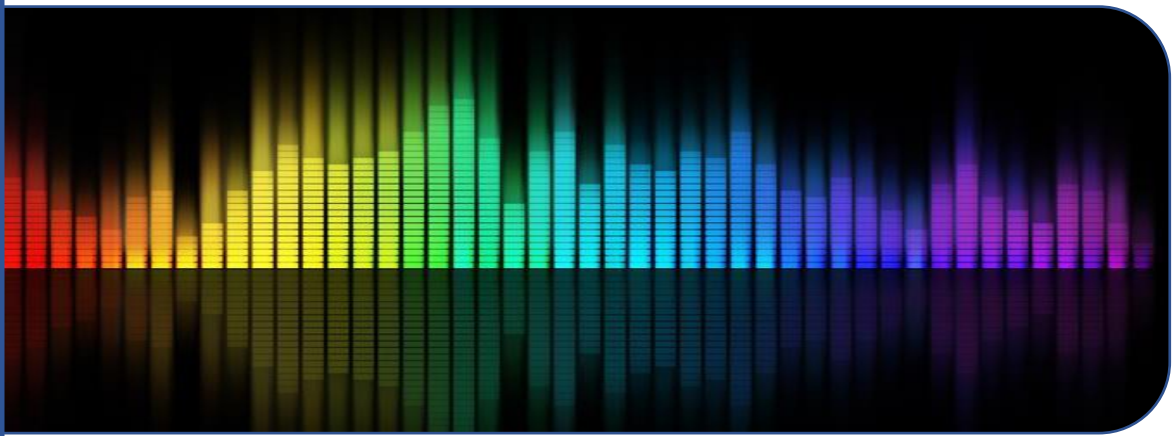
EEE 428

Measurement and Instrumentation Laboratory

A Project
on

"Real-time Audio Visualizer"



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Forwarding Letter

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Subject: **Report on the project entitled *"Real-Time Audio Visualizer".***

Dear Teachers,

With due respect and gratitude, we would like to state that we, the students of project group 04 of "Measurement & Instrumentation Laboratory" sessional course have the privilege to present before you the report on our lab project "Real-Time Audio Visualizer". In this report, we have discussed thoroughly about theoretical backgrounds and working principles of various circuit blocks like amplifiers, filters, comparators etc. Circuit diagrams of filters with suitable ranges and their frequency response wave-shapes have been added in the report with detailed descriptions. We have also explained in detail about various circuit components used in the project.

We are really indebted to our honorable teachers for facilitating us with the opportunity to do project work on such exciting feature and providing us with necessary support and suggestions. We are very much grateful to the authors of the related books, journals, articles where we found our required diagrams, data and other information. We would like to express our profound apology for any kind of unexpected discrepancies and shortcomings in this very report.

Sincerely yours
Students of group 04
Measurement & Instrumentation Laboratory

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Abstract

The processes of the project “Real –time Audio Visualizer” include amplifying, filtering, rectifying, audio level detection and then powering ON the certain set of LEDs according to the amplitude level of that signal for displaying. The hardest part of the project was to implement everything in real time which was done via analog circuitry. We hope that our reader would find our project report easily understandable and make them interested in electronics related projects with practical implementation ability.

1. Introduction

A good piece of music or a nice instrumental is always a treat for our mind. After a long hectic day or during a journey they are our best companions. A colorful animated visualizer enhances our experience of listening music to some great extent. Won't it be nice to have such an amazing visualizer on all over your wall or may be at the outer wall of a large apartment? That is how we came up with the idea to work on the project titled "Real-time Audio Visualizer". In this report, we have discussed about various technical aspects of how the system circuit was designed and built to create the real time visualizing effect with the help of LED board. Also, there is a demonstration about how each of the circuit blocks works and their internal circuitry and corresponding output wave-shapes are shown in the report.

Of course, there are huge possibilities of improvements and future expansions. These key points as well as the implementation difficulties and other technical problems & their solutions have been described in detail in the report.

This very project required the knowledge of high level electronics in combination with analog signal processing. We have tried to explain them in the report as much as possible in this small arrangement. Hope this report serves the purpose of explaining about our project works well.

2. System Overview

The Block Diagram of the "Real-Time Audio Visualizer System" and the work of its individual blocks are described below

2.1 Block Diagram

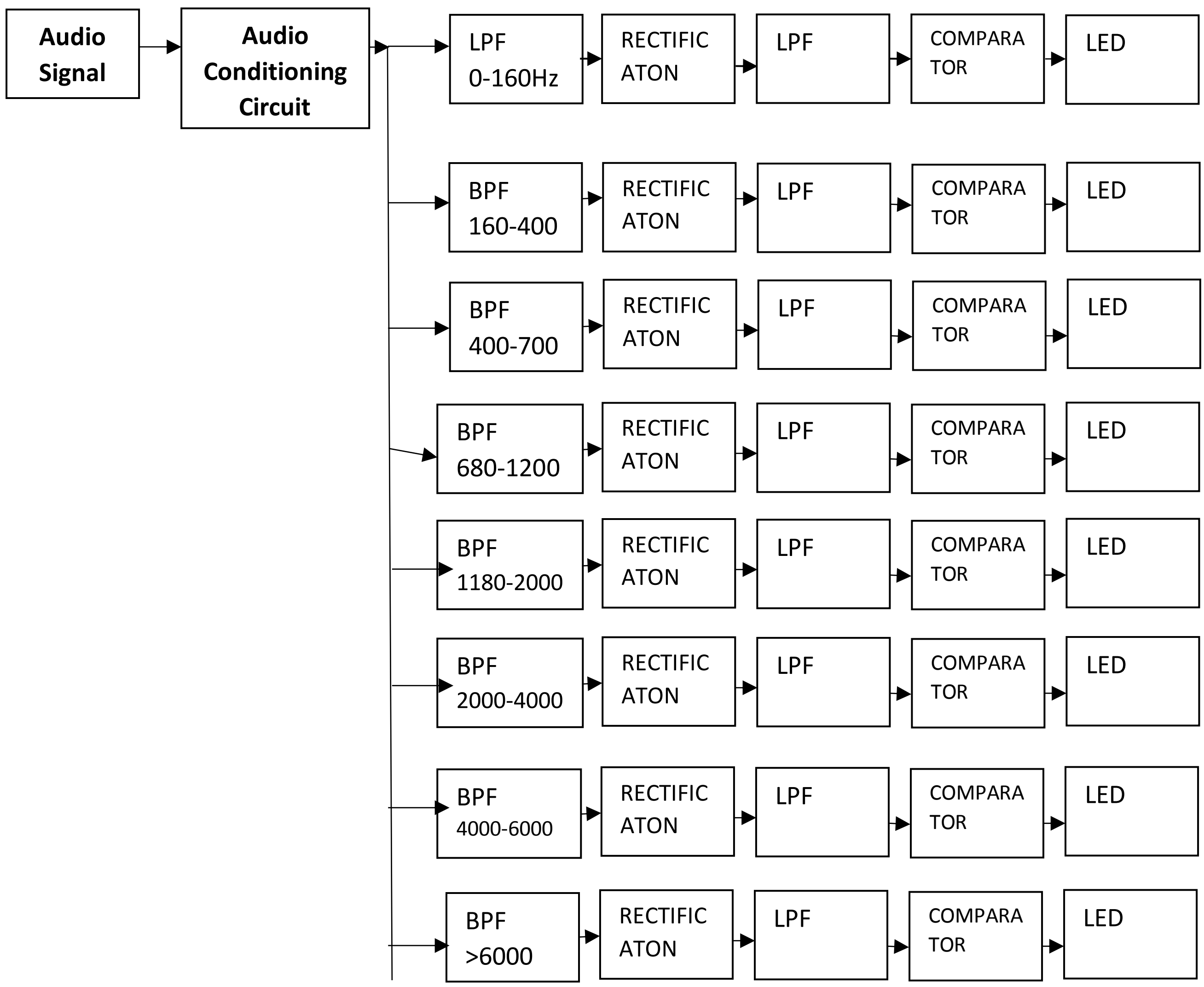

Fig: Block Diagram of the Real-Time Audio Visualizer

2.2 Audio Signal Level

In the audio world, there are 4 signal levels that we deal with: mic, instrument, line and speaker.

Mic level is the lowest, or weakest, level signal of the four and requires a preamplifier to bring it up to Line level.

Instrument level signals live between mic and line level signals and have the most variation. This kind of signal typically come from an electric guitar or bass. They also require a preamplifier to come up to line level.

