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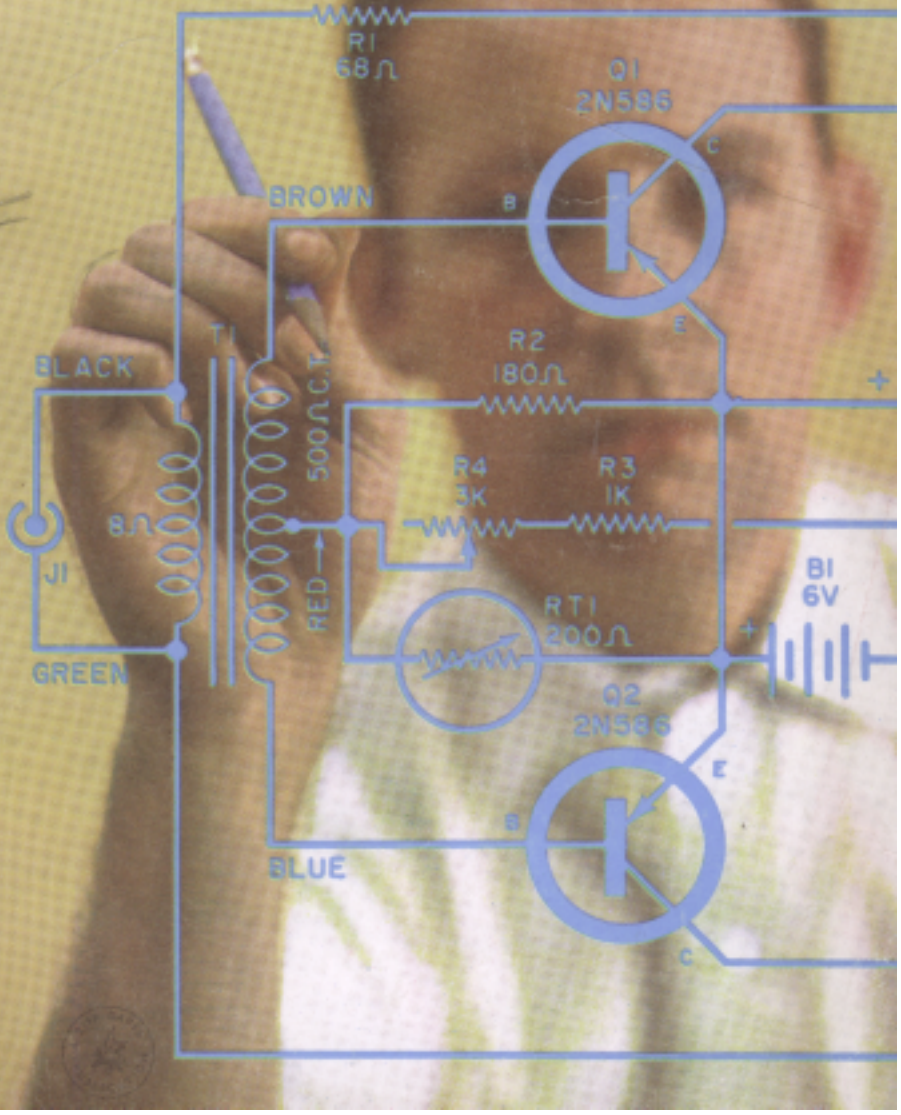


Sweet Sixteen

Compact enclosure

delivers solid sound from

sixteen 5-inch speakers

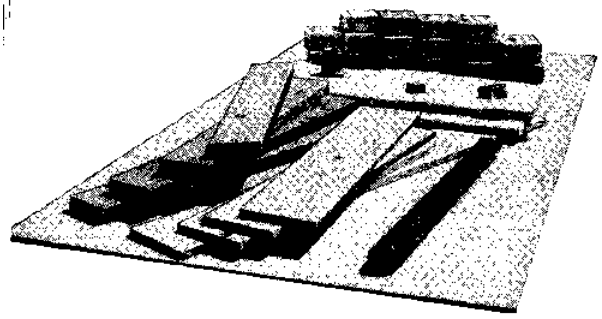
By JIM KYLE, K5JKX

CRISP, solid, bass reproduction—a hallmark of highest fidelity—can be yours for a little over $50 and a weekend's work. And there's no catch, even though $250 is a more likely price for a full-range speaker system capable of delivering useful output to 30 cycles and below.

