CONSTRUCTION

A HIGH-POWER MOBILE STEREO AMPLIFIER

Provides clean, 15-W/channel audio from a 12-V dc source.

BY EDGAR BRADEN

TRYING to get high-fidelity sound in a mobile environment presents very difficult problems. First of all, ambient (road and motor) noise must be overcome. But the direct-coupled, complementary output stages of many tape players and radios cannot produce more than a few watts of power. Output transformers could boost the power, but serious drawbacks such as bulkiness and high cost make them impractical.

In the face of these limitations, many camper, sports car, and boat owners still ask, "How can I get an appreciable amount of clean audio output using solid-state circuitry operating from a +12-V dc source?" This article provides the answer with the Mobile Stereo Power Amplifier.

The amplifier will provide 15 W rms/channel of low-distortion audio into 8-ohm loads (enough to drive even low-efficiency speakers). Only a +12-volt dc supply is required, and with slight modifications, it will operate from 6-volt supplies. Also, the amplifier sections for the two channels can be "bridged" (driven out of phase) to provide 30 watts monaural into a 16-ohm speaker, or paralleled for a 4-ohm load. Parts cost for the amplifier is about $25. Of course, two such units can be operated independently in the bridged or parallel mode to provide 30 watts per channel for stereo.

Among the amplifier's features are direct-coupled output circuitry, a high-frequency (20,000-Hz) dc-to-dc converter, and a low-distortion IC audio driver. The converter offers high efficiency and compact size as a result of its operating frequency. What's more, core (magnetostriction) and pickup noise lie beyond the audible spectrum. Above all, both the power converter and audio amplifier are easy to build!

About the Circuit. The dc-to-dc converter shown in Fig. 1 is a fairly standard design. Its frequency of operation is governed by saturating-core transformer *T1*. The winding (points 5 and 6) connected to the bases of transistors *Q3* and *Q4* is phased to provide positive feedback, which sustains oscillations. Thus a 12-volt, 20,000-Hz square wave is applied to the primary

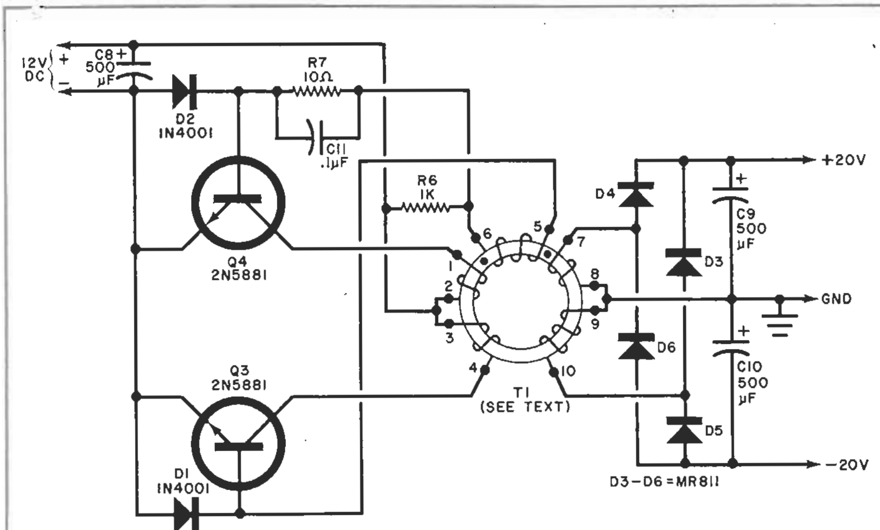


Fig. 1. Frequency of dc-to-dc converter is governed by T1.

POWER SUPPLY PARTS LIST

C8,C9,C10—500-µF, 25-volt electrolytic capacitor
C11—0.1-µF paper or Mylar capacitor
D1,D2—1N4001 rectifier
D3 through D6—MR811 (Motorola) or IN4933 fast-recovery diodes. (See the text)
F2—10-ampere slow-blow fuse
Q3,Q4—2N5881 (Motorola) npn power transistor—(do not substitute)
R7—10-ohm, 2-watt resistor
R6—1000-ohm, ½-watt resistor
S1—Spst switch
T1—See text. Requires a Ferroxcube No. 846T250-3E2A toroid core.
Note: an etched and drilled circuit board is available from EBCO, 10 Sherwood Drive, Nashua, NH 03060 for $4.50. The Ferroxcube toroidal core is available from Elna Ferrite Laboratories, Inc., Box 395, Woodstock, NY 12498, for $1.75 (first class postage paid).

of *T1* (points 1 and 4) via the collector leads. The stepped-up output of *T1* is rectified by the full-wave bridge *D3-D6* and filtered by *C9* and *C10*. A bipolar (±20 V, referenced to ground) output is obtained.

