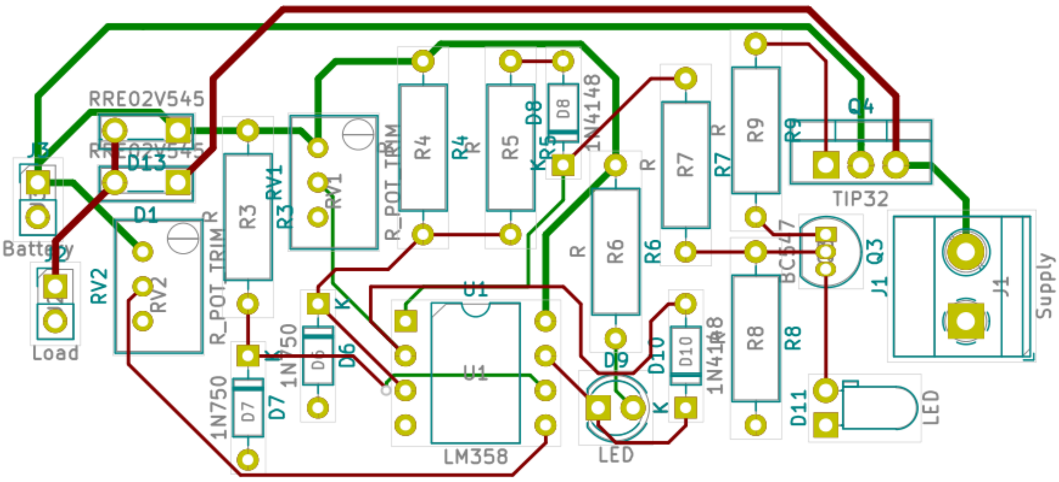
Op-amp based Battery Charger with Auto Cut-off

AV232 – ECAD Lab



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1. Abstract

The project proposes a two op-amp based auto cut off battery charger circuit which is not only accurate with its features but also allows a hassle free and quick setting up of its high/low cut-off threshold limits.

Objectives:

• To design a circuit which will automatically disconnect the battery and supply power to the system, when the circuit is connected to an external power source, in the meanwhile also charging the battery.

• Overcharging protection for the battery.

• Battery low and full charging indications.

Motivation:

Now-a-days electronic devices are reaching almost all houses, the most common being mobile phones, laptops, and many other devices which run on a battery. As such the lifetime of the battery becomes of utmost importance.

Overcharging of the battery can lead to electrochemical reactions between battery components and rapid increase of cell temperature. It can also trigger self-accelerating reactions in the battery, which can lead to thermal runaway and possible explosions.

So, we need some circuit mechanism which will automatically stop the charging of the battery at a certain threshold and hence prevent overcharging.

2. Components Required

- 1 x LM358 IC
- 1 x BC547 NPN Transistor
- 1 x TIP32C PNP Transistor
- 2 x 10k Potentiometers
- 1 x LXHL-BW02 LED (red), 1 x LXHL-BW02 LED (green)
- 2 x 1N4148 diodes, 2 x 1N750 Zener diodes, 2 x RR601BM4S Rectifier diodes
- 7 x Resistors (3 x 1 kΩ, 1 x 4.7 kΩ, 3 x 10 kΩ)
- 1 x Battery Test Unit
- DC Power Supply
- External Load

