Project Report

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Department of Electrical and Electronic Engineering

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Laboratory Section: A2

Group: 05

Report Title: Battery charger with variable DC output using Zeta converter with auto cutoff feature.

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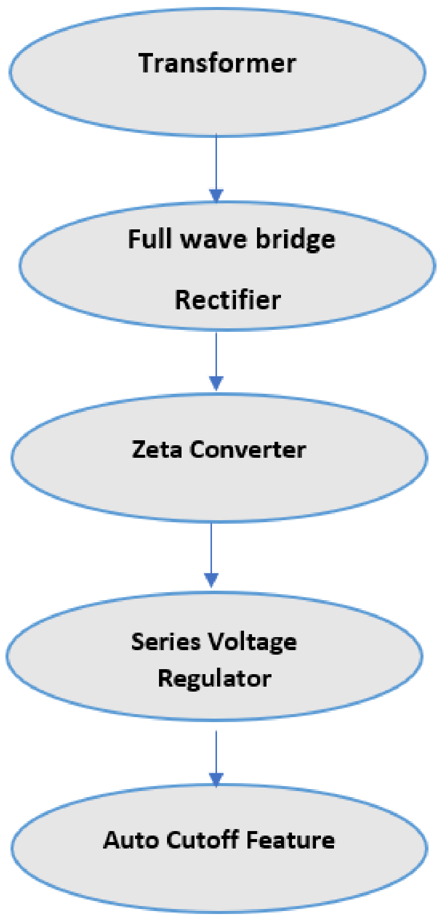
Introduction

The objective of this project was to simulate a battery charger with variable DC output using Zeta converter with auto cutoff feature. We created a Simulink model in MATLAB and illustrated the working principles of the battery charger. The model has combined with five main circuits in order to get the perfect desired output.



The main components used in this automatic battery charger are the bridge rectifier circuit, zeta converter, the series voltage regulator and the auto cutoff circuit with relays. The zeta converter was used to convert the rectified DC voltage to a constant output voltage which is the input of a series voltage regulator. Once the battery is completely charged the auto cut off circuit is used to drive the circuitry which will cut-off the charging voltage and protect the battery from overcharging.

While working on this project the circuit was first divided into small individual circuits such as AC to DC conversion, producing constant steady output voltage, creating the cut-off logic to turn off the charging when the battery is full. These circuits were created in Simulink to verify that each component was working as expected. Finally, all the circuits were assembled to create a battery charging circuit with automatic cut-off.

Modern day electronics use a lot of active components that are very sensitive to change in voltage applied across the terminal. Any change in the voltage for these components can result in malfunction which may lead to erratic results and may even permanently damage the component. To overcome this fluctuation in voltage, modern day advancements in integrated circuit technology have produced IC based Voltage regulators that can produce constant non-varying voltage. A Voltage regulator can regulate the voltage by using electronic components such as transistors, diodes etc. Voltage regulators are used in various applications where the voltage needs to be constant for example in switched mode power supply (SMPS) for powering computers or for regulating the voltage used for home appliances etc. Voltage regulators can be either fixed voltage regulators or adjustable voltage regulators which can maintain constant output voltage within the given range.

Theory & Simulation:

Transformer:

A transformer is an electromagnetic electrical device that is used to change the amplitude of the input AC voltage. A transformer can either increase or decrease voltage levels without changing its frequency. Figure shows a single-phase transformer consists of two electricals coils called primary and secondary winding placed in proximity of each other. Through the process of mutual induction, the voltage in one coil is magnetically induced on the other coil. The primary winding of the transformer is connected to the AC supply voltage as the secondary winding produces the step-up or step-down AC voltage. If the number of windings in the primary coil is higher than the secondary coils, then the transformer steps down the voltage. But if the number of windings in secondary coil is higher than the primary coil then output voltage is increased. The ratio of number of turns between primary and secondary coil gives the output voltage of the transformer.