The classic method for providing good bass response calls for big speakers, heavy magnets, low resonant frequencies, and carefully matched enclosures. This approach provides superlative sound in the bottom octaves, but its price tag is pretty super, too.

The performance of the "Sweet Sixteen" system is virtually unbelievable to those who haven't heard it. Coloration of sound—characteristic to some degree of almost every system—is conspicuous only by its absence. Measured response extends to 20 cycles—well below audibility—and is reasonably flat from that point up to just below 10 kc.

Unlike many hi-fi systems, this setup requires little driving power. Five "clean" watts applied to the system will drive all but the most hardened hi-fnat-



Required parts are few, but it's best to gather all of them together in one place before you start to work on the system.

ics out of the room. And the system will handle more than 30 watts without audible distortion!

Multiple Speaker Setup. The secret of the setup is hinted at in a good many reference books, and several similar systems have been built and described. (See POPULAR ELECTRONICS, September, 1960, for one of the most recent and most elaborate systems, built for the Wright Air Development Center.) Yet the idea appears to have been almost completely ignored by most audiophiles.

Here's how it works. Instead of mating a big woofer (to handle the bass) with a specially designed tweeter (for mid-range and treble), a large number of small speakers are made to work in unison. At low frequencies, the small cones acting together move the air just as if they were one huge unit. In the mid-range, their low mass and high efficiency produce results not attainable with a single larger speaker.

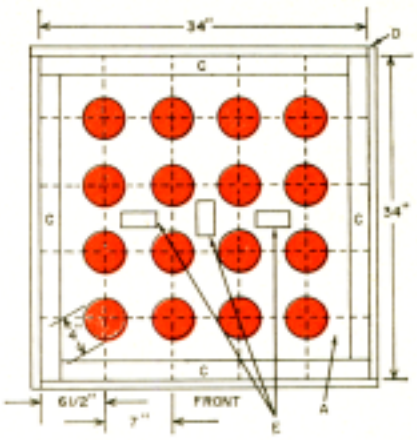
By using many speakers together, the peaks and valleys in each individual unit's frequency response tend to be statistically averaged into a smooth characteristic, difficult to attain with a single unit. The price tag is kept down, surprisingly enough, by the use of inexpensive replacement-quality speakers. Operated at extremely low power levels, these speakers are capable of hi-fi response even though the output from each speaker is so low that it can barely be detected at close range in a quiet room.

With enough of the small speakers working together, sound output comes up to a more-than-usable value. It's theoretically possible (and based on observations made with this unit, perhaps practical) to build a system which will reproduce frequencies as low as one cycle if you just use enough speakers.

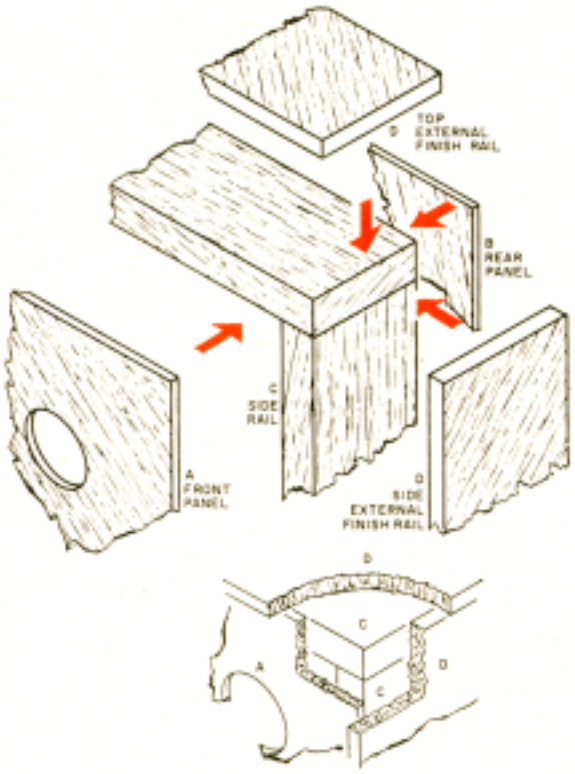
Interconnecting the speakers insures that the power fed to each remains small

