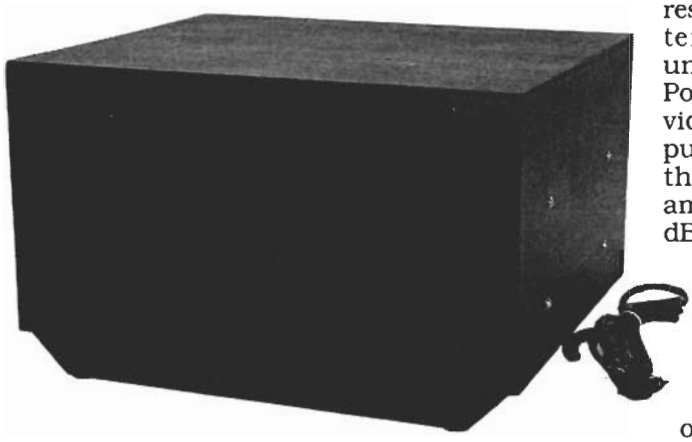
POWERED SUBWOOFER



The "Little Earthquake" home-theater subwoofer delivers the deep bass you've been missing.

RODRICK SEELY

BY NOW, JUST ABOUT EVeryone has heard about home theater, and anyone who has had the pleasure of hearing a demonstration can appreciate the incredible sound that home-theater systems can deliver. Unfortunately, those great sounding systems usually have high price tags. In this article, you will see how to save big bucks by building your own subwoofer—usually one of the most expensive home-theater components.

Many people have already started to experiment with home theater by connecting a television set or VCR to the auxiliary inputs of a stereo system. In most cases, this simple configuration provides a terrific improvement over the TV set's built-in speakers. However, popular compact bookshelf-style stereo systems usually don't have speakers that are big enough to provide the deep bass that gives volume and power to theater sound. This important feature of home-theater sound comes from the subwoofer speaker.

Subwoofers provide a clean, deep bass that you can feel. The rumble of spaceships blasting through the galaxy in Star Wars, the musical tremors of Close Encounters, and the thundering stampede of dinosaurs trampling across Jurassic Park are just a few examples of the great movie moments that a subwoofer can bring to life.

Subwoofers can be divided into two main categories: passive and powered. Passive subwoofers generally consist of a passive crossover network and a speaker mounted in an enclosure. Although this kind of subwoofer is the least expensive, it must be powered by an external amplifier, and the amplifiers of most integrated stereo systems are too small to drive a passive subwoofer adequately.

The Little Earthquake is a powered subwoofer that features an active crossover network, 50-watt power amplifier, a 10-inch driver, and a fourth-order bandpass enclosure. The built-in power amplifier enables the Little Earthquake to work with virtually any stereo system. You can build the Little Earthquake for less than $200.

Circuit design

Figure 1 is the schematic diagram of the powered subwoofer. The power supply consists of a center-tapped 48-volt transformer, bridge rectifier, and filter capacitors C7 and C8. The rectified and filtered output is about ±35 volts. The power supply for op-amp IC1 is regulated to ±15 volts by Zener diodes D1 and D2 and resistors R19 and R20.

Most of the circuit is built around a TL074 quad op-amp (IC1), which functions as an input buffer, bandpass filter, and output driver. The input circuit consists of a mixer and voltage divider formed by resistors R1 and R2, potentiometer R3, and unity-gain buffer IC1-a. Potentiometer R3 is provided to adjust the output of the subwoofer to the desired level. Op-amp IC1-b provides a 12 dB per octave high-pass filter with capacitors C2 and C3, and resistors R5 and R6. The cutoff frequency for this filter is $1/2\pi RC$, or about 34 Hz with the values shown. Resistors R8 and R7 set the gain and Q of the filter. Capacitor C1 and resistor R4 form an additional 6 dB per octave high-pass filter at about 20 Hz. A 12 dB per octave low-pass filter is formed by IC1-c, C4 and C5, and R9 and R10. The values shown set the low-pass cutoff at 72 Hz. The gain and Q of this stage are set by R11 and R12. These two filters, connected back-to-back, form a bandpass filter with the transfer function shown in Fig. 2.

