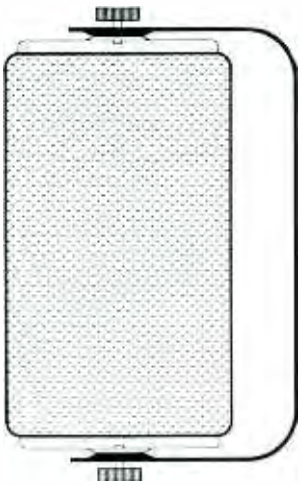
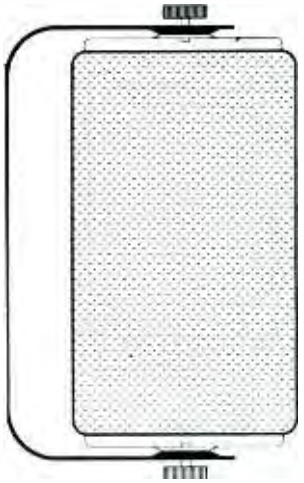


Building & Applying Active Minispeakers



By installing a driving amplifier inside its aluminum enclosure, you can greatly enhance a minispeaker's versatility

By Joseph O'Connell

Aluminum minispeakers are generally characterized by good sound as well as compact size. Originally designed for use in home hi-fi systems, they have found their way into automobiles and other vehicles, where space is more at a premium than in the home, and attached to the sides of portable radios, where size and weight are important. As versatile as they are, though, a pair of minispeakers can be greatly enhanced by building into each its own driving amplifier, as described here. This will make the speakers operate with signal sources that ordinarily cannot drive them, such as personal radio/cassette players, portable CD players and similar low-power devices. The amplifiers boost the signals from these sources to drive the speakers to quite loud levels. With greater power and high-quality signal sources, these "active" speakers produce better sound at higher volume than do typical boom boxes.

Applications for these active speakers are not limited to portable listening. For example these speakers can be used as the heart of a temporary stereo system in a car or other vehicle without requiring a separate power booster. They are also simple to remove to prevent theft and can easily be moved around inside a vehicle to obtain the best acoustical effect. Electronics enthusiasts can also use one on their testbenches as an audio signal tracer and hum detector. Around the home, an active speaker can be used as an intercom station and for setting up a stereo system for best effect.

Because power requirements are flexible, plenty of other uses suggest themselves. Finally, none of the minispeakers' original usefulness is lost when amplifier circuits are added. These speakers can still be used with a stereo system the way they were designed to be simply by flipping a switch.

About the Circuit

Use of a pair of power integrated circuits (*IC1* and *IC2*) greatly simplifies the amplifier circuit shown in Fig. 1. Few discrete components are needed, and the project is easier to build. Also, the low component count makes for an amplifier circuit that requires very little real estate. This is an important consideration when the amplifier is to be installed inside a tight enclosure from a mechanical point of view because the amplifier takes up less of the speaker's internal volume so that it has only a minimal effect on sonic characteristics.

A single LM383 power amplifier IC and a few passive components could have been used to make a simple amplifier circuit. However, the two shown in a bridged configuration allow the speaker output to be taken from across the outputs of two nearly identical amplifiers (instead of between an output and ground) to provide increased maximum power and eliminate the need for a bulky and distortion-producing output capacitor.

In the Fig. 1 circuit, the two amplifier ICs are connected so that they are out-of-phase with each other. When the output of one is positive, the output of the other will be negative. Placing a speaker between the IC outputs allows current to flow from one to the other. The advantage of this arrangement is that the speaker can receive almost the full power supply voltage in either direction on full-excursion input signals. This arrangement is necessary in mobile applications where the available supply voltage is relatively low (12 volts dc) and must be carefully maximized in an amplifier circuit.

With a 12-volt dc power supply, the unloaded output of the the amplifier circuit can theoretically be ±10 volts, for a total swing of 20 volts. Because they get a good deal of power from a low-voltage supply, bridged circuits like the one shown in

