Analog Spectrum Music Visualizer

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1 Objective & Description

This project aims to build an analog spectrum analyzer/music visualizer. The system uses three strips of LEDs to indicate the power in three different frequency bands of audio. The input music is amplified, bandpass-filtered, then outputted onto three LED bars based on their frequency.

This project consists of three stages: amplification, filtering, and output. In the amplification stage, an LM386 voltage amplifier, electrolytic capacitors, and resistors are used to construct a circuit that amplifies the input music waveform. The oscilloscope displays the amplified, music-like waveforms. Next, the filtering stage uses OP07s and comprises three bandpass filters with different cutoff frequencies. The amplified input audio is split into these three frequency bands. These three filters are tested with pure tones of set frequencies. Their outputs are displayed by three LEDs to ensure that the right LEDs light up. Finally, the output stage employs LM3914s and LED bars to display the filters' outputs as flashing lights. The three LED bars light up based on how much audio falls within their frequency ranges.

1.1 Calculations

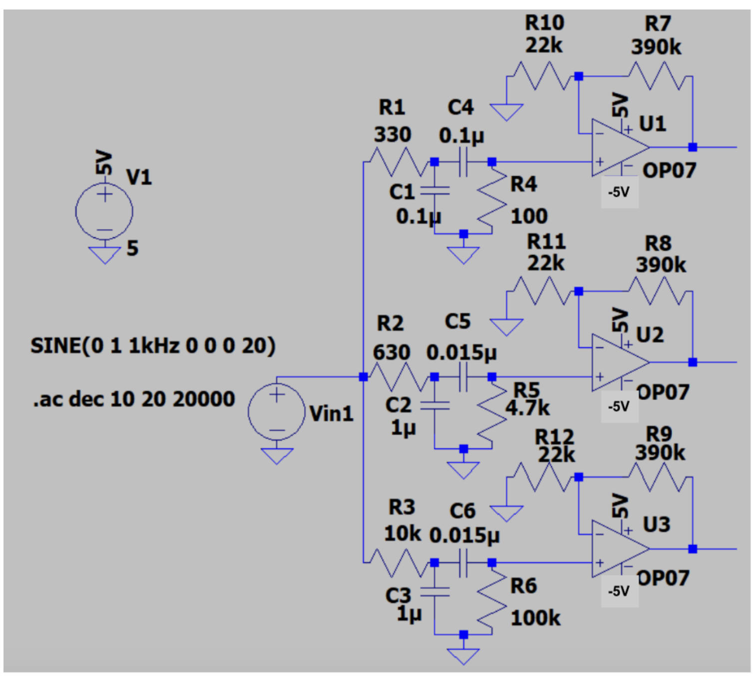

Figure 1: Schematic for filtering stage of analog spectrum analyzer

I calculated the lower and higher cutoff frequencies of each bandpass filter shown in Fig. 1 using the RC filter equation and the appropriate resistance and capacitance values.

1. Upper bandpass filter

- Lowpass cutoff:
$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(330\Omega)(0.1\mu F)} = 4.823kHz \tag{1}$$
- Highpass cutoff:
$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(100\Omega)(0.1\mu F)} = 15.915kHz \tag{2}$$

2. Middle bandpass filter
   - Lowpass cutoff:
$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(630\Omega)(1\mu F)} = 252.6Hz \tag{3}$$
   - Highpass cutoff:
$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(4.7k\Omega)(0.015\mu F)} = 2.258kHz \tag{4}$$
3. Lower bandpass filter
   - Lowpass cutoff:
$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(10k\Omega)(1\mu F)} = 15.92Hz \tag{5}$$
   - Highpass cutoff:
$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(100k\Omega)(0.015\mu F)} = 106.1Hz \tag{6}$$

