Home Audio System Project
ECE 2804

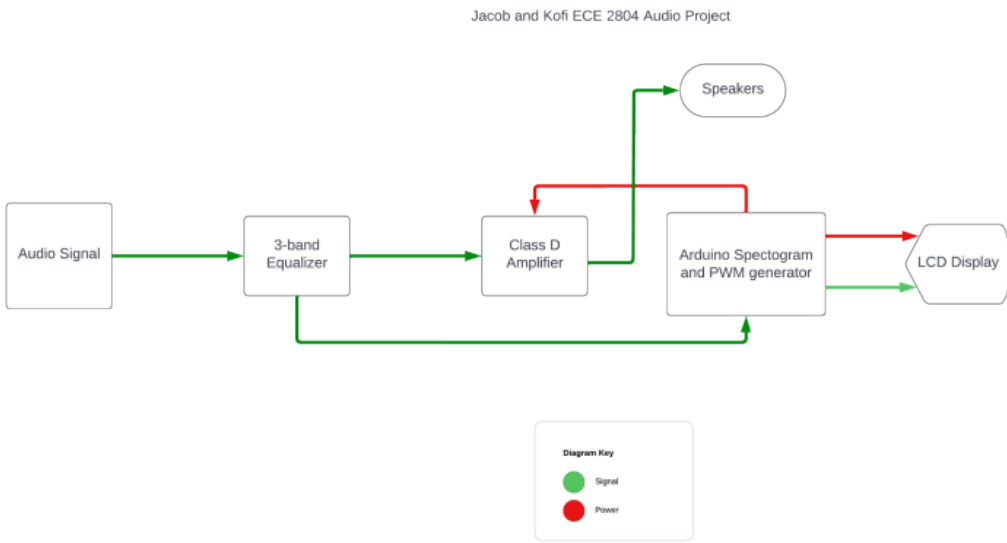
Jacob & Kofi

Project Goals

- Home Audio System
- 3-band Equalizer
- Class D Amplifier
- Arduino Spectrogram

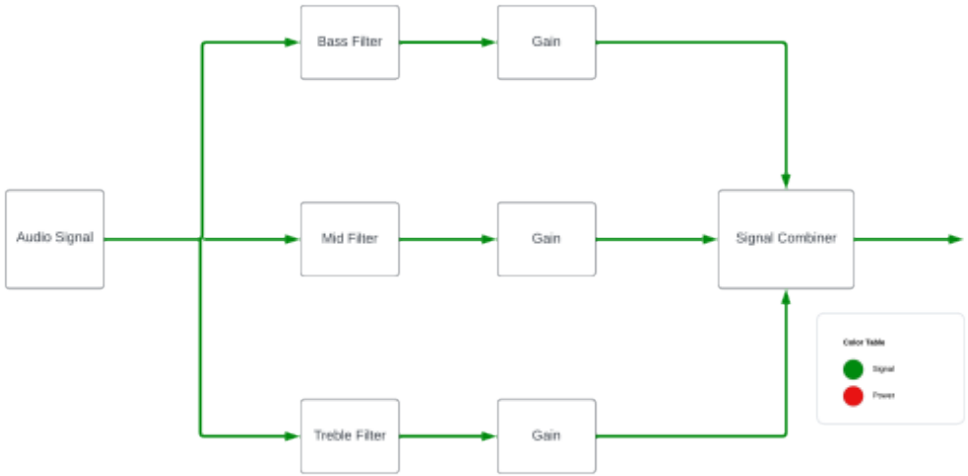
Project Overview

- 3-Band Equalizer (EQ)
- Designed, simulated, and built EQ
- Designed, simulated, and built Class D amplifier
- Arduino Spectrogram outputting to LCD Display
- Wrote pseudo code, wrote actual code, connected output to LCD Display.

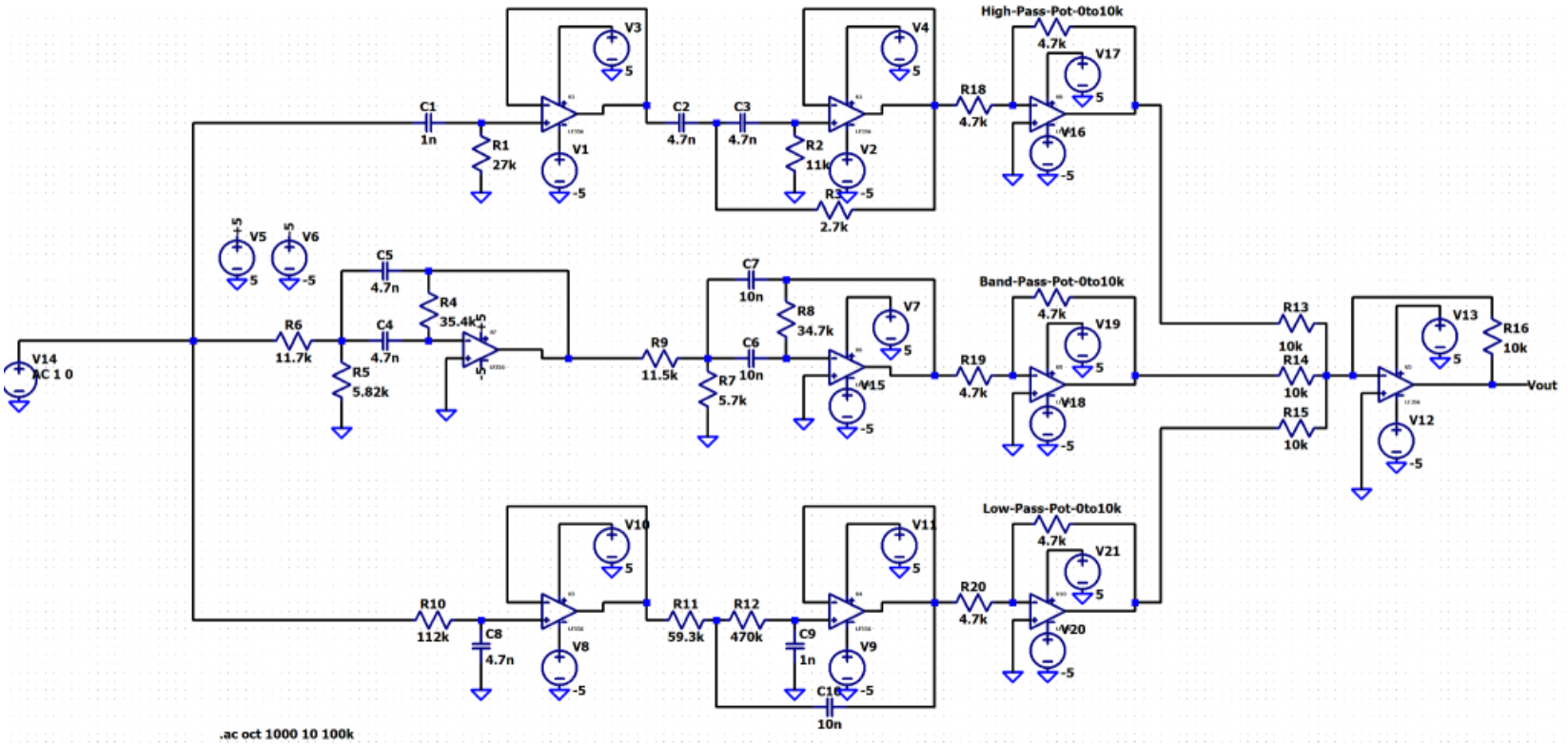


Audio Equalizer

- Three band EQ
  - - Bass
  - - Mid
  - - Treble
- Variable gain for each individual band
- Bands get recombined to form output signal

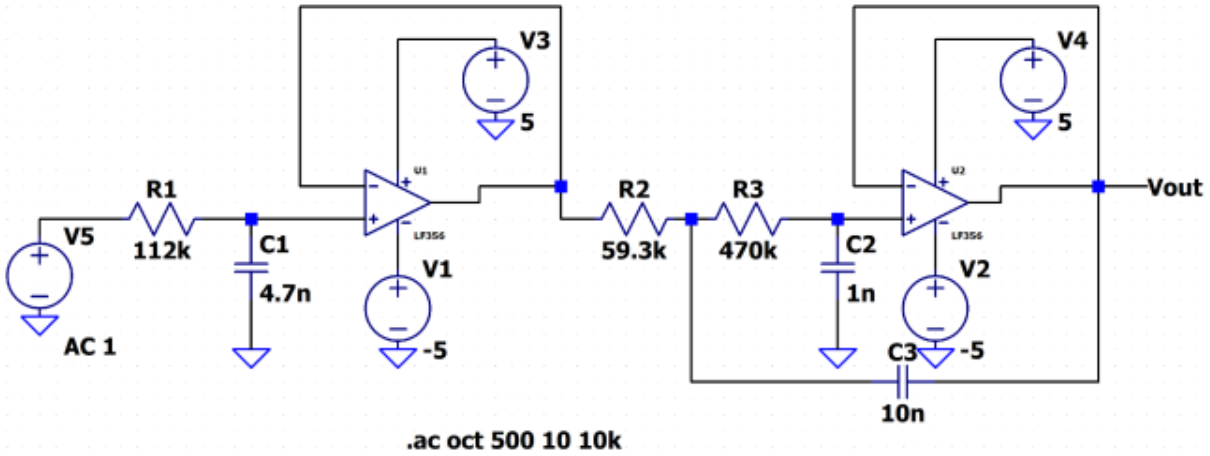


Graphic Equalizer



Bass Filter

- Chose cutoff frequency
- Design Filter using Analog Filter Wizard
- Derived Equation

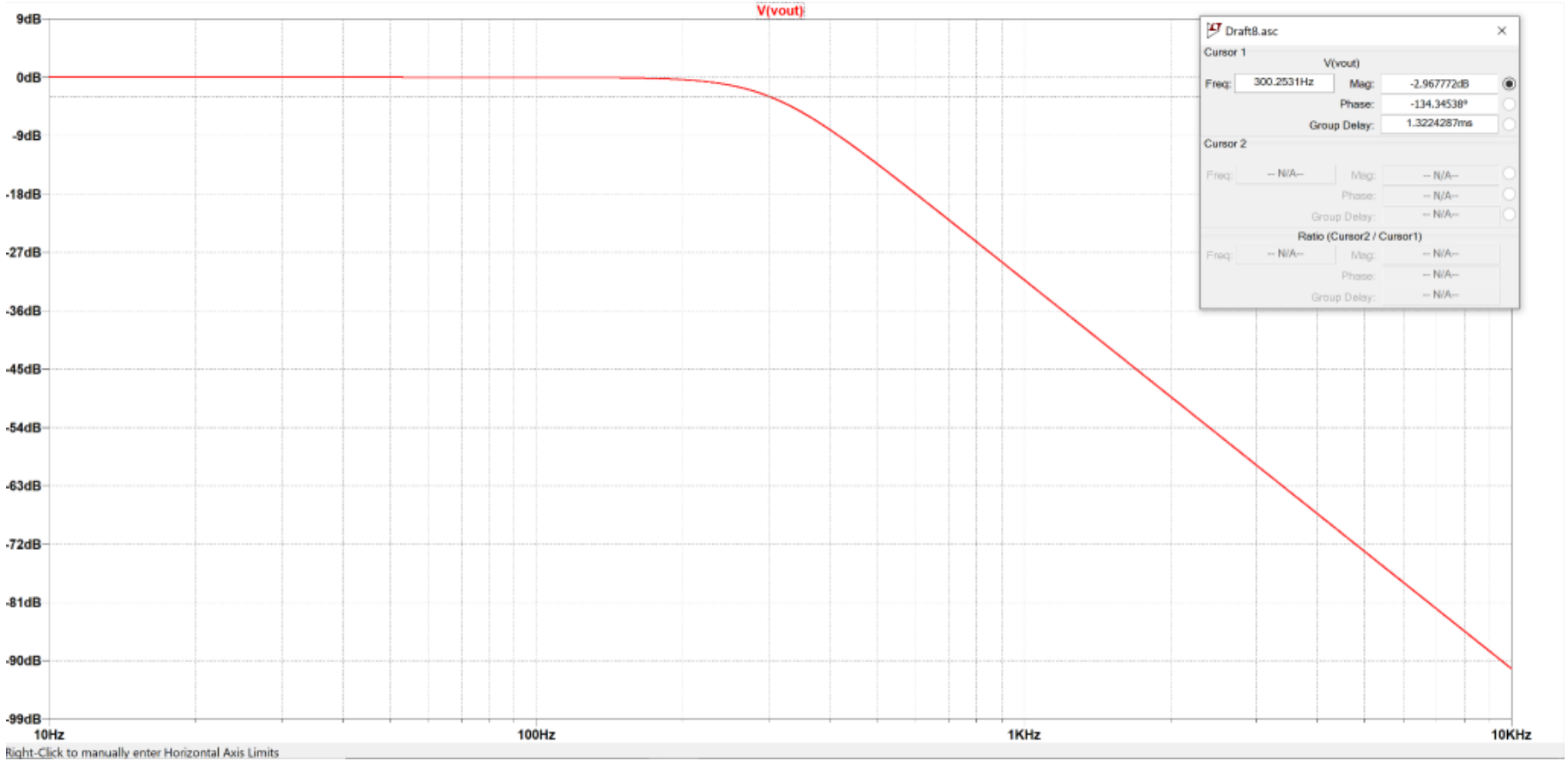


Bass Filter cont.

