Department of Electronic and Telecommunication Engineering

University of Moratuwa

EN-2160 Electronic Design Realization

Report on Digital Volt-Amp meter

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Abstract

This documentation report presents the design, development, and implementation of a Digital Volt-Amp Meter, a versatile electronic instrument capable of accurately measuring voltage and current in electrical circuits. The primary objective of this project was to create a market-ready and user-friendly digital voltmeter and ammeter with innovative features that cater to the evolving needs of today's technology-driven society. The initial phase involved comprehensive research into existing volt-amp meters, user requirements, and emerging trends in electronic instrumentation. Subsequently, a detailed technical specification was formulated, laying the foundation for the design process. For the successful implementation of the Digital Volt-Amp Meter, a comprehensive approach was adopted, covering all critical aspects connected to mass-scale production. This encompassed meticulous consideration and well-planned strategies for acquiring necessary components, designing printed circuit boards (PCBs), and manufacturing enclosures and packaging. These concerted efforts ensured the instrument's efficiency, reliability, and market readiness. Overall, this documentation report serves as a comprehensive reference, capturing the entire development journey of the Digital Volt-Amp Meter, and is intended to aid future enhancements and iterations of the product.

1.Introduction

1.1 Problem identification

Designing a Digital Volt-Amp Meter presents a host of critical challenges that must be meticulously addressed to ensure the instrument's accuracy, precision, and usability. One of the foremost concerns is achieving high levels of accuracy in voltage and current measurements. The design process must thoroughly consider factors such as component tolerances, noise reduction techniques, and robust calibration methods to ensure precise readings across a wide range of voltage and current values. The ability to deliver reliable measurements is paramount for meeting the diverse needs of users in various applications.

The selection and implementation of an appropriate Analog-to-Digital Converter (ADC) is another critical aspect that significantly impacts the meter's performance. The ADC choice influences parameters such as resolution, speed, and linearity, and the design must carefully evaluate various ADC options to select the most suitable one. Additionally, ensuring proper input protection is essential to safeguard the digital volt-amp meter and the connected circuits from voltage spikes, transients, and overloads. Robust input protection measures are crucial to maintaining the instrument's integrity and protecting it from potential damage during operation.

The stability of the power supply is paramount for consistent and reliable meter performance. The design should address noise reduction and voltage regulation to ensure a stable power supply, mitigating the adverse effects of power fluctuations on measurement accuracy. Temperature variations can impact the meter's performance, necessitating the incorporation of temperature compensation mechanisms to maintain accuracy under different environmental conditions.

To deliver a fast response time, the design must carefully optimize the meter's circuitry to capture transient events and dynamic changes in voltage and current quickly. Achieving a fast response time without compromising measurement accuracy is a significant challenge. Additionally, an efficient calibration process and comprehensive testing procedures are essential to validate the meter's accuracy and repeatability. A well-designed calibration process ensures that the instrument performs reliably and consistently over extended periods of use.

Integrating all components effectively and creating a compact and ergonomic form factor is a challenge that must be addressed during the design phase. Thermal management considerations are essential to prevent overheating, especially during extended usage periods. Cost optimization is also a critical aspect of the design process, requiring careful evaluation of cost-effective solutions without sacrificing essential functionalities and performance. Finally, compliance with safety standards is essential to ensure user safety during the operation of the digital volt-amp meter.

Effectively identifying and addressing these key challenges during the design process is instrumental in developing a successful and reliable digital volt-amp meter that meets industry standards and exceeds user expectations.

1.2 Project aims and objectives.

The project aim of designing a volt-amp meter is to create a sophisticated electronic instrument capable of accurately measuring both voltage and current in electrical circuits. The primary goal is to develop a versatile and reliable device that provides precise readings of voltage and current values, catering to a wide range of applications in various industries.

The designed volt-amp meter aims to offer high accuracy and precision in voltage and current measurements, ensuring reliable and repeatable results across different voltage levels and load conditions. The instrument should be user-friendly and easy to operate, with an intuitive interface that allows users to interpret the measured data effortlessly.

Additionally, the project aims to incorporate essential safety features, such as input protection and insulation, to safeguard the meter and connected circuits from voltage spikes and potential hazards during operation.

Overall, the key objectives of designing a volt-amp meter are:

1. Accurate Measurement: To provide accurate and precise readings of voltage and current values for a wide range of electrical circuits.

2. Versatility: To design a versatile instrument capable of handling various voltage levels and current ranges to meet diverse application requirements.

3. User-Friendly Interface: To create an intuitive user interface that allows users to operate the meter efficiently and interpret the measured data easily.

4. Safety: To implement robust input protection and insulation measures to ensure the safety of the meter and connected circuits during measurements.

5. Reliability: To build a reliable and stable volt-amp meter that delivers consistent performance over extended periods of use.

6. Cost-Effectiveness: To optimize the design for cost efficiency without compromising on accuracy and essential functionalities.

By achieving these aims, the designed volt-amp meter becomes an invaluable tool for engineers, technicians, and professionals in various fields, enabling them to make precise electrical measurements and ensure the efficient functioning of electrical systems.

2. Design procedure

2.1 Specifications

Figure 1 : Final product

2.1.1 Specifications of digital voltmeter:

1.Working voltage: DC5V
2.Working current: 35mA
3.Measuring accuracy: can be calibrated to get higher accuracy - 1%(±1digit)
4.Measuring range: divided into 3 grades:

- 0-2V gear Measuring small voltages
- 0-20V gear Measuring low and medium voltages
- 0-200V gear, measuring higher voltages

5.Display window size: 51*24mm
6.Display color: red
7.Operating temperatures: -15℃-70℃

2.1.2 Specifications of digital ammeter:

1.Working voltage: DC5V
2.Working current: 25mA
3.Measuring accuracy: can be calibrated to get higher accuracy - 1%(±1digit)
4.Measuring range: divided into 3 grades:

- 0-2A gear Measuring small currents-1mA resolution-1.999A
- 0-5A gear Measuring low and medium currents-10mA resolution- 9.99A
- 0-10A gear, measuring higher currents-100mA resolution-99.9A

5.Display window size: 51*24mm
6.Display color: red
7.Operating temperatures: -15℃-70℃

2.2 Extra Features:

1.) Rechargeable power supply to power the device.
    - Here I am going to use a 1000mAh Li ion battery which can run the digital volt-amp meter for 12 hours. Once it runs out of juice, we can charge the Li ion battery using a micro-usb cable. Here we want to safely charge the Li ion battery and we want to step up the battery voltage (3.7V-4.2V) into 5V which is the operating voltage of the device.

2.) Continuity tester.

2.3 Block diagram

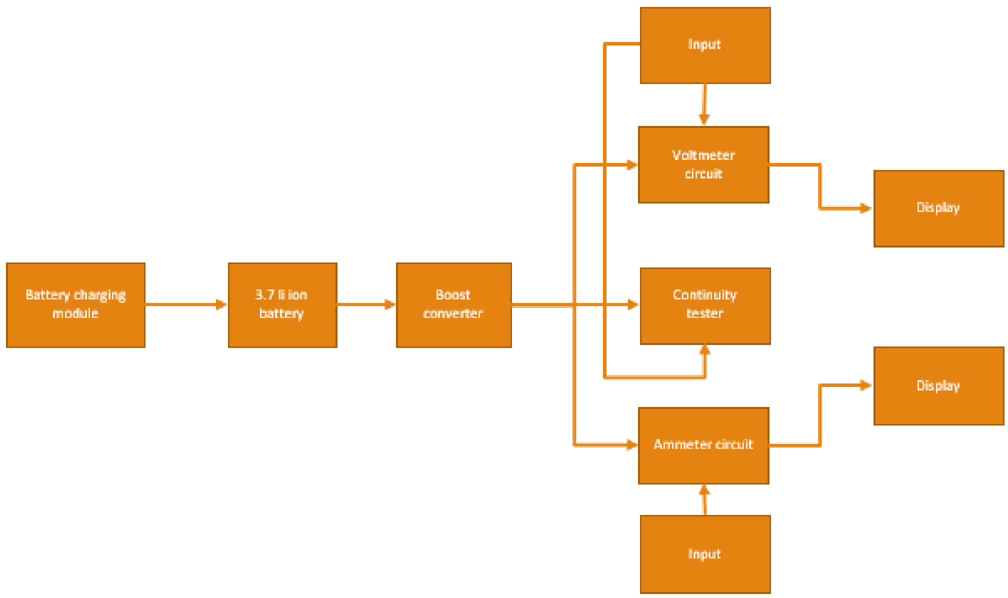


Figure 2: Block diagram of the product

2.4 Selection of Analog to Digital Converter

There are several methods that can be used as Analog-to-Digital Converters (ADCs) for a digital volt-amp meter. Some of methods as follows:

1.) Using Atmega micro controller.
2.) Using PIC micro controller.
3.) Using ICL7107 microcontroller.

