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Real Time Audio Spectrum Analyzer (Analog Project)

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Abstract

In this report, there is a detailed description of how to build an analog audio spectrum analyzer that can visualize the frequency components of an input audio signal . Leveraging analog electronics, signal processing, and visualization techniques, the spectrum analyzer provides a graphical representation of the audio spectrum. The report contains all the implementation details including functional block diagrams, PCB design, and enclosure design, and discusses the results obtained through the final product.

Contents

Chapter 1

Introduction and Functionality

The analog audio spectrum analyzer functions as a crucial tool for real-time analysis of audio signals, offering a comprehensive understanding of their frequency distribution. The system first captures the input audio signal and then utilizes a series of bandpass filters to isolate specific frequency bands. These filtered signals are subsequently rectified to obtain their amplitudes, which are then graphically displayed on the output spectrum. The resulting visual representation provides an intuitive depiction of the varying intensities of different frequency components within the audio signal. Users can readily identify and analyze the dominant frequencies, harmonics, and overall spectral characteristics.

This functionality proves invaluable in tasks such as equalizing audio signals and gaining insights into the frequency composition of musical or voice recordings. The analog nature of the spectrum analyzer emphasizes its practical application in scenarios where real-time, hands-on frequency analysis is essential for audio engineering, music production, and related fields.

1.1 Basic Block Diagram

The audio input first passes through a buffer stage that amplifies the signal. Subsequently, it is processed by 10 active bandpass filters. Each filter is linked to an LED driver, which activates the LEDs based on the audio signal within its respective frequency band

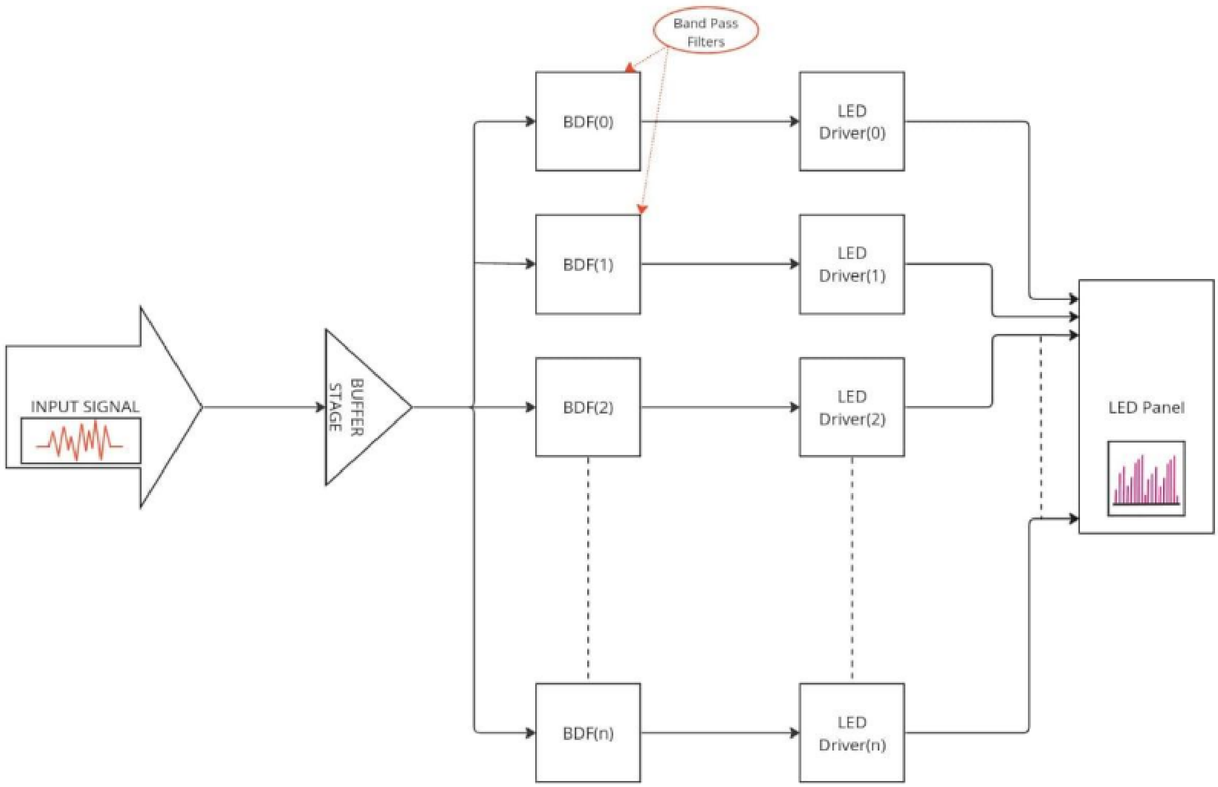


Figure 1.1: Block Diagram

1.2 Functionality

The functionality of the spectrum analyzer revolves around the analysis of the amplitude distribution across different frequency bands within the audio spectrum.

1.2.1 Signal Input

The spectrum analyzer begins by taking an input audio signal, typically from a microphone, audio source, or other input devices. In our design we are using a 3.5mm AUX port where we can get the input signal through an AUX cable.

1.2.2 Signal Conditioning

To ensure accurate analysis, first amplify the sound signal before filtering. Amplification is necessary because the input signal from the AUX cable may be too weak to drive the subsequent filtering stages effectively. By amplifying the signal, improve the signal-to-noise ratio, allowing the filters to operate more precisely and accurately represent the frequency components of the original sound wave.

1.2.3 Frequency Analysis

used op-amp-based Butterworth filters to divide the amplified signal into different frequency bands. The Butterworth design was selected for its flat passband response, ensuring minimal distortion and accurate frequency analysis across the spectrum.

1.2.4 Amplitude Display

The amplitudes of different frequency bands are then displayed on a visual output, often in the form of a bar graph or a series of dots on an LED display. Each bar or dot represents the amplitude of a specific frequency band.

1.2.5 Gain Calibration

The audio spectrum analyzer was designed with an initial gain stage that includes adjustable gain control to accommodate variations in peak signal levels from different devices. This means that for devices like laptops and mobile phones, the potentiometer must be adjusted using a reference signal. For example, output a 2kHz frequency signal from the device and adjust the potentiometer until all the LEDs in the 2kHz band are fully illuminated.

1.2.6 Spectrum Visualization

The displayed spectrum provides a visual representation of how the input audio signal is distributed across the frequency range. Higher bars or brighter dots indicate higher amplitudes, giving the user a quick overview of the dominant frequencies in the audio signal.

1.2.7 Real-Time Monitoring

The spectrum analyzer operates in real-time, continuously updating the display as the input audio signal changes. This real-time monitoring is crucial for observing dynamic changes in the audio spectrum, such as during music playback or live performances.

1.2.8 Applications

Analog audio spectrum analyzers find applications in various fields, including audio engineering, music production, and sound system optimization. Engineers and musicians use them to identify frequency imbalances, detect unwanted noise, and fine-tune audio systems for optimal performance.

Chapter 2

Component Selection

2.1 Main Components Used

- NE5532P (Op-Amp) - Buffer
- TL072CP (Op-Amp) - Filters
- LM3914N - Dot Bar LED Display Driver IC
- Transformer (230V to 30V)
- LM7812CT Voltage Regulator
- 2W10 Bridge Rectifier

2.2 TL072 Op-Amp

The TL072 was selected for its low noise, wide bandwidth, and low distortion, making it ideal for audio signal integrity in spectrum analysis. Its high input impedance prevents loading effects, and as a dual op-amp, it offers flexibility in design.

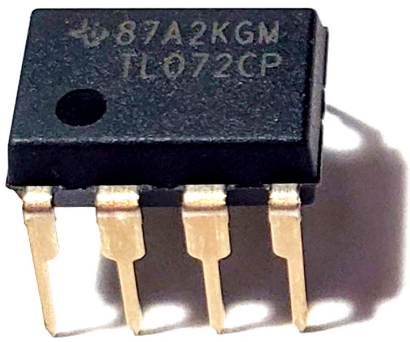


Figure 2.1: TL072 Op-Amp

2.3 NE5532 Op-Amp

The NE5532 was chosen for its excellent audio performance, featuring low noise, wide bandwidth, and low distortion, which is crucial for accurate frequency analysis in the spectrum analyzer. Its high input impedance ensures efficient signal processing.

2.4 LM3914N - Dot Bar LED Display Driver IC

The LM3914N, selected for its linear display capability, simplifies dot/bar LED displays without complex circuits. It accurately represents signal strength, essential in spectrum analysis, and is easy to integrate due to its minimal external components.

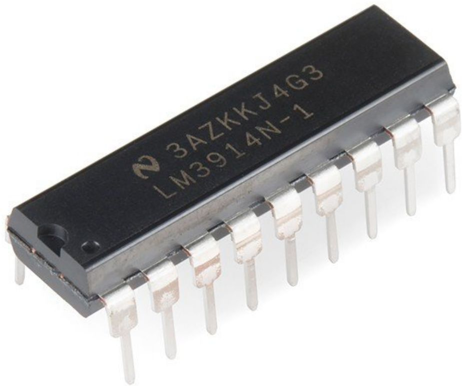


Figure 2.2: LM3914N

Chapter 3

Discussion - Filter

We will discuss how analog filters are made in this project.

