EN2090 - Laboratory Practice II

Lead Acid Battery Charger

Group 19

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ABSTRACT

This project is designed to charge 12V lead acid batteries using PWM switch mode power supply with a feedback voltage. This lead acid battery charger is using constant current and constant voltage charging techniques to charge the battery. The report consists the circuit design, functionality of the circuit, enclosure design and the PCB design of the project. This project is done using only 2 NE555 timers, op-amps, resistors, capacitors and multiplexers. No programmable ICs are used in this project. This charger charges the battery using 1A in the constant current stage until it reaches 13.4V voltage and then switches to constant voltage charging.

1. INTRODUCTION

A battery charger is a device used to put energy into a cell or (rechargeable) battery by forcing an electric current through it. The charging process can be applied in several implementations. Mainly, constant current charger (CC), constant voltage (CV) charger and multistage charger which uses both constant current and constant voltage (CC-CV).

1. Constant voltage charger

   This method is commonly used in lead acid battery charging. In this method a constant voltage is kept the terminals of the battery. Initially a large current will pass through the battery then with the increase of battery voltage current decreases exponentially. The best characteristic of this method is that it provides a way to return a large bulk of the charge into the battery very fast. The disadvantage is that to complete a full charge would take a much longer time since the current is exponentially decreased as the battery charges. A prolonged charging time must be considered as one of the issues to this design.

2. Constant current charger

   Constant current charging is another way of charging a lead acid battery which is also an effective method for charging. A current source is used to drive a uniform current through the battery in a direction opposite of discharge. This can be analogous to pouring water into a bucket with a constant water flow, no matter how full the bucket is. Constant current sources are not very hard to implement; therefore, the final solution would require a very simple design. There is a major drawback to this approach. Since the battery is always being pushed at a constant rate, when it is close to being fully charged, the charger would force extra current into the battery, causing overcharge.

3. Multistage charger

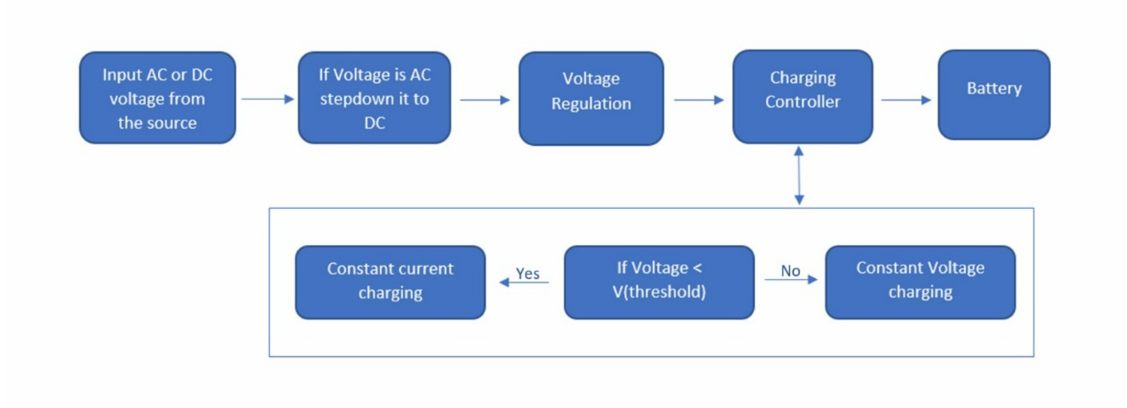
   In this project the implementation is the multistage charging. Since there are advantages and disadvantages in both CC charger and CV charger this implementation uses a combination of both. This implementation is also known as CC-CV charger. Multistage chargers have been developed which combine the two methods to achieve maximum charge time, with minimum damage to the charging cell. Mainly there are mainly three stages.

   (a) Constant Current Stage
   (b) Constant Voltage Stage
   (c) Float Stage

The purpose of this paper is to present the design and construction of a 12V lead acid battery charger with a maximum current of 1A implemented using CC-CV based on PWM technique.

