Speaker Frequency LED Display Final Report

E84 Sensor System Final Project

Alec Candidato and Liam Chalk

Team Members and Individual Responsibilities

Liam Chalk

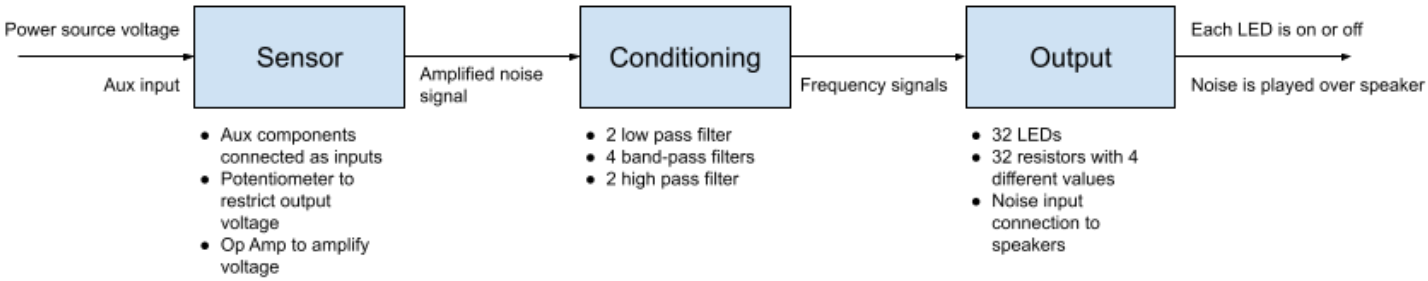
- Source materials from Analog Lab
- Get feedback from Professor Contreras at office hours
- Draw circuit diagrams
- Building and testing filters
- Building and testing LED display

Alec Candidato

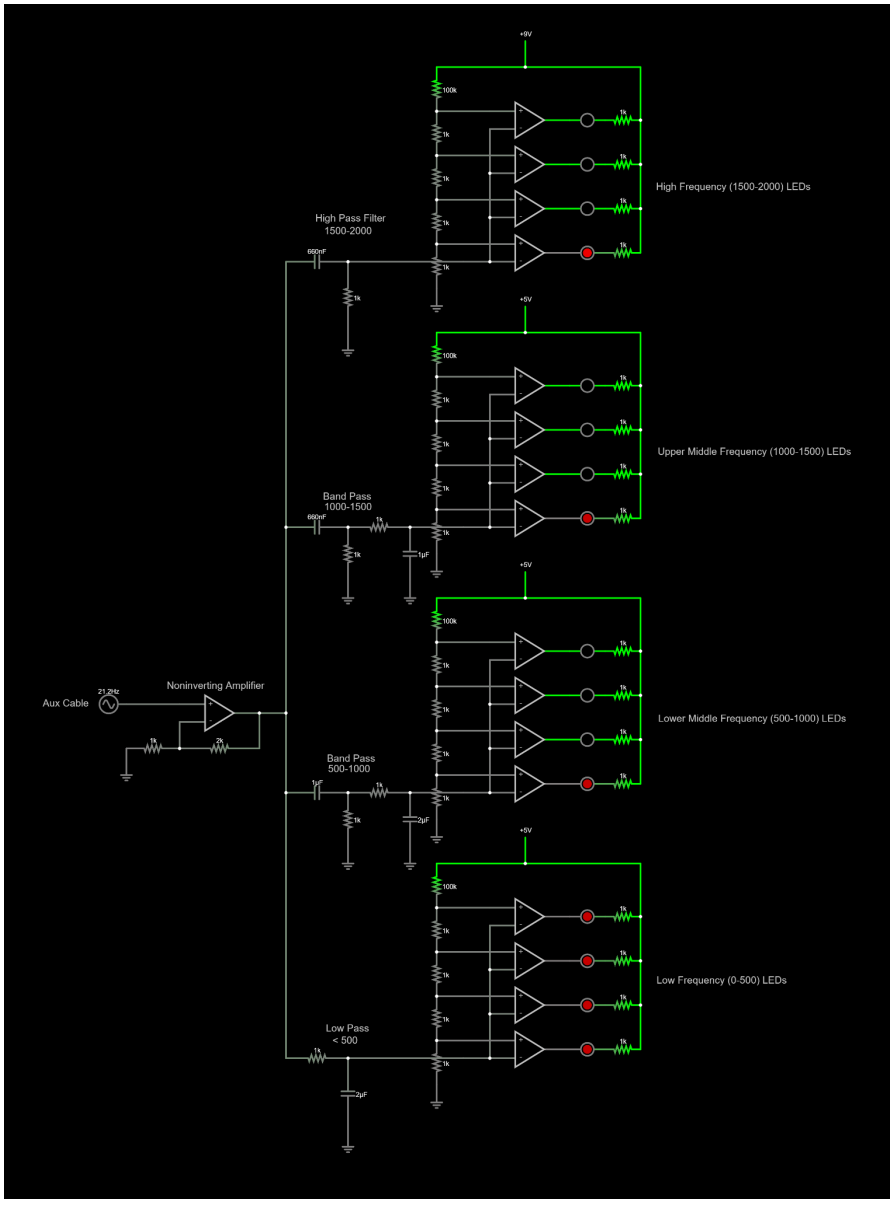
- Order components online
- Look into reimbursements
- Input stage testing
- Preliminary breadboarding for input signal and amplifier
- Building and testing sensor and conditioning breadboard