3.1 Filter Type

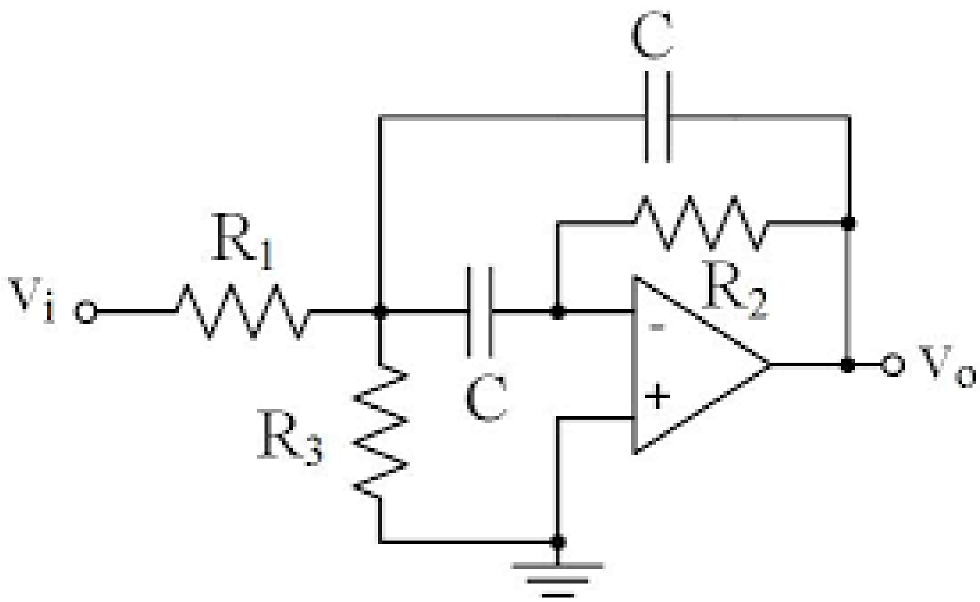


Figure 3.1: Filter

We decided to make 10 Band Pass Filters (BPFs). For each filter

- Filter Response - Butterworth
- Circuit Topology - Multiple Feedback (MFB)
- Gain (a) = 2
- Q factor (Q) = 4
- Capacitor Val (C) = 10nF

3.2 Calculations

With the help of software, we were able to find the remaining values of the other circuit components (R1, R2, R3)

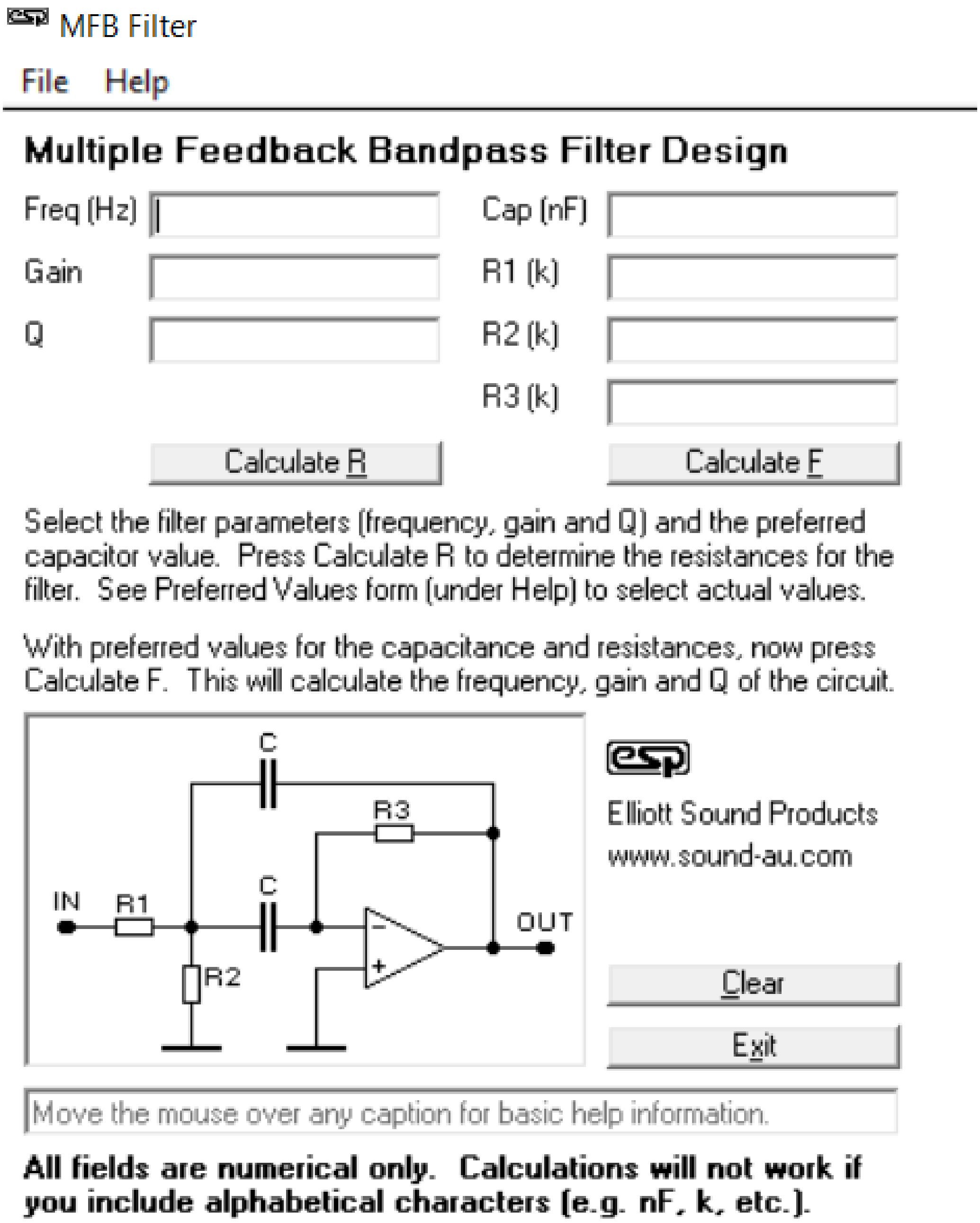


Figure 3.2: Software

The values we got from the software are given below.

Center F	R1	R2	R3
31.5	1010.5	67.36	4042.03
63	505	33.68	2021
125	254	16	1018.5
250	127.3	8.48	509.29
500	63.66	4.24	254.64
1000	31.83	2.122	127.32
2000	15.91	1.06	63.66
4000	7.95	0.53	31.83
8000	3.978	0.265	15.915
16000	1.99	0.132	7.95

Figure 3.3: Values Form Software

Since we cannot find resistors with the values generated by the software. We had to choose nearly equal resistor values. They are given below

Center F	R1	R2	R3
31.5	1000	68	4000
63	500	35	2000
125	250	16	1000
250	128	9	500
500	65	4	250
1000	32	2	128
2000	16	1	64
4000	8	0.5	32
8000	4	0.25	16
16000	2	0.13	8

Figure 3.4: Values We Have Chosen

3.3 Simulation Results

The simulation results are available here. For spice simulations, we used the LTSpice circuit simulation tool.

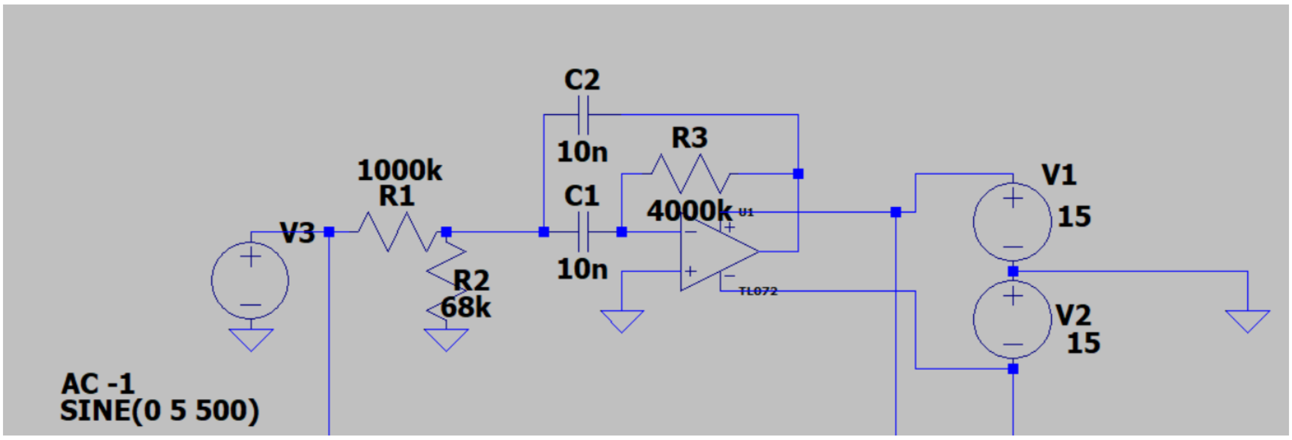


Figure 3.5: Filter Number One

We did the simulation with 10 filters. With the values that we have chosen for resistors.

