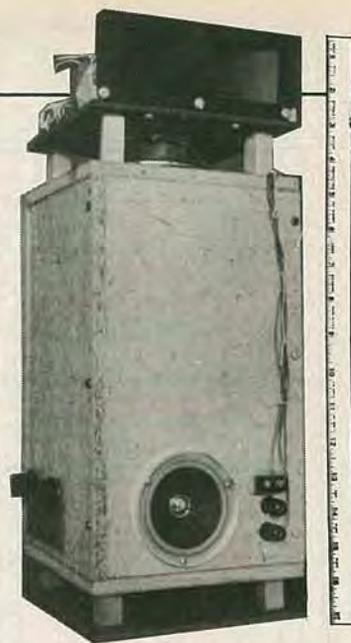


BUILD THIS

HI-FI MINI SPEAKER

The SAFE principle allows extended bass response from small speakers. Here's a 3-way mini-SAFE speaker you can build that's just 17 inches high; it will astound you with its performance and low cost.



GEORGE PAPPANIKOLAOU

ONE OF THE MANY PROBLEMS WITH MINI-SPEAKER SYSTEMS IS that it is difficult—if not downright impossible—to get full-size performance from them. (For example, it would be ludicrous to try to design a mini-Klipschorn!) By using acoustic-suspension techniques and special speakers, some manufacturers have managed to produce high-quality mini-speakers, although at a decrease in efficiency and an increase in price. Some people feel that there is no advantage to a mini-size speaker system that has to be used with a hefty amplifier.

There is an approach other than acoustic-suspension, however, that can be used for smaller speaker-systems. That is the SAFE (Symmetrical Air Friction Enclosure) configuration, covered by U.S. patent No. 4,168,761. Figure 1 illustrates the SAFE principles.

A SAFE speaker-system does not use a sealed enclosure, but, rather, makes use of both the front and back waves emanating from the woofer to provide clean, extended, bass response. The mid- and high-range radiators are conventional; the difference lies in how the bass is treated. The woofer is mounted near the top of the enclosure, facing downwards. The back wave propagates freely in all directions through the opening at the top of the enclosure. (Low-frequency sound is essentially non-directional to the ear—the idea is to generate as much of it as possible.)

The front wave from the woofer (represented by the dashed line) propagates along a path determined by a series of chambers formed by three centrally-located horizontal partitions and three other horizontal partitions with center holes (see Fig. 2). The wave is repeatedly split and recombined as it follows this path. That slows its speed, making it appear as if it had traveled a longer distance than the length of the path actually permitted. Upon reaching the center hole of the lowest partition, the back wave travels down the vertical port (tube) until it reaches the bottom plate of the enclosure and exits to the outside, again dispersed in all directions. The relatively long path (real and apparent) followed contributes to the low-frequency efficiency of the SAFE design.

Having already designed woofers and subwoofers using SAFE principles, I decided to try to use the same principles to build a three-way mini-size speaker that could be used by itself with a small amplifier, or with a subwoofer, to form a complete subwoofer-plus-satellite stereo-speaker system. While neither would be suitable for outdoor concerts, they