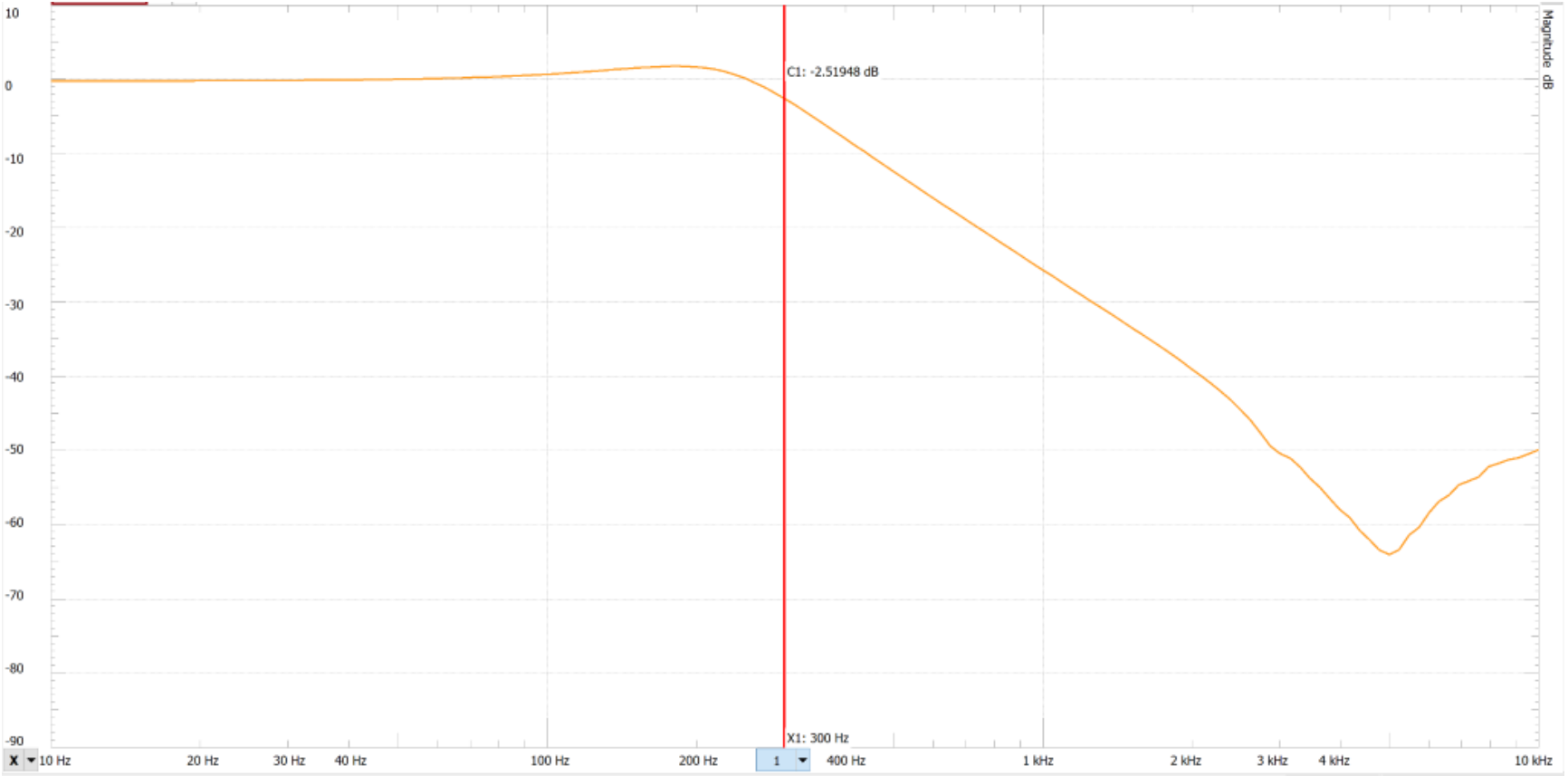
- Simulation of frequency response
- Measured frequency response
- Measured response closely matches simulated response

$$H(j\omega) = \frac{\left(\frac{1}{4.7nF * j\omega}\right)}{\frac{1}{4.7nF * j\omega} + 112k\Omega} * \frac{\left(\frac{1}{j\omega(10\ nF)}\right) * \left(\frac{1}{j\omega(1\ nF)}\right)}{(59.3k\Omega * 470k\Omega) + \left(\frac{1}{j\omega(10\ nF)}\right)(59.3k\Omega * 470k\Omega) + \left(\frac{1}{j\omega 10\ nF)}\right) * \left(\frac{1}{j\omega(1\ nF)}\right)}$$

Bass Filter Simulated Results

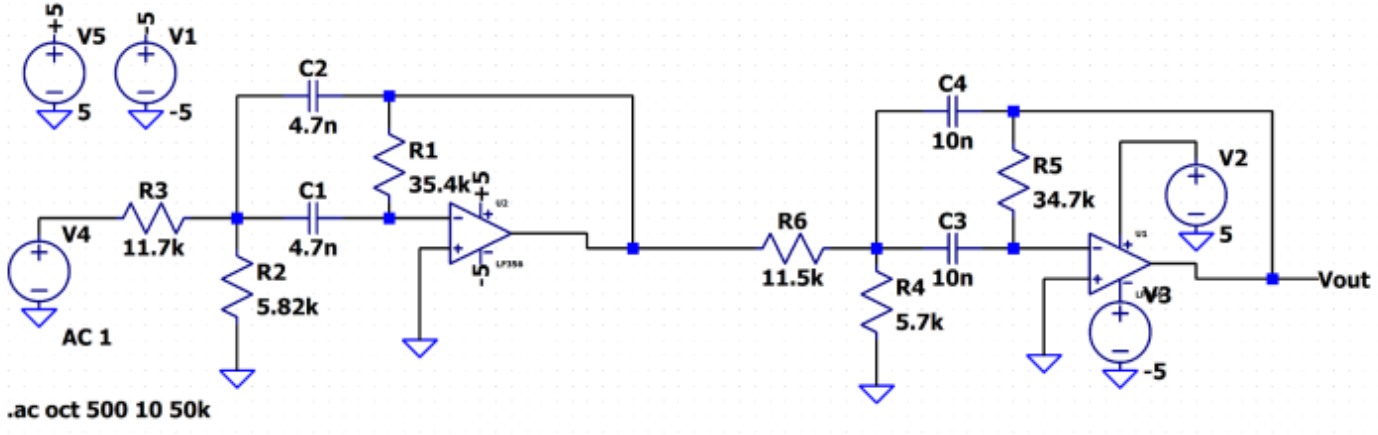


Bass Filter Validated Results



Mid Filter

- Repeated process we used to develop bass filter
- Chose cutoff frequency
- Design Filter using Analog Filter Wizard
- Derived Equation

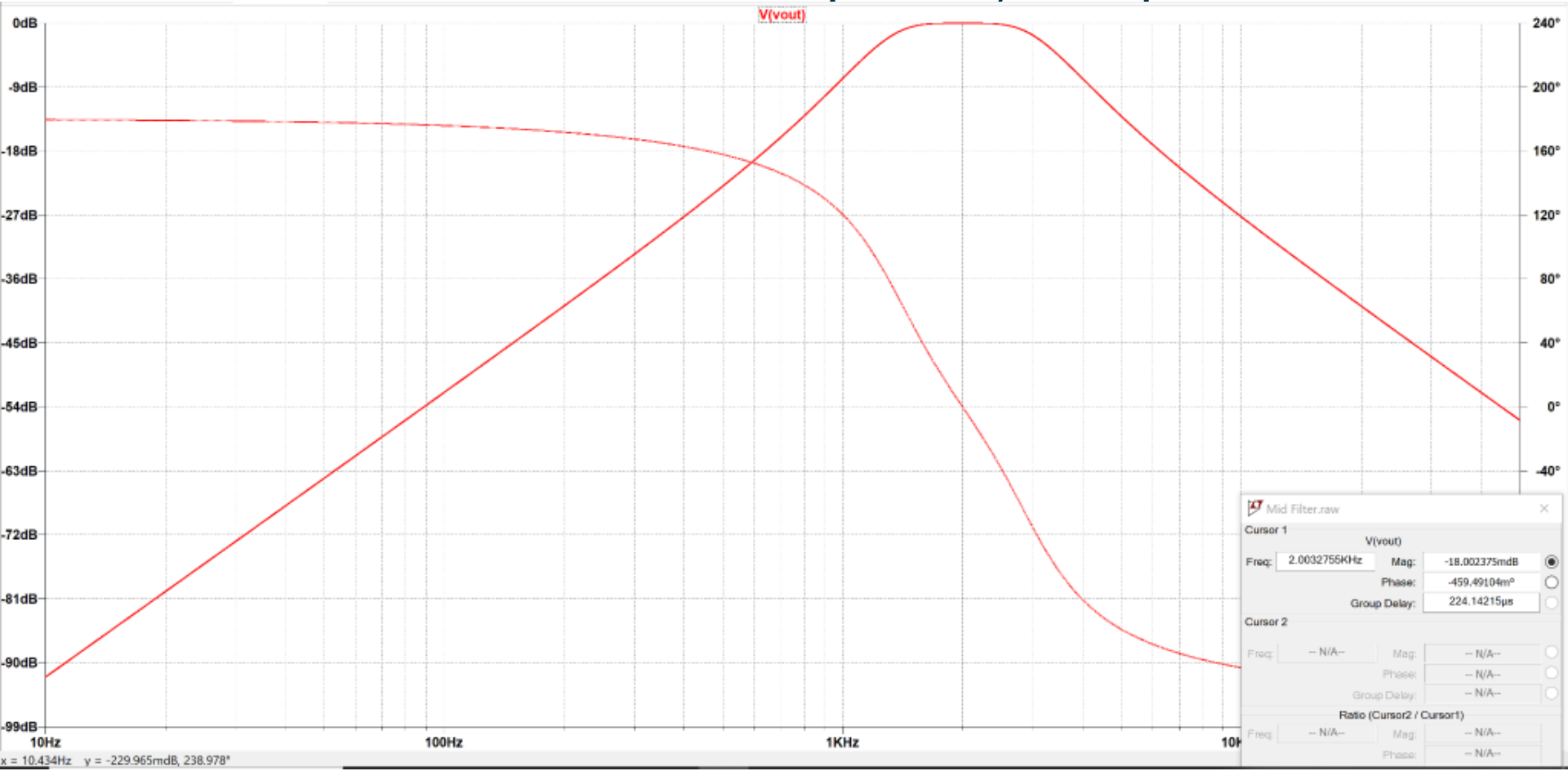


Mid Filter cont.

