BUILD THIS HIGH POWER HI-FI AUDIO AMP FOR YOUR CAR

Our build-it-yourself car amplifier has so much power that it ought to be illegal!

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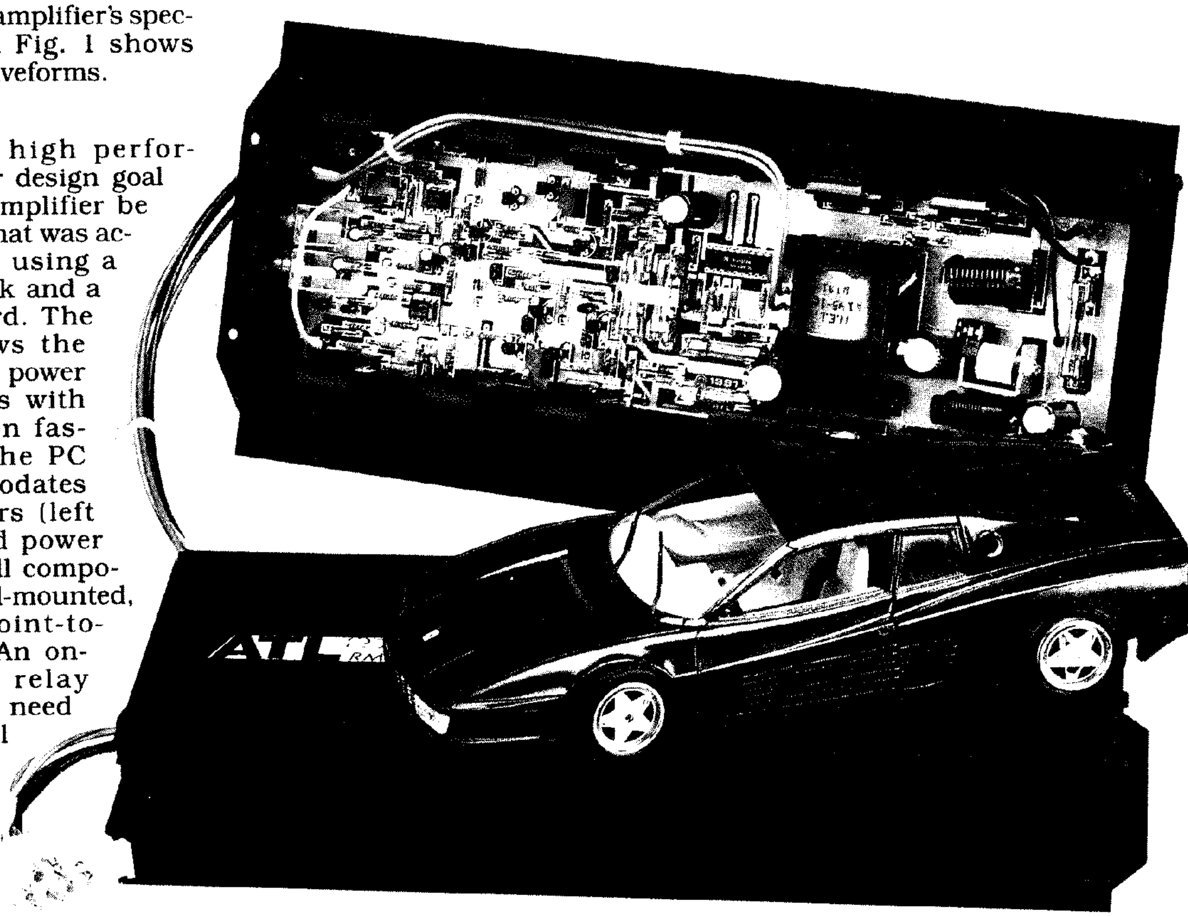
CAR STEREO AMPLIFIERS ABOUND, but most are compromises in performance, or are expensive. Our build-it-yourself car amplifier is a real goose-bump generator, offering performance in the high-end home-stereo range, yet is cost-effective and easy to build. Performance highlights include 270 watts output power (135 watts per channel, RMS, into 8 ohms), low distortion, and exceptional output current capabilities. The power supply itself is capable of delivering over 600 watts, giving the amplifier plenty of reserve power. Note also that the power rating is for real, continuous watts, into 8 ohms (not the way most car amps are rated), allowing the use of home-system speaker components, which are generally less expensive than 4-ohm versions, and offer a much broader selection of quality elements. If 4-ohm speakers are desired, the amplifier will deliver a whopping 200 watts per channel! Table 1 shows the amplifier's specifications, and Fig. 1 shows some output waveforms.