The output stage operates as class-B amplifier for higher efficiency. Because the TL074 has a high slew-rate, crossover distortion commonly associated with class B amplifiers is virtually eliminated. Any distortion caused by the amplifier is in a frequency band higher than the subwoofer speaker can reproduce. When operated with ±15-volt supplies, the output of op-amp IC1-d can swing about 10 volts peak to drive transistors Q1 and Q2. Resistors R17 and R18 provide negative feedback, and set the gain of the output stage at about three. Hence, the output can swing to about 30 volts peak. As long as the transistors are the high-

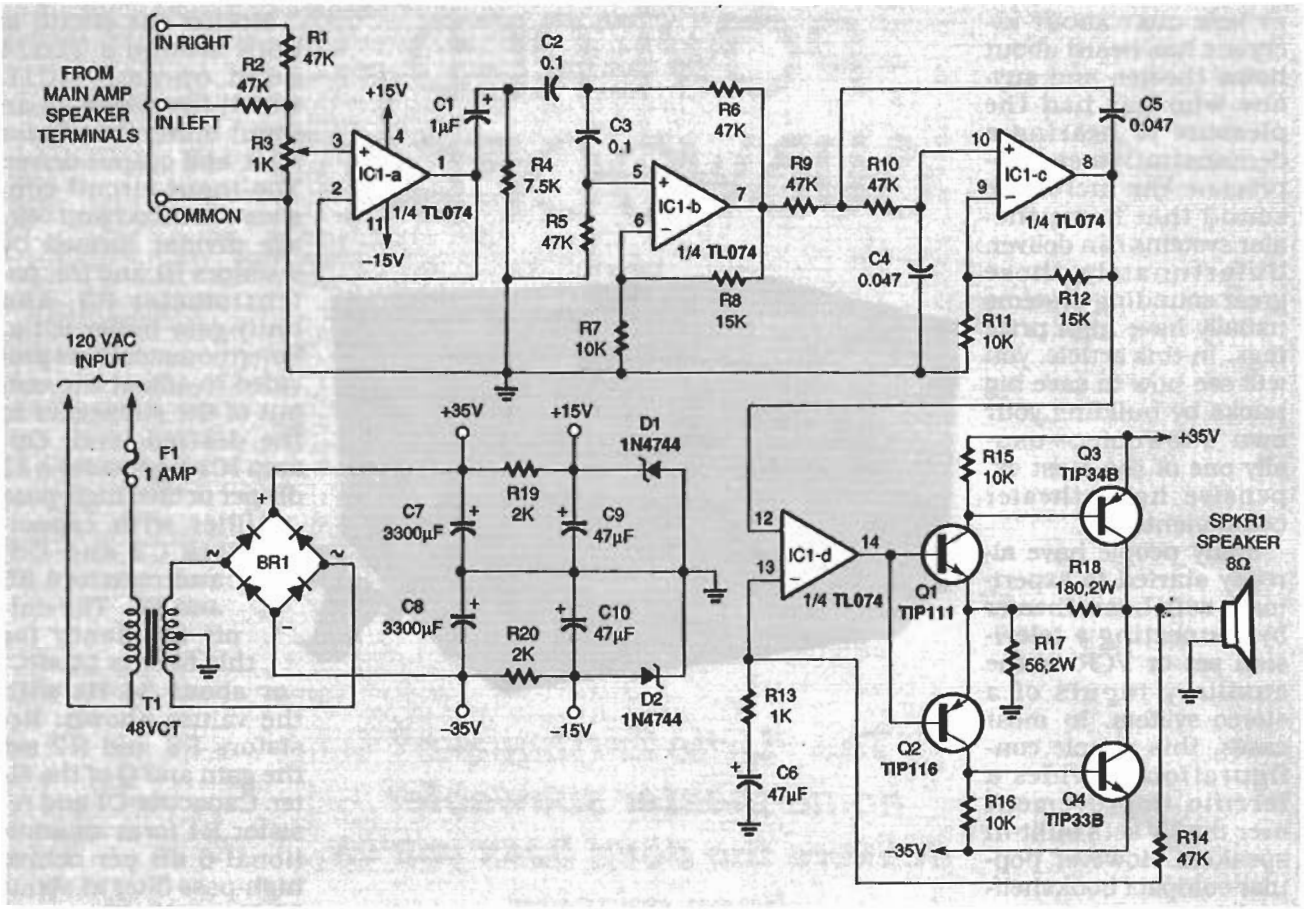


