Back

A Unique Stereo Column System

The author describes an unusual system that will produce a new listening experience for stereo imaging and bass. No crossovers are used and electronic equalization corrects for response.

By Roger Russell

After years of struggling to match woofers, mids, tweeters, and those frustrating compromises called crossover networks, I decided to toss it all away and start from a new perspective. Here is a full-range, single-column system that contains 20 identical 4″ drivers (**Photo 1**). There are no crossovers, woofers, mids, or tweeters. Although the system has a typical rolloff below 150Hz, I use electronic equalization to compensate for this lack of bass and extend the response to around 25Hz.

How can the little drivers handle any kind of power? Not only are they small, but the lows are being boosted as well. This seems very contradictory to good design and common sense. In fact, it seems totally unreasonable, but it works. . . and works unbelievably well!

Not only is the bass good, but my reaction when I heard it for the first time was the amazing coherence of the stereo images. When an entire orchestra is playing, the stereo image, depth, and spaciousness provided by this system are totally captivating and allow better appreciation of what the artist has produced. This unique listening experience is only possible because all frequencies are being radiated from the same vertical line.

The cabinet is the closed-back type you need to place close to a wall. It is 89″ tall, 6½″ wide, and 9¼″ deep, and includes a 1½″ thick base that is 14″ wide and 12″ deep. The total cost of the pair of speakers, including the cabinet materials, is about $200.

PHOTO 1: The finished system in my living room.

TYPICAL MULTI-WAY SYSTEM DESIGN

Almost all recordings are made with small, single diaphragm microphones that handle the entire frequency range; but when it comes to speakers, drivers are almost always divided into at least one (or even more) woofer and tweeter. A woofer needs a large area in order to reproduce low frequencies effectively. A large woofer cone is normally used to accomplish this. However, a large woofer becomes directional at higher frequencies and has high moving mass that serves to attenuate the higher frequencies.

To overcome this, use a mid-range or tweeter of smaller size and much lower mass to maintain wide dispersion and extend the response. Use of a tweeter to complement a woofer requires a crossover network, either passive or active. Achieving the optimum sound is often a challenge to select the best combination of crossover components that will make the system sound as good as possible. Systems can be made as a two-way, three-way, or more following this principle.

In the area of the crossover, both drivers radiate the same frequencies and may interfere with each other causing uneven response around the system. A different physical location for each driver adds to the problem. More important, and perhaps not so obvious, is that a driver used to cover one part of the frequency range does not have the same construction, tonal characteristics, or dispersion characteristics as a driver covering another part of the frequency range.

In the area of the crossover frequency, these differences between drivers

cause sudden discontinuities in the overall sound balance. It results in a loss of valuable stereo information. By using the same driver to cover the whole frequency range, you can avoid all of this and present a continuous coherent spectrum.

MULTIPLE DRIVERS AND POWER HANDLING

A popular misconception about small drivers is that they are not useful as woofers. However, you need to consider the cone area of all the drivers. The effective cone diameter for each 4″ driver is 3¼″, and the effective area is 8.3in^2. In comparison, the effective diameter for a 12″ driver is 10¼″, and the effective area is approximately 83in^2.

The area of 20 4″ drivers adds up to 165in^2, or as much as two 12″ drivers and more than a single 15″ driver. That makes the equivalent of four 12″ woofers for a pair of stereo speakers, and they can couple to the air very nicely. Very little excursion capability is needed when such a large area is available.

My solution to the power-handling problem is also provided by the 20 drivers. Each driver receives only 1/20 of the power. If each driver can handle a maximum of 15W, the entire column can handle 15 × 20, or 300W maximum. Twenty ¾″ voice coils can dissipate much more heat than two 2″ voice coils. Distortion is low because the demand on each driver is small.

The systems are relatively efficient and can be played very loud. Typically, I drive the systems at about 2W, which fills my relatively small living room, which is 13′ × 14′ and has a sloped ceiling from 8′ to 10′. I measured a sound level of about 85dB at 10′. You can obtain peak levels of up to 110dB if you drive them with over 100W (much too loud for me). The 25Hz heartbeats of Pink Floyd's *Dark Side of the Moon* are reproduced in stride, as well as the finale of Saint-Saens "Organ Symphony."

DIRECTIONALITY

The column is very directional vertically, but it extends essentially from floor to ceiling. So floor and ceiling reflections that would normally interfere with the direct radiation are effectively eliminated by the column. This also means that you are always directly in front of the coverage area. The sound will be the same whether you are standing, sitting, or at any other height.

This is a significant advantage over normal systems that not only radiate sound as much vertically as horizontally but also exhibit response changes with listening height. At the same time, the horizontal dispersion provided by the small drivers in the column ensures a wide radiation angle over most of the frequency range.

