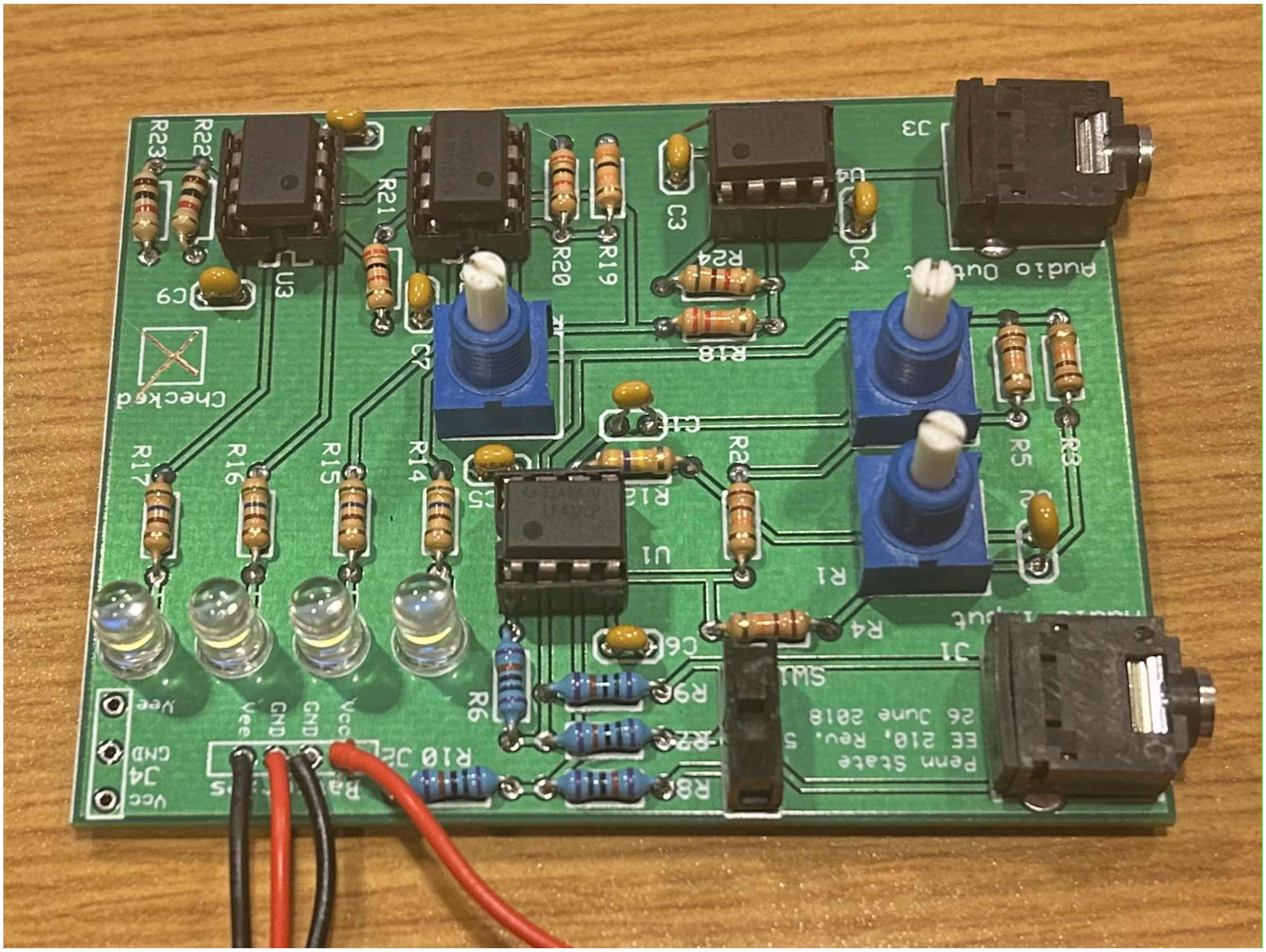
Baby’s First Mixer



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Baby's First Mixer

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EE210 Lab Section 7
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1. Introduction

The goal of this project is to develop a circuit that processes audio input in two modes: mixing the left and right channels or subtracting them to create a karaoke effect. Additionally, the circuit features a mixer component for adjusting the bass and treble of the audio. A volume control is also integrated, accompanied by LEDs that indicate the current volume level, with more LEDs illuminated for louder volumes.

2. Design and Simulation

2.1. Block 1: Mixer/Karaoke

Design Objective

This block takes an input audio signal and can perform two functions: mixing the left and right audio inputs or subtracting them. The subtraction operation creates a karaoke effect by eliminating frequencies shared between the left and right waves. The maximum output voltage is capped at 9V, aligning with the power voltage supplied to the op amp.

Schematic

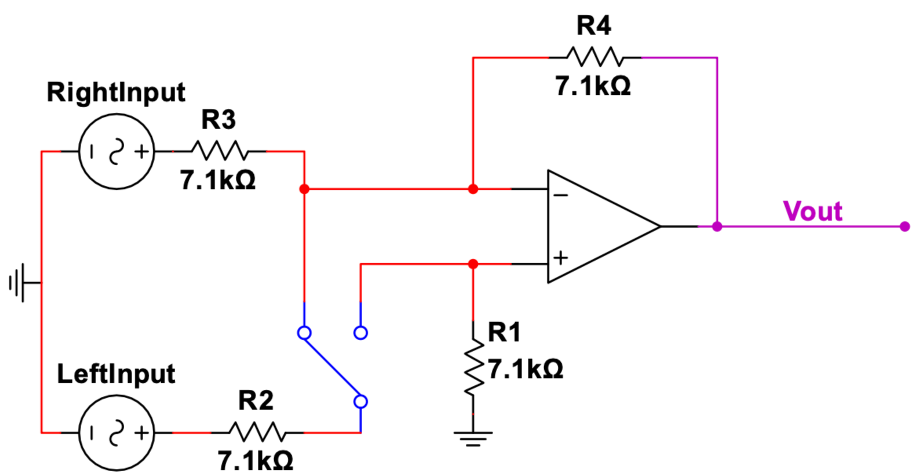

Figure 1: With switch in left position, the circuit is a inverted summing amplifier. In the right position, it is a difference amplifer.

Theory of Operation

When the circuit is in mixing mode, it is an inverting summing amplifier following the equation

$$V_{\text{out}} = -\frac{R_4}{R_2}V_{\text{left}} - \frac{R_4}{R_2}V_{\text{right}}$$

When the circuit is in karoke mode, it is a difference amplifer following the equation

$$V_{\text{out}} = \left(\frac{R_3 + R_4}{R_2 + R_1}\right)\frac{R_1}{R_3}V_{\text{left}} - \frac{R_1}{R_3}V_{\text{right}}$$

Derivations and Analysis

We want the right and left inputs to be equally mixed in mixer mode, and we want them to be exactly subtracted in karoke mode. For this to be the case, $R_1 = R_2 = R_3 = R_4$. All resistors being equal simplifies the equations to

$$\text{Mixer: } V_{\text{out}} = -\left(V_{\text{left}} + V_{\text{right}}\right)$$

$$\text{Karoke: } V_{\text{out}} = V_{\text{left}} - V_{\text{right}}$$

Since the only constraints are all values being equal, the values are not unique. $7.1k\Omega$ were choosen arbitrarily because they have a 1% tolerance. This is important in order to have precise subtraction of the sound waves.

Simulation Results

These images have been generated in a simulation used values idential to the actual circuit. These waveforms match an oscilloscope capture from the actual circuit. The left channel consists of a 0.25V amplitude 110 Hz sinusoid plus a 0.25 V amplitude 880 Hz sinusoid. The right channel consists of a 0.25 V amplitude 3520 Hz sinusoid plus a 0.25 V amplitude 880 Hz sinusoid.

