Lead Acid Battery Charger

Group 18

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Contents

Abstract

According to the EN2091 Laboratory Practice and Project module, we were assigned to design a lead acid battery charger for our analog project. We had to design a charger to charge a 12V lead acid battery based on the Pulse Width Module (PWM) technique, with maximum charging current of 1A for the 230V AC input voltage using the constant current, constant voltage (CCCV) method.

To satisfy these conditions, we built separate circuits for Pulse Width Modulation (PWM), Constant Current controlling (CC), Constant Voltage controlling (CV), switching, buck converter, and voltage regulator circuits. We used op-amps, resistors, capacitors, and transistors to design our circuit. Then we assembled all these circuit parts together to complete our circuit. We included functionality, enclosure design, and the PCB design of the circuit.

1. Introduction

1.1. Lead acid battery

The oldest rechargeable battery is the lead acid battery, which is composed of six cells with two lead plates (one negative and one positive) immersed in sulfuric acid solution in each cell and has a voltage range of 2.30 to 2.45 volts per cell when fully charged. The six cells are mounted together to build a fully charged battery at about 14 volts.

1.2. Constant Current Constant Voltage (CCCV) charging methodology

To maintain healthy battery the charging profile should be correctly followed.

In this method, battery is charged mainly through three stages,

- Constant Current charging stage (CC) – stage 1
- Constant Voltage / topping charging stage (CV) – stage 2
- Float charging stage – stage 3

These three stages are showed on the figure: 1 below.

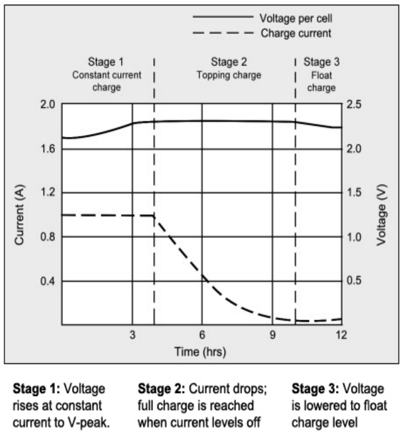


Figure: 1 Charge stages of a lead acid battery

A constant current stage takes half of the required charge time. In the topping charge stage, the charge current is lower and provides saturation. Float stage covers the loss caused by self – discharge which is very important stage to continue full charge of the battery

The battery charges 70% of its capacity in constant current stage and the remaining 30% charges in constant voltage stage.

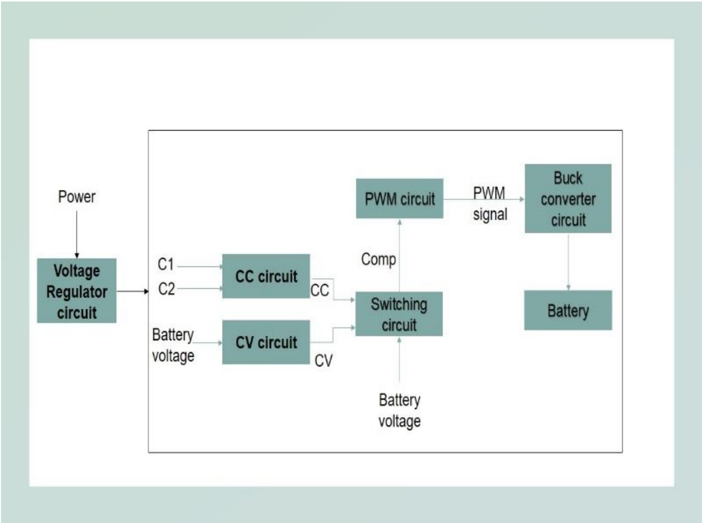
The main purpose of this project is to design a lead acid battery charger to charge 12V lead acid battery with the requirements,

- The system must be based on Pulse Width Modulation (PWM) technique
- Maximum charging current should be 1A
- Input voltage for the system should be 230V AC

We used the above mention constant current constant voltage (CCCV) method to design the battery charger.

2. Method

2.1. Functional block diagram



In our project, we used two stages to charging process which are constant current charging and constant voltage charging.