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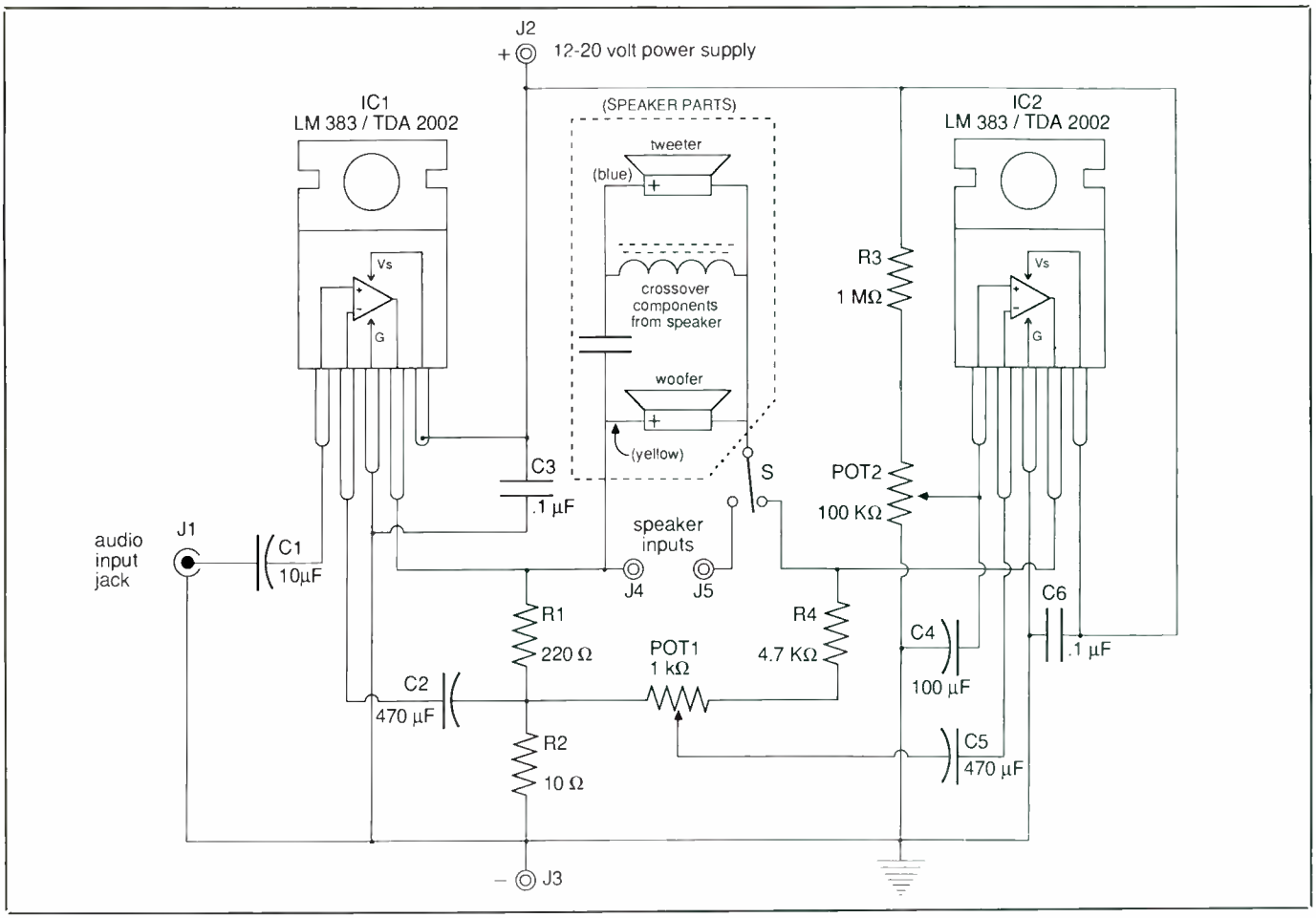

Fig. 1. Schematic diagram of amplifier required for each minispeaker.

Fig. 1 are commonly used in car stereos and power boosters.

Input signals are fed into the amplifier circuit through *J1* and are then capacitively coupled to the noninverting (+) input of *IC1* through *C1*, which blocks dc and passes only the audio signal. After undergoing amplifications, the audio signal at the output of *IC1* is applied to the *R1/R2* voltage divider. The divider feeds a portion of the amplified output signal back into *IC1* through its inverting (–) input to set the gain via the usual negative-feedback method. Hence, the voltage gain of *IC1* is set by (R1 + R2)/R2. Capacitor *C2* blocks blocks ac and feeds back only the audio signal component.

The voltage divider also applies a portion of *IC1*'s output signal to the inverting input of *IC2* through *POT1* and *C5*. Because the inverting input is now being used, the output of *IC2* is out-of-phase with the output of *IC1*. Negative feedback that sets *IC2*'s gain comes from the voltage divider made up of *R4, POT1* and *R2*. During calibration, the gain of *IC2* can be adjusted by *POT1* to precisely match the gain of *IC1*.

Resistor *R3* and trimmer potentiometer *POT2* apply a small dc bias to the noninverting input that is greatly amplified by and appears at the output of *IC2*. Potentiometer *POT2* provides a means for adjusting the amount of dc in *IC2*'s output to allow the dc offset between the two ICs to be nulled to zero.

As designed, the amplifier's specifications make it suitable for portable use. With a 13.8-volt dc power supply, which is typical for automotive electrical systems, the amplifier will produce a clean 8 or 9 watts of driving power into 4 ohms. The limitation on output power depends primarily on the supply voltage—not the ICs. The ICs can safely accommodate up to 20-volt dc power supplies. The greater the supply voltage—up to the 20-volt maximum, of course—the greater the power delivered to the speaker load.