1.2 Materials List/Bill of Materials

- Breadboard with BNC connectors
- Smaller breadboard
- Wires
- Red, green, and black banana cables
- Speaker with an aux splitter or a Mac computer
- 1 BNC cable
- 1 3.5mm audio jack
- 1 3.5mm aux cable
- 1 LM386 audio amplifier
- 3 OP07 operational amplifiers
- 1 LM3914 dot/bar display driver
- 3 LED bars
- 3 LEDs
- 1 100Ω resistor
- 4 330Ω resistors
- 1 470Ω resistor
- 1 630Ω resistor

- 1 2.2kΩ resistor
- 1 3.3kΩ resistors
- 2 4.7kΩ resistors
- 1 10kΩ resistor
- 3 22kΩ resistors
- 1 100kΩ resistor
- 3 390kΩ resistors
- 2 0.015μF capacitors
- 2 0.1μF capacitors
- 2 1μF capacitors
- 1 10μF capacitor
- 1 100μF capacitor

1.3 Procedure

1.3.1 Amplification

1. Construct the amplification stage using electrolytic capacitors according to the schematic in Fig. 2 and the wiring diagram in 3 (see next page).

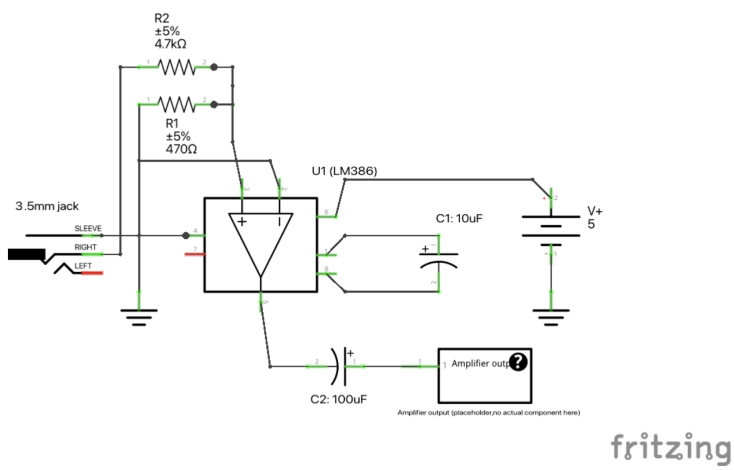

Figure 2: Schematic for amplification stage of analog spectrum analyzer

2. Connect the circuit to the Virtual Bench (VB) power supply and oscilloscope. Provide the breadboard with +5V, and play music through the 3.5mm aux cable and jack.

3. Observe the amplifier output, and ensure that music-like waveforms appear when music is playing and disappear when the song is paused.

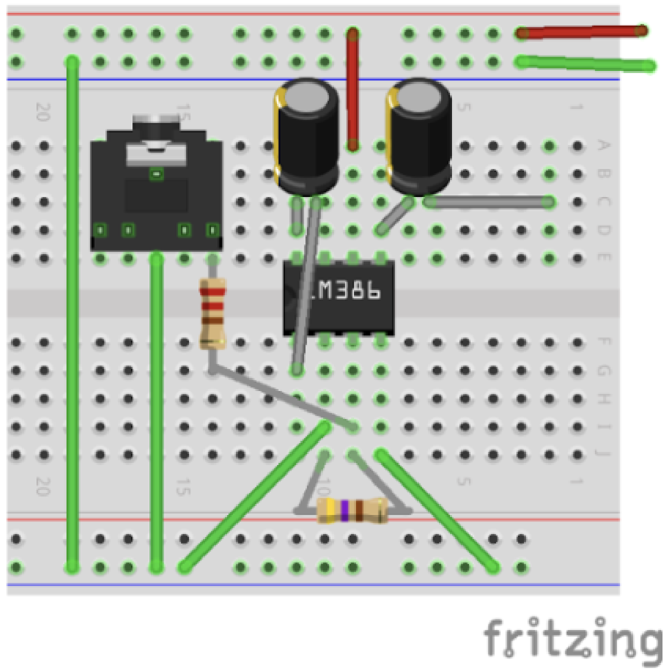

Figure 3: Wiring diagram for amplification stage of analog spectrum analyzer

1.3.2 Filtering

1. Construct the filtering stage using ceramic capacitors according to the schematic in Fig. 1, and connect the input of this stage to the output of the amplification stage.
2. Calculate the lower and higher cutoff frequencies for each bandpass filter in the filtering stage using the RC filter equation shown in Eq. 1-6.
3. Connect 330Ω resistors and LEDs to the output of each op amp as shown in Fig. 4 such that the LEDs represent increasing frequency bands moving left to right.