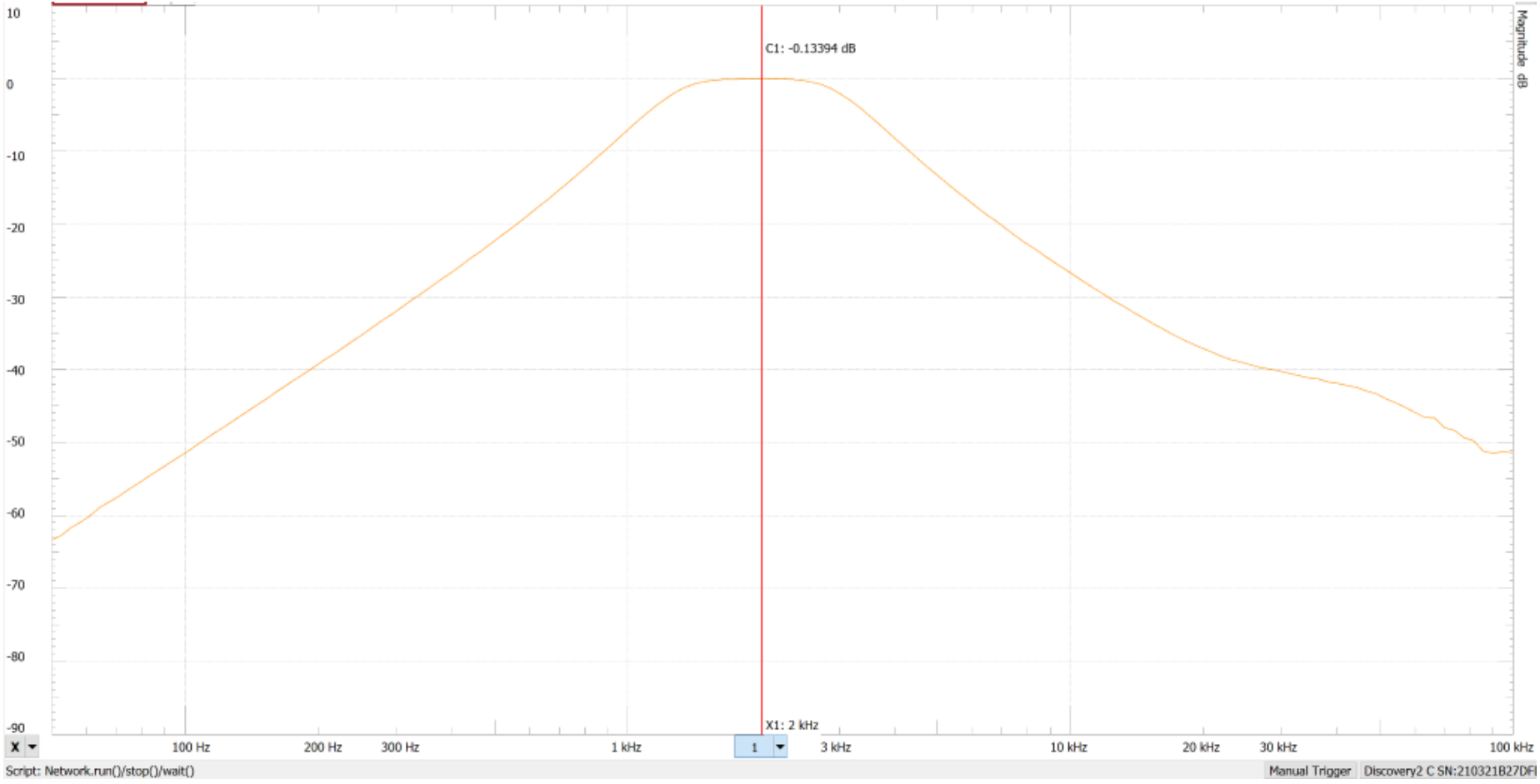
- Simulation of frequency response
- Measured frequency response
- Measured response closely matches simulated response

$$H(\omega) = \frac{-j\omega\frac{1}{(11.7k\Omega)(4.7nF)}}{(j\omega)^2+(j\omega)\frac{(4.7nF)+(4.7nF)}{(4.7nF)*(4.7nF)*(35.4k\Omega)}+\frac{1}{(35.4k\Omega)*(4.7nF)*(4.7nF)}(\frac{1}{(11.7k\Omega)}+\frac{1}{(5.82k\Omega)})} * \frac{-j\omega\frac{1}{(11.5k\Omega)(10nF)}}{(j\omega)^2+(j\omega)\frac{(10nF)+(10nF)}{(10nF)*(10nF)*(34.7k\Omega)}+\frac{1}{(34.7k\Omega)*(10nF)*(10nF)}(\frac{1}{(11.5k\Omega)}+\frac{1}{(5.7k\Omega)})}$$

Mid Filter Simulated Frequency Response

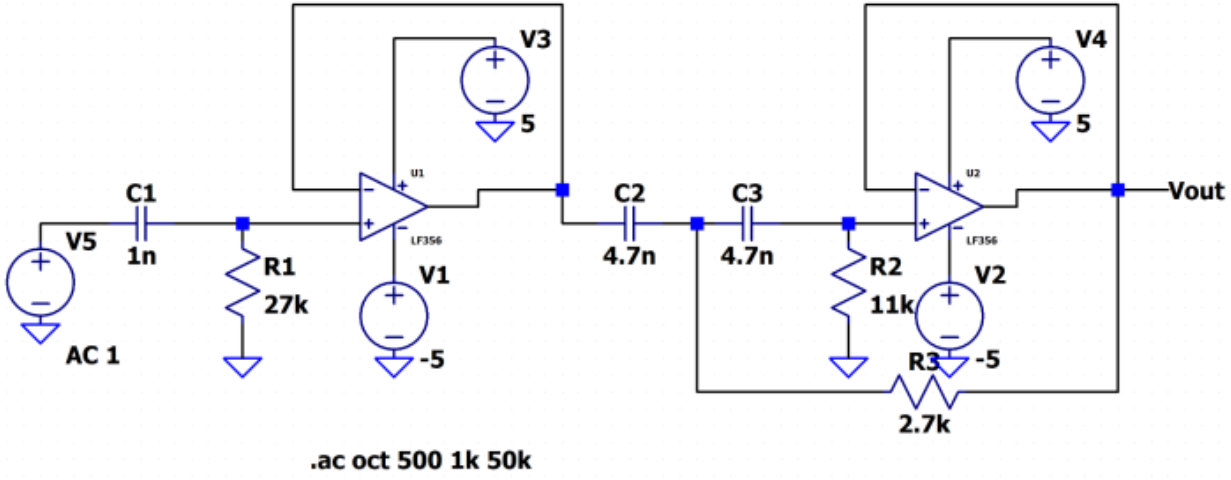


Mid Filter Measured Frequency Response



Treble Filter

- Repeated process we used to develop other filters
- Chose cutoff frequency
- Design Filter using Analog Filter Wizard
- Derived Equation

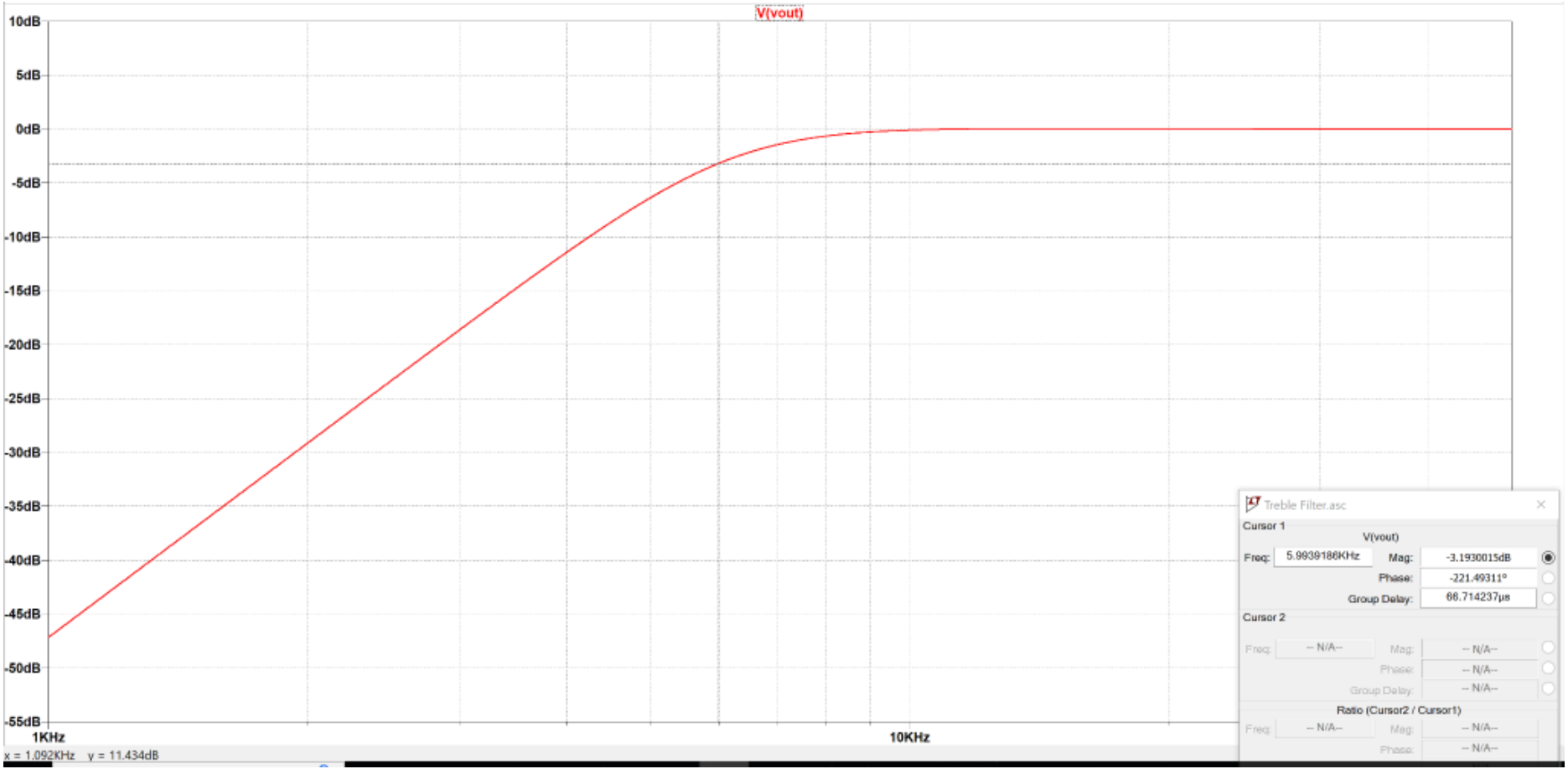


Treble Filter cont.

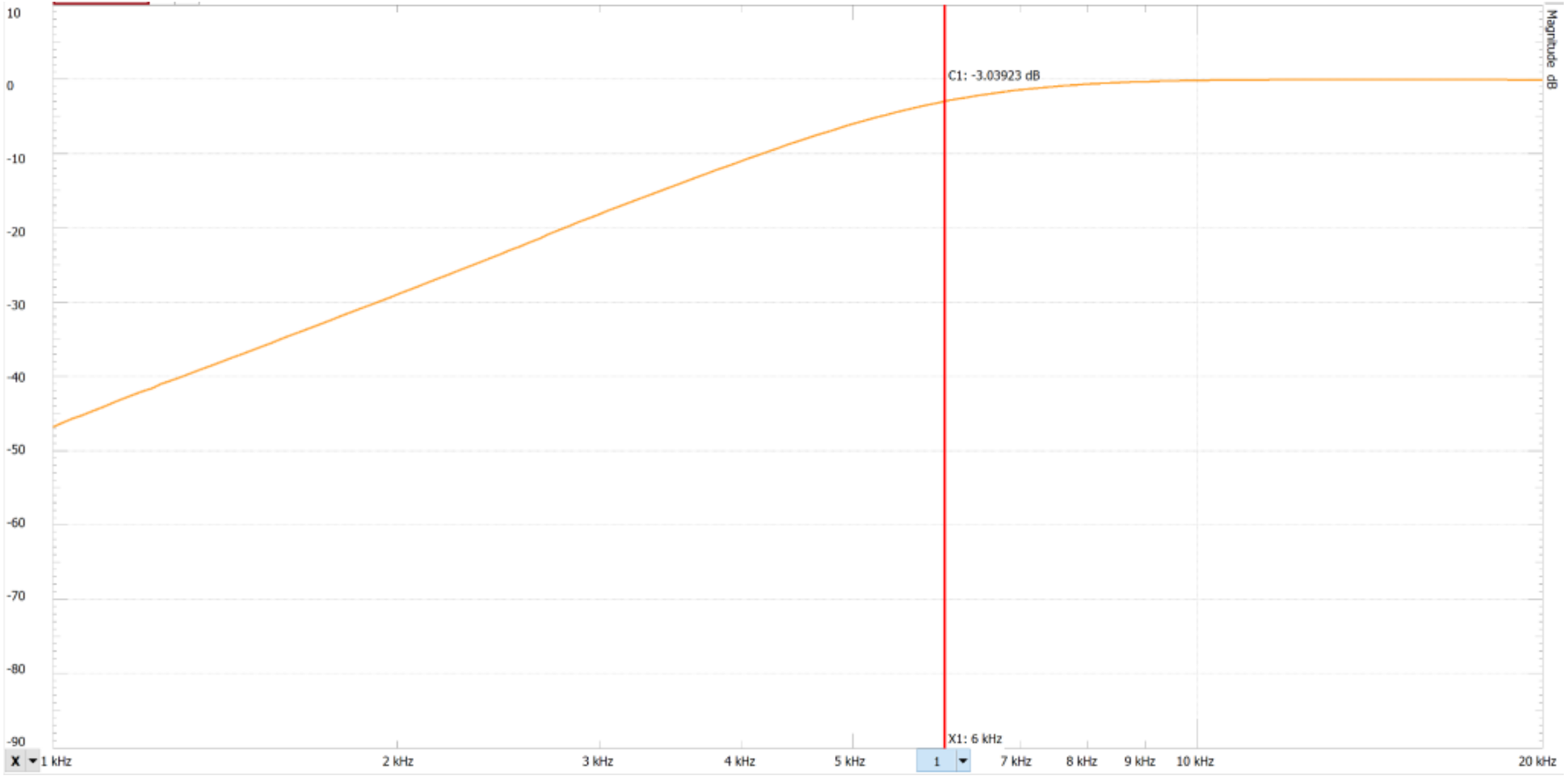
- Simulation of frequency response
- Measured frequency response
- Measured response closely matches simulated response

$$H(j\omega) = \frac{(27k\Omega)}{\frac{1}{j\omega(1nF)} + 27k\Omega} * \frac{2.7k\Omega * 11k\Omega}{(\frac{1}{j\omega(4.7\ nF)}) + 2.7k\Omega * (\frac{1}{j\omega(4.7\ nF)}) + (2.7k\Omega * 11k\Omega)}$$

