Audio Spectrum Responsive Lighting System

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***Abstract*—The aim of the project was to make a multi-band brightness-changing light system that responds to the amount of low, medium and high-frequency sound waves present in the ambient music/audio respectively. This project would come as a luxury use and, in some engineering cases, to detect the mechanical stability of systems(based on frequency). The algorithm works by taking analogue sound input, digitising it, finding its frequency spectrum and sending PWM output signals, corresponding to the required brightness levels of the various LED strips, through an amplification circuit to the LED lights.**

I. Aim

To develop a deployment-ready lighting system that responds to the frequency spectrum of a room's sound waves in the form of music or any other sound.

II. Principle

Our model has the analogue world as a closed space with sound in it. It is given an analogue input using the microphone module. The input signal is processed by using the **'arduinoFFT'** library, which determines the frequency spectrum along with amplitudes by sampling the input in a specific time interval. This data is binned down to 3 data points according to the specified ranges of frequency bands. The summation of the amplitudes of sound waves in the respective bands is then mapped to a brightness value for the LED strips, where each LED strip represents a specific frequency band. A PWM signal corresponding to the determined brightness level is sent to each LED strip respectively through an amplification circuit for appropriate power delivery to the strips.

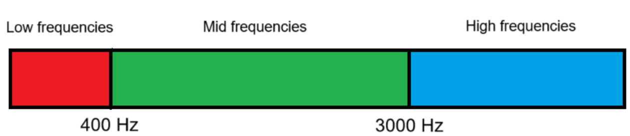

Fig. 1. Division of the Frequency Spectra into 3 bands

III. Components Used

1) 1 Microphone module
2) 1 Breadboard
3) 1 Arduino Uno Board
4) 3 IC-741 op-amps
5) Jumper Wires
6) 3 Resistors each of 20 kΩ and 8.2 kΩ
7) 12V White LED strips

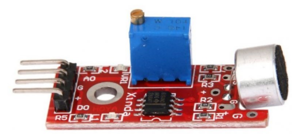

Fig. 2. Microphone Module

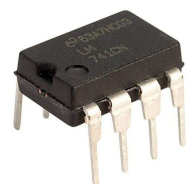

Fig. 3. IC-741 op-amp

IV. Working of Microphone

The microphone module acts as a simple voltage divider where the output is the voltage across a pressure-wave dependent resistor. The module also includes an amplifier, which ensures that we get a reliable voltage input for the Arduino. The module is operated at 5V and its output is taken from its Aout pin.

V. Finding Frequency Spectra and Binning into 3 Bands

Using the arduinoFFT library, we get the frequency analysis results of the audio input. The amplitudes of sounds of frequencies below 400 Hz were added to the first data bin. Amplitudes of sounds of frequencies above 400 Hz but less than 3000 Hz were added to a second bin, and similarly, amplitudes of sounds of frequencies more than 3000 Hz were added to the third bin. Therefore, we get the 3 bins of data as the result of the process. These 3 values are mapped to corresponding brightness levels for the LED strips, and the signals to each of the LEDs are given in the form of PWM waveforms using the Arduino's *analogWrite()* function.

VI. Working of Light strip

The light strips contain 38 LEDs each, whose brightness is controlled by the PWM output from the Arduino. This works by flickering the LEDs with the specified duty cycle, thus creating the effect of lowering or increasing the brightness.

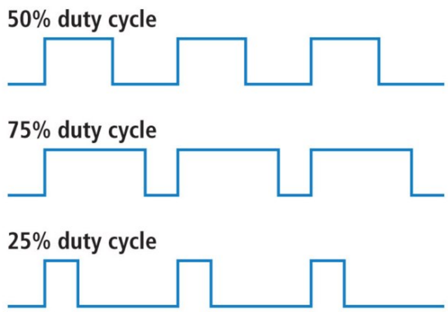

Fig. 4. analogWrite(127), analogWrite(191) and analogWrite(64) output examples (A full width corresponds to analogWrite(255))

The PWM output, which enables us to control the brightness of the LEDs, from the Arduino, gives us a pulse waveform with a range of LOW of almost 0V and HIGH of almost 5V, while experimentally, we had determined that the minimum input needed by the light strip is 5-6 V, at which it just starts glowing and the maximum limit of the LED strip is 12V, at which it exhibits maximum brightness.