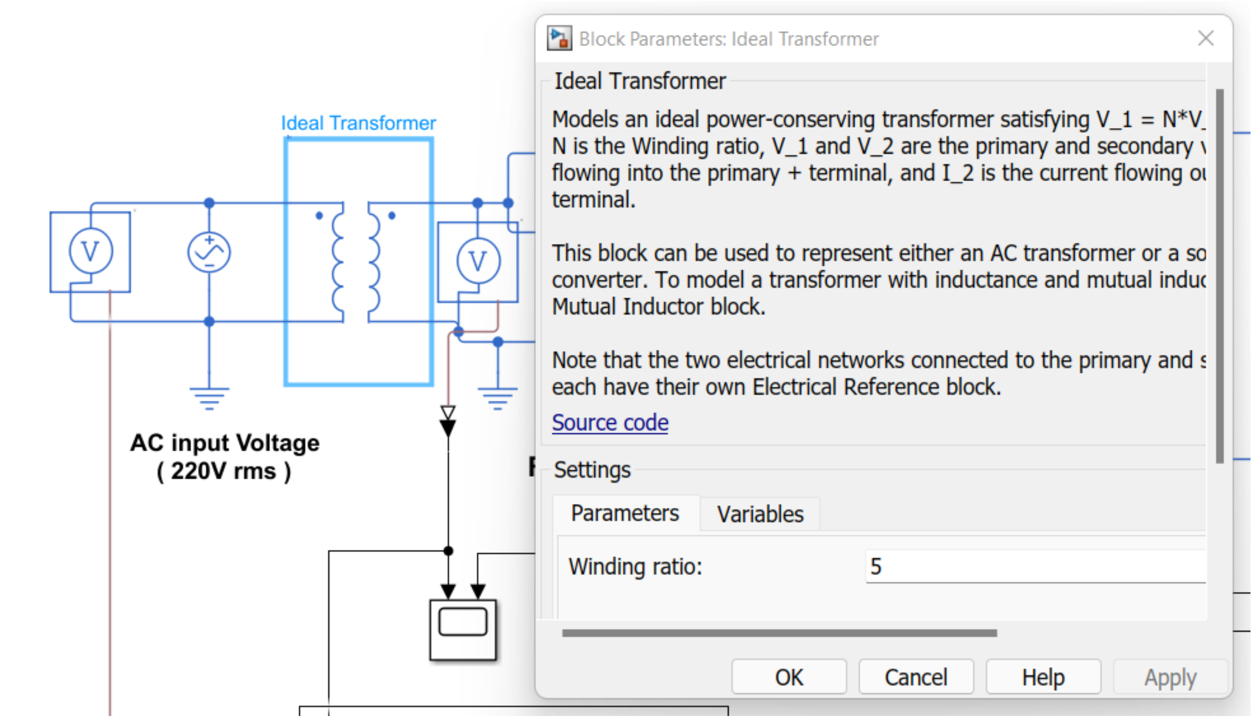
$$Turn\ Ratio, n = \frac{Vp}{Vs}$$

$$V_s = \frac{Vp}{n} = \frac{311.13}{5}$$

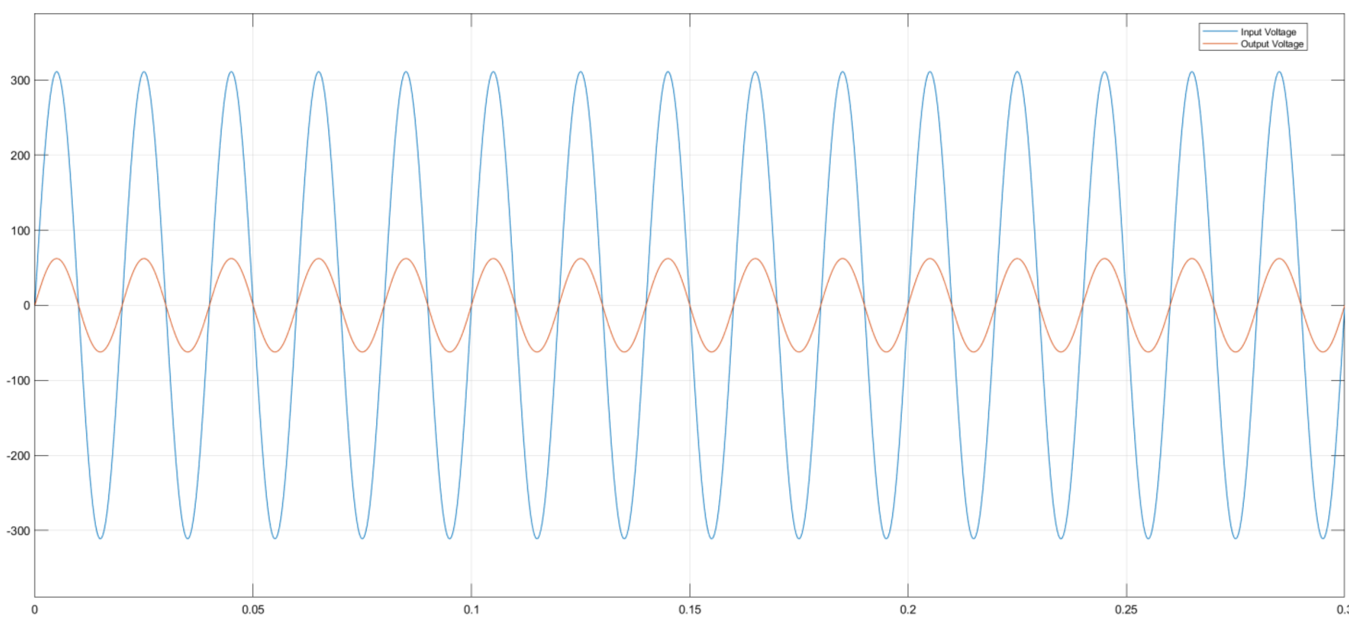
$$= 62.225 \text{ v}$$

For this project, we are using a step-down transformer to convert the AC mains voltage in Finland which is 220*√2 = 311.13V AC to step-down to 62.225V AC. So, the turn ration of this transformer is 5.

Simulink Model (Transformer):



Output:

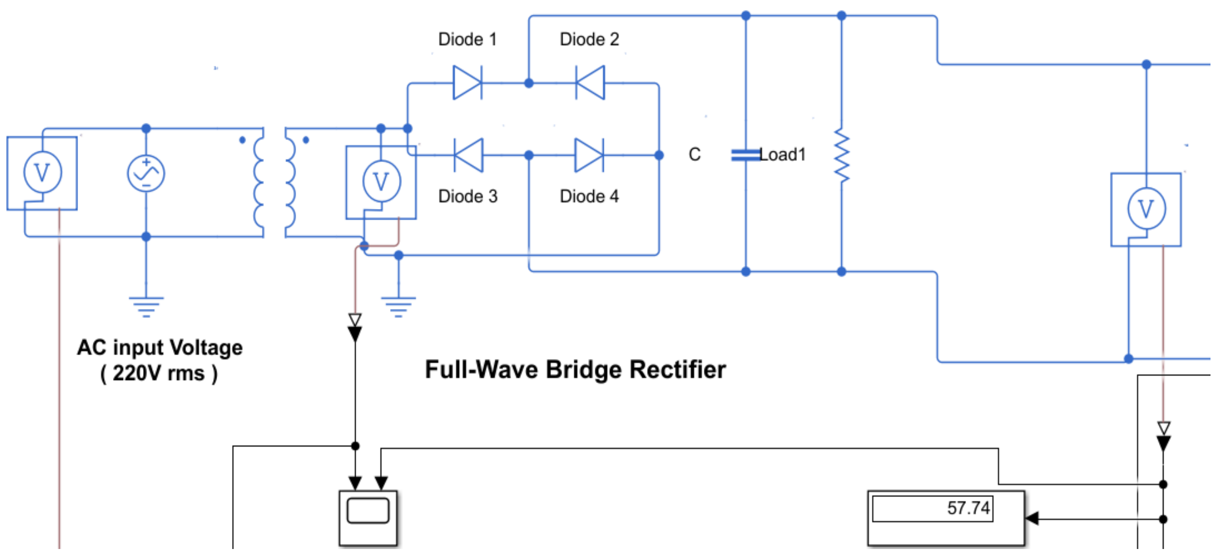


From the graph, the output of secondary winding of the transformer is also **62.223V**

Full Wave Bridge Rectifier:

This battery charger uses a full wave bridge rectifier which uses four diodes in bridge, so that it can rectify both positive and negative half cycles of the input. For positive half the cycle only two diodes D1 and D2 are forward biased and thus conducting, whereas the other two diodes are reverse biased and do not conduct. For the negative half cycle of the input diodes D3 and D4 conduct whereas diodes D1 and D2 do not conduct. On each half cycle of the input there are two diodes performing the rectification, so the output voltage is two voltage drops of the diode (2*0.7 = 1.4V) less than the input voltage.

Simulink Model:



Output:

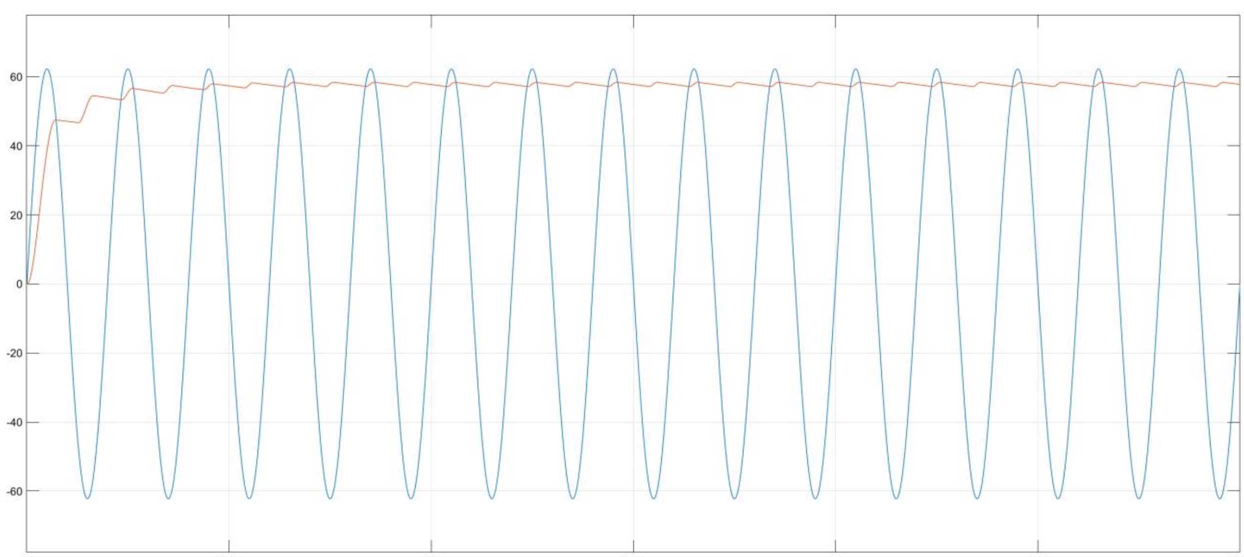


Figure shows the bridge rectifier circuit and its output waveform. The output of the bridge rectifier produces a pulsating DC signal which is not appropriate for operating components requiring DC voltage, so a smoothing capacitor is required to filter the output to provide a DC voltage without any ripples. But we get some ripples in the output which can be eliminated by a pi filter. Here, the highest and lowest peaks are **58.340V** and **57.163V.**

Zeta Converter (Positive Buck-Boost Converter):