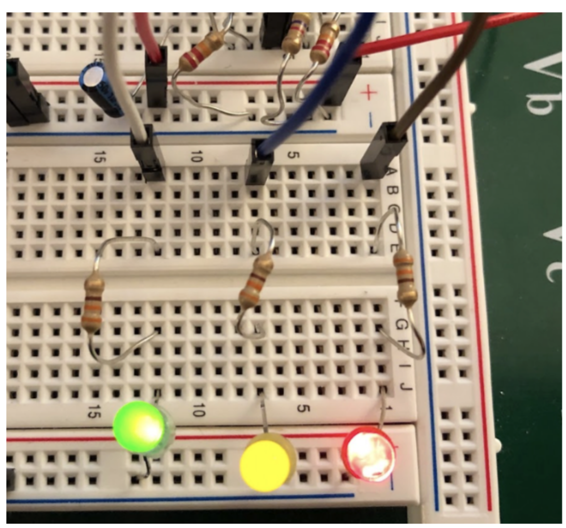

Figure 4: Testing setup for the filtering stage of the analog spectrum analyzer

4. Use the szynalski.com online tone generator to play pure tones to the analog spectrum analyzer, and ensure that the proper LEDs turn on and off as the frequency moves between 20Hz and 20kHz. Music can be used for additional testing.

1.3.3 Output

1. Construct the output stage using an LM3914 and an LED bar according to the schematic shown in Fig. 5 three times, and connect each one to the output of a bandpass filter from the previous stage. Bend one leg of the LED bar such that it touches another leg as shown in Fig. 6 before placing on the breadboard.