FIG. 1—SCHEMATIC DIAGRAM of the powered subwoofer. The power supply consists of a center-tapped 48-volt transformer, bridge rectifier, and filter capacitors C7 and C8.

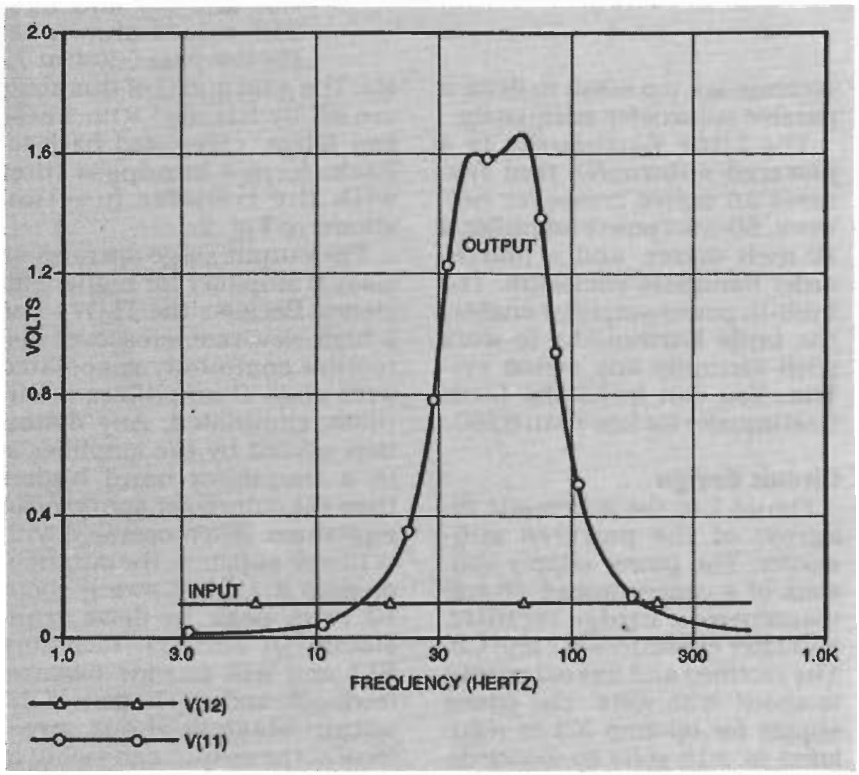


FIG. 2—TWO FILTERS connected back-to-back form a bandpass filter with this transfer function.

beta types specified, the peak power output into an 8-ohm load is (30 × 30/8)/2 = 56 watts RMS. The overall gain of the amplifier is set by resistor R13 and feedback resistor R14. Capacitor C6 provides DC blocking.

Cabinet design

The enclosure is a critical component of any subwoofer design. The Little Earthquake has a fourth-order bandpass enclosure which was designed with the aid of computer software.