The block diagram contains with six separate circuits,

- Constant Current (CC) controller
- Constant Voltage (CV) controller
- Switching circuit
- Pulse Width Modulation (PWM) generator circuit
- Buck converter
- Voltage regulator

First, the lead acid battery is connected to the 230V AC source. Since the battery should charge using DC voltage, before applying to the battery, the voltage should be stepped down and rectified to the 24V DC. Then it passes through the buck converter circuit to step down the voltage to output voltage of the circuit. The controlling process of power through the buck converter is done by using Pulse Width Modulation (PWM) circuit. PWM circuit feeds the output of the switching circuit which is used to switch between the Constant Current (CC) and the Constant Voltage (CV) circuits.

CV circuit is contained with voltage divider circuit and CC circuit is processed with sense resistor to measure the current through the buck converter.

The battery is charged in constant current stage until it voltage reaches to 13.6V after that it switches to constant voltage stage then charge in this stage.

2.2. Functionality

2.2.1. Constant Current (CC) Controller

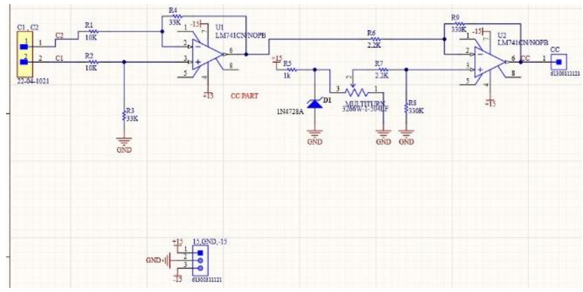


Figure: 2 CC controller circuit

Here voltage difference between two terminals of the sense resistor in the buck convertor circuit is applied for c1 and c2 terminals of the differentiator. Then the output of this part compare with 3.3V and error is outputted through the subtractor circuit. Then this error go through the switching circuit.

2.2.2. Constant Voltage (CV) Controller

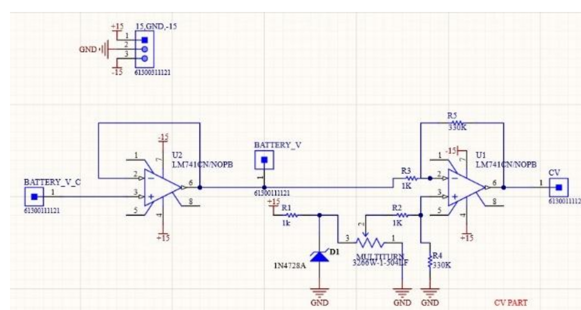


Figure: 3 CV controller circuit

Here, the battery voltage comes through the voltage divider circuit is applied to the buffer and then it compare with 4.25 V. Then the generated error voltage go through the switching circuit.

2.2.3. Switching Circuit

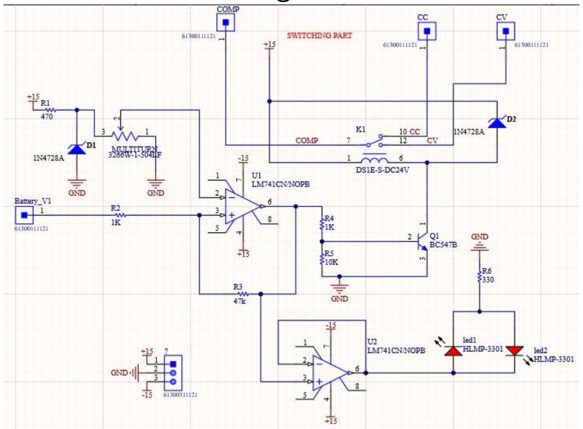


Figure: 4 switching circuit

The battery voltage which came through the voltage divider in the buck converter is applied to the differentiator. Then it compares with 4.25 V and goes through the transistor and relay to switching between CC and CV. When the battery voltage greater than 13.6 V, CV is connected and when lower than 13.6 V, CC is connected. Green and red led are used to indicate switching stage.

2.2.4. Pulse Width Modulation (PWM) generator Circuit

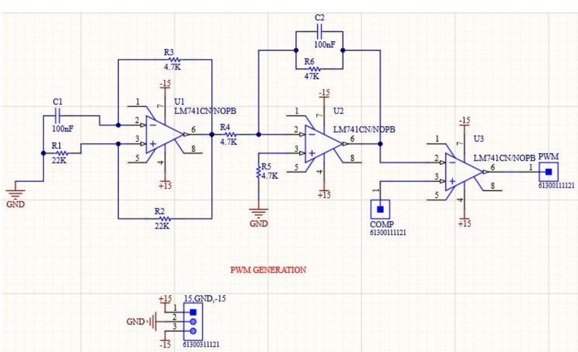


Figure: 5 PWM circuit

PWM generator circuit consists with three main parts

- As-table Multi-vibrator (Square Wave Generator)

Generate 1 kHz square waveform.