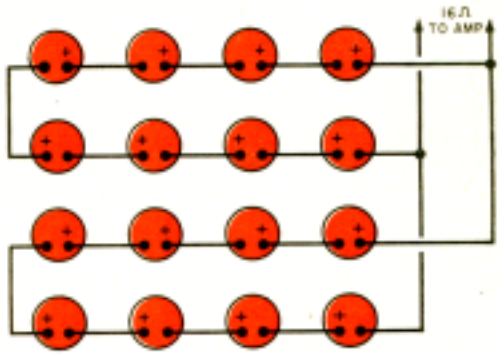
Speaker holes in front panel should be 4" in diameter and can be drilled most easily with a circle cutter mounted in a large electric drill. Side rails are intentionally designed to overlap at corners so they can be trimmed off to size.

Front panel (A) is drilled following layout at right before side rails (C) are attached. Spacers (E) can be cut to fit from pieces sawed off from side rails.



Final assembly is easy following pictorial below. External finish rails (D) hide joints in side rails (C); finish rails are covered with "Contact" material.



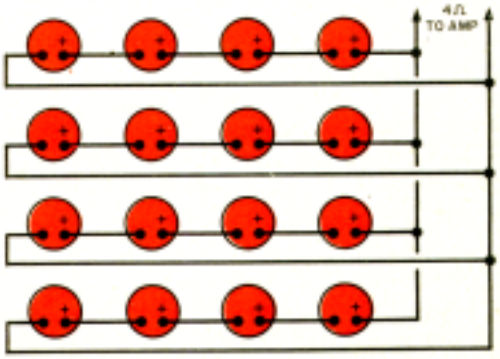


Wiring diagram for use with a 16-ohm amplifier output. See text for instructions on how to phase speakers properly.

BILL OF MATERIALS

2—34" x 34" x 5/16" plywood sheets (cut from a 3' x 6' sheet)
4—2" x 6" x 35" side rails
4—1" x 8" x 35" external finish rails
5 doz.—No. 8 flathead wood screws, 1¼" long
64—No. 6 sheet metal screws, ⅜" long
1 sq. yd.—Grille cloth
1 sq. yd.—Acoustic padding or Fiberglas insulation material
16—5" PM speakers (Quam 5A07 or equivalent)
6 ft.—No. 18 hookup wire
1 sq. yd.—"Contact" table-top material
Misc.—Black screen enamel, staples or tacks, solder, lamp cord, etc.

Speaker hookup for 4-ohm amplifier. Other series/parallel hookups are possible and should appeal to experimenters.



Connecting individual speakers is easy once you know the impedance you require. Simply use ordinary hookup wire and follow the appropriate schematic on page 57.

Decorative touch for finished system is furnished by wood-grained covering material purchased from a department store. Cut material to size before applying it.

—each cone's movement is in the neighborhood of only 0.01″ at top volume. Even loud drum passages reproduced at 30 watts cause no visible cone movement.

Simple Enclosure. Resonance problems and tricky enclosures are automatically eliminated in this approach, since they are important only when a speaker is being operated near its power limit. The baffle used with this system is a simple padded box to enclose the sound radiated from the rear of each speaker cone.

Two items are of prime importance for good results with this system. The speaker box must be solid, so don't try to skimp on the side braces or internal supports specified. Important, too, is speaker phasing—individual units must be connected with one another in such a way that all the cones move in the same direction at the same time.