Theory predicts that response becomes directional when half wavelength of the frequency being radiated is equal to the effective cone diameter. The effective cone diameter for these 4″ drivers is actually 3¼″, which corresponds to about 8.3kHz. Equalization above 8.3kHz does not compensate for the directional characteristics of the drivers. You can improve this by toeing the columns in toward your listening position by about 15°.

OTHER ADVANTAGES

Another unique feature of a long column is the radiation characteristic. Normally, for a single speaker, the sound level decreases by 6dB for every doubling of distance from the speaker. In the long column, this figure is only 3dB, which means that as you get nearer to the system, it does not become as loud as an ordinary system. You can listen as close as 3′ from the wall that the systems are against and still get excellent stereo sound including spaciousness. It means that you can also use these systems even in a fairly small room, where you can't avoid being close to them.

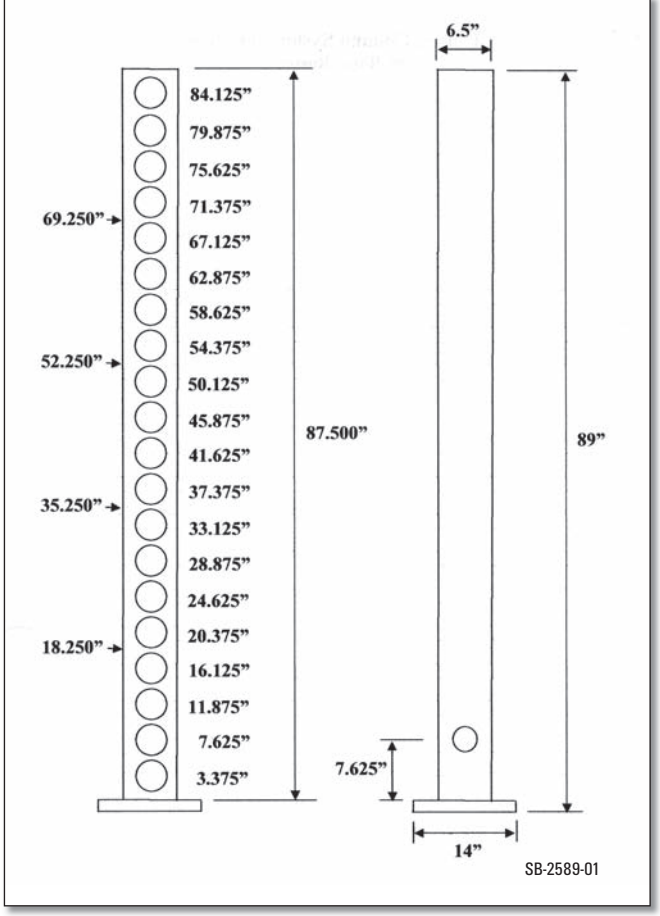
Elimination of unwanted floor and ceiling reflections, as well as less attenuation with distance, extends the useful listening area further into the room than conventional systems. This is sometimes referred to as the near field, where most of the sound comes directly from the speakers and not from room reflections. The sound coming mostly from reflections is referred to as the far field, and the sound will vary depending on your room construction and furnishings.

This single-column system has a unique sonic advantage over other column systems because all frequencies are radiated from the same vertical line. It provides additional sonic clues contained in recordings that would otherwise be lost to the listener. Systems that have adjacent columns of drivers, each radiating the same or different frequency ranges, do not have the same distance to the listener, which can cause various degrees of image distortion.

Room resonances are greatly reduced. This may be because the lows are radiated all along the height of the column and the low frequencies are distributed over a wide location. This helps to reduce the amplitude of low-frequency room resonances. In comparison, subwoofers on the floor may excite only a few resonances and at greater amplitude.

You can easily incorporate the system into a wall for built-in home designs. The base, of course, would not be needed and the width of the system would then be only 6½″.

FIGURE 1: Column outline drawing.



THE CABINET

The dimensions shown in **Fig. 1** are for the size of the drivers I used. The center-to-center distance of 4¼″ is the driver height plus ¼″ for the space between the drivers. The distance from the bottom of the cabinet to the center of the bottom driver hole is 3⅜″. I have used the same distance from the top of the cabinet to the center of the top driver hole. I located a 2¾″ diameter terminal hole in the back directly behind the second driver, which is 7⅝″ up from the bottom of the cabinet.