From the above methods I chose the ICL7107 microcontroller to this project.

2.4.1 Why ICL7107?

The ICL7107 is a high performance, low power, 31/2-digit A/D converter. Included are seven segment decoders, display drivers, a reference, and a clock. The ICL7107 will directly drive an instrument size light diode (LED) display. The ICL7107 brings a combination of high accuracy, versatility, and true economy. It features autozero to less than 10μV, zero drift of less than 1μV/oC, input bias current of 10pA (Max), and rollover error of less than one count. True differential inputs and reference are useful in all systems but give the designer an uncommon advantage when measuring load cells, strain gauges and other bridge type transducers. Finally, the true economy of single power supply operation, enables a high-performance panel meter to be built with the addition of only 10 passive components and a display.

Features

• Guaranteed Zero Reading for 0V Input on All Scales

• True Polarity at Zero for Precise Null Detection

• 1pA Typical Input Current

• True Differential Input and Reference, Direct Display Drive

- LCD ICL7106, LED lCL7107

• Low Noise - Less Than 15μVP-P

• On Chip Clock and Reference

• Low Power Dissipation - Typically Less Than 10mW

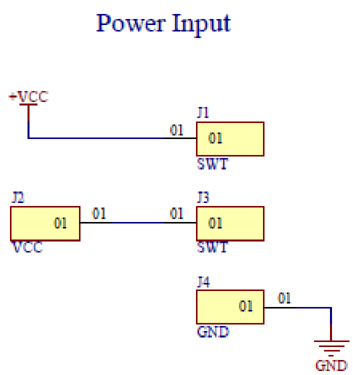
• No Additional Active Circuits Required

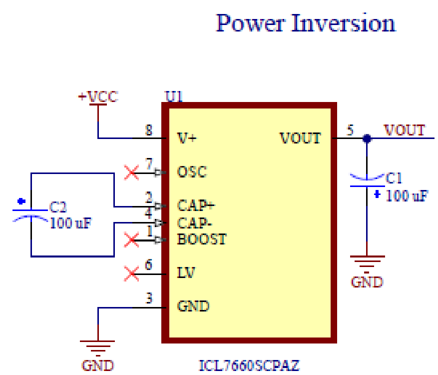
• Enhanced Display Stability

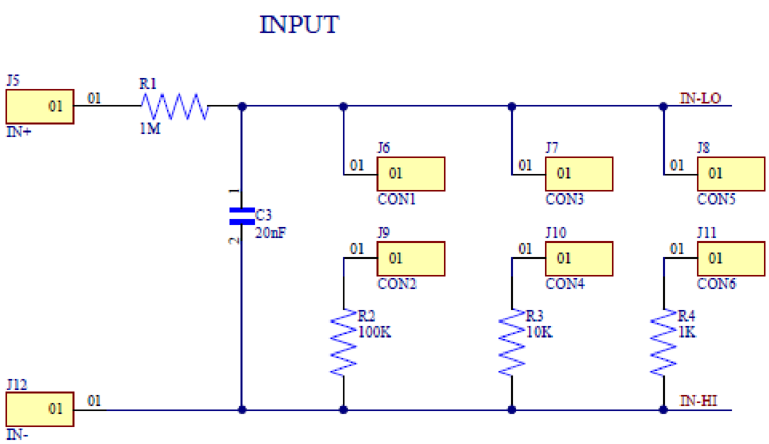
• Pb-Free Plus Anneal Available (RoHS Compliant)