Mixer mode

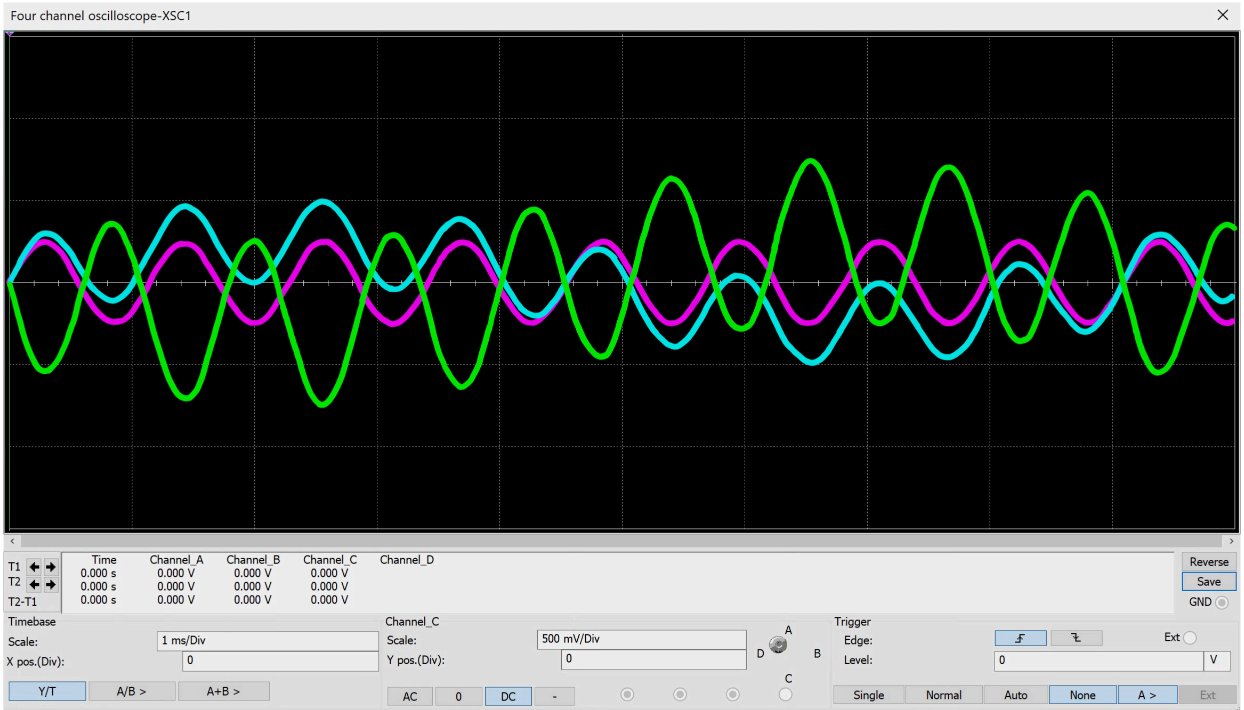

Figure 2: Simulated waveform showing the addition of the left and right wave forms, where pink is the right input, blue is the left input, and green is the output.

Karoke mode

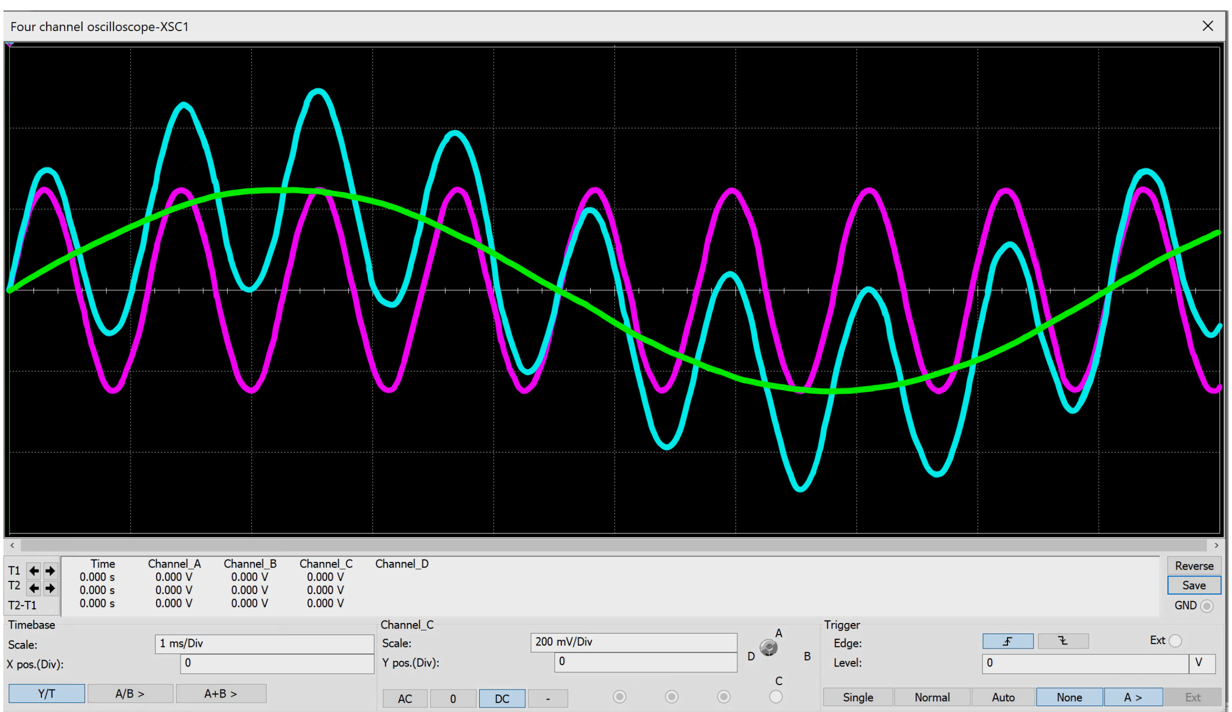

Figure 3: Simulated waveform showing the subtraction of the right from the left input, where pink is the right input, blue is the left input, and green is the output.

2.2. Block 2: Tone Control

Design Objective

This block is the Baxandall tone-control circuit, where the input is the output of block 1. The circuit controls the bass and trebel of the audio.

Schematic

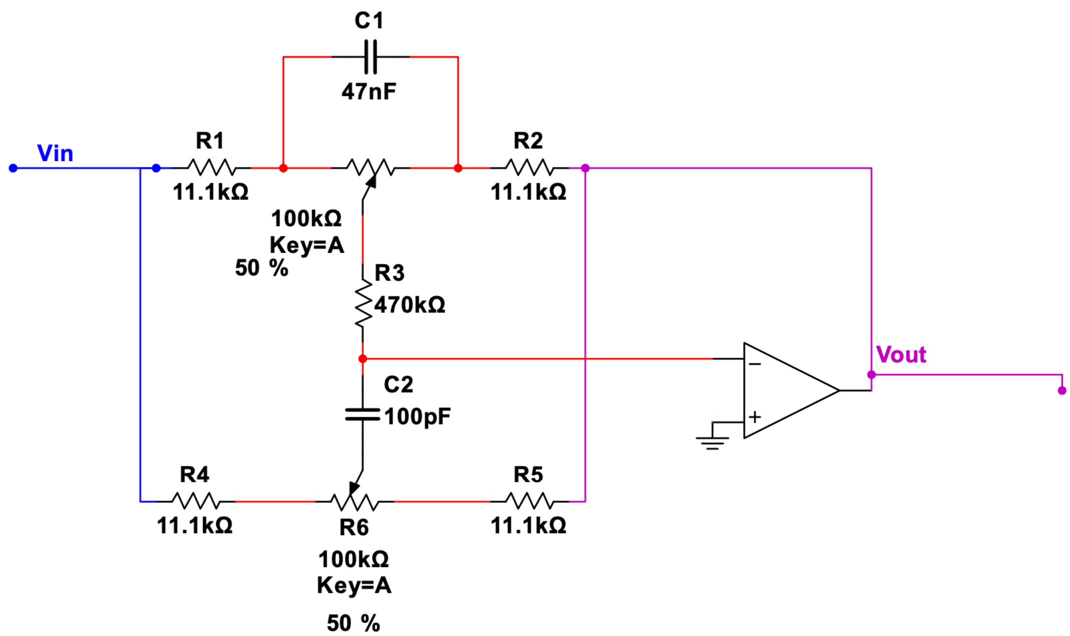

Figure 4: Baxandall tone-control circuit design.