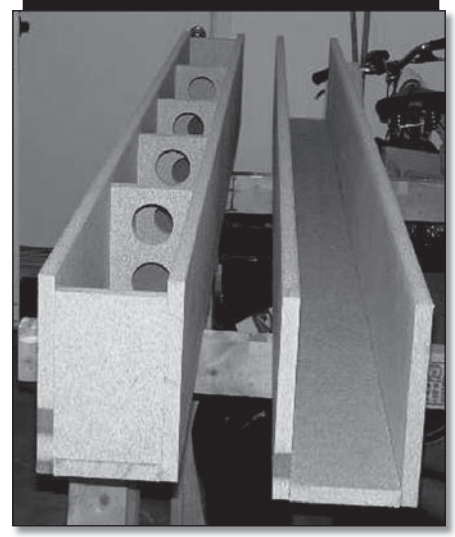
I had a second set of cabinets made by a friend who is also in the Central Florida Audio Society and has computer-controlled machinery, which can handle decimals, so I decided to show the centers for the driver holes and brace locations in decimal form. The location of the braces is indicated by the arrows on the left side of **Fig. 1**.

If this column is too tall for your home, simply construct a cabinet that is one or two drivers shorter. Substitute an 8Ω 15W resistor for each driver that you remove from the system. Removing one or two drivers will not make a big difference, but bear in mind that the fewer drivers you use, the lower the power handling and the less bass capability there will be. In any case, the column must run from floor to ceiling in your room to be effective. If your ceiling is higher than this column, you could use additional drivers, but these are not required, at least not for this design.

The cabinet is made of ¾″ kitchen-counter underlayment and is reasonably inexpensive. This is a very dense and fine grain particleboard. **Photo 2** shows a partial cabinet assembly. Other woods will certainly work as well. All the pieces are glued and nailed together with finishing nails, which are countersunk.

I used four ½″ thick internal braces with two 2½″ circular holes shown in **Fig. 2**. You can use more braces if desired. This helps to break up internal

PHOTO 2: Cabinet assembly.



resonances and strengthens the walls of the cabinet. They are located so they don't block the driver holes.

Because the front panel is so narrow and could be easily broken, I decided to cut all the driver holes after the cabinet was completely assembled. I located the centers of all the driver holes accurately and used a router with a pin attachment to make the circular cuts. The hole diameter for these particular drivers is $3^{11}/_{16}$″. The left and right front edges of the cabinet are beveled at 45°, which might reduce edge diffraction effects and provide a more pleasing appearance.

The finished cabinets are shown in **Photo 3**. I used filler for all the rough surfaces, joints, and nail holes. After sanding, I primed the cabinet with an alcohol base primer to prevent raising the surface. Then, I used several coats of white latex, water-base paint with sanding in between coats. I decided on white because I think the cabinets look less imposing, being so tall.

For the input terminal (**Photo 4**), I used a 5-way binding post that accepts a dual banana plug. You may prefer other types of terminals. I made the terminal board out of a piece of ¼″ tempered Masonite and sprayed it black. Be sure you make the board no bigger than the diameter of the driver hole. Otherwise, you will not be able to fit the terminal board through the driver hole of the finished cabinet.

For my system, the board is $3^5/_8$″ square. Drill a hole in each corner for mounting inside the cabinet. I used foam tape to seal between the terminal board and the cabinet.

The construction of the stand is shown in **Fig. 2**. Two ¾″ thick pieces of

FIGURE 2: The stand and column construction.

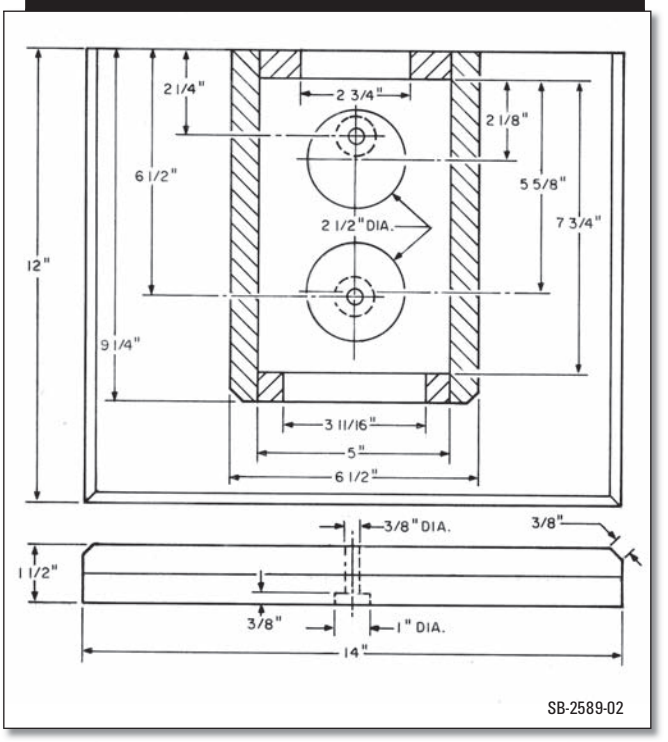


FIGURE 3: Schematic.