Line level signals are the highest-level signals before amplification. This is the type of signal that typically flows through the recording system after the preamplifier stage and before the amplifier that powers your speakers. These are two types. Consumer and Professional. Consumer line level is rated around -10dBV and is what can be find in products like a CD player. Professional line level is rated around +4dBV and is found in things like mixing desks and signal processing equipment.

Speaker level signals are post amplification. After a line level signal enters an amplifier, speaker level signals are output to your speakers. These signals are much higher in voltage than line level and require speaker cables for safe signal transfer.

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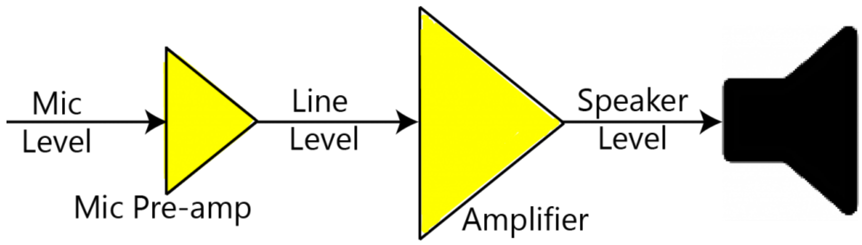


Fig: steps of bringing mic to speaker level

2.3 Audio Conditioning Circuit

An **amplifier** is an electronic device that can increase the power of a signal (a time-varying voltage or current). An amplifier functions by taking power from a power supply and controlling the output to match the input signal shape but with a larger amplitude. In this project, we used input dependent audio amplifier as an audio conditioning circuit. Here in this project we used non-inverting amplifier to bring Mic level and Instrument level signals to the line level.

Non-Inverting amplifier

The basic non-inverting amplifier circuit using an op-amp is shown below. In this circuit the signal is applied to the non-inverting input of the amplifier.

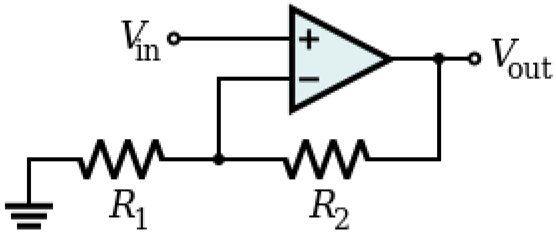


Figure 2: Non-Inverting Amplifier

The gain of the amplifier can be calculated using following formula.

$$\frac{V_{out}}{V_{in}} = Av = 1 + \frac{R_2}{R_1}$$

In this project, non-inverting amplifier is used to amplify 0-200 mV signal to - 5 V to 5 V signal.

2.4 Filters

In this project, we used two types of filters to divide the audio frequency by 8 parts. The frequency bands are:

1. 0-160 Hz
2. 160-400 Hz
3. 400-700 Hz
4. 680-1200 Hz
5. 1180-2000 Hz
6. 2000-4000 Hz
7. 4000-6000 Hz
8. 6000 -16000 Hz

For the first frequency band, we used a low pass filter. For others, we used band pass filter.

2.4.1 Op-Amp Low Pass Filter

Low Pass filter is a filter which passes all frequencies from DC to upper cut-off frequency and rejects any signals above this frequency.

There are two kinds of low pass filters

1. active low pass filter
2. passive low pass filter

We used active low pass filter.

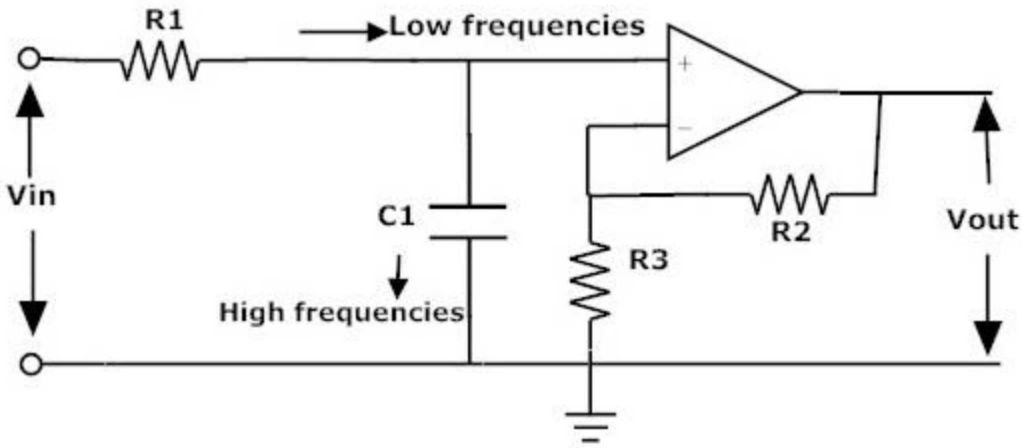


Fig 3: Active LPF using Op-Amp

Voltage gain of this filter is given by the equation:

$$Voltage\ Gain = \frac{V_{Out}}{V_{In}} = \frac{A_{max}}{\sqrt{1 + \left(\frac{f}{f_c}\right)^2}}$$

Where

- A_{max} = Gain of the pass band = $1 + \frac{R_2}{R_3}$
- f = operational frequency.
- f_c = Cut-off frequency.
- V_{out} = Output voltage.
- V_{in}= Input voltage.

When the frequency increases, then the gain decreases by 20 dB for every 10 time increment of frequency. When actual frequency is equal to the cut-off frequency, then the gain is equal to the 70.7% of the A_{max}. By this we can say that for every tenfold (decade) increase of frequency the gain of the voltage is divided by 10.

The response of the active filter is as shown in below figure

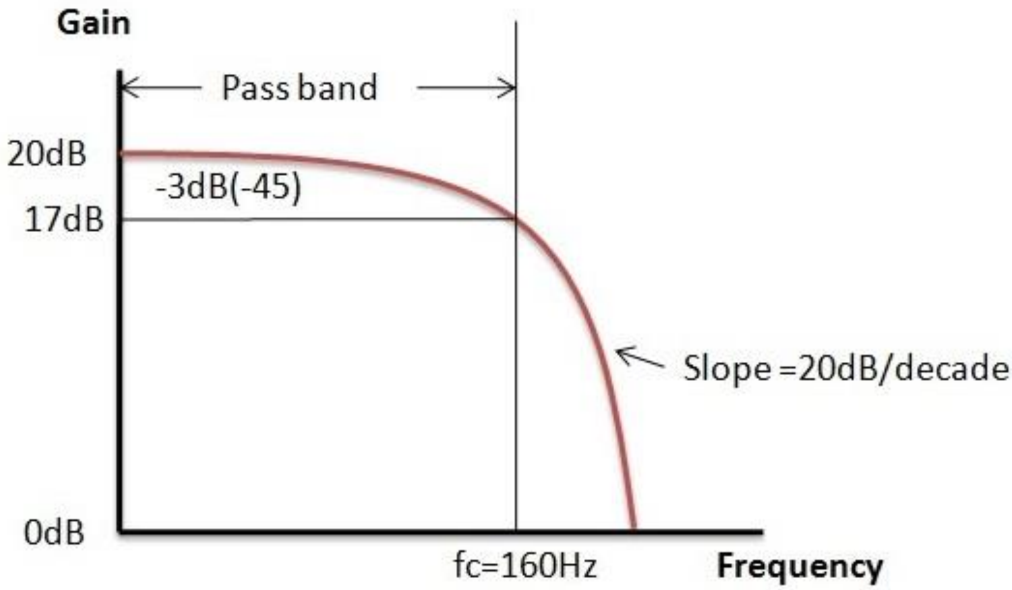


Fig 4: Frequency Response of Op-Amp LPF

2.4.2 Band Pass Filter

A bandpass filter is an electronic device or circuit that allows signals between two specific frequencies to pass, but that discriminates against signals at other frequencies. Some bandpass filters require an external source of power and employ active components such as transistors and integrated circuits; these are known as active bandpass filters. Other bandpass filters use no external source of power and consist only of passive components such as capacitors and inductors; these are called passive bandpass filters. We used active bandpass filters in this project.

Active bandpass filters are of two kinds

1. Wide Band Bandpass Filter
2. Narrow Band Bandpass Filter

We used narrow bandpass filter to separate frequencies.

Circuit Diagram of an active bandpass filter using Op-Amp is shown below.