The computer model is based on a 10-inch speaker with the parameters shown in Fig. 3. The maximum excursion of the speaker cone was selected to be ±¼-inch. For best results, a speaker with similar parameters should be selected. The amplifier and speaker are mounted in a sealed 17- × 14- × 8½-inch compartment, which has a volume of approximately

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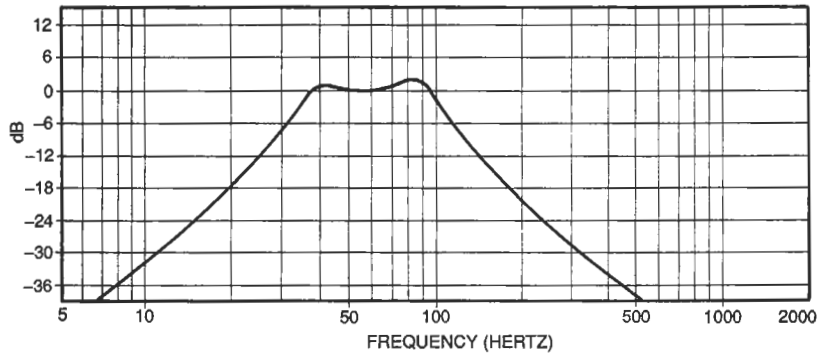
1.2 cubic feet.

The speaker cabinet is positioned so the speaker cone faces the floor. Rails on each side of the cabinet hold it 1½-inches off the floor to create a front chamber with a volume of 0.2 cubic feet. The open ends created by the rails act as two ports, each measuring 1½ × 12½ inches. The frequency response of the bandpass cabinet is also shown in Fig. 3.

Construction

The Little Earthquake crossover/amplifier circuit is built on a single-sided printed-circuit board, which can be etched from the template provided, or purchased from the source given in the Parts List. Use the parts-placement diagram in Fig. 4 as a guide for building the circuit board. The power transistors Q3 and Q4 must be heatsinked. The transformer and circuit board are mounted on an 8½ × 4- × ¼-inch sheet of aluminum.

Figure 5 shows how to drill the heatsink plate, and Fig. 6 shows how to mount the circuit board to the plate. Transistors Q3 and Q4 are inserted and soldered from the foil side of the board and should be formed so they make contact with the heatsink when the circuit board is mounted on ¼-inch spacers. Even though the tabs of Q3 and Q4 are the collectors, which are electrically connected in the circuit, mount them to the heatsink with insulating washers and bushings anyway. By doing so, the heatsink can be earth grounded for safety. Figure 7 shows how to drill a piece of ABS plastic, measuring 8- × 2½- × ⅛-inch, to form a panel to mount parts on.



SPEAKER DIAMETER = 10"
POWER HANDLING = 70 WATTS RMS, 100 WATTS PEAK
IMPEDANCE = 8 OHMS
SPL = 94 dB
F_S = 28.0 Hz
V_{AS} = 3.7 CU.FT.
Q_{TS} = 0.580

FIG. 3—THE ENCLOSURE is a critical component of the subwoofer design. The frequency response of the bandpass cabinet is based on a 10-inch speaker with the parameters shown here.

