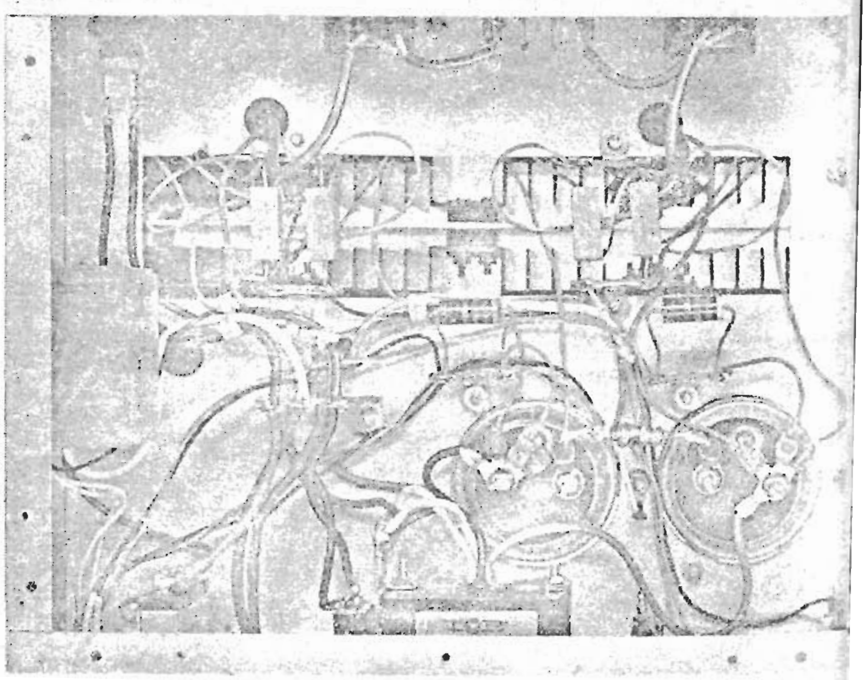
The power supply

The power supply in this amplifier will be used to power the preamp too. It is a simple, unregulated setup co[ntaining] little more than a transform[er], bridge rectifier and a couple of filt[er] capacitors (see Fig. 3).

The transformer listed is one [of] the best buys available and substi[tut]ing components offers little econ[omy] until power levels of less than [...] watts-per-channel are reached.

Several features of this ampli[fier] require detailed explanation. First

Under the amplifier chassis there is plenty of room for the components that are n[ot] mounted on the circuit boards. Do not crowd. This amplifier dissipates a lot of pow[er]



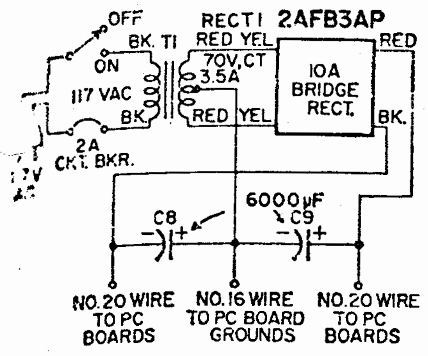


Fig. 3—Here's the power supply for the amplifier. All components used in the amplifier supply are used for both channels.

all, internal feedback eliminates the need for a control to set the dc output level of the amplifier. Looking at the schematic (Fig. 4) note that the base of Q1 is returned to ground through R3. The emitter of Q1 must be at 0.55-volt positive. Plus 50 volts is applied to the upper end of R5 and the current flow is just over 2.7 mA.

Less than 1 mA of this current flowing through R6 will bias Q3 into conduction. When Q3 conducts the resulting voltage drop across R9, R10, R11, D2 and D3 will bias the base of Q8 negative. The resulting voltage drop across R19 in turn places Q9 in conduction. As Q9 conducts, the output terminal which is also the right end of R8, becomes negative with respect to ground. Thus Q2's base is more negative than Q1's base.