Theory of Operation

The circuit works based capacitors act like open circuits are low frequencies and short circuits at high frequencies. Since $C_2 \ll C_1$, it has a higher impedance for any given frequency, so it acts like an open circuit for higher frequncies than C_1.

For high frequencies, both capacitors act like a short circuit, connecting the bottom potentiometer (pot), and making the top pot have no effect on the circuit.

For low frequencies, both cpacitors act like open circuits, so the bottom pot has no effect on the circuit because it is connected to an open circuit.

For mid frequencies, C_1 acts like a short circuit, and C_2 acts like an open circuit, meaning neither pot has effect on the circuit.

R_1 and R_2 control the max bass gain, while R_3 and R_4 control max trebel gain ($R_1 = R_2, R_3 = R_4$).

$$\text{Maxiumum gain: } \frac{R_{\text{pot}} + R}{R}$$

$$\text{Minimum gain: } \frac{R}{R_{\text{pot}} + R}$$

Derivations and Analysis

For my circuit I wanted a maximum gain of 10. With $R_{\text{pot}} = 100000$, meaning

$$\frac{100000\Omega + R}{R} = 10 \Rightarrow R = 11.1k\Omega$$

The values for the resitors vary depending on how much max gain wanted for bass and treble respectively.

Simulation Results

These images have been generated in a simulation used values idential to the actual circuit. These waveforms match an oscilloscope capture from the actual circuit, where green is the input and pink is the output. The input for the simulations are from the mix mode results from block 1.