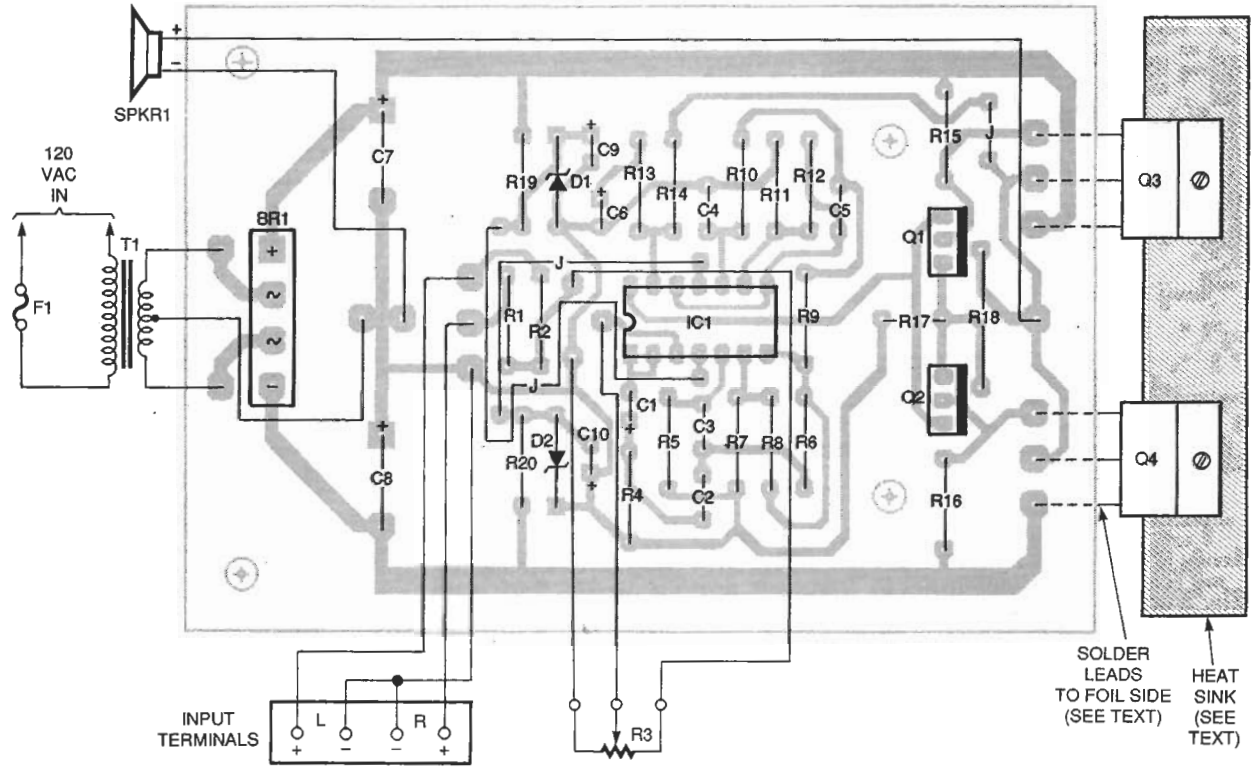


FIG. 4—PARTS-PLACEMENT DIAGRAM. Power transistors Q3 and Q4 must be heatsinked (see text and Figs. 5 and 6).

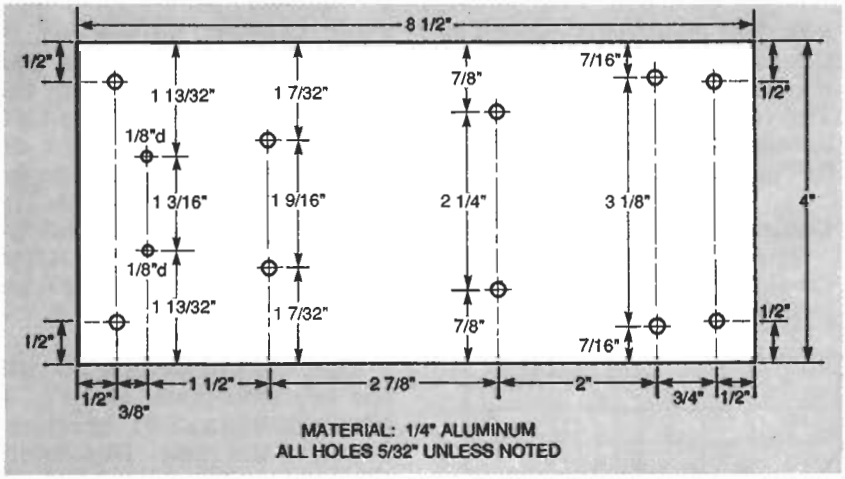


FIG. 5—DRILL THE HEATSINK PLATE (an 8½ × 4- × ¼-inch sheet of aluminum) as shown here.