2.5 Schematic diagrams

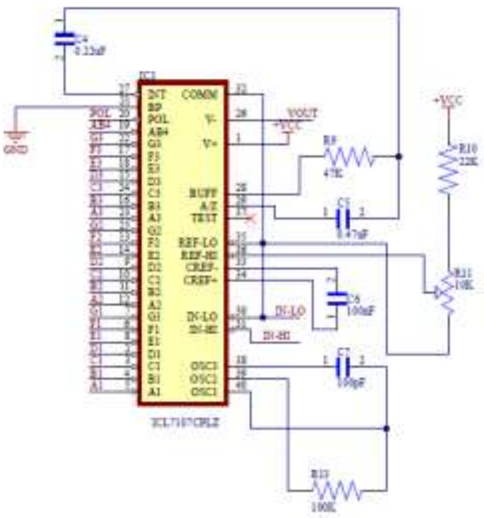
2.5.1 Digital voltmeter



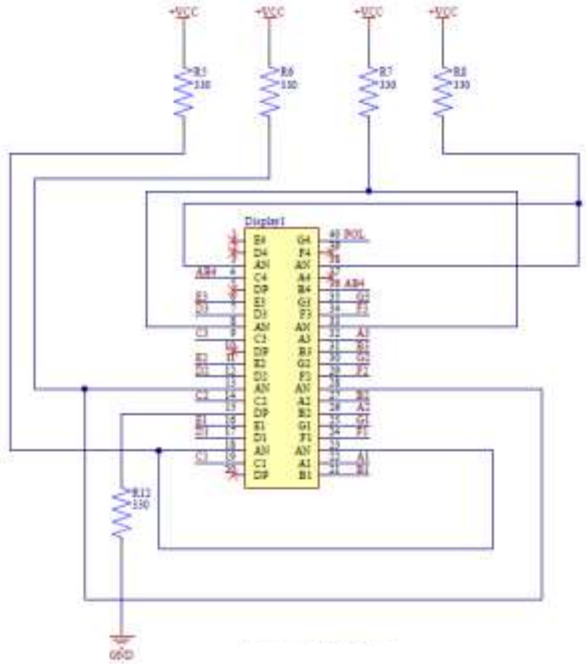




MICRO-CONTROLLER

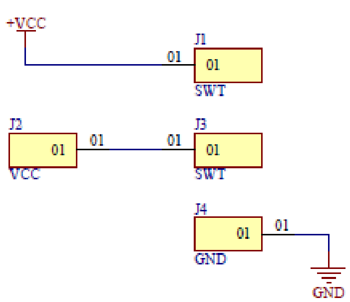


LED display

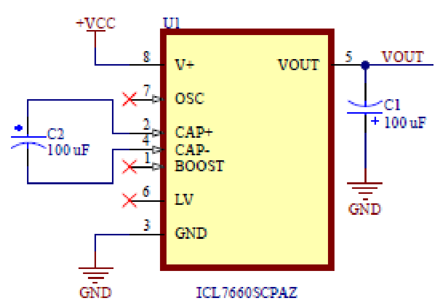


2.5.2 Digital Ammeter

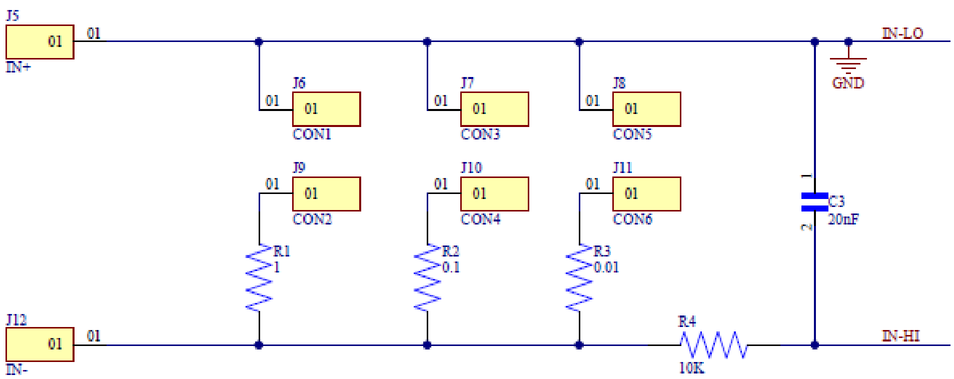
Power Input



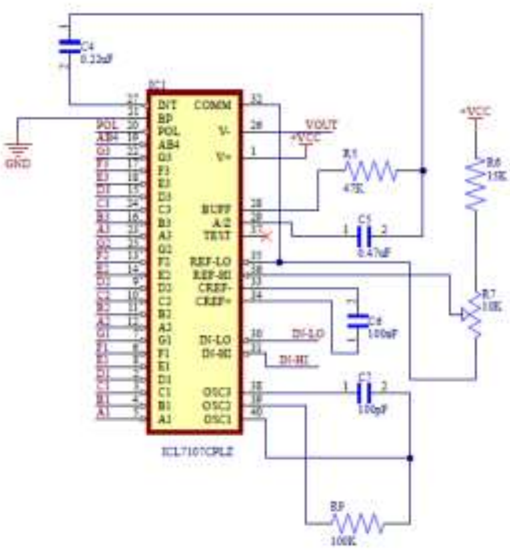
Power Inversion



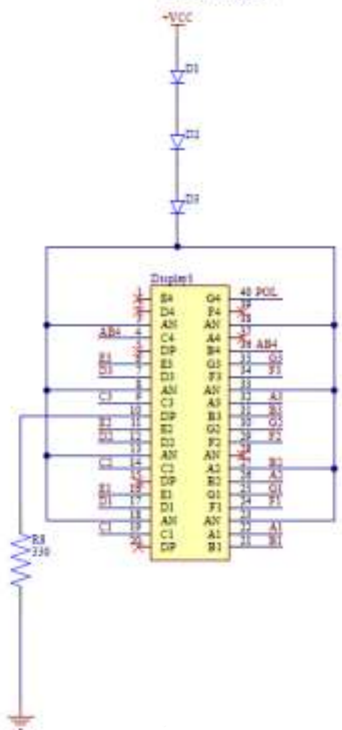
INPUT



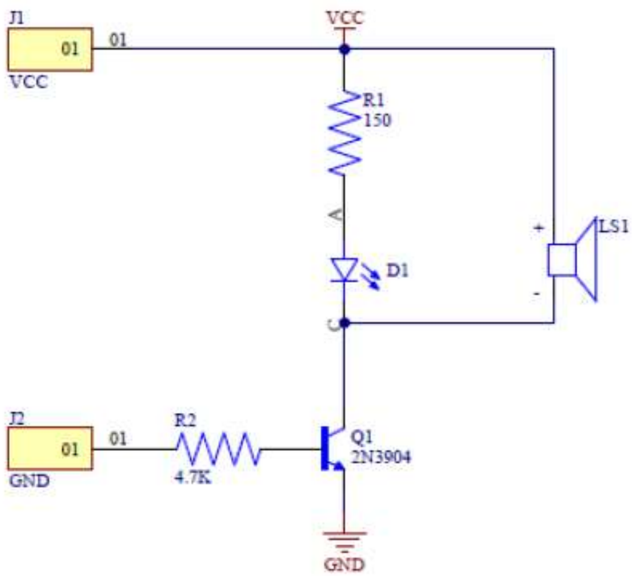
MICRO-CONTROLLER



LED display



2.5.3 Continuity tester



2.6 PCB design

This product consists of three PCBs. They are as follows.