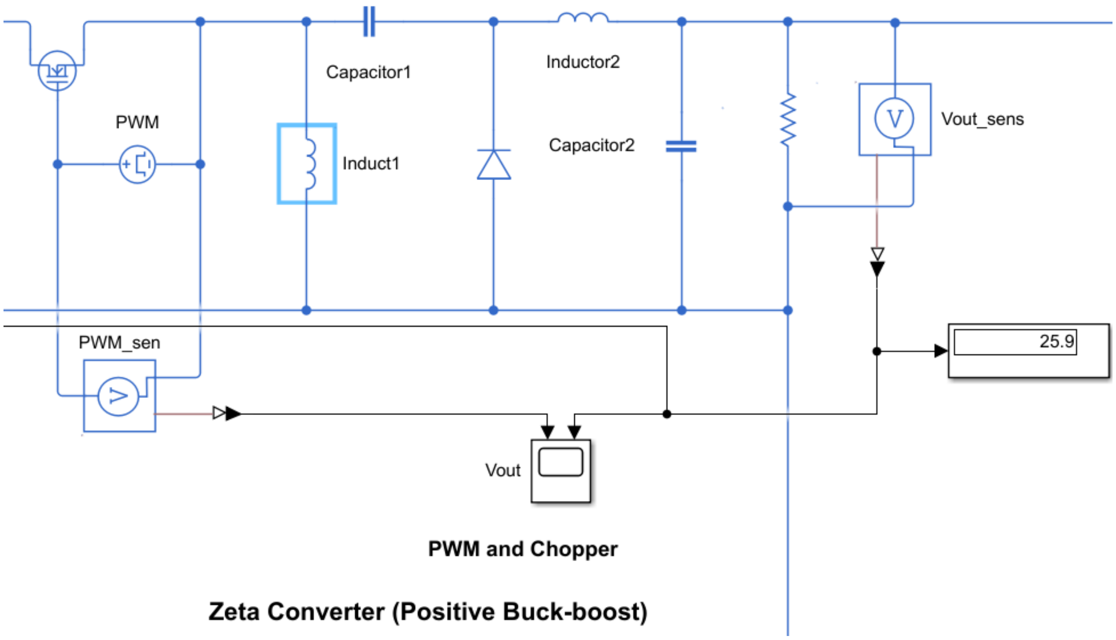
The ZETA converter provides a positive output voltage for input voltage that varies above and below the output voltage. The ZETA converter also needs two inductors and a series capacitor, sometimes called a flying capacitor. The zeta converter is used for to give the gate pulse for MOSFET which is used the driver circuit in our paper we can see that how the gate pulse is given to it, this converter, which is configured with a standard boost converter, the ZETA converter is configured from a buck controller that drives a high-side PMOSFET. The ZETA converter is another option regulating an unregulated input-power supply. All non-conventional system energy system requires power converters. seen the power electronic converter is the heart of the entire system, show proper design necessary. ZETA Converter Is mentioned, and it is use provide positive output from the input voltage it can be used to increase as well as decrease the voltage. This converter is used for power factor correction applications and short circuit protection.

A zeta converter is a fourth order Nonlinear system being that, about energy input, it can see as buck boost-buck converter and about the output, it can be seen as boost-buck-boost converter. The ideal switch-based realization of zeta converter is depicted. A non-isolated zeta converter. circuit is shown in the below. Although several operating modes are possible for this converter depending on inductance value, load resistance and operating frequency, here only continuous inductor current analyzed using the well-known state-space averaging method. The analysis uses the following assumptions.

- Semiconductors switching devices are ideal.
- Converter operating in continuous inductor current mode.
- Line frequency ripple in the dc voltage is Neglected

We are Simulating the ZETA Converter in MATLAB, so we are performing Bridge Rectifier circuit firstly in MATLAB. We are using 230 V AC Supply as an input to rectifier circuit, capacitor and resistance as load which act as a filter circuit and a linear transformer of 311V by 62.22V so we get the 62.22V at the output side of filter circuit of Rectifier.

Simulink Model:



Here, the capacitor and inductor values are

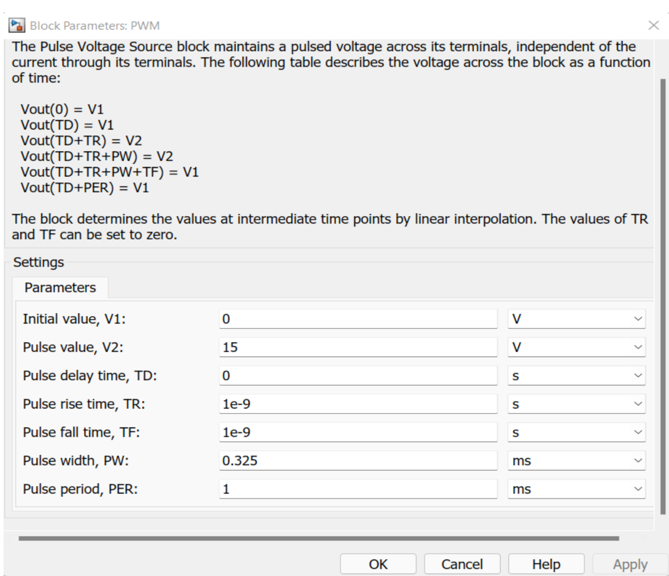
Capacitor1= 10uF

Capacitor2= 470uF

Inductor1 = 27mH

Inductor2 = 200mH

The gate pulse we use in the mosfet



Block Parameters: PWM

The Pulse Voltage Source block maintains a pulsed voltage across its terminals, independent of the current through its terminals. The following table describes the voltage across the block as a function of time:

Vout(0) = V1
Vout(TD) = V1
Vout(TD+TR) = V2
Vout(TD+TR+PW) = V2
Vout(TD+TR+PW+TF) = V1
Vout(TD+PER) = V1

The block determines the values at intermediate time points by linear interpolation. The values of TR and TF can be set to zero.

Settings

Parameters

Initial value, V1:	0	V
Pulse value, V2:	15	V
Pulse delay time, TD:	0	s
Pulse rise time, TR:	1e-9	s
Pulse fall time, TF:	1e-9	s
Pulse width, PW:	0.325	ms
Pulse period, PER:	1	ms

OK Cancel Help Apply

Calculation:

The duty cycle, D = 0.325 =32.5%

Input Voltage, Vin= 57.8V

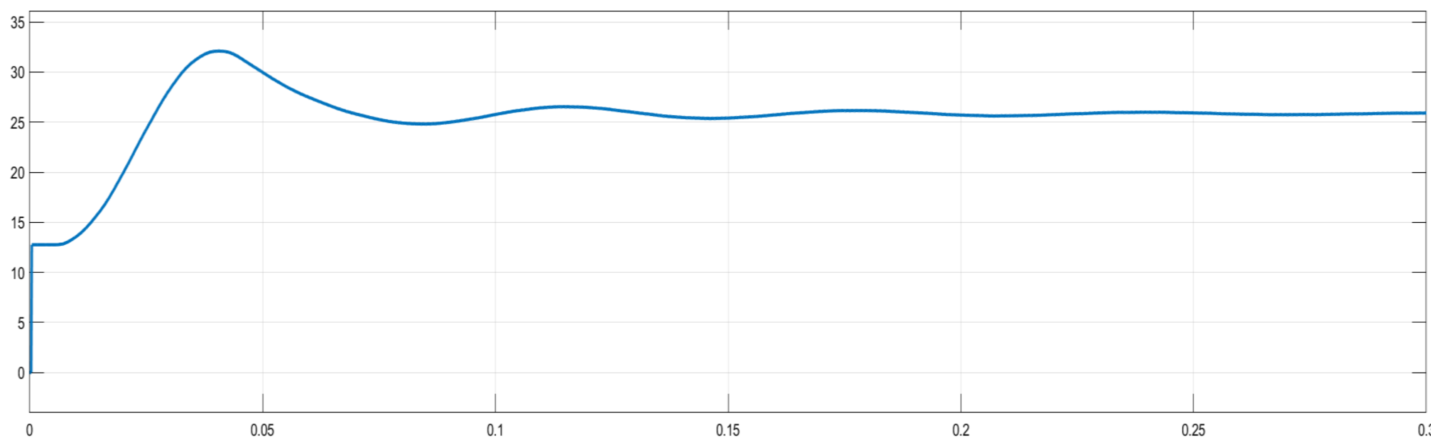
From the input output relation of a zeta converter,

Output Voltage, Vo= $(\frac{D}{1-D})$ Vin

= $(\frac{0.325}{1-0.325})$*57.8V

=26.3V

Simulink Input Output graph:



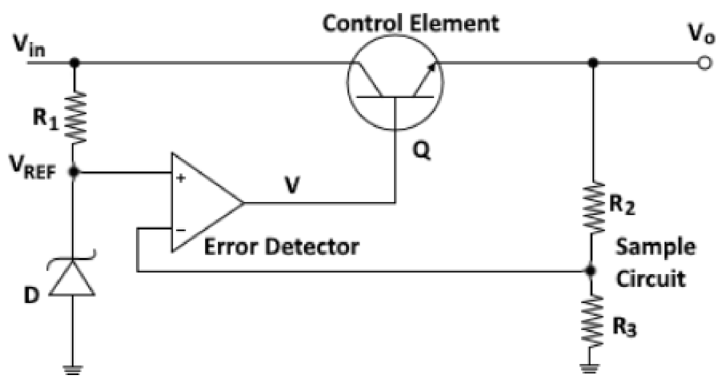
From the output of graph, we see the output voltage is approximately 26V with a negligible ripple. There was some transient situation going on from 0 to 0.1s. After 0.2s we get almost dc 26V voltage without any ripple.

For our project we used zeta converter instead of buck or buck-boost because the output voltage is positive in reference to the ground which makes the sensing circuit simple. Again, it provides a non-inverted output, stable output response is obtained, control over the circuit, proves to be effective, fewer transients in the output response. Circuit losses is less compared to other converter.

By using the zeta converter, we get perfectly stable dc output voltage, which will used for the input of our series voltage regulator to regulate in different dc output to charge different batteries.

Series Voltage Regulator:

In the figure of basic op-amplifier series voltage regulator, the op-amp is used as comparator. Resistor R1 and R2 is the voltage divider network which is used to sense any change at the o/p. The change sensed by the divider network is applied at the inverting i/p of the comparator, while the reference voltage hold by the Zener diode is applied at the non-inverting i/p of the comparator is applied at the base of transistor "Q".



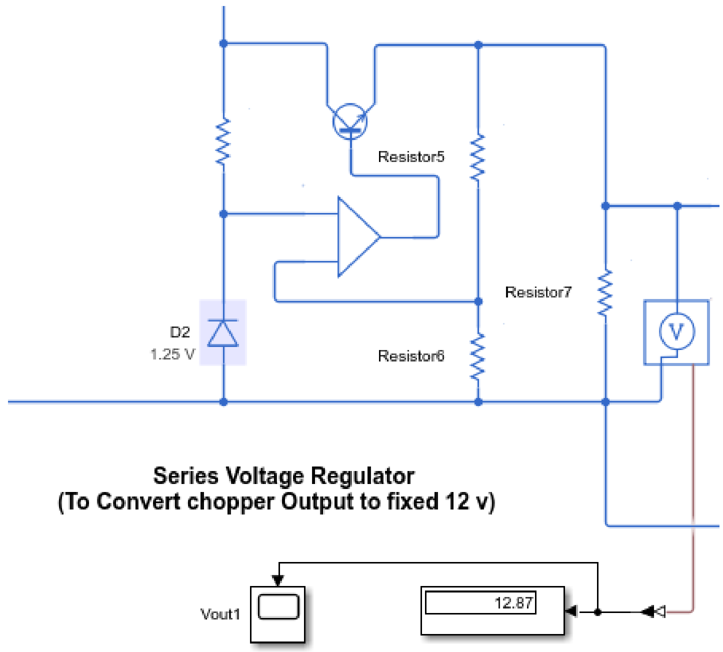
When the o/p voltage decreases because of the decrease in i/p voltage, the voltage drops across R1, R2 decreases and so this error voltage (-ve) is sensed by the divider network which is applied at the inverting i/p of the comparator. The comparator compares the reference constant voltage and the -ve error voltage and provide the difference (+ve) of the two voltages at the o/p as i/p at the base of transistor. The transistor conducts according to the forward bias voltage at the base and so, the o/p voltage remain constant. When the o/p voltage tries to increase, the voltage sensed by the divider network is increased. This is applied at the inverting i/p of the comparator. The comparator provides the difference (-ve) of the two voltages at the i/p of Q1 and so, the conduction of transistor decreases to the constant (required) voltage level.

