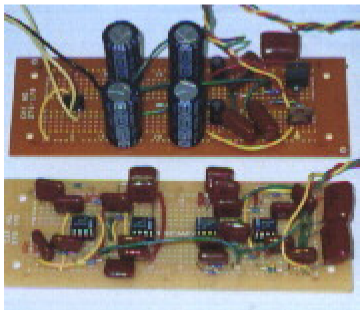
24db/octave Linkwitz-Riley

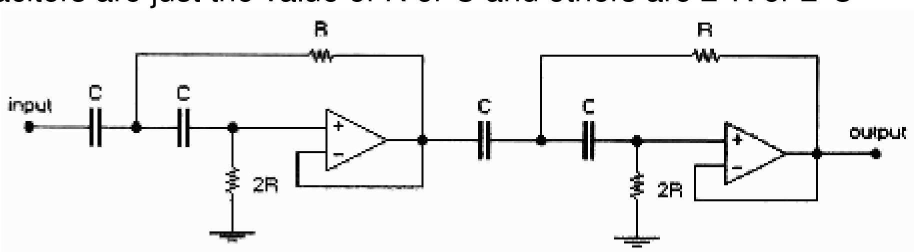


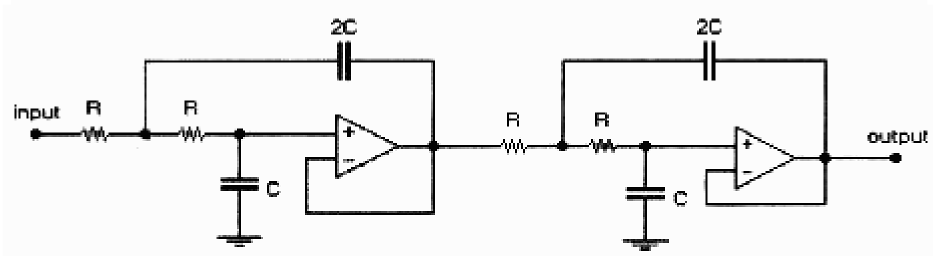
What the heck is a Linkwitz-Riley?

The type of filter (Butterworth, Linkwitz-Riley ect.) indicates the shape and roll off of the filter. The more common Butterworth has it's cut off frequency at the -3db point. This point is .7071 the amplitude of the pass band. The Linkwitz-Riley has its cut off frequency at the -6db point. The bode plots at the bottom of the page show this. This point is .5 of the amplitude of the pass band. If you put two Butterworths in series you get .7071*.7071=.5 You can see from my schematic below that my filter is two 12db/octave Butterworths in series. To calculate the cut off frequency (the -6db point) of the Linkwitz-Riley use the formula 1/(2*pi*R*C*1.414). Where R is in Ohms, C is in Farads, and pi=3.14 The 1.414 came from the square root of 2. The L-R filter has several advantages over a Butterworth. First, when a low pass and high pass L-R filter are used together for bi-amping the combined output sums flat. A Butterworth sums to +3db at the crossover frequency. Second, a 4th order L-R high pass filter is in phase with the low pass filter at the cut off frequency.
24db/octave L-R crossovers are the choice of high end manufacturers. A Lexicon dolby surround decoder uses that filter as well as several subwoofers made by PSB.