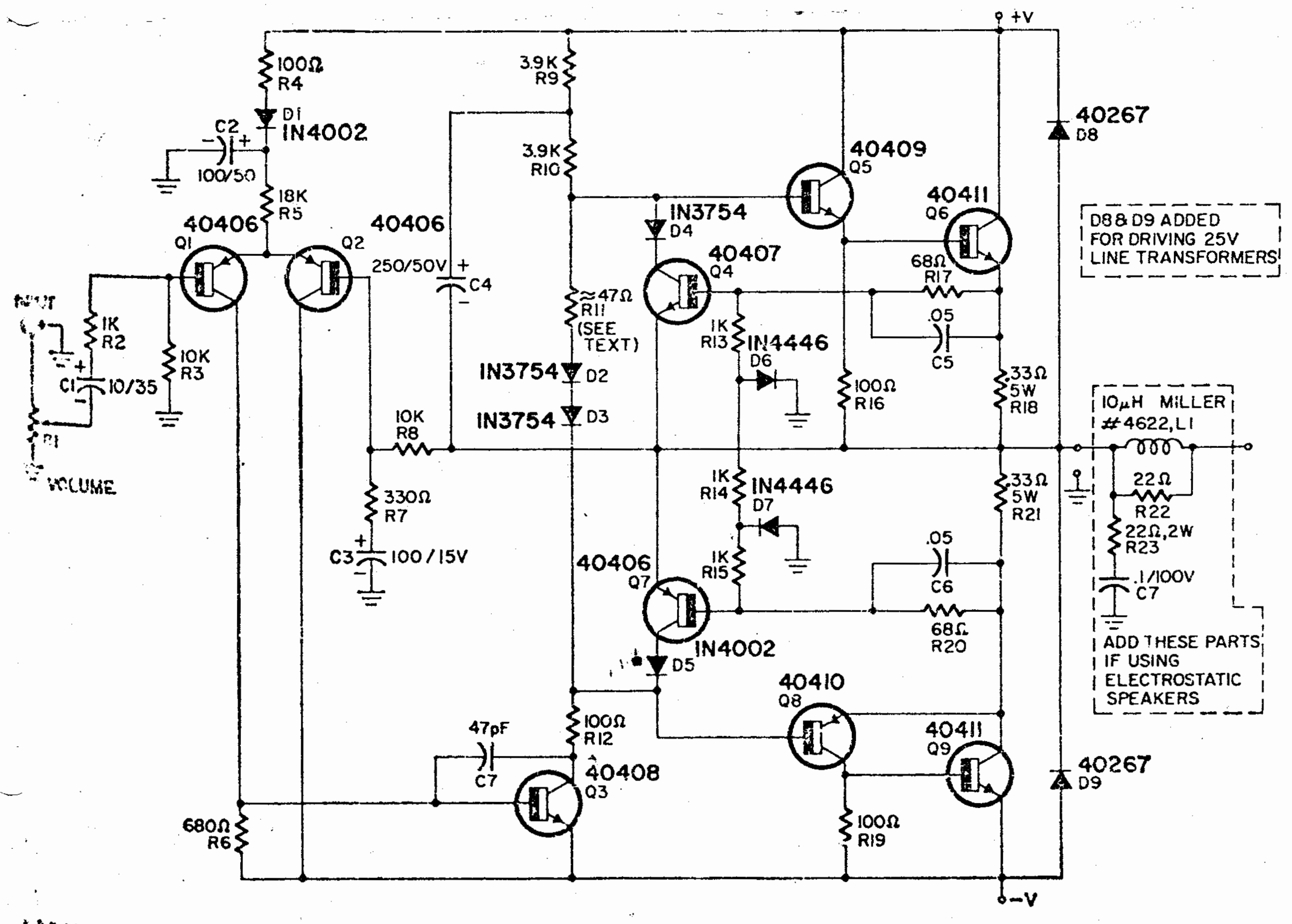
Since Q1 and Q2 emitters are connected, the current flow through Q1 decreases, thus reducing the bias developed across R6. Q3 now conducts less heavily and reduces the drive signals to Q8 and Q9. The cumulative action of this negative feedback is always in a direction which returns the output terminal to ground potential.

PARTS LIST

(two sets of parts are needed for stereo unit)

All resistors ½-watt 10% unless noted
—volume control, log taper (10,000 ohms for transistor preamp; 100,000 ohms for tube preamp)
R13, R14, R15—1000 ohms
R8—10,000 ohms
R12, R16, R19—100 ohms
—18,000 ohms
—680 ohms
—330 ohms
R10—3,900 ohms
—approximately 47 ohms (see text)
R20—68 ohms, 5%
R21—0.33 ohm, 5 watts
—22 ohms
—22 ohms, 2 watts
Capacitors
—10 µF, 35 V (Mallory MTR10D35 or equiv.)
C2—100 µF, 15 V 50V (Sprague TVA 1310 or equiv.)
C3—100 µF, 15 V (Mallory MTA100B15 or equiv.)
C4—250 µF, 50 V (Sprague TVA 1312)
C5, C6—0.05 µF, 20 V disc ceramic (Centralab UK-20-503 or equiv.)
C7—0.1 µF, 100 V paper (see text)
C8, C9—6,000 µF, 50 V (Sprague 36D602G050 BB2A. Allied Radio catalog No. 43F 5066 $3.52 ea.)
Other components
D1, D5—1N4002
D2, D3, D4—1N3754 (RCA)
D6, D7—1N4446 (G-E)
D8, D9—40267 (RCA)
L1—10 µH (Miller 4622 or equiv.)
Q1, Q2, Q7—40406 (RCA)
Q3—40408 (RCA)
Q4—40407 (RCA)
Q5—40409 (RCA)
Q6, Q9—40411 (RCA)
Q8—40410 (RCA)
T1—Power transformer, Pri. 117 VAC, Sec. 70V Ct @ 3.5 A (Triad R-82B or equivalent)
RECT 1—Full-wave bridge rectifier, 300 piV, 10 A (International Rectifier 2AFB3AP)
Heat sinks for 40411—Wakefield NC402K (Allied Radio #60C6506)
Heat sinks for 1N3754—Wakefield 255 (Allied Radio #60F6545)
Etched and drilled circuit board No. DLA-1 $3.75 each, postpaid from Transitek Co. P.O. Box 98205 Des Moines, Wash. 98016

