DIY PC Satelites

Welcome! Today we are going to design and build a set of satellites as companions to the recently completed subwoofer system.

Once again, it may be helpful to discuss some design issues before we start. Most inexpensive speakers that come with computer systems are of low power and did not have the depth and frequency range I wanted. Obviously, a speaker cone must vibrate and move in order to generate a sound wave that eventually reaches our ears. Simply put, the range of frequency is determined by the physical characteristics of the speaker. Woofers generate base tones and must have long throws and large cone diameters. They need stiff cones to handle the energetic movement and large voice coils to withstand the heat and large power requirements. Tweeters must vibrate and move very short distances to have high frequency output. Therefore, they must have very light vibrating elements that are capable of very quick response and physical movement. Midrange speakers combine strengths and weaknesses of both to provide output compromises.

As you can see, there is no one speaker that is capable of having all of these characteristics. The way around these physical limitations is to use multiple speakers to handle the output requirements needed, reproducing certain bands of frequencies for each speaker type. The overall target range for most speaker systems to cover is 20-20K Hz. However, the outer ends of this range are seldom used in what most people listen to, and the "most common" range - that is, the frequencies of the most common sounds - tend to reside in the 60-3000 Hz range. For our purposes, we are going to use the subwoofer to handle frequencies in the 30-150 Hz range, a midrange driver for the 150-2000 Hz range, and tweeters for the 2K-20K Hz range. There will be some overlap between the speakers, but this is fine if not excessive.

There is an interesting note to consider - depending on the listening environment (carpet, furniture, etc), in general, sound frequencies below 150-180 HZ are omni-directional. As the frequency rises, the directional effect becomes more and more significant (that’s why your car may have tweeters angled toward the listener’s heads). That’s also one reason that we can get by with only one subwoofer and why multiple satellites are needed. Also, regarding design characteristics - since the midrange speaker and tweeter do not have to physically move large amounts of air, they are made much smaller with lighter magnets and design weight, and require far less power input to get a strong sound. These factors give greater degrees of flexibility since the internal box dimensions are far less critical. Oh, and finally, I had a $50 budget to complete the two satellites.

First, Steve over at Apex Jr. had just received a new batch of shielded soft dome tweeters at very fair prices. Two of these would do rather nicely to meet our high-end requirements (scroll to the second item down on his speakers page).

Next, I had to find some midrange speakers at a reasonable cost. After making a few calls and digging in some catalogs, I just couldn’t find anything that met the combination price/performance point I wanted - Steve at Apex Jr. did not have an appropriate midrange driver in stock at the time. Soooooo... I headed over to my local auto salvage yard and started wheeling and dealing. You can often find some high quality OEM speakers in autos; I was able to find a set of four 7" round full range speakers with dual cones from a 1997 Jeep Grand Cherokee for $10 (I had to remove them from the vehicle myself). Alternately, you can buy full range 3-1/2", 4", 5-1/4", or 6-1/2" replacement speakers at Wal-Mart, Radio Shack, or a sound shop - but you’ll pay a little more. If you scavenge for speakers like I did, make sure you look out for water damage, corrosion on the speaker frames, and make sure you snip the wiring harness connectors to go with the speakers. For this project, I wanted full range speakers and not two-way or three-way speakers (with the tweeters already built in); any size such as those listed above or even 5 x 7" should be just fine. However, a little larger speaker is more likely to be able to handle higher wattage.

Now that I knew the sizes of the speakers to go in the satellite boxes, I could begin to measure and design the actual box itself. A simple sealed box seemed best for many of the same reasons that a sealed box was used for the subwoofer project. As before, I wanted to use material that could be obtained easily and inexpensively - I was able to use some of the same precut 12" shelving available at Lowe's, Home Depot, etc.

If you use ¾" thick material like I did, you will need four each of the following sizes: 9" x 12", 6-1/4" x 12", and 6-1/4" x 7-1/2". Even if you use a different sized driver set, you might want to keep these same dimensions to make it easier. If you want to use ½" material, change the dimensions up as required.

Next, you will need to measure the actual speakers you use to determine the size of holes you will need to cut out for the box faces. Note the notch on the side of the tweeter hole; this is due to the placement of the wiring connectors on the tweeter itself. Use a jigsaw or Dremel tool to cut these out. It might take a while with a Dremel, though since the material is ¾" thick and the medium density fiberboard (MDF) is pretty hard.

Next, you will need to assemble the six sides for each satellite box. Use plenty of yellow woodworking glue or even white Elmer’s glue. Instead of using a silicone sealer this time, I just made sure to use a larger than normal bead of glue on the inside corners of each box. I went behind and smoothed this out some as I went along. Hot melt glue or caulk could also be used to seal the interior corners.