2. METHOD

2.1. Block Diagram



Flowchart of the CC-CV charging process

2.2. Methodology

In this design the charging process is done in two stages namely,

- Constant Current – The stage where the battery is charged fast. Since the charging current is constant and the resistance of the battery increases with the time, charging voltage increases in this region. This process continues until the terminal voltages reaches about 14.4V. Approximately 70% of the battery is charged in this stage under a 1A constant current.

- Constant Voltage – The stage where the charging voltage is constant. This voltage is usually set at 14.4V for 12V lead acid batteries. Here the charging current decreases with the time since the resistance of the battery is increasing. In this stage, remaining 30% of the battery is charged but the charging speed is slower than the previous constant current stage.

2.3. Functionality

This lead battery charging design can be shown in several stages,

2.3.1. PWM Generation

For PWM generation 2 NE555 timers are used. Here the resistor and capacitor values of the first timer are set to obtain a PWM signal with a frequency approximately about 158kHz and that output is set as the input to the Trigger pin (pin2) of the second timer. By charging and discharging the capacitor connected to the second timer a triangular waveform is obtained. By changing the voltage given to the Control voltage pin (pin5) in the range 0 – 5V can change threshold given to the triangular waveform. Thereby we can change the duty cycle of the PWM without changing the frequency.

2.3.2. *Switching and Buck Converter*

For switching purpose, a MOSFET is used. When the timer outputs 5V, the transistor Q2 switches on and the transistor Q3 switches off and the MOSFET switches on. When the timer output is 0V the MOSFET switches off. Therefore, using the MOSFET, current is supplied to the battery as pulses and the Low pass filter out the noises and high frequency components.

2.3.3. *Constant current Stage*

In this stage 0.1Ω 5W resistor is used as the sense resistor to sense the current. When the current passes through the sense resistor it gives a small voltage difference (V=IR) which is sent to the differential amplifier. The voltage difference through the sense resistor is amplified and it is used to produce the control voltage to the timer.

The output through the sense resistor is passed through the differential amplifier which amplifies the voltage difference of the sense resistor. The amplification factor can be changed through the values of the resistors (Amplification factor of 50 is used here)

The comparator takes the output of the differential amplifier and is compared with a given voltage (5V). The supply voltages to the op-amp are 12V and ground. The difference between the given voltage and the output voltage of the differential amplifier is always zero or a positive value. Therefore, the voltage output of the comparator is always varying between 12V and 0V.

2.3.4. *Constant Voltage Stage*

Here the voltage across the terminals of the battery is obtained. If it is 13.4V we obtain an output as 5V using op-amps and if it is less than 13.4V we will get the output less than 5V by using a comparator with a 13.4V reference voltage. We use this value to change the value of the feedback given to the timer in a desired range.

2.3.5. *Switching from CC to CV*

To switch from CC to CV CD4051 multiplexer is used. Depending on the value obtained by the current feedback and voltage feedback (1 or 0) multiplexer switches from CC to CV.

2.4. Calculations

- At NE555 timer

$$t_{on} = 0.69 * C5 * (R1 + R2)$$

$$t_{off} = 0.69 * C5 * R2$$

$$T = t_{on} + t_{off}$$

$$\begin{aligned} f &= \frac{1}{T} \\ &= \frac{1}{0.69 * C5 * (R1 + R2) + 0.69 * C5 * R2} \\ &= \frac{1}{0.69 * (220 * 10^{-12}) * (1000 + 30000)} \end{aligned}$$

$$Theoretical\ frequency = 212.503kHz$$
$$Practical\ frequency = 162kHz$$

- At Constant current op-amp

  When sense resistor conducts 1A exactly,

$$voltage\ difference = 0.1V$$

$$\begin{aligned} output\ of\ the\ op-amp &= 0.1 * 100/2 \\ &= 5V \end{aligned}$$

  Using the trimmer it is possible to change the practical value to 5V.