Fig. 4—The full circuit for the amplifier is shown here. Remember this is only a single channel. Two of these circuits and one power supply circuit (Fig. 3) must be built to form one complete amplifier. It delivers 125-watts-per-channel.



Of course, like any other feedback system, the error can never be reduced to zero. In this circuit the error is always less than 0.1 volt. With an 8-ohm speaker this results in a dc power dissipation of less than .002 watt.

The dc gain of the total amplifier is very nearly unity since C3 prevents any voltage division between R7 and R8 at very low frequencies. Capacitor C3 has a reactance of 330 ohms at 5 Hz, the point at which voltage gain is down 6 db from a 1 kHz reference value.

Resistor, R4, diode D1, and capacitor C2 prevent a very annoying "thump" when the amplifier is turned off. Let's see what would happen without these parts in the circuit. At turn off the supply voltages start to decrease due to the quiescent current drain of the output stages. As the positive voltage decreases Q1's emitter and collector currents also drop.

A reduction in Q3's bias means that the voltage drop from R9 through D3 will also be less, resulting in a more positive drive to Q5 and Q6. The increased current flow through Q6 means an even heavier load on the positive voltage remaining. This effect is regenerative and similar, in its effect, to dumping the positive charge in the 6,000-μF capacitor directly across the load.

With D1 in the circuit, C2 stores a charge for the emitter currents of Q1 and Q2. The power supply capacitor will discharge faster than C2. No audible transients exist at either turn on or turn off.

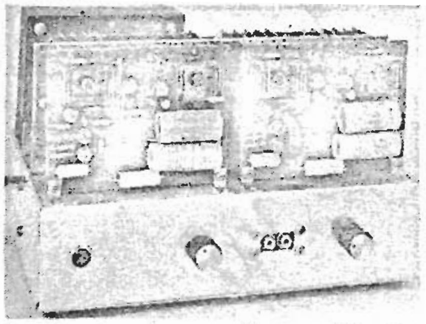
A regulated supply for this amplifier would be quite expensive since the output impedances, at dc, would have to be less than 0.02 ohm before the performance would be equivalent to what is now exists.

There are two reasons why this low impedance is needed. First, to prevent the large currents drawn from one channel from changing the output voltage of the supply, and thus, coupling a signal into the other channel. Second, to present an extremely low source of ripple current. The same effects are present in the connection of C4.

Note that one end of C4 is connected to ground through the load; the other is connected to the junction of R9 and R10. Any ripple voltage at the positive supply terminal is attenuated by a factor of 300 before it reaches the base of either Q5 or Q8. Since the ripple voltage across the power supply capacitors is solely a function of the load current, the ripple rises as the output increases—but always remains *at least* 50 db below the output voltage. The rejection from one channel to another is sufficient that one channel may be driven to full power output and the separation at 10 Hz will exceed 65 db.

Ripple on the negative supply results in a slight variation in collector to emitter voltage of Q1. Collector current, however, is not dependent on collector-emitter voltage in common-emitter amplifiers such as Q1. Consequently this ripple can not induce any voltage change across R6. Since the ripple peaks are in phase for both the positive and negative supplies their effects, small as they are, tend to cancel each other. Total hum and noise output is less than 500 mv with an 8-ohm load.

The values shown for R18 and R21 limit the output power to 125 watts for an 4-ohm load. Operation at higher powers are possible but require forced air cooling of the heat sinks. At 125-watts output power is current limited. An output power of 100 watts is available to an 8-ohm load. Although a 16-ohm load can be supplied with 60 watts per channel the output power is now becoming voltage limited since the supply voltages must be greater than the peak to peak excursions of the output voltage.