I used the same assembly technique on these boxes as I did on the subwoofer - I assembled the boxes first using some 4d finish nails and then installed a couple of 1-5/8" drywall screws on each edge for strength. Make sure that you pre-drill any screw holes (edge, at the speakers, etc.) to avoid splitting the material.

Next, I had to drill some holes on the back to install some terminal cups. These are the spring loaded terminals that the speaker wires plug into. It’s easier and cleaner to do this now instead of after you paint the

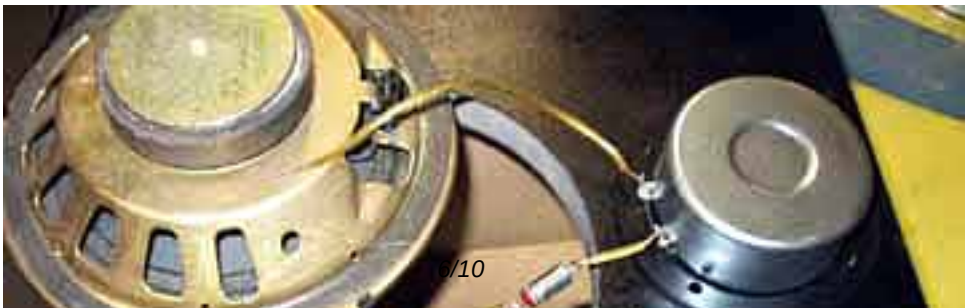
box. The terminal cups can be found at Radio Shack or sound shop, I think I paid about a buck each for mine. Pre-fit the terminal cup but do not install at this time.

After you've assembled the boxes and done all the drilling, sand the boxes to your satisfaction. Make sure you "ease" the sharp corners and edges with some lightweight sandpaper, but don't take the corners down too much. Fill any mistakes, holes, or scratches with a bit of wood filler and sand before painting.

Once you've sanded the boxes, it's time to paint them. I used a light coat of primer and a couple of coats of gloss black. However, I wish I had used some satin or flat black as my final coat instead. The MDF material I used for these tends to soak up more paint along the cut edges, and this shows up as a lighter "grayish" stripe along the edges. You can see this effect distinctly in the final assembly picture. Once again, using a different gloss level would have helped this, and I just didn't think about it until it was too late.

At this point as well, you will need to make two grille frames and paint them with a single coat of black as well. The procedure for making the frames can be found in the subwoofer article.

Next, we need to go back to the design board and do a little bit of electrical engineering. A piece of equipment called a crossover is used to separate the signal frequencies that need to go to individual speakers. The subwoofer amp already has a built-in filter for low frequencies, so we will need to break up the signal between the midrange driver and the tweeter. However, I wanted to keep this as simple as possible and knew that the 7" midranges had whizzer cones installed - that's the small additional cone in the middle of the speaker that allows full range speakers to extend the higher frequency response. I wasn't really concerned about the sound output of the midranges - high frequencies couldn't hurt them at all. The tweeters had a low end limit of 2000 HZ, though, and I needed to provide some protection to them so that they would never see the low frequencies that could damage them. You can find some background information about crossovers and their theory here. I installed a 16.7 microfarad capacitor inline with the input signal for the tweeters only (any value between 10 to 16 microfarad or so would work fine).



To begin to perform the final assembly, connect your speaker wires to the terminal cup first and then install; leave yourself about 15-18" of lead length. Then install the tweeter and midrange driver in parallel, making sure to install the capacitor as discussed above. Use electrical tape or heatshrink to cover any exposed wires. Next, pack the speaker with fiberfill until it is reasonably firm. One 20 oz. bag of fiberfill was just right to fill the subwoofer and two satellites. The fiberfill helps make the speakers sound a little smoother and less "**boomy**".

