Final Project Report

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5 May 2025

EE 210 Section 1

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# Introduction

*For the last 4 weeks of EE 210, I planned, designed, and created a tone-control/karaoke circuit with volume, bass, and treble adjustment controls. I planned out my circuit on paper and then designed and simulated each block in Multisim to verify if my designs were functioning correctly. Finally, I implemented my circuit on a breadboard and PCB.*

## Block 1: Mixer / Karaoke

### Design Objective

This block takes a left and right signal from an audio input, with the left being a 0.25V amplitude 110 Hz sinusoid plus a 0.25V amplitude 880 Hz sinusoid, and the right being a 0.25V amplitude 3250 Hz sinusoid plus a 0.25V amplitude 880 Hz sinusoid. The output of the block should manipulate the input signal in order to create a karaoke or mixer function, depending on the positioning of a SPDT selector switch.

### Schematic | Figure 1. Inverting Summing Amplifier / Subtracting Amplifier

A diagram of a circuit

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### Theory of Operation

In order to implement both the mixer and karaoke feature, I created a canonical inverting summing amplifier and subtracting amplifier circuit. When the switch is flipped up, the circuit becomes an inverting summing amplifier that adds the two signals together and produces an output that is –(L+R), creating the mixing feature. When the switch is down, the circuit now becomes a subtracting amplifier circuit where the output is L-R, which creates the karaoke feature.

### Derivations/Calculations

When building this circuit, it was important to have resistors that were identical in value to each other so that the gain is 1. Therefore, in my Multisim design, I chose to make all my resistors 10kOhms. When implementing Block 1 on my breadboard and PCB, however, I chose 7.5kOhm resistors because those resistors were available in the EE210 Parts Kit and had a low tolerance of 1%.

### Simulation Results

A diagram of a sound wave

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Figure 2. Block 1 – Mixer Mode

A screen shot of a graph

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Figure 3. Block 1 – Karaoke Mode

## Block 2: Tone Control

### Design Objective

The objective of this block is to take the output of Block 1 as an input and be able to control the bass and treble of the sound signal by turning the dials of two different potentiometers. This block is modeled after the Baxandall tone-control circuit, which uses RC filters so that one part of the circuit blocks high frequency signals, and the other part blocks low frequency signals, allowing the user to control the bass and treble.

### Schematic | Figure 4. Baxandall Tone Control Circuit

A diagram of a circuit

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### Theory of Operation

The purpose of Block 2 is implemented by taking advantage of capacitors. The impedance of a capacitor can be modeled as -j/wC, so at very high frequencies that capacitor’s impedance is small and at low frequencies the impedance is high. As a result, the capacitor acts like an open circuit at low frequencies and a short circuit at high frequencies. Since the value of C1 is much greater than C2, at middle frequencies C1 can be seen as a short and C2 as an open circuit. Therefore, by adjusting the potentiometers, the user is able to control the treble and bass of the audio signal.

### Derivations/Calculations

For Block 2, I calculated the values of the R1, R2, R3, and R4 using maximum and minimum gain equations.

Max Gain: (Rp + R) / R = 10 Min Gain: R / (Rp + R) = 0.1

100kΩ + R = 10 R R / (100kΩ + R) = 0.1

100kΩ = 9 R R = 10kΩ + 0.1R

R = 11.1kΩ 0.9R = 10kΩ

R = 11.1kΩ

### Simulation Results

A screen shot of a computer

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Figure 5. Block 2 – Bass Boost

A screen shot of a computer

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Figure 6. Block 2 – Treble Boost

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Figure 7. Block 2 – Bass and Treble Attenuation

## Block 3: Volume Control

### Design Objective

The purpose of this block is to take the output of Block 2 as an input and be able to control the volume of the audio signal using a potentiometer as a voltage divider.

### Schematic | Figure 8. Volume Potentiometer

A diagram of a circuit

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### Theory of Operation

Block 3 works by using a 100kΩ potentiometer as a voltage divider. By adjusting the dial of the potentiometer, the resistance either increases or decreases. When the potentiometer is set all the way clockwise at max resistance, the resistance ratio is 1 and you end up with max volume. Inversely, when the potentiometer is set all the way counterclockwise at no resistance, the resistance ratio is 0 and therefore volume is also 0.

### Derivations/Calculations

100kΩ Potentiometer from EE210 Parts Kit

General Equation: Vout = Vin \* (Rwiper / Rpot)

Max Volume Achieved: Vout = Vin \* (100kΩ / 100kΩ) = Vin

Min Volume Achieved: Vout = Vin \* (0 / 100kΩ) = 0

### Simulation Results

A screen shot of a computer

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Figure 9. Block 3 – Volume Control

## Block 4: Volume Display

### Design Objective

The objective of Block 4 is to as an input the output of Block 3 and create a voltage display using four LEDs that each light up individually once the audio reaches a certain volume threshold. To implement this, I used a voltage divider, operational amplifiers, and LEDs.