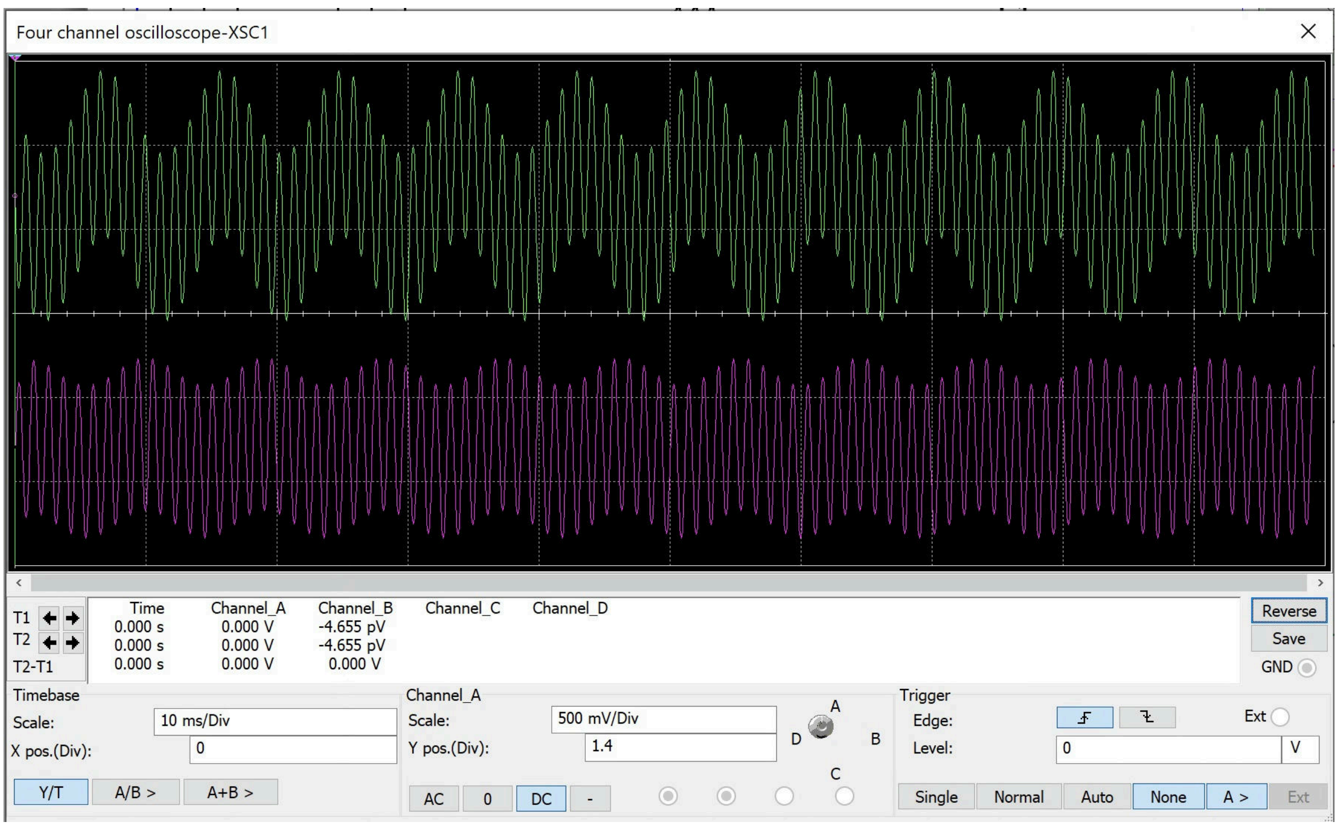

Figure 5: Max trebel

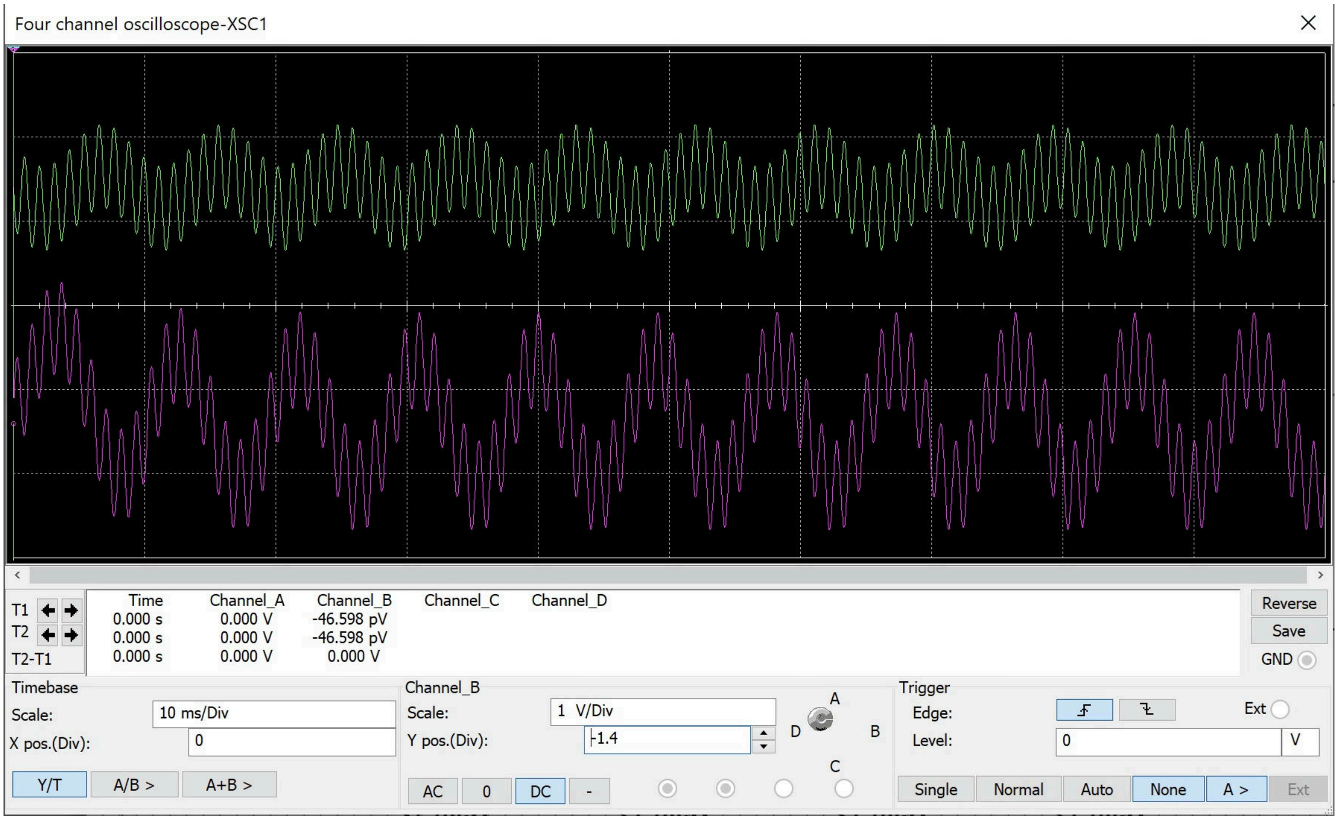

Figure 6: Max Bass

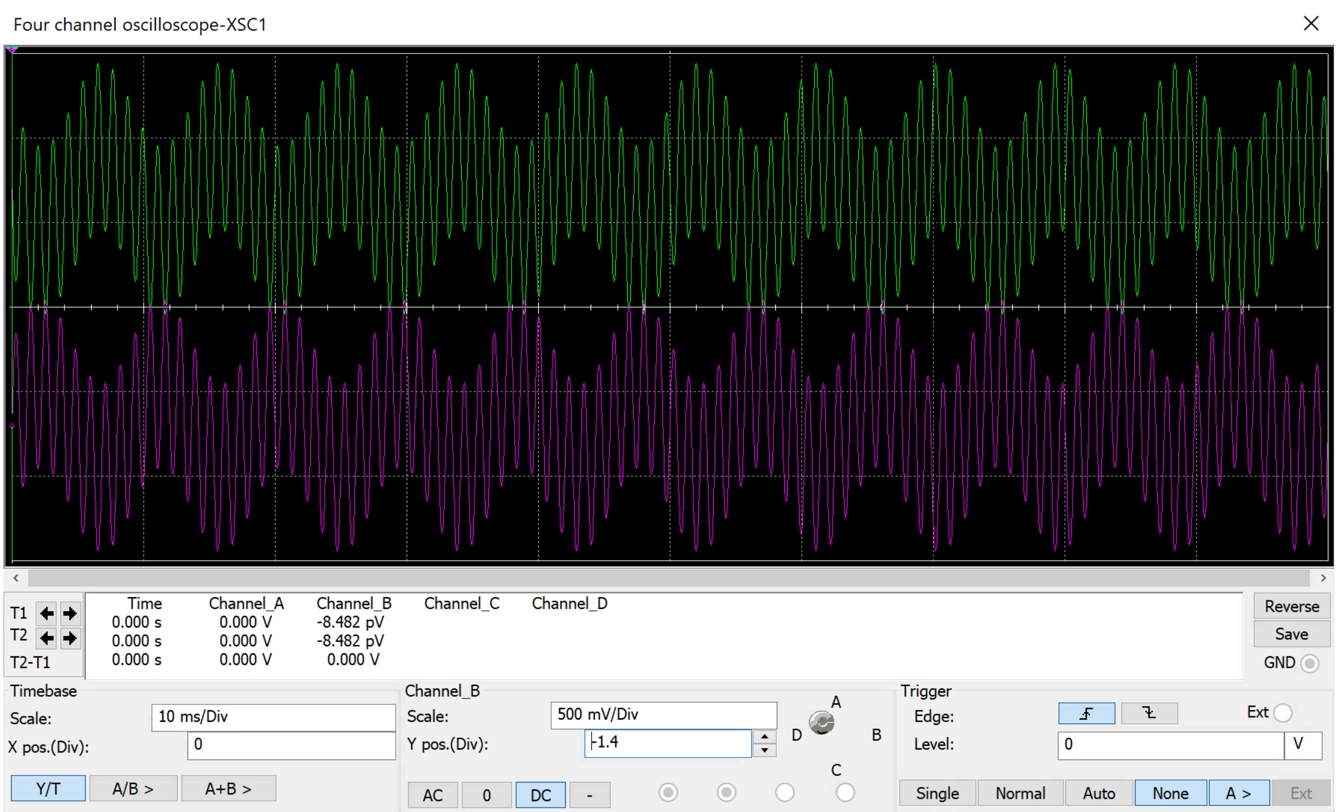

Figure 7: Flat response

2.3. Block 3: Volume Control

Design Objective

This block controls the volume of the output audio, where the input is the output of block 2. The volume can range from 0 to max.

Schematic

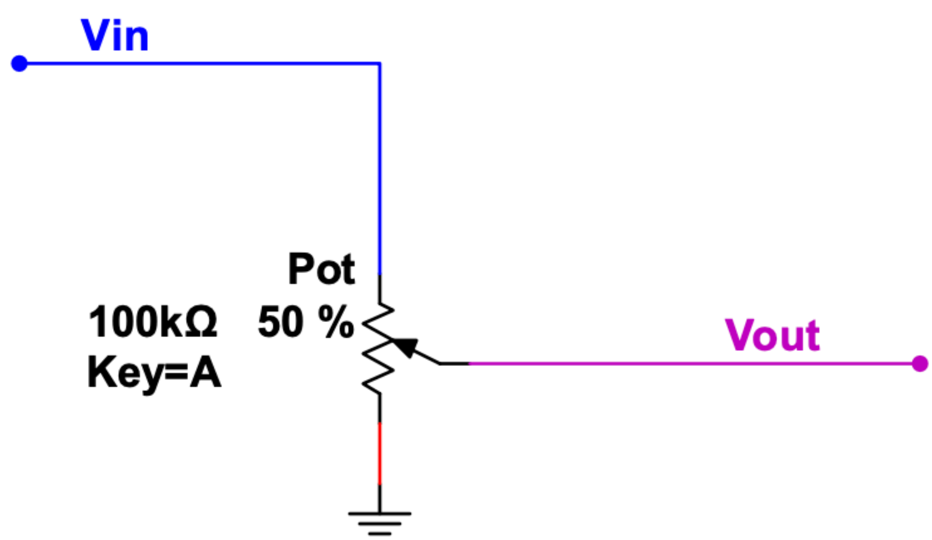

Figure 8: Potentiometer that controls output volume.

Theory of Operation

The vairable resistance from the potentiometer allows for it to controll the volume. It can range from 0 to the max output from block 2.

Derivations and Analysis

I have 100kΩ potentiometers, so that is what I used for this block of the circuit.

2.4. Block 4: Volume Display

Design Objective

This block takes in the output from block 3, and lights up 0-4 LEDs depending on the output voltage, corresponding to the volume of the output.