- At Constant voltage op-amp

  When the voltage across the output terminals is equal to 13.4V.

$$\begin{aligned} output\ of\ the\ op-amp\ &= 13.4 * 2/4.7 \\ &= 5.702V \end{aligned}$$

  Using the trimmer it is possible to change the switching voltage (Here we have mapped 13.4V to 5V)

- At buck converter

$$\begin{aligned} f_0 &= \frac{1}{2 * \pi * R_6 * C_7} \\ &= \frac{1}{2 * \pi * 10 * 1000 * 10^{-6}} \\ &= 159.15Hz\ (cut\ off\ frequency) \end{aligned}$$

- At feedback

$$\begin{aligned} f_1 &= \frac{1}{2 * \pi * R_{15} * C_8} \\ &= \frac{1}{2 * \pi * 100 * 220 * 10^{-6}} \\ &= 7.234Hz \end{aligned}$$

3. RESULTS

3.1. Outcomes

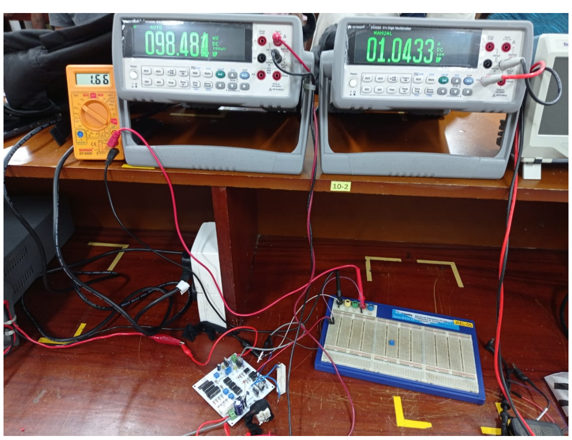
Until the battery charges up to 13.4 V, the system is in the constant current mode. The current is approximately 1A in every case. In the constant current mode, the Feedback voltage increases when the battery charges. After the battery reached 13.4 V, then the battery enters the constant voltage mode. Thereafter when the resistance is increased, the current and the feedback voltage decreases while keeping the terminal voltage constant around 13.4 V.

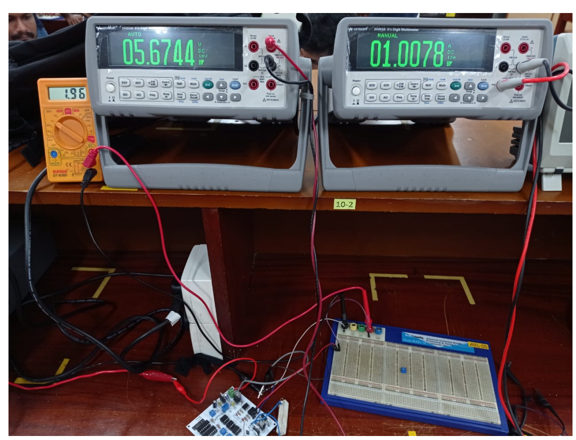
Constant Current Mode

Resistor used	Terminal voltage	Value of the current	Feedback Voltage
0Ω	0.0984 V	1.0433 A	1.66 V
5Ω	5.6744 V	1.0078 A	1.96 V
10Ω	10.6037 V	0.9714 A	2.46 V