The output voltage of series voltage regulator doesn't depend on input voltage. The Zener diode voltage in the non-inverting terminal and the negative feedback circuit tries to keep the voltage to a constant limit. Any change in voltage will be eliminated by the series voltage regulator. The input output relation is

$$Vout = Vz\ (1+\frac{R2}{R1})$$

For our project, we use this series voltage regulator to regulate the voltage to our desired output. Simple voltage divider circuit is used to get the 12V, 6V etc. sample voltage. Here, by changing the resistors we can control the output voltage which is more feasible than changing the duty cycle of the PWM in zeta converter.

Simulink model:



The circuit is constructed with Zener diode, Op-amp, NPN transistor and resistors. From the above description, the output voltage depends on breakdown voltage of the Zener diode which is 1.25V. The voltage divider circuit's resistors which are Resistor5, Resitor6.

The input output relation is Vo = Vz $(1+\frac{Resistor5}{\text{Resistor6}})$

Here, Resistor5= 9kohm

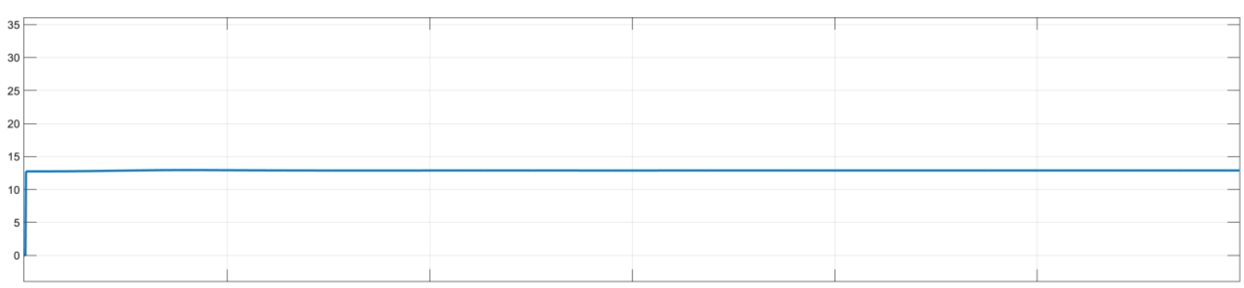
Resistor6= 1kohm

Vz= 1.25v

Vo = 1.25 $(1+\frac{9}{1})$

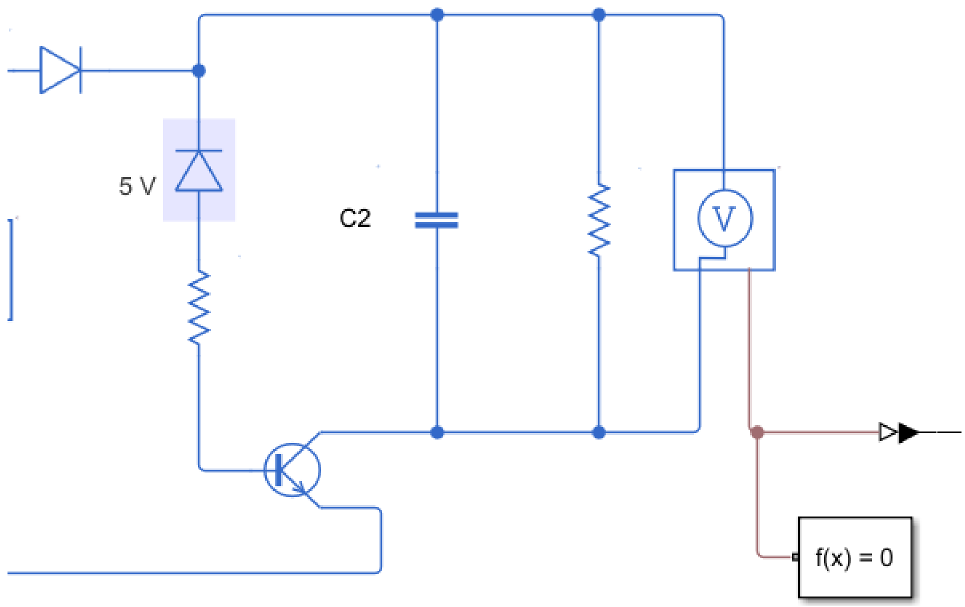
=12.5V

From the output, we get dc 12.87V which is nearly close to our theoretical calculation.



The auto cutoff circuit:

The auto circuit is consisted with diode, Zener diode, capacitor and a NPN transistor. When the battery is connected, there is a possibility to flow reverse current form battery to the main circuit. The diode we used here will block the reverse current