Overall design

Along with high performance, another design goal was that the amplifier be easy to build. That was accomplished by using a custom heatsink and a single PC board. The heatsink allows the mounting of all power semiconductors with simple snap-on fasteners, and the PC board accommodates both amplifiers (left and right) and power supply. Also, all components are board-mounted, minimizing point-to-point wiring. An on-board power relay eliminates the need for an external high-current switch, and allows the amp to be slaved to an auto radio's power-antenna lead. Both the power



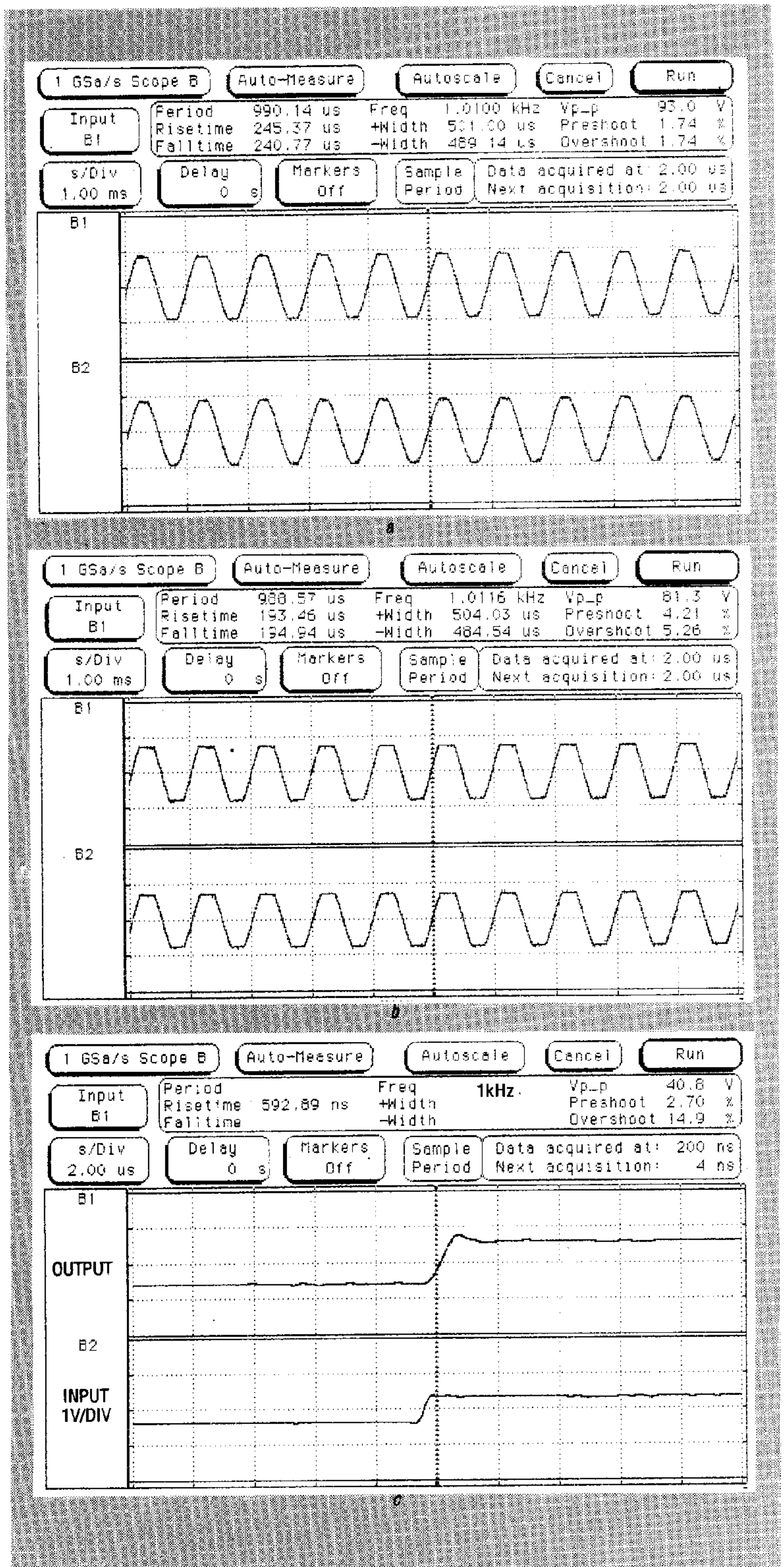


FIG. 1—OUTPUT WAVEFORMS. In *a*, the amplifier is driving an 8-ohm load on both channels at 1 kHz; the signal clips at 93 volts p-p with 135 watts per channel. Both channels are driving a 4-ohm load at 1 kHz in *b*; it clips at 81 volts p-p with 200 watts per channel. Using an 8-ohm load with the input filter removed, a rise time of 600 ns and a slew rate of 54 volts/μs can be seen in *c*.

supply and the amplifiers use state-of-the-art field-effect power transistors (FET's). A custom copper-tape-wound inverter transformer gives the power supply its punch. A CAD-supported printed-circuit board with ground plane, plated-through holes, silkscreened parts placement, and solder mask completes the picture. Let's take a more detailed look at how the unit works.

The power supply

Figure 2 shows the power-supply schematic. The basic design is a push-pull forward inverter with pulse-width modulation voltage regulation. Relay RY101 is energized via the 12-volt control lead, applying power to the pulse-width-modulator chip IC101 and the power transformer center tap. Alternating pulses generated by IC101 drive the output transistors at pins 16 and 13, turning on Q101 and Q102, and Q103 and Q104, one pair at a time. The transistors are paralleled for increased power handling capacity. Resistors R107–R110 eliminate the possibility of local transistor oscillation. As the transistors alternately conduct, an alternating current flows in the primary of transformer T101, in turn inducing an alternating current in the secondary.