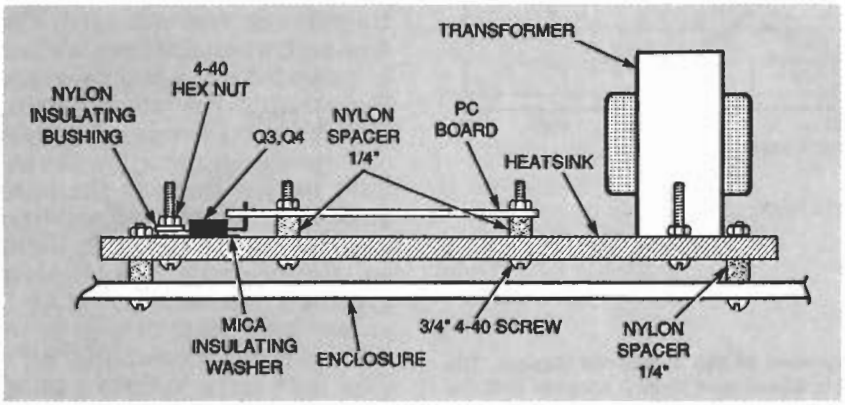


FIG. 6—TRANSISTORS Q3 AND Q4 are mounted from the foil side of the board and bent to make contact with the heatsink when the circuit board is mounted on ¼-inch spacers. Mount the transistors to the heatsink with insulating washers and bushings.

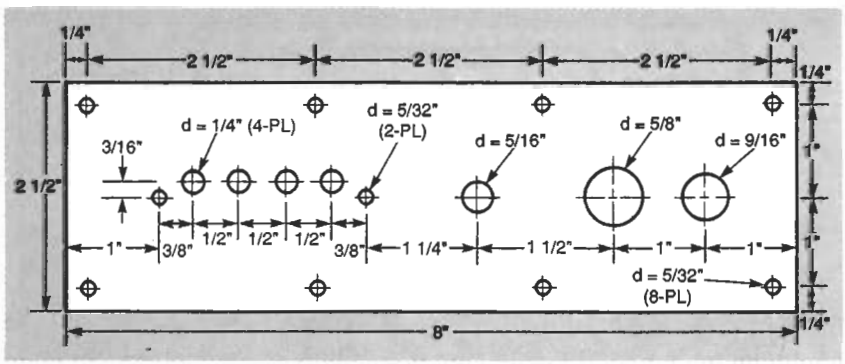


FIG. 7—DRILL A PIECE OF ABS PLASTIC, measuring 8- × 2½- × ⅛-inches, as shown here. Mount the input terminals, potentiometer R3, fuse holder, and linecord grommet on this panel.

Mount the input terminals, potentiometer R3, the fuse holder, and linecord grommet to a panel first, and then hardwire the panel to the circuit board. Then mount the panel over a rectangular cutout in the cabinet. Several tests should be made before connecting the speaker to the amplifier, so leave them disconnected for now.

Testing

The first step is to check the power supply. Verify that ±35 volts DC is supplied to the emitters of Q3 and Q4, respectively, and that IC1 has ±15 volts DC on pins 4 and 11, respectively. Also check the DC voltage at the output (the collectors of Q3 and Q4). If there is more than 0.1 volt on the output, make sure the components are installed correctly, especially C6. Too high a DC voltage on the output can damage the speaker.

If you have a function generator and an oscilloscope, verify the operation of the bandpass filter by connecting the function generator to the input terminal, and the oscilloscope to pin 8 of IC1. With a sinewave input signal of a few volts, perform a frequency sweep from 20 to 150 Hz or more, and verify that the output voltage on the oscilloscope follows the function shown in Fig. 2.