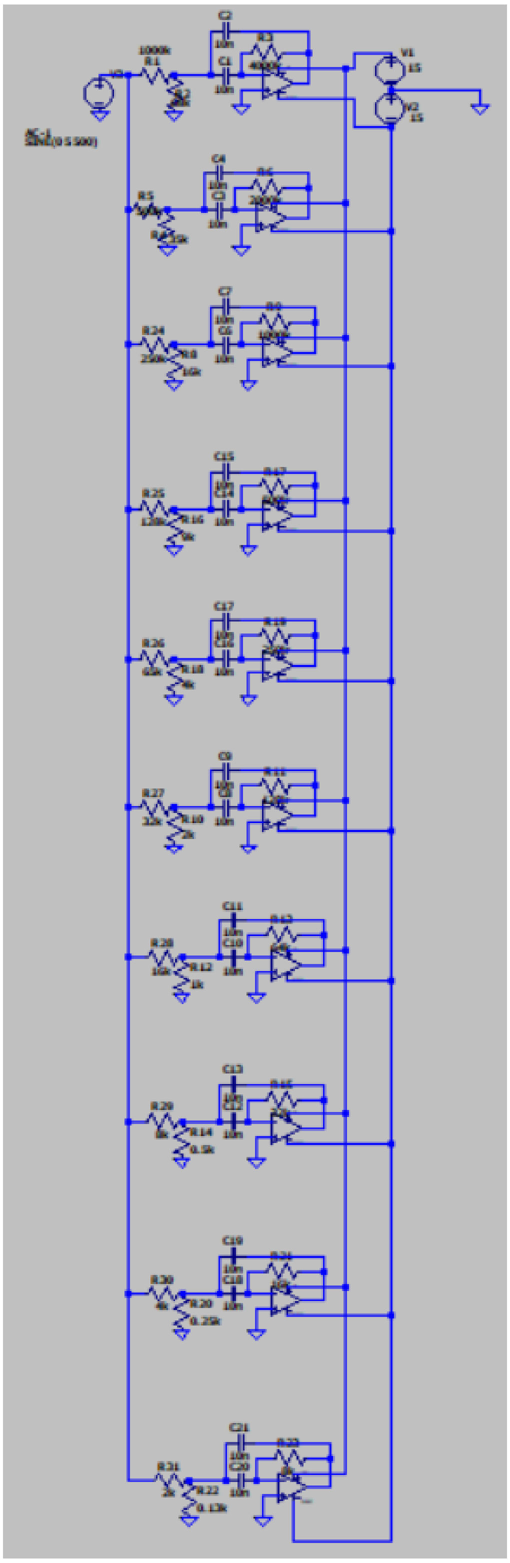


Figure 3.6: 10 Filters

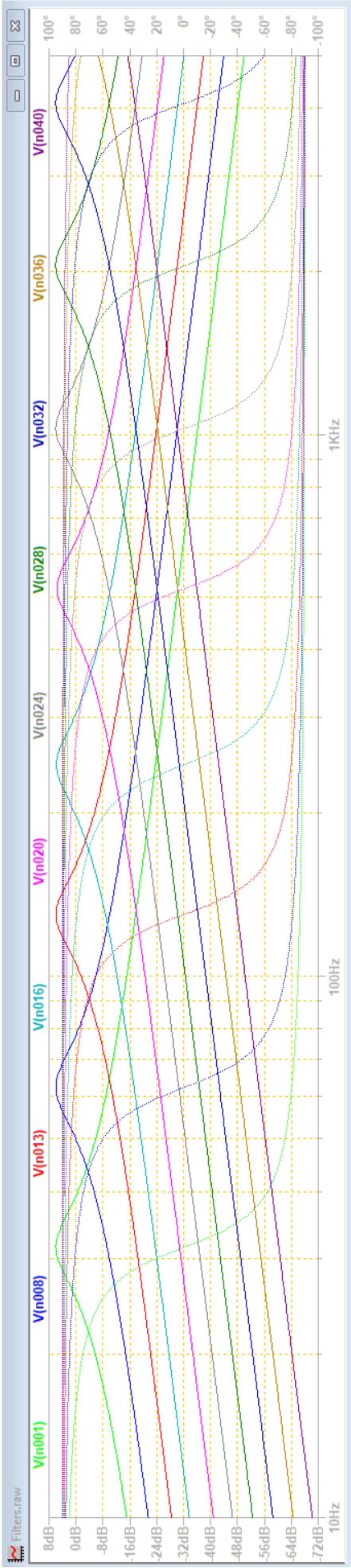


Figure 3.7: Simulated Waves

Chapter 4

Discussion - LED drivers and LED matrix

We will discuss things related to LED drivers here.
LM3914N was our LED driver IC.

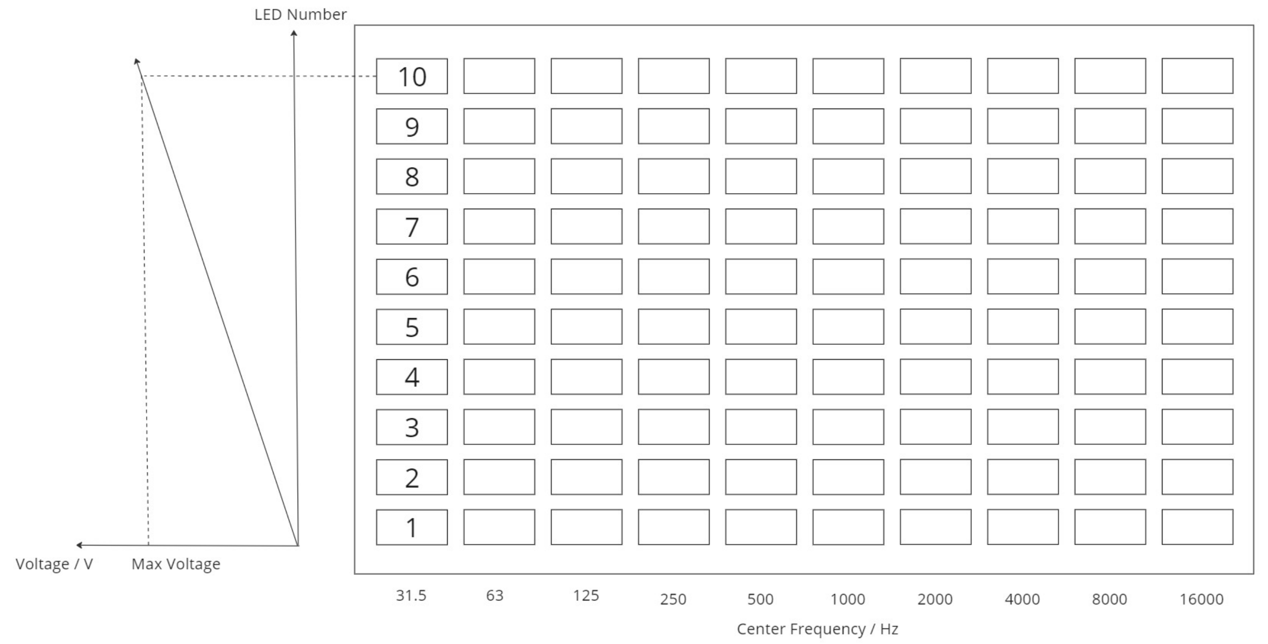


Figure 4.1: Values We Have Chosen

- Max Voltage of IC (Max Voltage) = 5V
- for each LED the voltage increases by = 0.5V

Chapter 5

Discussion - Power Supply

The power supply unit is designed to convert AC input into regulated +12V and -12V DC outputs, which are essential for powering the various components of the system.

5.1 Power Supply Circuit

The power supply circuit comprises several key elements:

- Bridge Rectifier: The bridge rectifier, specifically the 2W10, is used to convert AC input to DC output.
- Capacitors for Filtering: Capacitors are employed to filter the DC signal. The specific capacitors: C1 and C2: 1000 µF
- Voltage Regulators: The voltage regulators, LM7812CT and LM7912CT/NOPB, are used to provide stabilized +12V and -12V outputs, respectively.
- Decoupling Capacitors: These capacitors are included to stabilize the output voltage and reduce noise. The specific capacitors: C3 and C4: 100 nF, C5 and C6: 10 µF

5.2 Components

The specific components used in the power supply circuit are as follows:

- Bridge Rectifier: 2W10
- Capacitors:
  - C1, C2: 1000 µF
  - C3, C4: 100 nF
  - C5, C6: 10 µF
- Voltage Regulators:
  - LM7812CT
  - LM7912CT/NOPB

5.3 Functionality

To use the power supply, connect the AC inputs to the AC1 and AC2 terminals. The circuit will then provide regulated +12V and -12V outputs.

5.4 Connections

For connecting the power supply to the filter:

- Connect V+ from the power supply to V+ of the filter.
- Connect V- from the power supply to V- of the filter.
- Ensured all necessary ground connections were made.

5.5 Calculations

The trace width of 0.381 mm (1/2 oz) is designed to handle up to 3 A of current. Each LED has a maximum current draw of 30 mA. For a circuit with 100 LEDs, the total current required can be calculated as:

$$I_{\text{total}} = 100 \times 30\,\text{mA} = 3000\,\text{mA} = 3\,\text{A}$$

Since the total current of 3 A matches the maximum current capacity of the 0.381 mm trace width, and a polygon pour is used for the ground layer, this setup will work effectively for a circuit with 100 LEDs.

Chapter 6

PCB Design

In our endeavor to design a robust and cost-effective Printed Circuit Board (PCB) for our project, we have successfully created two distinct PCBs. The first PCB is a dedicated power supply unit, designed to provide stable and reliable power to our system. The second PCB is a multifunctional board that incorporates two filters along with two LED drivers, serving as the backbone of our spectrum analyzer.

During the design phase, we encountered a limitation in the availability of low noise Integrated Circuits (ICs). The ICs we sourced were equipped with only two operational amplifiers (op-amps) each. This constraint led us to the solution of integrating only two filters per PCB. While our project required a total of ten filters, manufacturing a single PCB with all ten would have resulted in prohibitive costs. Therefore, we opted for a modular approach, distributing the filters across multiple PCBs to balance functionality with financial viability.

Each PCB is constructed with two layers, a decision driven by the necessity to accommodate several components that could not be efficiently arranged on a single layer.

To further elevate the quality of our PCBs, we made several strategic choices. We replaced standard wire connections with JST connectors, ensuring a more secure and reliable electrical connection. Additionally, we meticulously optimized the PCB layout to minimize its size without compromising on performance or safety standards. This miniaturization effort not only reduced material costs but also paved the way for a more compact and elegant final product.

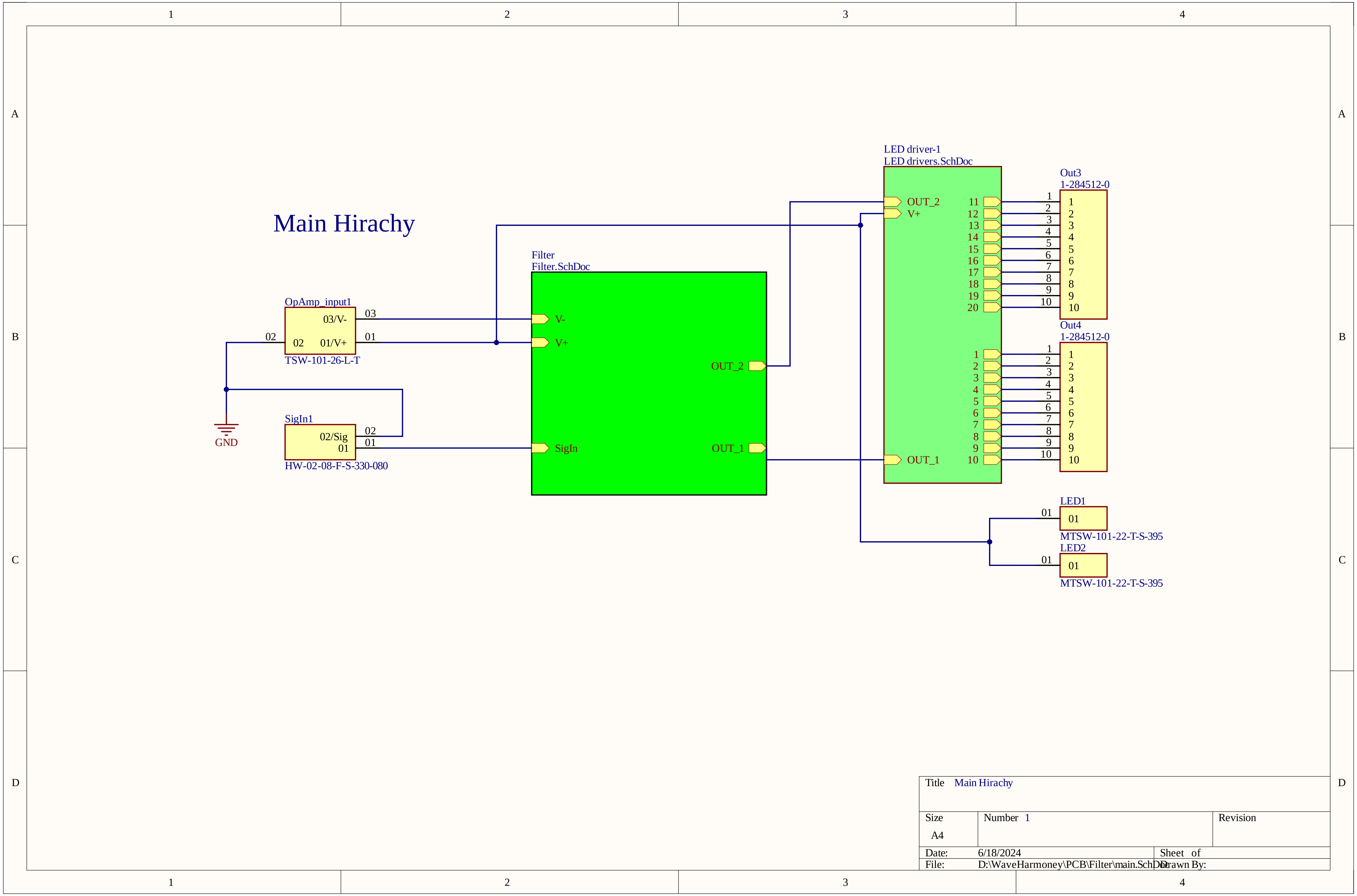
Our commitment to excellence is reflected in every aspect of the PCB design, from the careful selection of components to the precision of the layout. The result is a pair of high-quality PCBs that promise to be the cornerstone of our project's success.