Schematic

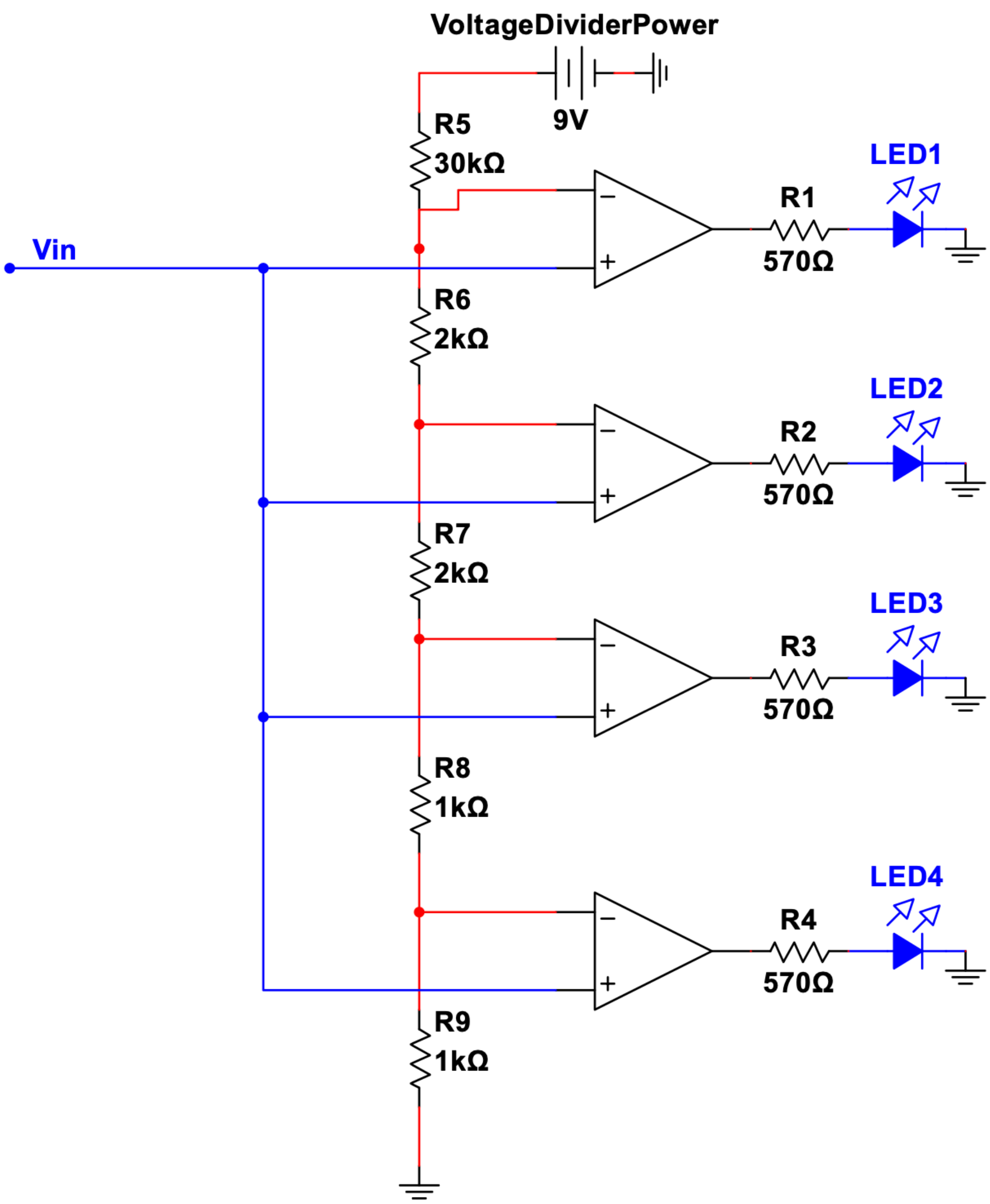

Figure 9: Comparitor circuit using voltage divider to sequentially light LEDs.

Theory of Operation

The circuit works by using op amps as comparitors, comparing the input voltage from block 3 to the voltage on input from the voltage divider. The comparison values are 1.5V, 1V, .5V, and .25V.

To determine the values for the resistors on the voltage divider, the following systems of equations must be solved:

$$\begin{cases} V_{\text{in}} \cdot \frac{R_9}{R_{\text{tot}}} = .25 \\ V_{\text{in}} \cdot \frac{R_9+R_8}{R_{\text{tot}}} = .5 \\ V_{\text{in}} \cdot \frac{R_9+R_8+R_7}{R_{\text{tot}}} = 1 \\ V_{\text{in}} \cdot \frac{R_9+R_8+R_7+R_6}{R_{\text{tot}}} = 1.5 \end{cases}$$

Derivations and Analysis

The V_{in} of the circuit is 9V, thus

$$\begin{cases} 9 \cdot \frac{R_9}{R_{\text{tot}}} = .25 \\ 9 \cdot \frac{R_9+R_8}{R_{\text{tot}}} = .5 \\ 9 \cdot \frac{R_9+R_8+R_7}{R_{\text{tot}}} = 1 \\ 9 \cdot \frac{R_9+R_8+R_7+R_6}{R_{\text{tot}}} = 1.5 \end{cases}$$

Since there are 4 equations and 5 unknowns, there are infinte many solutions, all following the pattern of $30 \cdot C = R_5, 2 \cdot C = R_6, 2 \cdot C = R_7, C = R_8, C = R_9$, for any constant C. For my design, I decided to choose C to be 1000.

2.5. Block 5: Attenuator and Output Driver

Design Objective

This block takes the output from block 3, and ensures that the output voltage is within the correct range for driving headphones (.5-1V). It is also the final block, meaning it gets connected to both the right and left output of the headphones.

Schematic

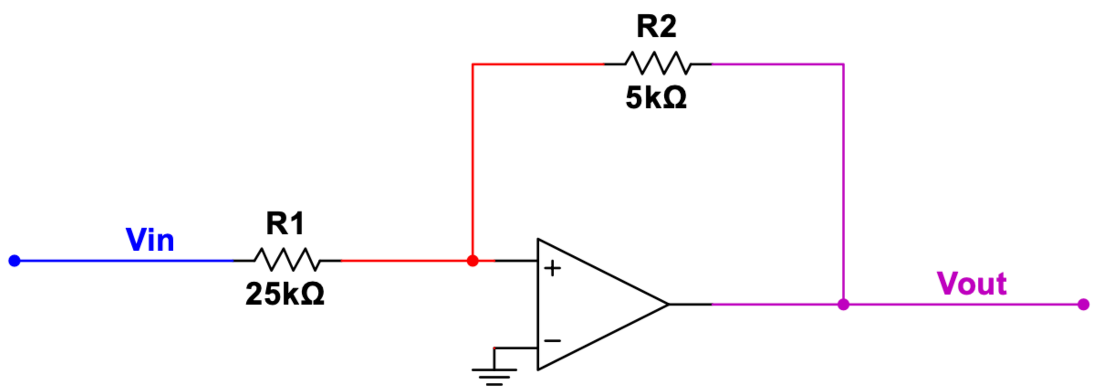

Figure 10: Inverting amplifier, cutting the output voltage by $\frac{1}{5}$.

Theory of Operation

The circuit uses an inverting amplifer to cut down the output voltage.

$$G = \frac{R_1}{R_2}$$

Derivations and Analysis

Using the max possible gains from block 1 and block 2, theoretically, the gain should be $\frac{1}{10}$, but after real life experimenting, the best gain found was $\frac{1}{5}$.

Simulation Results

This image has been generated in a simulation used values idential to the actual circuit. This waveforms matches an oscilloscope capture from the actual circuit, where green is the input and pink is the output.