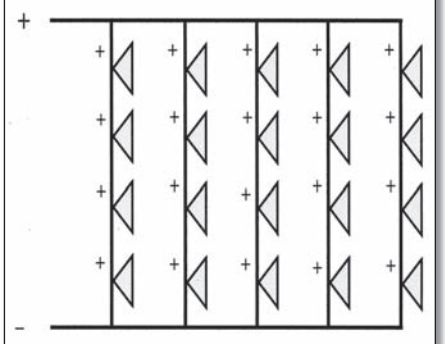
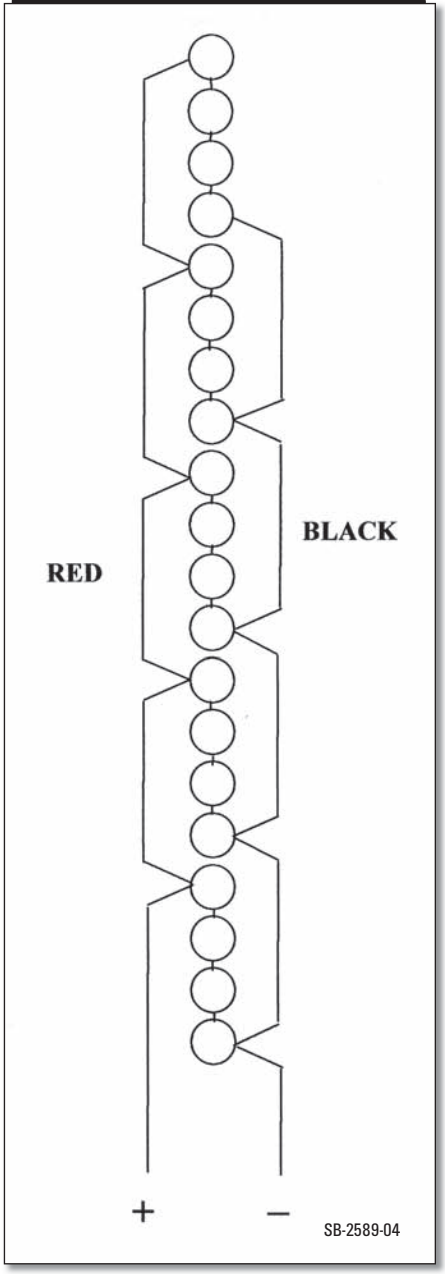


FIGURE 4: Wiring diagram.



particleboard are glued together. The bolt heads are countersunk in the bottom of the stand so they don't stick out below the bottom. The front and both sides are beveled at 45°. The position of the cabinet is shown where it is attached to the stand. The location of the holes for the bolts is shown for both stand and the bottom of the cabinet.

FINAL ASSEMBLY

I have wired the drivers in series-parallel as shown in **Fig. 3**. There are five groups with four in series in each group. All the drivers are in the same electrical phase. You could use other series-parallel arrangements, but I believe the net impedance of 6.4Ω is satisfactory for most amplifiers. It is pleasing for me to look at the entire circuitry for the system and experience the freedom from being bogged down with the choice of the best kind of crossover theory and crossover parts. In addition, there is no need for electronic crossovers or multiple amplifiers.

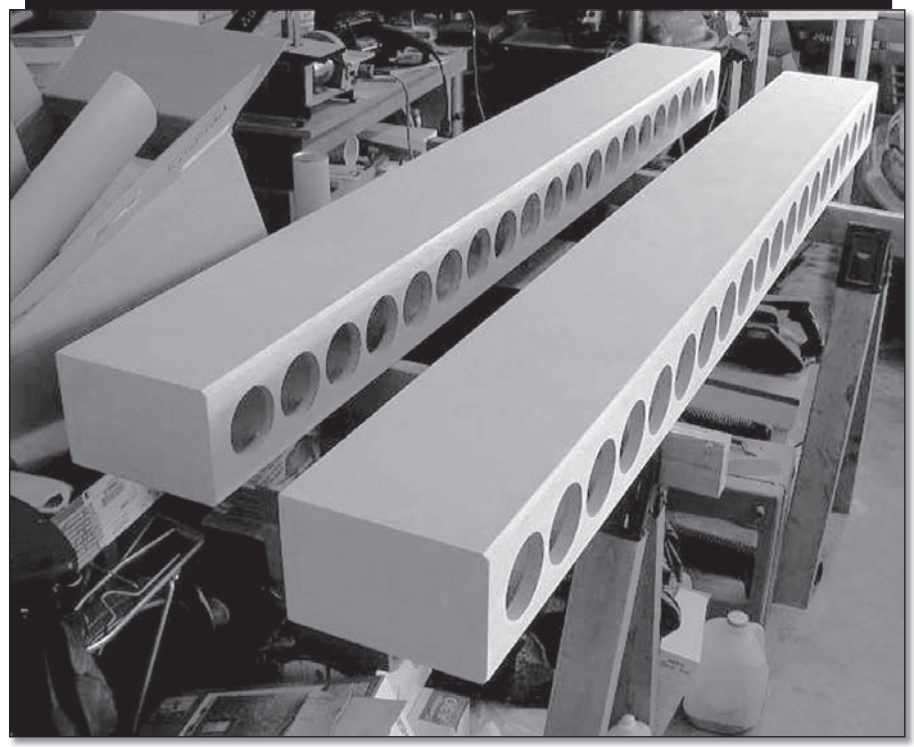
The wiring is shown in **Fig. 4**. I used #19 stranded hookup wires to connect all the drivers. You could use heavier wire, but the resistance of this wire is negligible compared to the speaker resistance. I used 20″ red wires for the positive and 20″ black wires for the negative. Use 12″ long white wires for the connections between the drivers in series. I soldered all connections.