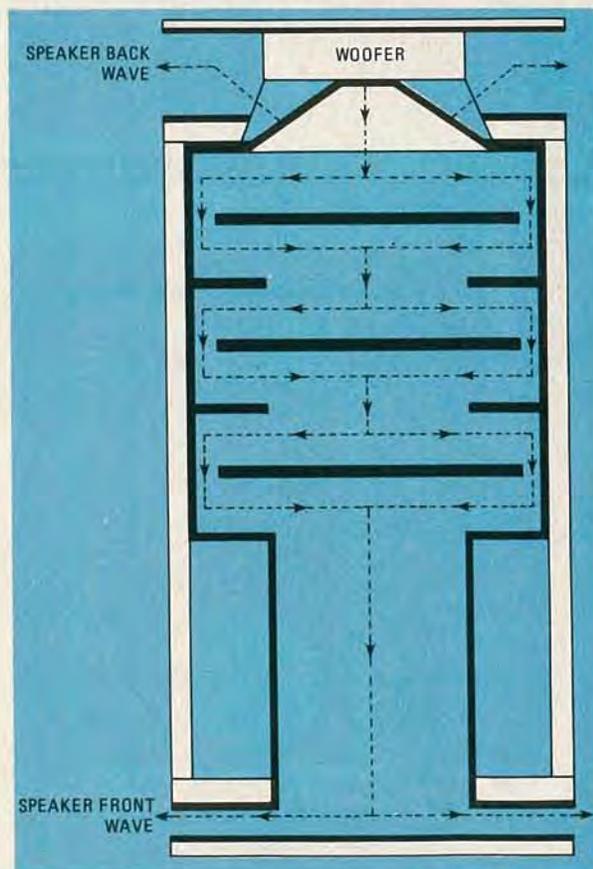


FIG. 1—SAFE EFFECT uses both the front and back waves from the woofer to extend bass response. The front wave travels through an acoustically long labyrinth to increase apparent size of enclosure.

would be more than adequate to fill the average-size listening room with sound.

Speaker selection

The 8-ohm speakers needed for the mini-SAFE system should be available from a number of sources: mail-order houses, audio outlets, and even car-stereo dealers.

The 5/4-inch woofer must be of the free-cone type—that

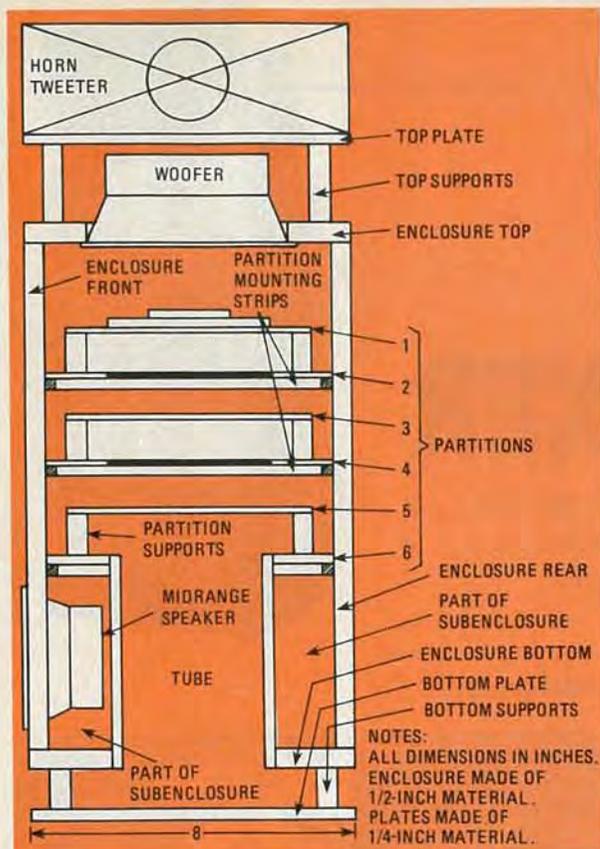


FIG. 2—LARGE HORN-TYPE TWEETER can be mounted above woofer. Sealed mid-range speaker is fitted into its own airtight sub-enclosure.

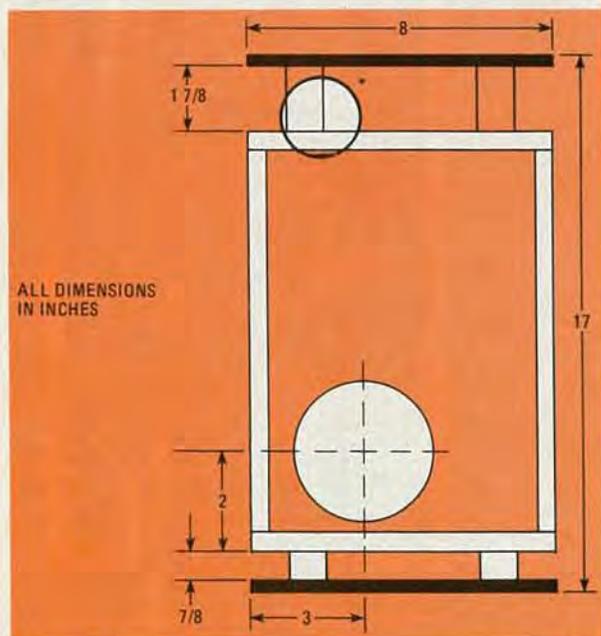


FIG. 3—POSITION OF CONE or dome-type tweeter is marked by asterisk. Note that both tweeter and mid-range speaker are mounted off-center—the latter to eliminate standing waves.