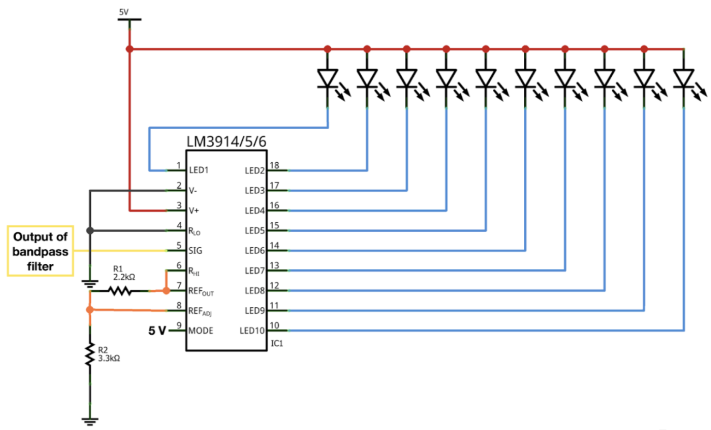

Figure 5: Schematic for the output stage of analog spectrum analyzer

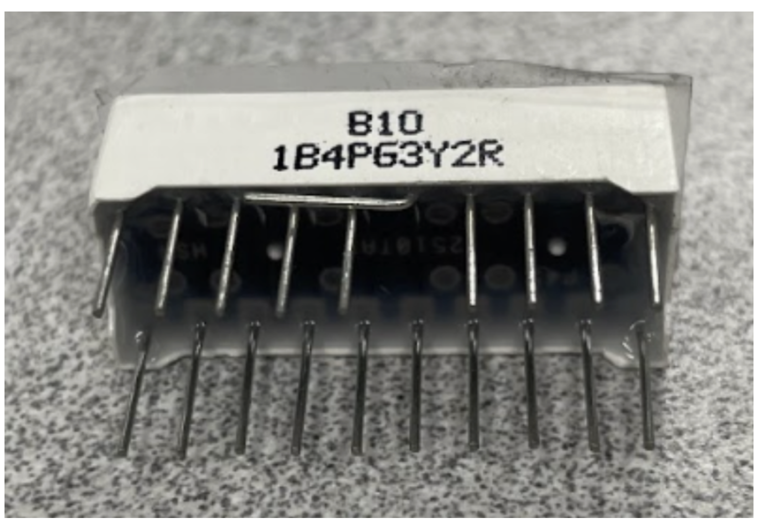

Figure 6: An LED bar with a bent leg

2. Using a speaker with an aux splitter, another device in sync with the input to the analog spectrum analyzer, or a Mac computer, play music and watch as the analog spectrum analyzer visualizes the sound frequencies.

2 Project Results

2.1 Amplification Stage

Using an oscilloscope, it is observed that music-like waveforms appear when music is being played. Pausing the song also makes the waveforms disappear. The amplifier stage setup is therefore successful.

2.2 Filtering Stage

In the Calculations section above, calculations for lower and higher cutoff frequencies of the bandpass filters are included. The lower band ranges from 15.92 to 106.1 Hz, the middle band ranges from 252.6 to 2258 Hz, and the upper band ranges from 4.823 to 15.915 kHz. For the actual results, the leftmost green LED (which represents the lower band) starts lighting up at around 30 Hz and does not dim completely until 200 Hz. The middle yellow LED (which represents the middle band) starts lighting up at around 90 Hz and does not dim completely until around 3000 Hz. The rightmost red LED (which represents the upper band) starts lighting up at around 500 Hz and is still pretty bright at 20154 Hz.