At 13.8 volts dc, playing a music signal at maximum volume into 4 ohms, the amplifier draws an average of about 500 mA. Quiescent current (no input signal) is approximate-

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PARTS LIST (for one speaker)

Semiconductors

IC1,IC2—LM383 or TDA2002 audio amplifier (Radio Shack Cat. No. 276-703 or equivalent)

Capacitors (25-volt)

C1—10-μF electrolytic
C2,C5—470-μF electrolytic
C3,C6—0.1-μF disc
C4—100-μF electrolytic

Resistors (¼-watt, 10% tolerance)

R1—220 ohms
R2—10 ohms
R3—1 megohm
R4—4,700 ohms
POT1—1,000-ohm pc-mount trimmer potentiometer
POT2—100,000-ohm pc-mount trimmer potentiometer

Miscellaneous

J1—Phono jack
J2 thru J5—5-way binding post
S—Spdt miniature toggle switch
Two aluminum minispeakers (Radio Shack Realistic Minimus 7 or similar—see text); printed-circuit board plus extra pc blank for switch panel (see text); materials for making portable carrier (see text); machine hardware; audio cable; speaker cable; hookup wire; solder; etc.

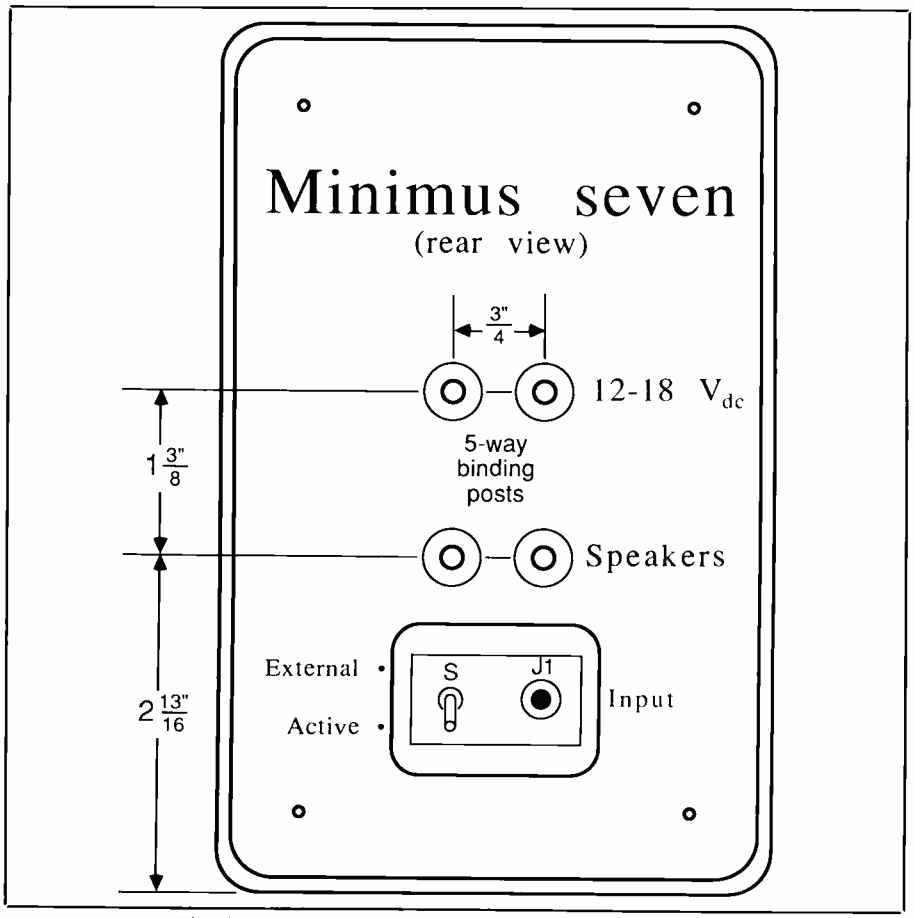

Fig. 2. Rear panel details of modified minispeaker.

ly 125 mA. The low current drain makes the amplifier suitable for portable use with rechargeable cells.

Modifying the Speakers

The first step in building the circuit is to open the speaker (or speakers if you are modifying a pair for stereo use) to gain access to the interior. With some minispeakers, you might be able to remove a few screws and drop off the back. However, the backs of the Realistic Minimus 7 speakers specified in the Parts List are sealed. (If you use a minispeaker other than the Minimus 7, make sure it has an aluminum enclosure and has sufficient room inside to accommodate the amplifier circuit assembly without interfering with the drivers, crossover network or any connectors there might be.) This means that all access to the interior of the enclosure must be through the holes in which the drivers are mounted. Therefore, you will first have to pry off the protective aluminum grille. The following modification procedure is based on the Minimus 7 speaker; if you are using a different speaker, make suitable adjustments in the procedure.