Treble Filter Simulated Results

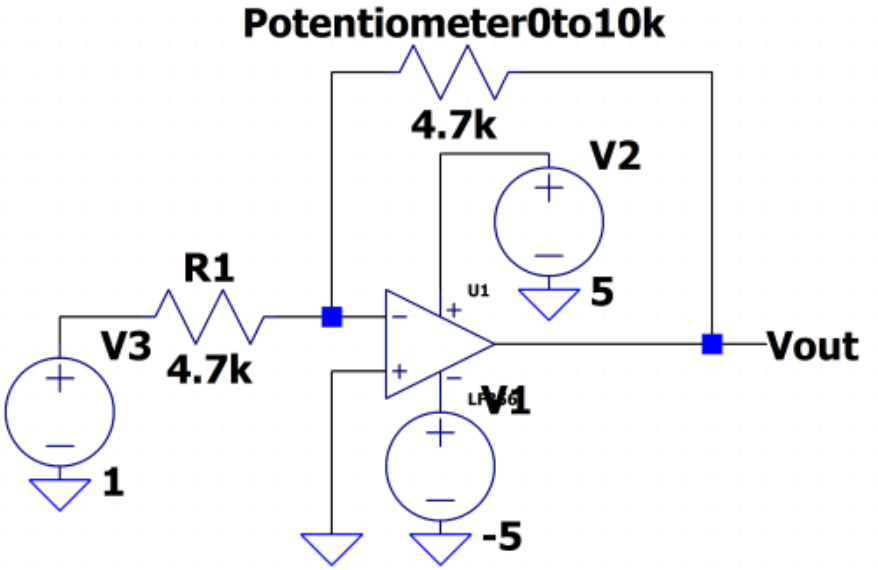


Treble Filter Validated Results



Variable Gain

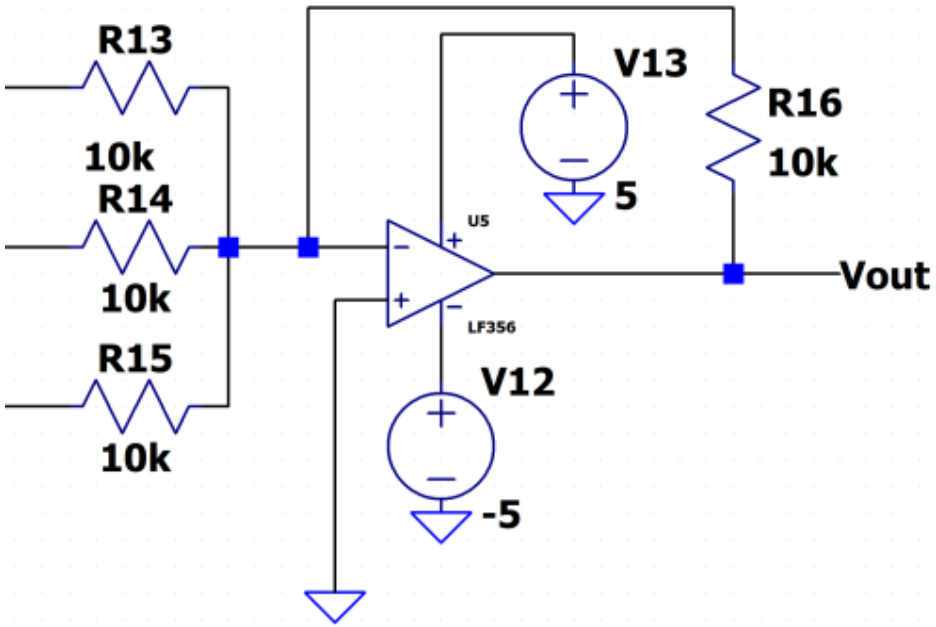
- Inverting op-amp
- Used potentiometer as output resistance
- Simple design
- Able to cut and boost signal strength



$$H = -\frac{R_{Pot}}{R_{In}}$$

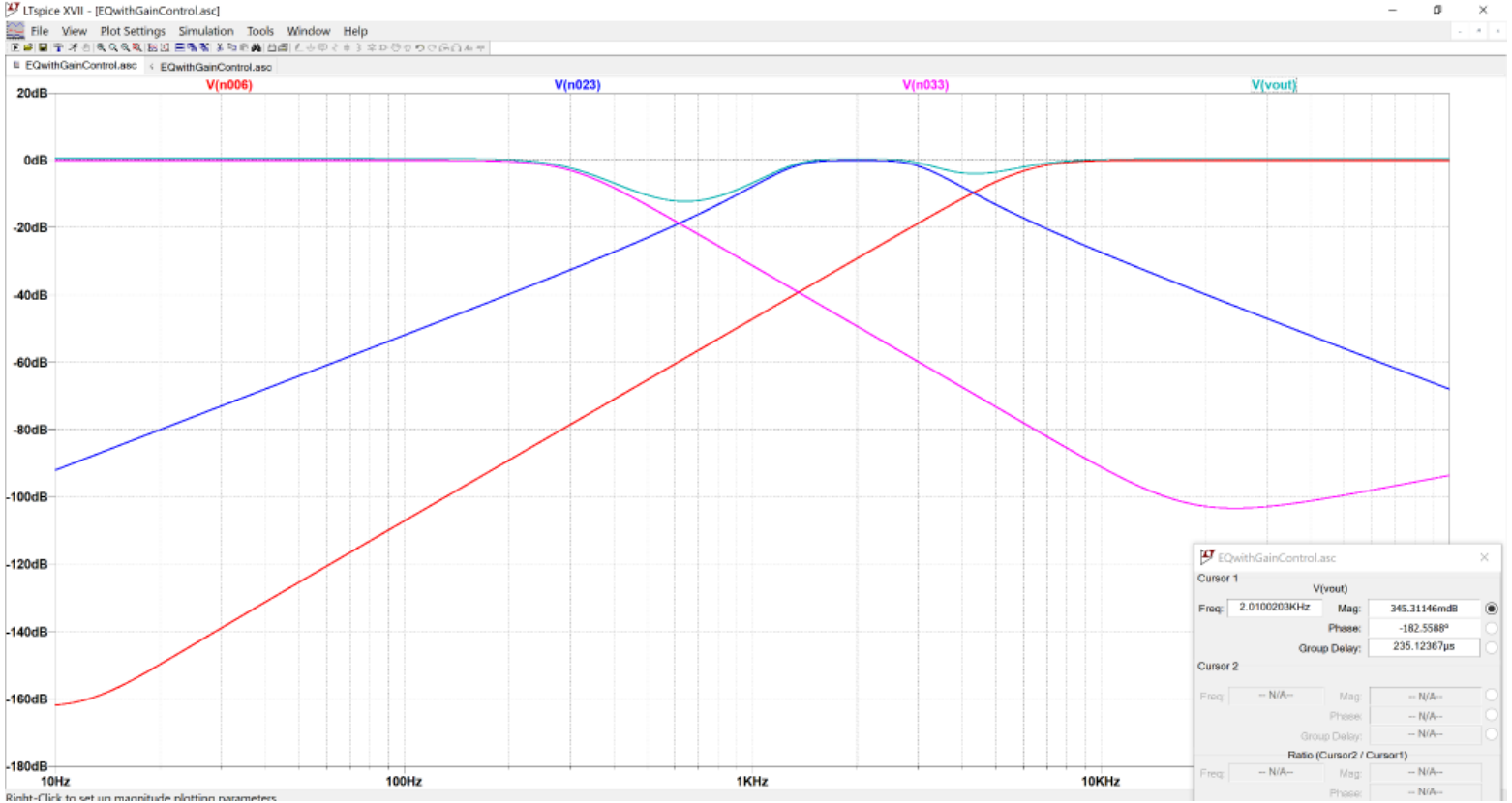
Summing Amplifier

- Used to combine signals
- Possible to vary strength of each band
- Can also gain entire circuit output