The output of T101 is full-wave bridge rectified and then filtered by L101, L102, C106, and C107. With a winding ratio of 4 to 1, a maximum of about 58 volts can be generated at the output. That is regulated down to ± 47 volts by sending a sample back to resistor divider R112+R113 and R105. The divided voltage is applied to pin 2 of IC101, where it is compared to a 2.5-volt reference, generated in turn by dividing the chip-provided 5-volt reference at pin 10 by R101 and R102. When the supply output drops below 47 volts, IC101 drives the transistors with longer pulses, and with shorter pulses when the output goes above 47 volts, thus achieving voltage regulation. Components C102, C103, and

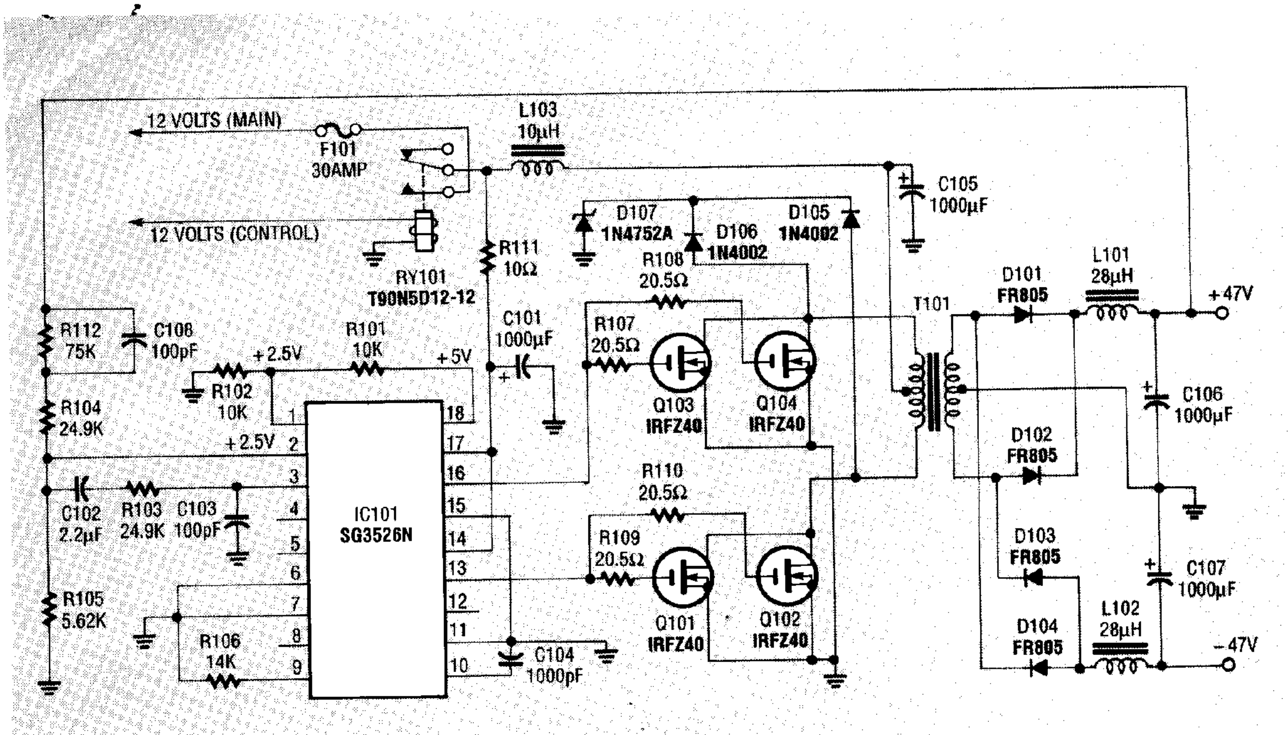


FIG. 2—POWER-SUPPLY SCHEMATIC. It's a push-pull forward inverter with pulse-width modulation voltage regulation. Relay RY101 is energized via the 12-volt control lead, applying power to the pulse-width-modulator chip IC101 and the power transformer center tap.