3. Circuit Schematic

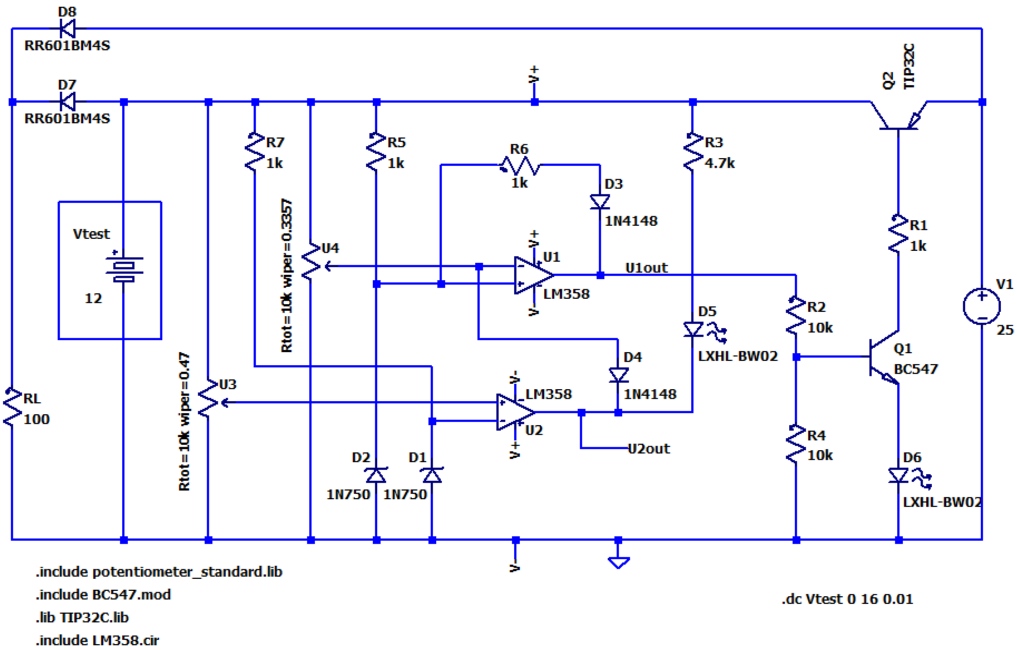

Figure 1 Circuit Schematic

4. How the Circuit Works

- V1 is the input charging supply, and Vtest is the battery which needs to be charged.
- We can set the threshold preset for the op-amps by adjusting the wiper of the potentiometers. We set the U2 preset to be at 10V and U1 preset to be at 14V threshold.
- Suppose we connect a battery that is partially discharged and is at 11V. At this voltage, negative pin of U1 will be below its positive pin potential.
- This will cause the output of U1 to be high, turning ON the transistor BC547 and TIP32. The battery will now start charging via TIP32, until its terminal voltage reaches 14V.
- At 14V, as per the preset, negative pin of U1 will go higher than its positive pin, causing its output to turn low. This will switch OFF the transistors, and stop the charging process.
- This will also latch the U1 through D3-R6, so that even if battery voltage drops slightly, U1 will continue to output low.
- As battery begins discharging via an output load, its terminal voltage starts dropping. When it reaches below 10V, as per the U2 preset, positive pin of U2 will drop below negative pin, causing U2 output to be low. This low of U2 output, pulls negative pin of U1 to 0V, such that positive pin of U1 becomes higher. This breaks U1 latch, and output of U1 again becomes high. This turns on the transistors and again initiates the charging process.

5. Simulation and Results

This section we will discuss the simulation results of our circuit using LTspice. As discussed above we have set our lower and upper thresholds to 10V and 14V respectively. To observe the behaviour of our circuit we will sweep our test battery from 0 to 16V and verify the responses of different circuit elements.

Comparator Response:

Since we have our threshold set at 10V and 14V we need turn on and off the switch depending on the state the battery using op-amps. Here the upper graph gives the response of op-amp U1 and the lower graph gives that of U2.

We can note that:

1. U1 gives a low output whenever the test battery voltage exceeds 14V upper threshold.
2. U2 gives a high output whenever the test battery voltage exceeds 10V lower threshold.

This will further help in switching action of our transistors.

