MULTISIM DEMO 9.3: SPEAKER CROSSOVER CIRCUIT (PLOTTING MULTIPLE FILTERS AT ONCE)

A classic example of an everyday use of filters is in the crossover circuits of speaker systems. In many nice speaker setups, there are three types of speakers, woofers used for low frequencies, mid-range speakers used for, you guessed it, mid-range frequencies, and tweeters for the higher frequencies.

Why the different speakers? Why not just one speaker? Well it turns out that the different constructions of the speakers give different physical frequency responses. Woofers vibrate at low frequencies very well, and can respond to some high frequencies too, but they will have distortion when they do so. One doesn't want all three speakers putting out the same tone at equal volumes when one of the speakers is heavily distorting. So as a result, we use crossover circuits. These essentially assign the appropriate frequencies to the appropriate speaker, with high frequencies going to the tweeter, low frequencies going to the woofer, and the mid-range frequencies going to the mid-range speaker. A rough cartoon of this concept is shown below in Fig. 9.3.1.

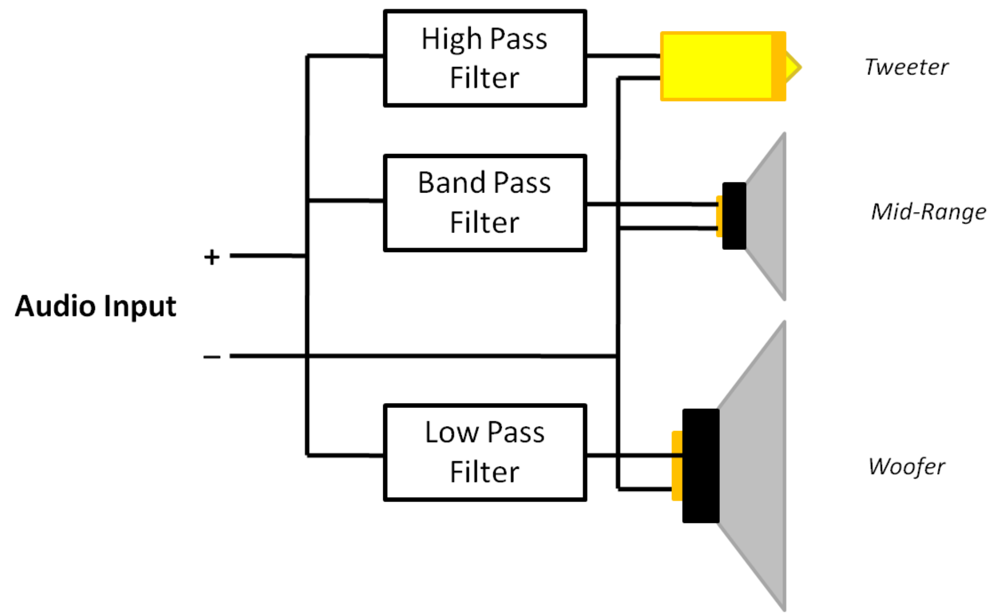

Figure 9.3.1 General block diagram of a speaker crossover assembly.

A simple crossover circuit is shown in Fig. 9.3.2. The high pass filter is composed of a series capacitor, the band-pass filter is an series inductor and capacitor pair, and the low pass filter is a series inductor. The components have been selected to give a pretty good crossover response.

To build this in Multisim, we'll use 8 Ω resistors to represent the speakers. You can properly name them if you want, I did. You may encounter a problem when you tried to label your resistor "Mid-range", however. The "-" is a delimiter, which Multisim does not permit in naming its components or nodes (or really anything for that matter), so you'll have to name the mid-range resistor "Midrange." Of course you may have not even tried to add the dash. In that case you are lucky.

The input source V1 representing the input audio signal is an AC_VOLTAGE component. By default, the magnitude of its AC Analysis Voltage should be 1 V, but double check just to make sure. The frequency of the component won't matter since we'll be doing a AC Analysis.