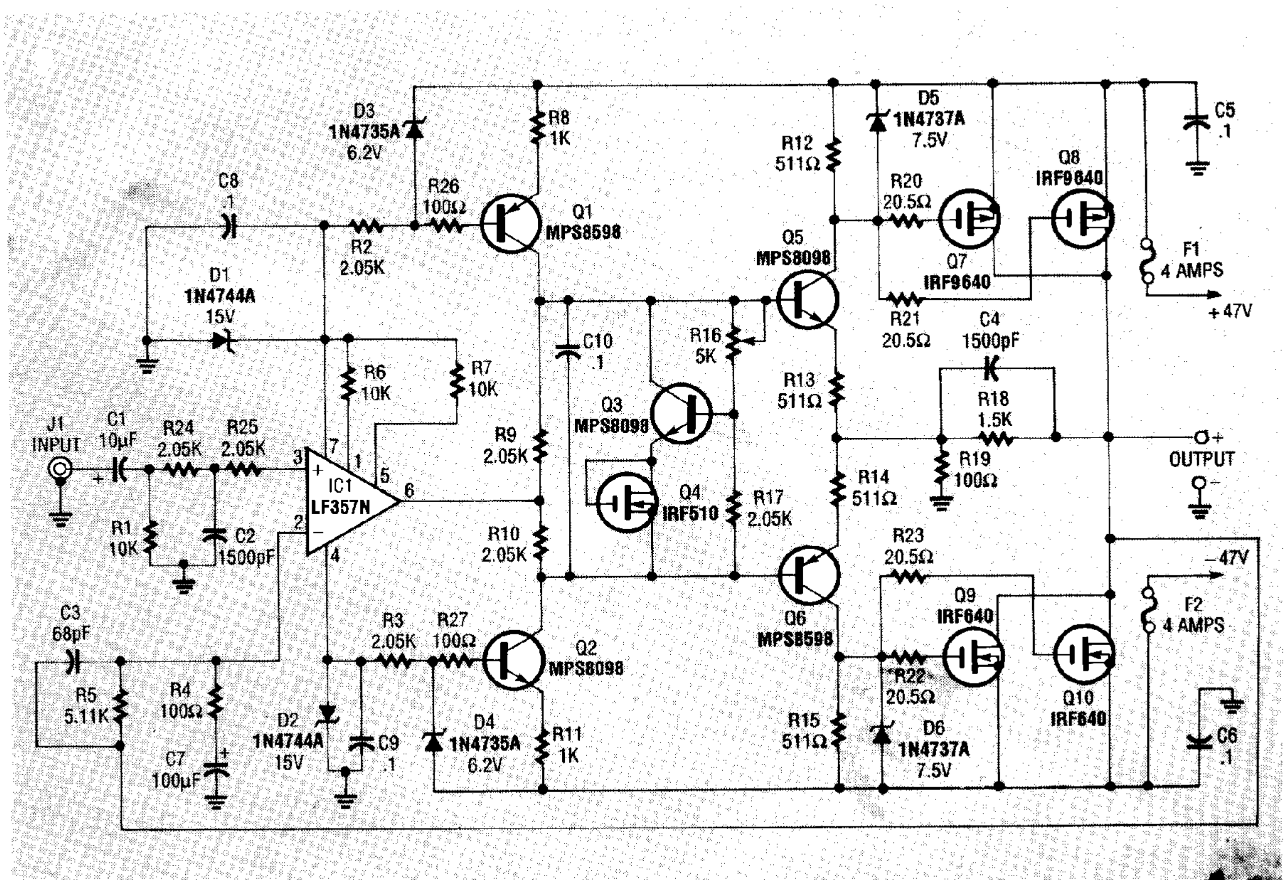


FIG. 3—THE LEFT AND RIGHT AMPLIFIERS are identical and the parts numbered the same except for an L or R suffix; here's one of the amplifiers.

R103 form a filter network that stabilizes the voltage-regulation feedback loop. The inverter operating frequency is set via C104 and R106 to about 50 kHz. Finally, L103 keeps noise from the inverter from getting back into the car power system, and D105–D107 form a snubber network that limits ringing voltages generated by the alternating high currents in the transformer primary.

The amplifiers

Both amplifiers (left and right) are identical, and parts are numbered the same, with an L or R suffix, as appropriate. Therefore we'll show only one of them—see Fig. 3. Input signals are applied to IC1, an LF357A op-amp, via filter network R1, R24, R25, C1, and C2. The output of IC1 drives resistors R9 and R10, which are in series with current source Q1 and current sink Q2. The result is that voltage swings at the output of IC1 (at pin 6) are translated and applied to the bases of Q5 and Q6.

The DC voltage between the bases of Q5 and Q6 is set by voltage multiplier Q3. The voltage is nominally about 8 volts, and can be set as desired by R16. It appears across R13 and R14 by emitter-follower action of Q5 an Q6. In turn, a current flows through R12 and R15, generating a voltage across them, which is applied as the bias for the output transistors. FET output transistors Q7–Q10 each require about 3.5 volts bias from gate-to-source to begin conduction, which is supplied as described above. The output transistor bias is adjusted to provide an optimal idle current in the output stage. To keep that current stable, the output transistor temperature is sampled by Q4, which is mounted on the heatsink, and the Q3 bias generator voltage is varied to track the temperature accordingly.

Transistor Q4 has its gate connected to its drain, causing the drain-to-source voltage to be roughly equal to the gate turn-on threshold, which varies with temperature and tracks the output transistors. Transistor Q3 multiplies that voltage by a factor of two, to provide the bias required by both the positive and negative output transistors. Transistors Q5 and Q6 also provide a phase-inversion function, taking the AC signal voltage at the output of IC1 and applying it to the gates of the output transistors. As the gates are driven, the drains, connected to the output, swing in the opposite direction, driving the load. Components C4, R18, and R19 form a local feedback loop, setting the output stage gain at about 15. Components C3, R5, R4, and C7 provide overall amplifier feedback, and set the total amplifier gain at about 51. Zener diodes D5 and D6 limit the output transistor gate drive voltages, which in turn limit the maximum output current.