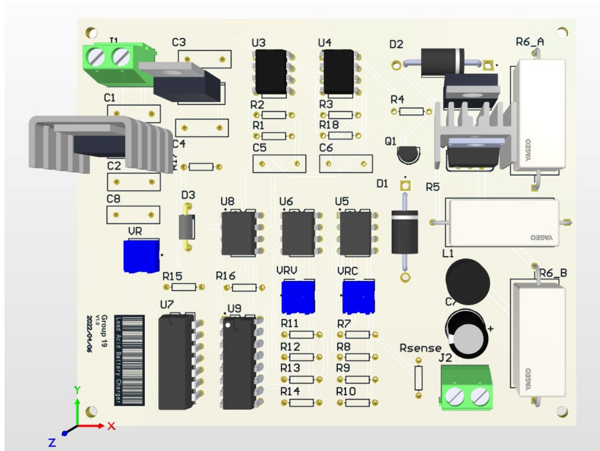
Constant Voltage Mode

Resistor used	Terminal voltage	Value of the current	Feedback Voltage
15Ω	13.425 V	0.8851 A	2.18 V
20Ω	13.434 V	0.6744 A	1.91 V
25Ω	13.448 V	0.4856 A	1.61 V



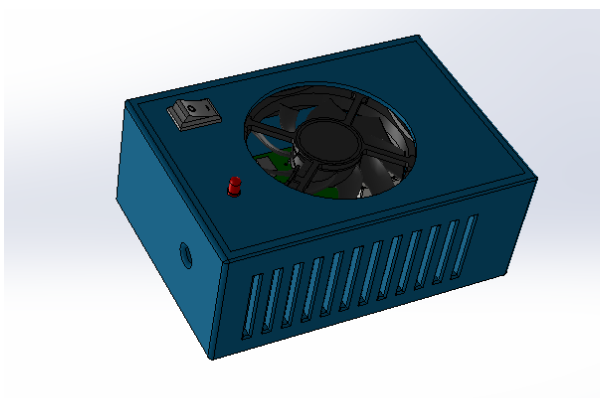


3.2. PCB 3D Model



PCB 3D model

3.3. Enclosure CAD Design



CAD Design

4. CONCLUSION

The main objective of this project was to design a lead acid battery charger. This product was designed to charge a 12V lead acid battery with a maximum current of 1A. Our design was able supply a current nearly to 1A (within a range 0.937A - 1.07A) and the voltage was kept constant at 13.4V as expected. The product has a high heat dissipation therefore, heat sinks were added to the PCB and the enclosure was also designed appropriately.

Given below are the reasons for the slight variations from the required reading,

- Tolerances in the component values
- Absence of thermal management mechanism in the prototype

5. ACKNOWLEDGEMENT

The accomplishment of this project was not an easy task for us; novices to this field. We faced various challenges and gained many new experiences through this project. There were many individuals behind this project without whom this would not be possible.

First, we would like to pay our profound gratitude for our lectures, Dr. Jayathu Samarawickrama and Dr. Kithsiri Samarasinghe for giving us theoretical knowledge about the fundamentals of Electronics and electronic components. Also, we would like to thank our supervisor Mr. Hiran Perera, for guiding us by giving a lot of advice throughout this project. We would also like to expand our deepest gratitude to all those who have directly and indirectly guided us. Many people especially our team members themselves have made valuable comments and suggestions to make this project a success.