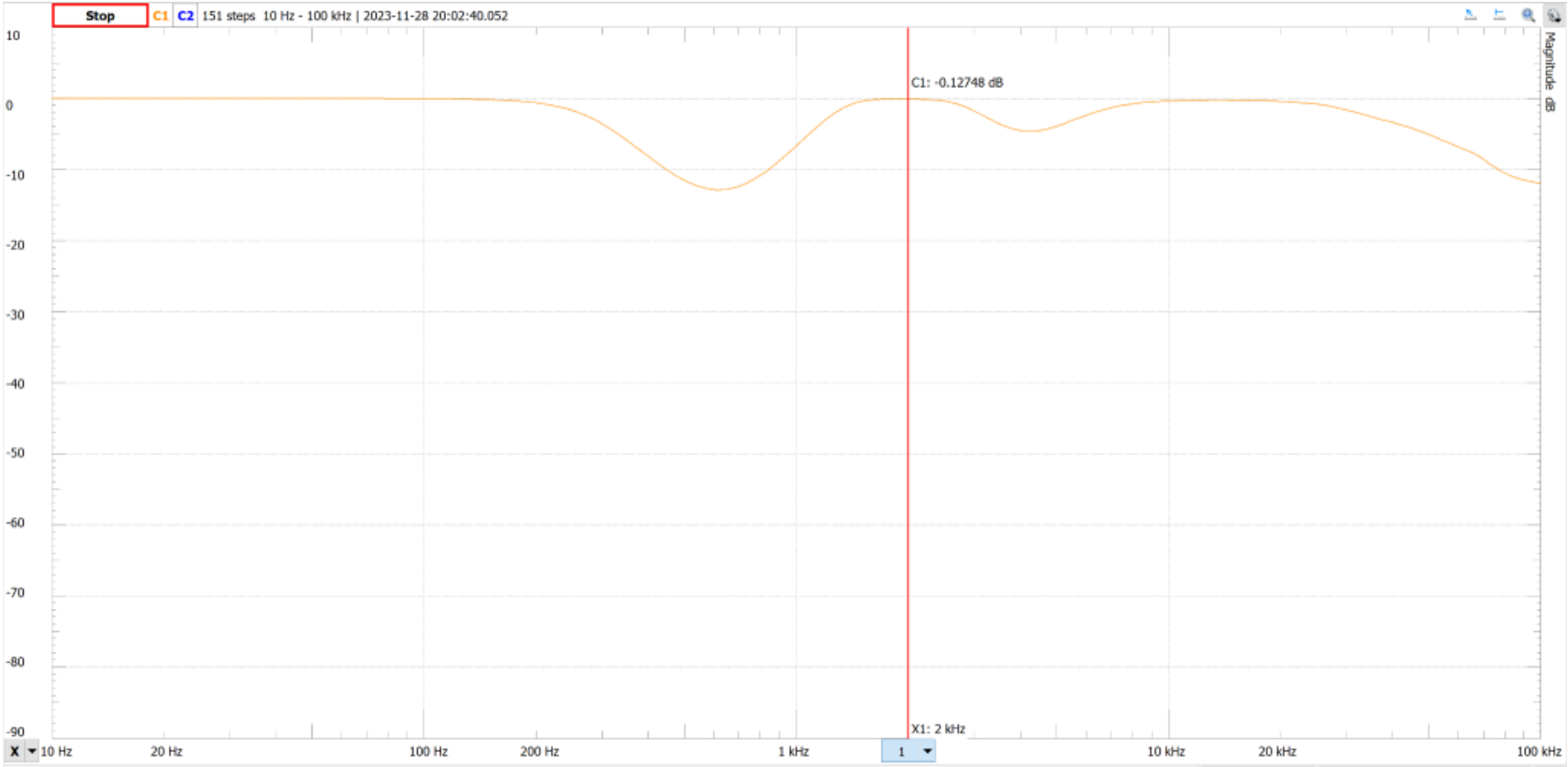


$$-Vout = \frac{Rf}{Rin}(V1 + V2 + V3)$$

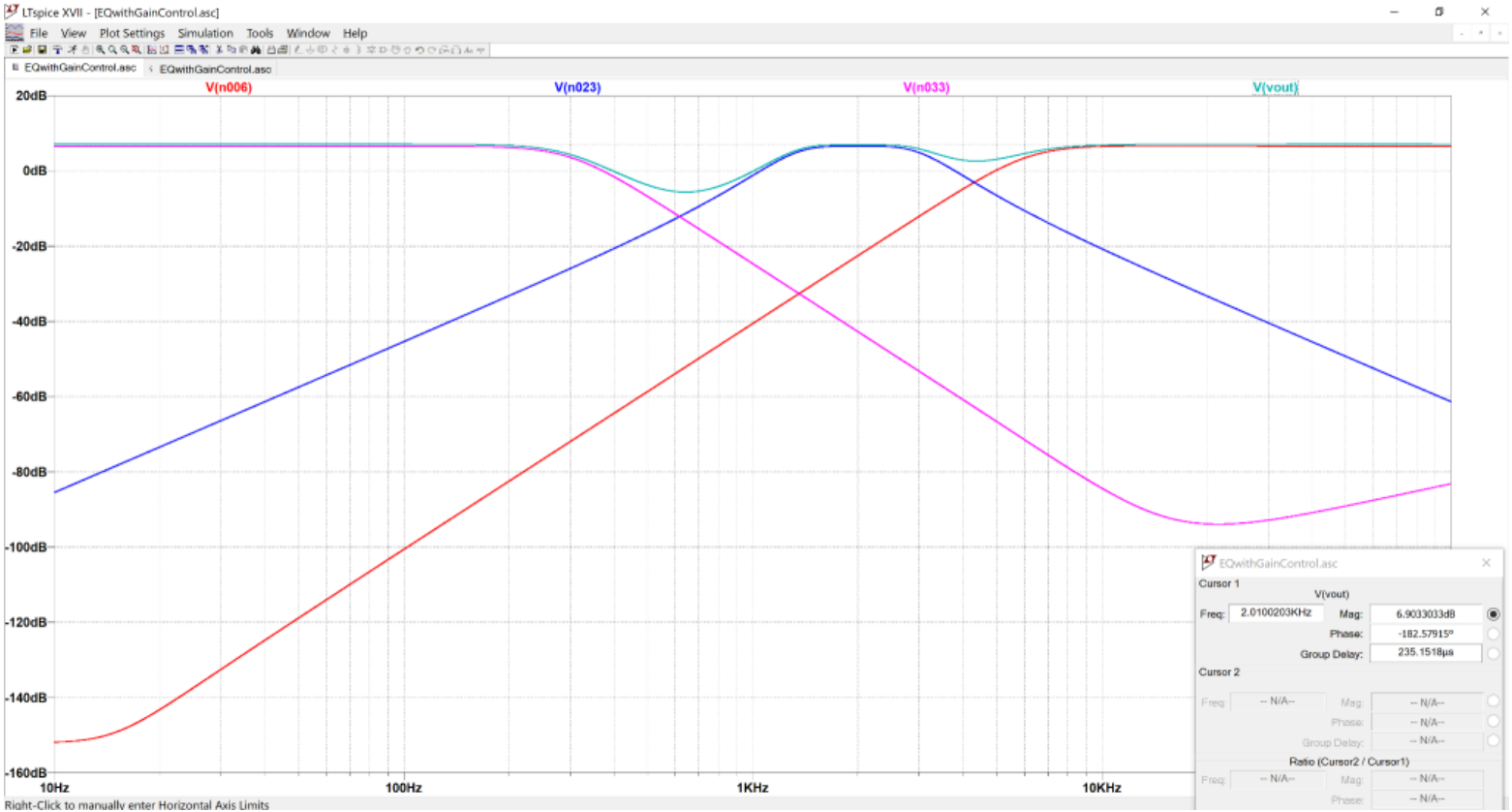
Variable Gain- LTspice neutral position



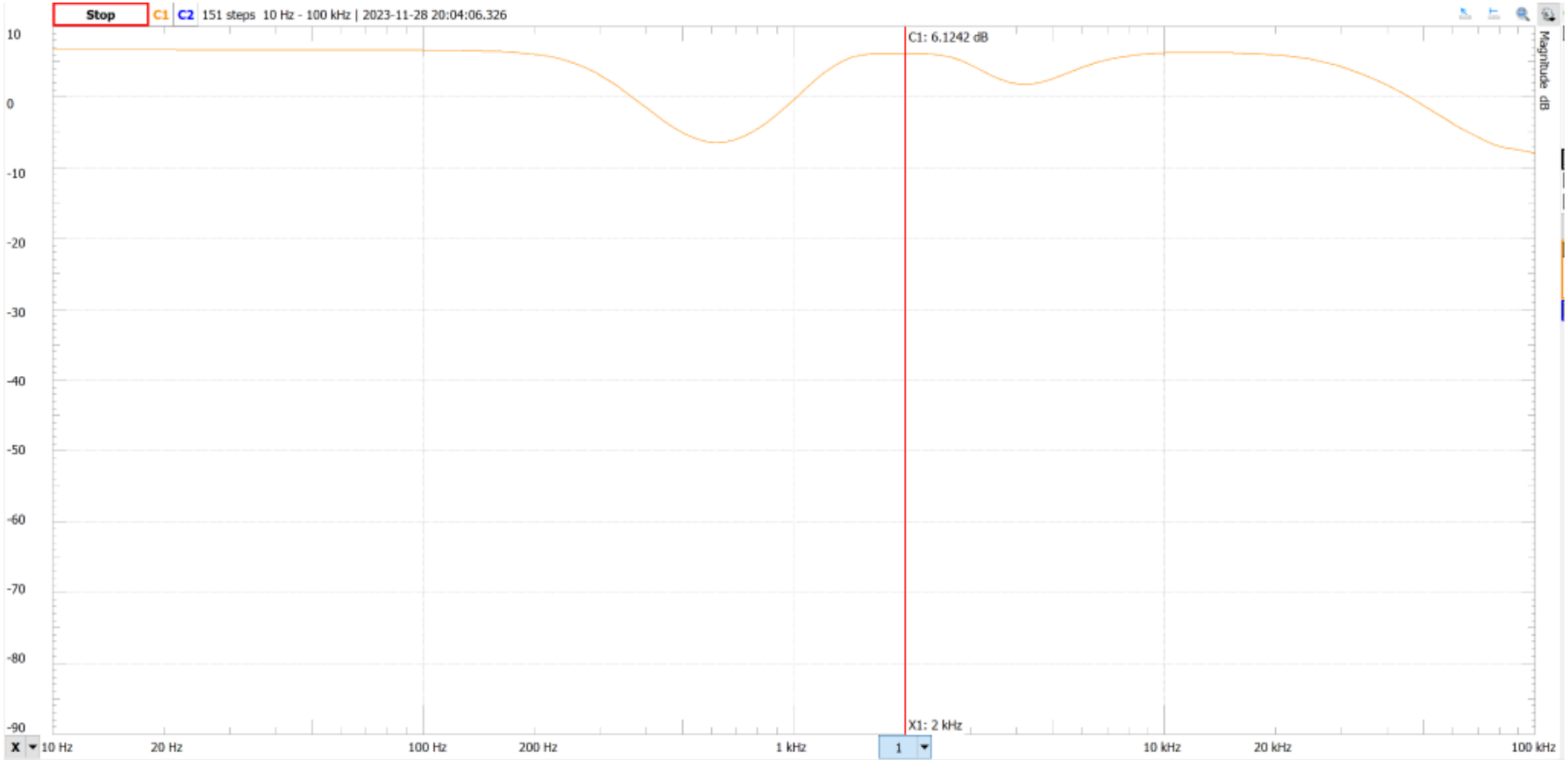
Variable Gain- Waveform neutral position