Building the amplifier

If you are fabricating your own circuit board, remember that you will have to provide feed-throughs and solder component leads on both sides of the board in several places. We've provided foil patterns if you want to do that, but you can also buy a ready-to-use PC board, as well as various other parts, from the source mentioned in the parts list. Figure 4 is the parts placement diagram. Begin assembly by installing all parts except the TO-220 power components and potentiometers R16L and R16R. Carefully verify resistor and capacitor values before installing them, and check diode and electrolytic capacitor polarities.

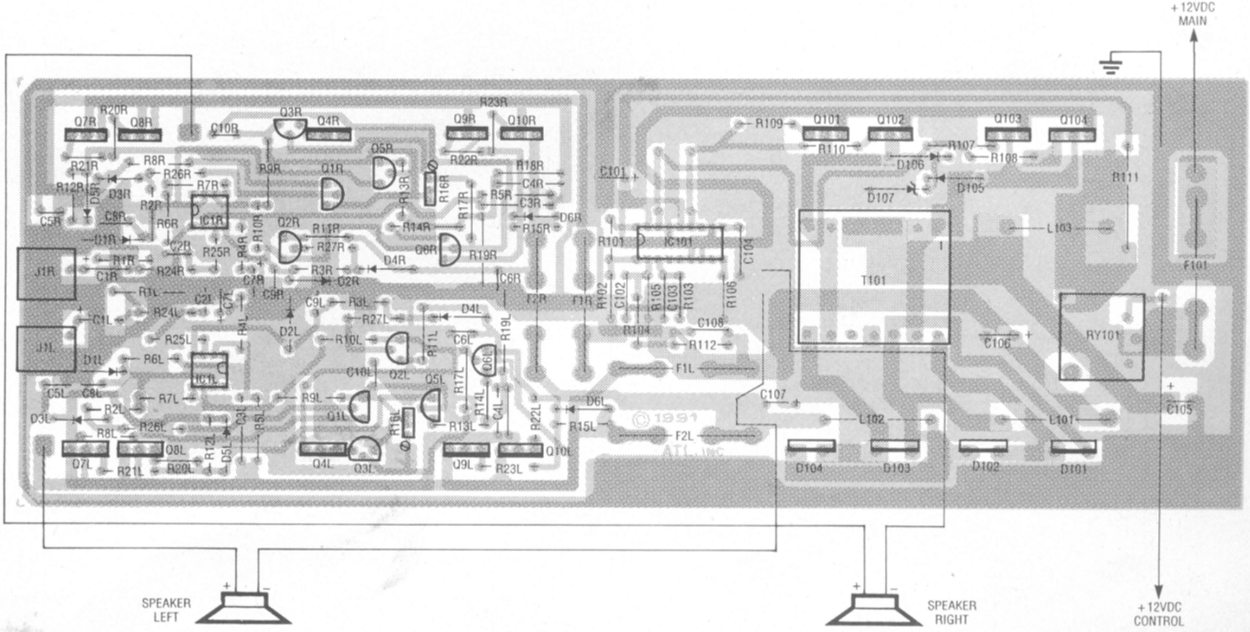


FIG. 4—PARTS PLACEMENT DIAGRAM. First install all parts except the TO-220 power components and potentiometers R16L and R16R. Before installing the output FET's, they must be matched in pairs within each particular type (see text and Fig. 5).

Before installing the output FET's, they must be matched in pairs within each particular type to ensure proper current sharing and power dissipation. As an example, Q7L and Q8L must be matched to each other, but they don't have to match the right-channel components. (Q7R and Q8R must, of course, match each other.) The same goes for Q9 and Q10. A simple circuit for matching them is shown in Fig. 5. The parts should be matched to be within 100 millivolts of gate voltage at 50 mA of drain current, and 200 millivolts of gate voltage at 2 amps of drain current. Make the 2-amp measurement quickly—otherwise you must heatsink the transistor. Note that P-channel devices (the IRF9640's) must be supplied with −5-volts DC and N-channel devices (the IRF640's) must be supplied with +5-volts DC.

Once you have matched the transistors, insert them in the PC board. Make sure they are straight up with their leads protruding uniformly about 1/16-inch from the *bottom* of the board. Check to see that the transistors are centered on the heatsink rail, and then solder. Next, prepare potentiometers R16L and R16R by adjusting them for a resistance of 1000 ohms between pins 1 and 2 (see Fig. 6), and then install them.

Finally, install the three power and ground lead-in wires, as well as the speaker outputs and grounds. Check that all parts are the correct type and value, and in the correct orientation.