Cabinet construction

The dimensions for the cabinet were determined with computer software. The software calculations showed that inside dimensions of 17- × 14- × 8½-inches would achieve the desired sound. Any rigid wood-based material can be used to make

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.
R1, R2, R5, R6, R9, R10, R14—47,000 ohms
R3—1000 ohms, panel-mount potentiometer
R4—7500 ohms
R7, R11, R15, R16—10,000 ohms
R8, R12—15,000 ohms
R13—1000 ohms
R17—56 ohms, 2-watts
R18—180 ohms, 2-watts
R19, R20—2000 ohms
Capacitors
C1—1 µF, 35 volts, electrolytic
C2, C3—0.1 µF, mylar
C4, C5—0.047 µF, mylar
C6, C9, C10—47 µF, 35 volts, electrolytic
C7, C8—3300 µF, 50 volts, electrolytic
Semiconductors
BR1—Bridge rectifier, 4 amps, 100 PIV (KBL01 or equivalent)
D1, D2—1N4744 15-volt Zener diode, 1 watt
Q1—TIP111 NPN Darlington transistor
Q2—TIP116 PNP Darlington transistor
Q3—TIP34B PNP power transistor
Q4—TIP33B NPN power transistor
IC1—TL074 quad op-amp
Other components
T1—120-to 48-volt centertapped

FIG. 8—CUT A 9-INCH DIAMETER HOLE in the bottom panel for the speaker and make a 7- × 1½-inch cutout for the control panel. Rails formed from 1- × 2-inch furring strips are glued to the bottom panel to hold the subwoofer above the floor.

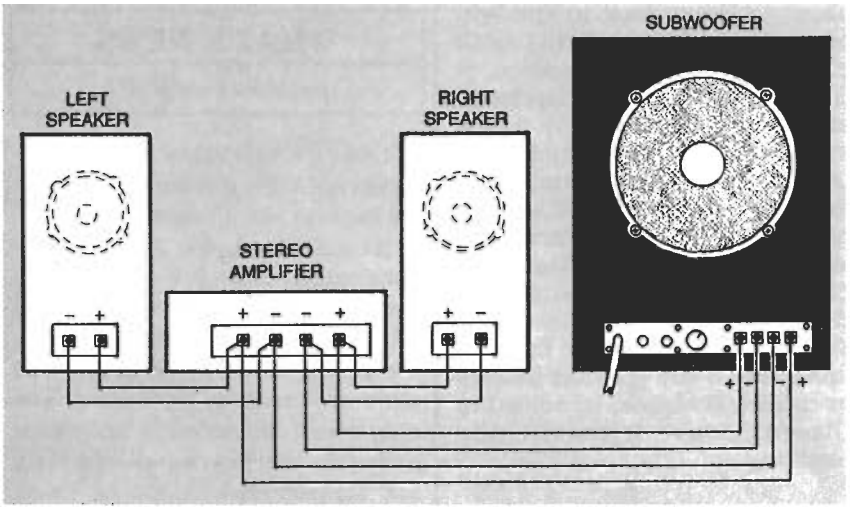
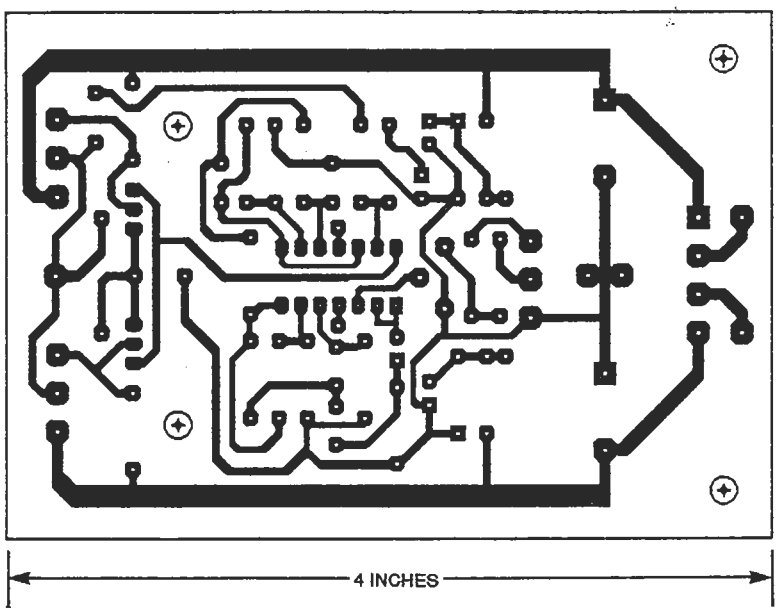


FIG. 9—IT IS VERY IMPORTANT that the subwoofer be connected properly to the stereo amplifier, or else the amplifier can be damaged.

the cabinet, as long as the inside dimensions remain the same. The prototype cabinet was constructed from ¼-inch birch veneer plywood with 1- × 1-inch furring strips for reinforcement along every inside seam.