For a single wire to a driver, I twisted a ½″ length of the strands together and tinned it with solder. Then I bent ¼″ of this 180° with thin nose pliers, fit the U-shape around the driver terminal, crimped it in place and soldered. When connecting two wires to the same terminal, you can twist the pair together, then tin, bend, crimp, and solder in the same way.

I used pink building fiberglass 3½″ thick R-13 as acoustic material. I cut the fiberglass in pieces about 4″ × 6″ and distributed 30 of these pieces evenly throughout the enclosure. The 4″ edge of the fiberglass should be toward the driver. The total weight of the fiberglass is 826 grams, or 1.82 lbs. I used gloves to install the fiberglass in the cabinet. I use two ⅜″ × 3½″ plated bolts (**Photo 5**) to attach the base to the cabinet, then a ⅜″ lock washer and ⅞″ washer under each bolt head and nut.

You can cut soft foam weather stripping to ¼″ width and attach it around the perimeter of the driver cutout. The foam compresses very easily and forms a good seal between the driver and the

PHOTO 3: The finished cabinets.



cabinet. It has adhesive on one side. The preferred screws are #6 × ¾″ deep thread, pan, black. The Parts Express number is 081-435.

After wiring the system, you can make a final polarity check by connecting a 6V battery to the input terminals. With the positive lead connected to the red terminal and touching the black to the negative, all of the cones should move outwards.

THE DRIVERS

I used 4″ extended range drivers (**Photo 6**) that were originally intended for use in a TV set. I purchased them from Parts Express for 69 cents each. Part number is 269-469.

Although these particular drivers were in a closeout sale and are no longer available, you can substitute other drivers with similar parameters and smooth response. The square construction allows you to space them closely for best performance. The magnet structure includes an additional ceramic magnet attached to the back plate. This is magnetized in the reverse direction to cancel out the stray magnetic field from the main magnet. It prevents rainbow patterns on a color TV picture tube that would otherwise be induced by the stray magnetic field when the speaker is placed near the set.

RESPONSE TAILORING

The advertised driver parameters are shown in **Table 1**. Free-air resonance for the drivers averages 118Hz, and the

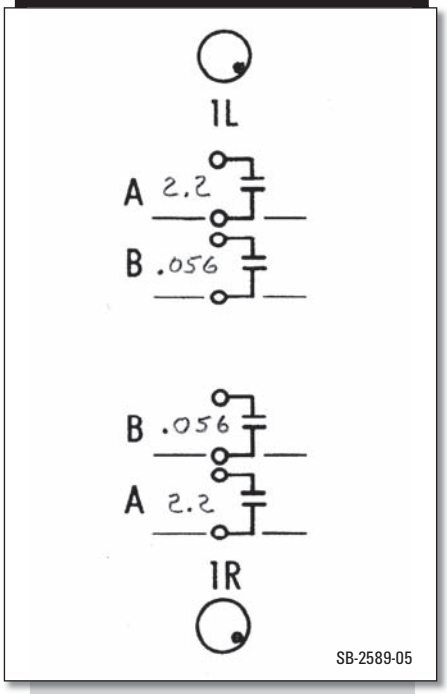
TABLE 1: DRIVER PARAMETERS

Impedance: 8Ω
DC resistance: 7.52Ω
Frequency response: 118Hz–18kHz
Magnet weight: 3.3 oz
Fs: 118Hz
SPL: 90.5dB 1W/1m
VAS: 0.11ft³
Qms: 5.27
Qes: 0.71
Qts: 0.63
Net weight: 3/4 lb

PHOTO 4: The input terminal.

PHOTO 5: Lowest driver cutout showing bolts.