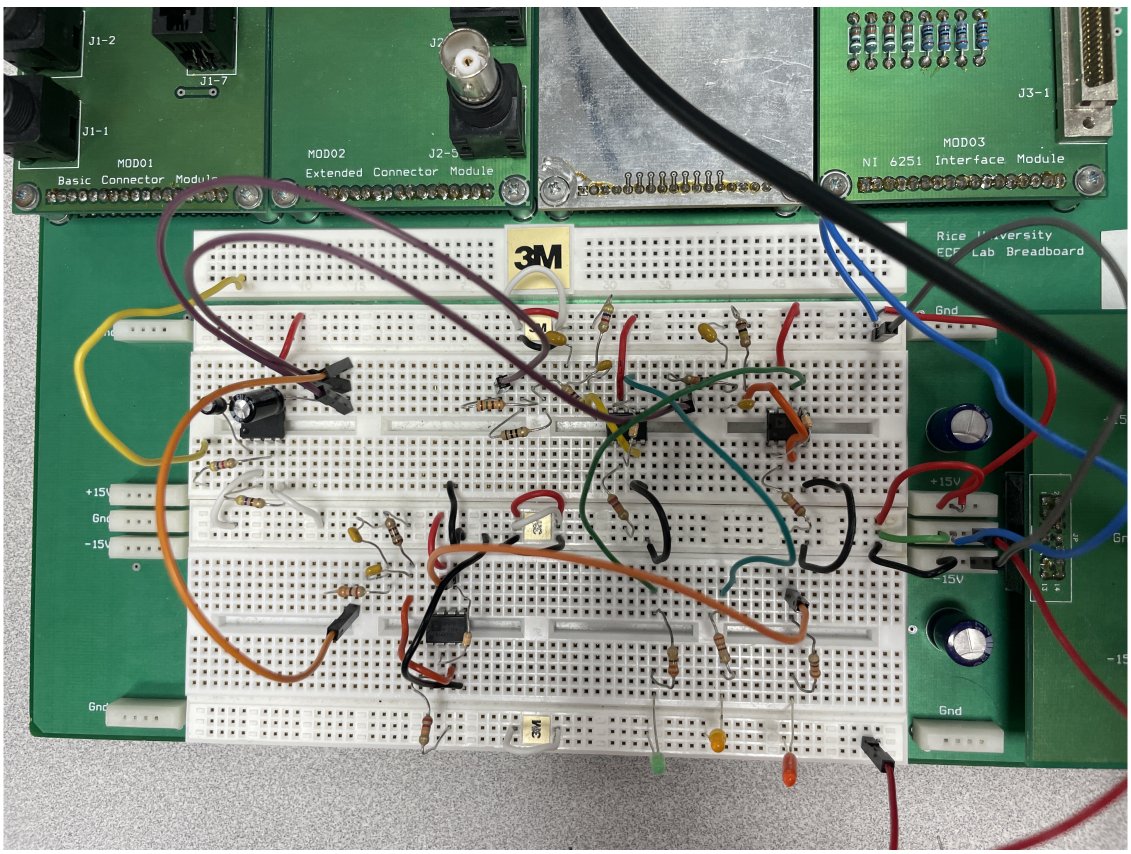

Figure 7: Breadboard setup after the amplifier and filtering stages are constructed

2.3 Output Stage

For this part, three circuits were wired as shown in the schematics in Fig. 5, and connected each one to the output of a bandpass filter from the previous stage. Then a song was played and each led showed the different frequencies of the song being played, as shown in the video.

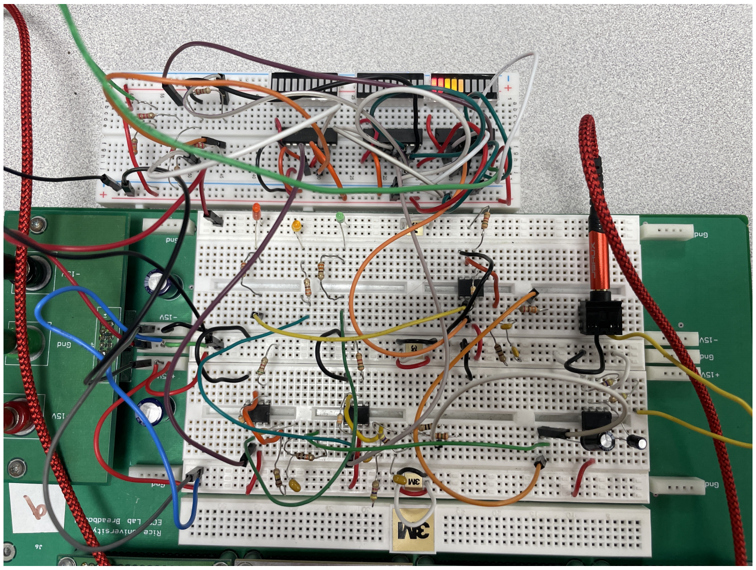

Figure 8: Breadboard setup after the output LED stage is constructed

2.4 Discussion

The project involved three main stages: amplification, filtering, and output.

In the amplification stage, an LM386 voltage amplifier, along with electrolytic capacitors and resistors, was utilized to amplify the input music waveform. Observations using an oscilloscope confirmed the appearance of music-like waveforms when music was played, with the waveforms disappearing when the music was paused. This indicates the successful setup of the amplifier stage.

Moving on to the filtering stage, OP07S were employed to construct three bandpass filters with different cutoff frequencies. These filters divided the amplified input audio into three frequency bands. Pure tones of set frequencies were used to test the filters, and their outputs were visualized using LEDs. The leftmost green LED representing the lower band lit up at around 30 Hz and remained illuminated until 200 Hz, the middle yellow LED representing the middle band lit up at around 90 Hz and remained lit until around 3000 Hz and the rightmost red LED representing the upper band lit up at around 500 Hz and remained relatively bright even at 20154 Hz. This indicates that the filters effectively split the audio signal into the desired frequency bands.

Finally, in the output stage, LM3914s and LED bars were used to display the outputs of the filters as flashing lights. Three circuits were wired according to the provided schematics, with each circuit connected to the output of a bandpass filter from the previous stage. When a song was played, each LED bar showed the different frequencies present in the song, as demonstrated in the provided video.

Overall, the project successfully demonstrated the amplification, filtering, and visualization of audio signals across different frequency bands, showcasing the functionality of the implemented electronic circuits.