A ferrite toroid is used as the core of *T1* because of its high permeability and residual magnetization (remanence), which aids the switching between the transistors. Further, the toroid's form factor keeps core losses low as there is a minimum of magnetic material for a large power-handling capability. Toroids are self shielding —all magnetic flux remains in the core. This isolates the switching circuit from the power amplifier. Also, fewer turns are required, so heavier gauge wire can be used, resulting in lower I^2R losses. And, practically speaking, the toroid is much easier to wind by hand than the bobbin of a laminated-iron core!

A Signetics NE540 integrated circuit acts as the power amplifier's input stage and supplies base drive to power transistors *Q1* and *Q2*, which form a complementary-symmetry output stage (Fig. 2). It also controls the transistors' bias current to minimize crossover distortion.

The 540 IC is a high-fidelity device, having a bandwidth exceeding 100,000 Hz. Its output stage can drive a 600-ohm load to 3 dB below maximum, with a typical distortion figure of 0.5% at 40 dB gain. The circuit configuration shown in Fig 2 has a gain of 34 dB, which should reduce distortion to about 0.25% for high-fidelity listening. Note that only one channel (Channel A) is shown.

Construction. The task of winding *T1* is not really difficult, but care must be exercised to keep track of the start and finish ends of each winding to assure proper phasing so the circuit will oscillate.

Use No. 20 enameled magnet wire for both the primary and secondary windings. (No. 22 wire can be substituted.) Fold in half a 5′ (1.52-m) length of the wire and wind this around the toroid for a total of 14 turns. Distribute the wire as evenly as possible all the way around the core. Bend the wire sharply around the corners of the core to make tight windings. When you are finished, label the two free ends with pieces of tape numbered 1 and 3. Snip through the fold loop. Then use an ohmmeter to determine which of the newly cut ends has continuity with lead 1; label the unmarked end lead 2. Then label the remaining unmarked lead with a 4. (It should have continuity with lead 3).

Next, wind the feedback winding. This consists of five turns of No. 22 or No. 24 wire, evenly distributed around the core. Start and finish the winding