If all of the units are identical, you'll have no trouble. But if you must mix models and manufacturers (and it's sometimes hard to find 16 of these speakers in stock at the same supply house), you'll have to check the phasing before making connections. This process will be described later.

Layout and Construction. The first step, naturally, in building the system is to gather all the materials and components called for in the bill of materials. The only tools required are conventional ones —a ruler, saw, hammer, screwdriver, and soldering iron—but a ¼″ electric drill equipped with an adjustable hole cutter and with woodscrew speed bits will simplify construction.

Begin by laying out and cutting the front and rear plywood panels (*A* and *B* in the diagram) to size. Mark the location of the 16 speaker holes on the front panel (*A*) and cut them out. The hole diameter will be exactly four inches for a 5″ speaker.

If you're using a hole cutter in an electric drill, check the setting by cutting a hole in scrap lumber first. Then drill the hole halfway through the panel from one side, turn the panel over, and complete the cut from the other side. This will prevent the plywood from splintering when the cutter breaks through.

The next step is to attach the side rails (*C*) to the front panel. Note that the rails are overlapped at the corners in

(*Continued on page* 122)

Sweet Sixteen

(*Continued from page* 58)

such a manner that each can be easily cut to length after assembly. Tack each rail in place with small nails before drilling holes for the assembly screws. Place screws at 6″ intervals down the side, turning them in tightly, and proceed around the square in this manner until all four rails are attached firmly to the front panel.

Cut the extending ends of the side rails off flush. Be sure that the cut edge is even so that the external finish railing (*D*) will fit properly as shown in the illustrations. Save the pieces of 2″ x 6″ you cut off for use in the next step.

Internal bracing is provided by the short pieces of 2″ x 6″ (*E*). Attach them as shown in the photo, at the center and two other spots on the inside of the front panel, using at least two screws in each bracing block.

Now paint the entire front panel black with screen enamel so that the speakers won't show through the grille cloth in the completed unit. Let the paint dry—it shouldn't take more than 30 minutes—before proceeding.

In the meantime, you can attach the acoustic padding to the inside surface of the back panel (*B*), being sure to leave a 2″ clearance at each side for the side rails. Use carpet tacks or a stapler to attach the padding.

After the paint dries, it's time to apply acoustic padding to the inside surface and attach the speakers. Center each speaker over its hole and secure it with No. 6 sheet-metal screws through the mounting holes in the speaker frame. Tighten the screws lightly, and be careful not to damage the cones.

Wiring the Speakers. With all speakers attached, you're ready to wire them up. If phasing must be checked because of mixed models, connect a 1.5-volt flashlight cell to the terminals of each speaker in turn and note whether the cone moves in or out. If necessary, reverse the connections to make the cone move out. Then mark the speaker lug which is connected to the positive terminal of the cell, using a crayon or china marking pencil.

If all your speakers are identical, phasing is not necessary. Simply mark one terminal of each speaker, marking the corresponding terminals on all speakers. Consider the marked speaker terminals to have positive polarity, and wire the speakers together as shown in the diagram. Standard No. 18 hookup wire is satisfactory for connecting the speakers, but it's best to use a generous length of lamp cord for the wire (see diagram) which runs from the system to the amplifier.

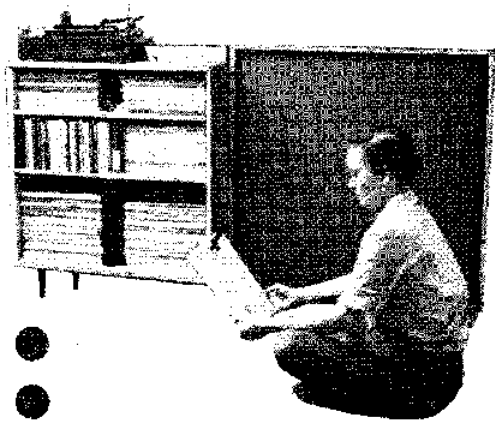
At this point, only one step remains to complete the system so far as sound is concerned—attaching the back panel (*B*). Drill a small hole near one corner of the panel and thread the wire from the amplifier through the hole. Then position the back panel on the speaker box and tack it in place temporarily with small nails. Use wood screws at 6″ intervals for permanent attachment.