The bottom panel, which holds the speaker and control panel, was made from ½-inch particle board for added strength. A 9-inch diameter hole was cut out of the bottom panel for the speaker, and a 7- × 1½-inch cutout was made for the control panel. Rails to hold the subwoofer unit above the floor were formed from 1- × 2-inch furring strips glued to the long edges of the bottom panel. Glue and screw every seam of the cabinet and seal the seams inside with silicone caulking. Solid construction of the cabinet will prevent annoying rattling and buzzing noises while the subwoofer is operating. Figure 8 shows the underside of the completed cabinet. For those who prefer to avoid woodworking, an assembled and sealed cabinet is available from the source given in the Parts List.



FOIL PATTERN for the amplifier/crossover board.

transformer, 1.2 amps
F1—1-amp fuse
SPKR1—8-ohm, 10-inch speaker
Miscellaneous: PC board, line cord and strain-relief bushing, panel-mount fuse holder, 4-position spring terminals, knob for R3, 8½ × 4- × ¼-inch aluminum heatsink plate, 8- × 2½- × ⅛-inch ABS plastic for control panel, hardware, nylon spacers, wire, assembled speaker enclosure with 17- × 14- × 8½-inch inside dimensions.

Note: The following items are available from Lynn-Eren Electronics, 17093 SW Lynnly Way, Sherwood, OR 97140, 503-625-2205:

- **Complete kit including speaker, assembled cabinet, and all parts—$169**
- **Assembled and tested subwoofer unit—$199**
- **Drilled heatsink plate and plastic control panel—$20**
- **PC board only—$15**

Check, money order, VISA, and MasterCard are accepted. Add $10 S&H to orders that include cabinets or speakers. All cabinets are supplied unpainted.

Final assembly

Install the speaker last so that the speaker mounting hole can provide access to the inside of the cabinet to install the heatsink assembly and control panel. Securely fasten the control

panel to the cutout in the bottom panel of the cabinet with eight No. 6 screws to prevent it from vibrating. Mount the heatsink/PC board assembly to the side panel of the cabinet adjacent to the control panel with four No. 6 screws and ¼-inch nylon spacers. The spacers allow air to pass underneath the heatsink. Once the control panel and heatsink assembly are installed, the speaker can be mounted. If the speaker buzzes or rattles, it should be sealed to the enclosure with silicone caulking.

Installation and use

Place the completed subwoofer somewhere in the listening room where the input wires and power cord can be concealed. A wiring diagram is shown in Fig. 9. It is very important that the subwoofer be connected properly to the stereo amplifier.

With the power off and the speakers disconnected from your stereo, place an ohmmeter across the negative terminals of your stereo amplifier. If the terminals are not shorted together, or if your stereo amplifier is operated in mono-bridged mode, connect only one input. The negative terminals of the subwoofer are shorted together to ground. Connect the negative terminals of your stereo amplifier to the negative terminals of the subwoofer. Your stereo amplifier will almost certainly be damaged if its positive output terminals are short-circuited together.

When the input connections are made, turn the volume knob down all the way and plug the subwoofer into an AC outlet. Adjust the volume on your stereo, then adjust the subwoofer volume. If you have tone controls on your stereo, fine-tune the subwoofer volume by adjusting the bass control on your stereo system.

With the Little Earthquake subwoofer, you can discover the world of sound and suspense hidden deep in the audio spectrum. Listen again to all of those great movies, and feel them at home for the first time! Ω