Thus, a need to amplify the output signal from the microphone of the Arduino was there. An amplification of 2.2, i.e. 11V corresponding to 5V, was decided to be done, keeping the LED lights safe from burning. At first, we tried to achieve this amplification by using a PNP transistor. However, we failed to implement the idea and moved on to using an op-amp circuit, which we had a lot of experience with. Moreover, we wished to achieve the amplification using a single op-amp instead of two. A circuit as such was made to achieve the required positive amplification.

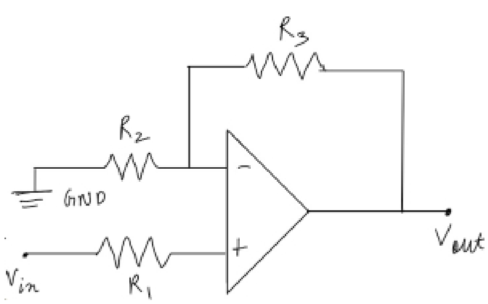

Fig. 5. Op-amp configuration

TABLE I
TABLE OF AMPLIFICATION

Input frequency	Input magnitude	Output magnitude	Amplification
1 kHz	1 V	2.24 V	2.24
1 kHz	2 V	4.32 V	2.16
1 kHz	3 V	6.32 V	2.11
1 kHz	4 V	8.32 V	2.08
1 kHz	5 V	10.32 V	2.06
1 kHz	6 V	12.42 V	2.07

[a] Average amplification theoretically is 2.12

A. *Equations*

The equations involved are as such:

$$R_1 = 10\ \Omega \tag{1}$$

$$R_2 = 10\ k\Omega, R_3 = 15\ k\Omega \tag{2}$$

$$Amplification = 1 + R_3/R_2 = 2.5 \tag{3}$$

Theoretically, it should give us an amplification of 2.5. However, while we checked by connecting with the Arduino, the maximum output of the op-amp corresponding to the 5V output given by the Arduino came out to be 9.2V. Hence, it was evident that somewhere in the process, there was a loss of power. Hence, we *decided to increase the amplification further* so that the reduction compensates for it, and we get the desired voltage output. After making R3 = 20 kΩ and R2= 8.2 kΩ, we got an output of 11.4V corresponding to the 5V output of the Arduino.

We had one of our test op-amps ready, and now we have to add another such two to the breadboard so as to account for all three inputs.

CONCLUSION

The project turned out to be a success, as it could accurately respond to frequencies in the three frequency bands($\leq$400 Hz, 400-3000 Hz, $>$3000 Hz) and change the brightness of the output LEDs according to their relative amplitudes. Moreover, for other purposes, if the situation arises that the ranges of bands of low, mid, and high frequencies be changed, they can be changed by simple alteration of the parameters in the code. This system can also be expanded to have more frequency bands and more LED outputs.

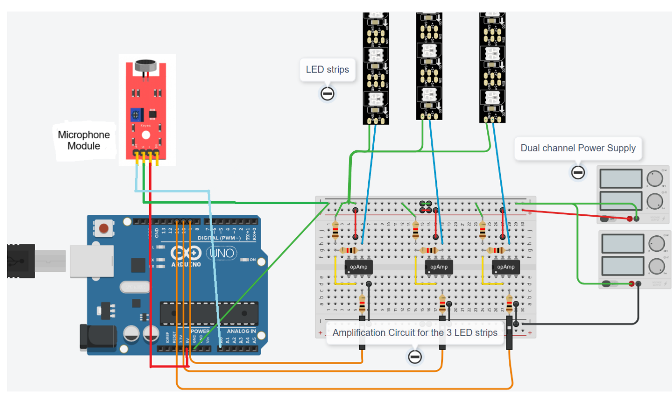

Fig. 6. Final Circuit Diagram

ACKNOWLEDGMENT

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