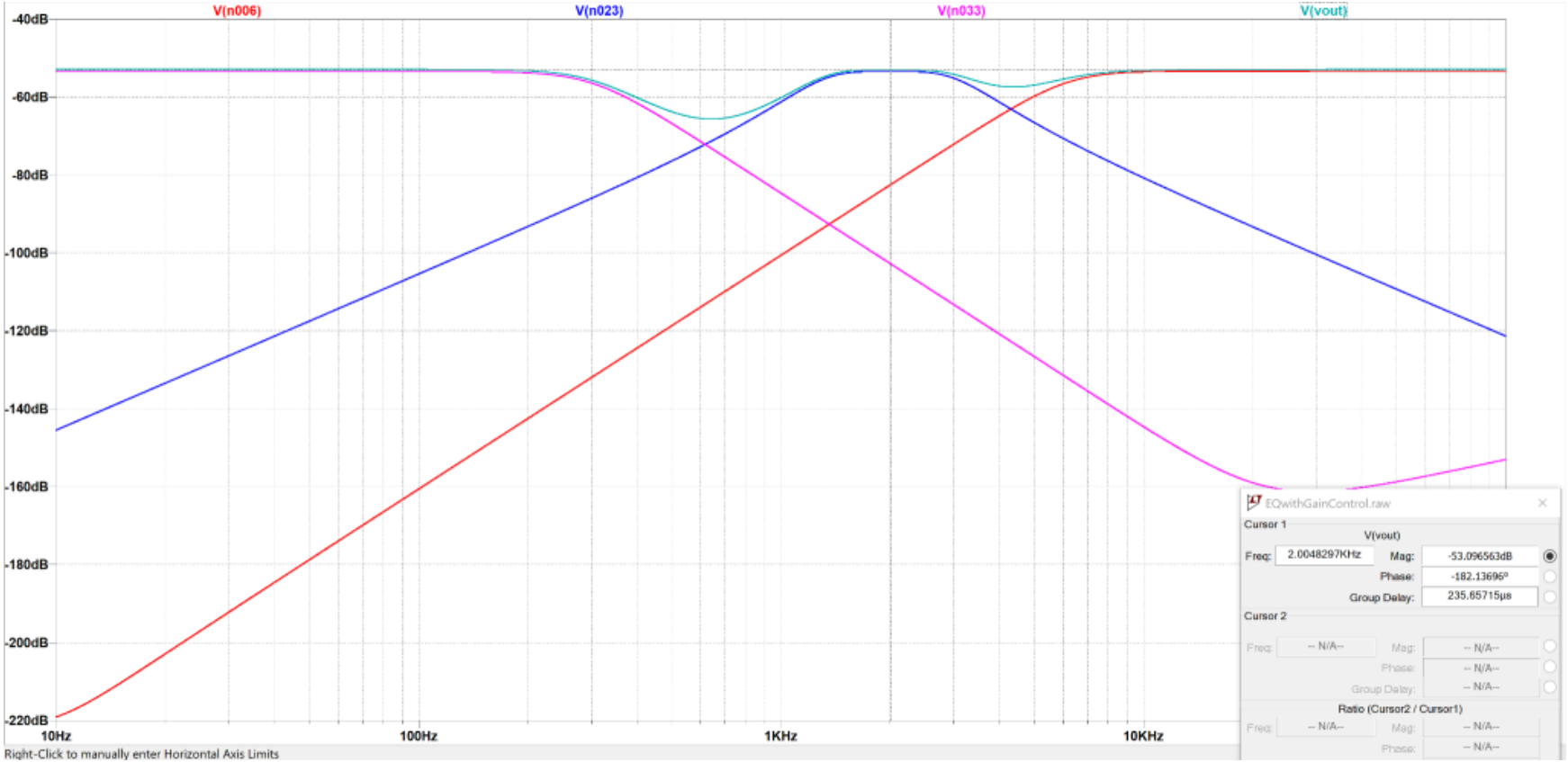
Variable Gain- LTspice max position



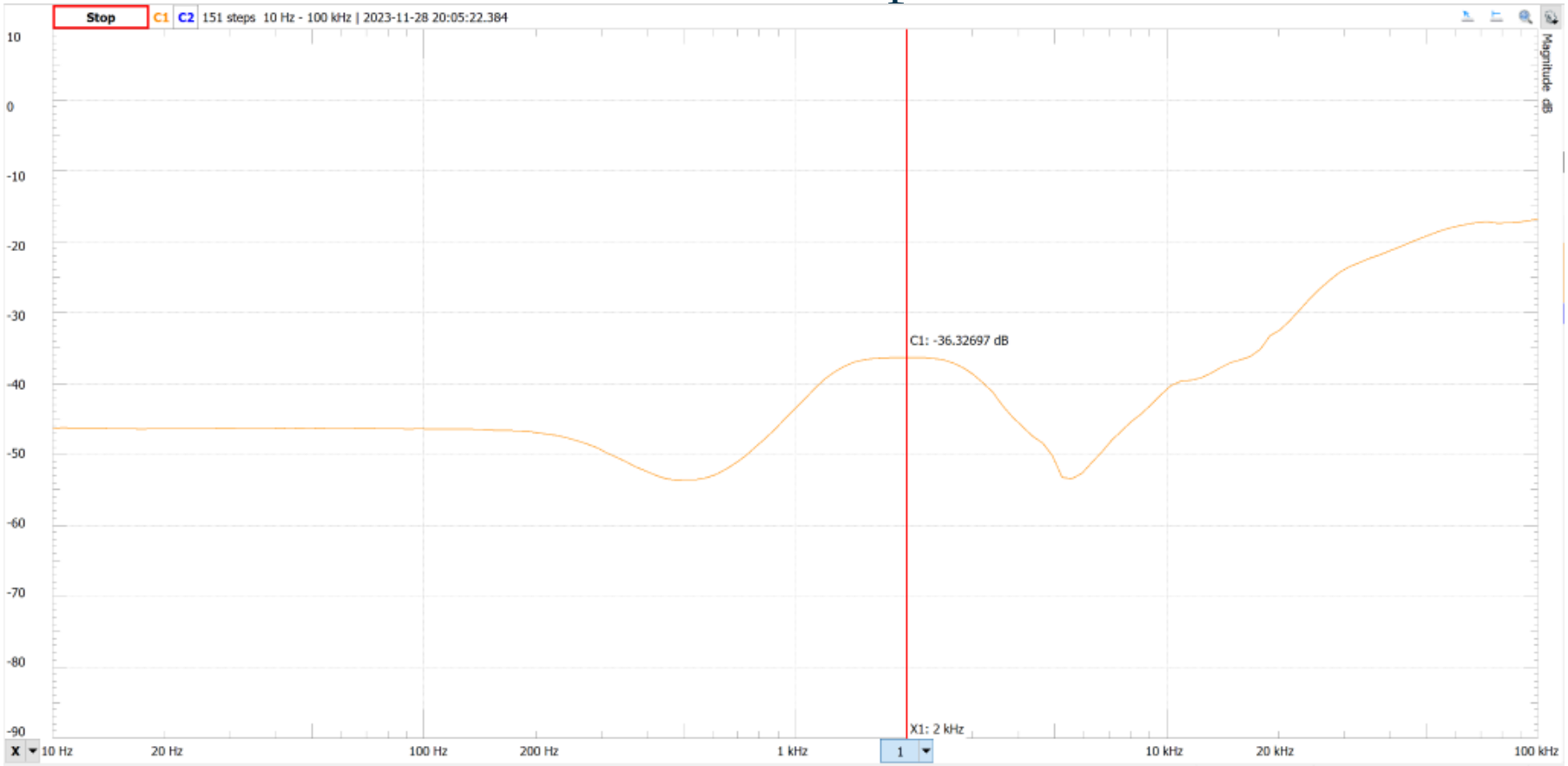
Variable Gain- Waveform max position



Variable Gain- LTspice min position



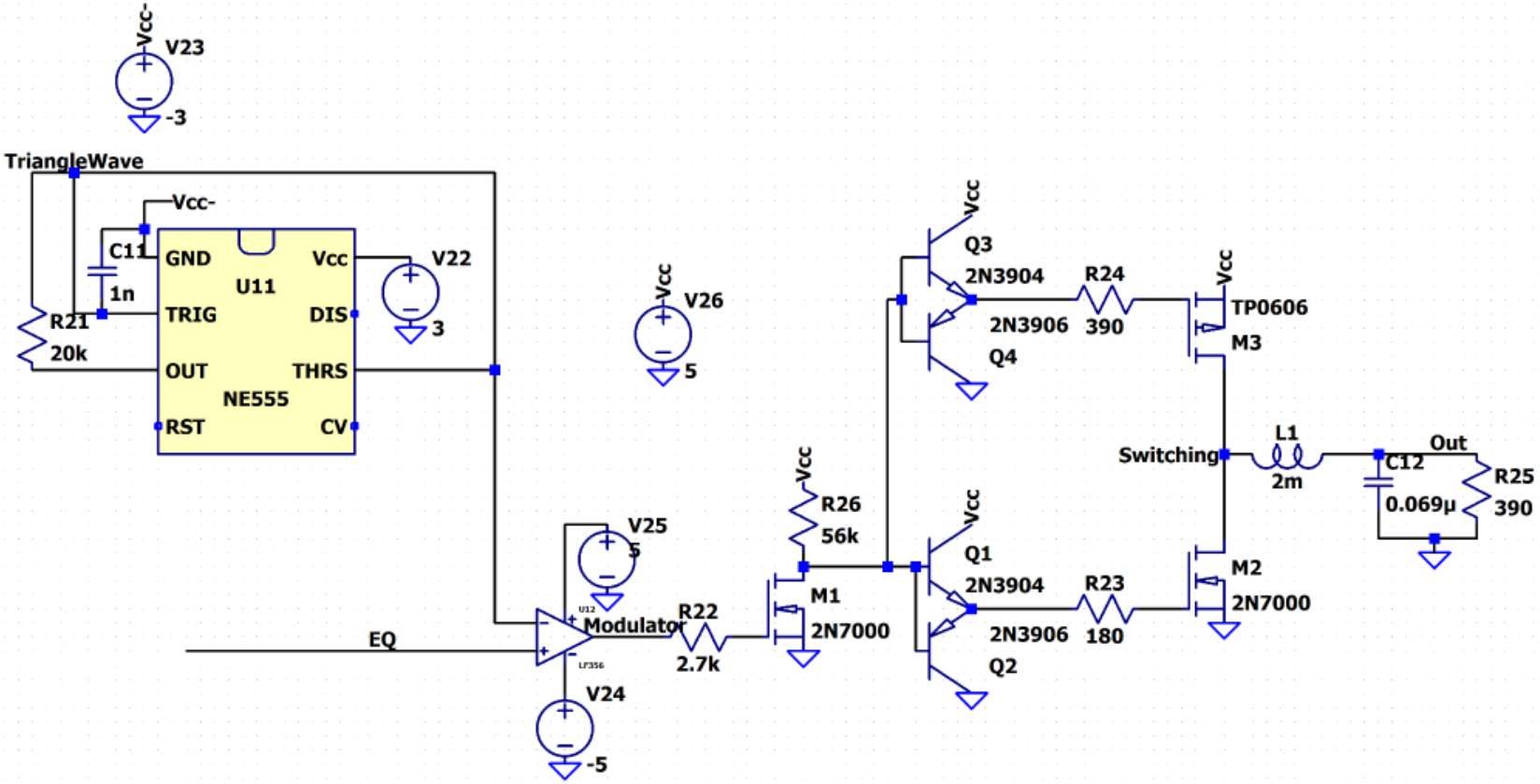
Variable Gain- Waveform min position



Class D Amplifier

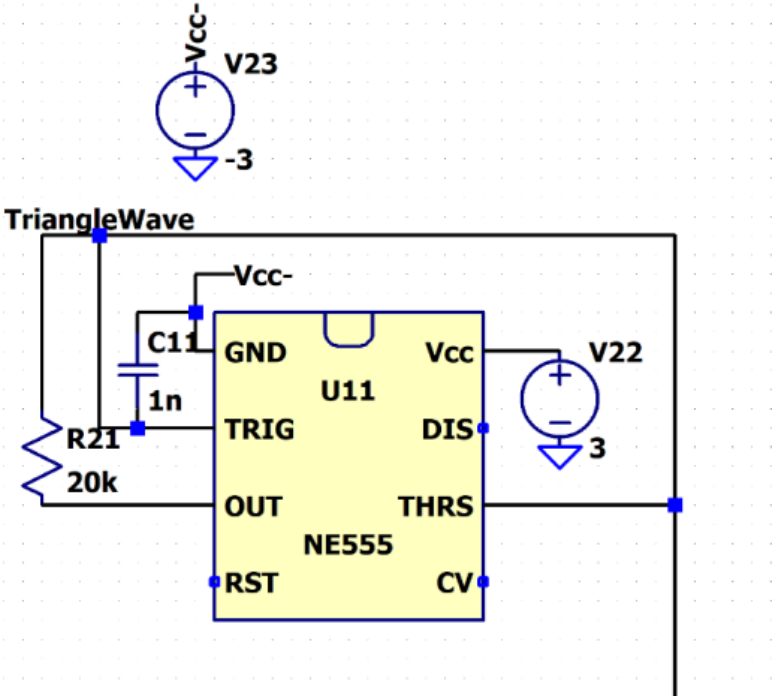
- What is Class D Amplifier?
- Why Class D?
  - Power Efficiency!!
- Half-Bridge design
- Dedicated modulation from 555 Timer
- Goal: 5V peak-to-peak voltage

Class D Amplifier



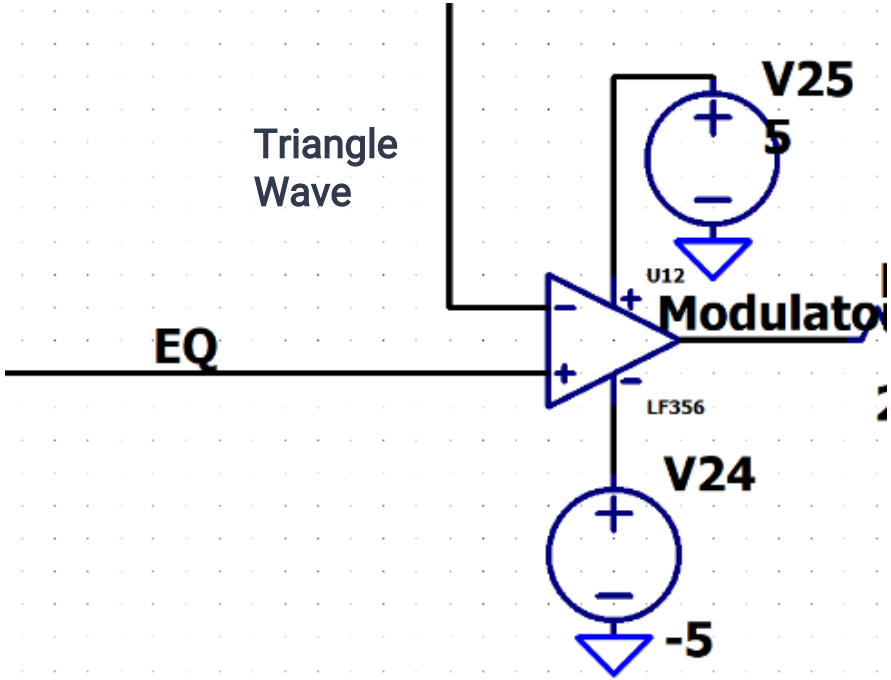
Triangle Generation

- Triangle Generation from 555 timer
- Based on charging and discharging of capacitor
- No need for extra integrator circuit
- Capable of generating 200 kHz triangle wave
  - For this project we brought it down to 50 kHz



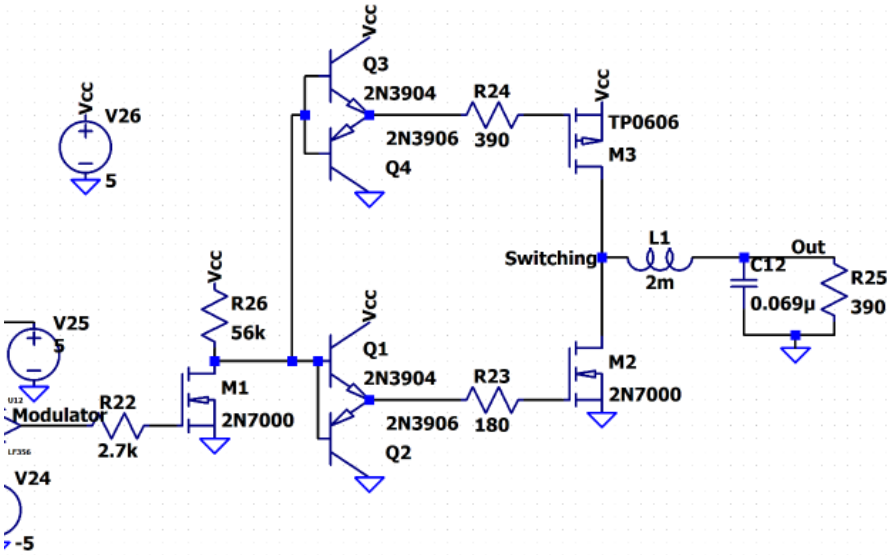
Modulator

- LF356 op-amp as comparator
- Compares audio signal with triangle wave to produce PWM



Class D Amplification

- PWM signal is sent from the modulator to a gate driver.
- Why a gate driver?
- CMOS output stage configuration



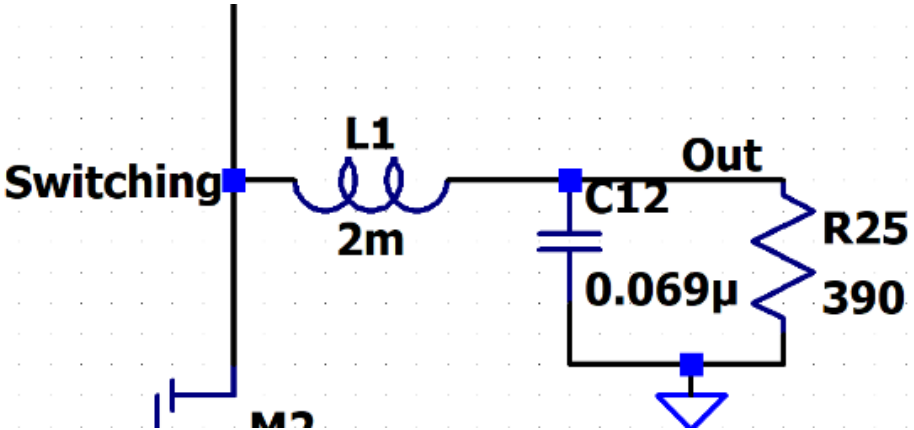
Filter stage

- Why do we need to filter?
- Filter used: Second order LC load pass with resistive load
  - For this project, we are working with a 390 Ω load