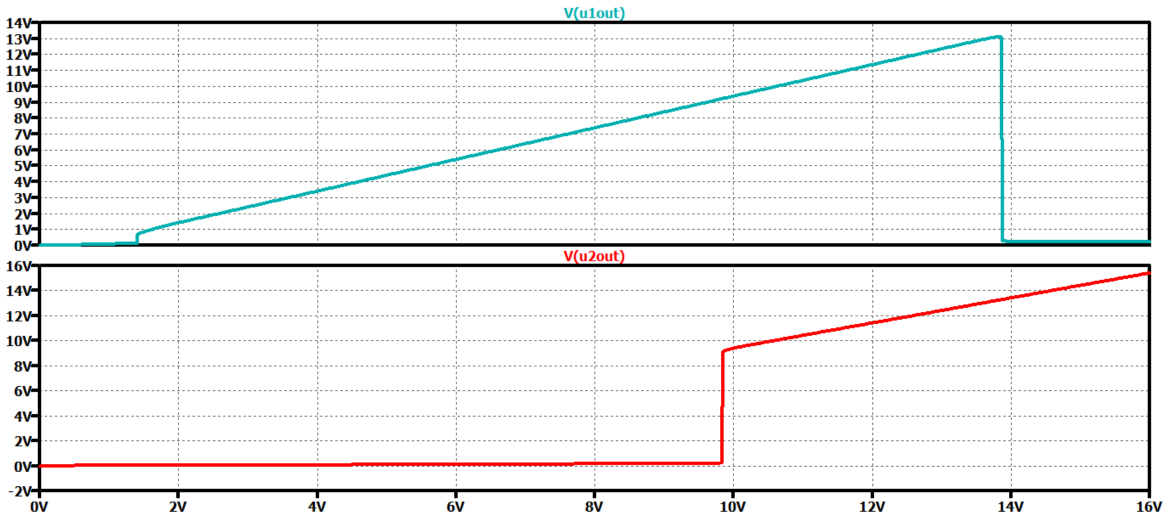

Figure 2: Op-amp Response vs Voltage across V(test)

Charging Response:

As we have to charge our battery, we would expect that there should be a current flow into the battery in charging cycle. The graph given below gives us the relation of current flowing into the battery vs test battery voltage. We can notice a constant current is present through the battery within our threshold values, and no current when exceeding the threshold. Thus, we can say that our test battery voltage will always be in the limits of our threshold during its operating time.

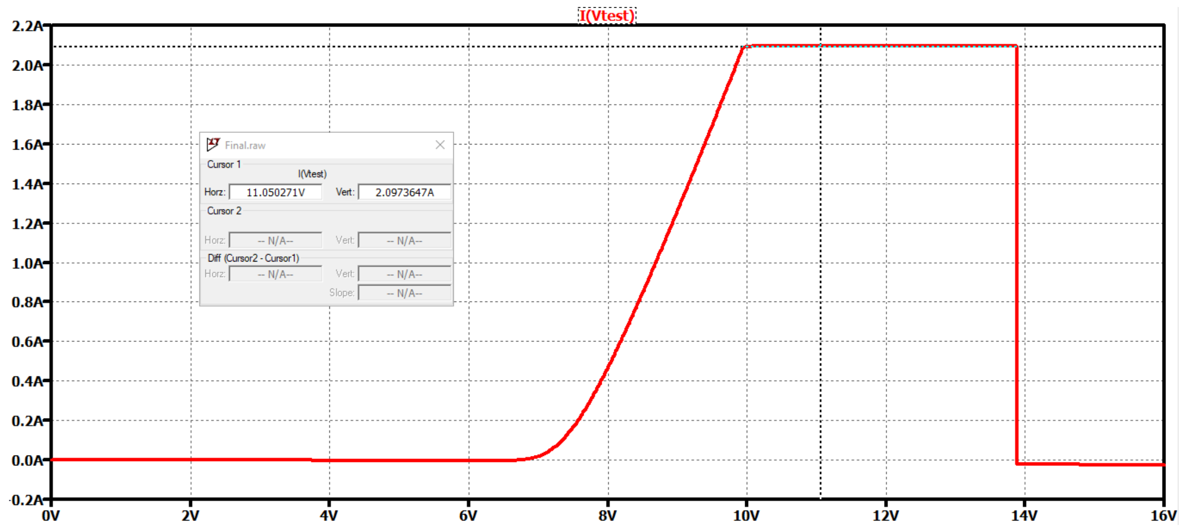

Figure 3: Current through V(test) vs Voltage across V(test)

Switching Response:

Our transistor TIP32C is expected to switch on when there is a need to charge the circuit; that is mainly in the threshold range we have decided. From the below graph we can see that, within our threshold range, NPN transistor BC547 allow collector current to flow creating a potential drop across the base of transistor TIP32C and thus switching on the transistor allowing the charging of the battery and switch off when completely charged.