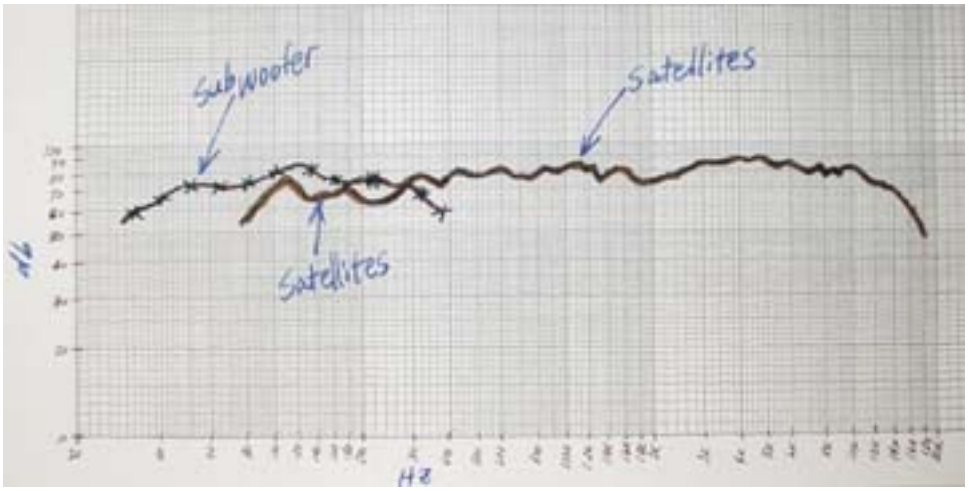
Install the tweeter and midrange driver using #6 x ¾" screws, and pre-drill your holes. At this time, complete your grille construction as described in the previous article and install. As you make the final wiring connections, keep in mind the polarities. Before you install the grilles, you might want to hook the speakers up for a final listening test.

Once you have the grille made, install it using four to six 4d finish nails on each frame and dab the nail heads with a black magic marker. These will not be visible more than a couple of feet away, and makes the grille "semi-permanent" - I have two inquisitive young boys! These can easily be pried off if necessary. If you would like to remove the grilles on a more frequent basis, you can buy grille "sockets" at Radio Shack or similar. If you use these, make sure you build a small triangular block in the corner of the grille frames to accommodate them. You might also want to place some feet on the boxes... a cheap way to do this is to use some adhesive felt. I personally used four rubber pads on each box that are intended for use as kitchen cabinet door bumpers.

Here’s the final assembly picture:

Once again, the gray stripes caused by the cut edges soaking up the paint is probably more pronounced in the pictures than in real life. They are noticeable but it doesn’t really detract from the look of the boxes in place. Here’s a picture of one of the satellites in place; they wired directly into the subwoofer amp powered output terminals.

I promised that I would provide a response plot for the speaker system. I got out my trusty Realistic sound level meter, mini-tripod, and used the NCH tone program to generate the discrete frequency signals. I combined the plots for both the subwoofer and satellites on the same graph.



The satellites began to respond at about 120 Hz due to the crossover in the subwoofer amp. There was a slight dip between 200-240 Hz, but was strong across the remaining spectrum. The frequency began to roll off at about 15K Hz. This was a bit lower than I expected. However, as discussed above, high frequencies are VERY directional and sounds in this range are easily absorbed. I have carpet, curtains, many bookcases, etc. in my home office, and I attribute any dips in the response curve to these factors. As with the subwoofer, I am very pleased with the sound of these satellite speakers. To my ear, they are very smooth and have handled the 50 watts or so that I've thrown at them. Coupled with the 100 watt subwoofer amp, I believe my sound system is now loud enough to annoy my neighborhood (and I have a ¾ acre home lot!).

Here's a list of what you will need to complete this project:

Tools: Saw (or cut at the store), jigsaw or Dremel for holes, drill and drill bits, screwdriver, hammer, staplegun.

Materials: Apex Junior shielded dome tweeters ($20), midrange drivers (mine cost $5 for two at the auto salvage yard), 12" wide x ¾" x 48" shelving (one at $4, I used some scraps left over from the subwoofer project), paint ($3), two terminal cups (2 at $1 = $2). I used hardware nails and screws, fiberfill, black cloth for grille, and wire that were left over from the subwoofer project. I salvaged two capacitors from some old power supplies, they should cost about a buck each at Radio Shack.

TOTAL: $41, under my goal of $50 - even less if you already have some wood scraps or some of the other materials laying around. I had tentatively allotted $150 for the subwoofer and $50 for the satellites, so the overall project fit under the total budget allotment by about $15.

Once again, after the materials were gathered and the design work done, I was able to complete the entire project in about four hours. These were no more difficult to make than the subwoofer although there was a bit more design work to perform because of the multiple speakers and tweeter capacitor to hook up. They sound great in conjunction with the subwoofer and I am well pleased with the way they sound. I confess that there is a great deal of satisfaction in building them instead of paying for something that would sound inferior.

Finally, I would like to thank Steve at Apex Jr. once again for his help and suggestions. Go check his site out for components and other supplies as well. And, be on the lookout for my final satellite speaker article, where I build a pair of amplified satellite speakers so that you can use the subwoofer amp without having to use a receiver or home stereo. Good luck on your next project!