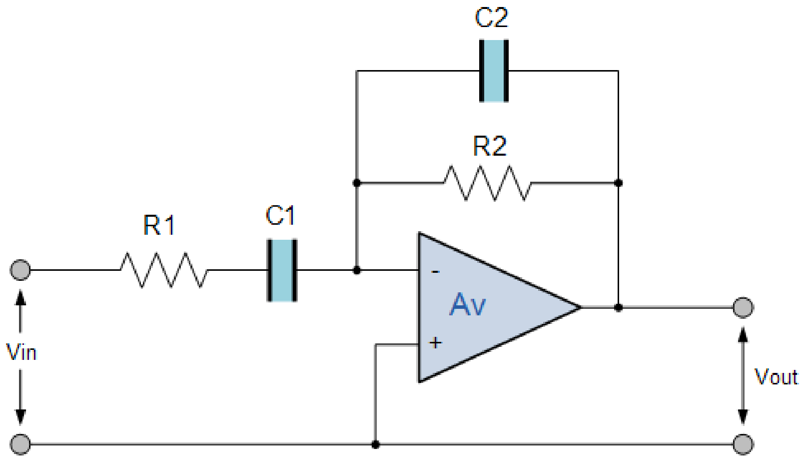


Fig 5: Circuit Diagram of an Op-Amp BPF

The voltage gain of the above filter circuit is,

$$Av = -\frac{R_2}{R_1}$$

And the cut-off frequencies of the filter circuit are,

$$f_{c1} = \frac{1}{2\pi R_1 C_1}$$

&

$$f_{c2} = \frac{1}{2\pi R_2 C_2}$$

The frequency response of the circuit is,

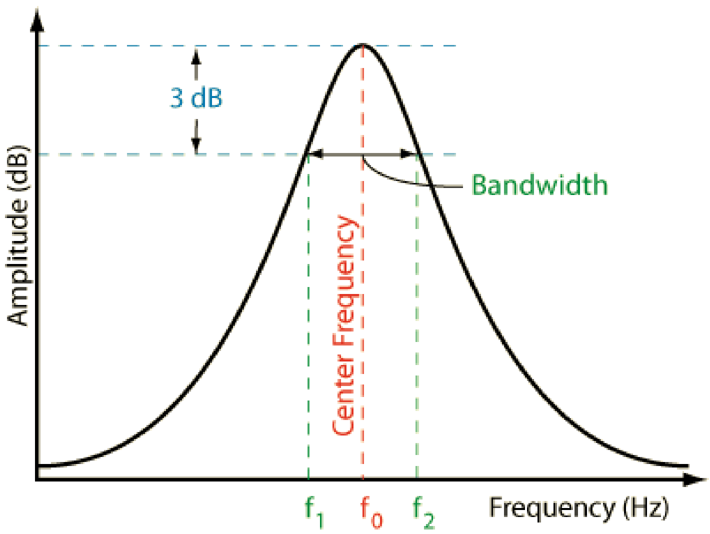


Fig : Frequency Response of Op-Amp BPF

2.5 Half Wave Rectifier

A **rectifier** is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification. A rectifier that utilizes one half cycle of alternating current and suppresses the other is known as half wave rectifier. Half wave rectification circuit is given below.

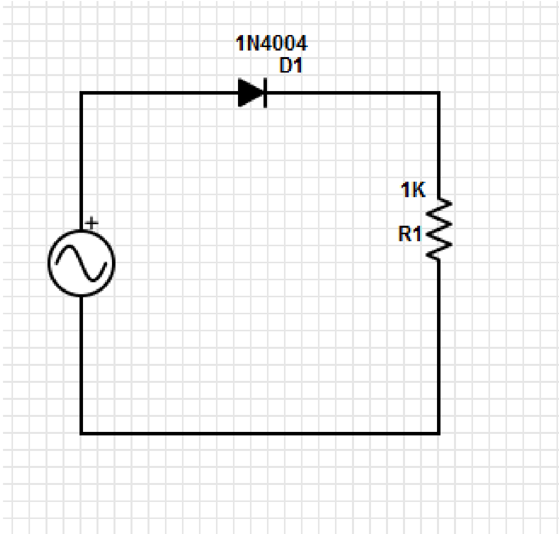


Fig: Half Wave Rectifier

2.6 LC Low Pass Filter

A low-pass filter is a filter that passes signals with a frequency lower than a certain cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency. There are many kinds of low pass filters here we use LC low pass filter. Circuit diagrams of low pass filters are given below.

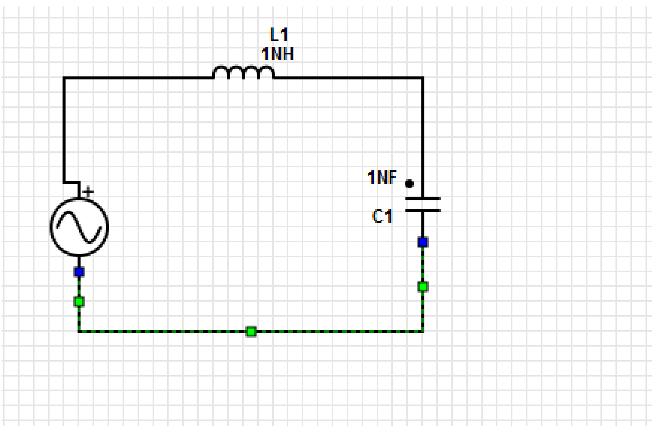


Fig: LC Low Pass Filter

Cutoff frequency of LC low pass filter:

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

Here low pass filters are used not to do low pass filtering but to get DC output. To do so we have to use an LC filter having 10 times less cut off frequency than the signal frequency.

2.7 Comparator

The comparator is an electronic decision making circuit that makes use of an operational amplifiers very high gain in its open-loop state, that is, there is no feedback resistor. The Op-amp comparator compares one analogue voltage level with another analogue voltage level, or some preset reference voltage, V_{REF} and produces an output signal based on this voltage comparison. In other words, the op-amp voltage comparator compares the magnitudes of two voltage inputs and determines which is the largest of the two.

Circuit diagram of Comparator Using Op-Amp is given below.

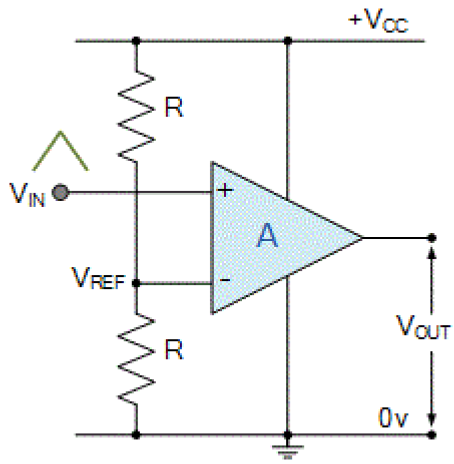


Fig: Comparator Using Op-Amp

3. System Functioning:

Making the system real-time was the most prominent challenge of the project. To achieve the challenge, we adopted the analog circuitry for the whole project. The system consists of few sub-parts which perform certain actions. The sub-circuit of the system is given below.

1. Power supply section for bi-polar biasing
2. Audio signal conditioning circuit
3. Frequency Division Section
4. Low pass filtering section
5. Audio level detector section
6. LED driving section

In our circuit, we had kept the option for receiving different audio level signal like mic-level, line level, pre-amp level. After receiving the small signal audio, the audio conditioning circuit amplify the small signal into -5V to +5V Large audio signal.

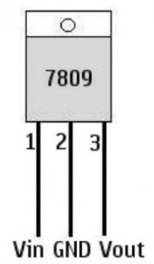
After proper amplification, the signal is passed through a filter network (Frequency division section) which separates the audio frequency of different ranges according to our pre-defined audio range.

After frequency division, the sinusoidal audio signal is rectified and then passed through a LC low pass filter the extract the fundamental Dc component of the Single tone audio signal.

Then the DC component of the single tone audio signal is fed to the comparator networks which drove the LED according to the amplitude of that particular frequency.

4. Components Description:

i) **7809:** The LM7809 is a 3-terminal 1A positive voltage regulator IC. In our circuit, we used this IC for maintaining +9V voltage. The pin and circuit diagram for 7809 IC are given below:



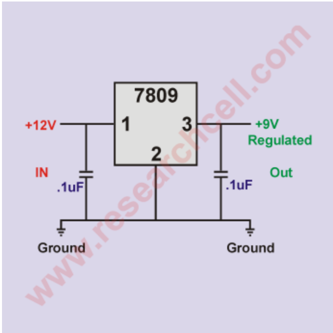


Fig 11: 7809 IC pin & circuit diagram

ii) **7909:** LM7909 IC is also a 3-terminal 1A regulator similar to 7808 but it gives negative voltage output. We used this IC for maintaining -9V Voltage for our operational circuit. The pin diagram for 7909 is shown below:

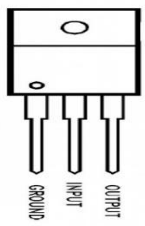


Fig 12: 7909 IC pin diagram

iii) **1N5819 Schottky Diode:** 5819 is a medium power, fast, low voltage schottky diode. Its current & voltage ratings are 1.0A & 40V respectively. Other features include high surge capability, low power loss, high efficiency, low forward voltage drop etc.