Circuit Diagrams and Analysis:

Block Diagram:



Full Circuit Diagram First Iteration:



Components:

Input Stage and Noninverting Amplifier

- 3.5mm Auxiliary Cable
- MCP601 Op Amp
- 1kOhm Resistor
- 2kOhm Resistor

High Pass Filter

- 660 nF Capacitor
- 1kOhm Resistor

Upper Middle Band Pass Filter

- 660 nF Capacitor
- 2 x 1kOhm Resistor
- 1 uF Capacitor

Lower Middle Band Pass Filter

- 1 uF Capacitor
- 2 x 1kOhm Resistor
- 2 uF Capacitor

Low Pass Filter

- 1kOhm Resistor
- 2 uF Capacitor

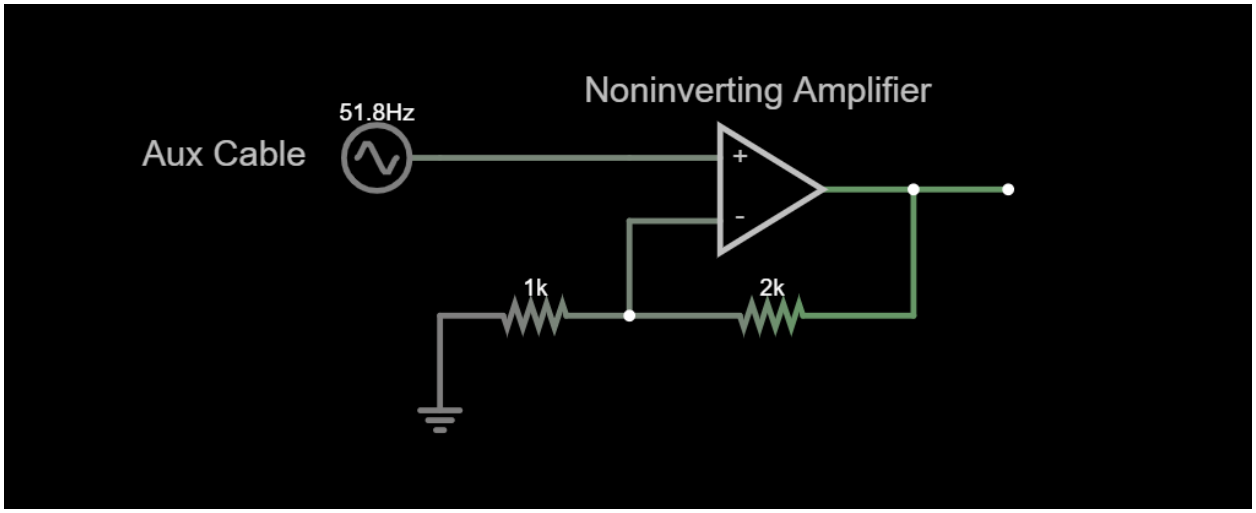
4 x LED Displays

- 100kOhm Resistor
- 8 x 1kOhm Resistor
- 4 x MCP601 Op Amp
- 4 x (Red, Green, Blue, Yellow) LED