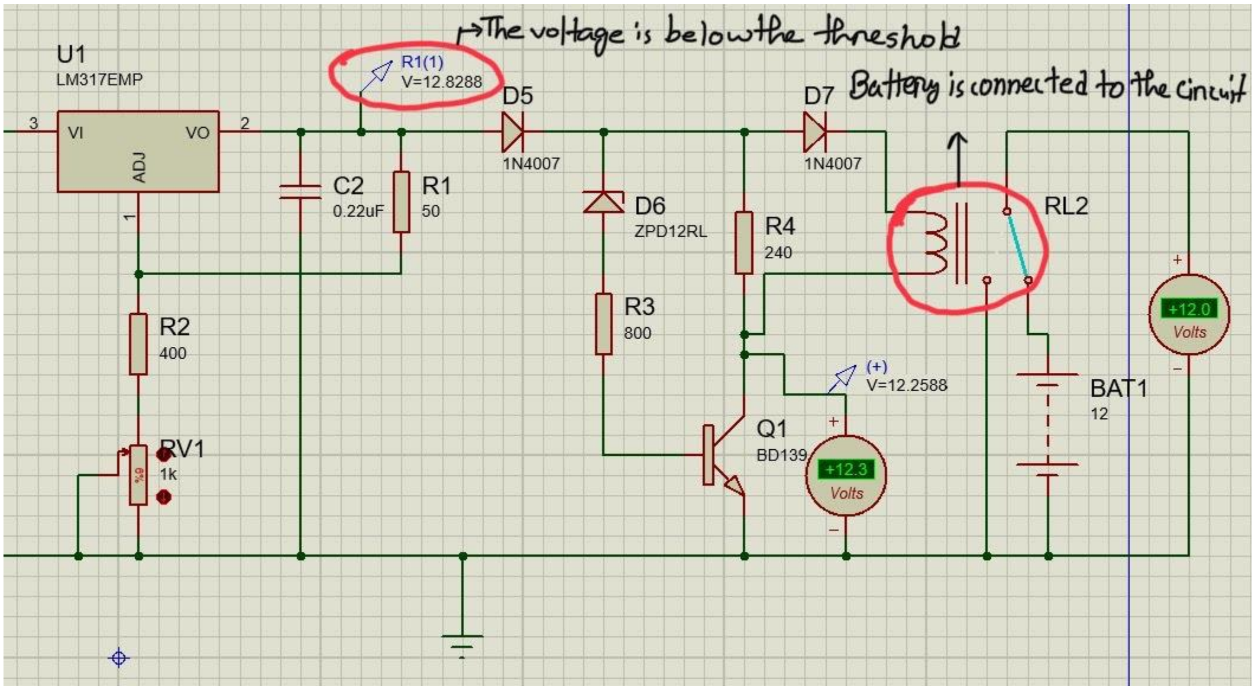
Auto cut off Circuit

flow into the circuit. Again, when the voltage is below 12V the Zener diode will turn on and the base of the transistor will get some current. When the transistor base current flow occurs, collector-base junction remains reverse biased while base-emitter junction remains forward biased. It leads the transistor to active region. The relay connects the battery to the main circuit and start charging the battery.

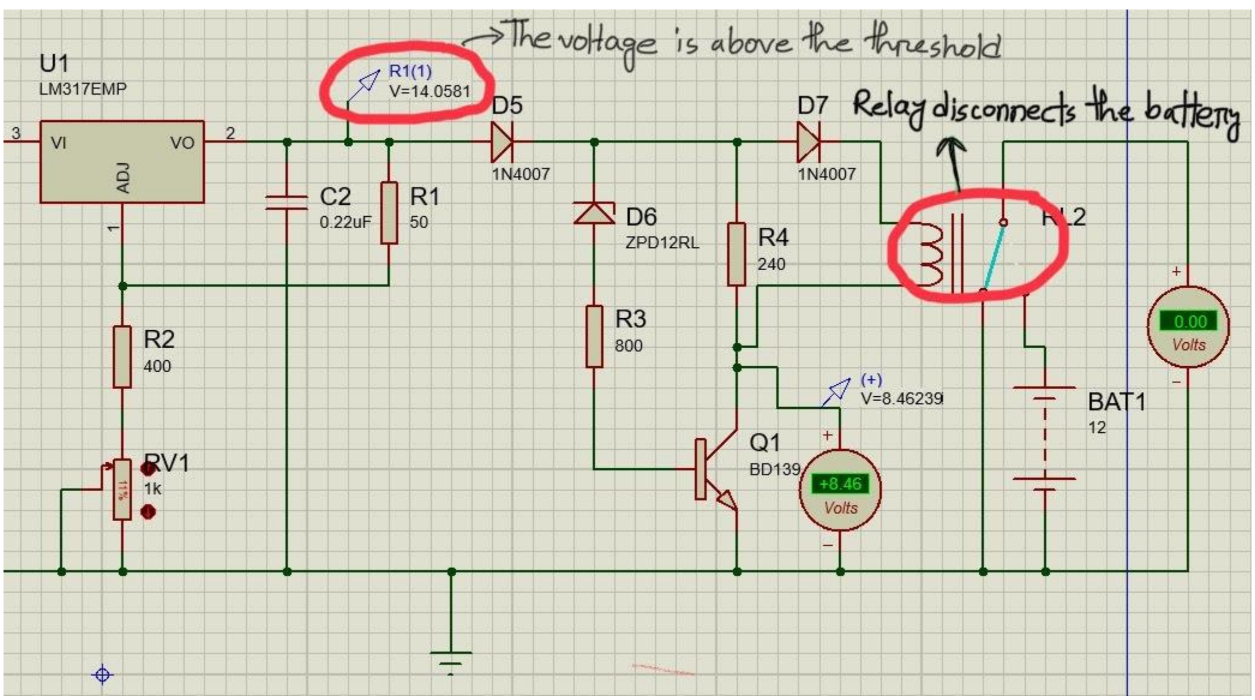
Again, when the voltage is over the threshold 12v, the Zener diode stops passing the current to the base of the transistor, the base-emitter junction no longer remains forward biased, it will go to cutoff region and normal transistor action is lost. Then the relay changes its position and disconnects the battery from the circuit. And the battery will stop charging.