- Integrator circuit

Triangular waveform generated through the integrator from the square waveform generated in As-table Multi-vibrator.

- Comparator

The triangular waveform compares with the output of switching circuit (CC / CV). Then generated PWM signal according to the switching circuit's output.

2.2.5. Buck converter

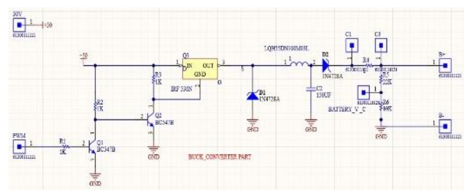


Figure: 6 Buck converter circuit

In this part, the PWM signal goes through the MOSFET which is driven from a MOSFET driver to satisfy the 1 A current condition. Then the PWM signal which comes from the MOSFET goes through the buck convertor part of the circuit which consists with inductor and capacitor to hold the current.

2.2.6. Voltage regulator

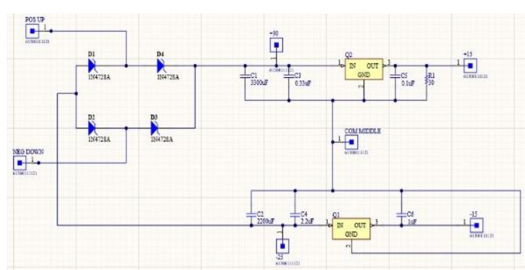
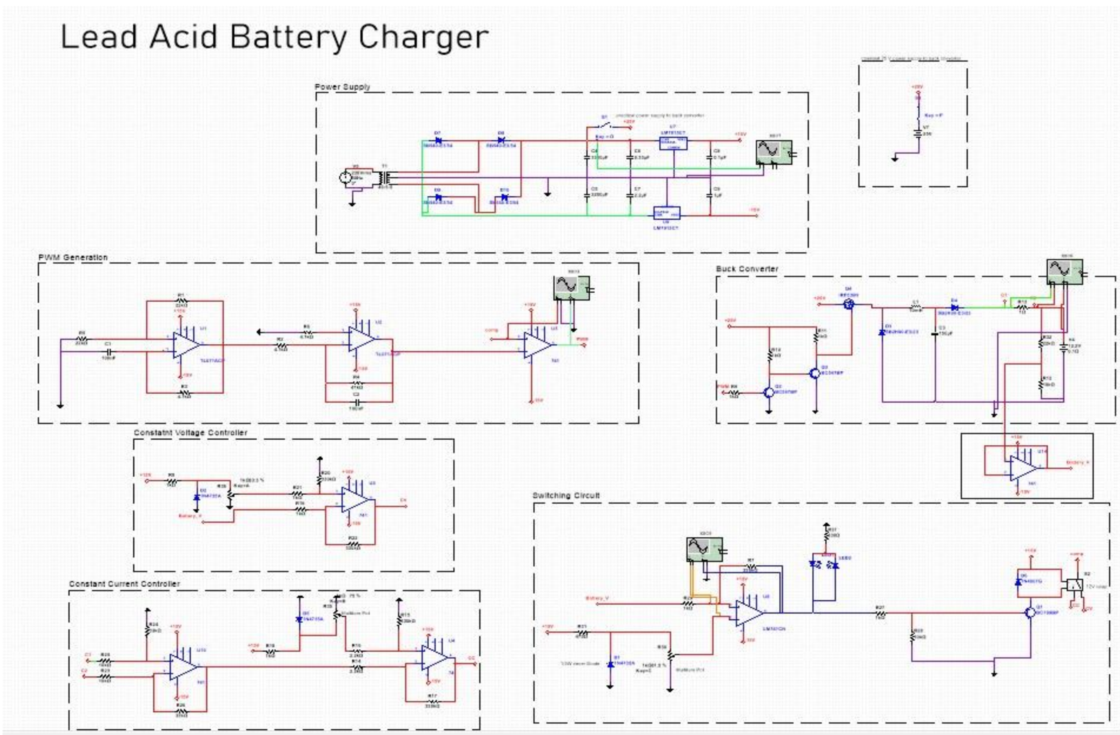