The best place to start prying off the grille is at one of the corners where the risk of deforming the grille is minimal. Small pieces of sticky clay are all that hold the grille in place. So the grille should release without much persuasion.

Once the drivers are exposed, carefully remove them. As you remove each driver, make a note on a piece of paper its physical orientation and which color wire goes to which terminal. You will need this information to successfully reassemble the speaker system.

Set aside the drivers in a safe place. Then reach into the enclosure and remove the fiberglass batting that serves as acoustical damping. It is a good idea to wear gloves for this step, especially if your hands are particularly sensitive or have small cuts. The type of fiberglass batting used in minispeakers produces small splinters of glass when handled. If the splinters pierce your skin, they will be painful and difficult to remove.

Inside the enclosure on the rear wall is a plastic plate on which are mounted the crossover components. Remove this panel, which will be re-

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placed by the amplifier circuit-board assembly. Desolder from the panel the crossover capacitor and inductor coil and set both aside for mounting on the amplifier circuit board later. It is also a good idea to save the wires from the crossover network, since they are easily removed and have the proper connectors for the speakers.

You might want to replace the original crossover capacitor with a better-quality one. An audible improvement can be heard if you replace the nonpolarized capacitor that comes with the speaker with a polystyrene or film type of the same value. For a substantial improvement without going to extreme lengths, almost any type of replacement capacitor is better than the original.

Referring to Fig. 2, drill four holes through the rear of the enclosure for mounting 5-way binding posts. Size these holes to accommodate the threaded mounting screws and the shoulders of the insulating fiber washers that come with the binding posts. Set aside the enclosure.

Fig. 3. Actual-size etching-and-drilling guide for printed-circuit board.

Building the Amplifier

Printed-circuit board construction is highly recommended for the amplifier circuits. As you can see in the actual-size etching guide in Fig. 3, holes must be drilled only for the two potentiometers and the resistors. Since all components mount on the foil side of the board, no holes are needed for the leads of the larger components and wires that go on the board; these can simply be "spot" soldered to the copper lands in much the same manner as you would solder surface-mount components in place.

Prepare a 3¼" × 1¼" × ⅛" aluminum plate by drilling the mounting holes for the ICs, phono jack *J1* and switch, as illustrated at the bottom in Fig. 4. Then drill the holes for the mounting hardware that will secure the plate to the inside rear wall of the enclosure using the same locations used by the screws that secured in place the plastic panel on which were mounted the crossover-network components. (Use the plastic crossover-network plate as a template for locating and marking the mounting holes on the aluminum plate.) Also, drill a ⅛" hole in one of the lower corners of the plate. Locate the aluminum plate so that it completely fills the opening in the enclosure and *J1*'s and *S1*'s holes are centered in the cutout area. Loosely mount *IC1* and *IC2*, using 4-40 × ¼" machine screws lockwashers and nuts. Then solidly mount *J1* (along with its solder lug) and the switch on the aluminum plate, using the hardware supplied with them. Do not use insulators between the ICs and the aluminum plate.

Once the board has been etched and is ready for wiring, mount the amplifier and crossover components on the foil side exactly as shown in Fig. 4. As you solder one lead of a component to the board's land, hold it in place with your fingers, without moving, until the liquid solder has set. Then solder the other lead into place. (Note: It will be easier if you pretin the land locations and component leads and wires to which they attach with solder prior and then "sweat" the connections as you go.)

Secure the crossover coil to the surface of the board with double-sided tape, silicone cement or hot-melt glue. Pay close attention to electrolytic capacitors *C2, C4* and *C5* as you solder their leads into place. Use small-diameter insulating tubing on all leads that cross more than one copper land and insulated hookup wire for the wire jumper between the IC1/J2 and IC2/R3 lands. Mount the components with their bodies flat

