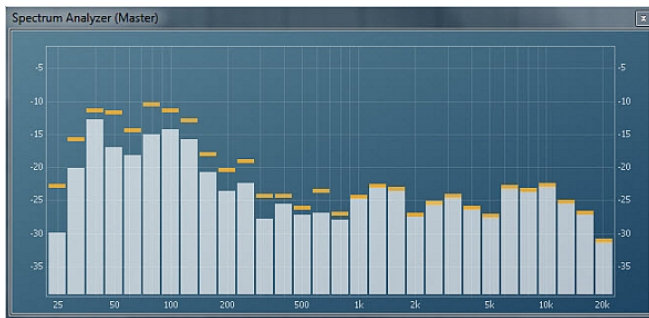


## LED Color Organ

### Introduction

It is always amusing to watch music visualizers using different songs and comparing them to other music visualizers. However, this requires a lot of programming knowledge and that is not the easiest thing to come by in a short time. Another option is to take the AC current output from audio devices and use analog circuitry to analyze music. This is sometimes referred to as a Color Organ, which used to be the main form of music visualization before the digital realm was devised. Some Color Organs are incredibly sophisticated arrays of LEDs linked to different musical filters, and some are quite simplistic LED Bar graph displays. Neither of these extremes seemed to “fit the bill” for a 400-level physics class project, since one seemed like it would take longer than a semester to build and the other seemed to not require enough skill. As I delved into information on the subject it seemed like it would actually be a moderate task to build a 3-filter LED Bar Graph (shown at left below), but it still seemed like the end result wouldn't be that satisfying. To accommodate for this, I decided to build an Infinity Mirror (shown at right below) with the “Bar Graph” embedded inside as the light source.



Frequency Bar Graph Example



Infinity Mirror Example

### Outline of the Overall Design

A Programmable LED strip would be placed on the outline of a mirror facing inwards. Then a piece of tinted glass would be placed on top and secured into place with the tinted side facing the mirror behind it. This serves for a 2-way functionality that reflects the LEDs back and forth inside, creating a depth effect to the lights.

Three frequency filters would be applied to the input sound and create 3 different bands of energy to be output to an Arduino Uno device. This device would be used to set the input energy as a bar-graph display and output 3 different starting points in the LED strip. Each band would be assigned a different color to distinguish

visually one band from the next. The first band picks out the extreme lows and extreme highs of the frequency spectrum; this is where most Kick Drum and Snare Drum frequencies are. The second band picks out the vocals and main instrument or synthesizer frequencies. The third band picks out the leftovers, which would be the upper harmonics of instruments and synthesizers.

As for the display of the “Bar Graph”, I wanted something more visually appealing than just a 3-color bar graph wrapped in a circle. To look more interesting, I decided to offset each “Bar-Circle” by 120° so that each filter began and ended in a different spot in the mirror. This would also be very easily implemented with the Arduino Uno.