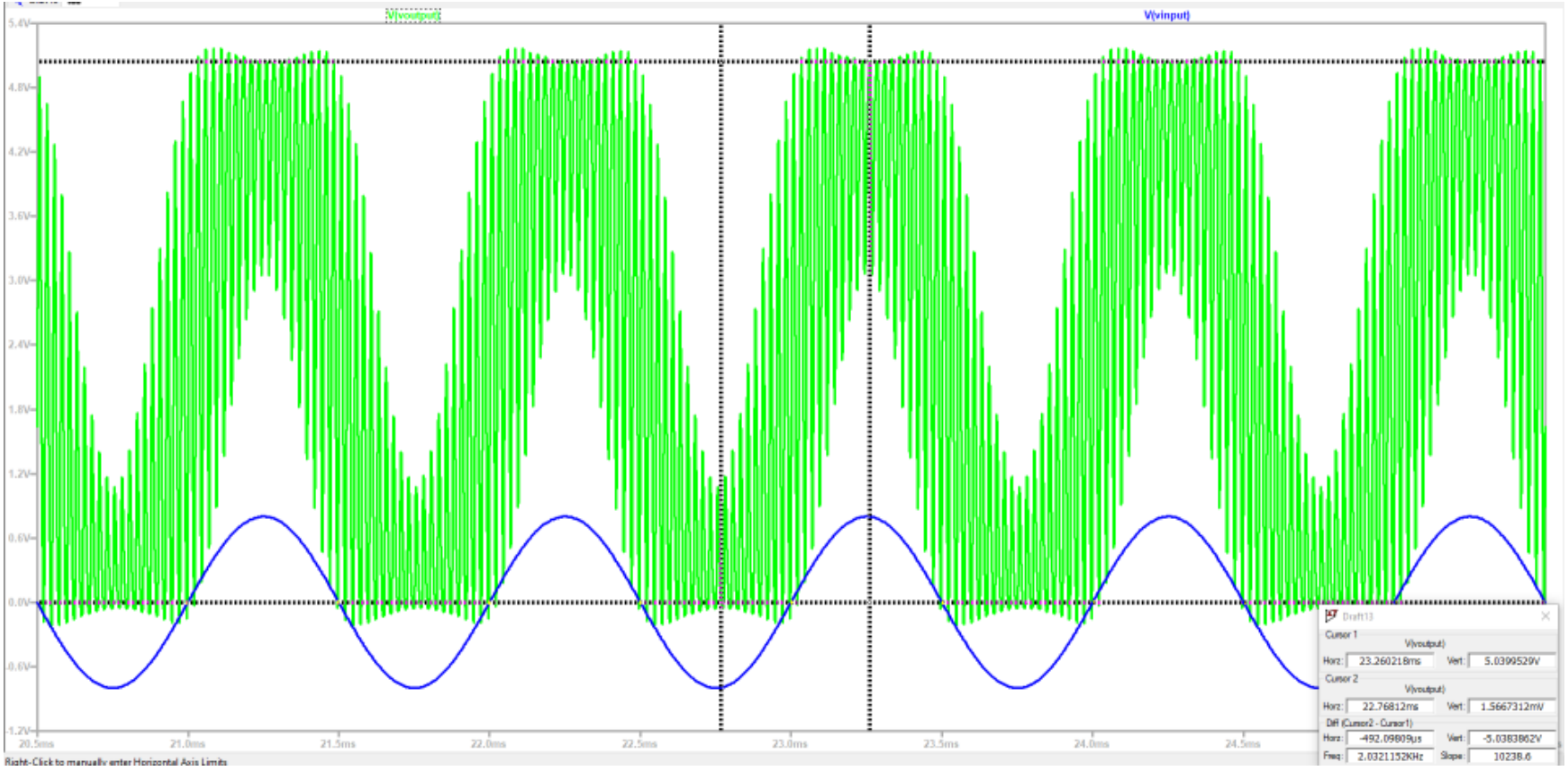
$$f_c = \frac{1}{2\pi\sqrt{LC}}$$

$$L = \frac{R_L \times \sqrt{2}}{2\pi f_c}$$

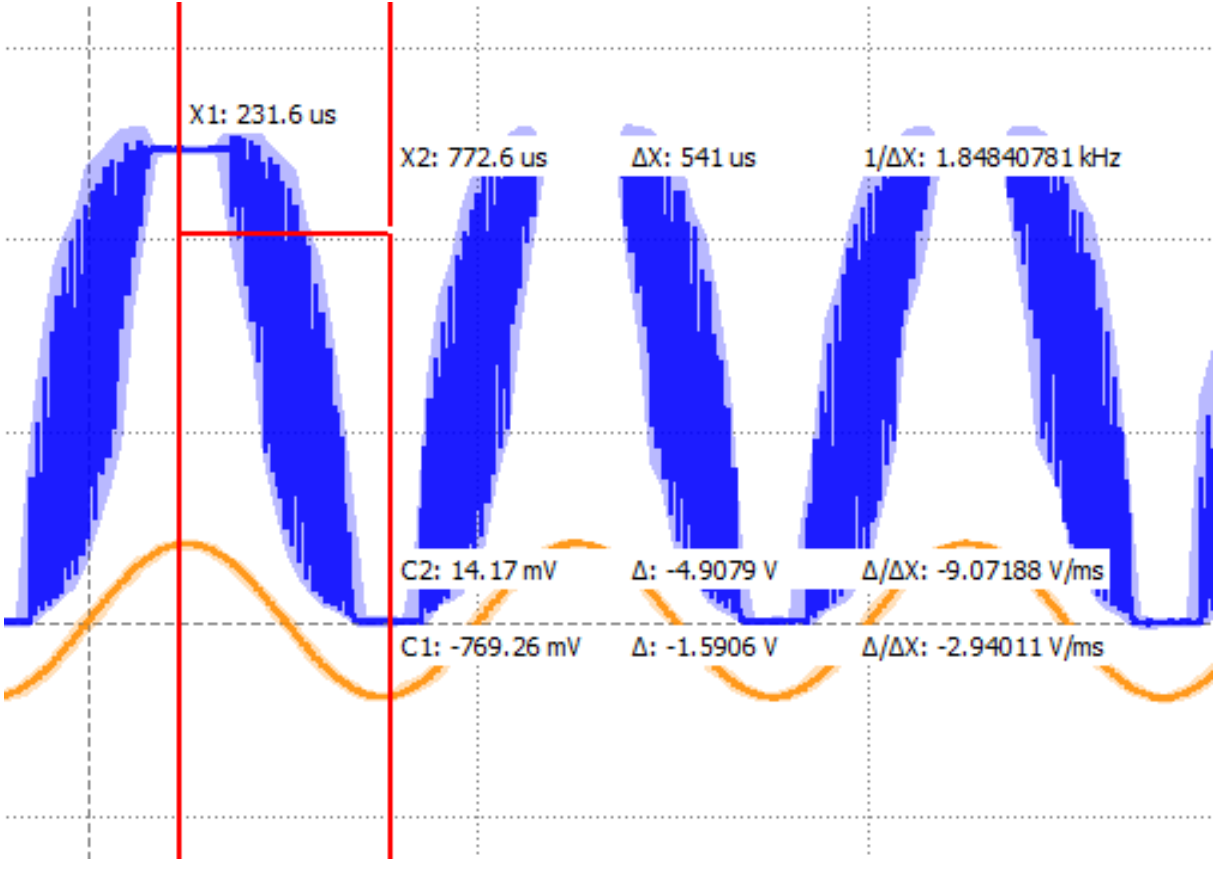
$$C = \frac{1}{2\pi f_c \times R_L \times \sqrt{2}}$$



Simulated Results

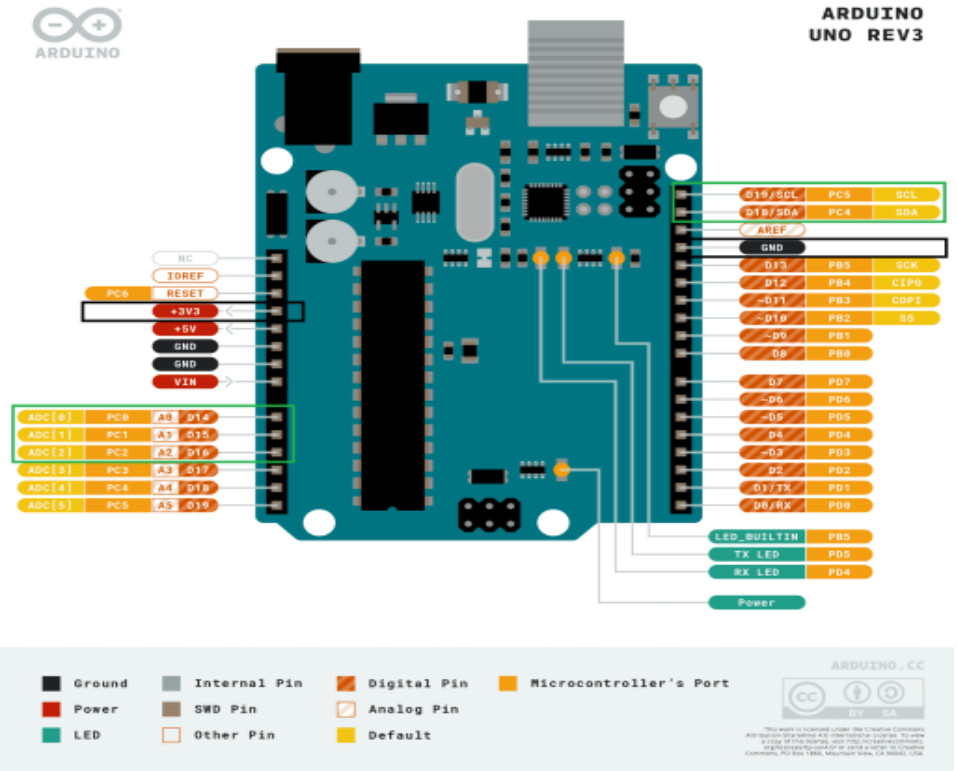


Validated Results



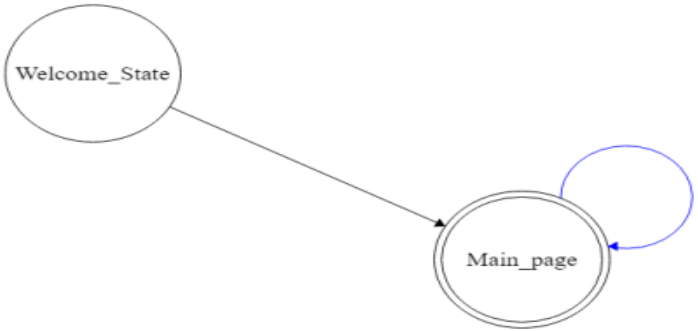
User Interface

- Arduino with 128x64 LCD screen (I2C)
- 1 pins reserved for spectrogram
- 3.3V power and ground for LCD