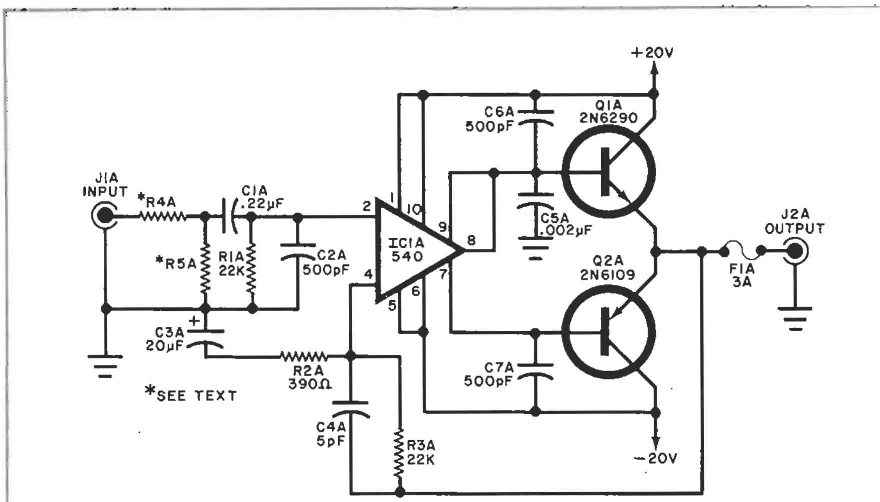
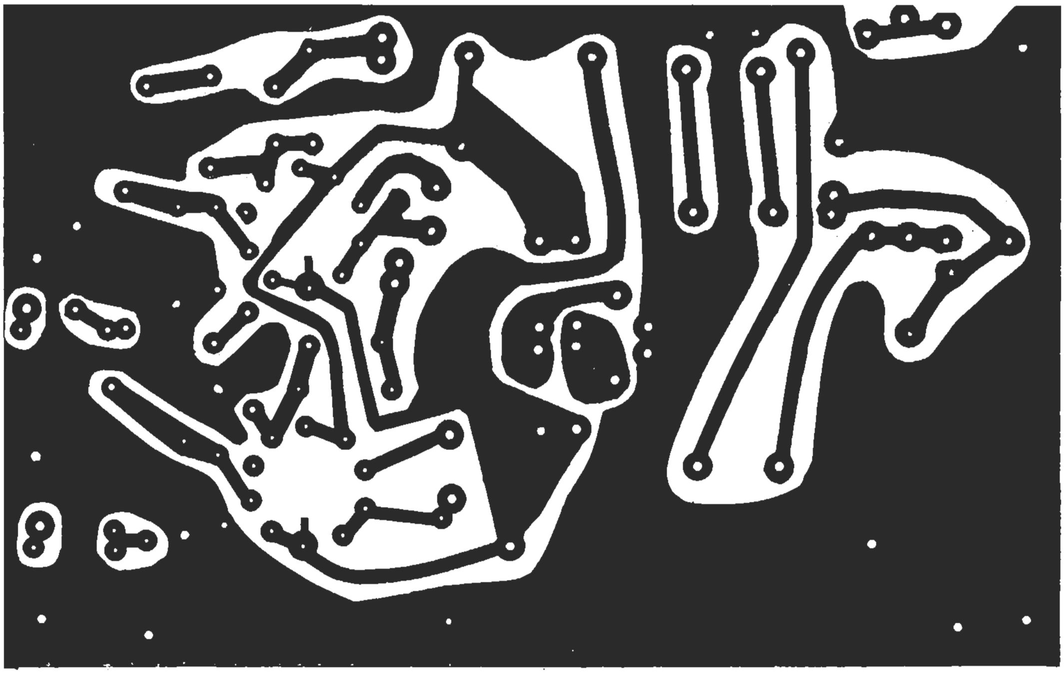


Fig. 2. First stage of amplifier is an integrated circuit.

AMPLIFIER PARTS LIST

C1—0.22-µF Mylar capacitor
C2,C6,C7—500-pF disc capacitor
C3—20-µF, 15-volt electrolytic capacitor
C4—5-pF silver mica or ceramic capacitor
C5—2000-pF (0.002-µF) disc capacitor
F1—3-ampere fast-blow fuse
IC1—NE540 or SE540 integrated circuit (see text)
J1,J2—Phono jack
Q1—2N6290 npn power transistor
Q2—2N6109 pnp power transistor
R1,R3—22,000-ohm, ½-watt resistor
R2—390-ohm, ½-watt resistor
RA,RB—Input attenuator resistors (see text).
Misc.—Printed circuit board; fuse holders (3); heat sink or chassis box; 22,000-ohm, ½-watt resistor for bridge hookup (see text); spacers (4); mica and plastic-film insulators for transistors; silicone heat sink paste; magnet wire for T1; silicone adhesive; machine hardware; hookup wire; solder; etc.



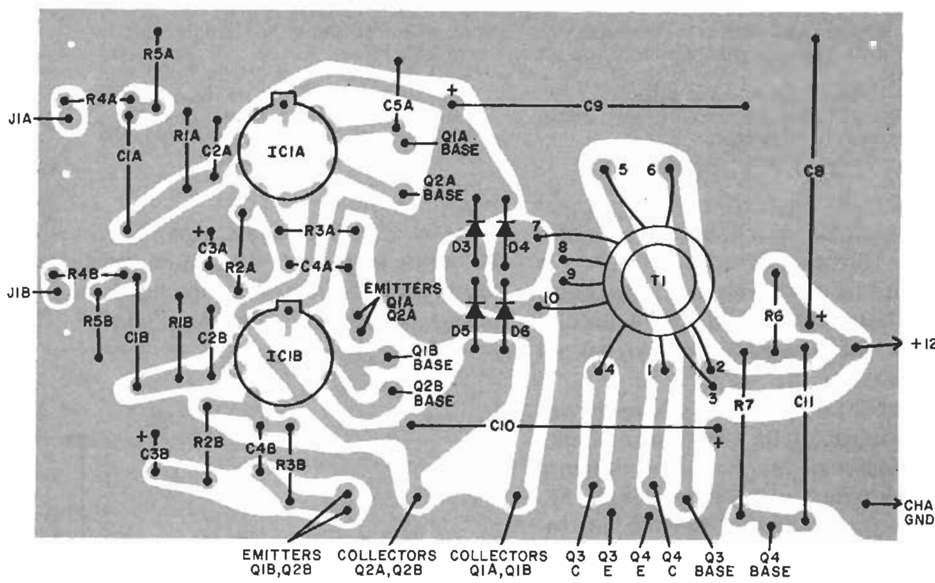


Fig. 3. Actual-size etching and drilling guide for pc board is shown above with component layout at right.