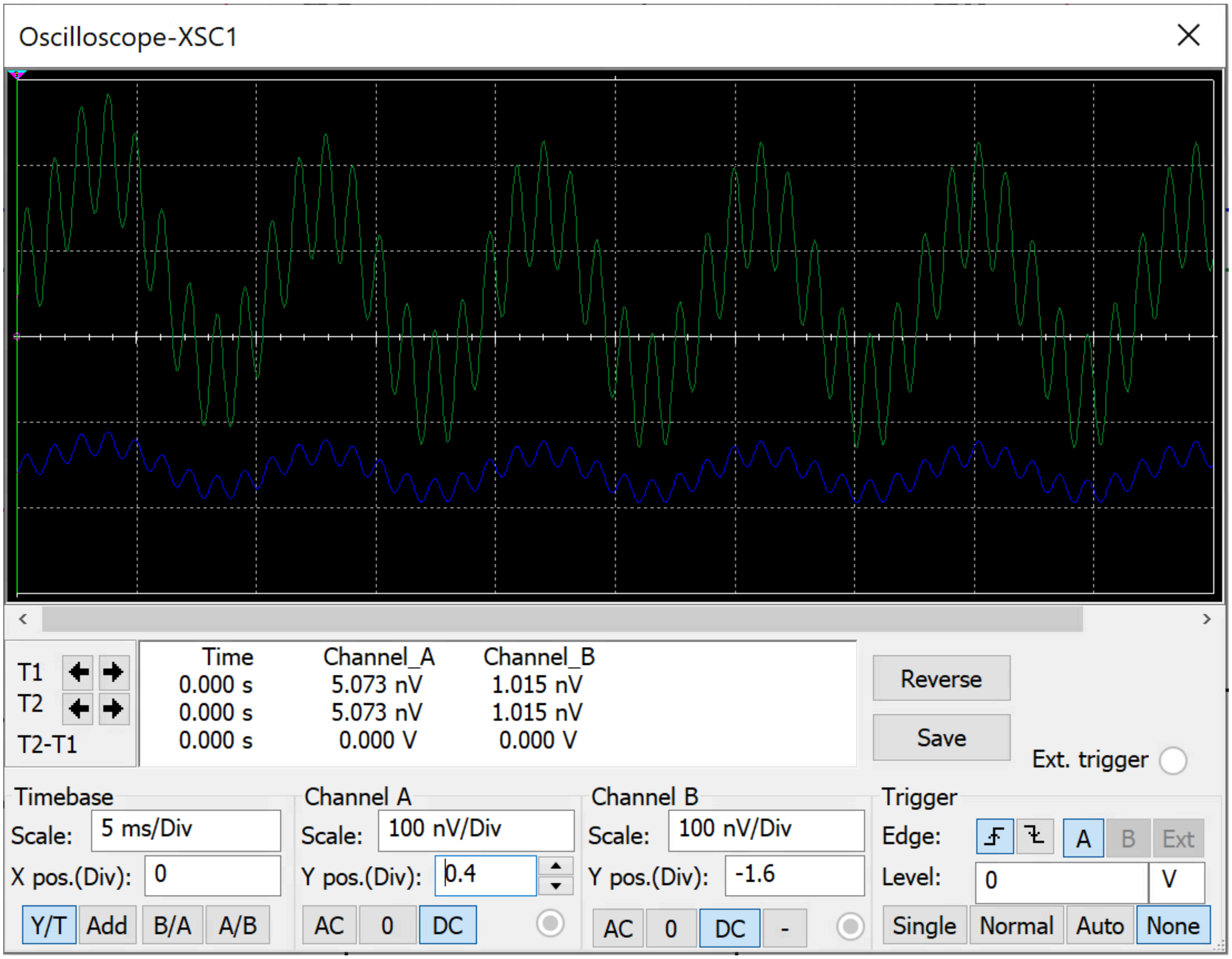

Figure 11: Output of block 5, where green is input and blue is output.

3. Breadboard and PCB Photos

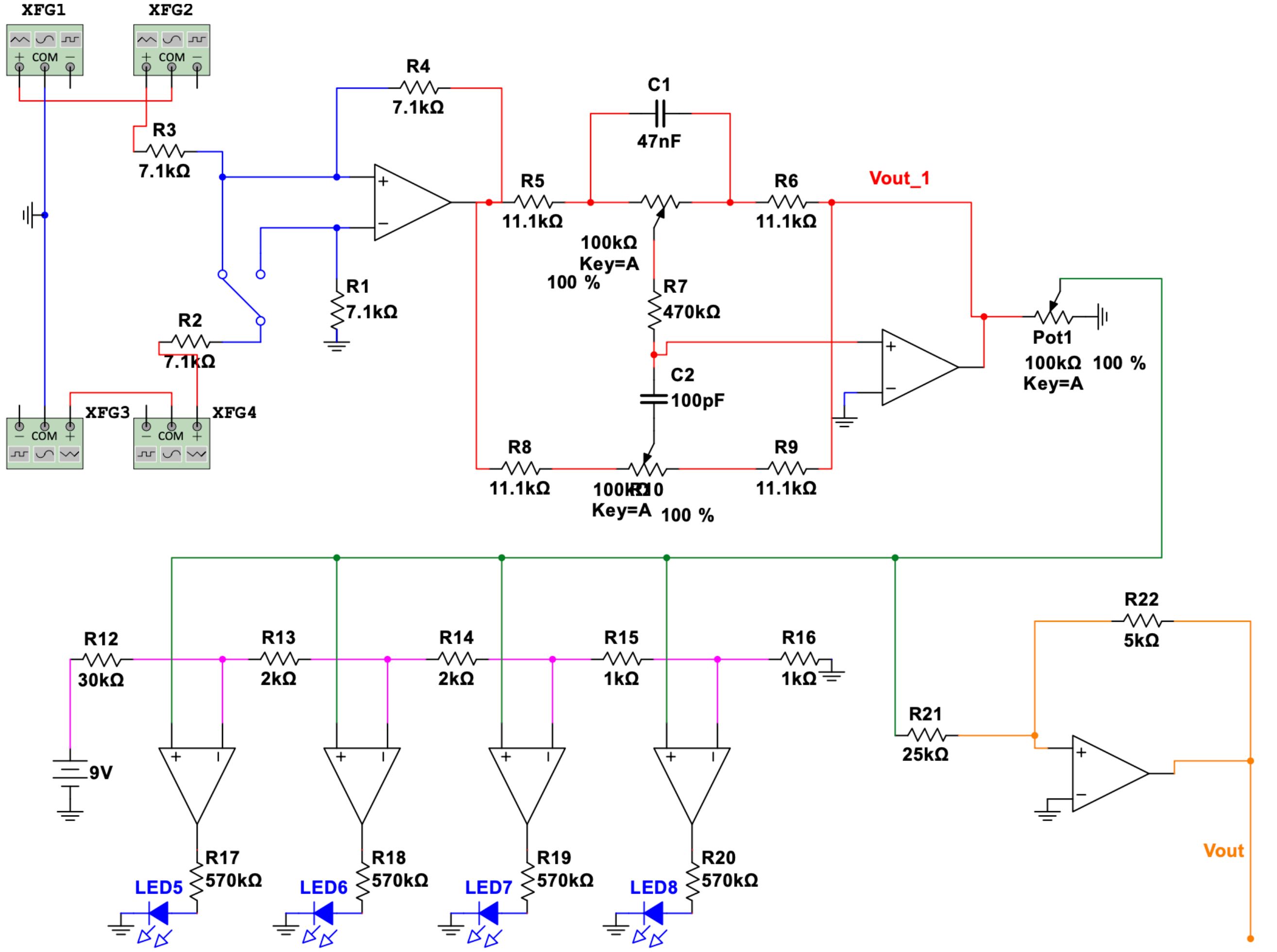

Figure 12: Full circuit schematic with all blocks connected, right and left inputs are represented by function generators.