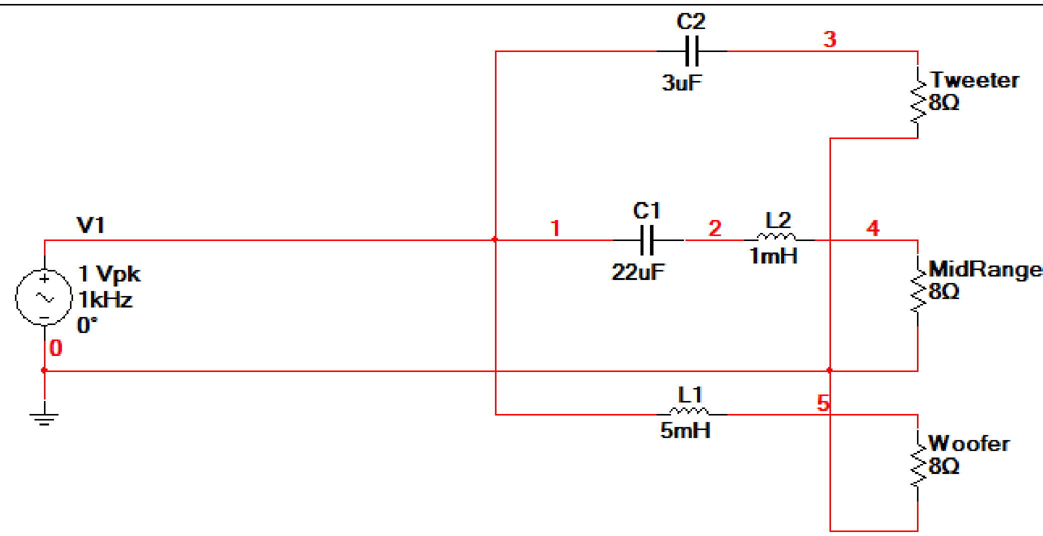

Figure 9.3.3 Multisim schematic of the speaker crossover and speaker assembly.

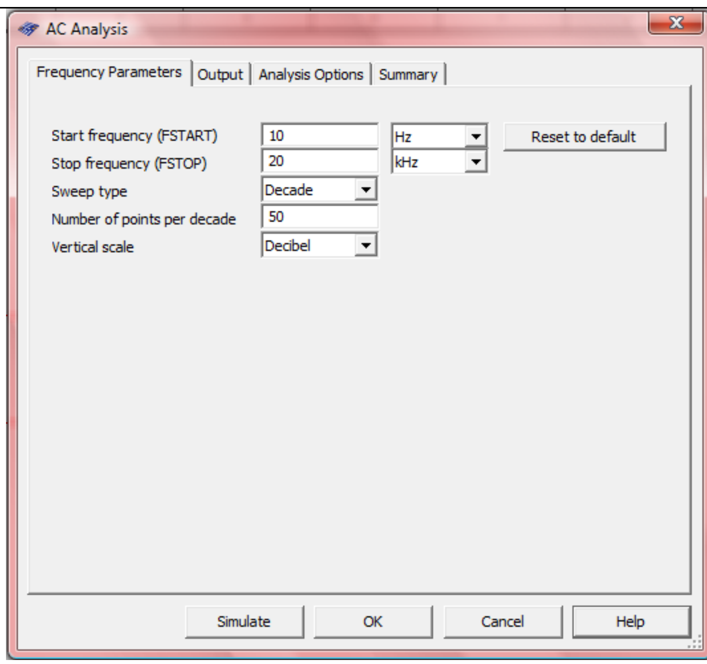

Figure 9.3.4 Frequency Parameters for the AC Analysis. We'll sweep from 10 Hz to 20 kHz which is a good general approximation for audio range. Make sure that you pick enough points per decade in order to get good resolution.

Open up the AC Analysis simulation window and under the Frequency Parameters tab, select the frequency range to be about the range of sounds that would be fed into an audio system (10 Hz to 20 kHz) as shown in Fig. 9.3.4. Of course, one may argue on these frequency limits, but they are good ballpark values.

The value which we want to measure will be the output voltages at each speaker In the Multisim schematic in Figure 9.3.3 this corresponds to V(3), V(4), and V(5). If you'd like to do the ratio of output over input to get transfer function plots, that's fine as well… in that case you'd enter three equations: (V3)/V(1), V(4)/V(1), and V(5)/V(1). Our input voltage has a unity magnitude, however, so this will make no difference for us. Do what you prefer. When you simulate you should generate a plot similar to that shown in Fig. 9.3.5. (The plots shown have been color-adjusted for clarity.)