2.6.1 Digital voltmeter

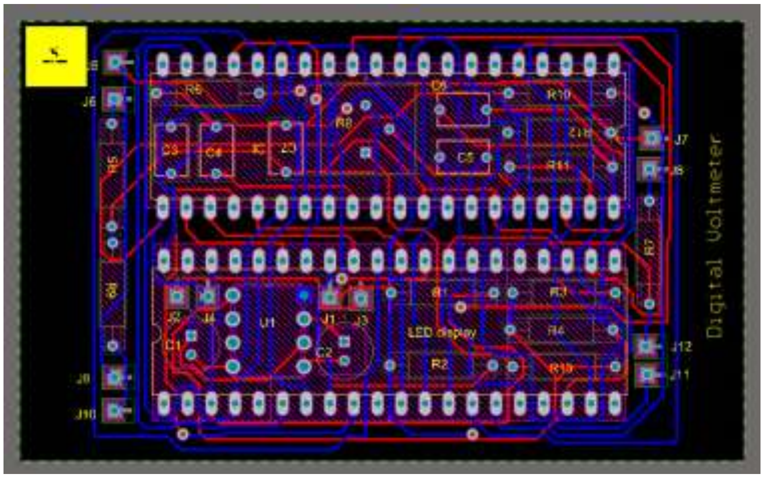


Figure 3: PCB design view

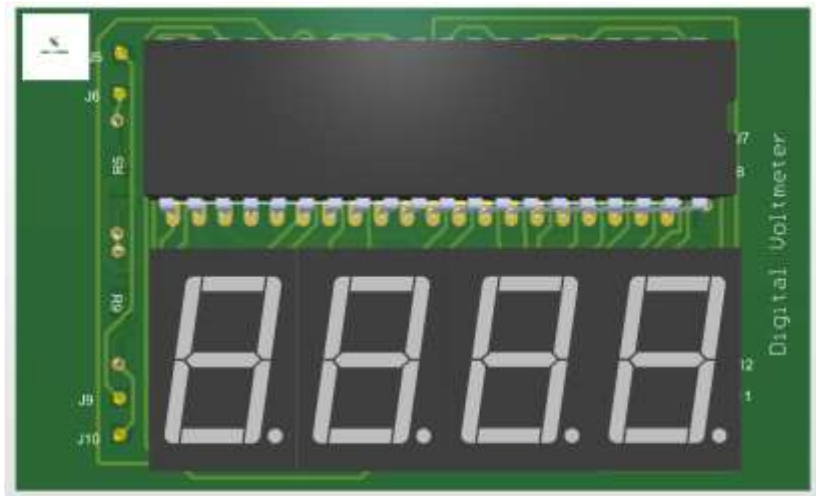


Figure 4: 3D Top view

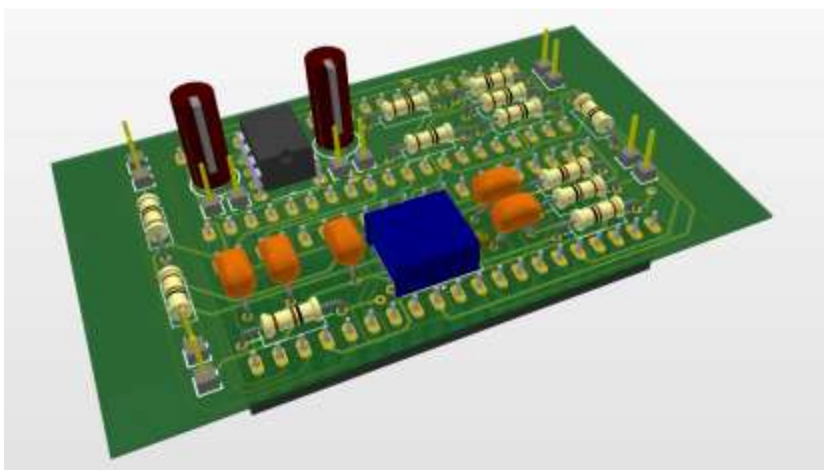


Figure 5: 3D bottom view

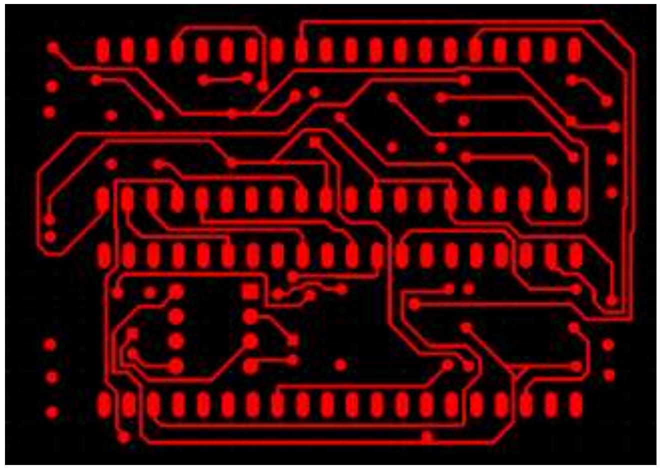


Figure 6: Bottom copper signal layer

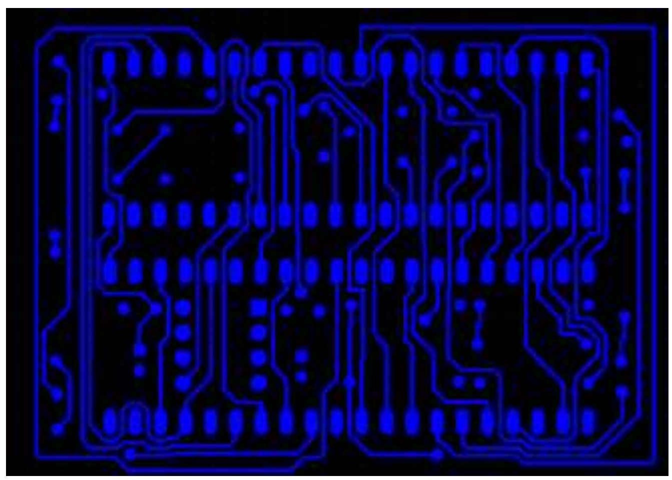


Figure 7: Top copper signal layer

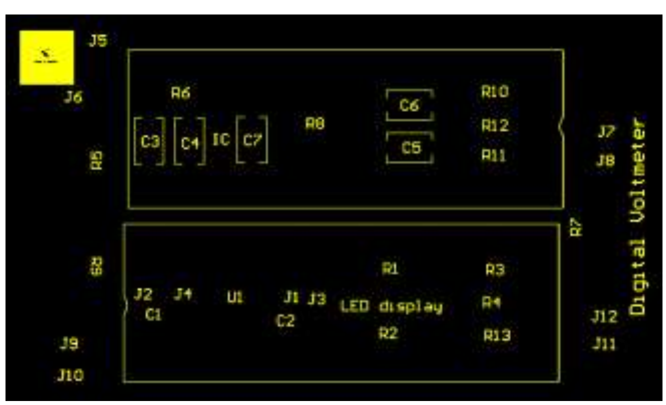


Figure 8: Top legend layer

2.6.2 Digital Ammeter

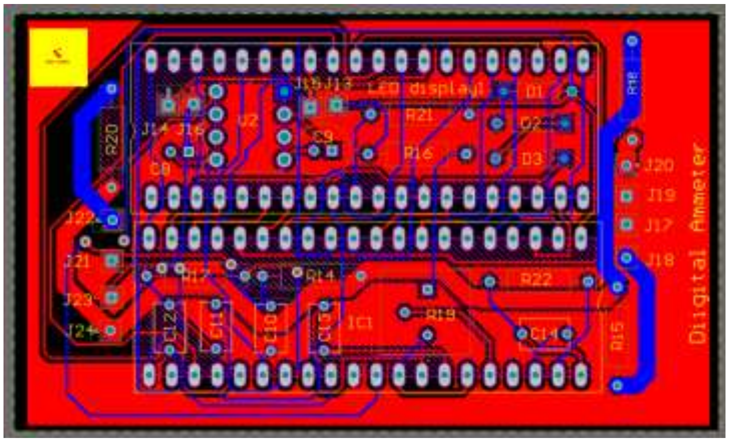


Figure 9: PCB Design view

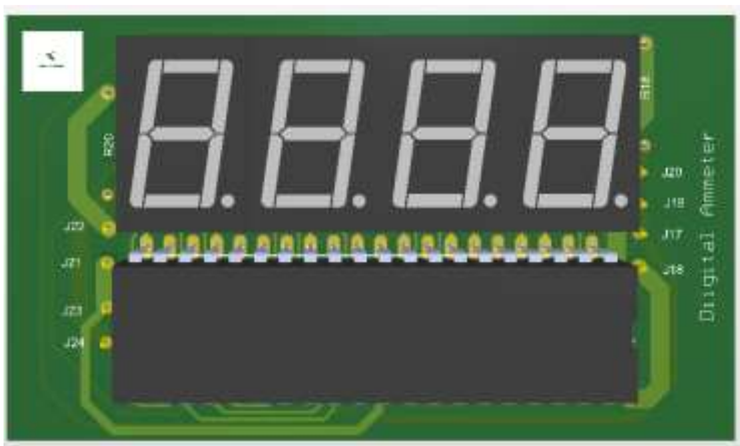


Figure 10 3D Top view

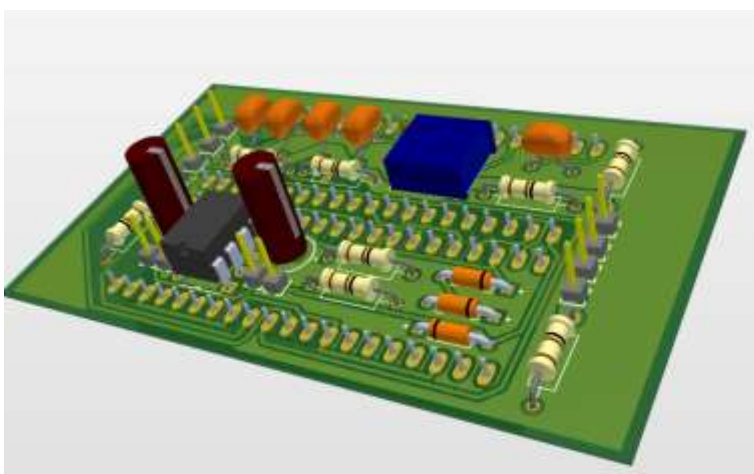


Figure 11: 3D bottom view

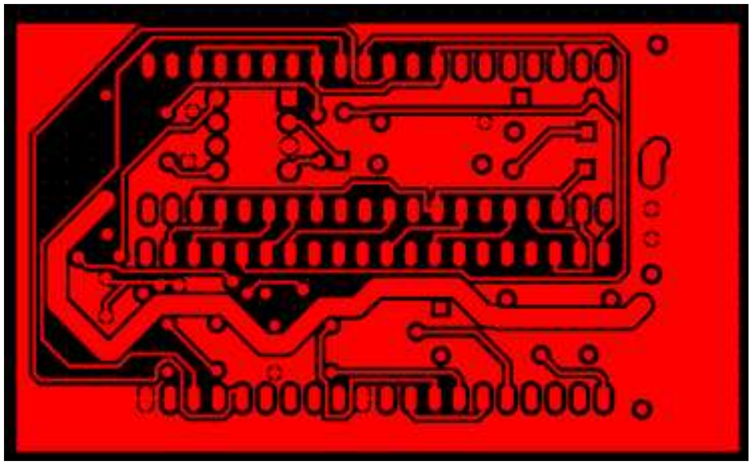


Figure 12: Bottom copper signal layer

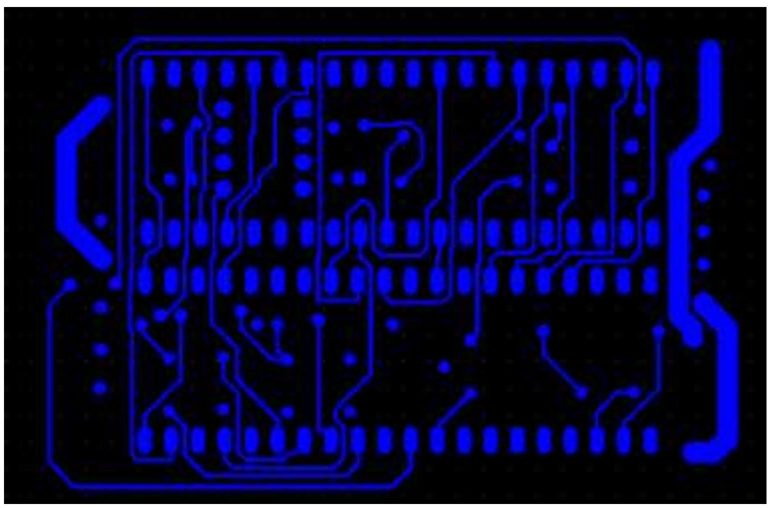


Figure 13: Top copper signal layer

Figure 14: Top legend layer

2.6.3 Continuity tester

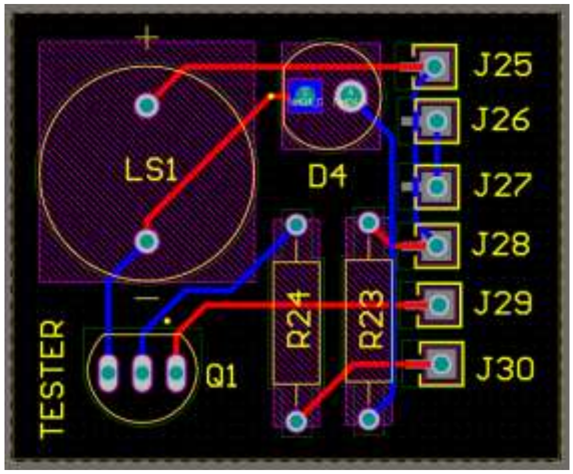


Figure 15: PCB design view

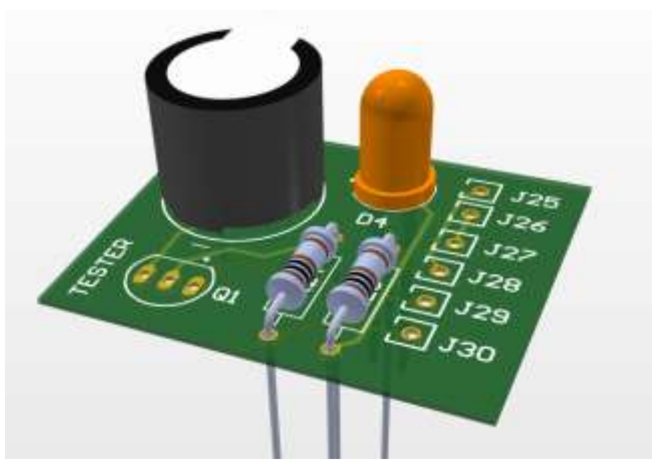


Figure 16 3D view

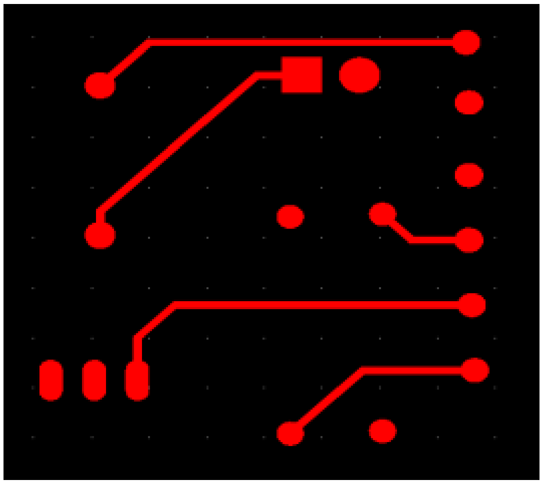


Figure 17: Bottom copper signal layer

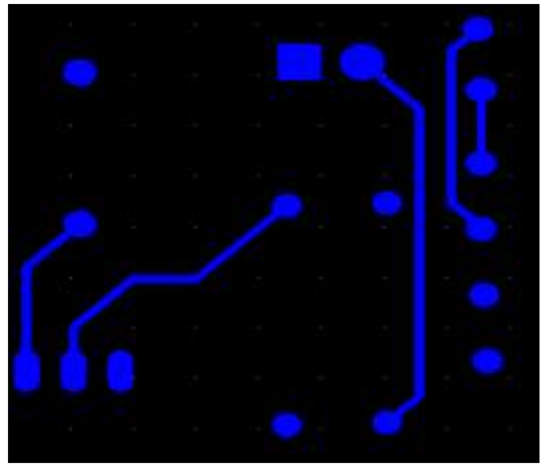


Figure 18: Top copper signal layer

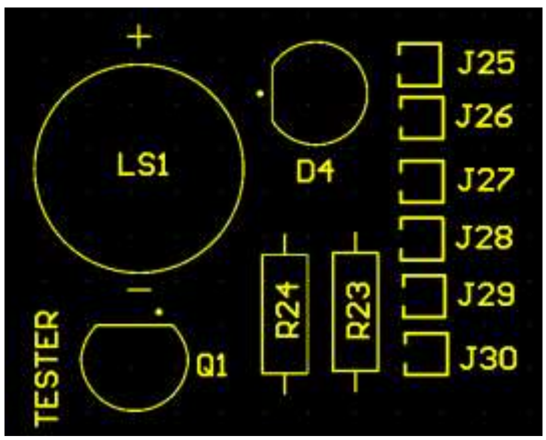


Figure 19: Top legend layer

2.7 Rechargeable power supply

For this purpose, I used TP4056 li ion battery charging module to safely charge the Li ion battery.

Figure 20: TP4056 module

Figure 21: Boost converter

Figure 22: Li ion battery

Why TP4056?

- Lithium-ion battery charging and discharging module which supports a constant current – constant voltage charging mechanism.
- Full charge voltage of 4.2 V.
- Over-discharge protection feature which prevents the battery from being discharged below 2.4V by cutting off output power until the battery is recharged above 3V.
- The 5V input voltage is applied through micro-USB or solder pads IN+ and IN-.
- The charging current is 1A and it is adjustable. You can change it by connecting a resistor of 1kΩ at IN- pad.
- It can protect the battery from overcharging.
- Soft start protection is provided to limit the inrush currents.
- It can protect the battery from overcurrent and short circuits by cutting off the output from the battery. This happens in a case when the discharge rate becomes greater than 3A.