Figure: 7 Voltage regulator circuit



Complete circuit diagram

2.3. Calculations

<u>Constant Current</u>

Constant voltage = 13.6 V

V at A.S. = 13.6 $\times \frac{10}{32}$ V = $4.25\ V$

We need to set reference voltage to 4.25V

If error is ΔV

V1 = $\frac{330\ k\Omega}{1\ k\Omega} \times$ ΔV is given to PWM input

<u>Square wave generation circuit</u>

$$\boldsymbol{T = 2RC.ln(1 + \beta)/(1 - \beta)}$$

$$= 2 \times 4 \times 7 \times 1000 \times 100 \times 10^{-7} \times \ln\left(\frac{1+\frac{1}{2}}{1-\frac{1}{2}}\right)$$

$$= 9.4 \times 10^{-4} \ln(3)$$

$$= 0.00163\ s$$

f = 968.334 Hz

3. PCB design

We designed six separate one-layer (bottom layer) PCBs using Altium Designer software (Ver 22.9.12). The dimensions of each PCB are 110mm x 60mm.

We chose to use six PCBs for ease of implementation, as it allows us to debug each board individually before assembling them together in a stack. All of the traces are 1mm wide and the ground is connected to a copper pour on the board. The minimum clearance between traces is 1mm, and the drill hole size in the PCB is 0.9mm.

To make it easier to design the routes and connect all the necessary components, we separated the circuit into six blocks on separate PCBs. These blocks include the voltage regulator, PWM, constant current, constant voltage, switching circuit, and buck converter.

By using this approach, we were able to design the routes and assemble all the PCBs with ease.