### Schematic | Figure 10. Volume Display Reference Voltages

A diagram of a circuit

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### Theory of Operation

The basis of the volume display is four comparator op-amps that are each wired to a specific LED. When the voltage at the noninverting terminal exceeds the voltage at the inverting terminal, the op-amp drives its +15V power rail to its output. This output goes to an LED that is then turned on, with a resistor in between to limit the current so that it does not burn out the LED. As inputs for the comparator circuit, each op amp’s noninverting terminal is wired to the output of Block 3. For the inverting terminals, I created a ladder of resistors that act as voltage dividers, with four points of voltage drops being wired to their respective comparator op amp’s inverting terminal. As you go down the ladder, the voltage drop is greater, so the reference voltage decreases, meaning that the LED for that comparator will turn on at a lower volume threshold.

### Derivations/Calculations

For LED 1, LED 2, LED 3, and LED 4 to turn on at 0.25V, 0.5V, 1.0V and 1.5V respectively, I did the following math…

V1 = (1.5V/15V) \* 60Ω (Total Resistance) = 6 Ω below

R1 = 60 Ω - 6 Ω = 54 Ω

V2 = (1.0/15V) \* 60 = 4 Ω below

R2 = (60 Ω - 4 Ω) – R1 = 2 Ω

V3 = (0.5/15V) \* 60 = 2 Ω below

R3 = (60 Ω – 2 Ω) – (R1+R2) = 2 Ω

V5 = (0.25/15V) \* 60 = 1 Ω below

R4 = (60 Ω - 1 Ω) – (R1+R2+R3) = 1 Ω

R5 = 60 – (R1+R2+R3+R4) = 1 Ω

Rlimiting = 15V /

### Simulation Results

A screen shot of a graph

AI-generated content may be incorrect.Figure 11. Block 4 – Volume Display

## Block 5: Attenuator and Output Buffer

### Design Objective

The purpose of Block 5 is to attenuate the audio amplitude from Block 3 so that it can be received safely by headphones or audio hearing devices. This block should attenuate the audio signal to an appropriate range of 0.5V to 1V. The output of this block should be connected to the audio jack of a headphone or hearing device.

### Schematic | Figure 12. Inverting Operational Amplifier

A diagram of a circuit

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### Theory of Operation

Block 5 works by using a canonical inverting operational amplifier. Since the gain of this op-amp is the feedback resistor over the input resistor, we can create a small gain by making the input resistor far greater than the feedback resistor. Additionally, to minimize the loading from Block 3, both resistors should be very large.

### Derivations/Calculations

Vout = (-Rf/Rin) \* Vin

Block 1 Max Output : -(1+1) = -2V

Block 2 Max Output: Max Gain \* (-2V) = 10 \* -2V = -20V

Block 3 Max Output: 1 \* (-20) = -20V

We want -Rf/Rin \* (-20V) <= 1V

So Rf/Rin <= 1/20

Rf = 1M Ω

Rin = 20 Ω

### Simulation Results

A screen shot of a computer

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Figure 13. Block 5 – Circuit Output

# Complete Assembly and Breadboard Images

*Block 1 (GREEN) : The implementation of Block 1 was a bit difficult for me at first because I was unfamiliar with how to wire the SPDT switch. After figuring out how the switch worked on the breadboard, the rest of the implementation of this block went rather straightforward.*

*Block 2 (RED) : The implementation of Block 2 was not too difficult, but the need to keep track of the different paths and being neat and organized caused me to take extra time in creating this block. The implementation of this block was similar to a previous lab so it was not too bad understanding how to wire things.*

*Block 3 (BLUE): The implementation of Block 3 was by far the easiest since it was only a potentiometer which I have used countless times in lab.*

*Block 4 (PURPLE): The implementation of Block 4 was the hardest for me because I had to troubleshoot it the most out of any of the blocks. More specifically, my LEDs were not turning on when they were supposed to. Eventually I found out that it was a grounding problem, and my LEDs started operating normally.*

*Block 5 (ORANGE): The implementation of Block 5 was straightforward since its just an inverting op-amp, but my output signal was a bit small which tells me that my gain of 1/20 was attenuating too much of the signal and I needed to make the ratio of the resistors closer in value. This was not too much of an issue, and it did was solved completely in the PCB version since I used different resistors for that.*

A circuit board with wires and wires

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*Figure 14. Breadboard Image*

# Figure 15. PCB Image

A green circuit board with black wires

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# Figure 16. Complete Schematic

A diagram of a computer

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# Conclusion

*Overall, the final project for EE210 was a success because I was able to create a mixer/karaoke circuit that had treble, bass, and volume controls. I had a lot of fun making this project and it was really exciting to finally be able to test and see all the features of the circuit working in both the breadboard and PCB versions. Additionally, the project was fulfilling because it required me to apply knowledge of the material I learned all semester in EE210.*