External Signals and Power

- Auxiliary cable audio signal of different frequencies
- 5V Power to power Op Amp rails

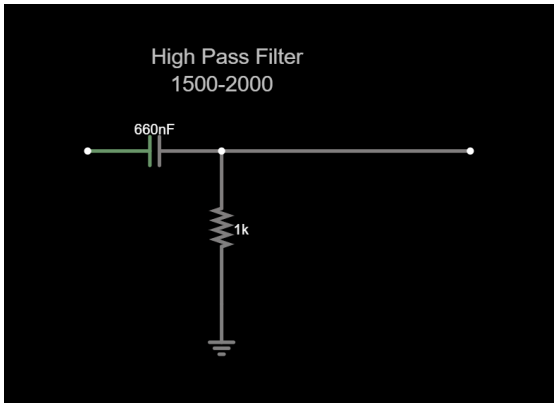
Input Stage

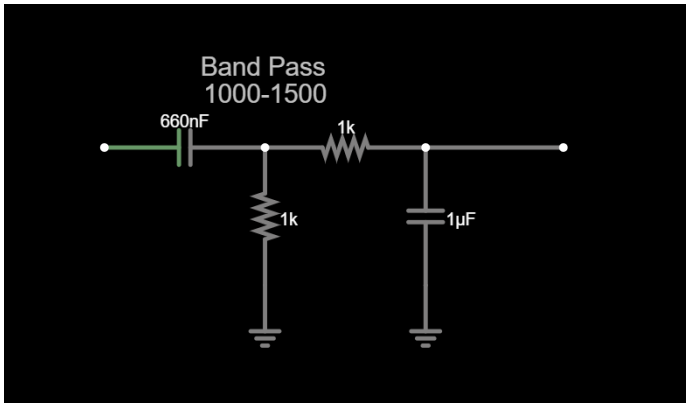


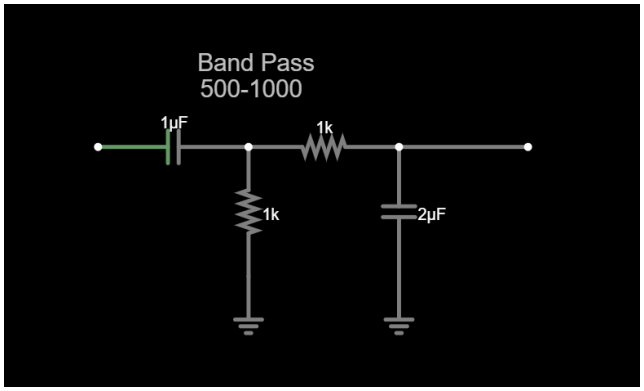
Input/Output Voltage Ranges:

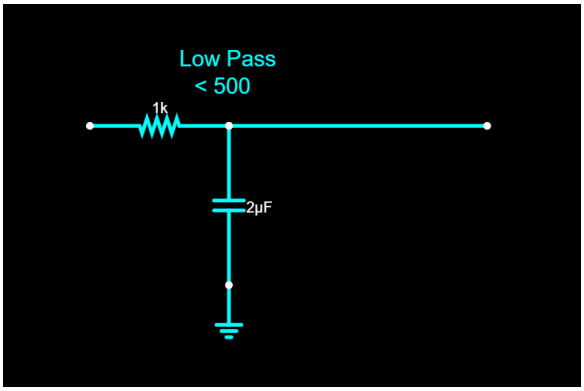
- Aux Input: Drives 1 milliwatt to a 600 ohm load
    - For an AC sine wave, this means a voltage of 0.77 volts RMS (2.2 volts peak-to-peak) and a current of 1.3 milliamperes RMS (3.6 milliamperes peak-to-peak)
- Amplified noise signal: Amplify the 0.77 V RMS signal to a range of 0-5 V.
- Frequency signals: 1.8-3.3V to power LEDs
- Speaker power: 5V
- The input impedance is 1KOhm and the output impedance is 8 - 3.2 ohm

Filters:









The 4 different filters measure the different frequencies that make up the signal and produce a voltage corresponding to the strength of each frequency in the signal.