- It does not have reverse polarity protection.

2.8 Enclosure design

The enclosure design of a digital volt-ampere meter is an essential aspect of its overall functionality, safety, and user-friendliness. The enclosure serves as a protective housing for the internal components of the meter, safeguarding them from external elements and potential damage. So, here are some considerations that should follow when designing the enclosure.

1.) Material: The choice of material for the enclosure is critical. It should be sturdy, durable, and provide adequate protection against physical impacts and environmental factors like dust and moisture.
2.) Size and Form Factor: The enclosure's size and shape should be ergonomic and easy to handle. It should fit comfortably in the user's hand and allow for easy access to the controls and display. The display size should be large enough to be easily readable.
3.) Button and Dial Placement: If the meter has buttons or dials to switch functions or ranges, they should be strategically positioned on the enclosure for easy access and intuitive use. Proper labeling or iconography is crucial to assist users in selecting the appropriate settings.
4.) Input Terminals: The input terminals where the test leads are connected should be well-insulated and designed to prevent accidental contact with live circuits. They may be color-coded to indicate the type of measurement (e.g., red for positive voltage and black for ground).

5.) Battery Compartment: The meter is powered by batteries. So, the battery compartment should be easily accessible for recharging. Additionally, it should be designed to prevent battery leakage from damaging the internal electronics.
6.) User Interface: The user interface should be intuitive and user-friendly, with a clear layout of functions and measurement readings. The display should have adequate contrast and backlighting for easy readability in various lighting conditions.
7.) Portability: Depending on the intended use, the enclosure should be designed for portability, with features like a built-in handle or provisions for mounting on a stand.

So, according to the above considerations I initially designed a enclosure using hand sketches.