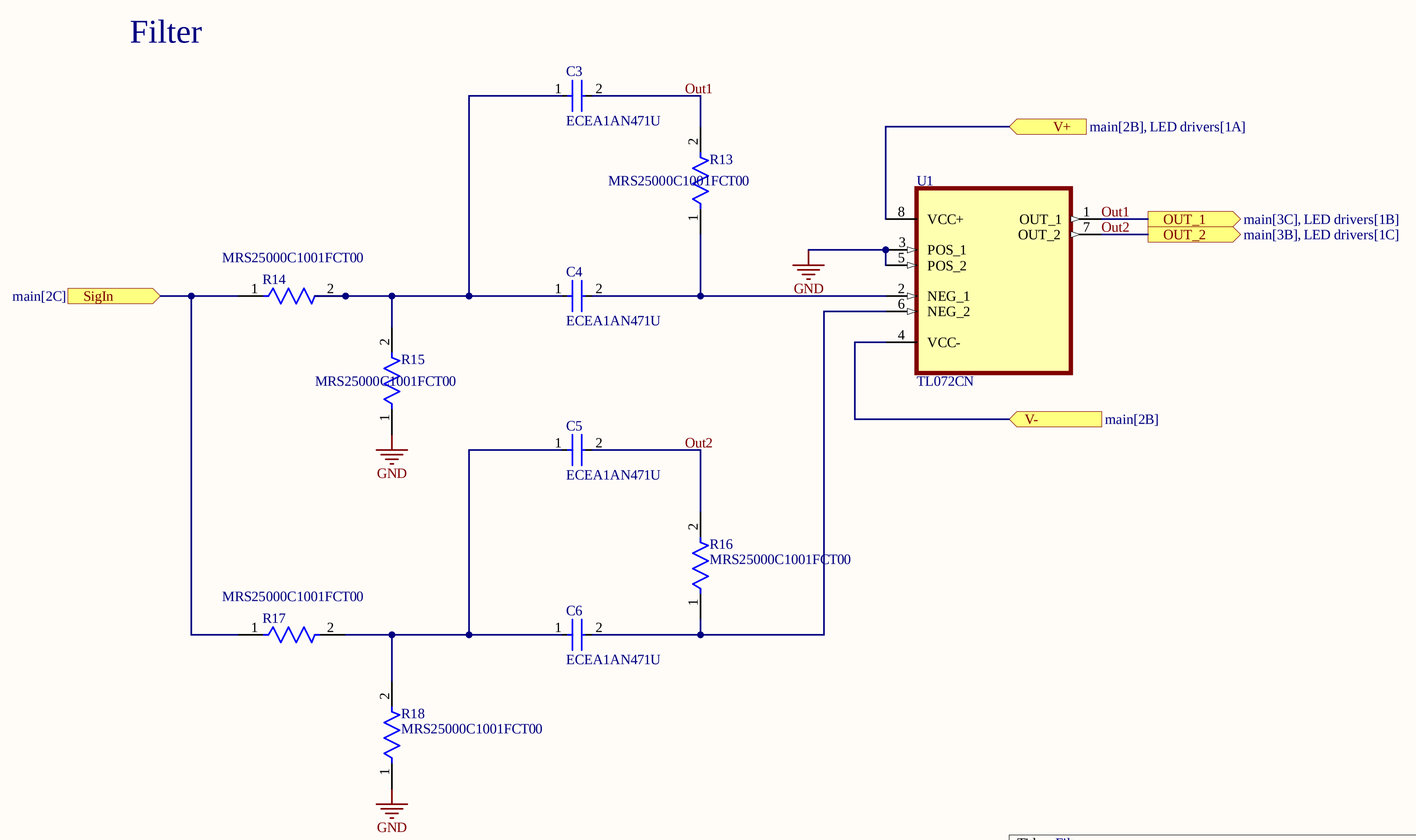
We made 2 PCBs

1. Filter And LED Driver
2. Power Supply

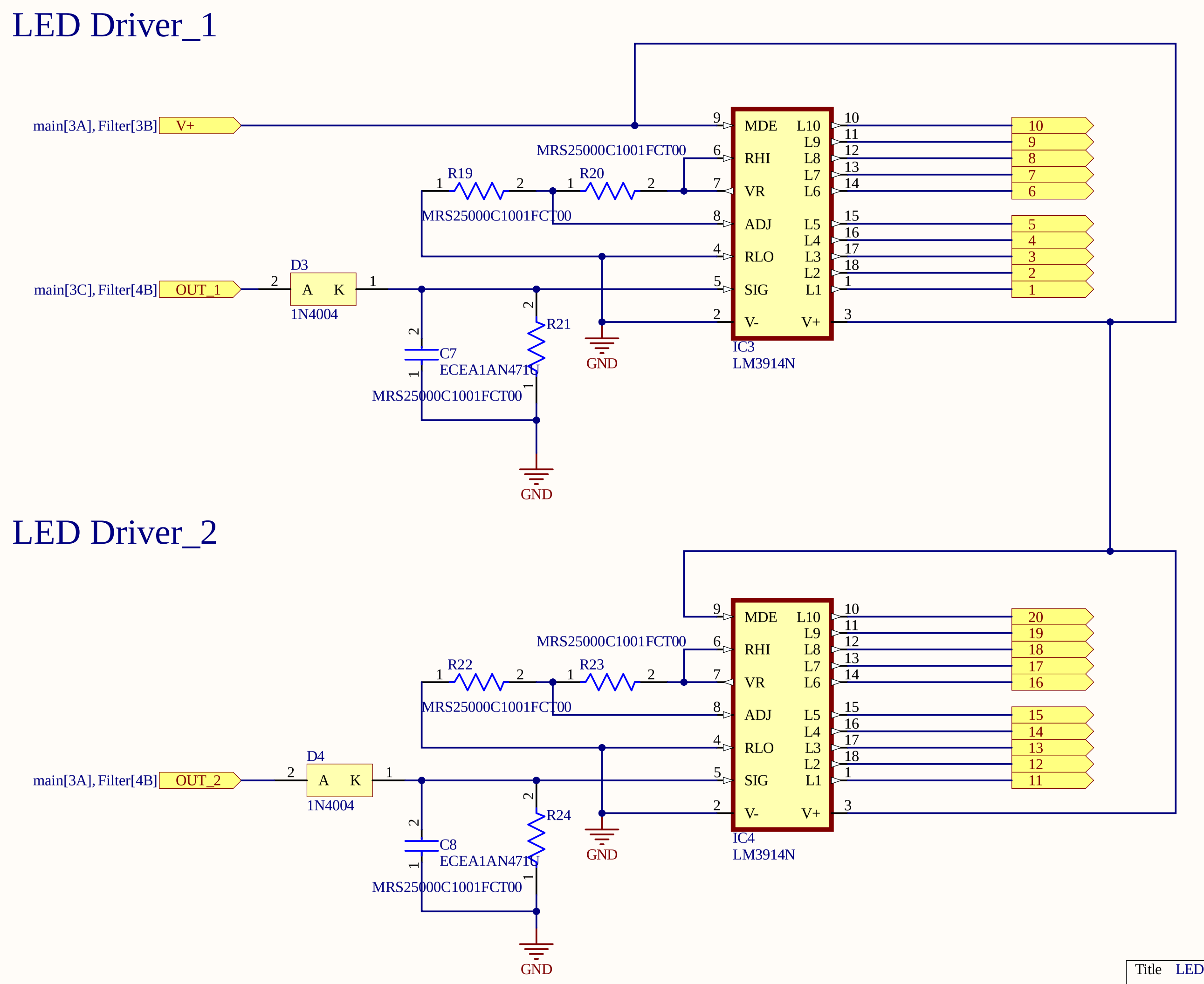
The Schematic and PCB files are arranged in the following order

1. Top Level Filer And LED Driver Schematics
2. Filter Schematic
3. LED Driver Schematic
4. BOM of Filer And LED Driver PCB
5. PCB Layout of Filer And LED Driver PCB
6. Power Supply Schematic
7. BOM Power Supply PCB
8. PCB Layout of Power Supply PCB


Main Hirachy
OpAmp_input1
03/V-
02
01/V+
TSW-101-26-L-T
03
01
02
SigIn1
02/Sig
01
HW-02-08-F-S-330-080
GND
Filter
Filter.SchDoc
V-
V+
SigIn
OUT_2
OUT_1
LED driver-1
LED drivers.SchDoc
OUT_2
V+
OUT_1
Out3
1-284512-0
Out4
1-284512-0
LED1
MTSW-101-22-T-S-395
LED2
MTSW-101-22-T-S-395
Title Main Hirachy
Size A4
Number 1
Revision
Date: 6/18/2024
Sheet of
File: D:\WaveHarmoney\PCB\Filter\main.SchDoc
Drawn By:

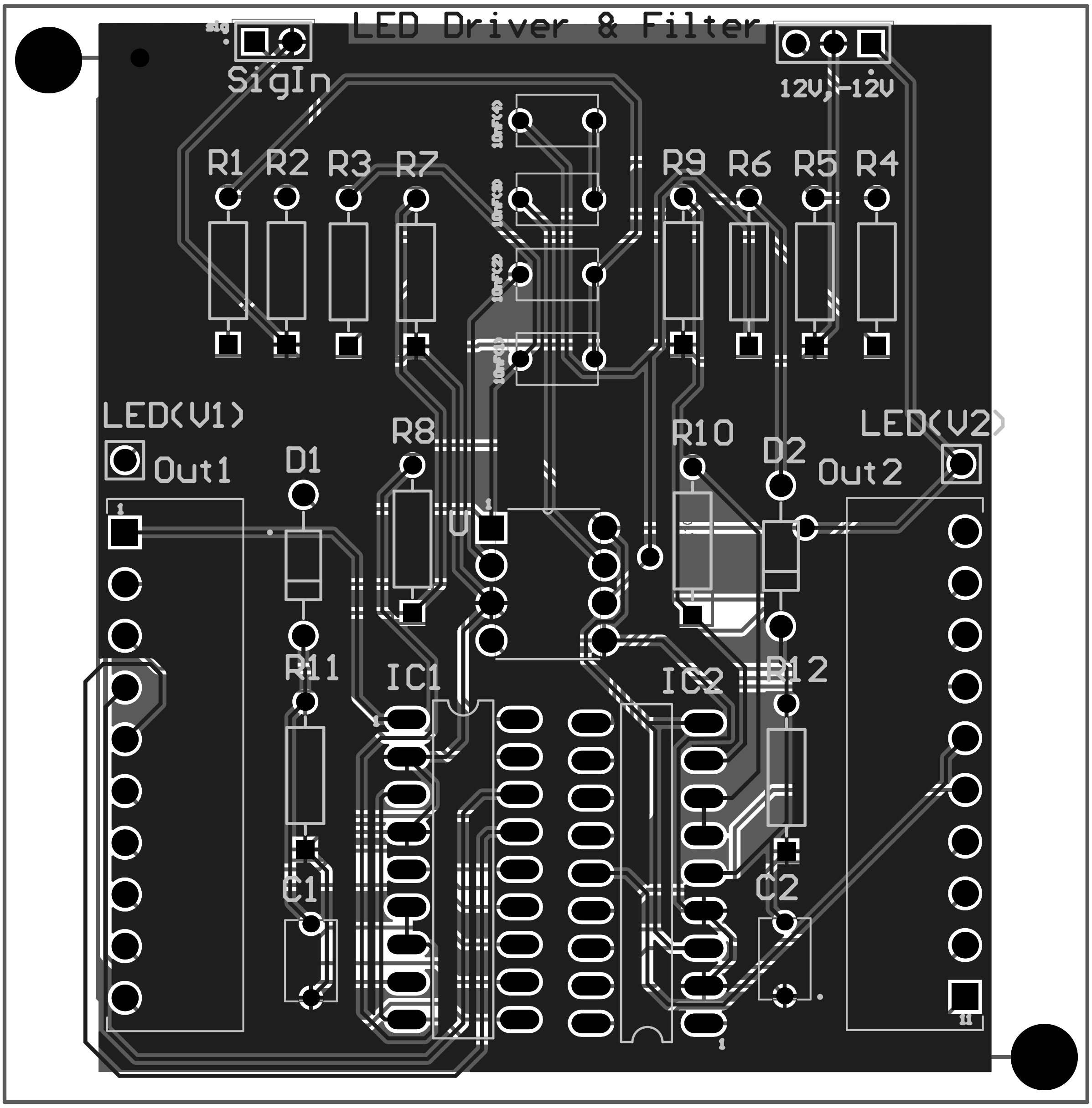


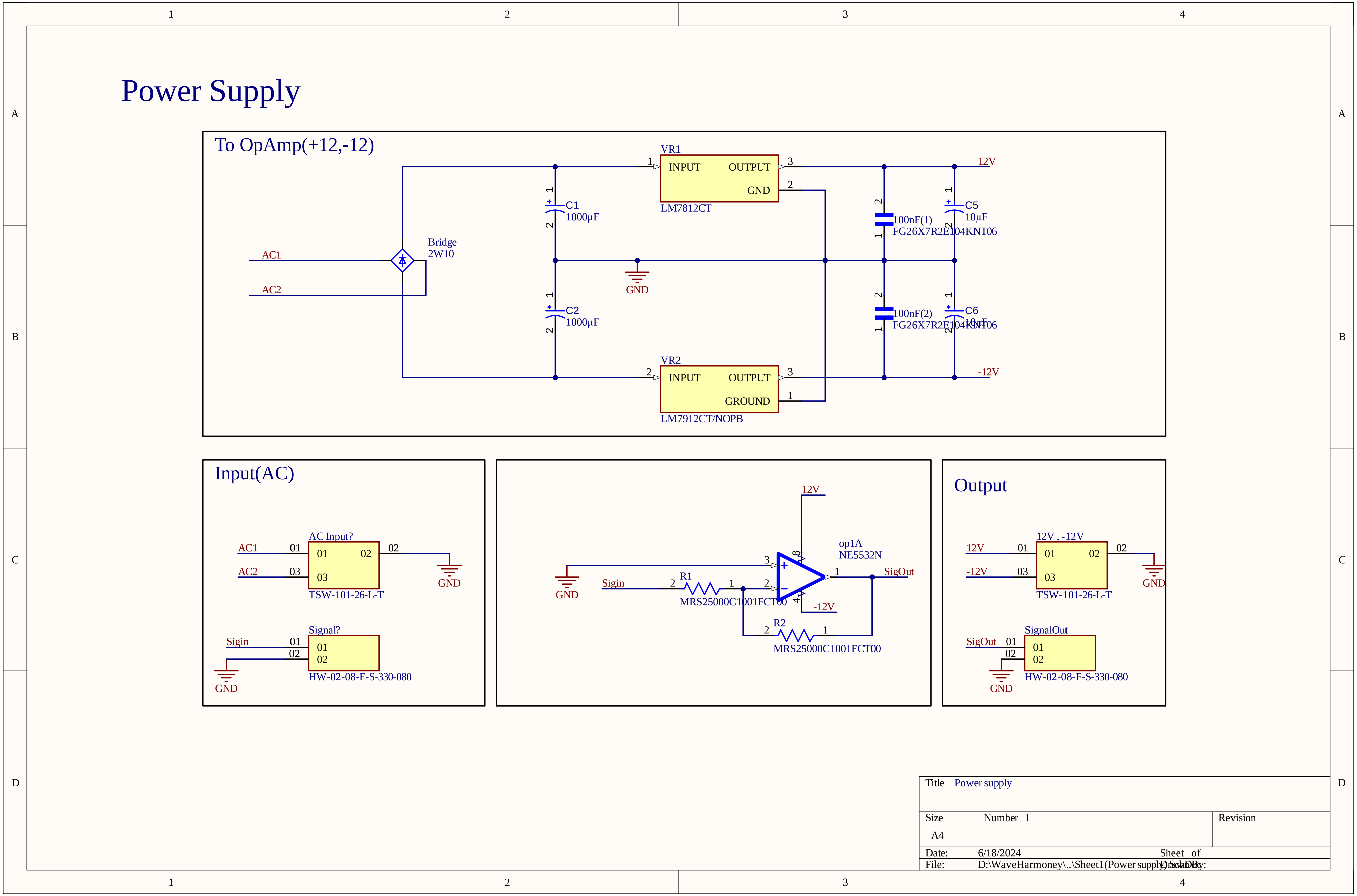
Title Filter			
Size A4	Number 2		Revision
Date:	6/18/2024	Sheet of	
File:	D:\WaveHarmoney\..\Filter.SchDoc	Drawn By:	



Title LED drivers		
Size A4	Number 3	Revision
Date: 6/18/2024		Sheet of
File: D:\WaveHarmoney\..\LED drivers.SchDoc		Drawn By:

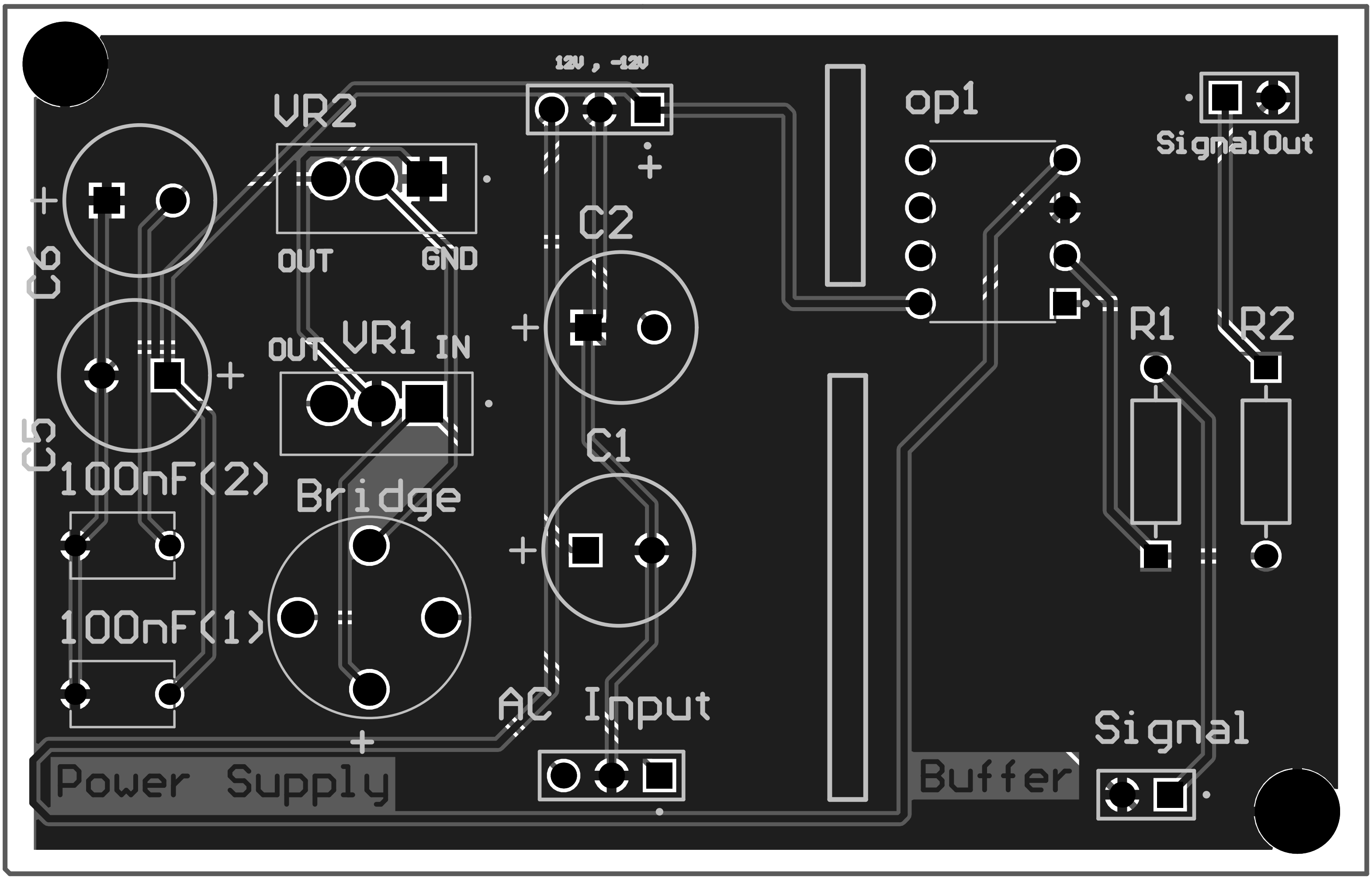
Comment	Description	Designator	Footprint	LibRef	Quantity
ECEA1AN471U	Aluminum Electrolytic Capacitors (Radial Lead Type) 470uF ±20% 10V	C3, C4, C5, C6, C7, C8	FP-RAD-TH-D_10_0_5-L_16_1-MFG	CMP-05427-001928-1	6
1N4004	Standard Recovery Rectifier, 2-Pin Axial_Lead, Pb-Free, Bulk Bag	D3, D4	ONSC-AXIAL_LEAD-2-59-10_P	CMP-0902-00115-1	2
LM3914N	LED Lighting Drivers	IC3, IC4	DIL18	LM3914N	2
MTSW-101-22-T-S-395	Connector Header Through Hole 1 position	LED1, LED2	SAMTEC_MTSW-101-22-T-S-395	MTSW-101-22-T-S-395	2
TSW-101-26-L-T		OpAmp_input1	SAMTEC_TSW-101-26-L-T	TSW-101-26-L-T	1
1-284512-0	10 POS TERMI-BLOK HDR 900 POLA	Out3, Out4	TE_1-284512-0	1-284512-0	2
MRS25000C1001FCT00	RES 1K OHM 0.6W 1% AXIAL	R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24	FP-MRS25-MFG	CMP-02408-000051-1	12
HW-02-08-F-S-330-080		SigIn1	SAMTEC_HW-02-08-F-S-330-080	HW-02-08-F-S-330-080	1
TL072CN	J-FET Amplifier 2 Circuit 8-DIP	U1	DIP254P762X533-8	TL072CN	1