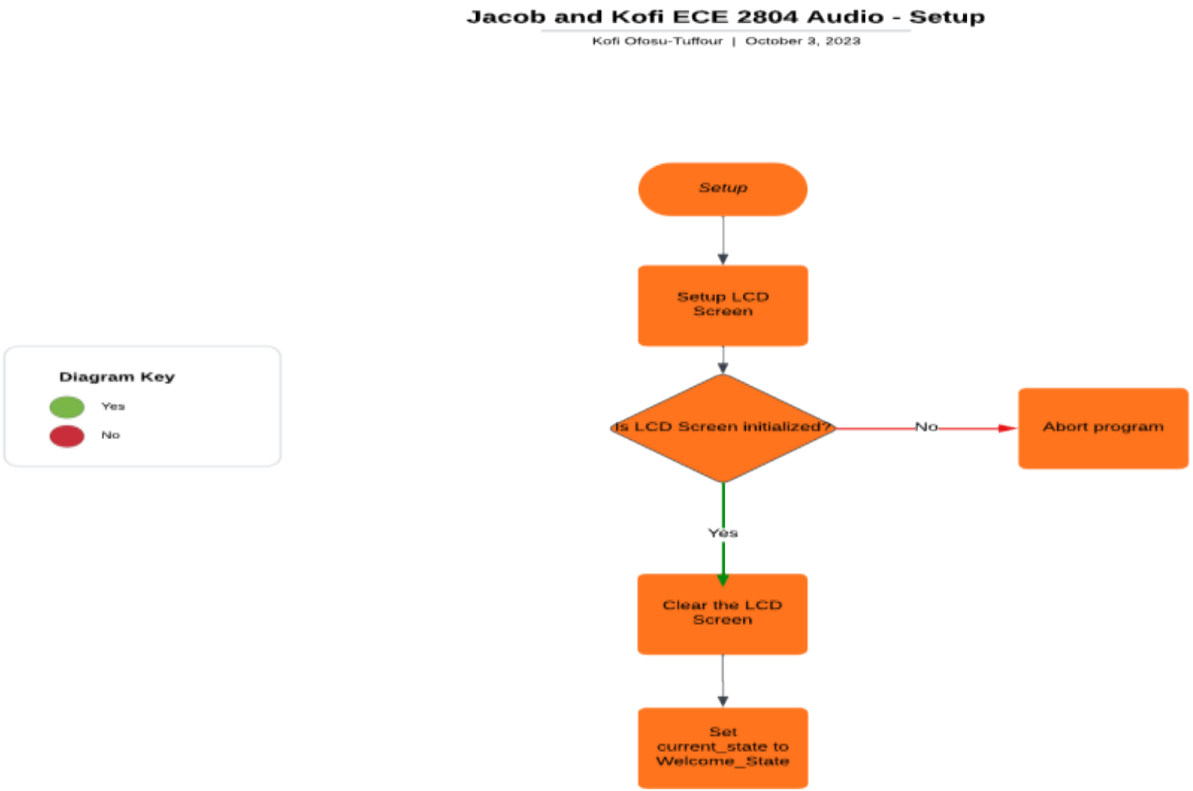


User Interface

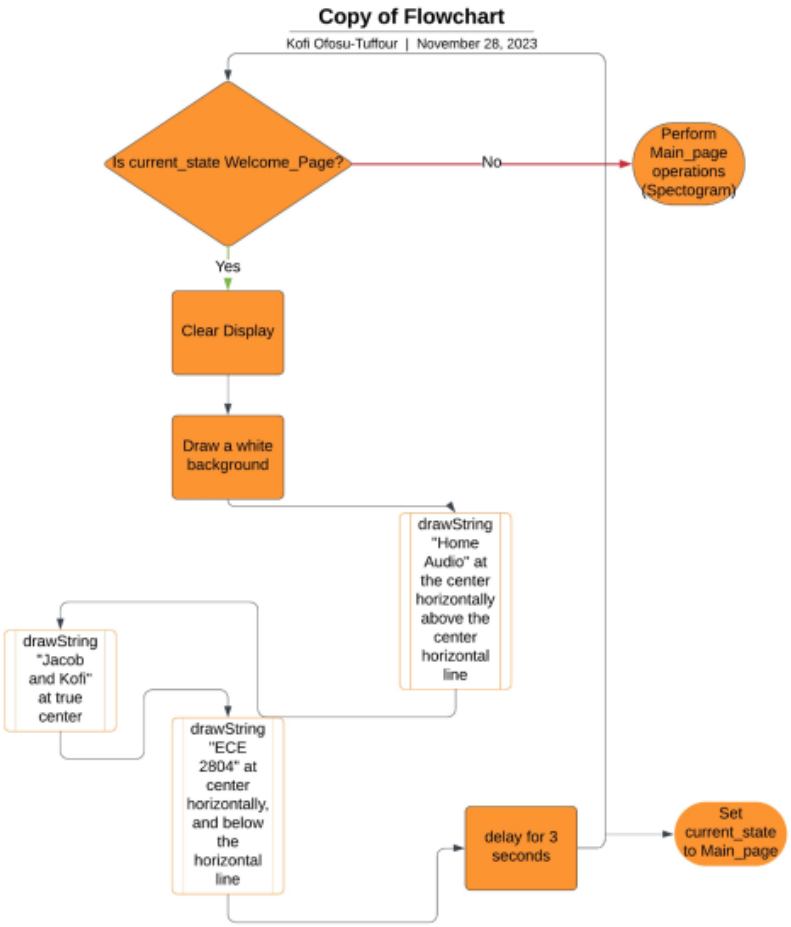
- Two important states
  - Welcome state
  - Main page state



User Interface – Setup

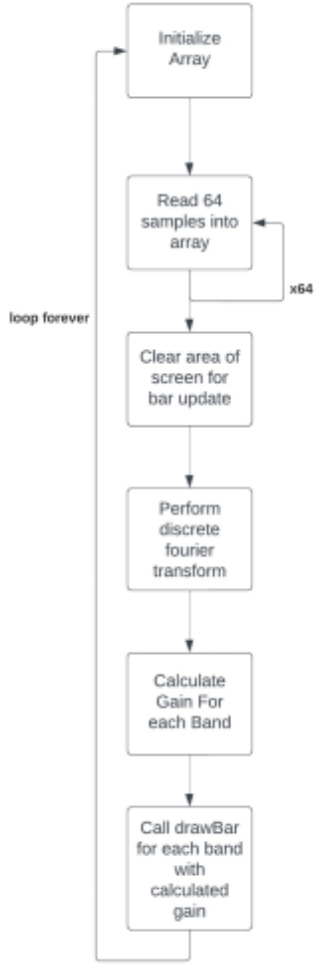


User Interface – Loop

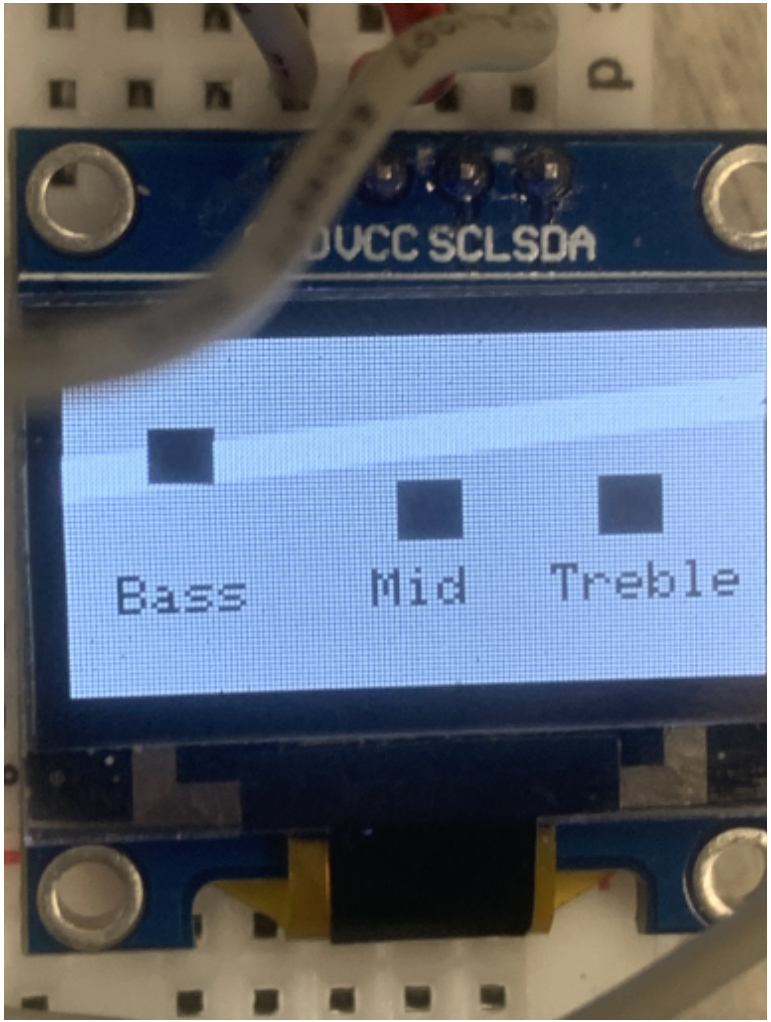


User Interface - Loop

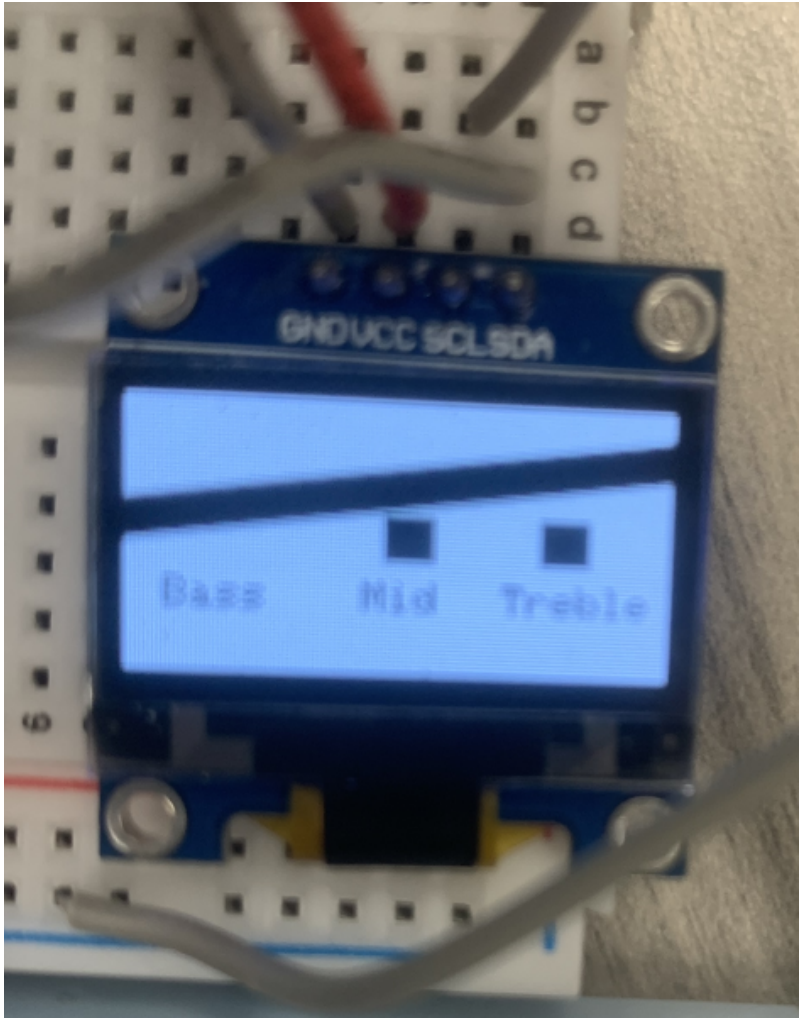
Spectrogram



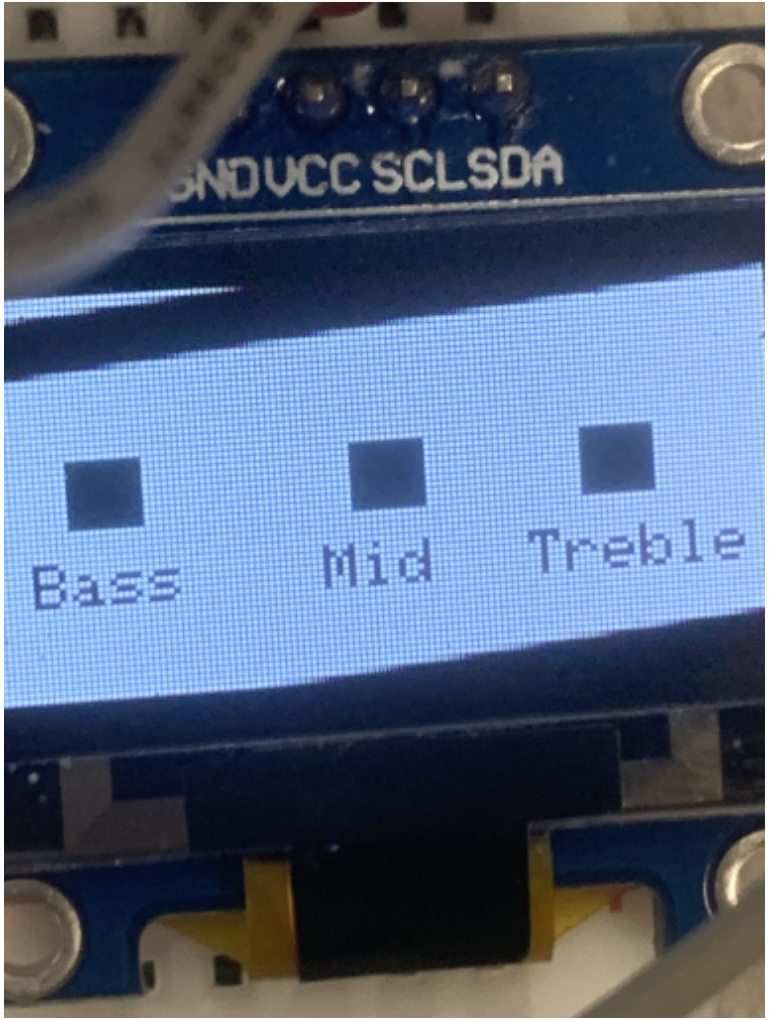
Bass Testing - Max Gain



Bass Testing - No Gain



Bass Testing - Attenuated Gain



Questions?