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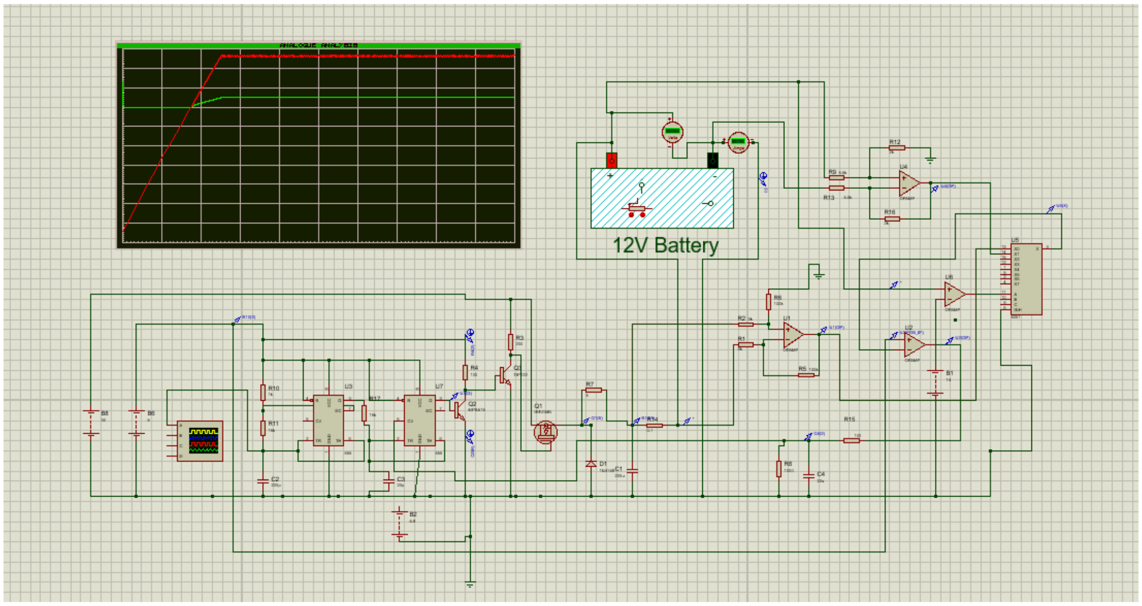
7. CONTRIBUTIONS

190497K	R.A.D.V.C. Ranasinghe	Enclosure Design, Final Report and Circuit Design
190498N	R.M.C.D.H. Ranasinghe	Circuit Simulation, Design and Implementation
190501V	R.A.C.D. Ranathunga	Circuit Simulation, Design and Implementation
190504H	R.G.S.M. Ranatunga	PCB Design, Final Report and Circuit Design