FIGURE 5: MQ107 filter settings.



sealed box is designed to go down to about 150Hz and then output decreases, reaching a slope of 12dB/octave. The bass equalization curve is the opposite of this rolloff. You can accomplish compensation of as much as 20dB or more. This is a lot of low-frequency power to boost, but remember that each speaker handles only 1/20 of this power.

I have used a McIntosh MQ107 equalizer (**Photo 7**) for the necessary response adjustments. The equalizer was made from 1981 to 1993 and is often available through eBay or other places. The low-frequency and high-frequency compensation controls are used, plus seven adjustable filters are available to tune and further boost the low frequencies.

You can make the filters have a 1/3 octave or 1 octave width. They can each boost or cut 12dB in the 1/3 octave mode or 15dB in the octave mode. Select the center frequency and filter width by plugging in two small capacitors for each filter. **Table 2** shows capacitor values for center frequencies and widths from 20Hz to 1kHz. All capacitor values are shown in microfarads.

TABLE 2: Capacitor Values.

	Narrow Filter		Wide Filter	
Frequency	Capacitor A	Capacitor B	Capacitor A	Capacitor B
20	1.0	.39	–	–
25	1.0	.27	4.7	.056
31.5	.82	.22	–	–
40	.56	.18	–	–
50	.56	.12	2.2	.022
63	.39	.12	–	–
80	.22	.12	–	–
100	.22	.082	1.0	.012
125	.18	.056	–	–
160	.12	.056	–	–
200	.12	.039	.56	.0082
250	.12	.022	–	–
315	.082	.022	–	–
400	.056	.018	–	–
500	.056	.012	–	
630	.039	.012	–	–
800	.022	.012	–	–
1000	.022	.0082	–	–

PHOTO 6: The 4″ driver used in this system.

You can insert capacitors in the corresponding A and B slots in the equalizer. Three holes are available for each capacitor. Only two holes are actually used, depending on the lead spacing of the capacitors. Each filter has a control with a center detent that can adjust the amplitude to boost or cut. The center position is electrically flat.

A compartment box with capacitors originally came with the equalizer, but may not be included with the equalizer that you find. You can purchase capacitors from Mouser Electronics. Preferred capacitors are metallized polyester or equivalent for values up to 0.56µF. Non-polar electrolytic capacitors are used for higher values. Capacitors must have a voltage rating of 50V or higher.

You can use additional frequencies by calculating new capacitor values. The formula for these is indicated in **Table 3**. Please note that "stock" values are normally the only ones available. If, for example, you calculate a capacitor value of 0.095µF, the closest value available will be 0.1µF.

Figure 5 shows the capacitors and control settings that I have used. Only one of the seven filters is needed for each channel plus the low-frequency and high-frequency compensation controls that are set at maximum. I used the same settings in both channels. All capacitor values are in microfarads.

You can use other equalizers as long as the adjustments can complement the driver rolloff without exaggerating other areas where boosting is not wanted. The closer you match the initial equalization to the opposite of the woofer rolloff, the better the low frequencies will sound. However, further adjustments to compensate for room resonances could smooth response even further at your listening area.

The drivers are reasonably smooth through the mid-range but have a gradual rolloff above about 4kHz. This is not related to their directionality. A high-frequency boost is needed to maintain smooth and extended response. You can adjust high frequencies to suit your preference by using the high-frequency

SOURCES

Parts Express
725 Pleasant Valley Drive
Springboro, OH 45066-1158
1-800-338-0531
www.partsexpress.com

Mouser Electronics
1000 N. Main Street
Mansfield, TX 76063
1-800-346-6873
www.mouser.com

compensation controls at the right side in **Fig. 1**.

MEASUREMENTS

For the measurement shown in **Fig. 6**, both speakers were driven using random phase pink noise as a source. The Bruel & Kjaer 4133 microphone output is then fed to a ⅓ octave filter and automatically swept from 25Hz to 25kHz. The microphone is located at the listening area about 9′ from each speaker. The microphone height is 4′. Each major division on the graph is 10dB. The first section at the left is 25-250Hz, the center section is 250–2500Hz, and the right section is 2500–25kHz.

The response in my room is reasonably smooth from 25Hz to 15kHz. There is no question that room resonances have influenced the measurement at low frequencies at this distance. Although I had initially designed the equalization to follow only the opposite of the driver rolloff, I later decided to go a step further and make a few minor adjustments for the room resonances. This was fairly easy to accomplish using an Audio Control real-time analyzer and adjusting the filters in the MQ107 equalizer. You can make further equalizer adjustments at low frequencies

TABLE 3: Capacitor Calculation.

Capacitor	Narrow Filter	Wide Filter
Capacitor A	23.5 divided by frequency in Hz	118 divided by frequency in Hz
Capacitor B	7.2 divided by frequency in Hz	1.44 divided by frequency in Hz

FIGURE 6: Combined system response.