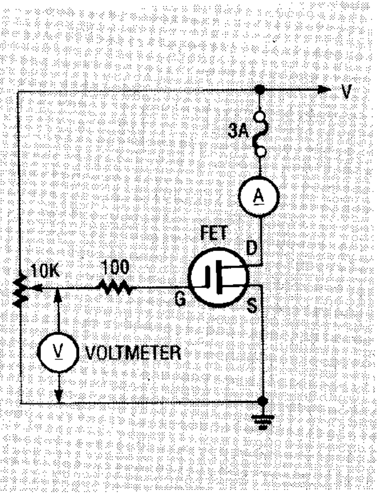


FIG. 5—PAIRS OF FET'S MUST BE MATCHED using this circuit (see text). First set the potentiometer's wiper voltage to zero, turn it up to the desired drain current, and measure the voltage as shown. Match the parts to within 100 millivolts of gate voltage at 50 mA of drain current, and 200 millivolts of gate voltage at 2 amps of drain current. N-channel devices (the IRF640's) require a +5-volt supply, and P-channel devices (the IRF9640's) require −5 volts.

Chassis assembly

Prepare the heatsink by checking to see that the mounting surfaces for the power components are clean and smooth. Temporarily slide the circuit board assembly into the heat-

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.
R1, R6, R7 (two of each, L&R), R101, R102—10,000 ohms
R2, R3, (two of each, L&R) 2050 ohms, ½-watt
R4, R19, R26, R27 (two of each, L&R)—100 ohms
R5 (two, L&R)—5110 ohms
R8, R11 (two of each, L&R)—1000 ohms
R9, R10, R17, R24, R25 (two of each, L&R)—2050 ohms
R12–R15 (two of each, L&R)—511 ohms
R16 (two, L&R)—5000 ohms, potentiometer
R18 (two, L&R)—1500 ohms
R20–R23 (two of each, L&R), R107–R110—20.5 ohms
R103, R104—24,900 ohms
R105—5620 ohms
R106—14,000 ohms
R111—10 ohms, 1/2-watt
R112—75,000 ohms

Capacitors
C1 (two, L&R)—10 µF, 35 volts, electrolytic
C2, C4 (two of each, L&R)—0.0015 µF, ceramic
C3 (two, L&R)—68 pF, ceramic
C5, C6, C8–C10 (two of each, L&R), C104—0.1 µF, Mylar
C7 (two, L&R)—100 µF, 10 volts, electrolytic
C101, C105—1000 µF, 15 volts, electrolytic
C106, C107—1000 µF, 50 volts, electrolytic
C102—2.2 µF, 15 volts, electrolytic
C103, C108—100 pF, ceramic
C104—0.001 µF, ceramic

Semiconductors
IC1 (two, L&R)—LF357A op-amp
IC101—SG3526N pulse-width-modulator
D1, D2 (two of each, L&R)—1N4744A diode
D3–D6 (two of each, L&R)—1N4737A diode
D101–D104—FR805 diode
D105, D106—1N4002 diode
D107—1N4752A 33-volt Zener diode
Q1, Q6 (two of each, L&R)—MPS8598 PNP transistor
Q2, Q3, Q5 (two of each, L&R)—MPS8098 NPN transistor
Q4 (two, L&R)—IRF510 N-channel MOSFET
Q7, Q8 (two of each, L&R)—IRF9640 P-channel MOSFET
Q9, Q10 (two of each, L&R)—IRF640 N-channel MOSFET
Q101–Q104—IRFZ40 N-channel MOSFET

Other components
L1, L2—28 µH coil
L3—10 µH coil
RY101—T90N5D12-12 relay (Potter and Brumfield)
T101—transformer, 4 turns, center-tapped primary, 16 turns, center-tapped secondary; 5-mil copper-foil wounded on a Ferroxcube ETD-34 core.
F101—30-amp fuse
F1, F2 (two of each, L&R) 4-amp fuse
J1, J2—RCA-type input jack
Miscellaneous: PC board, 16 "Q" clips, 16 insulators, 10 fuse clips, heatsink/case strain relief, 4 "L" brackets, wire, solder, etc.

Note: The following items are available from A&T Labs, Box 4884, Wheaton, IL 60187:
- **Complete kit of parts including heatsink and covers, PC board, and transformer—$245**
- **Fully assembled and tested unit—$315**
- **PC board (Mil-spec glass, double-sided, silkscreened, with solder mask)—$29**
- **Transformer T1—$40**
- **Custom heatsink with covers—$44**

Please add 5% of total order for shipping and handling, 12% in Canada. IL residents must add 7% sales tax. Check, money order, or C.O.D. in cont. U.S. All inquiries must include a SASE.

sink. Install the endplate with the input connector holes, and slide the board up against it. Take a look at Fig. 7, the inside of the author's completed prototype, to get a feel for the overall assembly and close-up details. Lightly mark each power component site on the case. Remove the amplifier and prepare each site with a thin coat of thermal heatsink grease. Apply a mica insulator at each site.