This is what the assembled amplifier less the protective cover looks like. Like it?

This amplifier is stable under all conditions from short to open circuit loading on the output terminals, without signal or heavily overdriven, during normal operation, turn on or turn off situations.

Construction techniques

Using the specified parts, both amplifier channels and the power supply neatly fit onto an 8 x 10 x 2½-inch chassis. A soft aluminum chassis is not only easier to work with, but also will not transfer magnetic fields from the transformer into sensitive input circuits.

The first construction step is mounting components to the printed circuit boards. A half size layout of the board is included (Fig. 2) for the convenience of constructors who may wish to make their own boards. Be sure to mount R4, D1, and R5 first since C4 and C2 obstruct the b... entry. Use a small soldering iron and rosin core solder. If you should accidentally fill a hole with solder, heat the area while inserting a toothpick through the hole. Insert each component, bend the leads outwards slightly to hold it in place, then clip the leads about 1/16-inch above the copper. Solder the leads for a few components at a time. Keep your iron tip wiped clean. After each board is complete attach small angle brackets to the two corners. These brackets should not touch the copper foil; a separate No. 16 wire returns the circuit board to the power supply ground.

Remove the transformer shells and attach ½" aluminum angles to provide mounting feet.

Mount each 40411 transistor to a heat sink. Insulate the heat sinks from ground. This technique substantially improves heat flow out of the transistor and also reduces collector capacitance to ground. On two of the heat sinks a small bracket is used to mount D2 and D3. These diodes provide thermal compensation for the output transistors and their cases should make good thermal contact to the heat sink.

Mount all heat sinks to a 1/16-inch aluminum plate about 4 x 9... inches. Fasten this plate to the chassis with angle brackets placed at each end. After all assemblies are ready to mount, position them carefully. In particular, be especially careful of parts placement on the back of the chassis. The locations of the power supply capacitors should be examined carefully to avoid any interference with the output terminals.

An adequate vertical flow of air must be provided for the heat sinks. A large 2 x 8-inch slot is "nibbled" out beneath the heat sink mounting plate. If a bottom plate is used, provide a number of large holes to complete the air flow path. Use ⅝-inch high mounting feet on the chassis.

Test before using

After completing assembly, a few simple tests are in order. Temporarily connect a 100 Ω pot set to minimum resistance in place of R11. Connect a 50-watt light bulb in series with the ac line cord. Leave the output terminals unloaded and set the input level controls to their minimums. Apply power to the unit. Measure the voltage across each supply capacitor (C1 and C2). This reading should be near 48 volts and a dc voltmeter connected across each output should read ...

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(continued from page 44)

than 0.1 volt when set up in this fashion.

If power supply voltages are correc the dc output voltage is nearly zero, apply a small audio signal to the input. Monitor the output signal with a scope or ac voltmeter while advancing the level control slowly. With no other output load, the output voltage should reach about 33 volts rms. If severe clipping on half of the signal swing is noticed, do not proceed further until the difficulty is corrected. Crossover distortion will be noticed, but this is a normal condition at this time.

Turn the amplifier off and insert a milliameter set to its 100-mA range in series with the collector lead of Q6. Turn the input level controls all the way down and apply power to the amplifier. Slowly increase the potentiometer substituted for R11 until the meter reads 20mA. Turn the amplifier off, measure the pot resistance and insert the nearest 5% value to this resistance as R11. This resistor might need changing if transistor Q5, Q6, Q8, or Q9 are changed in the amplifier.

Repeat this procedure for the other channel. It is not necessary to set the current to exactly 20mA. After reconnecting the Q6 collector lead to PC board, you are ready to test the amplifier with a load. Connect your resistive lead (4 ohms) across the output terminals, apply power and monitor output voltage as the input level is increased. At only a few watts, severe clipping will be noticed since the power supply cannot deliver rated output with the lamp resistance in series with the line input.

If the amplifier operates correctly thus far, it is unlikely that higher power operation will disclose any problems. However, you may wish to test with higher wattage lamps in series with the ac input.

After all tests are completed, a perforated protective cover may be fabricated if needed. In the final installation, be sure the bottom of the chassis is at least ½-inch off the mounting surface. Allow at least ¾-inch clearance above the heat sinks for heat dissipation.

If you plan to drive 25 volt line transformers install D8 and D9. The output network shown on the schematic should be added when electrostatic speakers are used with this stereo power amplifier. **R-E**

COMING NEXT MONTH

If you think this amplifier is a honey, just wait until you see the preamp the author has dreamed up. Watch May.