PARTS LIST—CROSSOVER NETWORK

- L1—620 turns No. 18 enameled wire one-inch core, three inches long.
- C1—2.2 μ F, non-polarized (1.0 μ F may be required if large horn-type tweeter is used)
- C2—47 μ F, non-polarized
- L-pads—standard, 8 ohms (Radio Shack 40-980 or similar)

PARTS LIST—ENCLOSURE

Quantity	Size (inches)	Description
2	8 × 8 × 1/4	Top and bottom plates
2	3 1/2 × 5 5/8 × 1/4	Part of tube
2	4 × 5 5/8 × 1/4	Part of tube
1	2 × 2 × 1/4	Part of partition-1 assembly
1	7 × 7 × 1/4	Partition 6 (with 4 × 4-inch hole for tube)
4	1 7/8 × 1 × 1	Top supports
4	7/8 × 1 × 1	Bottom supports
12	1 × 1 × 1	Partition supports
6	7 × 1/4 × 1/4	Mounts for partitions 2, 4, and 6
6	6 1/2 × 1/4 × 1/4	Mounts for partitions 2, 4, and 6
2	7 × 7 × 1/8	Partitions 2 and 4 (with 4 × 4 center holes)
3	6 × 6 × 1/8	Partitions 1, 3, and 5
2	8 × 12 3/4 × 1/2	Enclosure sides
2	7 × 12 3/4 × 1/2	Enclosure front and rear panels
1	4 × 4 × 1/2	Part of partition-1 assembly
2	8 × 8 × 1/2	Enclosure top with woofer mounting-hole and enclosure bottom with 4 × 4 center hole

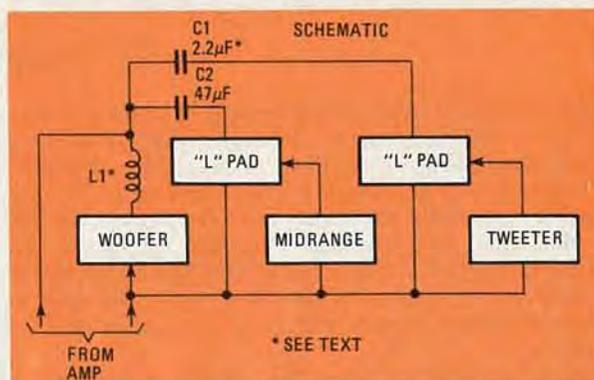


FIG. 4—SIX dB/OCTAVE crossover network is simple to build. L-pads balance sound from the three sections of the system.

is, the cone has to be able to radiate from both its front and back. A sealed acoustic-suspension type woofer is not suitable for use in a SAFE system. Woofers of the free-cone type are frequently found in car-stereo upgrade systems and can usually be purchased separately. A good heavy magnet is also essential—about 16-20 ounces.

A car-stereo outlet may also be able to provide the mid-range unit. It should be an acoustic-suspension type, about 3 3/4-inches in diameter with a 6-10 ounce magnet.

Both the woofer and mid-range units should be as shallow as possible, to fit into the small enclosure. If the woofer is too deep, it is possible to add some height to the cabinet, but the mid-range speaker is fairly critical in that respect.

The choice of a tweeter is not critical—it can be a high-efficiency cone or dome type, or even a relatively large horn mounted on top of the cabinet as shown in Fig. 2. A cone or dome-type tweeter should be mounted in the area indicated by an asterisk in Fig. 3. The tweeter is mounted to one side so that, if the mini-SAFE system is used in a horizontal position, the tweeter will be located higher than the mid-range speaker. (With a large horn, the positioning doesn't seem to make a difference.)