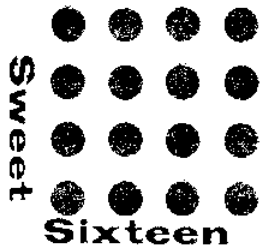
Dressing Up the System. All subsequent construction steps deal with the decorative finish of the system. First, the grille cloth must be attached. It's best to lay it in place, tack the center of one side, stretch the opposite side and secure it, then work from the center to each corner. When two sides are secure, repeat the process on the other two sides. A stapler works well for tacking the cloth in place, and if all tacks or staples are driven into the sides rather than into the front panel, they will be hidden when the external finish railing is attached.

The 1″ x 8″ external finish rails (*D*) should be attached in the same "ring" fashion as the side rails—secured by sixpenny finishing nails hammered flush, then cut to final length after assembly. Note that they mount flush with the rear of the box, leaving an overhanging lip around the grille cloth. Fill any cracks or knotholes with "Plastic Wood," let it dry, and sand smooth with a fine grade of sandpaper.

Now you're ready to apply the furniture finish, which consists of a square yard of "Contact" table-top material available from larger department stores (usually in the "notions" department). This material, a photographic replica of hand-rubbed wood grain in a number of patterns, is self-adhesive. Simply cut it to size, smooth it down carefully on the finish railing, and your "Sweet Sixteen" speaker system is ready to go! Want to try another for stereo? —30—

Step-by-step instructions for adding a super-tweeter to the POP'tronics "SWEET SIXTEEN" speaker system





Sweeter with a Tweeter

By **JIM KYLE,** K5JKX/6

WANT to turn your "Sweet Sixteen" into a speaker system second to none? With an evening's work and an investment of less than $20, you can do it—by adding a super-tweeter.

Response of the basic Sweet Sixteen, described in the January 1961 issue of POPULAR ELECTRONICS, extends from below audibility to just less than 10,000 cycles. As a basic unit, it's hard to surpass. But for the more sophisticated listener, addition of a super-tweeter to extend the range up past 16,000 cycles can add a whole new dimension of sound.

One of the best comparison tests is to play a record of snare drums through the system. With response flat to 10,000 cycles the drums sound real but somewhat muffled. With the super-tweeter added, the drums seem to move out through the speakers into the room! This test, incidentally, is used by a number of professional critics and equipment reviewers to compare speakers, since the sound of snare drums is one of the most difficult to reproduce.

Hold That Transient! While addition of the tweeter will sweeten the sound of the entire system if done properly, it can destroy system performance if you're not careful. Here's why:

As explained in the original article, the Sweet Sixteen acts in different ways at the two ends of the audio spectrum. At the lower end, it behaves like a single, large cone moving a mighty mass of air. In the upper octaves of its range, it becomes 16 independent speakers moving together, preserving transient response because of the small mass of each individual cone. This excellent transient response in the mid-range is the major reason for the system's sweet sound.

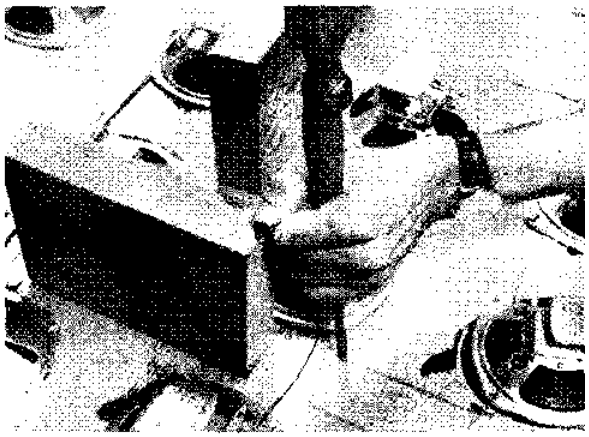
Haphazard addition of a tweeter can completely destroy this characteristic, producing muddiness in the mid-frequencies. Conventional crossover networks made up of inductors and capacitors are major offenders in this respect, since the inductance and capacitance usually resonate at some one frequency and reflect an unrealistic load back into the amplifier.