LED Driver & Filter
SigIn
12V,-12V
R1
R2
R3
R7
R9
R6
R5
R4
LED(V1)
Out1
LED(V2)
Out2
D1
R8
R10
D2
R11
IC1
IC2
R12
C1
C2



Power Supply
To OpAmp(+12,-12)
VR1
INPUT
OUTPUT
GND
LM7812CT
VR2
INPUT
OUTPUT
GROUND
LM7912CT/NOPB
C1
1000µF
C2
1000µF
C5
10µF
C6
10µF
100nF(1)
100nF(2)
FG26X7R2E104KNT06
Bridge
2W10
AC1
AC2
GND
12V
-12V
Input(AC)
AC Input?
TSW-101-26-L-T
Signal?
HW-02-08-F-S-330-080
Sigin
op1A
NE5532N
R1
R2
MRS25000C1001FCT00
SigOut
Output
12V , -12V
SignalOut
Title Power supply
Size A4
Number 1
Revision
Date: 6/18/2024
Sheet of
File: D:\WaveHarmoney\..\Sheet1(Power supply).SchDoc
Drawn By:

Comment	Description	Designator	Footprint	LibRef	Quantity
TSW-101-26-L-T		12V , -12V, AC Input?	SAMTEC_TSW-101-26-L-T	TSW-101-26-L-T	2
FG26X7R2E104KNT06	0.1ÂµF Â±10% 250V Ceramic Capacitor X7R Radial	100nF(1), 100nF(2)	CAPRB500W50L550T350H600	FG26X7R2E104KNT06	2
2W10	Bridge Rectifier Single Phase Standard 1 kV Through Hole WOM	Bridge	2W10	2W10	1
ECA1HM101	Aluminum Electrolytic Capacitor, 100 uF, +/-20%, 50 V, -40 to 85 degC, 2-Pin THD, RoHS, Bulk	C1, C2, C5, C6	CAPPR65-350-1150X800X1250	CMP-001-00026-7	4
NE5532N	General Purpose Amplifier 2 Circuit 8-PDIP	op1	DIP766W45P254L1016H533Q8	NE5532N	1
MRS25000C1001FCT00	RES 1K OHM 0.6W 1% AXIAL	R1, R2	FP-MRS25-MFG	CMP-02408-000051-1	2
HW-02-08-F-S-330-080		Signal?, SignalOut	SAMTEC_HW-02-08-F-S-330-080	HW-02-08-F-S-330-080	2
LM7812CT	Linear Voltage Regulator IC Positive Fixed 1 Output 1A TO-220-3	VR1	TO253P1057X470X2040-3	LM7812CT	1
LM7912CT/NOPB	1.5-A, negative linear voltage regulator	VR2	TO254P1054X470X1955-3	LM7912CT/NOPB	1


12V , -12V
VR2
OUT
GND
C6
OUT
VR1
IN
C5
100nF(2)
Bridge
100nF(1)
C2
C1
AC Input
Power Supply
op1
SignalOut
R1
R2
Signal
Buffer

Here are the 2D, and 3D views of the PCBs

1. Filter And LED Driver PCB 2D Top Layer
2. Filter And LED Driver PCB 2D Bottom Layer
3. Filter And LED Driver PCB 3D View 1
4. Filter And LED Driver PCB 3D View 2
5. Power Supply PCB 2D Top Layer
6. Power Supply PCB 2D Bottom Layer
7. Power Supply PCB 3D View 1
8. Power Supply PCB 3D View 2
9. Fabricated PCBs