If desired, two systems can be made mirror-images of each other—that can improve the stereo effect, although, since the systems are so small, it may not be an important factor.

Crossover and L-pads

The mini-SAFE's crossover networks and L-pads are shown in Fig. 4. The L-pads are used to balance the system and also to optimize its bass response, which can vary depending on where in the listening room it's placed. (The bass

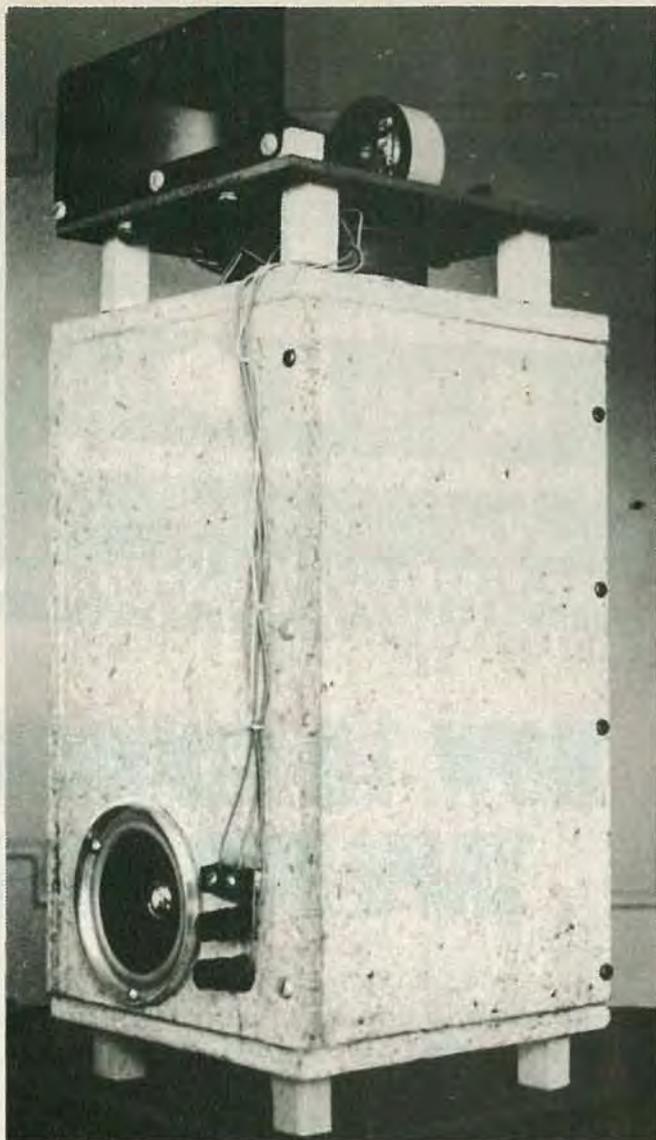


FIG. 5—CONNECTIONS FROM crossover network and L-pads are brought out through mid-range sub-enclosure. L-pads are on left side of enclosure.

PARTS LIST—SPEAKERS

Woofer: 5- or 5¼-inch woofer, 16-20 oz. magnet, open front and rear (not acoustic suspension) (Herald S-22 or equivalent)

Mid-range: 3¾- or 4-inch, 6½-10-oz. magnet, sealed (air-suspension) (Pioneer TS-107 or equivalent)

Tweeter: Cone, dome, or horn-type, high efficiency. Size not critical

will generally increase if the system is located near a room boundary and decrease as it is moved away from the walls and/or floor.)

The L-pads are standard 8-ohm units, available from a number of sources. It's important to make sure that they have adequate power-handling capacity. (The entire system is rated at 15-20 watts, maximum.)

The crossover networks are designed with a 6 dB/octave rolloff. The mid-range crossover network is designed to take effect at about 450 Hz; the high-frequency one has a crossover point of about 10 kHz. If a horn-type tweeter is used, the value of C1 should be changed from 2.2 μ F to 1.0 μ F. Coil L1 is made from 620 turns of No. 18 enameled wire wound on a one-inch core three inches long. Do not try to wind a shorter, thicker, coil—it may not fit into the space intended for it.