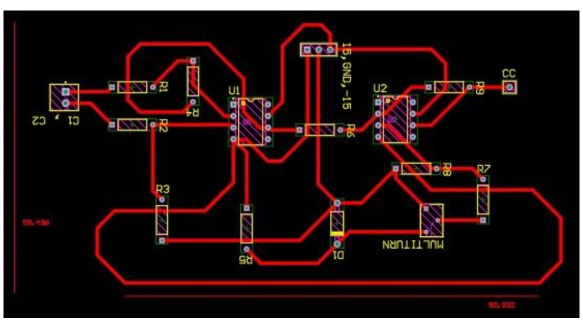


Figure: 8 Top layer of the CC circuit

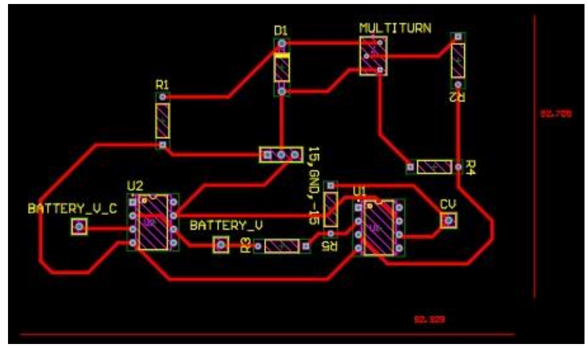


Figure: 9 Top layer of the CV circuit

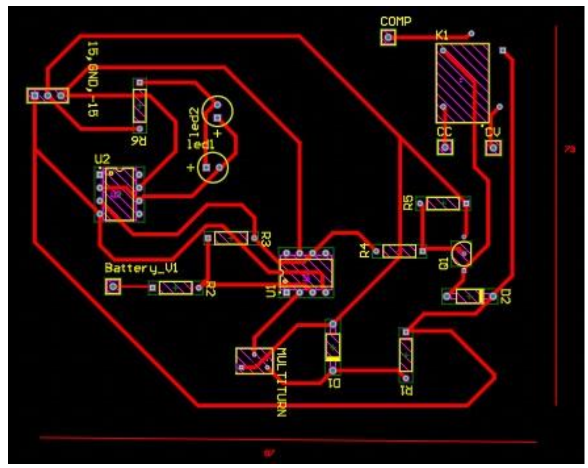


Figure: 10 Top layer of the switching circuit

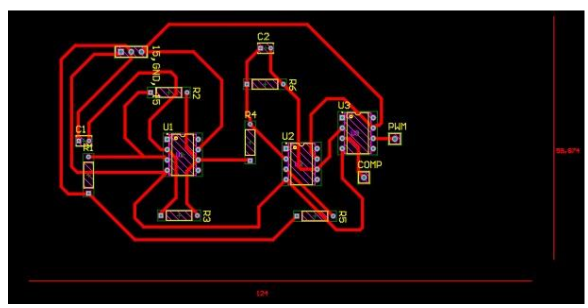


Figure: 11 Top layer of the PWM circuit

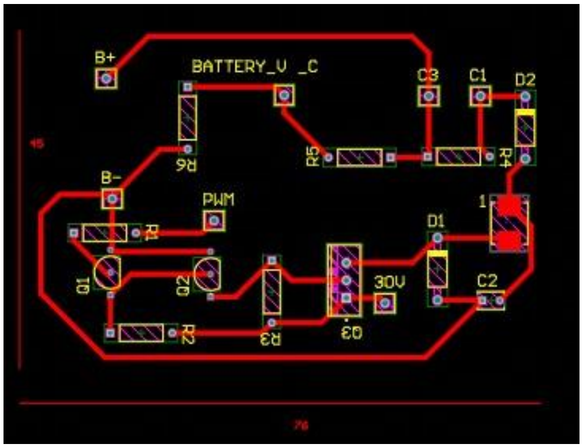


Figure: 12 Top layer of the Buck convertor circuit

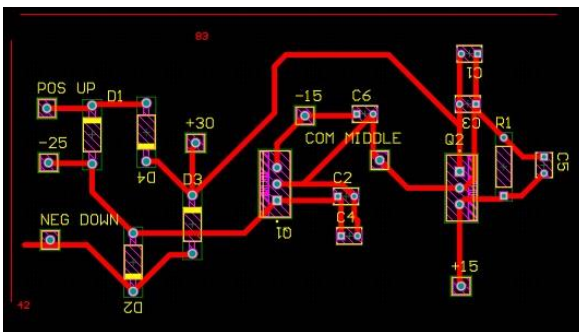


Figure: 13 Top layer of the voltage regulator circuit

4. Enclosure design

The enclosure design for the lead acid battery charger was done by using SOLIDWORKS 3D design software. The enclosure of the lead acid battery charger consists with two parts that are base part and cover. The six PCBs are placed on the base part of the enclosure as a stack.

Figure: 14 the enclosure design

ABS Plastic is used to make the enclosure of the battery charger.

The dimensions of the enclosure:

Length: 195mm

Width: 130mm

Height: 55mm

Table I: The weight of the different parts of enclosure

Part of the enclosure	Weight
Base	75.68g
Cover	67.76g
Total	143.44g

5. Results

The following images are showed the observation that are taken from the MultiSim simulator.

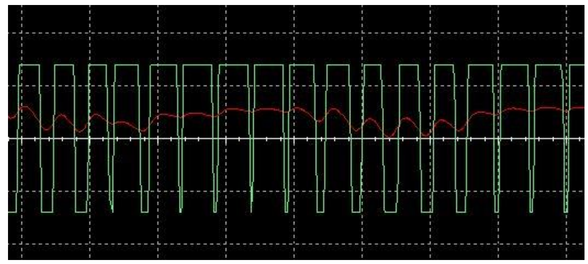


Fig: 15 PWM and error signal in CC stage

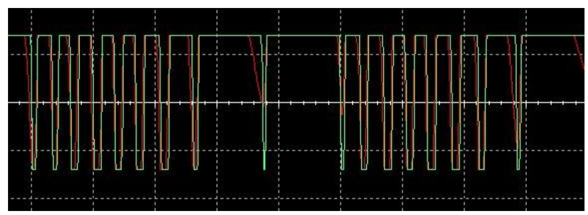


Fig: 16 PWM and error signal in CV stage

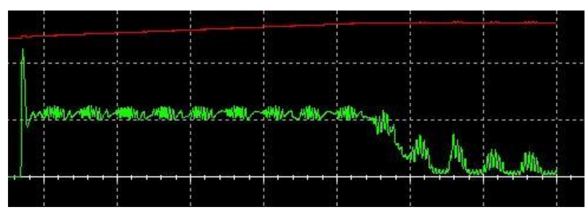


Fig: 12 Current and Voltage between battery terminals

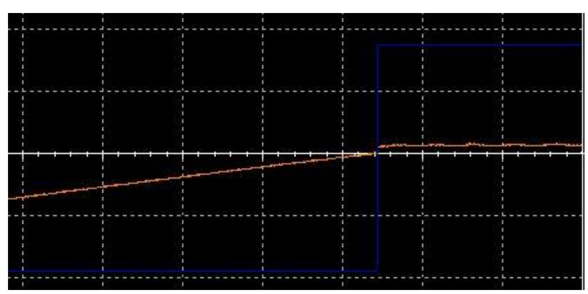


Fig: 13 Voltage between switching terminals' output

Table 2: detail table of the battery charger

Specification	Details
Battery voltage	0-12 V
CC to CV switching voltage	13.6 V
The maximum current flows through the Buck converter	1 A
Buck converter's supply voltage	+15 V & -15 V
PWM signal frequency	1 kHz
Buck converter supply voltage	25V