Low Pass Filter (0-500) Equations:
$G(jw) = 1/ (jwRC+1)$
$|G(jw)| = 1/ \text{sqrt}((wRC)^2+1)$

$w_c = 1/RC$
$C_w = 1/Rw$
For R = 1k Ohm
$C_{500} = 1 / (1000*500)$
$C_{500} = 2$ uF

Lower Middle Band Pass Filter (500-1000) Equations:
$w_l = 1/R_2C_2$
$C_2 = 1/R_2w_l$
For R_2 = 1k Ohm
$C_2 = 1/1000*500$
$C_2 = 2$ uF

$w_h = 1/R_1C_1$

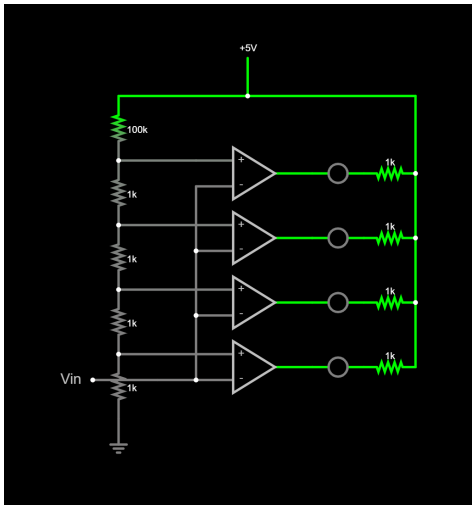
$C_1 = 1/R_1w_h$
For R_1 = 1k Ohm
$C_1 = 1/1000*1000$
C_1 = 1 uF

Upper Middle Band Pass Filter (1000-1500) Equations:
$w_h = 1/R_2C_2$
$C_2 = 1/R_2w_h$
For R_2 = 1k Ohm
$C_2 = 1/1000*1000$
C_2 = 1 uF

$w_h = 1/R_1C_1$
$C_1 = 1/R_1w_h$
For R_1 = 1k Ohm
$C_1 = 1/1000*1500$
C_1 = 0.66 uF

High Pass Filter (1500-2000) Equations:
$w_c = 1/RC$
$C = 1/Rw_c$
For R = 1k Ohm
$C = 1/1000*1500$
C = 0.66 uF