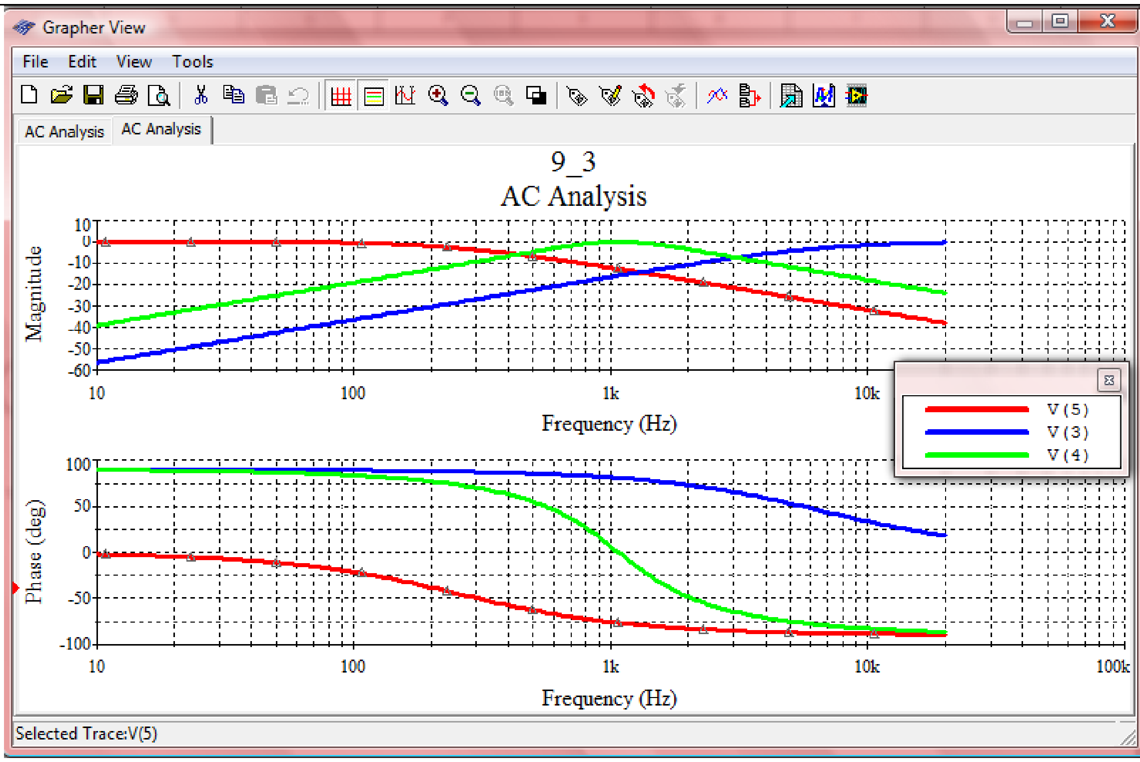

Figure 9.3.5 Bode Plot Output of the frequency response of the crossover network.

When we investigate this plot we see that the magnitude of the frequency response for V(5) which corresponds to the woofer is almost 0 dB up until about 100 Hz, and from there it starts to fall. At around 300 Hz, the mid-range speaker V(4) suddenly picks up. This peaks at around 1 kHz, before falling back down. After this the dominant speaker is the tweeter, V(3). This is good…the three speakers are getting the frequencies they should to ensure proper operation.

Now in all honesty, this is not that good of a crossover. There are significant "dead frequencies", specifically at about 400 Hz and at about 3 kHz, where none of the three speakers have a very high output. In reality, crossovers are generally composed of filters of higher orders (more components) which results in steeper cutoffs and just better overall performance. As a result, they do not really result in dead frequency spots as ours does.

If you want to, change the values of the filters or make them higher order based on what you've learned from the textbook so far you should go ahead. See if you can get really good response across the entire audio spectrum. If you're an audiophile, you can save yourself 75 dollars by designing, modeling and then building a crossover for your speaker system from scratch rather than buying it.