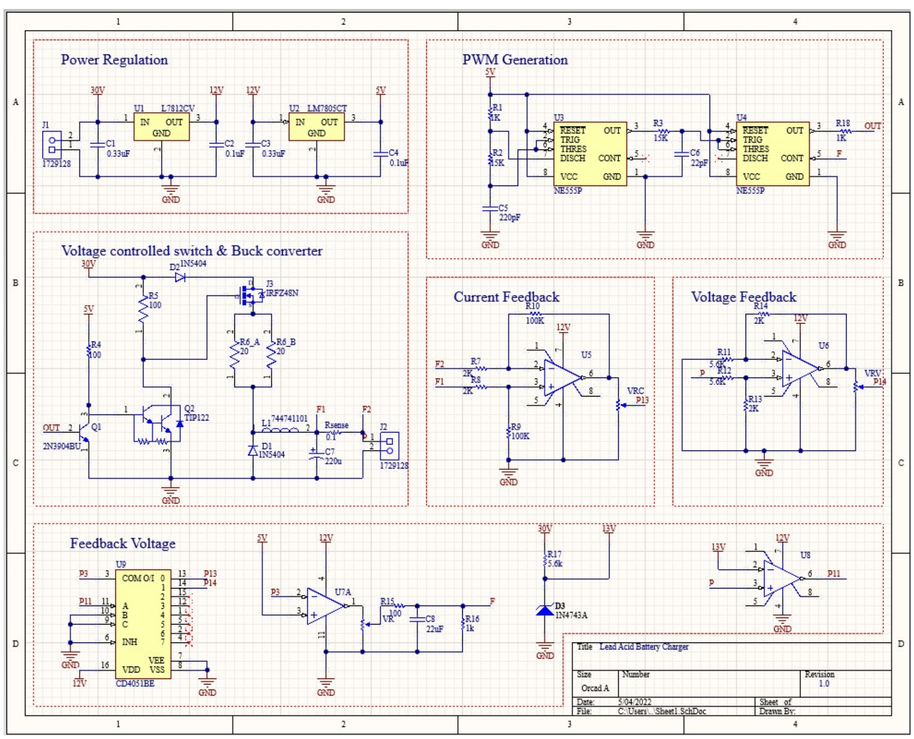
8. APPENDICES

8.1. Circuit Diagram



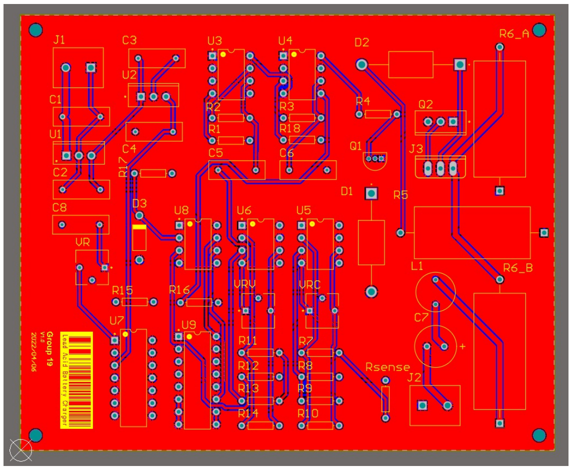
Circuit diagram

8.2. PCB Schematic

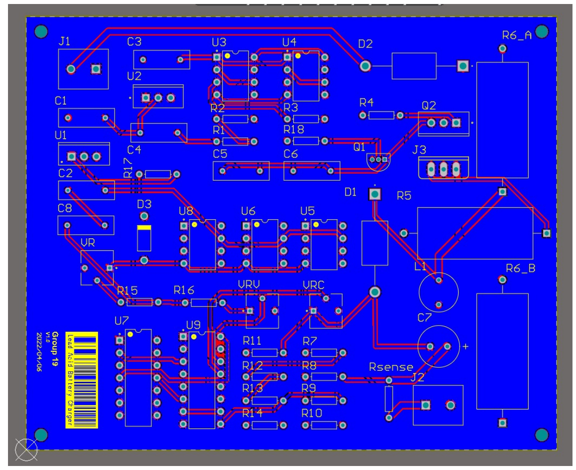


Schematic

8.3. PCB Layout

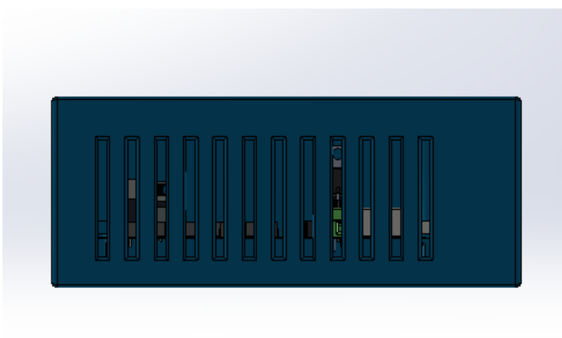


Top Layer

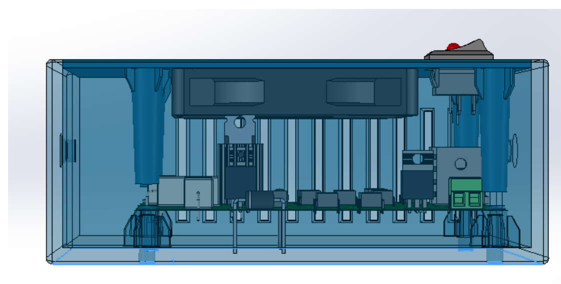


Bottom Layer

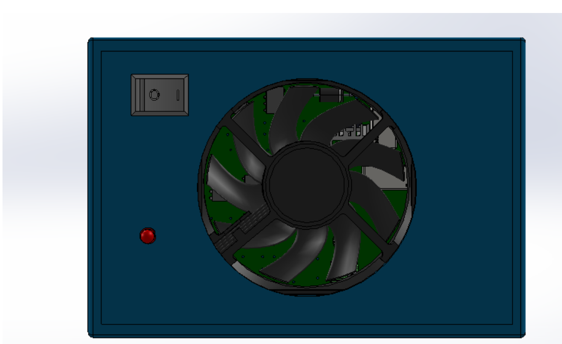
8.4. Enclosure Designs



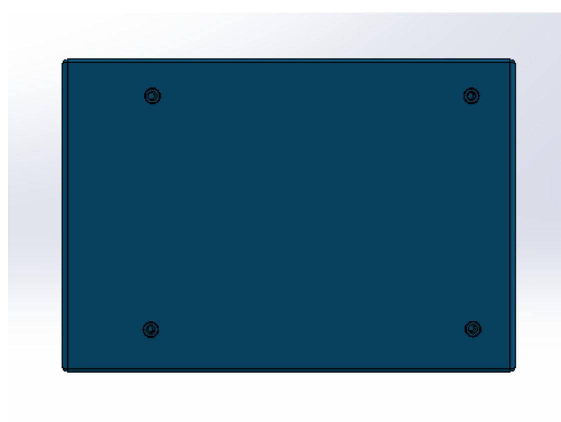
Front View 1



Front View 2



Top View



Bottom View

9. DATASHEET

LEAD ACID BATTERY CHARGER
DATA SHEET

Application:

- Charging a 12V Lead acid battery with a maximum charging current of 1A.

Features:

- Constant current charging
- Constant voltage charging
- Sensitive current controlling
- LED Power Indicator