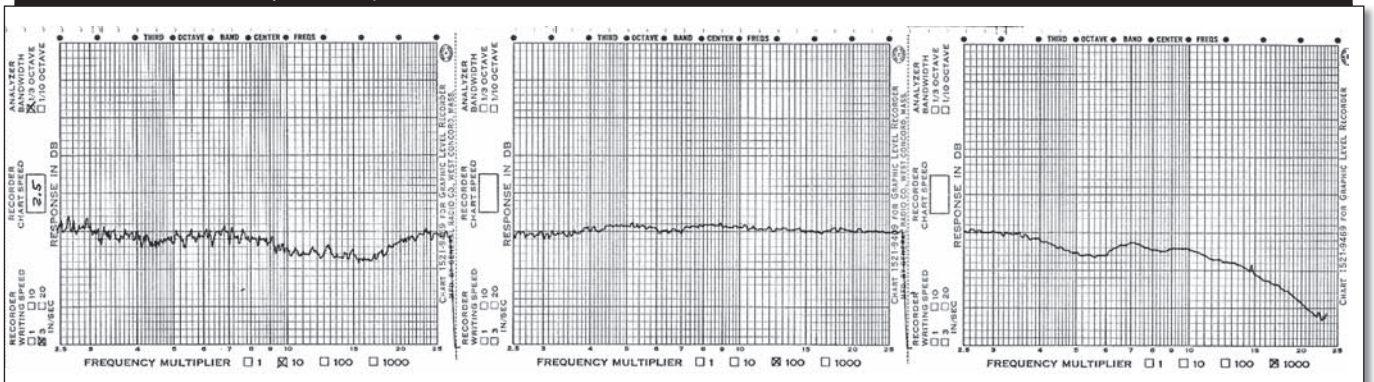


FIGURE 7: Equalizer response.

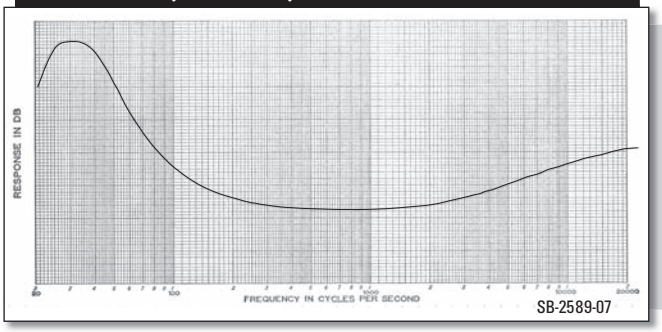
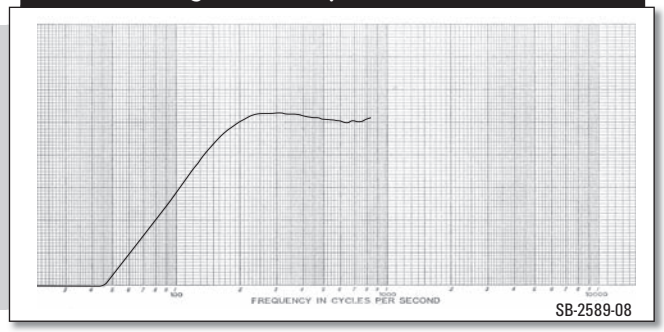


FIGURE 8: Single driver response.



for your room.

The final correction for the system is shown in **Fig. 7**. Each major division is 5dB. The measurement is from 20Hz to 20kHz. **Figure 8** shows the response of a single driver in a small test box. Each major division is 5dB.

The impedance curve for the entire system is shown in **Fig. 9**. The vertical scale is in ohms and is shown on a dB scale of 5dB per major division. The measurement is from 20Hz to 20kHz. System resonance is 158Hz.

SAFETY FIRST

Due to the possible tipsy nature of such a tall column, the base by itself may not make the system stable enough for your use. Each system weighs 81 lbs. You could increase the size of the base.

In addition, I recommend adding at least a set of floor spikes, particularly if you place the system on a soft carpet with thick padding underneath. You can find typical spikes (like those shown in **Photo 8**) at Parts Express. Drill holes in the bottom of the thick base near the corners for the spikes, which are thin and go through the carpet without damaging it. Even this may not be adequate if there are young children or large pets around.

You can further stabilize it by anchoring the top of the cabinet firmly to the wall. I found two different friction lid supports (**Photo 9**) at Home Depot that you could use. The first is on the right in the photo, made by Ives-Schlage, H. B. Ives, New Haven, CT 06511 (*www.schlagelock.com*). Two screws anchor the support to the wall and two more screws anchor the support to the top of the cabinet. The support is adjustable for the angle and distance of the cabinet to the wall.