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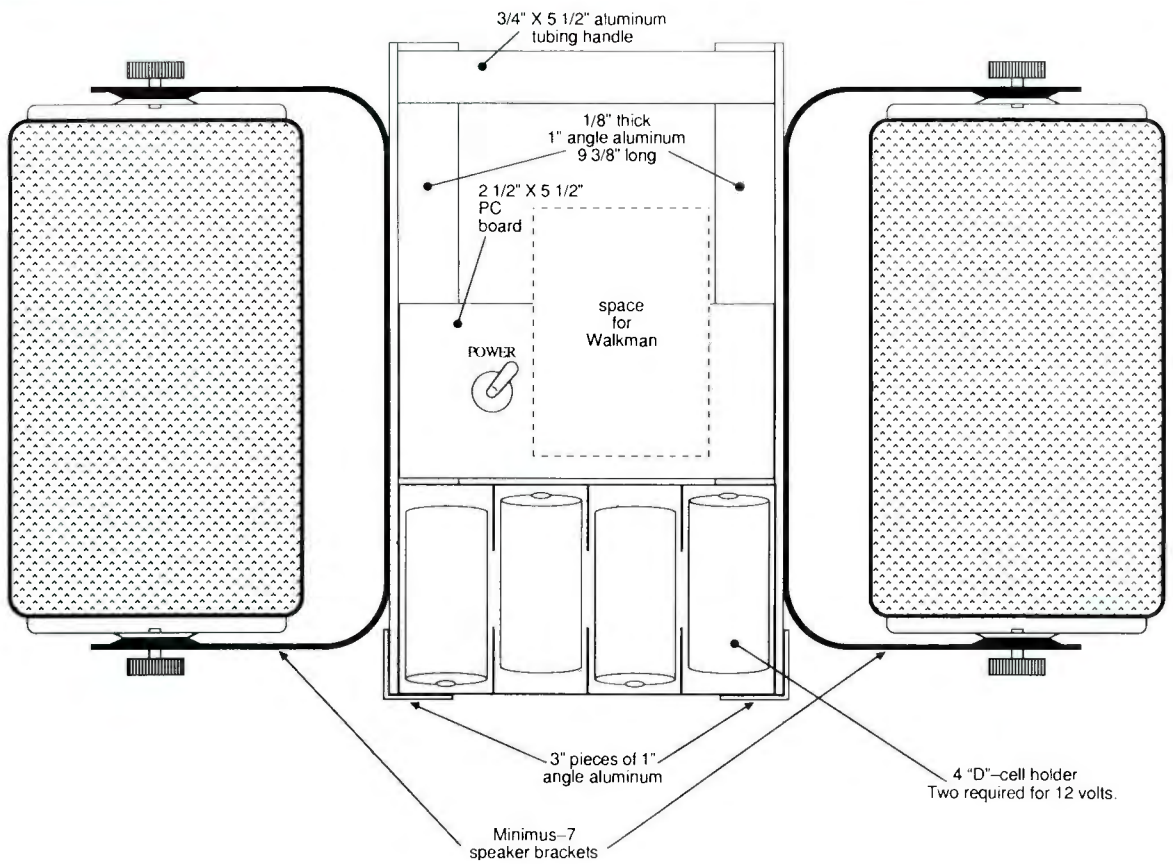
Building a Portable Carrier

An arrangement that has a handle and built-in battery power supply will let you use a Walkman-type radio/cassette player or portable Compact Disc player in a fully portable configuration. The portable carrier arrangement shown in the illustration provides vastly improved sound quality with lower distortion and noise and greater volume level, allows the speakers to be separated by up to 12 feet for better stereo separation, and allows you to tilt the speakers for best sonic effect without removing them from the carrier.

To be able to build the carrier, you need a pair of swivel-mount brackets for the Minimus 7 speakers (or whatever minispeakers you use instead). These brackets should also be used in your home or vehicle.

Since the power supply cells and signal-source device will have a direct effect on the size of the carrier, no dimensions are given in the drawing. Simply adjust the sizes of the elements that make up the carrier as needed for your particular combination of power supply and signal-source device.

Power Considerations. You want to build into the carrier a rechargeable battery supply that can deliver at least 12 volts to drive the active minispeakers. For reasonably long playing time, the cells selected should be no smaller than "D" size. If you use nickel-cadmium cells, you need 10 cells in all (each delivers 1.2 volts) for a 12-volt output. Specific battery requirements depend on how loud and how long you wish the speakers to be able to play between recharges. D-size Ni-Cd cells are available in different capacities, ranging on up to 4 ampere-hours (AH), though most of the commonly available ones are rated at only 1.2 AH. The 4-AH cells should keep the active minispeakers going for several hours but are quite expensive when you can find them. Lower-capaci-



Details of portable carrier show active minispeakers mounted via swivel brackets to both sides and spaces for battery power supply, signal-source device and power- switch/connector panel.

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ty D-size Ni-Cd cells should be adequate for most applications.

If you really need long playing time at loud volume, it is more economical to use a 12-volt battery pack rather than make up a supply using individual cells and holders. Battery packs have other advantages, too. They are more compact, have higher current ratings and have fewer problem-causing contacts than do individual cells and holders. Common current ratings for battery packs are 1.8, 3, 5, 6 and 10 AH. Good sources for suitable rechargeable battery packs are Mouser Electronics and other mail-order houses.