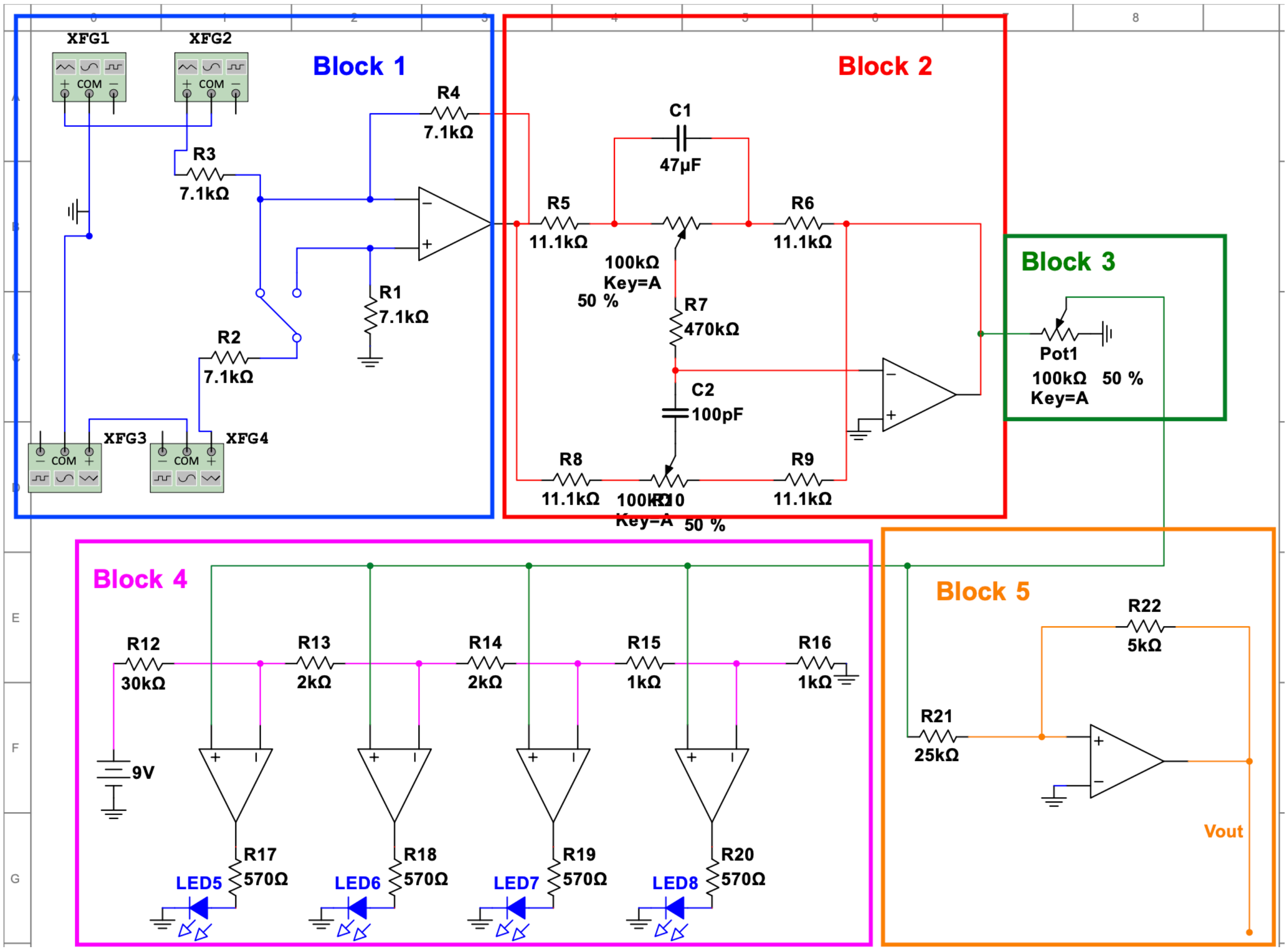

Figure 13: Full circuit schematic with blocks outlined.