2D Views

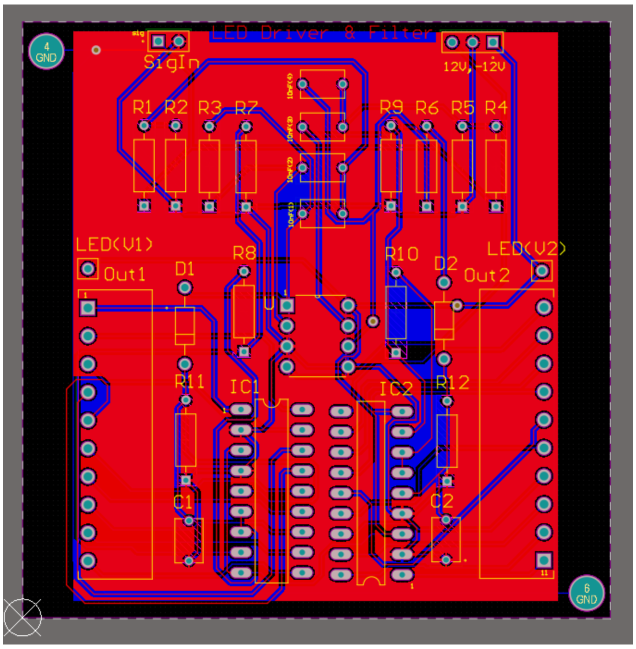


Figure 6.1: Filter And LED Driver PCB 2D Top Layer

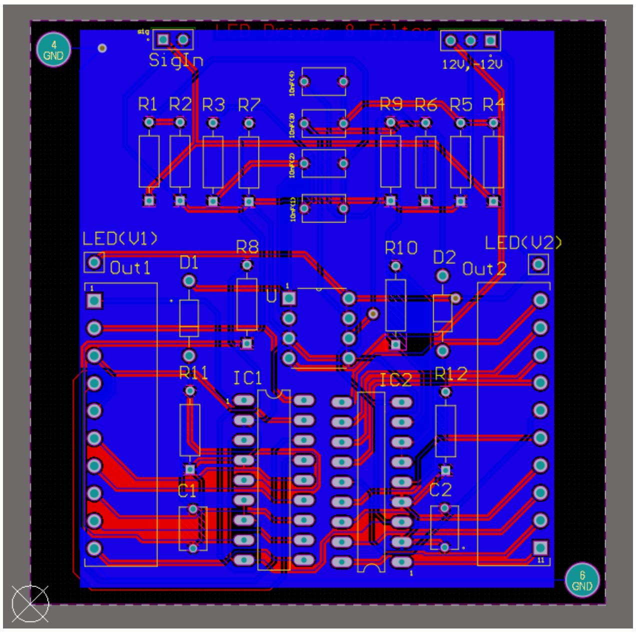


Figure 6.2: Filter And LED Driver PCB 2D Bottom Layer

3D Views

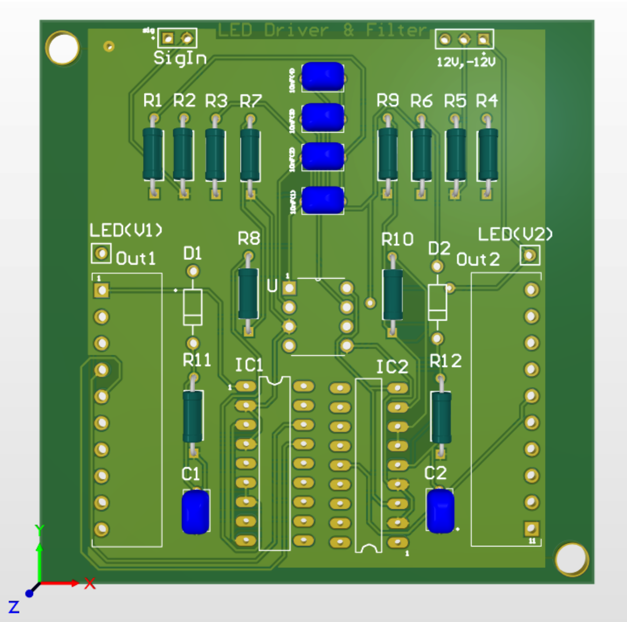


Figure 6.3: Filter And LED Driver PCB 3D View 1

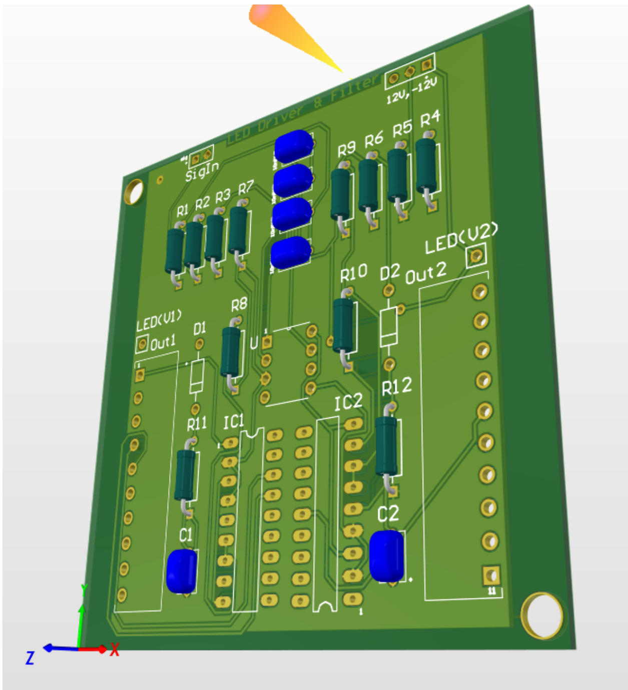


Figure 6.4: Filter And LED Driver PCB 3D View 2

2D Views

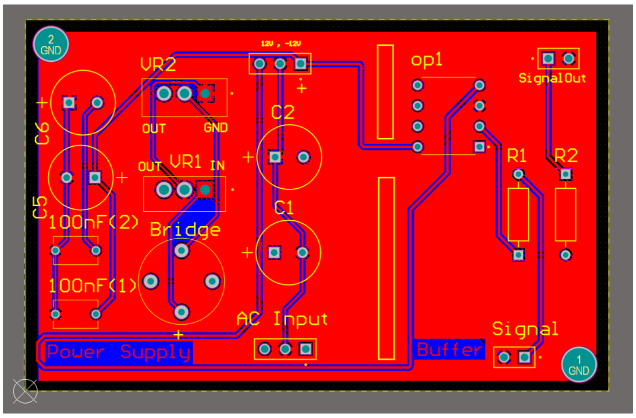


Figure 6.5: Power Supply PCB 2D Top Layer

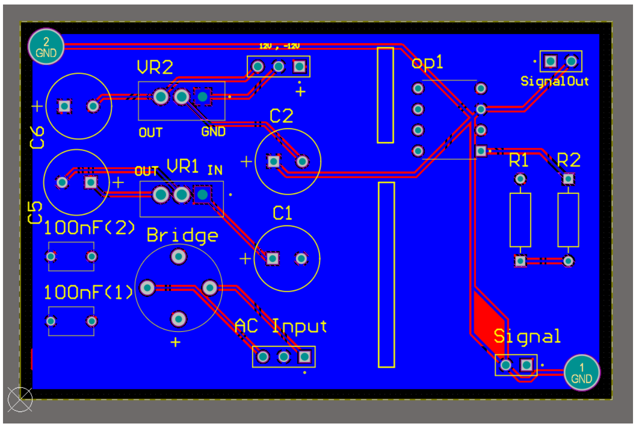


Figure 6.6: Power Supply PCB 2D Bottom Layer

3D Views

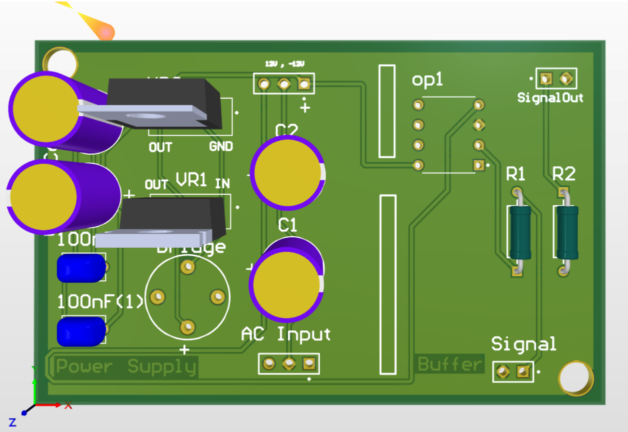


Figure 6.7: Power Supply PCB 3D View 1

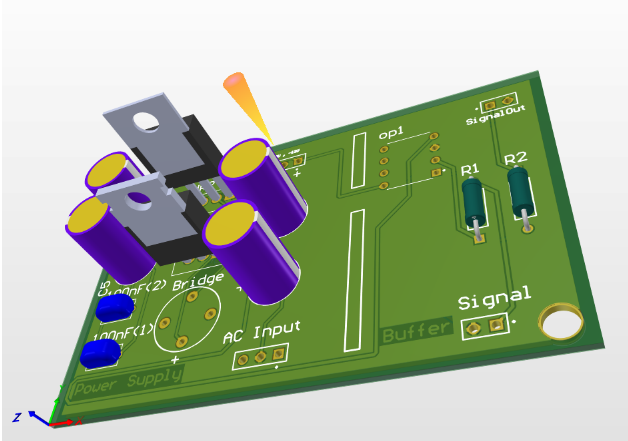


Figure 6.8: Power Supply PCB 3D View 2

PCB After Fabrication

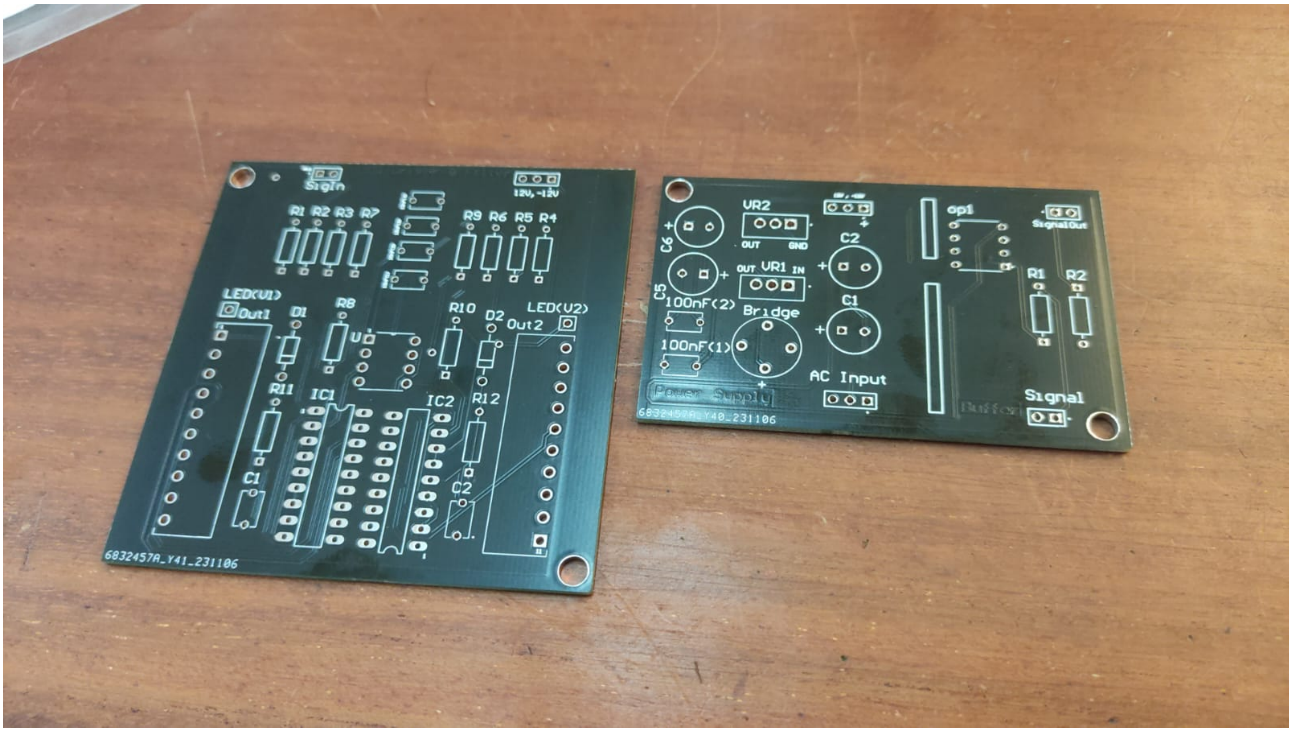


Figure 6.9: Fabricated PCBs

Chapter 7

Enclosure Design

The enclosure is made up of Acrylic and Wood.
It was designed to hold 100 transparent acrylic cubes for 100 LEDs

Black Acrylic sheets were laser cut and mounted vertically on a wood base as in the below figure. Transparent acrylic cubes were glued onto the sheet. LEDs were grilled into each cube. All the electronic circuitry was mounted to the back of the panel. The wooden box in the above figure was made to mount the transformer.

To enhance light diffusion, the acrylic cubes were abraded using sandpaper.

Color of LEDs are 1, 2 3, 4, 5 green and 6, 7 orange and 8, 9, 10 red

The sizes are given as follows (in mm)