If you want long playing time and do not mind the extra expense involved, you can use gelled lead-acid—or so-called "gel"—cells. These generally have higher current capacities than Ni-Cd cells. Each has an output of 1.5 volts, reducing the number of individual cells needed for a given power-supply output voltage, and is available either singly or as part of multiple-cell batteries. Three 6-volt gel cells in series make an 18-volt battery that is near the maximum recommended voltage for the power lines to the active minispeakers. The only real difficulty with gel cells is finding a source for them.

If you do not plan to use the minispeakers as a portable sound system very often, separate cells (as opposed to a battery pack) is probably a better idea. When not in use, you can remove the cells from their holders and use them in other battery-powered devices. An advantage of separate cells is that it is easy to tap off a lower voltage between cells (typically 3 to 6 volts) to power whatever is being used to drive the speakers. If you do use a low-voltage tap for this purpose, make sure you take it from between cells referenced to the negative side of the battery to give the signal source and minispeakers' amplifiers the same "ground" reference.

Physical Considerations. The carrier illustrated in the drawing can be built from six pieces of aluminum. Two pieces of angle aluminum form the sides to which the speaker brackets attach. Each side piece can be supported by a 3-inch "foot" made of angle aluminum attached at a right angle to the bottom. The aluminum brackets at the bottom are the only points that provide support and can be equipped with small rubber feet to prevent marring any surface on which the carrier is placed.

Four-cell battery holders attach front and rear to the side pieces, which can be moved closer together or farther apart to accommodate a battery pack, if desired. It is the size of the dc power supply that has the most influence on the size of the carrier.

In the middle of the carrier, a piece of pc board can be attached to provide the means for mounting the power switch for the battery supply (wire it in series with the supply's positive line) on the front and two more D cells on the rear, for a total of 10 cells with the two four-cell units attached to the side pieces. You can etch and drill the pc board to provide a convenient means for making the connections to the battery supply, power switch and speaker cables. Your signal source can also be hung off the pc board via its belt clip or be fastened to it more securely with machine hardware.

For a handle, you can use a ¾-inch-diameter aluminum tube slid onto a length of aluminum bar stock mounted by its ends to the side pieces of the carrier. Alternatively, you can shape a piece of wood into a comfortable handle or use a nylon or leather strap or even a door handle.

Use 6-foot lengths of standard speaker cord to deliver power from the battery supply to the speakers. When wiring the cord into the supply and fastening the connectors to the other end, make sure to observe proper polarity. Also, use 6-foot-long shielded audio cable with a phono plug at the speaker end and an appropriate connector to match the output of whatever device you are using to drive the active speakers at the other end.

against the surface of the board. Trim away any pin length of the potentiometers and lead lengths of any other components whose leads plug into holes in the board flush with the bottom of the board.

Orient the aluminum-plate assembly with respect to and about ⅛" from the pc assembly as shown in Fig. 4, carefully spread the pins on the ICs so that they match up with the lands on the pc board, and solder the leads to the lands. Note that the center lead of each IC does not go to any land on the pc board. These ground leads are tied directly to the metal mounting tabs on the ICs and to each other through the aluminum plate and to circuit ground through the wire that connects *J1*'s ground lug to circuit-board ground.

Do not cut off the center pins of the ICs. Instead, bend them upward at a right angle to the ends of the ICs. Trim both leads of the two 0.1-microfarad capacitors (*C3* and *C6*) to ½" in length. Form a small hook in one lead of each and wrap these leads separately around the center leads of the ICs. Tack solder the other lead of *C3* to the J2 (lower-left-most) pad on the pc board. Similarly, tack solder the other lead of *C6* to the pad to which *R3* and the jumper wire connect.

Now solder appropriate lengths of insulated hookup wire between the points indicated on the circuit-board assembly and the switch and *J1*'s ground lug. Cut each lead of *C1* to 1" in length, slip over each a ½" length of insulating tubing, and solder the capacitor between the indicated pc-board land and the center contact of *J1*. Solder the free ends—not the connector ends—of the wires removed from the speaker's crossover network to the indicated lands on the pc board. Then strip ¼" of insulation from both ends of four 5"-long stranded hookup wires, twist together the fine wires at both ends and tin with solder. Solder one end of each wire to the J2 and J4 lands on the pc board, the lower lug on the

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switch and the solder lug on *J1*.

Mount the four binding posts on the rear wall of the enclosure via the holes you drilled earlier. Three of these binding posts must be fully insulated from the metal of the enclosure with the shoulder fiber washers or plastic bushings supplied with them. If such washers or bushings are not supplied, you must obtain them separately. The fourth binding post should not be isolated from the metal enclosure. Eliminate its shoulder fiber washers or bushing, if any, and replace them with a pair of lockwashers.

Adjustments

Before an amplifier circuit can be installed inside a speaker enclosure it must be adjusted so that it will work properly. For this step, you need a bit more heat sinking than the aluminum plate on which *IC1* and *IC2* are mounted can provide, which is the reason why you drilled that extra hole in one of the corners. Bolt the assembly to a metal object—even a much larger aluminum plate than you are using in the project—to assure good heat sinking.