- High switching speed

Components Table

Part No.	Component	Part
1	PWM Generator	NE555P
2	N-channel Switching Mosfet	IRFZ48N
3	Low voltage complementary power Darlington transistor	TO-220 NPN
4	General Purpose Single Operational Amplifier	LM741CN
5	General Purpose NPN –Silicon Transistor	2N3904
6	Analogue multiplexer/demultiplexer (8:1)	CD4051BE
7	Low-Noise JFET-Input Operational Amplifier	TL074ACN

Primary Characteristics

Output current at CC Stage	1A
Output voltage at CV Stage	13.4V
Operating temperature	25C
Supply voltage	30V
Switching Frequency	162kHz

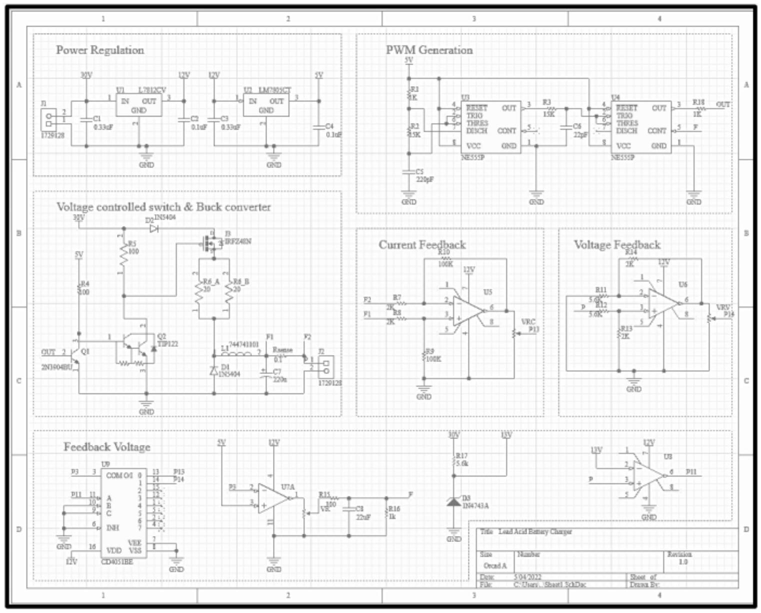
Maximum Ratings (at Room temperature or 25C)

Maximum input voltage	30V
Maximum output voltage	13.4V
Maximum output current	1A
Maximum output power rating	13.4W