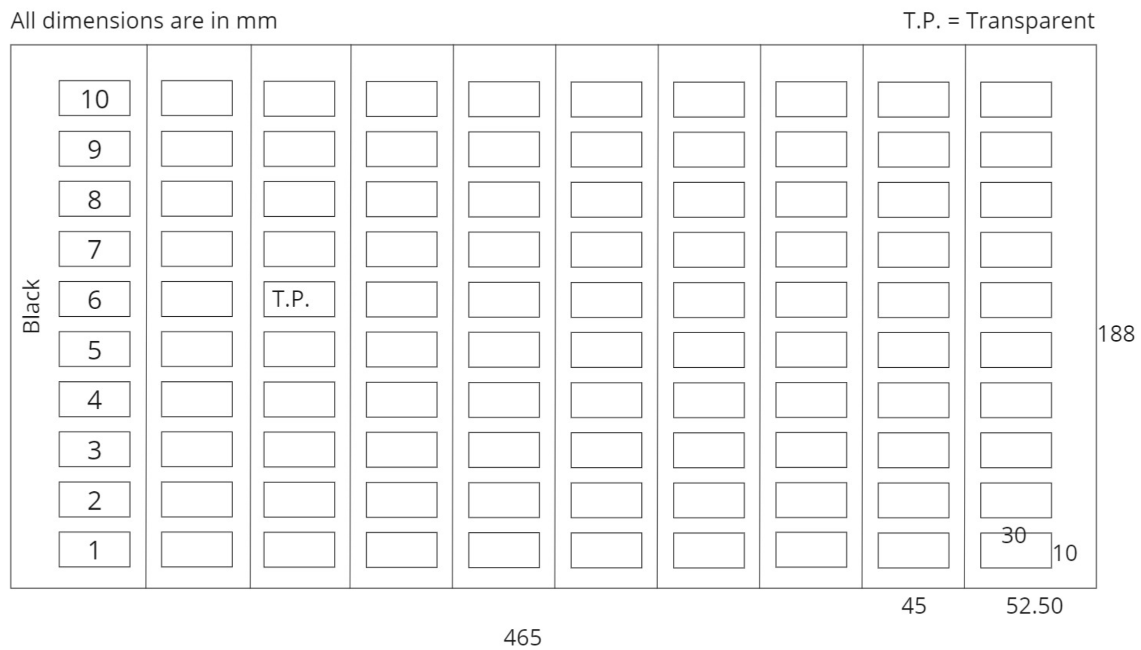


Figure 7.1: Sizes

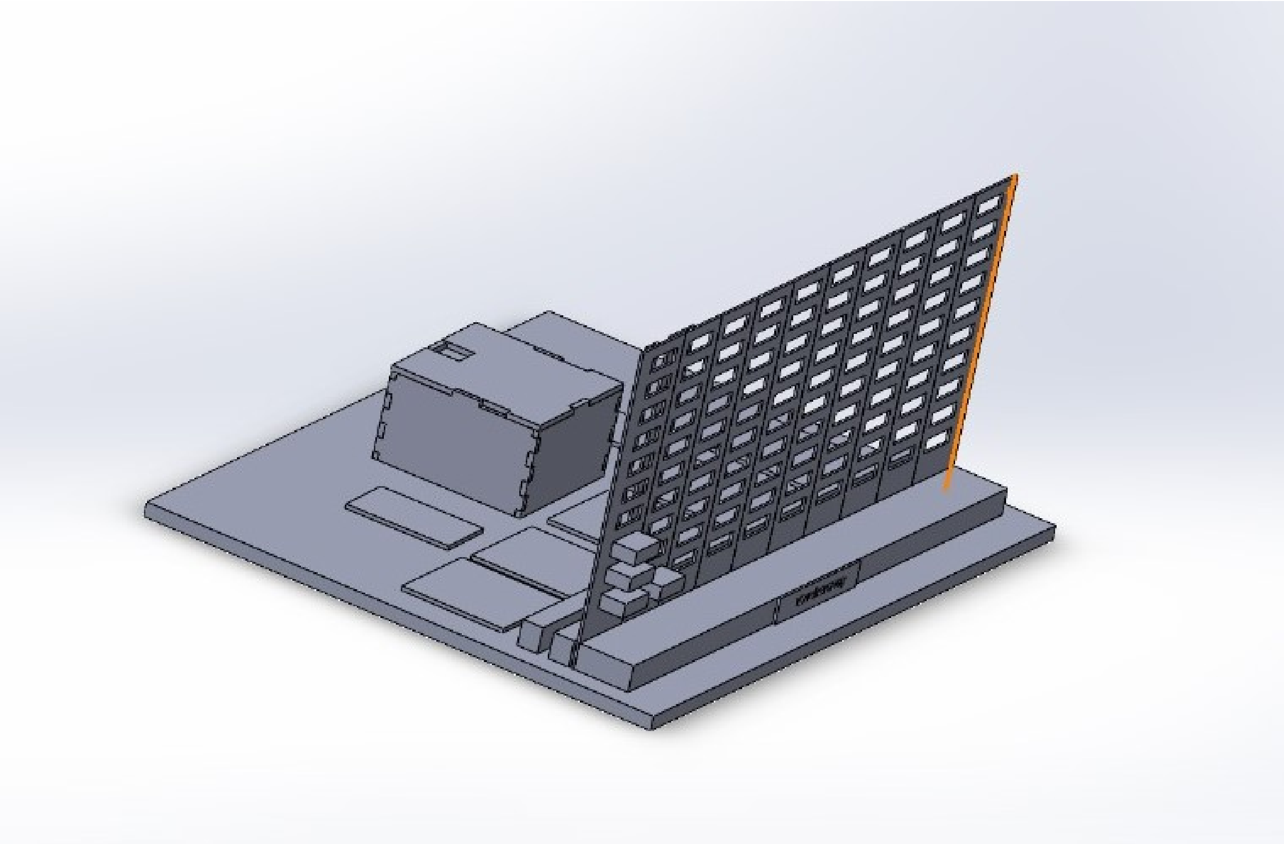


Figure 7.2: View 1

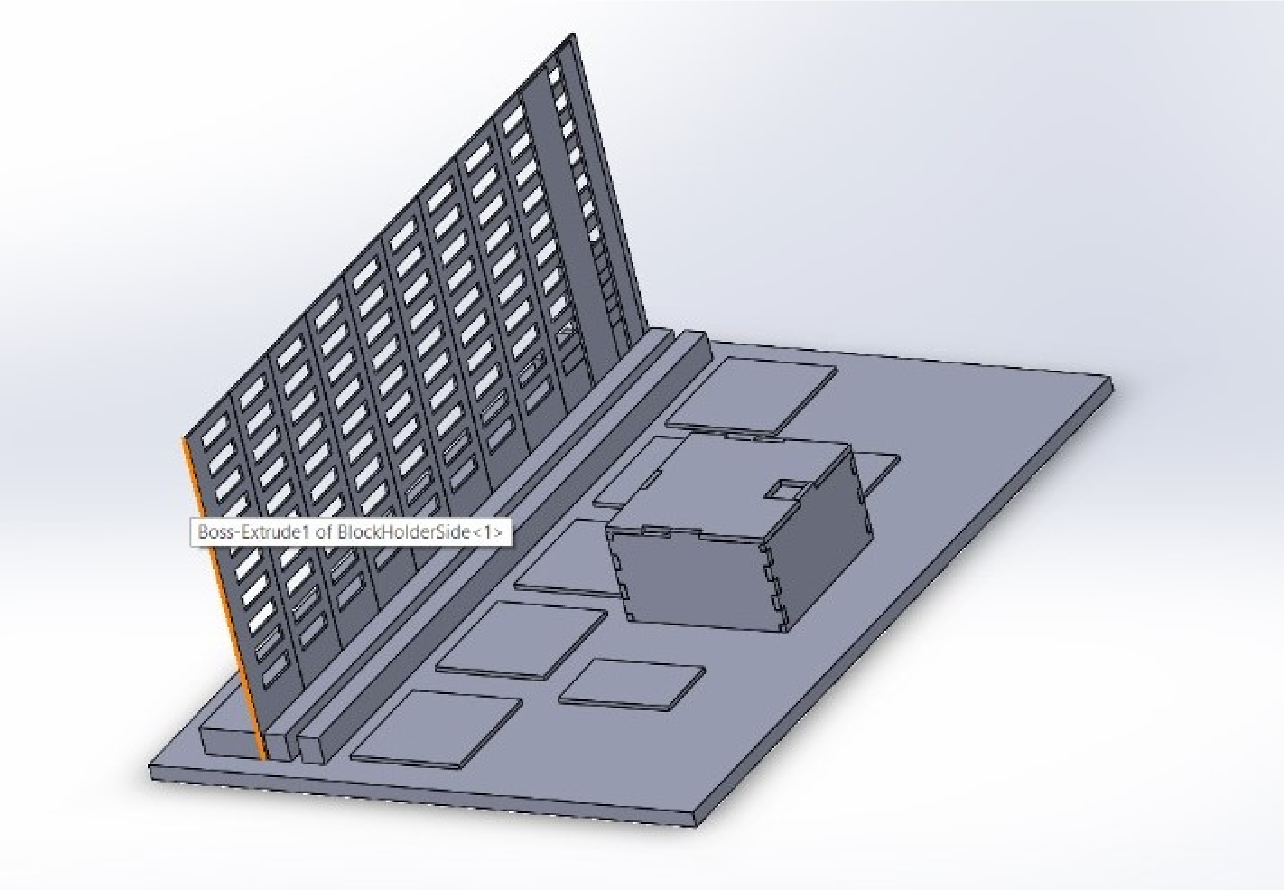


Figure 7.3: Veiw 2

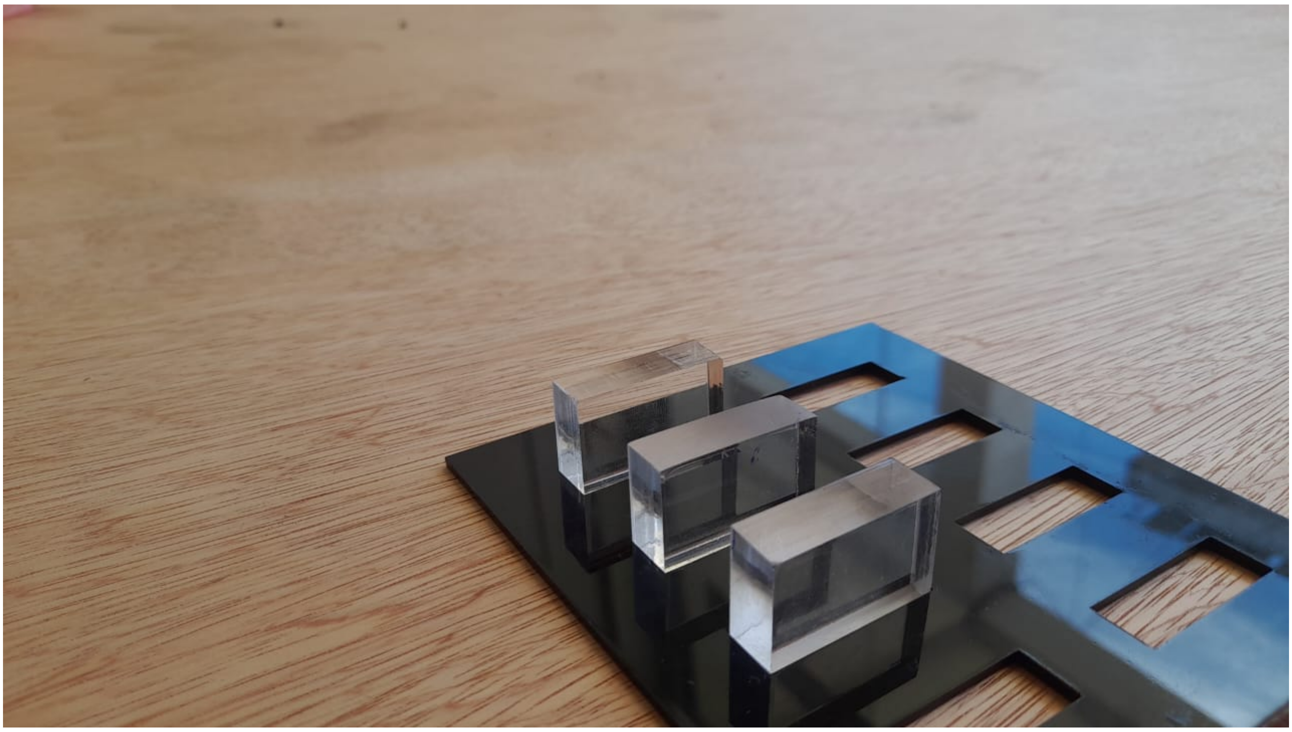


Figure 7.4: Acrylic for LEDs

Figure 7.5: Final Design View 1

Figure 7.6: Final Design View 2

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