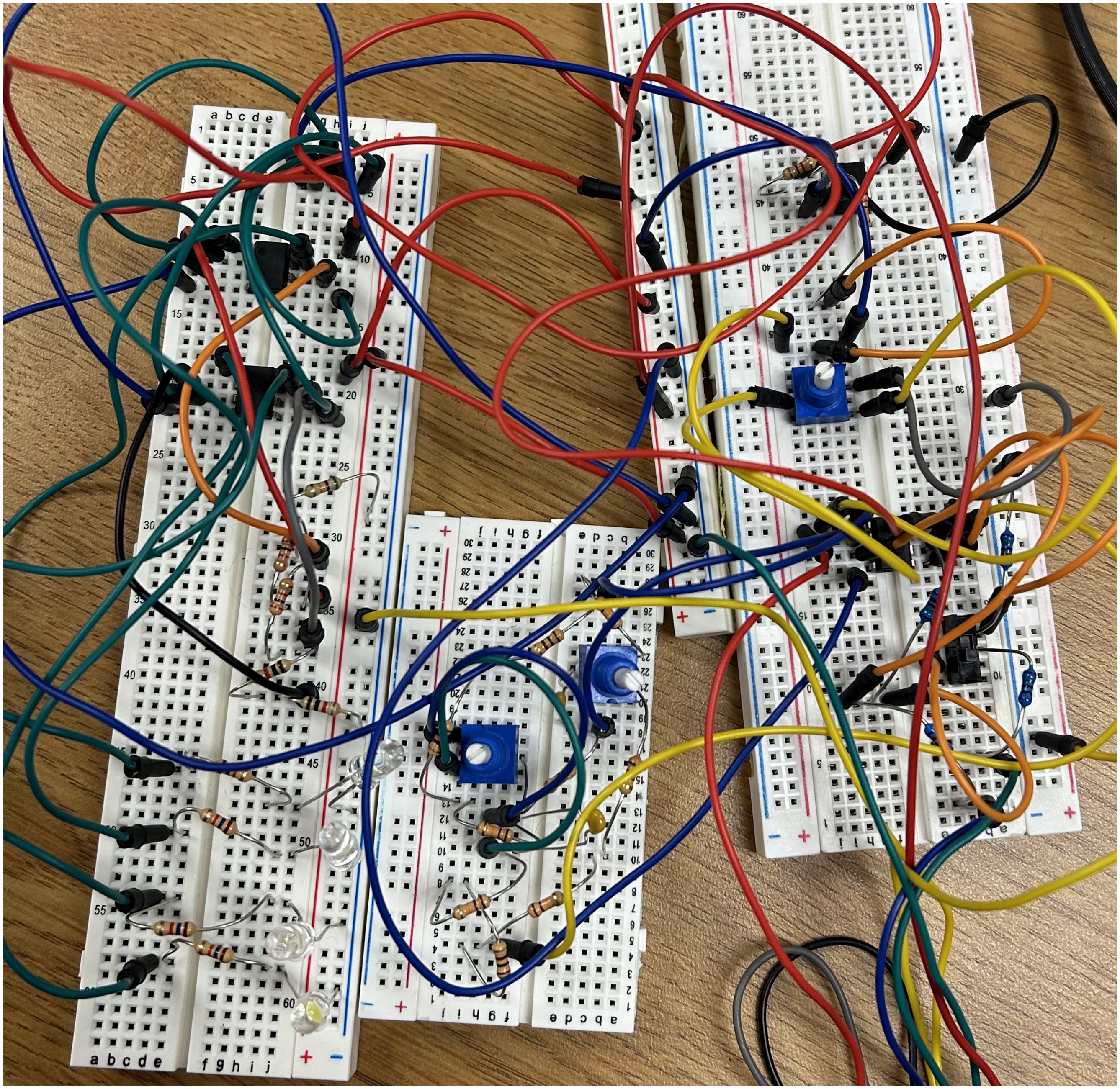

Figure 14: Breadboard prototype

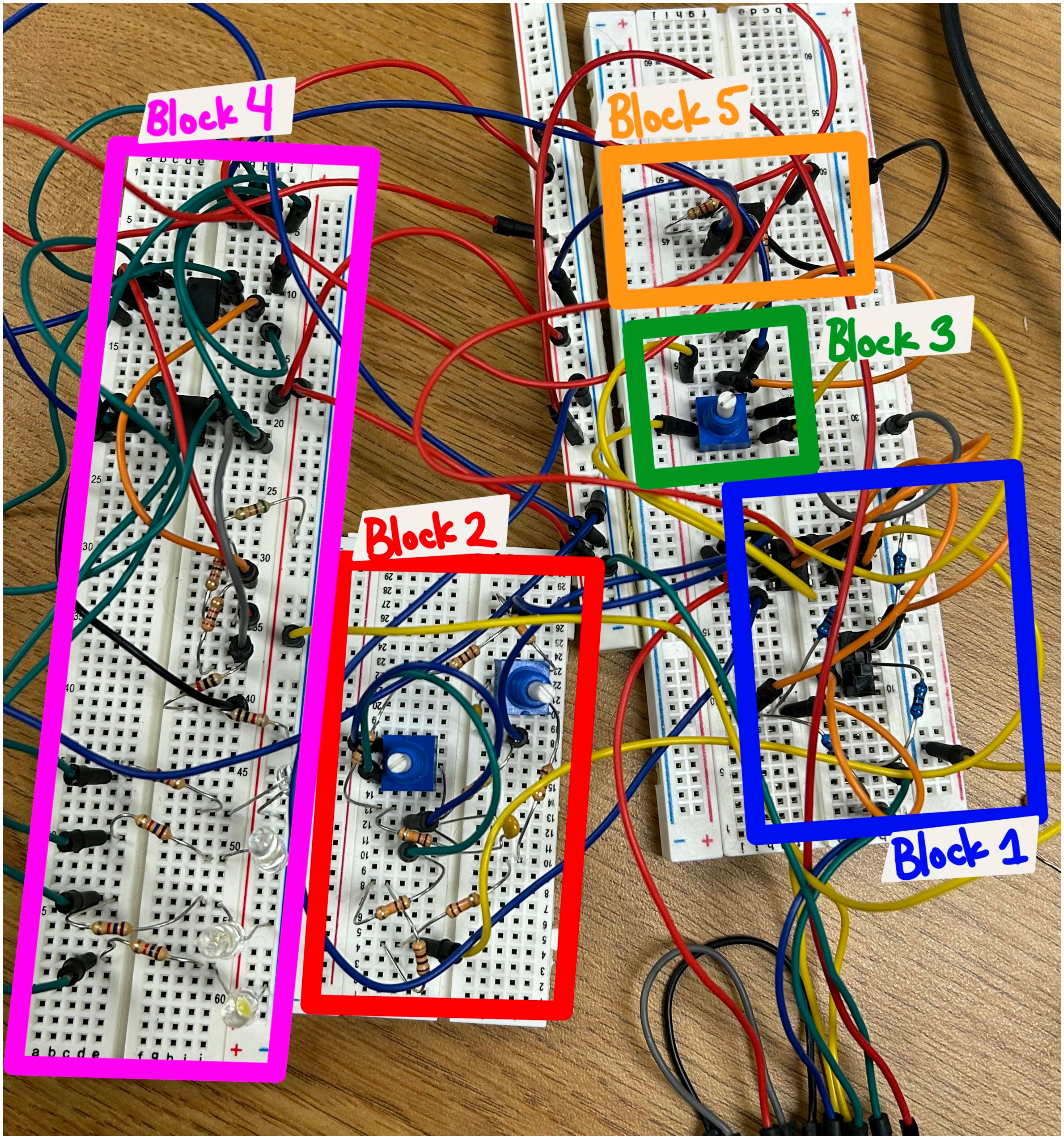

Figure 15: Breadboard prototype with blocks outlined

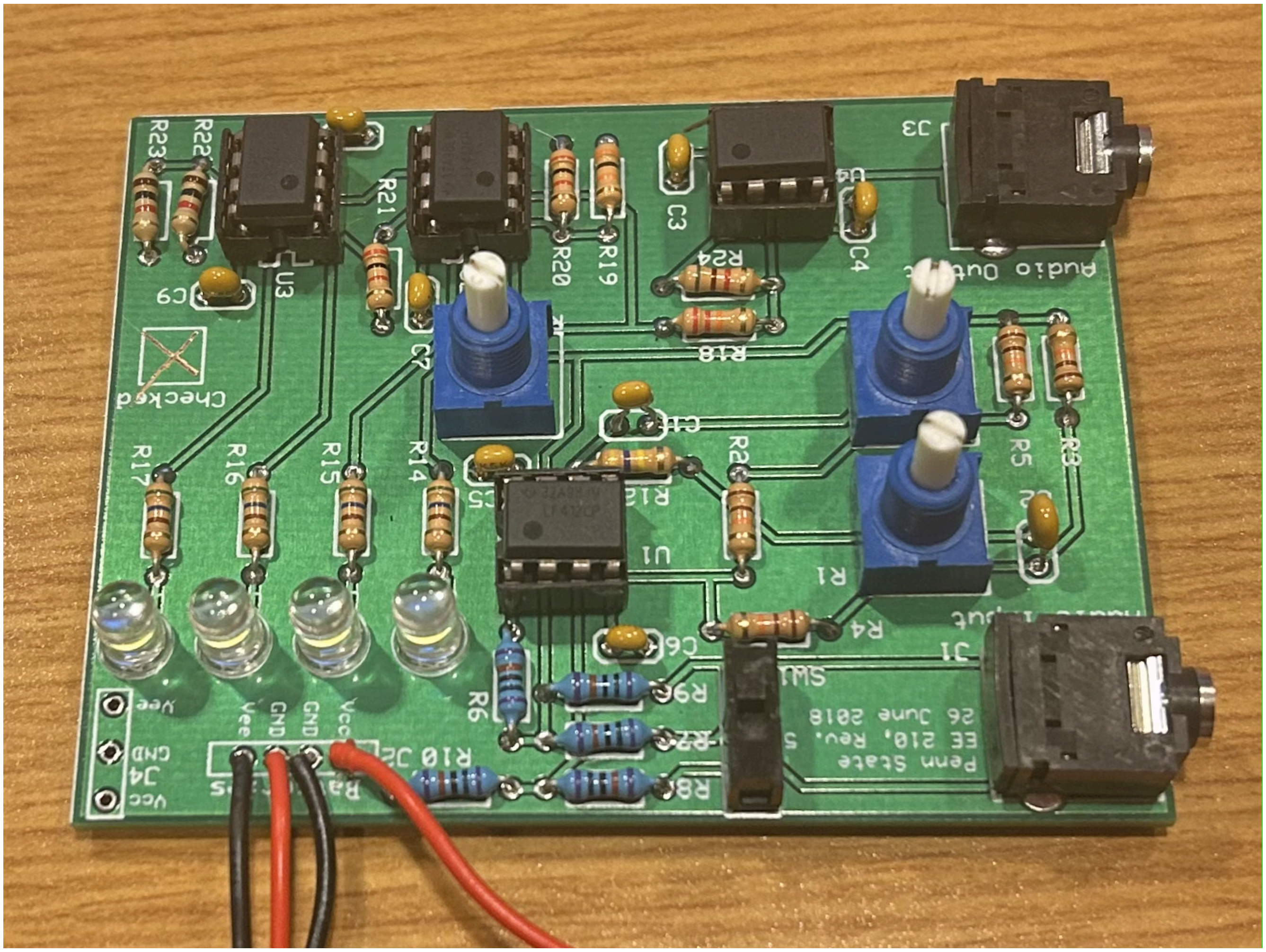

Figure 16: Fully soldered final PCB

4. Conclusion

The successful completion of this project involved the design, assembly, and testing of multiple blocks of a multi-block circuit intended for audio signal processing. The meticulous construction of each block was crucial to achieving the desired functionality and performance of the overall system.

While I did not face many bumps along the way, one issue arose because at first I soldered the op amps directly into the PCB and did not realize they needed to be in cradles. Luckily I hadn't soldered too many components yet, so I made the decision to start from scratch.

This project provided valuable insight into the complexities of circuit design, and the importance of adapting designs to realworld constraints. The successful integration of the circuit components onto the PCB and the subsequent testing in real life scenarios proved the project an overall success.