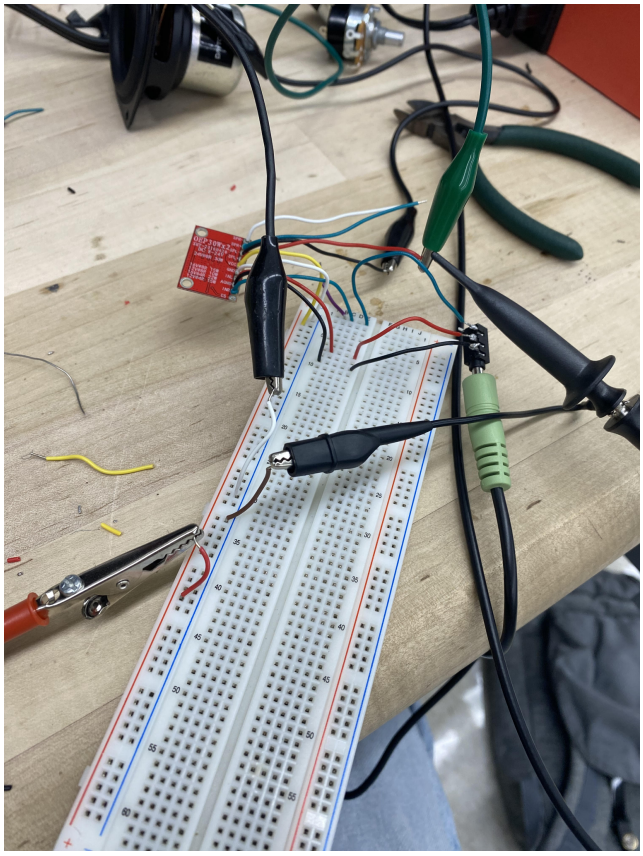
LED Voltmeter Circuit



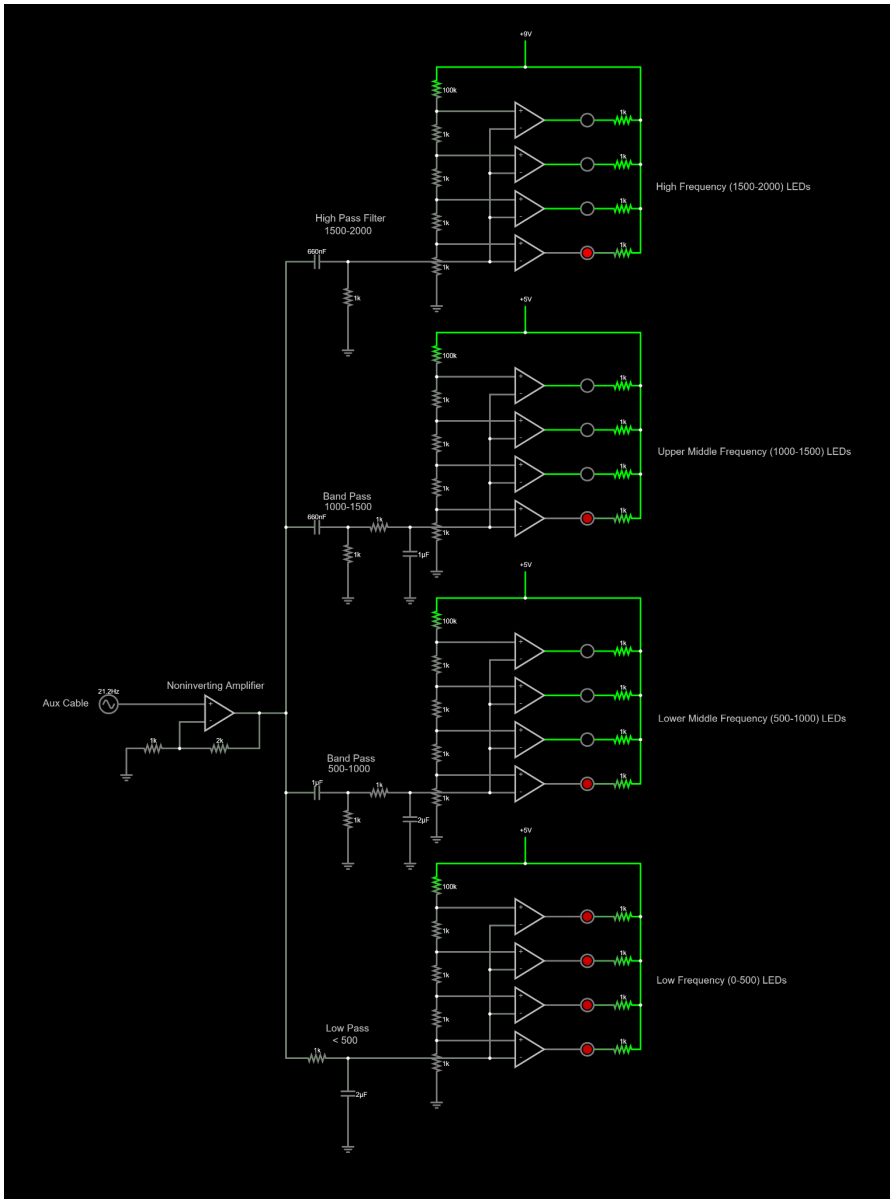
The voltmeter circuit for the LEDs is an augmented version of one found online used by Electronic Projects but with 5V power and MCP601 Op Amps.
The LEDs turn on from the lower most to the upper most depending on the amplitude of the input signal.

Initial Sensor or Input Stage Testing:

The sensor works and successfully amplifies the aux input. It powers the speakers and plays music well. The frequency range matches the expected 20Hz to 20000Hz range as mentioned in the op amp specs.



Simulation of First Iteration:

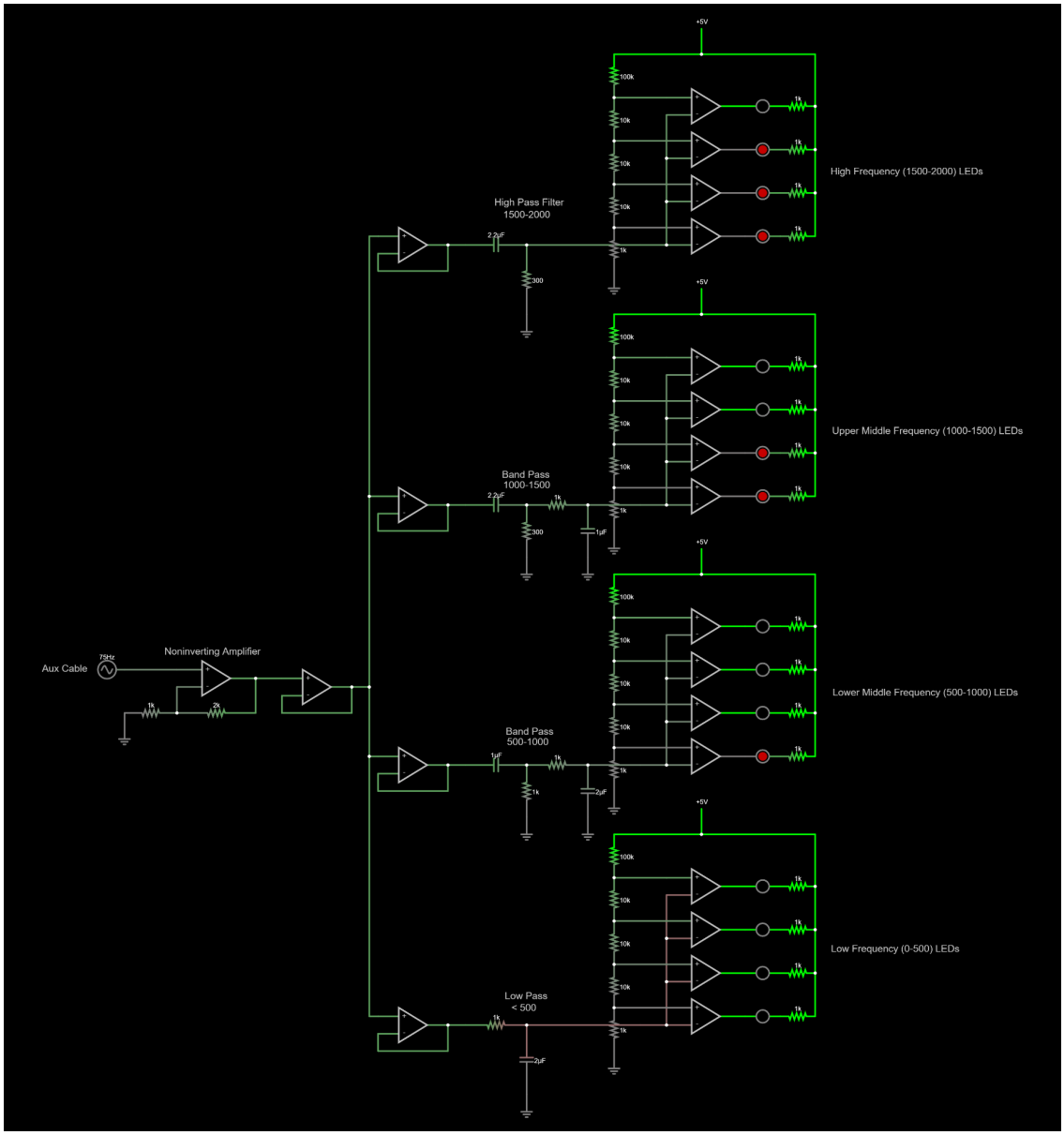


We simulated our circuit using Falstad and had some success in identifying different frequencies and getting the LEDs to light up appropriately.
The AC voltage source used as the input signal does not fully capture the complexity or noise of the auxiliary cable audio signal.
The non-inverting amplifier is currently increasing the maximum voltage input to 1V.
The frequency filters are simple and proven in class; however, they may be interacting with each other and the amplifier, loading impedance of one stage onto other stages and changing the behavior. Also, they may have to be adjusted to capture a different frequency range and to avoid overlap between the ranges.
The LED voltmeter circuit is turning on the LEDs in the correct order but may have to be adjusted based on the amplitude of the input signal.