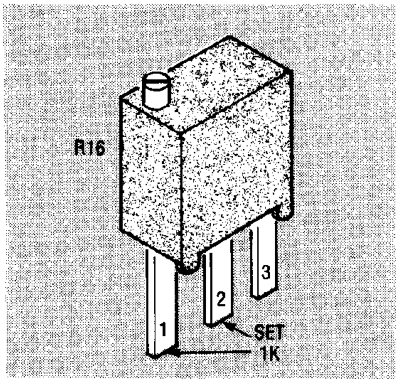


FIG. 6—PREPARE POTENTIOMETERS R16L AND R16R by adjusting them for a resistance of 1000 ohms between pins 1 and 2.

TABLE 1—SPECIFICATIONS

Power Output	135 watts/channel RMS into 8 ohms with both channels driven
	200 watts/channel RMS into 4 ohms with both channels driven
Frequency Response	12 Hz–45 kHz (+0, −3 dB) 12 Hz–400 kHz with input filter removed
Distortion	<0.03% THD at 1 kHz, <0.1% 20 Hz–20 kHz
Rise Time	$<0.6\ \mu s$
Slew Rate	$>100V/\mu s$
Power Input	12–14.5 volts, 0.5 to 50 amps maximum

Re-install the amplifier board with each of the power parts bent slightly away from the heatsink surface. Apply a thin layer of thermal grease to each part. Then bend the part back against the heatsink, and hold it in place with a spring clip as shown in Fig. 8. Use a piece of cardboard or plastic as an insulator between the part and the clip. After each clip is in place, remove the two wire bales from the clips. Make a final check with an ohmmeter to see that none of the power parts are shorted to the heatsink. We are now ready to make a few safety checks on the circuitry.

Testing

Install a 5-amp fuse for F101, and apply power. The inverter should now generate plus and minus 47 volts, as measured at the fuse clips for F1 and F2. Now install a 1-amp fuse for F1L and a milliammeter for F2L. Apply power and adjust R16L for a cur-

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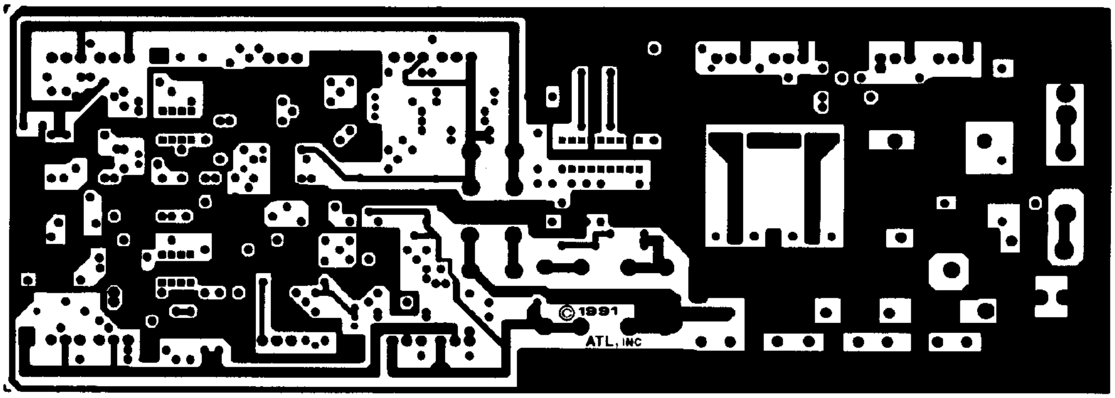
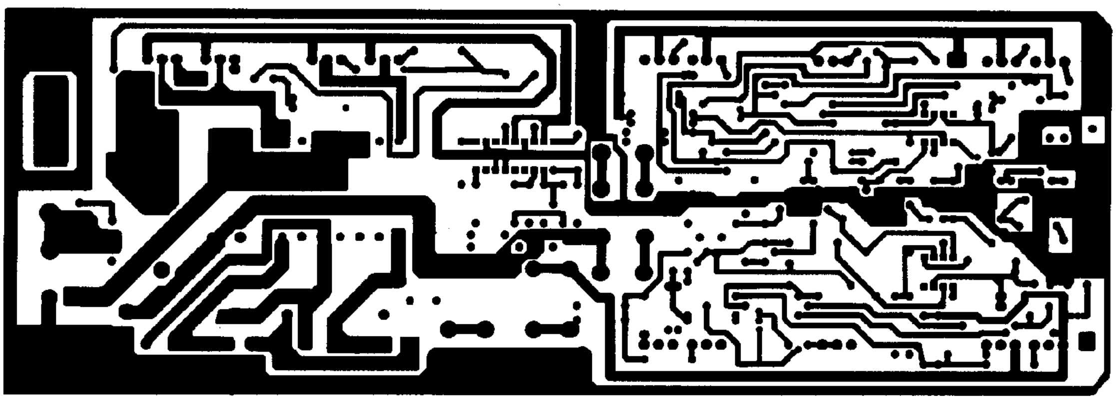


11³/₈ INCHES

COMPONENT-SIDE FOIL PATTERN shown half-size.



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SOLDER-SIDE FOIL PATTERN shown half-size.