However, if you use capacitance-only high-pass crossovers, the excellent tran-

sient response of the system will be preserved. In addition, since frequency response will now extend beyond the limits of hearing in both directions, the result will be almost complete removal of the "loudspeaker wall" between the music and the listener.

Any tweeter used with the Sweet Sixteen must be a high-efficiency unit to be able to blend with the rest of the system. A Calrad type CT-3 was chosen by the author, but the S-307 (Olson Radio) or H90LX204 (Radio Shack) are similar and would also be suitable; other possibilities include the Electro-Voice T35B and University T202. The procedures described here are based on the use of the CT-3, so the size of the mounting hole and manner of installation may have to be altered slightly if you choose a different tweeter.

Backup block slid under front panel protects grille cloth from damage as tweeter hole is cut.



Chisel and hammer combination is best for making required cutout; tweeter placement is not critical.

Mounting the Tweeter. Place the Sweet Sixteen face down and remove the back, disconnecting the amplifier leads if necessary. To mount the tweeter on the front panel, it's necessary to cut another hole in the plywood.

Since the panel is already covered with grille cloth which cannot be removed without damage, this new hole can pose a problem. The author solved it by removing one speaker from the panel and sliding a small piece of plywood through the hole thus exposed into the space between the panel and the grille cloth (see photo at left). With the plywood acting as a "backup," it was then possible to cut the new hole with a sharp wood chisel.

Dimensions and placement of the new hole are shown on the drawing at right —don't forget to remove the backup block and to replace the speaker after the hole is cut.

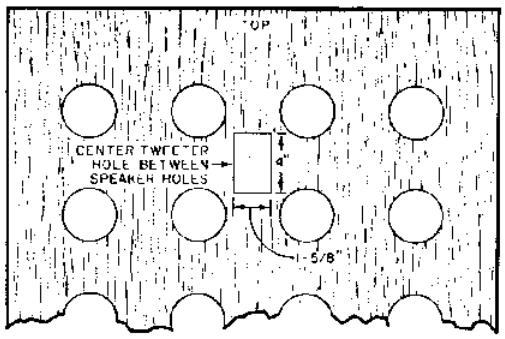
Since the original Sweet Sixteen used 5/16" plywood for front and rear panels, adding the CT-3 will cause the tweeter horn to project approximately 7/16" in front of its mounting lips. To avoid this projection, cut shims from scrap pieces of ¾" plywood and place two shims under each mounting lip. (If your Sweet Sixteen uses a ¾" or thicker front panel, you won't need the shims.) Tighten the tweeter down with the four ¾" screws specified, and the job is half finished.

Crossing Over. The next step is assembly of the crossover network and presence control. Before this can be done, you must pick the proper value of crossover capacitor, and this value will be determined by the impedance for which your system is built. With a 16-ohm unit, use a 3-μf. capacitor. If your Sweet Sixteen is connected for a 4-ohm impedance, use a 12-μf. capacitor. For other impedance levels, divide 48 by the impedance level in ohms and the result will be the capaci-

tor value in microfarads. A miniature metallized-paper unit will serve very nicely, but do *not* use an electrolytic. Voltage rating of the capacitor need not be greater than 50 volts.