Completed Circuit:

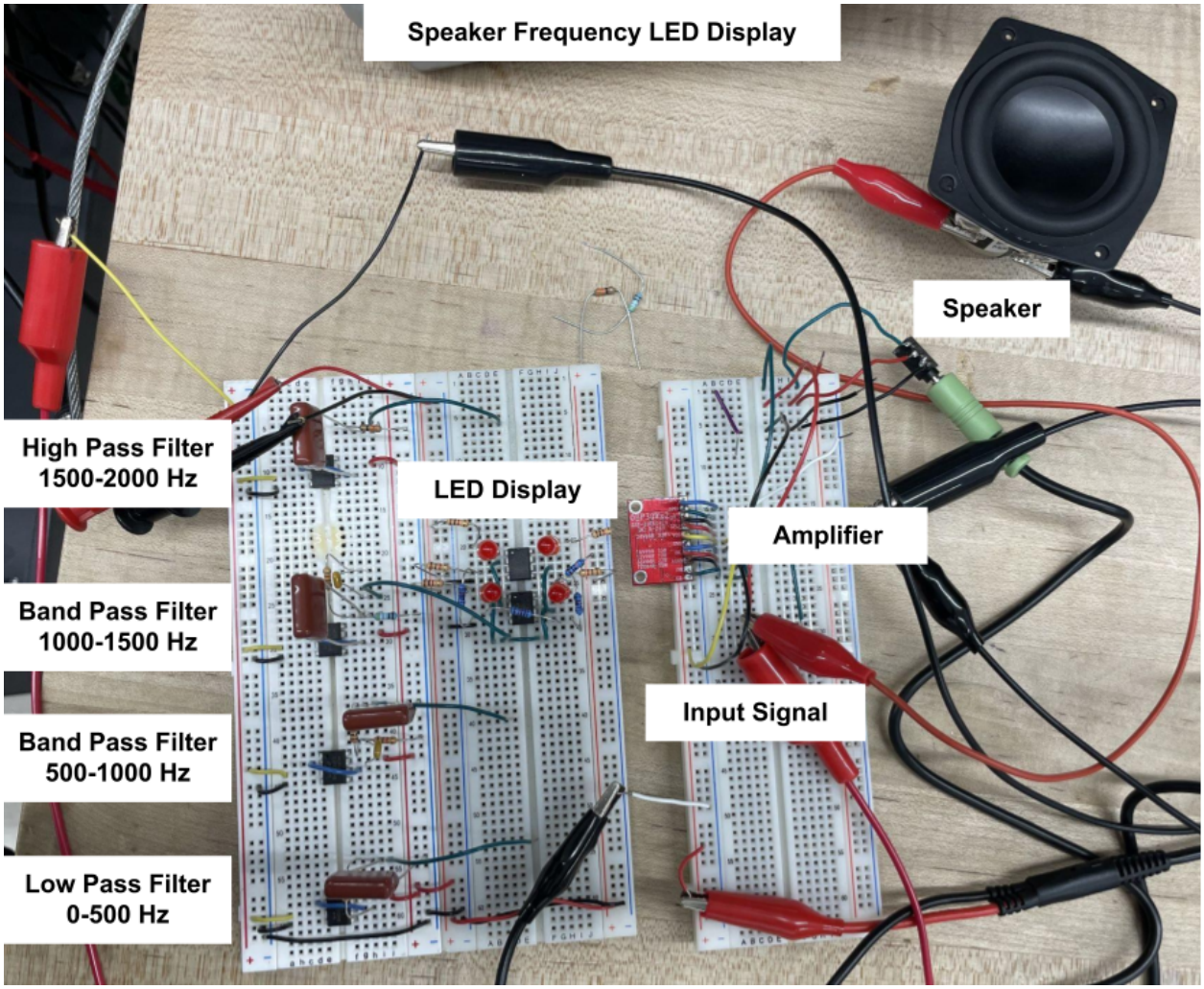
The completed circuit takes in the music signal, breaks down the sound by frequency, and lights up the respective LEDs to show the magnitude of each frequency range. The breadboard does not have the duplicates of the four LED displays but any of the filters can be used as the input to the LED display.

Updated Circuit Simulation:



The circuit was updated to add unity buffers before the filters to ensure that the voltage drawn from the filters was not loading the amplifier or the other filters. Resistor values for the LED display were increased to require a higher voltage to light up each subsequent LED which allowed for a better visualization of the amplitude of the output of each signal.

Labeled picture of circuit breadboard:



Link to video of the circuit operating:
https://drive.google.com/file/d/1hxy_4fRZagwfNQX21tC7BlUfimCPeUrQ/view?usp=sharing