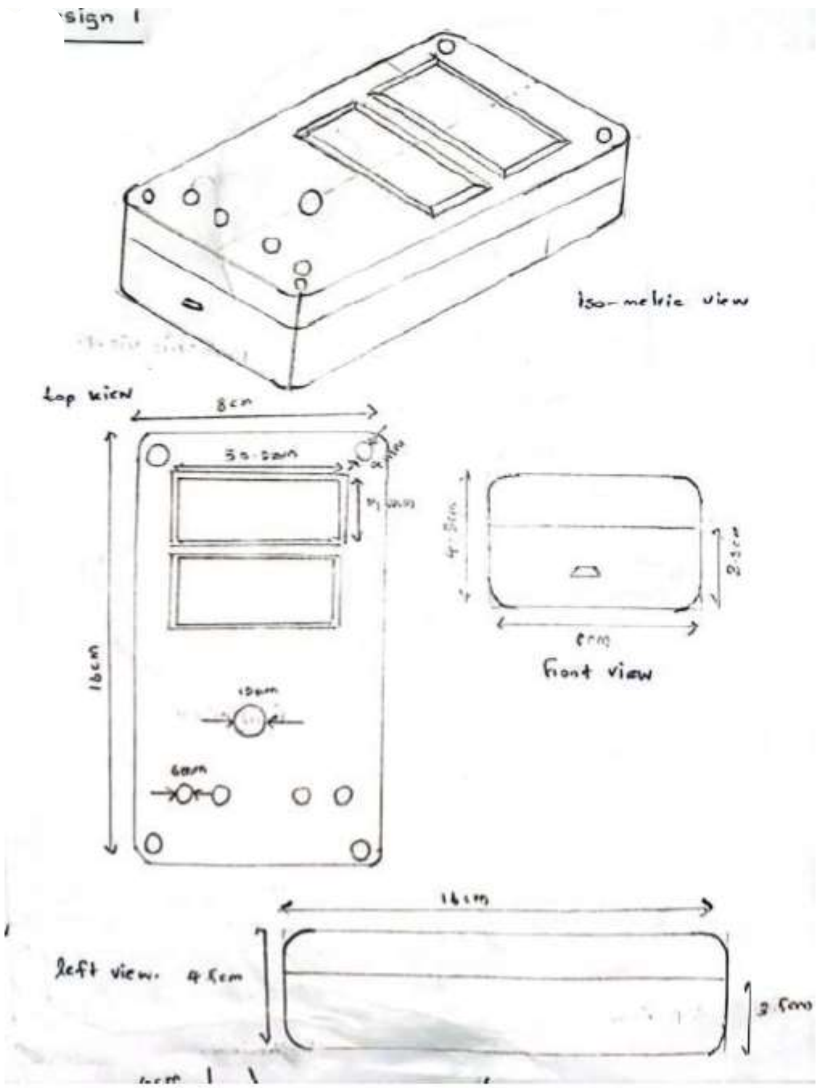


Figure 23: Hand drawn sketches

Then, I designed the enclosure using SOLIDWORKS 2020 software. The enclosure consists of two parts.