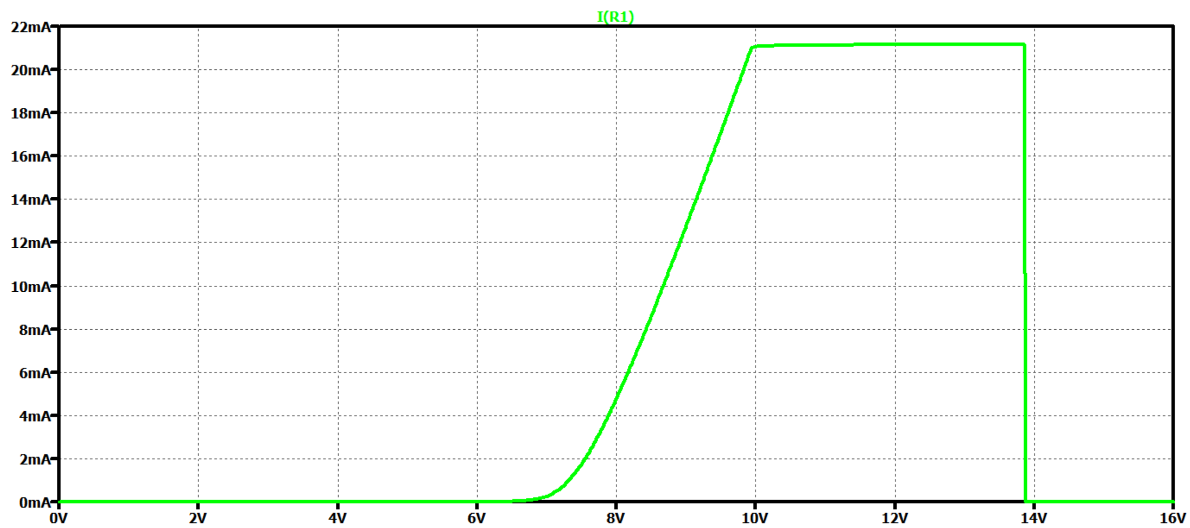

Figure 4: Collector Current through BC547 vs Voltage across V(test)

Load Response:

We expect to drive our load whatever be the state of the test battery. The graph below shows that the load is provided with the required specifications throughout the complete cycle of the battery charging and discharging. Thus, our load will be continuously driven by the power supply when battery is charging i.e., battery in discharged state and by the battery when it is fully charged.

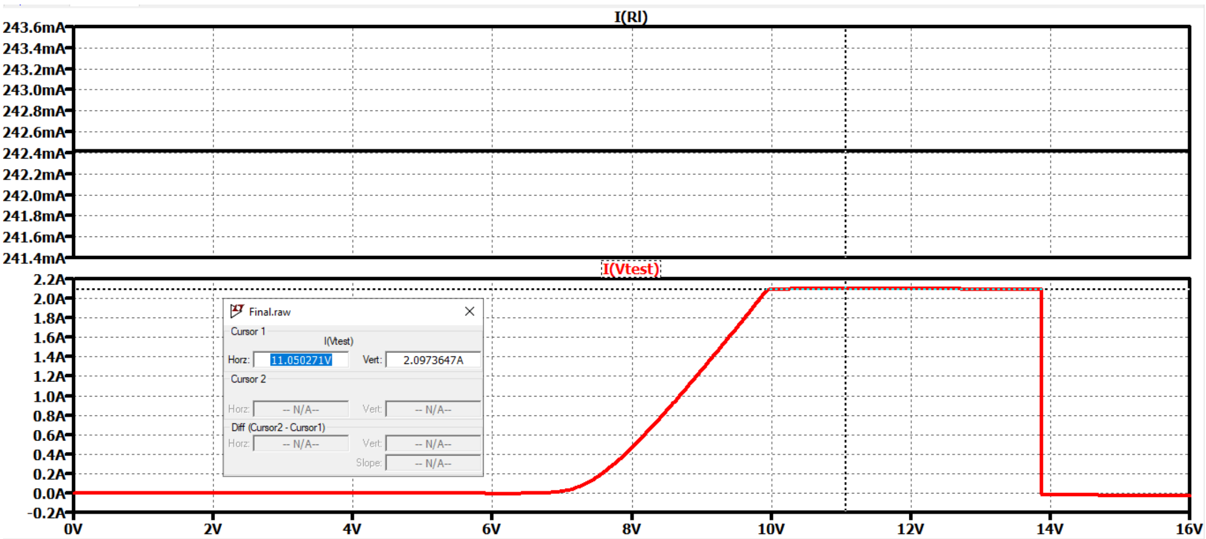

Figure 5: Current through the Load vs Voltage across V(test)