To perform the adjustment of the amplifier, you also need an oscilloscope, audio signal generator, voltmeter and 8-ohm power (say, 20-watt or more) resistors. You need two resistors for each amplifier you built, one for each speaker driver. The voltmeter and resistors should be easy to come by. If a signal generator is not available, a signal source playing a slow piano will do. However, there is really no adequate substitute for the oscilloscope.

Connect a power resistor to the amplifier circuit where each driver will be connected and plug the signal generator's output cable into the amplifier's input. Set the signal for a 50-millivolt rms output at about 1,000 Hz (1 kHz). Then connect an adequate dc power supply to the amplifier circuit, observing proper polarity. Turn on the signal generator and use the oscilloscope to check each IC's output separately.

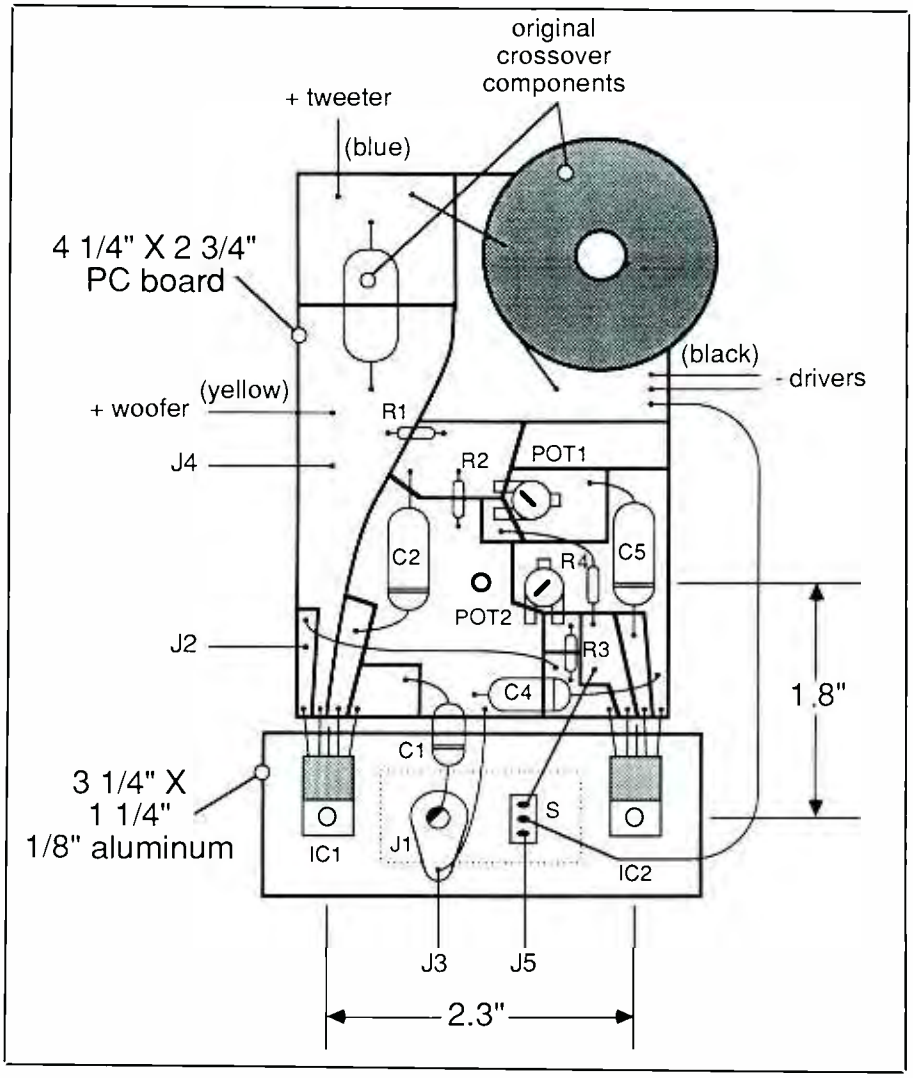

Fig. 4. Wiring guide for pc board. All components mount on foil side of board.

When checking the IC outputs, set the oscilloscope for ac input, attach its ground wire to amplifier circuit ground and use the "signal" input probe to verify that the amplifier's output resembles its input. Adjust *POT1* so that the outputs of the two ICs are roughly equal in amplitude.

Next, connect the oscilloscope between the outputs of both ICs. Before doing this, however, disconnect the scope's ground. Because neither output of a bridged amplifier is tied to ground, it should not be measured with a grounded device. Since the signal generator and oscilloscope probably share the same three-conductor ac power line, they will have the same ground. This being the case, connecting the oscilloscope across the amplifier's outputs in the next step would short out whichever IC got the scope's ground wire. To prevent this from happening, temporarily unground the oscilloscope at its power outlet. Use a three-conductor adapter with its third terminal not connected between the scope's line-cord plug and the ac receptacle. (Caution: Do not forget and leave the scope permanently ungrounded.)