on the opposite side of the core from the primary leads 1 and 4 to facilitate matching the leads with their pads on the pc board. Label the ends of the feedback winding 5 and 6, taking careful note that current flowing *from* 5 *to* 6 should pass through the hole in the core in the same direction as current flowing *from* 1 *to* 2 or *from* 3 *to* 4 in the primary winding.

The secondary winding comes next. As with the primary, the secondary must be bifilar wound to provide tight coupling between the two halves of the winding. It also makes the job of winding easier. Fold in half a 6′ (1.83-m) length of No. 20 or No. 22 enameled magnet wire and wind 21 turns of the double strand around the core. Evenly distribute the turns around the core and press them tightly around the edges to allow sufficient room within the core's hole for the entire winding. When all 21 turns are on the core, label the two free ends 7 and 9. Cut the loop and, using an ohmmeter, pair up the wire that terminates with 7 and label it lead 8. Label the remaining unmarked lead 10. The direction in which the secondary is wound is not important.

(Note: For 6-volt electrical systems, reduce the number of primary windings to seven bifilar turns and the feedback winding to three turns.)

An actual-size etching and drilling guide for the pc board is shown in Fig. 3. After preparing the board, proceed with circuit assembly. Start by mounting *T1* in place as shown in the component guide (also shown in Fig 3.). Do not forget to remove the enamel coating on the ends of the leads so they can be soldered to the copper pads on the circuit board. The leads will normally hold the transformer solidly against the top of the board, but it's a good idea to use a dab of silicone adhesive between board and transformer since the project will be subjected to vibration and other stresses. Taking care to observe polarities and IC pin basing, mount and solder into place the remaining components.

All transistors must be mounted on a heat sink that has at least 10 sq in. (6.54 sq cm) of radiating area. Standard 1/16″ (1.6-mm) thick aluminum plate will do for the 15-W/channel stereo version of the amplifier if cut to the same size as the pc board. After machining the heat sink, mount the transistors, using mica or plastic film insulators, silicone heat-sink compound, and insulating shoulder washers under the mounting screws for the board.

Solder *C6* and *C7* directly to the leads of transistors *Q1* and *Q2*, respectively. Similarly, solder diodes *D1* and *D2* directly to the leads of transistors *Q3* and *Q4*, respectively. Or, if preferred, the capacitors and diodes can be soldered to the appropriate pads on the foil side of the pc board. When this is done, solder interconnecting hookup wire between the transistor leads and the appropriate points on the pc board.

Now, using ¾" to 1" (19-25.4-cm) spacers and machine hardware, sandwich the pc board and heat-sink assemblies together. The transistors must be on the side of the aluminum plate that is opposite the pc board to provide shielding between the transistors and amplifier inputs.

If desired, connect an SPST switch (*S1*) in series between the +12-volt supply and the appropriate pad on the pc board. However, the vehicle's ignition switch can be used in place of *S1*. It is also advisable to insert *F2*, a 10-ampere, slow-blow fuse between the supply and *S1*.

If you plan to use a box to house the amplifier, select one that measures 6"L × 4"W × 1½"D (15 × 10 × 3.8 cm). Mount the transistors on the top of the box, cases outward and secure the circuit board assembly with spacers and machine hardware. Don't forget to mount the fuse blocks where they will be easily accessible. When you mount the project inside your vehicle, bear in mind that the transistor cases are electrically "hot." So, take care that they do not short out against the project or vehicle chassis. Insulate them with a layer of electrical tape or a cardboard shield. Note that we assume a negative-ground 12-volt source. A positive-ground supply can also be used, but make sure that the amplifier pc board "ground" is not connected to the vehicle's chassis ground.