Figure 2 shows a sub-enclosure for the mid-range speaker.

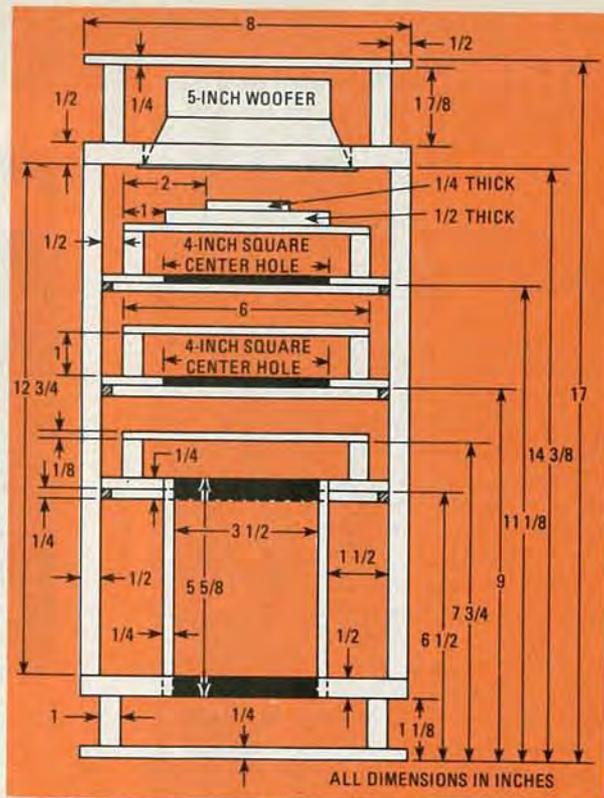


FIG. 6—CRITICAL DIMENSIONS for mini-SAFE enclosure. If woofer is deeper than one shown, top supports may be lengthened.

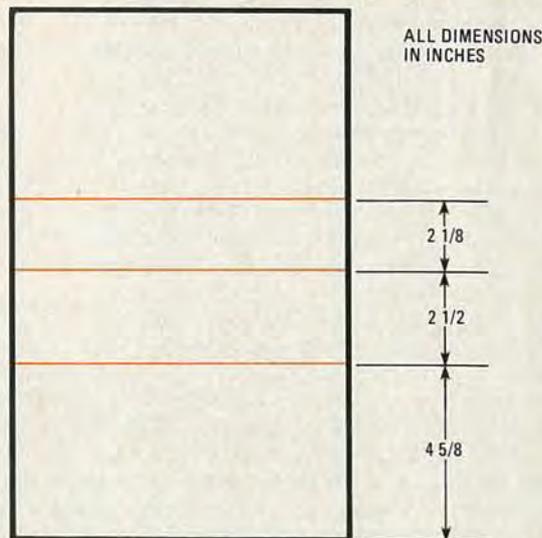


FIG. 7—INSIDE OF FRONT, BACK, AND SIDES should be marked as shown. Pieces should also be marked to indicate function ("FRONT," "L. SIDE," etc.).

That is where the L-pads and crossover networks are mounted. Wiring from them is brought out to terminals mounted on the front of the enclosure (see Fig. 5) to preserve its air-tightness. Wiring to the woofer and tweeter is run along the outside of the cabinet. The L-pads should be located on the side of the cabinet that will remain facing up if the speaker is to be used on its side instead of upright.

Construction

Refer to Figs. 2, 6, and 7, and to the Parts List, as we go through the assembly of the mini-SAFE system step-by-step. Before we start, here are a few helpful hints.

The flat parts (sides, top, bottom, and partitions) can be

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made from particle board or plywood. The supports are made from square lengths of wood. Dimensions are given in the Parts List. With the exception of the screws required to hold the sides of the enclosure together, to mount the speakers, and to connect the support-ends to their attachment points, glue can be used to secure one piece of the enclosure to the other. A hot-melt glue gun and glue sticks are recommended.