Fig 13: Sample photo of a 5819 diode

iv) **Electrolytic Capacitors:** The specialty of an electrolytic capacitor is that it uses an electrolyte to achieve larger capacitance than other capacitor types. An electrolyte is a liquid or gel containing a high concentration of ions. Almost all electrolytic capacitors are polarized, which makes them suitable for DC circuits only. For our project, we needed electrolytic capacitors of 10 & 100 µF.

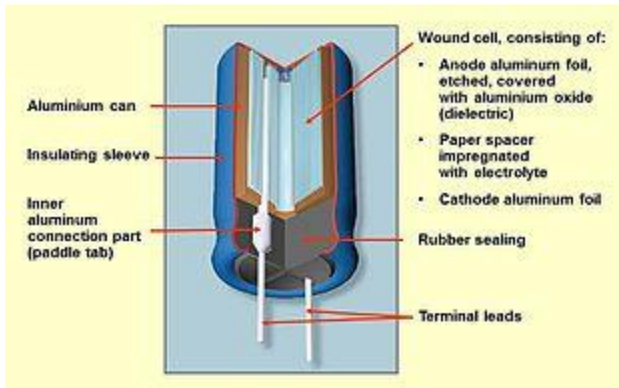


Fig 14: Internal structure of electrolytic capacitor

v) **Fuse:** Fuse is a low resistance resistor that acts as a sacrificial device to provide overcurrent protection. Its metal wire or strip melts when too much current flows through it, interrupting the circuit that it connects.

vi) **Poly Capacitor:** Polyester Capacitors use a polyester film for its dielectric which sits between the two capacitor plates. These capacitors are known by trade name Mylar capacitors. The most common used polyester material is Polyethylene Terephthalate (PET). The main properties of poly capacitors are their high dielectric strength, high dV/dt characteristics, and tolerance of around 5-10%.

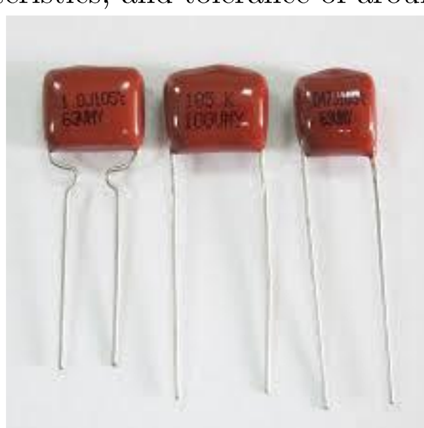


Fig 15: Poly Capacitors

vii) **UA741:** The µA741 device is a general-purpose operational amplifier featuring offset-voltage null capability. Its main features are short- circuit protection, large common-mode and differential voltage ranges, no frequency compensation required & no latch-up.

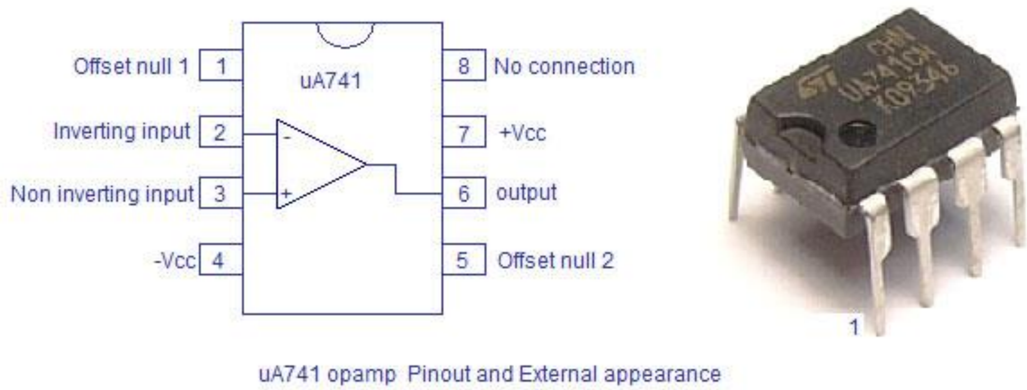


Fig 16: UA741 internal pinout diagram.

viii) **LM324 Comparator Op-amp:** The LM324 is a 14 Pin dual in-line Plastic Package chip which has four independent, high-gain, internally frequency compensated operational amplifiers Op-amp designed to operate from a single power source. It can accept a very wide power supply range from 3v – 32v. The internal pin diagram is as follows:

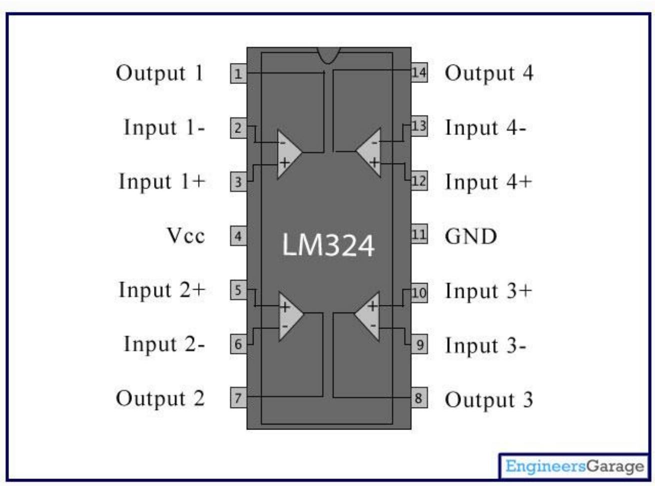


Fig 17: Internal pin diagram of LM324 OP-AMP

ix) **SPDT Toggle Switch:** Single Pole Double Throw (SPDT) switches were used in our project for switching purposes.

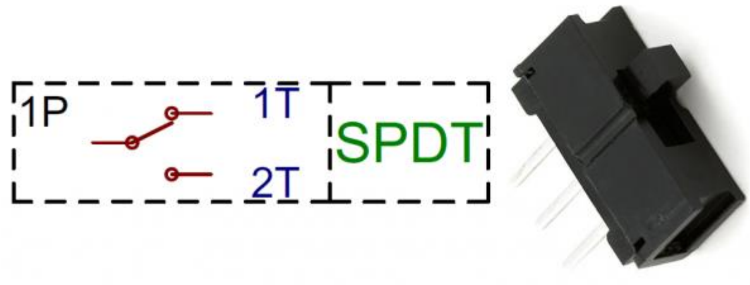


Fig 18: SPDT Switch

x) **PCB Board:** A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. In our project, all the PCB designs were done using Eagle PCB Suite 7.5.0.

Other components needed for the project were resistors (1k, 10K Ω), potentiometers (5K, 10K, 50K Ω), inductors, 3.5mm audio socket, 3.5mm jack, connectors, wires etc.

5. Simulation Results:

With bandpass filters the audio input signal was divided into eight different sections based on their frequencies. They are:

a) <160Hz
b) 160-400Hz
c) 400-700Hz
d) 700-1200Hz
e) 1200-2000Hz
f) 2000-4000Hz
g) 4000-6000Hz
h) >6000Hz

The schematic diagram of the band-pass filters designed for particular frequencies and their corresponding Voltage-frequency waveforms are shown below:

1. Below 160Hz:

I. Schematic:

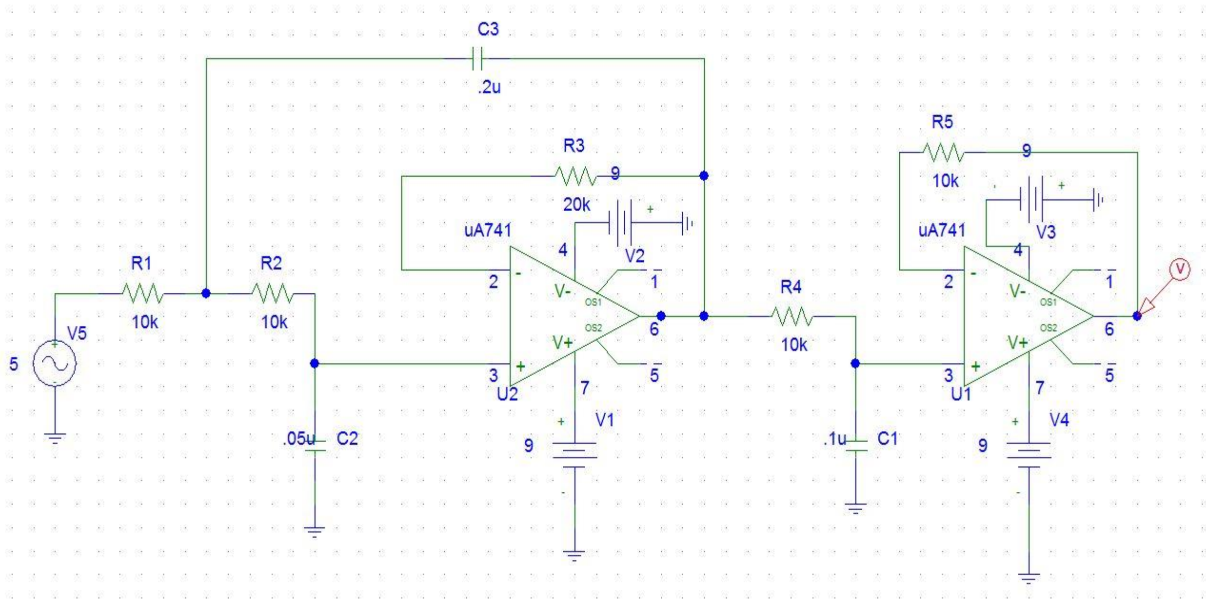


Fig 19: Circuit diagram for 160Hz low-pass filter

II. Waveform:

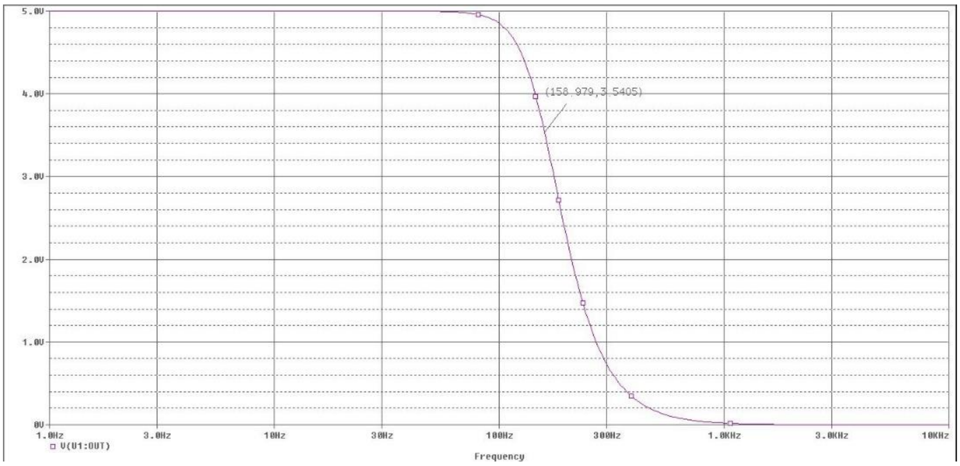


Fig 20: Frequency response of low-pass filter with cut-off freq at 160Hz

2. 160-400Hz:

I. Schematic:

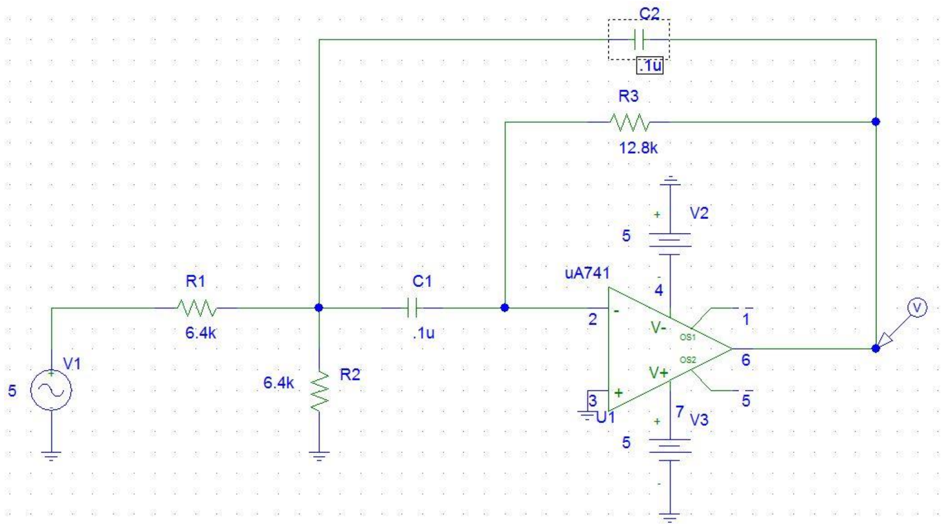


Fig 21: Circuit diagram for bandpass filter of 160-400Hz

II. Waveform:

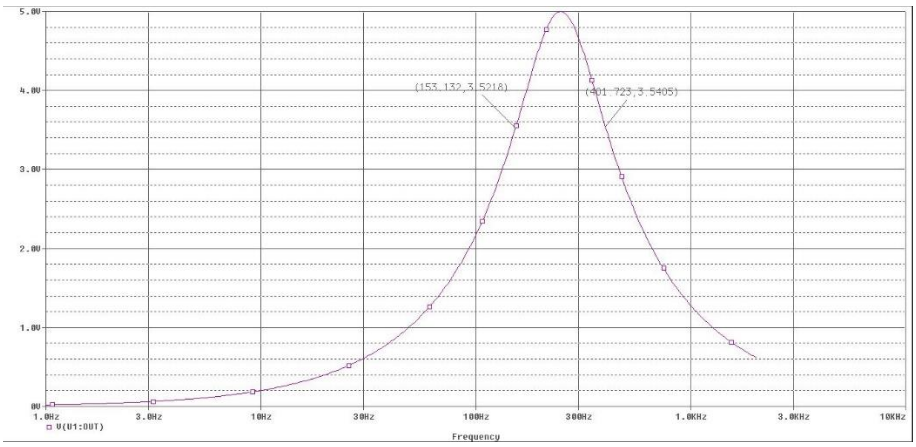


Fig 22: Frequency Response of band-pass filter

3. 400-700Hz:

I. Schematic:

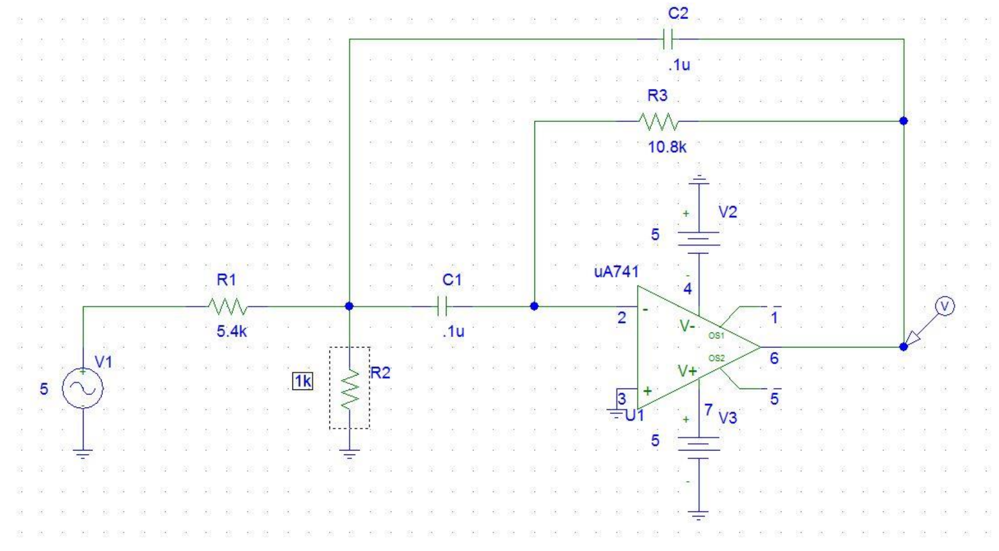


Fig 23: Circuit diagram for bandpass filter of 400-700Hz

II. Waveform:

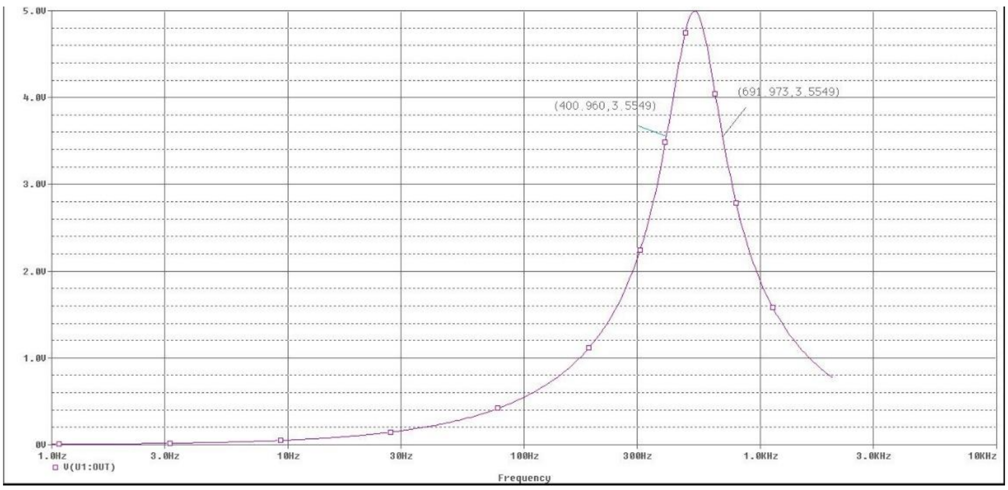


Fig 24: Frequency Response of band-pass filter

4. 700-1200Hz:

I. Schematic:

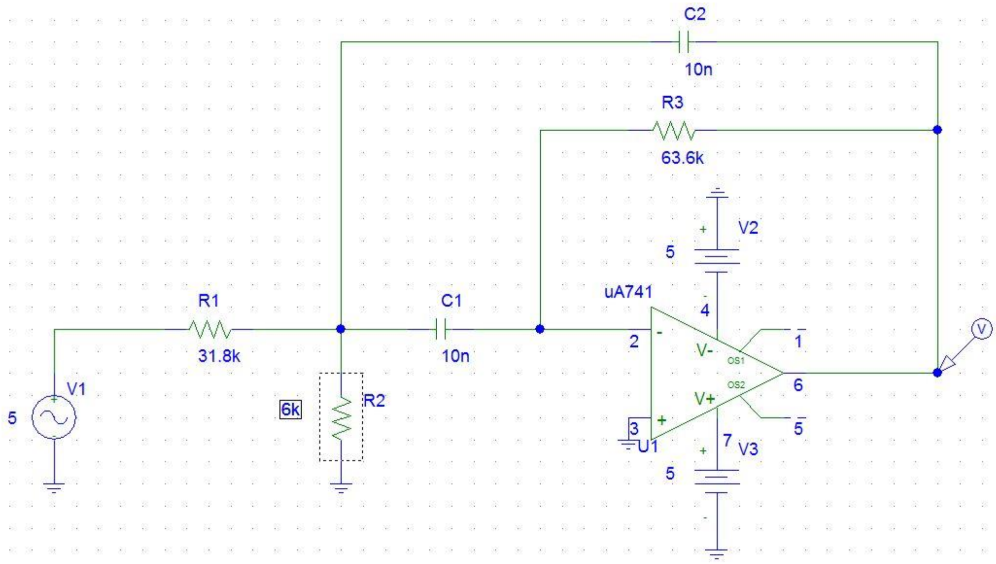


Fig 25: Circuit diagram for bandpass filter of 700-1200Hz

II. Waveform:

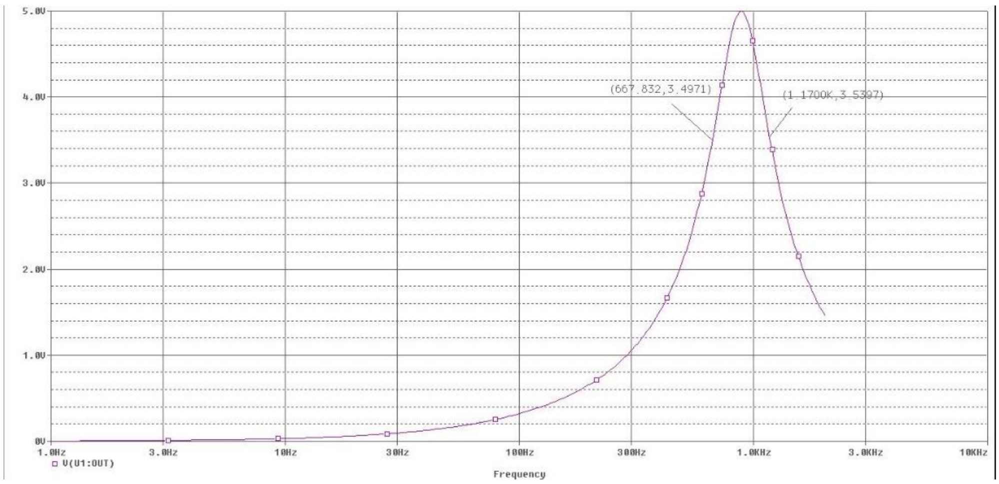


Fig 26: Frequency Response of band-pass filter

5. 1200-2000Hz:

I. Schematics:

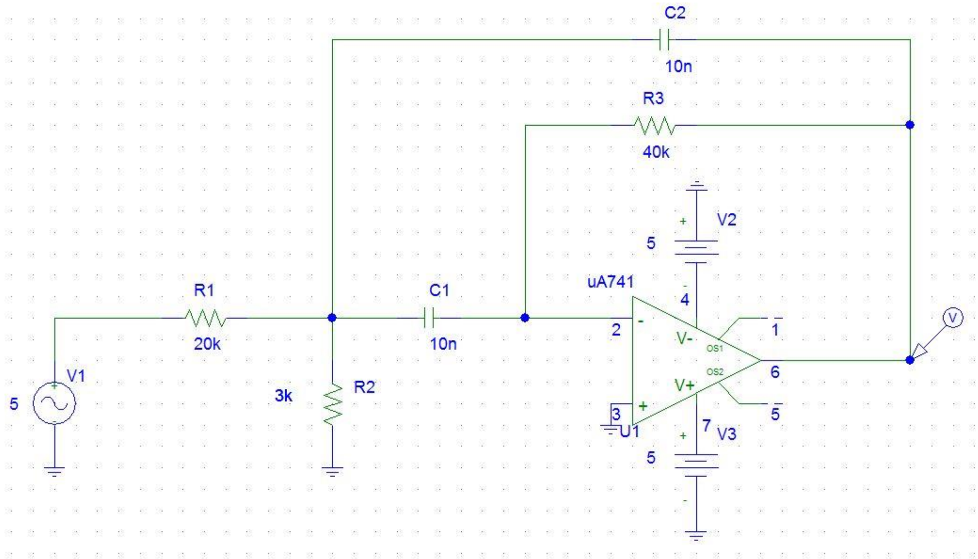


Fig 27: Circuit diagram for bandpass filter of 1200-2000Hz

II. Waveform:

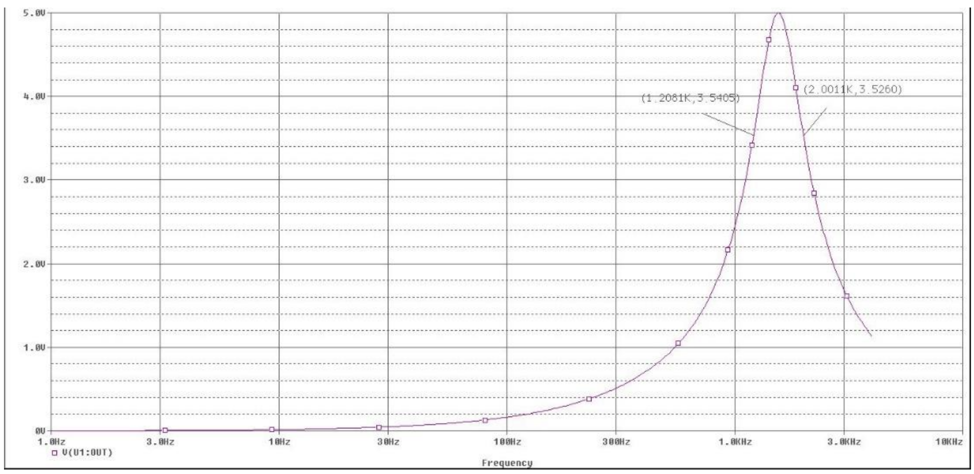


Fig 28: Frequency Response of band-pass filter

6. 2000-4000Hz:

I. Schematics:

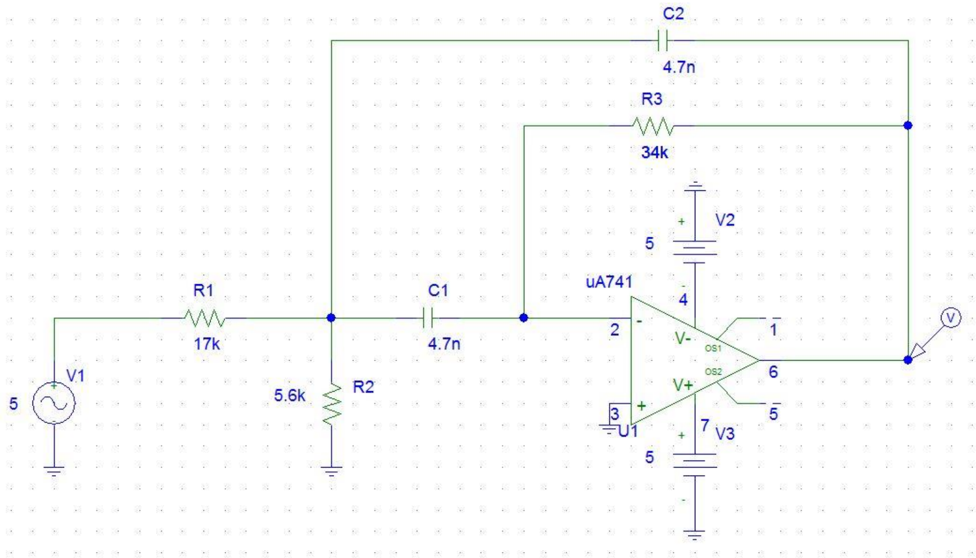


Fig 29: Circuit diagram for bandpass filter of 2000-4000Hz

II. Waveform:

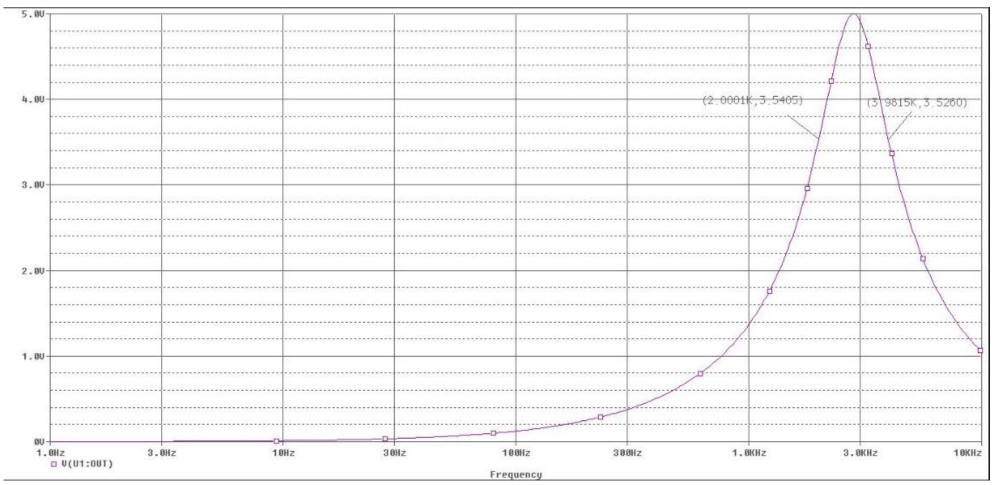


Fig 30: Frequency Response of band-pass filter

7. 4000-6000Hz:

I. Schematics:

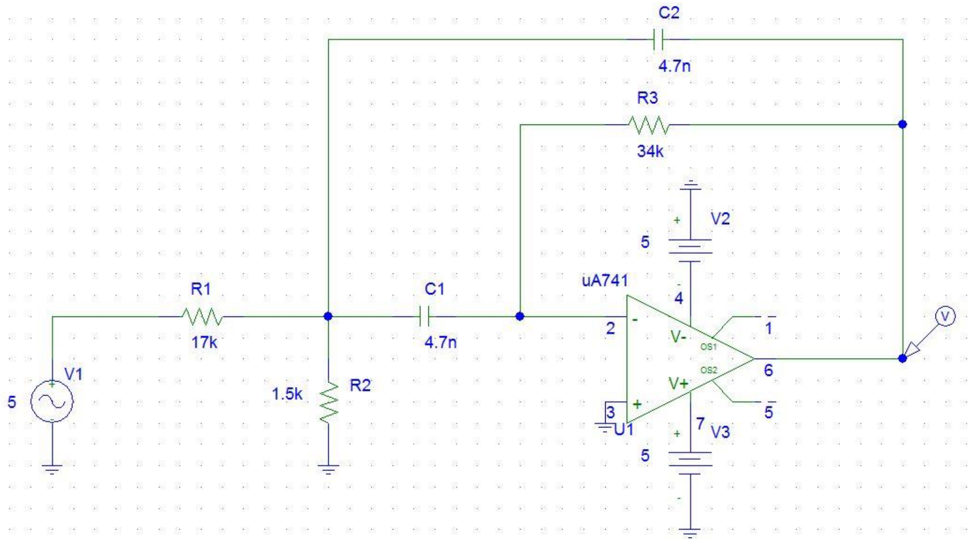


Fig 31: Circuit diagram for bandpass filter of 4000-6000Hz

II. Waveform:

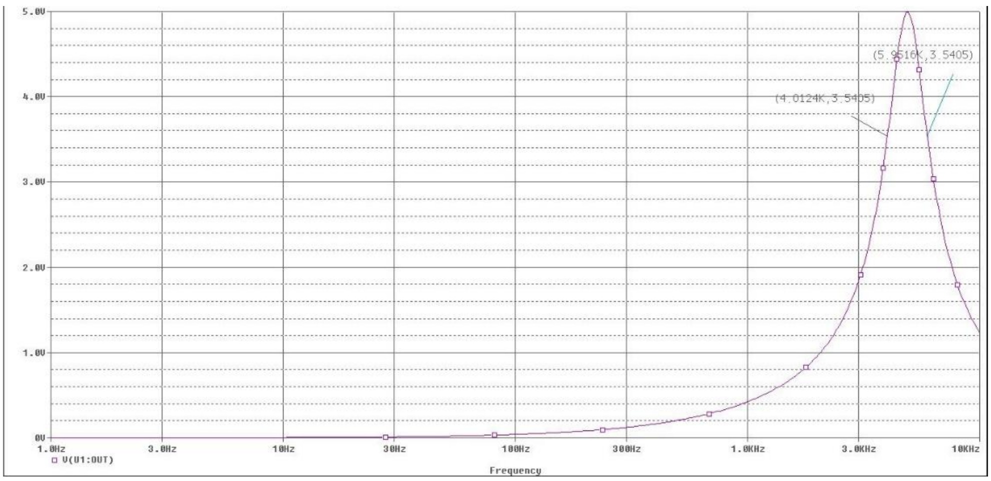


Fig 32: Frequency Response of band-pass filter

8. Above 6000Hz:

I. Schematics:

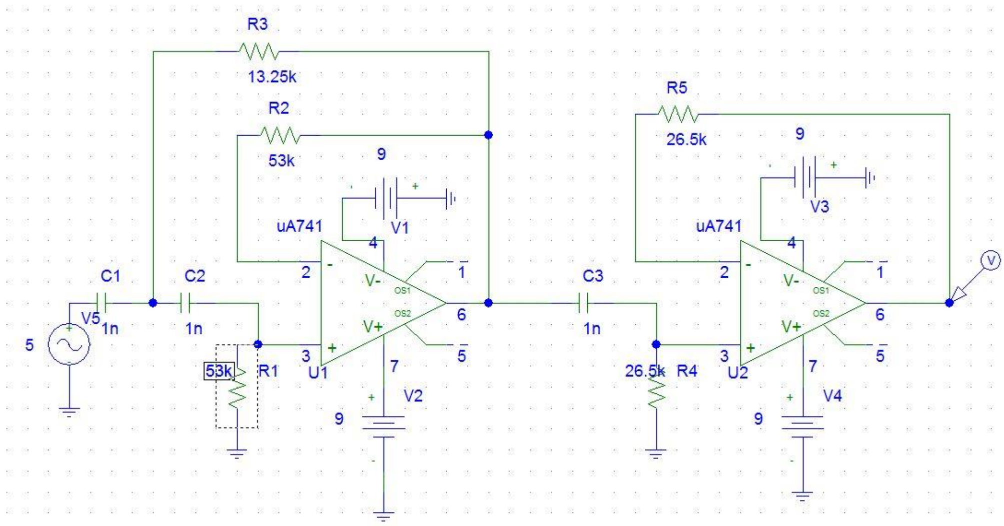


Fig 33: Circuit diagram for high pass filter with cut-off frequency at 6000Hz

II. Waveform:

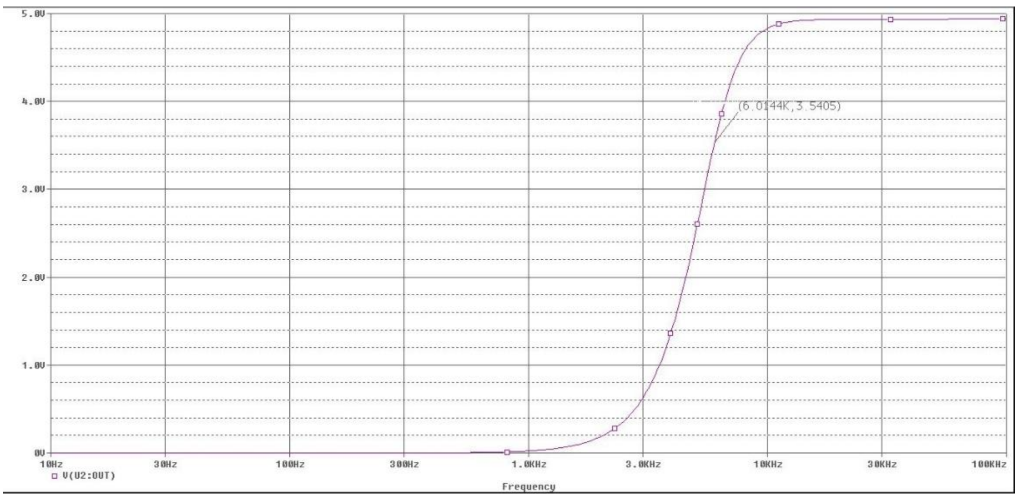


Fig 34: Frequency Response of band-pass filter

6. PCB Layouts

i) Band-pass filters of different frequency ranges:

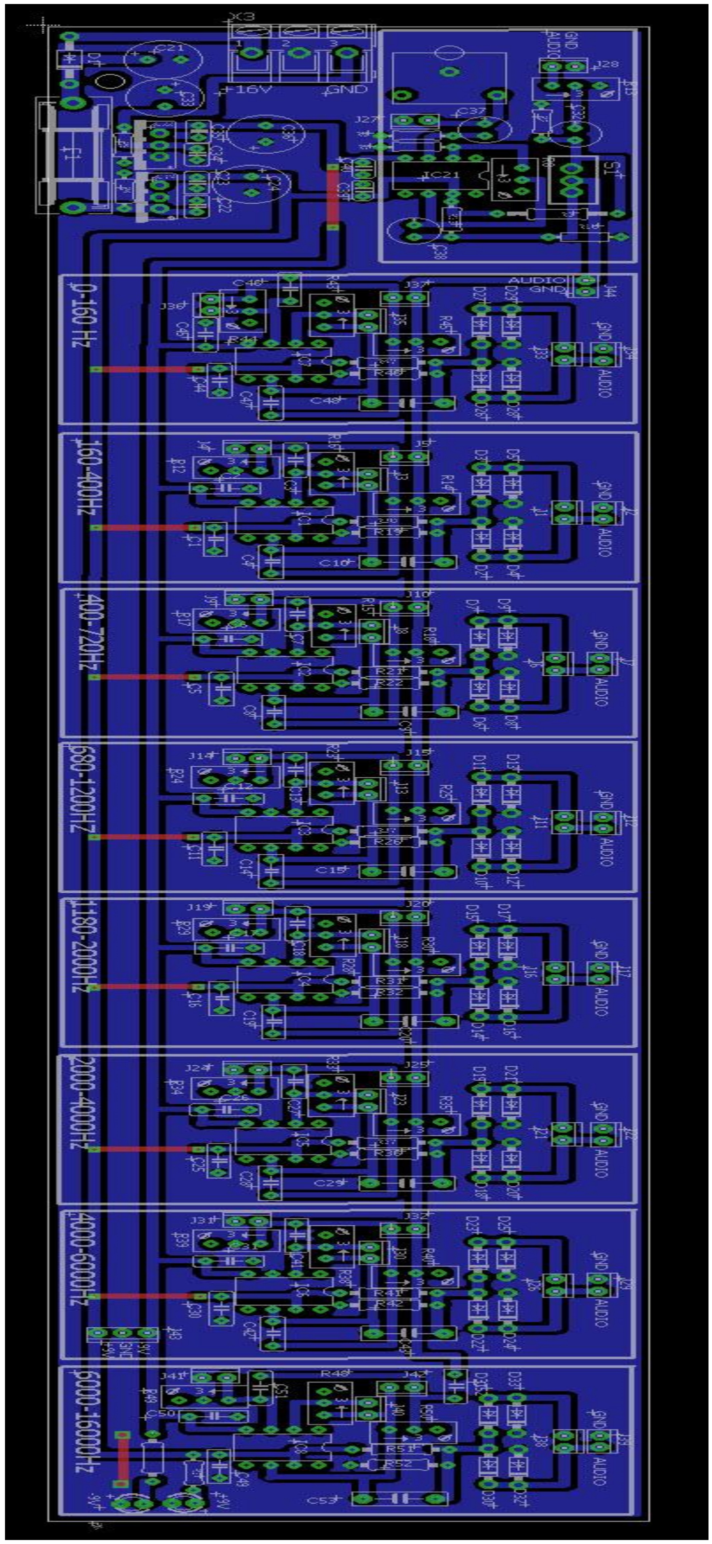


Fig 35: PCB Layout of band-pass filters

ii) LED Board:

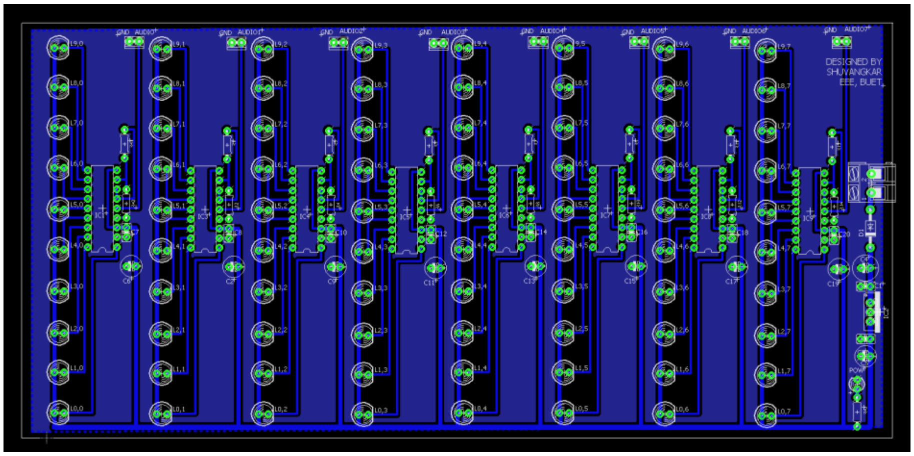


Fig 36: PCB Layout of LED boards

7. Applications

As apparent from the title, the main application of the project is for decoration purpose. It can be implemented in concerts & various other occasions for visually interactive musical performances. It has already been implemented once on the twelve-storied ECE Building of BUET for “EEE Day 2k16”.

Fig 37: EEE Day 2K16 ECE Building Decoration Using Real-Time Audio Visualizer

8. Future Expansion Possibilities:

We would like the implement the project in larger scale with few more eye-catching and exciting features like adding custom texts & designs, changing colors of LEDs etc.

Apart from decoration purpose the signal division part of Real-Time Audio Visualizer can also be used to build medical device such as ECG, EEG at very low cost.

9. Problems Faced During Project Completion

We spitted a 24V power supply into +9V and -9V using capacitors. As the impedance of the same valued capacitor was not same. So, unbalancing of the power supply occurred few times.

The noise was the main culprit of the system as our whole system was analog circuity and there was millivolt level signal.

The output of each filter was distinct sinusoidal signal which was fed into the comparator network. The comparator networks saw time varying signal as a result flicking of the LED output was visible.

The band width of the signal was very small so we needed precise valued capacitors and resistors. In the market, there was few valued resistors and capacitors which did not meet our specifications.

10. Conclusion

The real-time Audio visualizer project was fun, interesting and needed a lot of experience of our previously done projects and also knowledge from more than what we acquired from measurement lab experiments. It was a painstaking task to device such a project for the EEE DAY 2016 and to show the entire BUET area the dancing of light with the beats of music. Yet we find solace as history has been made on those specific days.

For this project, we would be immensely thankful to our teachers firstly for allowing us to do this project and secondly for helping us at the time of our need with inspiration and technical ideas to overcome few problems.

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