6. Discussion

Initially the circuit was implemented in breadboard and the functionality was tested. PCB was designed using Altium and the enclosure was designed using Solid works. In the power supply part we needed to convert 230v to 15 v. In the process we used a transformer. It got damaged due to overcurrent. Fuses need to be added to interrupt over currents. In constant current and constant voltage sections normal potentiometers were used but they proved useless as the outputted voltage did not stay at a stable value when fixed. Multiturn potentiometers were hence

used. Six separate PCBs were made. But the Lead Acid Battery Charger did not work properly.

7. Conclusion

The main objective of this project is to design a lead-acid battery charger that meets the given requirements. This battery should be 12 V, which is charged through this battery charger, and the maximum charging current should be 1 A. Our design could supply nearly 1 A of current and kept the voltage at 13.6 V at a constant value, as expected.

The PCB and the enclosure could be designed to satisfy the physical conditions of the battery charger, such as heat dissipation.

8. References

BU-403: Charging Lead Acid - Battery University

https://makingcircuits.com/blog/ 12v-100ah-battery-charger-circuit/

https://www.baseapp.com/embedded/types-sealed-lead-acid-chargers/

https://www.alldatasheet.com

9. Contribution

Index	Name	Contribution
200105F	**DE SILVA A.L.U.P.**	**Circuit simulation, testing and Implementation**
200310E	**KODITHUWAKKU K.A.W.T.**	**PCB design, circuit simulation and implementation**
200473E	**PRABUDDHIKA M.W.R.**	**Enclosure design, report writing, testing**
200709K	**WICKRAMANAYAKE R.S.D**	**Circuit design, simulation, testing and implementation**