(Continued on page 90)

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Once you have ungrounded the oscilloscope, connect it across the outputs of the amplifier. Adjust *POT1* for maximum undistorted output as observed on the scope's CRT screen. Increase the input level of the signal source until the output waveform just begins to clip. Readjust *POT1* for maximum output level without clipping of either positive or negative peaks.

Finally, connect a dc voltmeter across the amplifier's output and adjust *POT2* for a 0-volt reading. Because of the presence of *C4*, the meter may take a few seconds to settle down after each change of the pot's setting. With patience, you should be able to trim the offset to 10 mV or less. If a large offset adjustment must be made, it will be necessary to go back and readjust *POT1* for maximum undistorted output level.

Once the amplifier has been properly adjusted, disconnect the oscilloscope, meter and signal generator. Then power down the amplifier and remove the power resistors connected across its speaker outputs. Install the amplifier in the speaker enclosure.

Before mounting the amplifier in the enclosure, however, connect and solder the free ends of the wires coming from the pc board lands to the appropriate binding posts, since the latter will not be accessible after the amplifier board is installed. Refer to Fig. 4 for wiring details.

Slip the board into the speaker enclosure through the hole in which the woofer mounts. Mount the circuitboard assembly to the rear of the enclosure with the three screws that originally held the crossover network in place.

Minispeakers are mostly acoustic-suspension types that depend on an airtight enclosure of fixed volume to work properly. To obtain maximum possible benefit from them, you should strive to maintain the original conditions. Therefore, to maintain a good air seal between the aluminum plate on which the ICs are mounted and the enclosure, seal the perimeter of the cutout with a small amount of Plasticine or other sticky clay. Also, to assure an airtight enclosure when *J1* is not being used, plug into the jack a dummy phono plug (stop up the hollow center pin with solder).

After mounting the amplifier assembly, replace the fiberglass batting in the enclosure. Pull the ends of the four speaker wires attached to the amplifier board through the fiberglass and their respective speaker holes (yellow for woofer, blue for tweeter and one each black "drivers" for each—see Fig. 4). When all the fiberglass batting has been replaced, connect the free ends of the wires to the speakers. Either slip the attached connectors onto the speaker lugs or—if you are a purist who believes that such connectors detract from the quality of the sound—clip off the connectors and solder the wires to the speaker lugs.

Observing the original orientations, reinstall the speakers in their respective holes, using the original screws to secure them into place. Replace the protective aluminum grille, gently tapping it with a mallet or through a board with an ordinary hammer until it is fully seated. You can discard the sticky clay that originally held the grille in place because it is not really needed. The grill will be held in place by friction.

Accessory Inputs

Obviously, any audio signal source that has line-level outputs can be used to drive the active minispeakers, including the preamp outputs of a home hi-fi system, the outputs from a tape or CD player, the headphone outputs of a portable radio/tape player, etc. Additional input devices and accessories can extend the usefulness of the active minispeakers. For example, a telephone pickup coil plugged into the input of one minispeaker can be used to enable more than one person to share in a phone

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conversation. Substituting a crystal microphone for the pickup coil turns a minispeaker into a continuous sound monitor for a baby's room.

With a probe and alligator clip connected across a potentiometer's outer lugs and a shielded cable connected between the pot's center and either outer lug and terminated at the other end in a phono plug, you have a convenient means for tracing an audio signal in an audio circuit. When using the minispeaker in this manner, always start with the pot set for minimum output signal into the amplifier circuit and adjust as needed for a loud enough signal from the speaker.

You can also use an active minispeaker to trace magnetically induced hum to its source by using a coil-type pickup. Again, start with minimum signal going into the speaker's amplifier and adjust accordingly with the potentiometer.

One or both active minispeakers can be used to amplify the audio outputs available from some computers. Additionally, these speakers can temporarily replace headphones at a test bench when it would be too much effort to build a dedicated amplifier (make sure to include the attenuator potentiometer).

As a final note, do not overlook non-portable applications for the active minispeakers. If you plan to use the minispeakers where ac power is available, it is a good idea to use an ac-line-power instead of a battery supply. You can easily put together such a supply using a 12.6-volt transformer, four rectifier diodes, a filter capacitor or two and a bypass capacitor in a classical unregulated circuit. Due the wide range of supply voltages that can be used and the low current drain of the amplifier/speaker arrangement, no regulation is needed. Properly designed, such a power supply will yield an 18-volt or so dc output that is near the maximum recommended for the active minispeakers. **ME**