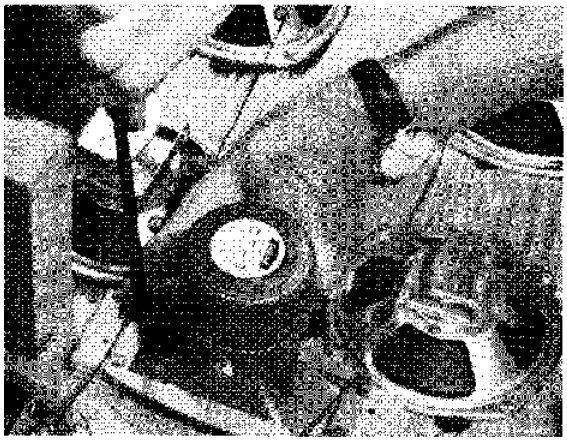
Solder the capacitor to one of the outside terminals of the 50-ohm wire-wound "presence control" potentiometer as shown in photo below, right. Connect 2-foot wires to the other capacitor lead and to the central terminal of the potentiometer.

Next, decide where on the rear panel you want to locate the presence control (the author chose the top center) and drill a ¾" hole from the outside of the panel. Cut away just enough of the acoustic padding to allow space for the potentiometer, and mount the control on the panel.

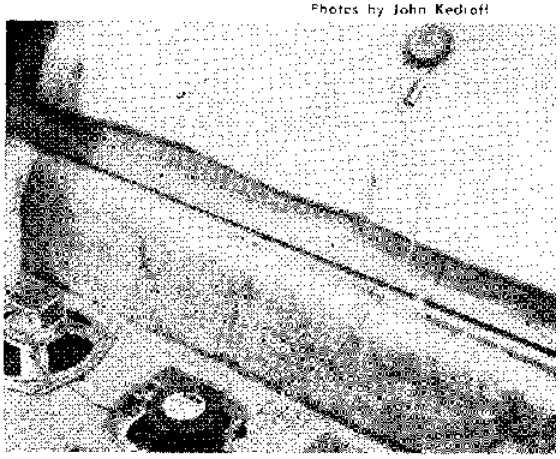


Cutout for tweeter should measure 4" x 1⅝" as shown if a Calrad type CT-3 is used; other tweeters may require a different size hole.

Photos by John Kedroff



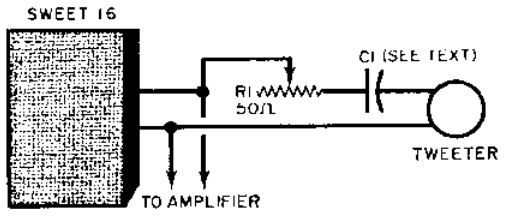
Screws hold tweeter securely to front panel; shims prevent unsightly bulge due to projections on horn.



Potentiometer and capacitor are added to prevent low frequencies from reaching delicate tweeter cone.

Connect the wire from the capacitor to one terminal of the tweeter, and attach another length of wire to the other tweeter terminal. Connect this new wire to one of the amplifier leads, and solder the wire from the presence control to the other lead as shown in the wiring diagram. Phasing is immaterial. Now replace the rear panel.

Final Touches. The only thing left to be done is to balance the super-tweeter with the 16 basic speakers. With the presence control at one end of the range, high notes will sound shrill; at the other end,



Schematic diagram of a recommended hi-pass filter for use with super-tweeter.

PARTS LIST

C1—Paper capacitor—see text
R1—50-ohm, 2-watt wire-wound potentiometer
1—Super-tweeter (Calrad CT-3 or equivalent)
4—No. 8 wood or sheet-metal screws, ¾" long
4—¼" x ⅝" x 1⅜" plywood shims—see text

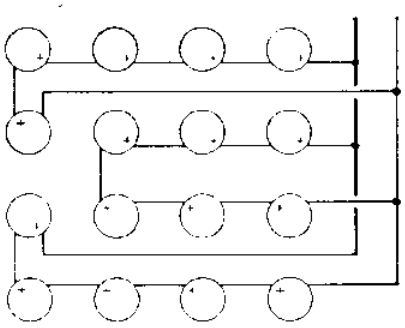
the modification will not be detectable. The proper balance is somewhere in between.