The second is a lid support made by The Stanley Works, New Britain, CT 06053 (*www.stanleyworks.com*). Two screws anchor the bracket to the wall and one screw anchors the bracket to the top of the cabinet. Again, the support is adjustable.

As with many other systems, I found that the best listening position is one that forms an equilateral triangle between the listener and each speaker and between each speaker. In my living room (**Photo 1**), the speakers are about 8′ apart. My best listening spot is around 8 or 9′ from each speaker. The systems are about 3″ from the wall.

SUMMARY OF ADVANTAGES

1. High power handling through the whole frequency range
2. Single wide-range line source
3. More uniform sound level in a room
4. No floor or ceiling reflections
5. No right- and left-hand versions
6. Distributed low-frequency radiation
7. Less attenuation with distance
8. Wide dispersion
9. Uniform response at any listening height
10. Magnetic shielding
11. Small footprint
12. No woofers
13. No mid-ranges
14. No tweeters
15. No crossovers
16. No image distortion
17. No subwoofer needed
18. No bi-amping or tri-amping
19. No bi-wiring or tri-wiring

CONCLUSIONS

This single-column, full-range system provides a unique stereo listening experience. When you listen to some of the spacious new-age recordings, the sound field produced by the speakers seems to pull your full awareness right into the field. This is particularly true when listening in the dark where visual distractions are eliminated.

The coherence, depth, and spaciousness of the classical recordings are immediately apparent, and this is what first captures your attention. Imaging is extremely stable and permits you to easily hear how the recordings have been mixed. Smooth jazz and new-age music image exceptionally well.

You may spend weeks listening to your entire collection of recordings to hear stereo information that you have not heard before. That's what happened

FIGURE 9: Impedance curve.

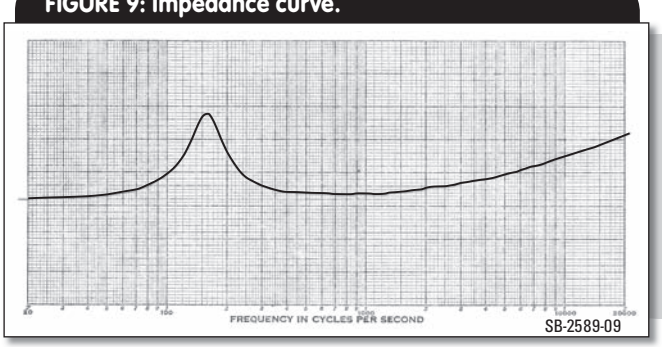
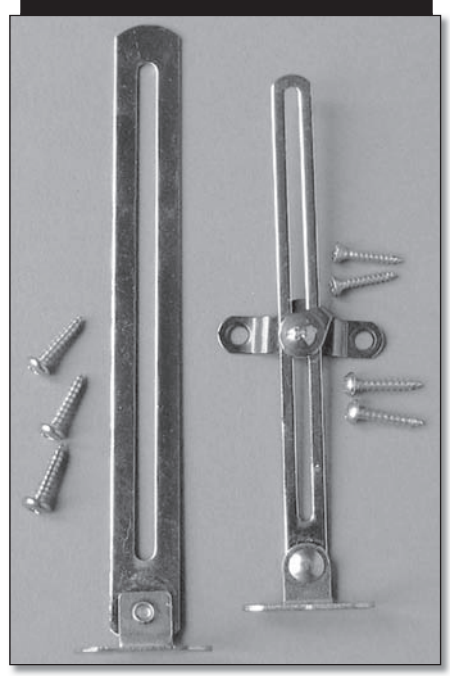


PHOTO 7: The McIntosh MQ107 equalizer, with cover removed.

to me, and I never seem to get used to the excellent bass from such small drivers. I was so encouraged by the sound of this system that I decided to build another pair using even smaller and much more expensive drivers that are of higher quality. Although the work is not completed, I expect excellent results. *aX*

PHOTO 8: Spikes.

PHOTO 9: Support brackets.



Roger Russell *has a degree in electrical engineering from Rensselaer Polytechnic Institute. He has written several articles about loudspeaker design, testing, and other audio devices. Several patents have been awarded for some of his designs. Although retired now, he was a member of the Audio Engineering Society and the International Society for General Semantics for many years. His interests range from stereo sound to photography, new-age music, mystery clocks, and science fiction. He has a web page at www.roger-russell.com.*

REFERENCES

Patent number 3,715,501 Loudspeaker System

Awarded to Roger Russell, February 6, 1973

This patent describes the use of equalization to compensate for the natural low-frequency rolloff of a loudspeaker system.

Patent number 4,267,405 Stereo Speaker System for Creating Stereo Images

Awarded to Roger Russell, May 12, 1981

This patent describes closely-spaced drivers arranged in a long column.