1.) Top part

Figure 24: Top part of the enclosure

2.) Bottom part

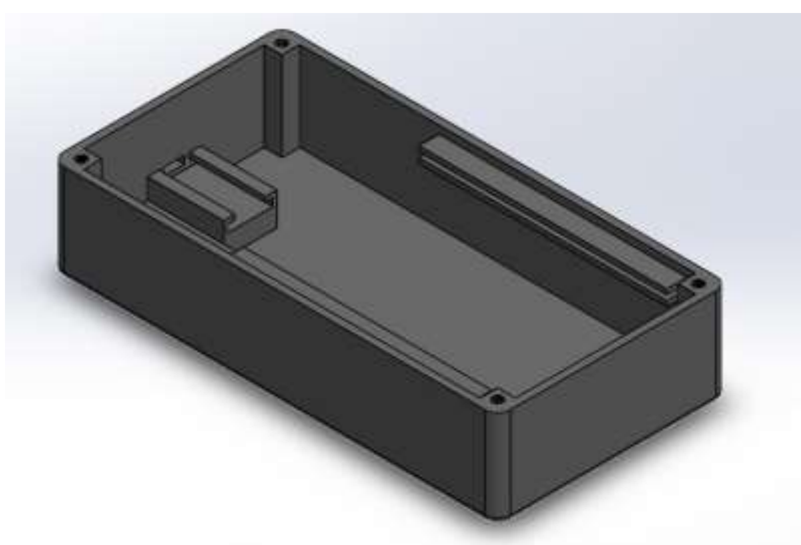


Figure 25: Bottom part of the enclosure

Final product

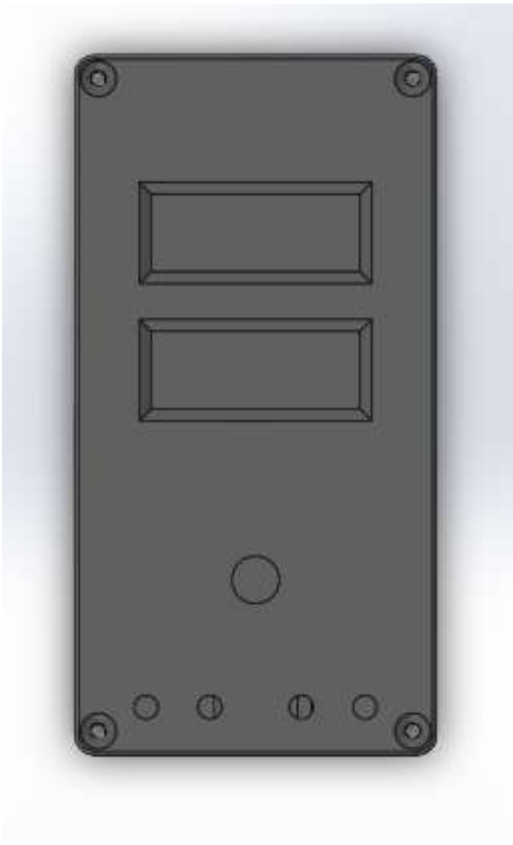


Figure 26: Top view

Figure 27: Front view

Figure 28: Side view

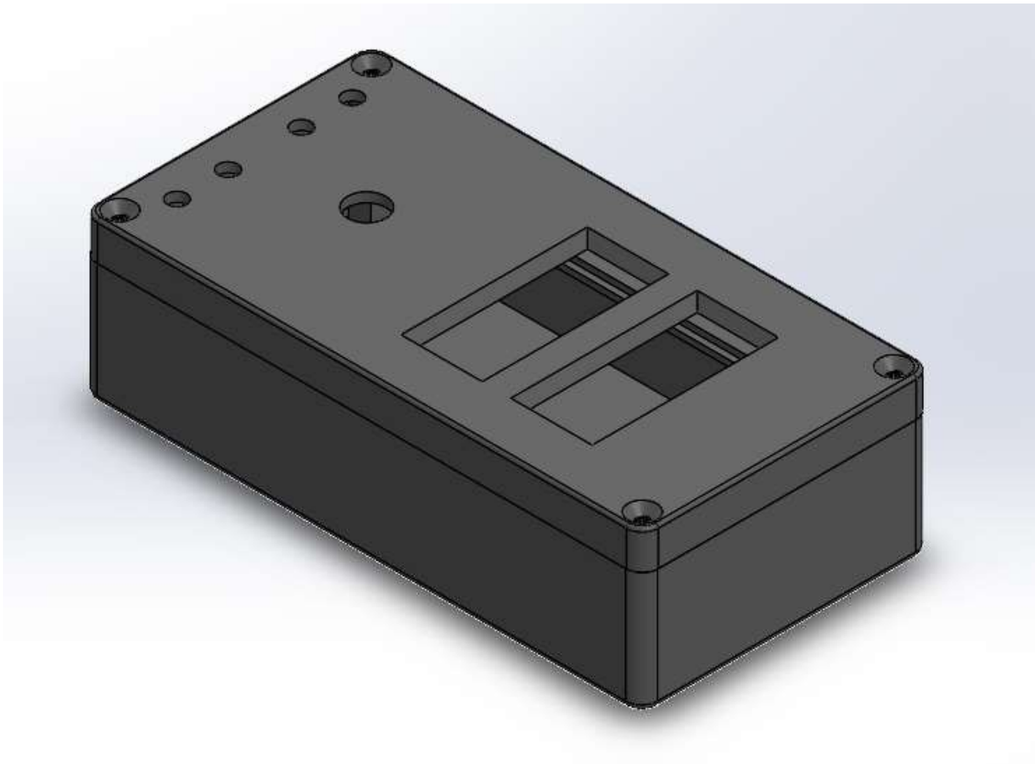


Figure 29: Isometric view

3. Cost consideration

Bill of materials

Component	Quantity	Suppliers	Unit price (USD)	Price (USD)
100uF	4	Mouser	0.77	3.08
0.22uF	2	Mouser	0.51	1.02
0.47uF	2	Mouser	0.51	1.02
100nF	2	Mouser	0.51	1.02
100pF	2	Mouser	0.51	1.02
20nF	1	Mouser	0.51	0.51
10nF	1	Mouser	0.51	0.51
1N4148	3	Future Electronics	0.61	1.83
ICL7107CPLZ	2	Mouser	11.22	22.44
Display	2	Mouser	1.91	3.82
330E	6	Mouser	4.65	27.9
1K	1	Mouser	4.65	4.65
47K	2	Mouser	4.65	9.3
10K	2	Mouser	4.65	9.3
10K	2	Arrow Electronics	2.39	4.76
100K	3	Mouser	4.65	13.95
1M	1	Mouser	4.65	4.65
22K	1	Mouser	4.65	4.65
0.01 ohm	1	Mouser	5.37	5.37
15K	1	Mouser	4.65	4.65
0.1 ohm	1	Mouser	5.37	5.37
1 ohm	1	Mouser	5.37	5.37
ICL7660SCPAZ	2	Mouser	2.44	4.88
Li ion battery(1200mAh)	1	Mouser	18.00	18.00
TP4056	1	Mouser	12.00	12.00
LT8330ES6TR	1	Mouser	15.00	15.00
PCBs	3	JLPCB	4.00	12.00
Enclosure	-	Xydder	22.02	22.02
Total				208.07

4.Testing

Testing a digital volt-amp meter is essential to ensure its accuracy and reliability in measuring voltage and current. Here are some steps carried to ensure that digital volt amp meter is working well.

1.) Checked the physical condition of the meter, including the display, buttons, and test leads. And ensured that there are no visible damages or loose parts that could affect its performance.
2.) Confirmed that the meter has a sufficient power to work. (Battery checkup)
3.) Set the meter to the "Voltage" mode. Touched the test leads together. If it gives 0 V, then the digital volt amp meter is working well. Otherwise calibrate the voltmeter circuit till it get 0V.
4.) **Voltage measurement**: Connect the red test lead to the Voltage port and the black test lead to the ground port. Set the meter to voltage mode. Touch the test leads across the component or circuit wish to measure. Ensure the readings taken from digital volt amp meter is correct using a correct multimeter.

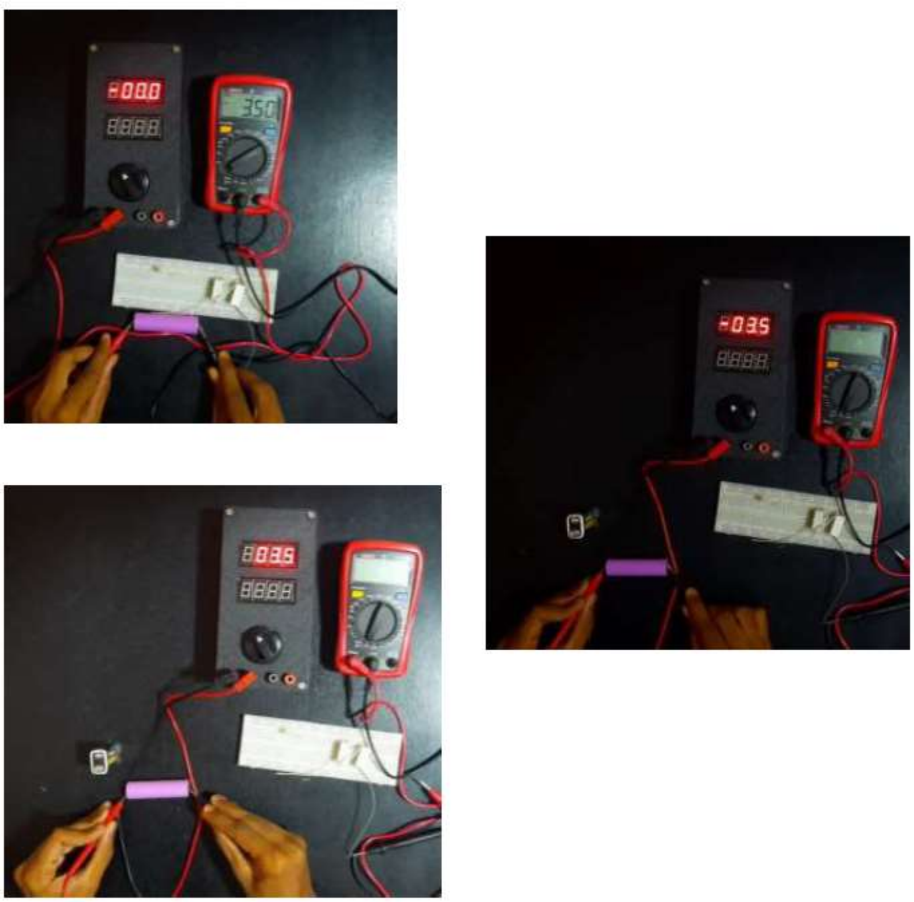


Figure 30: Voltage across li ion battery

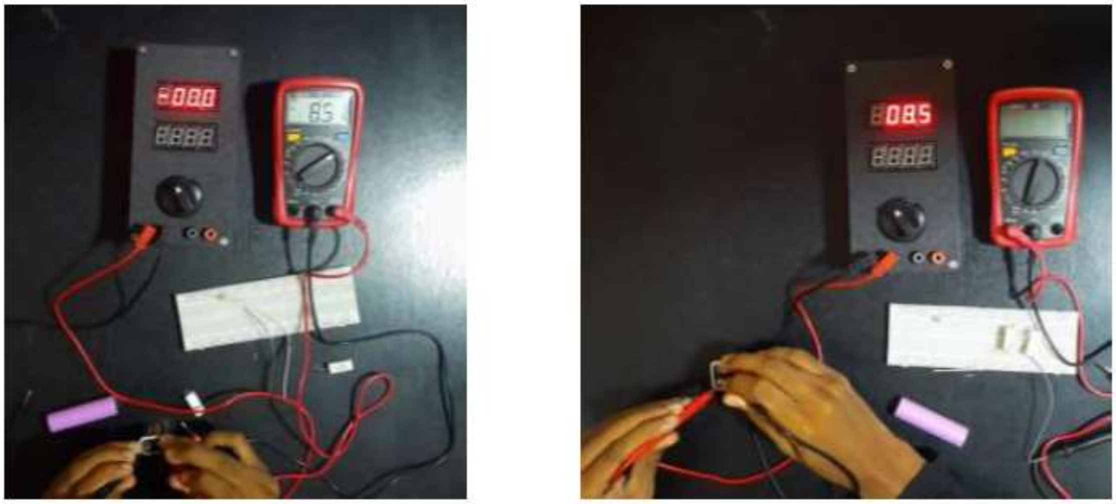


Figure 31: Voltage across 9V battery

5.) **Current Measurement**: Make sure the circuit or component you want to measure is disconnected from the power source. Move the red test lead to the 10A port on the meter, and keep the black test lead connected to the ground port. Set the meter to the current measurement mode. Then connect the circuit or component in series with the meter. Restore power to the circuit and observe the reading on the meter. And ensure that readings taken from the device is correct using a correct multimeter.