10.Appendix

10.1. Enclosure design

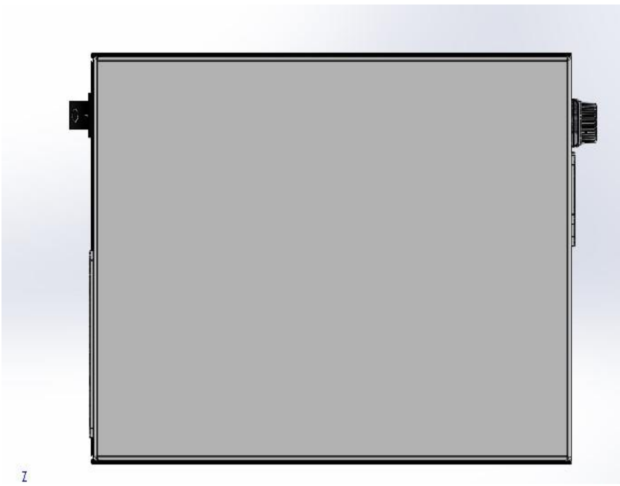


Fig: 1 Bottom view

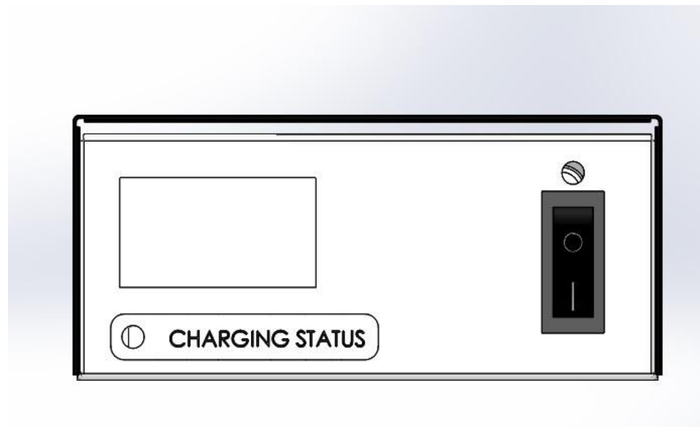


Fig: 2 Side view 1

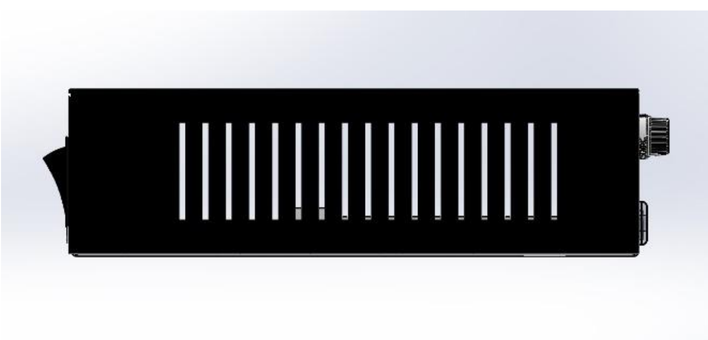


Fig: 3 Side view 2

Fig: 4 Top view

Lead-Acid Battery Charger Data Sheet

Group 18

Application

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

Features

- Constant current charging
- Constant voltage charging
- Charging with PWM technique
- Operating with domestic power supply