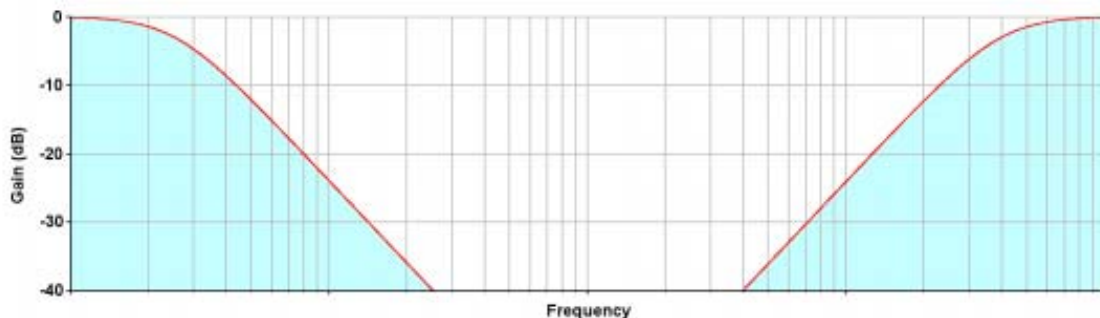
### Filter Specifics and Design

In order to analyze music in the frequency spectrum, analog frequency filter circuits needed to be built. The filters that I chose to implement are 2<sup>nd</sup>-order Butterworth filters with unity-gain (same level of output as input), and are composed of an Operational-Amplifier and several specifically valued capacitors and resistors. For the 3 types of filters that I used I chose a Band Reject Filter and two wide Band Pass Filters. The Band Reject filter takes in the sound and outputs unity gain only for values above the high threshold and below the low threshold. The Band Pass Filters do the opposite; they output unity gain only for values above the low threshold and below the high threshold.

Using this knowledge it is easy to see that both types of filters can consist of a low-pass filter to pass all the values below a given threshold, and a high-pass filter to pass all the frequency values above a different given threshold. When placed in series, the energy output of one filter is passed to the next and the two can combine into one overall filter. This approach works well for the Band Pass filters only since the energy above the low threshold is also part of the energy below the high threshold. If this approach was used for a band reject filter, then the low pass filter would pass only the higher frequencies to the next filter; since the energy of the lower portion is reduced by the first filter, the output of the system overall would be flat and close to nothing. So for a Band Reject filter, a third Op-Amp is used as a summation between the two filters in parallel. The values of the resistors and capacitors are decided by the following equations:

**\*pic of eqns\***

BRF



A Band Reject filter consists of 3 op-amps; one op-amp is for a regular low pass filter, one for the high pass filter, and one to sum the two together. The circuit diagram for the BRF is shown below. For the High-Pass filter (bottom outline) the threshold frequency (also called cutoff) was chosen to be 10,000 Hz, and the Low-Pass filter's cutoff was chosen as 150 Hz. With these frequencies, many of the common Snare and Kick drum frequencies are grabbed (Kick drums are all low frequency except for their attack, and snare drums are all low frequencies and essentially very high frequency noise). Shown below the resistor and capacitor values is the circuit schematic for the BRF.

High Pass Values:

Resistor 1: 75 k $\Omega$

Resistor 2: 37.4 k $\Omega$

Capacitors: 0.3 nF

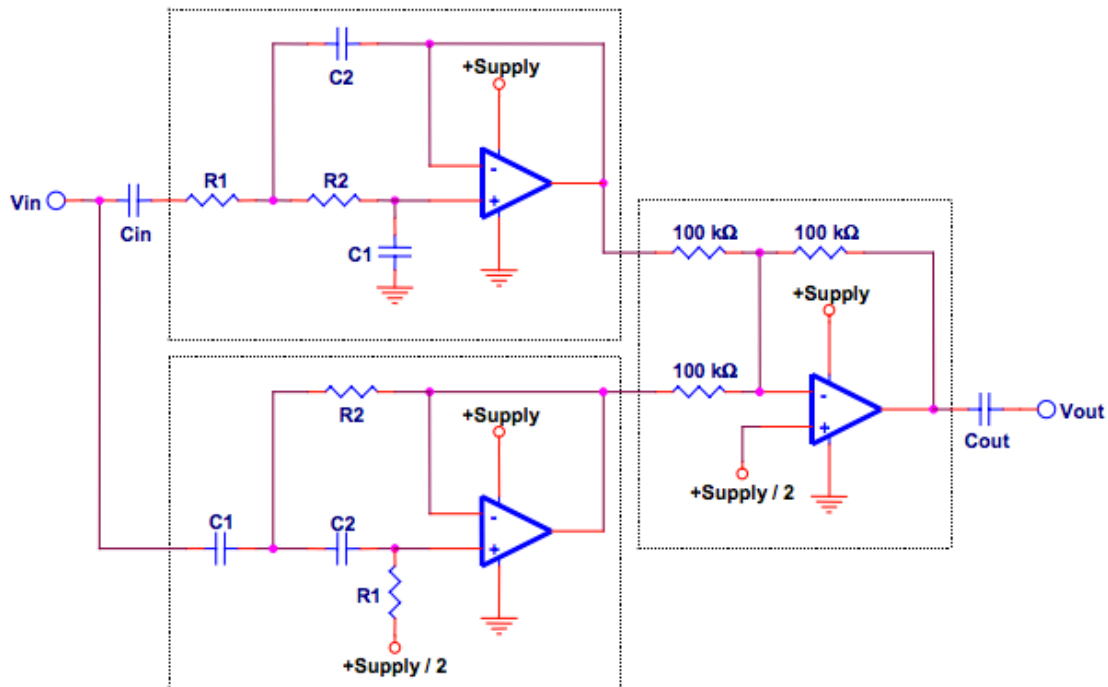
Low Pass Values:

Resistors: 75 k $\Omega$

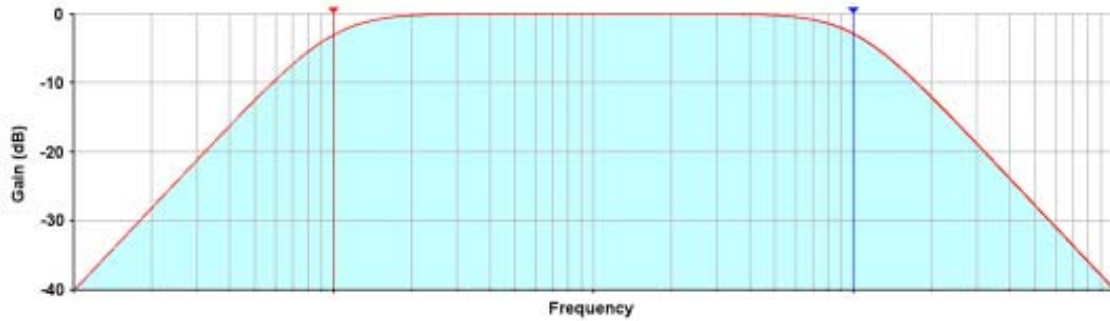
Capacitor 1: 10 nF

Capacitor 2: 20 nF

Cin == Cout: 3.3 uF



## BPF1



A Wide Band Pass filter consists of 2 op-amp circuits, a high-pass filter feeding into a low-pass filter. For the High Pass filter the cutoff frequency was chosen to be 200 Hz and the Low Pass filter's cutoff was chosen to be 3,000 Hz. This band of frequencies consists of many pitches in the vocal range, as well as many frequencies used as the fundamental for lead synthesizers and other instruments. Shown below the resistor and capacitor values is the circuit schematic for BPF1. High pass is located in the left box, cascading into low pass on the right.

### High Pass Values:

Resistor 1: 56.2 k $\Omega$

Resistor 2: 28 k $\Omega$

Capacitors: 20 nF

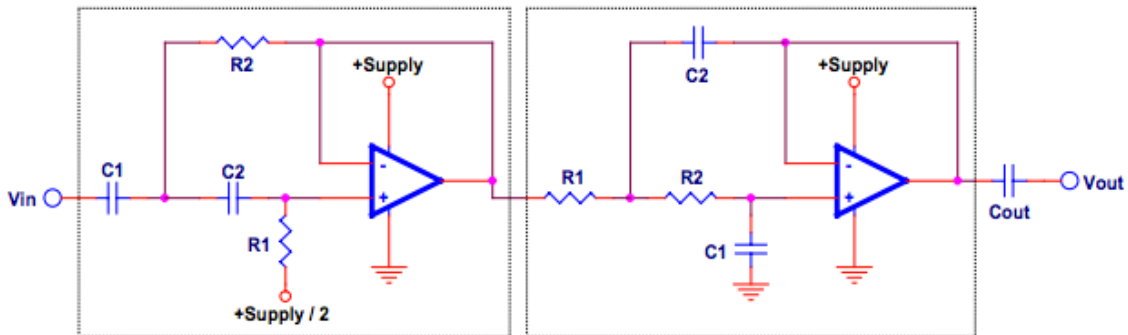
### Low Pass Values:

Resistors: k $\Omega$

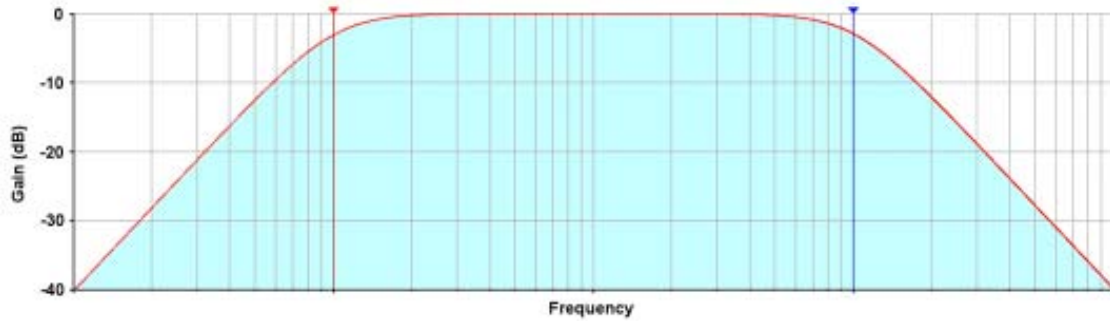
Capacitor 1: 1 nF

Capacitor 2: 2 nF

Cout: 3.3  $\mu$ F



## BPF2



For the High Pass filter the cutoff frequency was chosen to be 5,000 Hz and the Low Pass filter's cutoff was chosen to be 8,000 Hz. This band of frequencies consists of pitches most commonly found in the mid-upper harmonics of synthesizers, the vocal range and other instruments, especially electronic instruments. Shown below the resistor and capacitor values is the circuit schematic for BPF2. High pass is located in the left box, cascading into low pass on the right.

### High Pass Values:

Resistor 1: 15 k $\Omega$

Resistor 2: 7.5 k $\Omega$

Capacitor 1: 3 nF

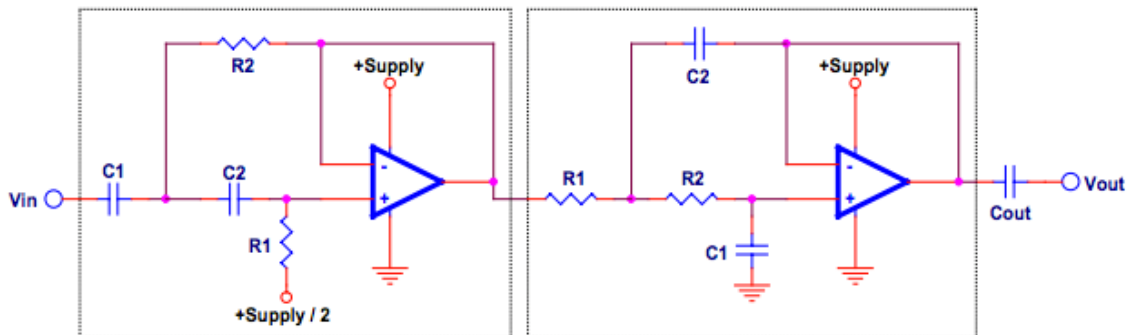
### Low Pass Values:

Resistors: 27.4 k $\Omega$

Capacitor 1: 1 nF

Capacitor 2: 0.5 nF

Cout: 3.3  $\mu$ F



## Mirror Specifics and Construction

An Infinity mirror is a visually interesting display and is much easier to create than it first appears. The mirror is composed of a framed mirror as a back, a slight amount of space containing a perimeter of LEDs and a pane of glass with highly reflective window tint on the side closest to the mirror. Currently I have constructed the back mirror portion of the Infinity mirror, which is composed of 4 1x1ft pieces of mirror on a 2x2ft slab of plywood. Originally I found 4 small pairs of

glass on par with the mirror pieces' size, however they ended up being too small for the frame overall, not to mention they would be difficult to apply film to all 4 pieces at once.