6. KiCAD Design

<u>Circuit Schematic</u>:

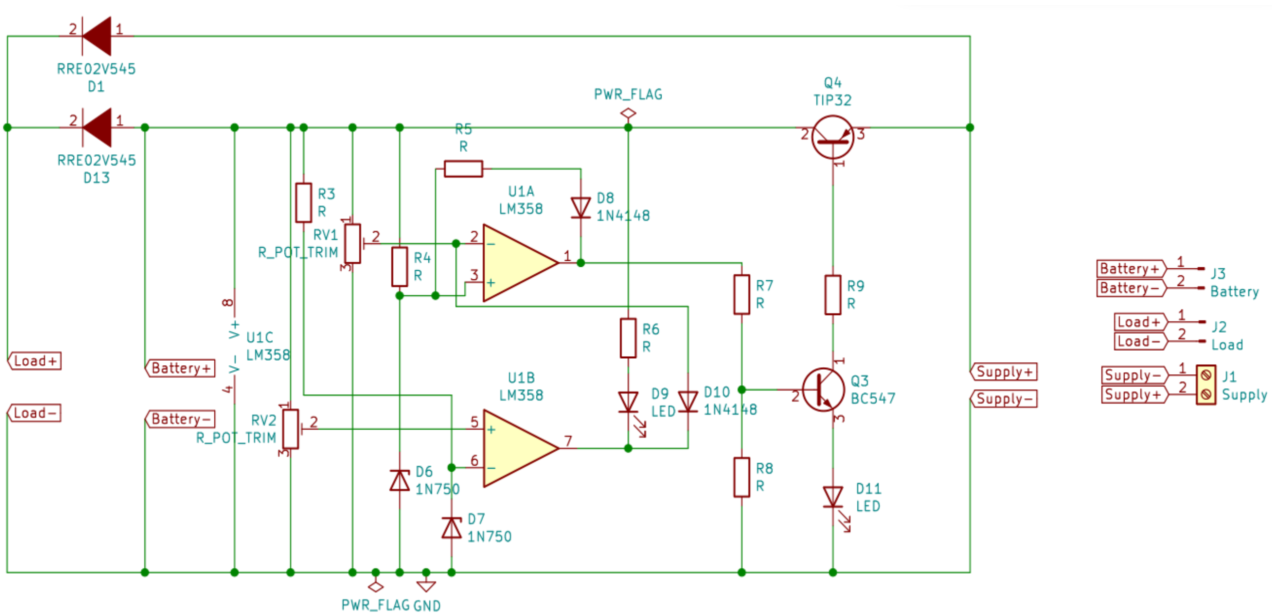

Figure 6: KiCAD Circuit Schematic

<u>PCB Layout</u>:

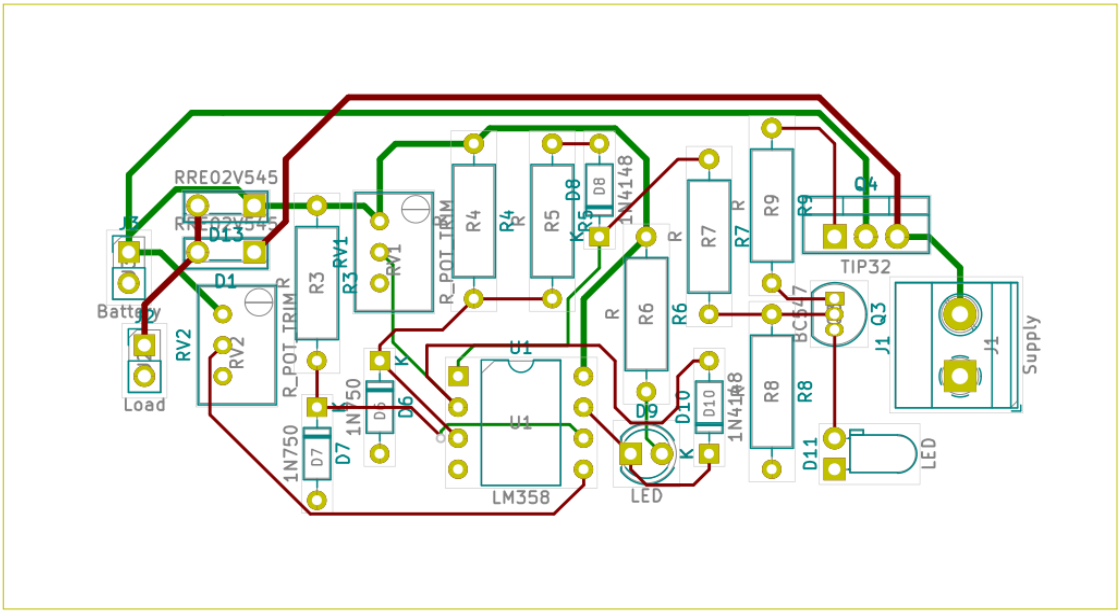

Figure 7: PCB Layout

Component	Footprint
LM358	Package_DIP:DIP-8_W10.16mm
R	Resistor_THT:R_Axial_DIN0309_L9.0mm_D3.2mm_P12.70mm_Horizontal
1N4148	Diode_THT:D_DO-35_SOD27_P7.62mm_Horizontal
1N750	Diode_THT:D_DO-35_SOD27_P7.62mm_Horizontal
LED	LED_THT:LED_D4.0mm
BC547	Package_TO_SOT_THT:TO-92_Inline
LED	LED_THT:LED_D3.0mm_Horizontal_O1.27mm_Z2.0mm
Supply	TerminalBlock_Phoenix:TerminalBlock_Phoenix_MKDS-1,5-2-5.08_1x02_P5.08mm_Horizontal
Load	Connector_PinHeader_2.54mm:PinHeader_1x02_P2.54mm_Vertical
RRE02V545	Package_TO_SOT_THT:TO-251-2_Vertical
TIP32	Package_TO_SOT_THT:TO-220-3_Vertical
Battery	Connector_PinSocket_2.54mm:PinSocket_1x02_P2.54mm_Vertical
R_POT_TRIM	Potentiometer_THT:Potentiometer_Bourns_3299W_Vertical

PCB Layout (3D):