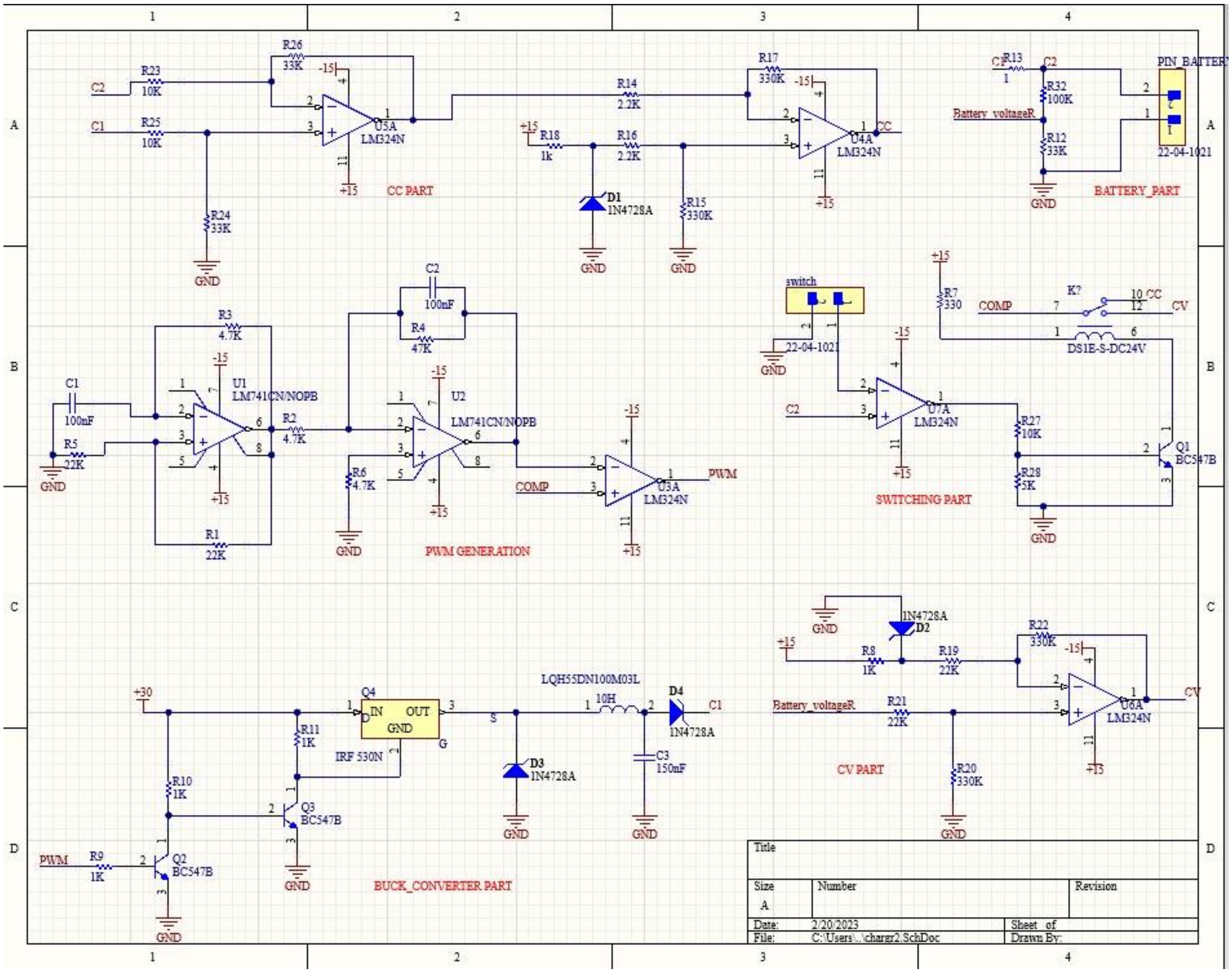
Specifications

Constant current	1 A
CC to CV transform voltage	13.6 V
Op-amp supply voltages	+15 V, -15 V
PWM signal frequency	1 kHz
Supply voltage of the Buck convertor	25 V
Maximum current drawn through the battery	1 A

Mechanical Specifications

- Dimensions of the PCBs
    1. Power Supply – 11 x 6.3 cm^2
    2. Constant Current – 11 x 6.5 cm^2
    3. Constant Voltage – 11 x 6 cm^2
    4. Switching – 11 x 8.7 cm^2
    5. PWM generation – 11 x 6.7 cm^2
    6. Buck convertor – 11 x 7.3 cm^2
- Dimension of the Enclosure – 25.4 x 20.32 x 10.16 cm^3
- Output connector – Fasten tabs

Circuit Diagram



Enclosure

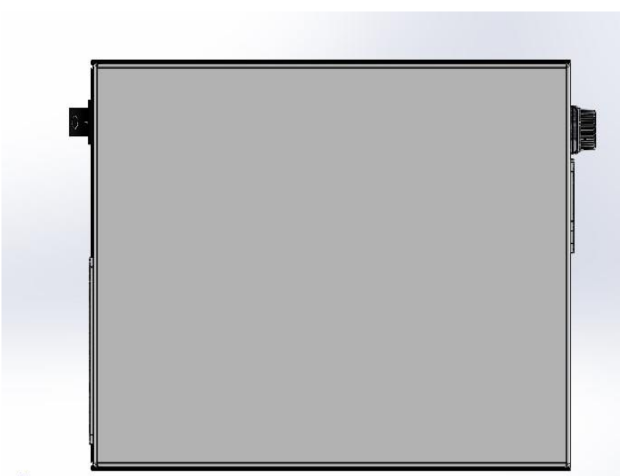


Fig: 1 Bottom view

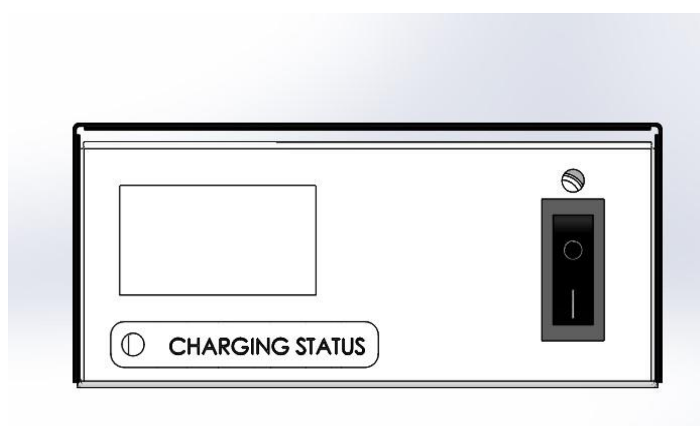


Fig: 2 Side view 1

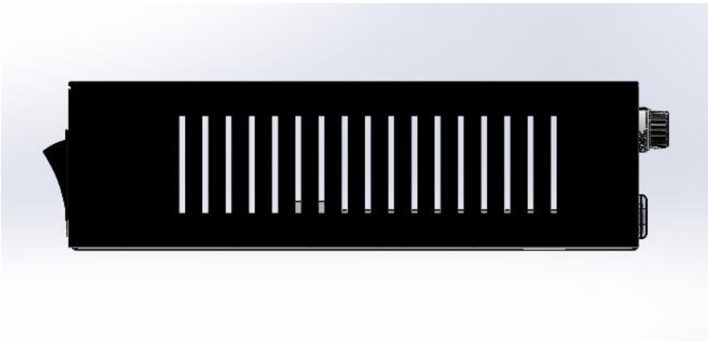


Fig: 3 Side view 2

Fig: 4 Top view