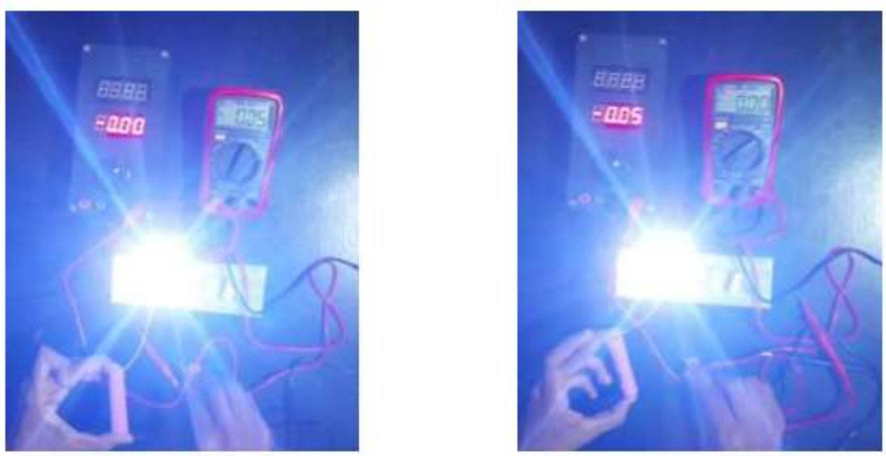


Figure 32: Current through a LED

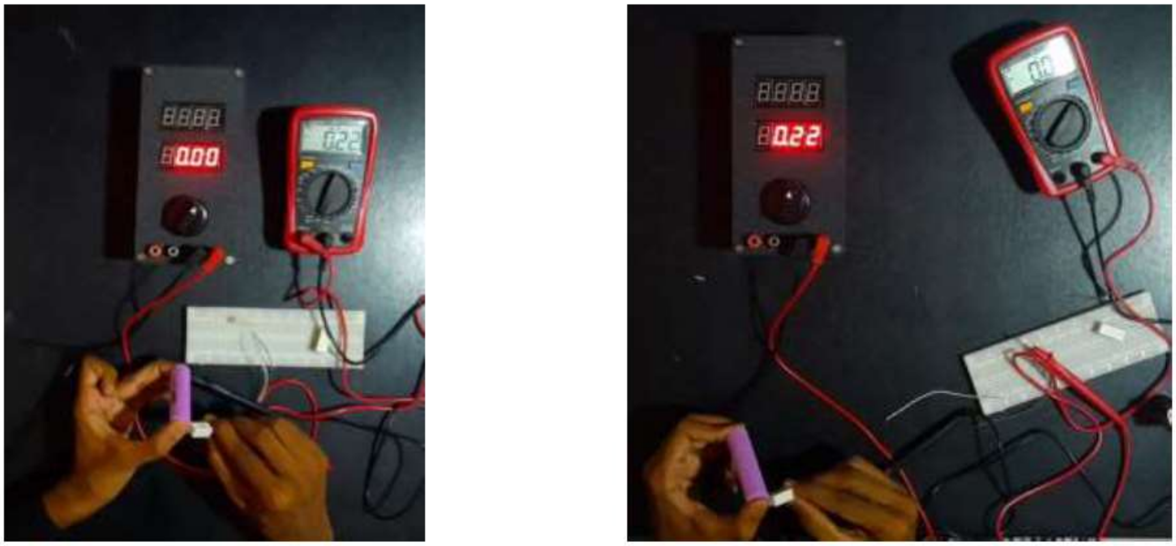


Figure 33: Current through 10-ohm resistor

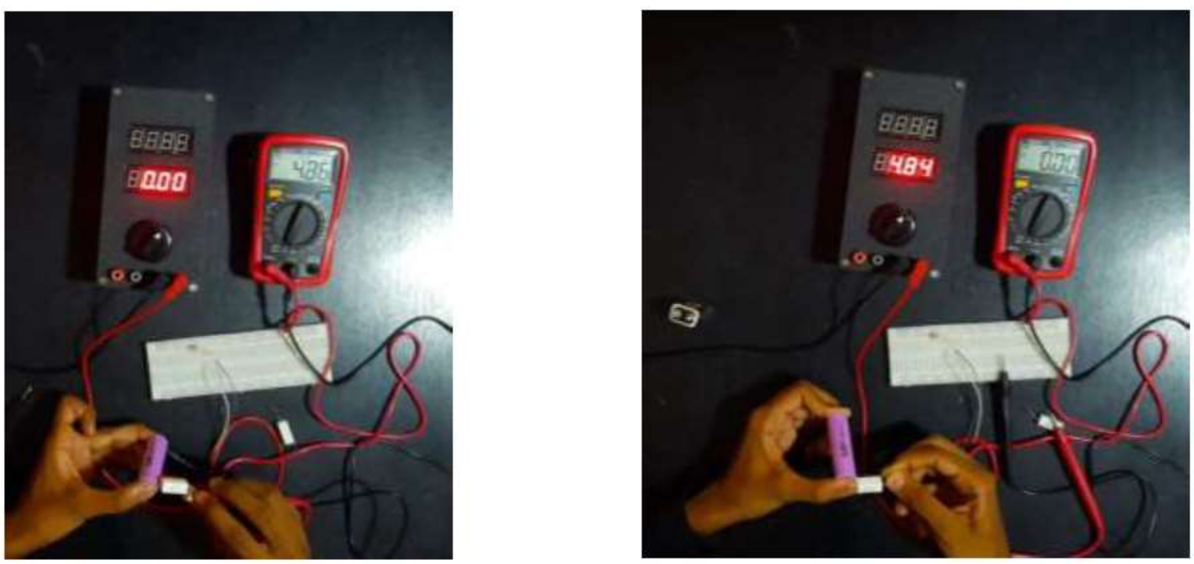


Figure 34: Current through .22-ohm resistor

6.) **Continuity tester**: Connect the red test lead to the Voltage port and the black test lead to the ground port. Set the meter to continuity test mode. Touch the test leads across wire. If it gives a sound the tester is working well.

5. Instructions

5.1. Digital Voltmeter

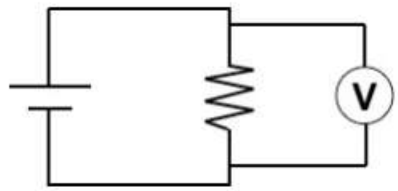


Figure 35: Measuring voltage across a resistor.

A voltmeter is used to measure the voltage drop across a circuit element or set of circuit elements. For our purposes, we will just consider measuring the voltage across a single light bulb. The most important thing to remember is that the voltmeter should be connected in parallel with the light bulb. That means you can always connect the voltmeter last. You do not have to disconnect any circuit elements in order to properly add a voltmeter to a circuit. A voltmeter is designed to have a very high resistance so that it does not affect the rest of the circuit. In a circuit diagram, a voltmeter is represented by a circle with a "V" inside as shown in Figure 35. To use the digital volt amp meter as a voltmeter, put leads into the "GND" jack and the "Voltage" jack. Then turn the knob until it points Voltage.

5.2 Digital Ammeter

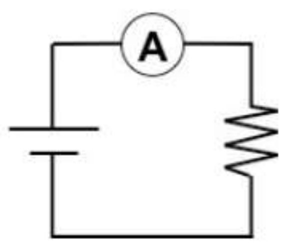


Figure 36 Measuring current through a resistor.

An ammeter is used to measure the current through a circuit element. (Once again, we will consider a light bulb.) The most important thing to remember is that an ammeter must be connected in series with the light bulb. This means that you must break the circuit in order to add an ammeter. That is, you must disconnect a lead or two in order to use an ammeter in a circuit. If you add an ammeter without disconnecting anything, you have added it incorrectly. Ammeters are designed to have very low resistance. That means that connecting an ammeter in parallel with a circuit element will cause a short circuit. You must be very careful with ammeters. In a circuit diagram, an ammeter is represented by a circle with an "A" in it as shown in Figure 36. To use the digital volt amp meter as an ammeter, put leads into the “GND” and the “Current” jack. Then turn the knob until it points to the Current mode. This setting can measure currents up to 10 A, which is much larger than any current you will encounter in this class.

6. Conclusion

In conclusion, the design and development of the digital volt-amp meter have been successfully completed, meeting the initial project objectives. The meter is capable of accurately measuring voltage and current, making it a valuable tool for electronic testing and troubleshooting.

Throughout the project, I encountered various challenges, including component selection, calibration, and user interface design. However, through systematic testing and iteration, I was able to overcome these hurdles and achieve a reliable and user-friendly design.

During the testing phase, the meter demonstrated consistent and accurate readings when compared to reference instruments, validating its precision and reliability.

Moving forward, I recommend further exploration of integrating new capabilities into the meter to enhance its functionality and data analysis capabilities.

In conclusion, this digital volt-amp meter design has been a rewarding and educational experience, resulting in a functional and practical tool that can significantly benefit electronics enthusiasts.