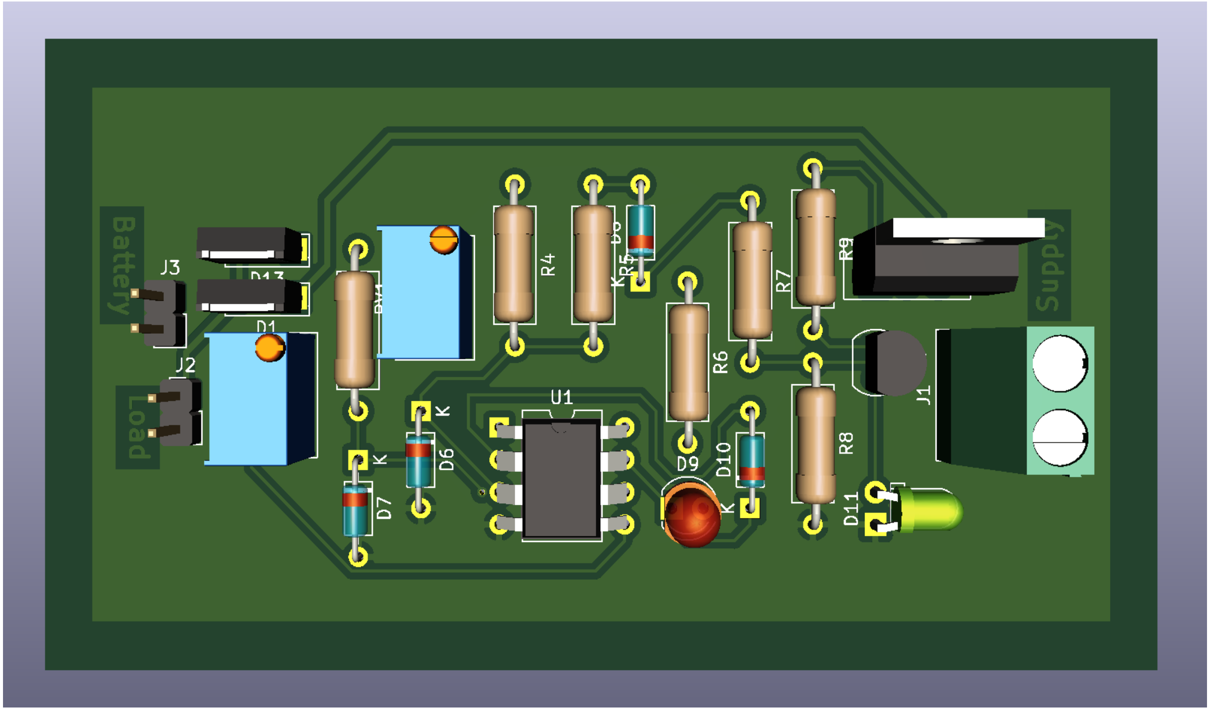

Figure 8: Front View of PCB in 3D

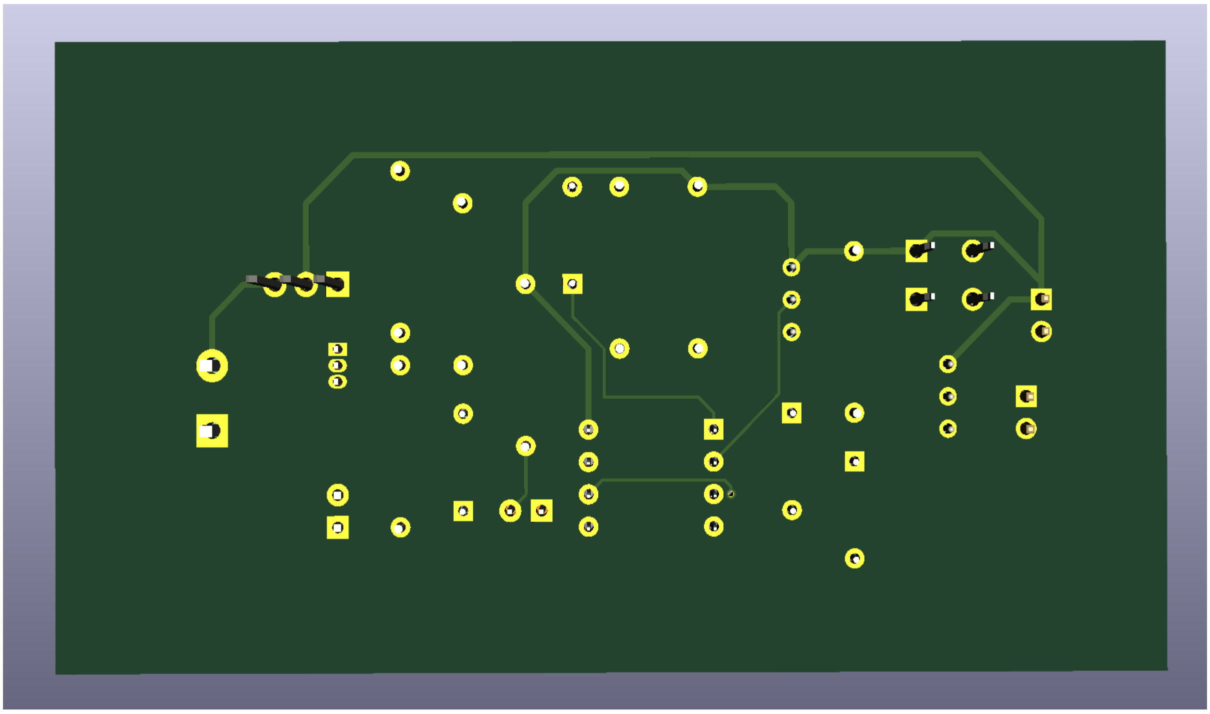

Figure 9: Rear View of PCB in 3D

7. References

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