The L-pads, crossovers, and terminals should be mounted before the rear panel is installed—it would be virtually impossible to work on them afterwards. The mid-range speaker should be mounted off-center to prevent standing waves from developing and its enclosure should be filled with an acoustic insulating-material such as fiberglass. Glue the crossover coil and capacitors in place so they will not shift when the speaker is moved.

Partition 1 (see Fig. 2 for partition numbers) has two smaller partitions mounted on it to prevent standing waves. A thin layer of fiberglass, not more than 1/4-inch thick, should be placed over the entire partition-1 assembly, again to aid in preventing standing waves.

Finally, remember that the enclosure and sub-enclosure joints must be air-tight for the mini-SAFE speaker to work properly. Bear that in mind when you glue your joints!

Now for the assembly instructions—read them thoroughly before you begin:

1. Cut all parts to size, using the dimensions given in the Parts List and Fig. 6. Don't forget the 4-inch-square center holes in partitions 2, 4, 6, and the enclosure bot-

tom; and the holes for the speakers and L-pad shafts (see step 11).

2. Using four partition supports, mount partitions 1 and 3 on partitions 2 and 4, respectively.
3. Mount four partition supports on partition 6. *Do not* mount partition 5 at this time!
4. Mount the two squares on top of partition 1.
5. Assemble the four-sided tube.
6. Attach the four bottom supports to the enclosure bottom.
7. Attach the four top supports to the enclosure top.
8. Place the enclosure's front, rear, and side pieces on a flat surface. Assuming that the sides facing up will become the inside of the enclosure, use a marking pen to indicate the function of each piece ("front," "left side," etc.). Also indicate which end of each piece will be at the bottom.
9. Draw three parallel lines on each panel as shown in Fig. 7.
10. Attach the front and sides to the enclosure bottom. *Do not* attach the rear panel yet.
11. Mount and connect all the crossover components, L-pads, binding posts, and the mid-range speaker in the sub-enclosure bottom. Use the area between the enclosure bottom and the lower lines on the inside of the front and sides for this so that the square tube will be able to fit into its center hole in the enclosure bottom.
12. Place the tube in the center hole in the enclosure bottom and glue it in place. Then fill the empty spaces in the sub-enclosures with a loosely-fluffed acoustical material such as fiberglass.
13. Attach the rear of the enclosure to the rest of the assembly.
14. Glue the partition mounting strips to the front, rear, and sides of the enclosure so that the bottom edge of each strip is even with the lowest line marked on the bottom of those panels. They should form an even

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ledge around the four sides of the enclosure. (Note: it is easiest to glue the two longer strips to opposing sides of the enclosure first, and then install the remaining two.)

15. Spread some glue evenly on the tops of the four partition mounting strips just installed.
16. Take the assembly prepared in step 5 (partition 6) and lower it through the top of the enclosure (with the partition supports on top) until it sits firmly on the four mounting strips to which glue has just been applied. Make sure that the tube fits into the center hole.
17. Hold the partition-6 assembly in place until the glue has set. Then glue the tube to the center hole of that partition to form an airtight seal.
18. Mount partition 5 on the four partition supports of the partition-6 assembly.
19. Repeat step 14, this time using the remaining partition strips and the partition-1, 2, 3, and 4 assemblies.
20. Mount the woofer on the enclosure top as shown in Fig. 6. Note that it is attached *inside* the enclosure.
21. Attach the top to the rest of the enclosure.
22. Make the electrical connections to the woofer.
23. Attach the top plate to the four top supports.
24. Attach the bottom plate to the four bottom supports.
25. Mount and connect the tweeter as shown in Fig. 3 or Fig. 4. If a horn-type tweeter is used, you may need to reduce the value of capacitor C1 to 1.0 μF to prevent lower frequencies from being shunted to the tweeter and being distorted.

That completes construction of the mini-SAFE speaker system. Use it with a good medium-power (15-20 watts-per-channel) amplifier, and you'll have performance worth many times more than what you paid for the components. **R-E**