AMPLIFIER

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rent of about 60 mA. Repeat the same procedure for the right channel, adjusting R16R. Check the voltage at the two speaker output terminals. The DC value should be less than 50 mV. If all is well so far, replace F1 and F2 with 2-amp fuses, connect a pair of test speakers to the output leads, and apply an input signal.

If everything still checks out, feed the wires through the end plate using a plastic strain relief to secure the wires. Now install the final fuse values, slide the cover in place, and attach the other end plate.

Installation and use

The first thing you must do is decide on an appropriate location for the amplifier. Good choices include under a seat or in the trunk. Once the unit is mounted, wire the power, ground, and speakers. Ground can be picked up from the chassis of the vehicle, if desired, making sure it is a solid ground. Use appropriately heavy wires for the main power and ground, as they will have to conduct as much as 40 or 50 amps. You may wish to pick up the main power close to the battery, in which case you should use a fuseable link as the very first piece of the connection. Fuseable links are readily available from most automotive parts stores. You may also wish to install an engine noise filter in series with the main supply.

The 12-volt control lead is ideally connected to the radio's electric antenna output, if it is so equipped. If not available, a separate switch can be used. Finally, wire the inputs with shielded cable. It's best if the car radio you're using has a volume-controlled line-level output, which most of the better radios have. In any case, do not drive the amplifier from the speaker output of the radio—the signal levels could damage the amplifier inputs, and the signal would include the inherent distortion of the radio's amplifier. One last word of caution: the heatsink is designed for the peak-to-average power ratio of music. Therefore, for applications which require continuous output at the rated power levels, forced cooling or a bigger heatsink are recommended. Happy listening! **R-E**

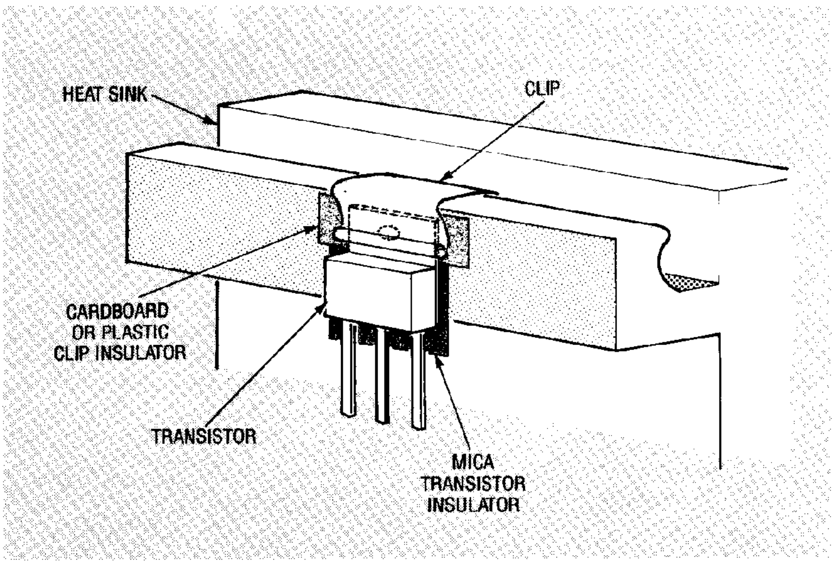

FIG. 8—HOLD EACH POWER COMPONENT IN PLACE with a spring clip, and use a piece of cardboard or plastic as an insulator between the part and the clip. Check with an ohmmeter to see that none of the power parts are shorted to the heatsink.

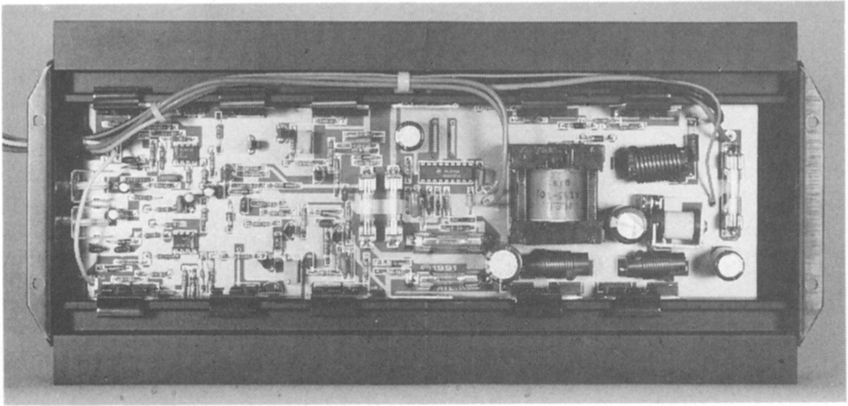

FIG. 7—THE MOUNTING SURFACES of the heatsink and power components must be clean and smooth. Mark each power component site on the case, remove the amplifier board, and prepare each site with a thin coat of thermal heatsink grease and a mica insulator. Then re-install the amplifier board with each of the power parts bent slightly away from the heatsink surface. Apply a thin layer of thermal grease to each part and then bend the part back against the heatsink. Now take a look at Fig. 8.

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