The circuit

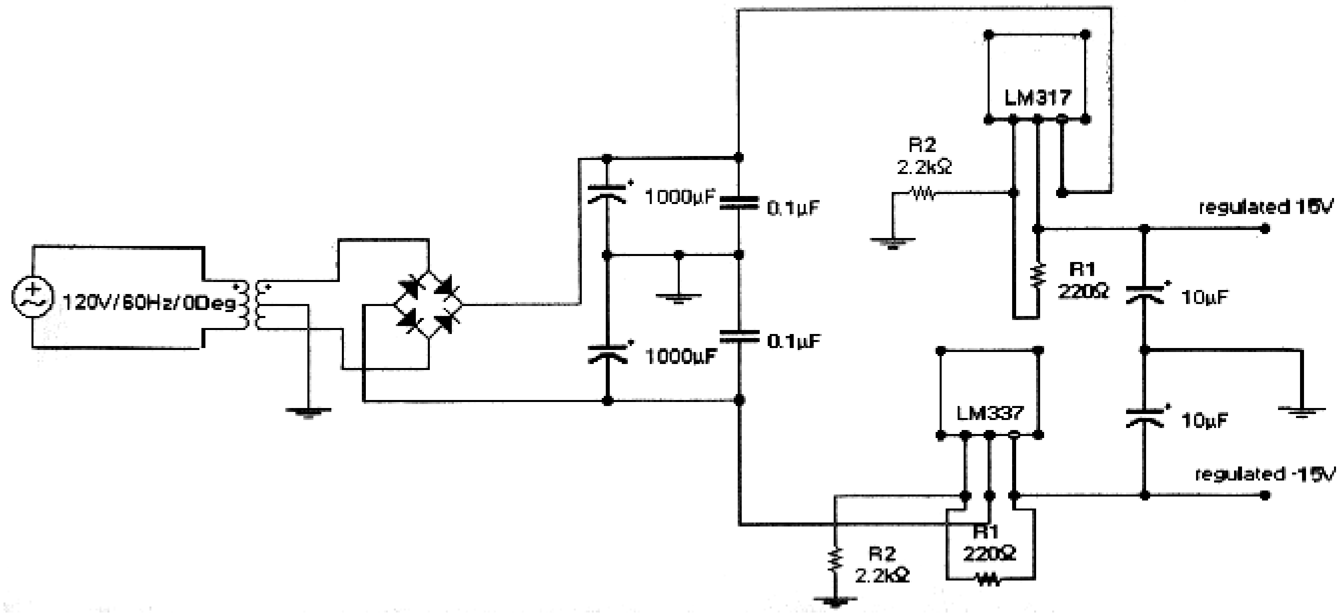
The four op-amps down the center (lower board, horizontal) are the TL082CP bi-fet type. They are inexpensive op-amps. Some better op-amps from Analog devices or Burr-Brown could be used. I hope to try some out eventually. All the capacitors in the signal path are 2% polypropylene from Digi-Key. I used 1% metal film resistors from Mouser Electronics. The sockets are the gold plated machine hole type from Mouser. They are the best sockets I have tried. The schematic can be found below. The circuit boards are the bread board look-alikes available at Radio Shack ect. I don't make my own printed circuit boards. I find that it is just as easy to connect the rows of the breadboard style together as needed. The first schematic is the high pass and the 2nd is the low pass. I used R=28K Ohms and C=.047uF to get my cut off frequency of 85 HZ. I chose these exact values because Mouser had 28K and 56K (56K being 2*R, see the schematic) ohm resistors. I used two .047uf capacitors in parallel to get .094uf (2*C). Again, the formula 1/(2*pi*R*C*1.414) gives the cut off frequency. Where R is in Ohms, C is in Farads, and pi=3.14 Notice on the schematics that some resistors and Capacitors are just the value of R or C and others are 2*R or 2*C





The power supply

The large toroid transformer is a bit overkill considering the four op-amps draw next to nothing but it was laying around and only cost me $12 (at Mendelson's). The voltage output was too high so I pulled off the plastic wrap and unwound at least ten feet on the secondary wires. As a engineering student you have to learn to be thrifty. The power supply (upper board, top picture) is made up of a full wave bridge rectifier, good size electrolytic capacitors, and .1uf polypropylene capacitors before and after the regulator I.C.'s. The regulators are the standard LM317,337 (in the T0-220 cases). There are also 10uf electrolytic capacitors after the regulators. Below is the power supply schematic for the x-over. You can use bigger capacitors before and after the filter but be sure to use the .1uF bypass capacitors. They keep high frequency junk from floating around. Use 2 more of the bypass capacitors on the actual filter board as close to the op-amps as possible. I used the 317/337 3 terminal regulators for the ease of use and they are better the fixed 3 terminal regulators. The input voltage to the regulators should be about 2V higher than the desired output voltage. A 24 volt center tapped transformer will give about the desired input voltage (12*1.414=17V). The schematic shows the 2.2K Ohm and 220 Ohm resistors used to determine the output voltage of the regulators. The formula for the output voltage is Vout=1.25*(1+R2/R1). The values I used give an output of about 14 Volts. You can change the value of R2 to get the value you want. R1 should stay at 220 Ohms. Be sure to observe the correct polarity on the electrolytic capacitors. If you are only driving the op-amps with the power supply you shouldn't need any heatsinks on the regulators.



The lower right boxes in the bode diagrams show the db level versus the frequency. You can see that at -6db the frequency is the calculated 85HZ. At -24db the frequency is one octave down (85 Hz/2=approx. 43HZ).