### LED Mini Analog Bar Graph

Shown above are 3 identical LED Driver circuits--one for each filter. This project ended up being quite a bit more expensive than I had originally anticipated, so to accommodate for this I took a few measures. Firstly, I decided to put off buying a programmable LED strip, and instead purchase the components to create 3 LED bar graphs. To run the 10-segment LED blocks, I ordered 3 LM3916 LED Driver chips from the Texas Instruments webpage. These chips take DC input values from 0V to 10V. This would mean that I would have to amplify the output of the filters by a scale of 10, build another circuit for each filter to create a DC amplitude following signal, or set up an arduino file to output DC current in 3 separate input/output lines. I decided that setting up an arduino file to change the AC input to DC output would not be difficult or add on further expenses. However, this portion of the project ended up seeming quite trivial however, since the end goal of the project will not have any bit of these 3 LED circuits. The reason that I created them in the first place is so that I could test that my filters worked.

In response to this circuit being a moderate waste of time, I took my filters back to the 406 lab and tested them on an Oscilloscope with a function generator as an input to sweep through the audio range of frequencies.

### Testing the Filters

In response to this circuit being a moderate waste of time, I took my filters back to the 406 lab and tested them on an Oscilloscope with a function generator as an input to sweep through the audio range of frequencies. This process was quick and painless compared to building the LED Driver circuits and told me that all of my filters were functional in the frequency aspect. There was a bit of trouble with the amplitude portion of the Band Reject filter, however the output seemed to be 3-6 dB larger than Unity Gain. This could potentially be remedied by scaling this filter up by 5 and the others by 10 if the LED Driver circuits were chosen to be the output. It could also be solved in Arduino code if the programmable LED tape is chosen to be the output.

### Conclusion

During the construction of the mirror, my goal was to have the entire entity be overall fairly inexpensive. At some hardware stores, they have scrap wood available for free, however I could not find any in the Champaign-Urbana area that had this option. This ended up making the project much more expensive than I had originally anticipated. I couldn't find any programmable LED strip for under \$20 either, so I ended up moving to a 3-filter bar graph display for this project. The schematic for one of which is shown below, and the same circuit is tripled for use by each filter. A picture of the finished circuits is shown below that. \*pic of single bar graph schematic\* \*picture of LED breadboard\*

All of my filters ended up working correctly, however the output of the summation circuit of the Band Reject Filter needed to be halved to achieve Unity Gain. I'm not sure of the cause of this, however the fix is incredibly easy--2 equal valued resistors from output to node to ground. The node in between has a voltage of half of the output value.

Another problem that I ran into, probably the most detrimental to the project as a whole, during the assembly of my project was that the input of the LM3916 chips that I got as free samples did not function the same way that I had originally anticipated; it takes DC input as opposed to AC input. Its output LEDs all had threshold voltages of 1V increments from 1-10 respectively. So to fix this problem in the future, I found code to turn the input voltage to be maximum-amplitude-following and will amplify the circuit outputs to 10v each.

One final problem that I had was during the actual construction of the mirror. I found 4 equal sized mirror pieces for a quarter each, and glass panes about the same size for about a dollar each. I put them in my car, and forgot about them thinking that the glass panes were slightly larger than the mirror pieces. This would translate into a quite easy construction of layering the two together to create an infinity mirror. All that I would have had to do was wedge the glass panes in between a couple pieces of the wood I had bought for trim and that would be that. However it turned out that the mirror pieces were larger and this would not work the same way. At this point though, I had already run out of money that I allotted for this project and it wasn't a huge issue. To remedy this problem in the future I plan on finding one solid piece of glass to cover the entire thing. This way, applying the window tint film will also be much easier.

Overall I am impressed with how well the filters worked, in spite of not being able to display them easily in any particular way. There are many further steps that can be taken in this project and I am only excited to try them out.