The procedure is simple. Play a record with drums, trumpets, or vocal performances. Set the presence control for least treble, then gradually increase it (amplifier tone controls should be in the flat position). When the drums *just begin* to sound "live," the trumpets "raspy" (like live trumpets), or the vocalists "breathy," you have the proper balance. Further adjustments should be made with your amplifier tone controls. —30—

MORE ABOUT THE "SWEET SIXTEEN"

Enthusiastic reader response to the "Sweet Sixteen" speaker system (described in the January, 1961, POPULAR ELECTRONICS) has exceeded our wildest expectations. Our offices have been deluged by literally hundreds of letters and we've done our level best to answer each one individually. Since some of the points raised are of general interest, we thought you might like to hear about them, too.

One of the most frequent questions we have received concerns impedance—many speaker systems are rated at 8 ohms and readers want to use the Sweet Sixteen with existing systems. Several different arrangements will fill the bill, and a hookup which produces an impedance of 7 ohms is shown in the diagram. But we recommend wiring the Sweet Sixteen for 4 ohms as shown in the original article and paralleling it across the existing 8-ohm speaker; don't worry



about the slight apparent mismatch since speaker impedance ratings are only nominal anyway.

An allied question is that of which impedance to use with an amplifier when you have a choice. In this case, the 16-ohm hookup is recommended, since amplifier feedback taps are usually taken from the 16-ohm output. Connecting the system there will bring the speakers more under control of the amplifier's feedback loop.

The next most frequent inquiry has to do with the dimensions of the enclosure. They're not critical; in fact, hardly anything connected with this system is critical—and that's one of its greatest advantages. The box need not be square, and its depth can be whatever you like. Just be careful not to move the cones farther apart than twice their own diameter, or they may fail to couple properly to the air at very low frequencies. Wood thickness can be whatever is handiest, and the final decor can naturally be changed to suit your own taste. However, use of extra-heavy front and rear panels is unnecessary, since the internal bracing and 2" x 6" side rails provide all the physical strength needed.

Although the original article specified Quam Type 5A07 speakers, any similar unit should give equal results. Theoretically, using speakers from a number of different manufacturers should give a smoother response—slight differences in construction would tend to fill in "valleys" and to level "peaks." But using speakers from the same manufacturer does simplify the problem of speaker phasing.

Magnet weight isn't critical. In fact, the 0.65-oz. magnet of the 5A07 is heavier than needed. The only time magnet weight becomes important in a speaker is when the cone is traveling over a long path, and cone movement is imperceptible in the Sweet Sixteen.

Several readers have inquired about using a larger number of smaller speakers or fewer but larger units, and many have asked why the number 16 was chosen. The answers to these questions are interwoven.

If a speaker much larger than 5" is used, cone mass will be larger and transient response will suffer in the upper mid-range. However, bass response will remain good and fewer speakers will be necessary (the author's first system of this type used two 8" and one 12" unit, giving response to 30 cycles and below). If a speaker much smaller than 5" is chosen, many more will be needed for adequate bass response, but treble response will be slightly better. The best compromise is obtained with 5" or 6" speakers, and the 5" unit was chosen so that holes could be cut with a drill rather than with a saber-saw.

Why 16 speakers? Without going into deep theory, it has been determined by experiment that bass response goes down approximately one octave every time the number of speakers is doubled. Thus, with response flat to 320 cycles for a single 5" speaker, two speakers are flat to 160 cycles, four to 80 cycles, 8 to 40 cycles, 16 to 20 cycles, 32 to 10 cycles, 64 to 5 cycles, and so on. To reach 1 cycle, you would need at least 256 speakers. Since true response to 20 cycles will meet all musical needs, 16 speakers were chosen.

By the same token, splitting the Sixteen for stereo use probably wouldn't give the results you would expect. The formula holds true only when all the speakers are close together, so a Split Sixteen would be flat only to 40 cycles, thus losing some of the essential bass.