Minimum Ratings (at Room temperature or 25C)

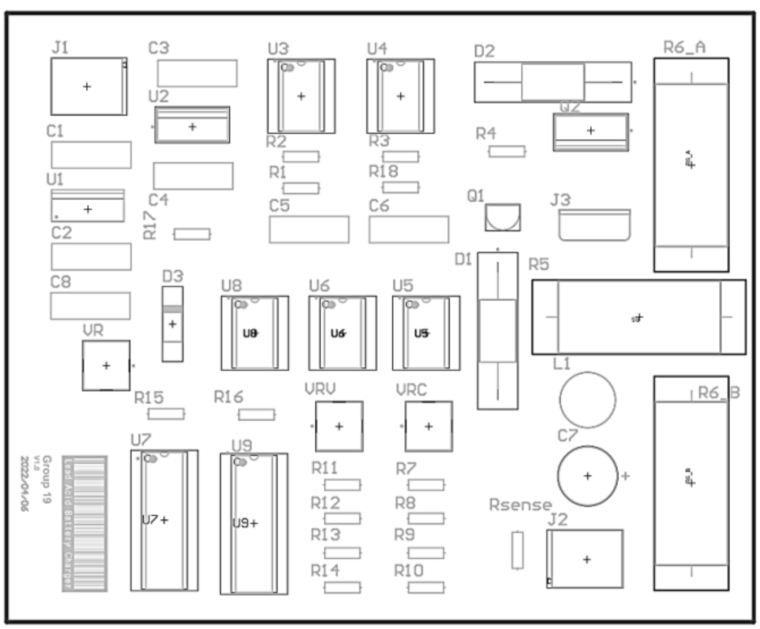
Minimum dc input voltage	25V

Schematic



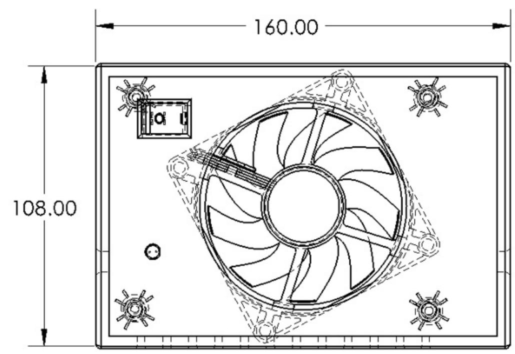
Schematic

Component Placement

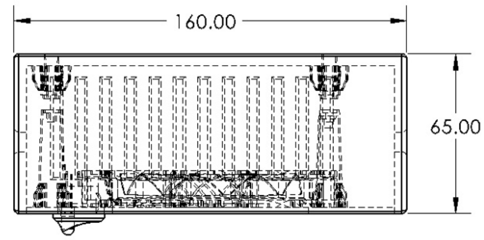


Component placement

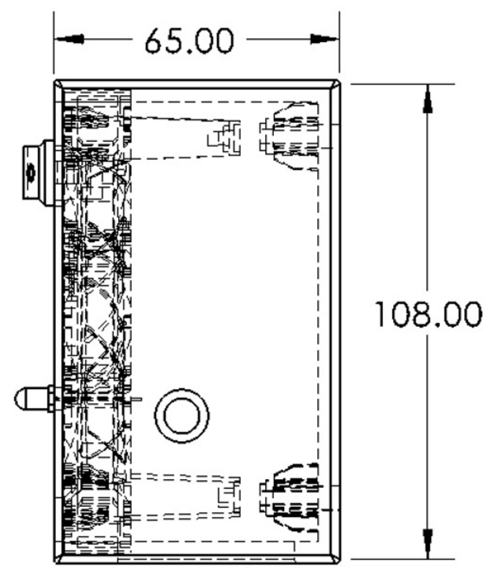
Enclosure



Top View



Side View 1



Side View 2