A word about rectifiers *D3* through *D6* is in order here. These are MR811, fast-recovery devices. If you expect full sustained output power from the amplifier, *do not substitute devices.* Power supply transistors *Q3* and *Q4* must be high-frequency devices with an f_T of at least 4 MHz. They should have a beta of at least 20 at 6-A collector current. Lower frequency transistors have a tendency to overheat at the switching frequency employed.

Getting More Power. The amplifier can provide 30 watts of output power into a *monaural* load for 4- or 16-ohm speakers. For 4-ohm speakers, simply parallel the inputs and outputs. For 16-ohm speakers, a bridge configuration can be used as shown in the simplified schematic of Fig 4. Note that a 22,000-ohm resistor must be connected from pin 4 of the channel B driver IC to the junction of *C4* and *R3* in the channel A circuit. Also, channel B's input must be grounded at the input jack *J1B*. Connect a 16-ohm speaker directly across the "hot" sides of jacks *J2* of both channels.

With the system wired as shown in Fig. 4., the second amplifier channel is driven out-of-phase with the *IC1* channel. This doubles the voltage across the speaker load, and thus quadruples the power into the load. However, the output transistors cannot handle this much power. By doubling the load impedance to 16 ohms, however, power is merely doubled to 30 watts. This is well within the power rating of the audio transistors.

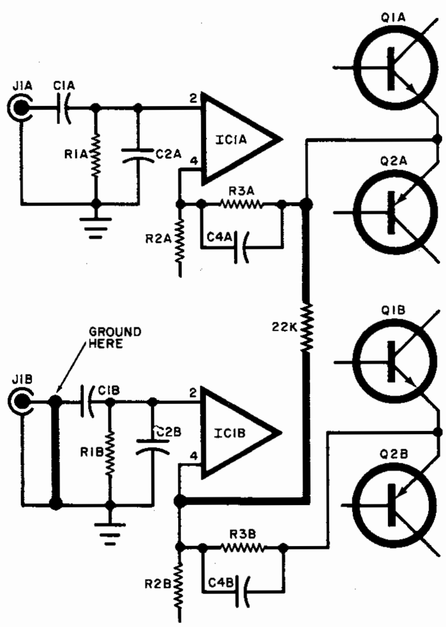


Fig. 4. Additional connection shown in bold will drive the amplifier, in bridged mode, giving 30 W rms (monaural) into 16 ohms.

Output power from each channel in this OTL (output-transformerless) circuit is limited by the maximum supply potential rating of ±22 volts for the NE540 IC. However, if you can obtain the SE540 version of this IC, you can raise the clipping power level by about 15%. To do this, the supply voltage must be increased to ±27 volts by adding four turns to the secondary winding of *T1*.

Using the Amplifier. The low-level outputs of most tape decks and tuners can directly drive the amplifying system. However, if you tap the signal at the speaker output jack, the attenuator network consisting of *R4* and *R5* must be used on each input to reduce signal amplitude to a reasonable level. A good choice of values for *R4* and *R5* would be 10,000 and 1000 ohms, respectively. These values can be varied according to the output level of the tape player or radio used.

If the driving signal is taken from across a volume control, the attenuator network can be eliminated altogether. But if the attenuator is used in this situation, put a coupling capacitor in the input line to avoid placing too heavy a dc load on the source and to prevent upsetting bias levels.

The pc board for the amplifier (Fig. 2) has provisions for installing *R4* and *R5*. If you do not need the attenuator, connect the input line directly to one of the free holes on the board common with *C1*.

Because the amplifier uses feedback, it is possible that "parasitic" oscillations may occur at a few hundred kilohertz. Although they are inaudible, these oscillations can affect quiescent bias conditions, and thus increase distortion. If you suspect the amplifier is oscillating, install a suppressor (a single layer of No. 24 wire wrapped on a 10-ohm, 1-watt resistor) between the emitters of the complementary pair, *Q1* and *Q2*, and the fuseholder for F1. The suppressor will not affect *audio* response in any way.

Much ignition noise pickup can be eliminated by bolting the amplifier right to the radio receiver or vehicle chassis. This will also prevent ground-loop currents from getting into the amplifier; but it will probably not be necessary if a high-level input is fed to the attenuator network. When used with an AM receiver, the amplifier must be shielded or located several feet away from the receiver. Otherwise harmonics of the switching frequency of the power supply will get into the receiver's i-f section. ◈