The auto cutoff feature is more feasible in proteus model. Proteus simulation is given below:

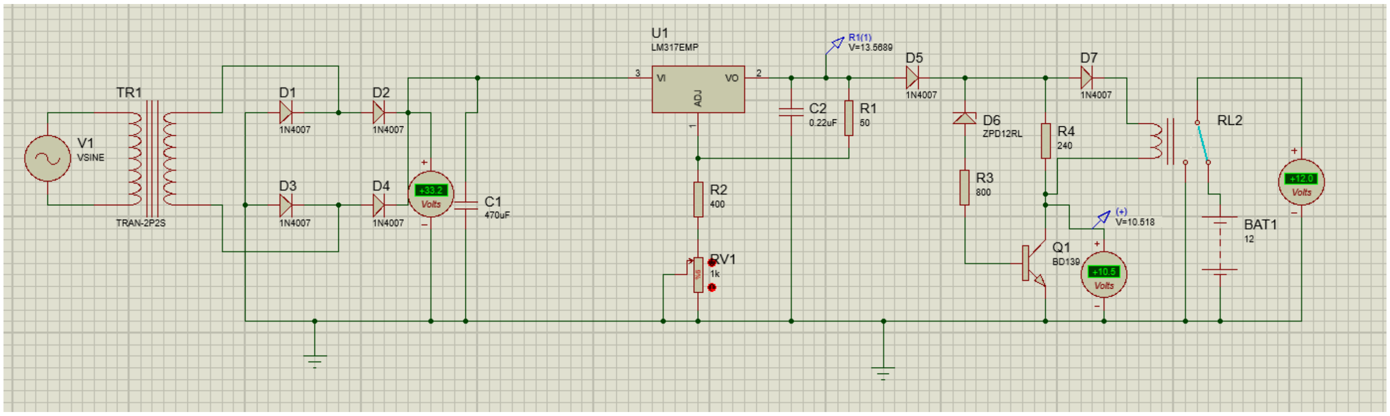
When battery is connected to the circuit



When the battery is disconnected



Proteus Model:



For practical design of a battery charger, we can achieve our desired output using the LM317 IC. We are using LM317 linear voltage regulator IC which is a three terminal adjustable voltage regulator. It consists of the input, output and the adjust pin. The adjust pin is used to adjust the output voltage. It can supply output adjustable voltage from 1.2V to 37V. This IC can supply up to 1.5A of current to the load. The dropout voltage of LM317 regulators is about 3V, that is the output should be at least 3V less than input voltage. In this figure, the voltage across the feedback resistor R1 is constant reference voltage Vref produced between output and adjust pins. Since the reference voltage across resistor R1 is constant, a constant current flow through the resistor R2, which gives output voltage of For the LM317 regulator the reference voltage is 1.25V. So the output voltage is given by the expression

$Vout = 1.25V \times (1 + R2/R1)$

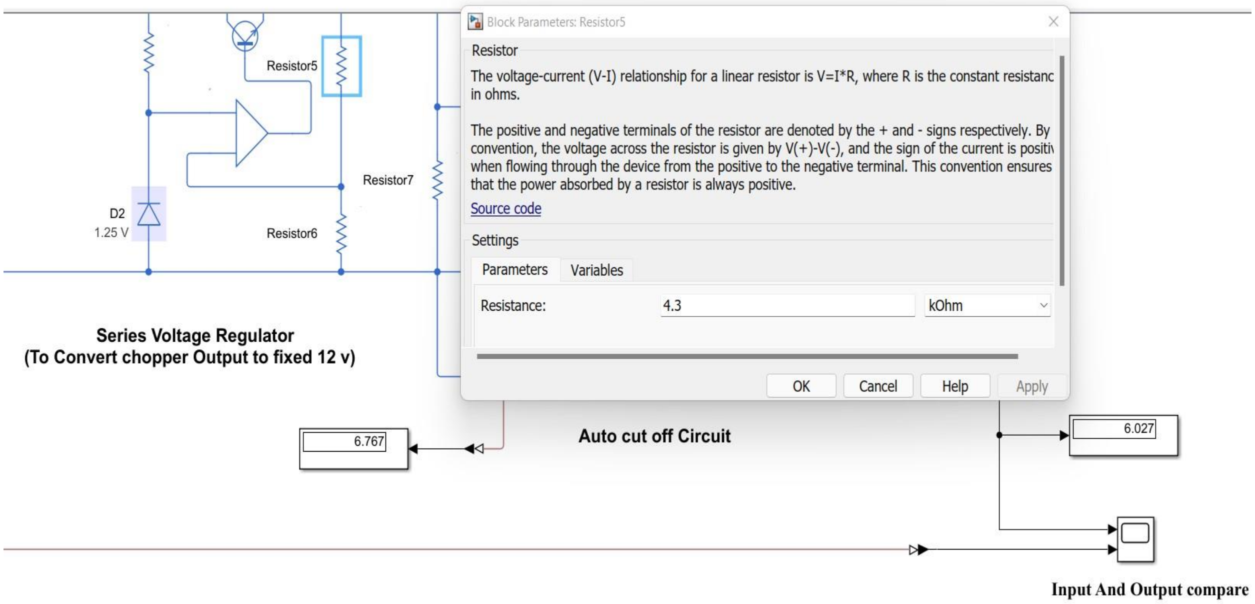
Adjustable output voltage is achieved by using a fixed resistor R1 and a potentiometer in place of resistor R2, by adjusting the resistance of the potentiometer, appropriate output voltage given by is achieved. The difference in input and output voltage is dissipated in form of heat, so for proper operation of LM317 the difference between input and output voltage should not be very high. To dissipate the heat generated during the operation, a proper heat sink must be attached to prevent thermal shutdown or permanent damage to the regulator.

$Vout = Vref \times (1 + R2/R1)$ The charging voltage and current is controlled by the Transistor Q1, resistor R1 and POT RV1. when the battery is first connected to the charging terminals, the current through R1 increases. This in turn increases the current and voltage from LM 317.When the battery is fully charged the charger reduces the charging current and the battery will be charged in the trickle charging mode. Again, the auto cutoff feature is mentioned before.

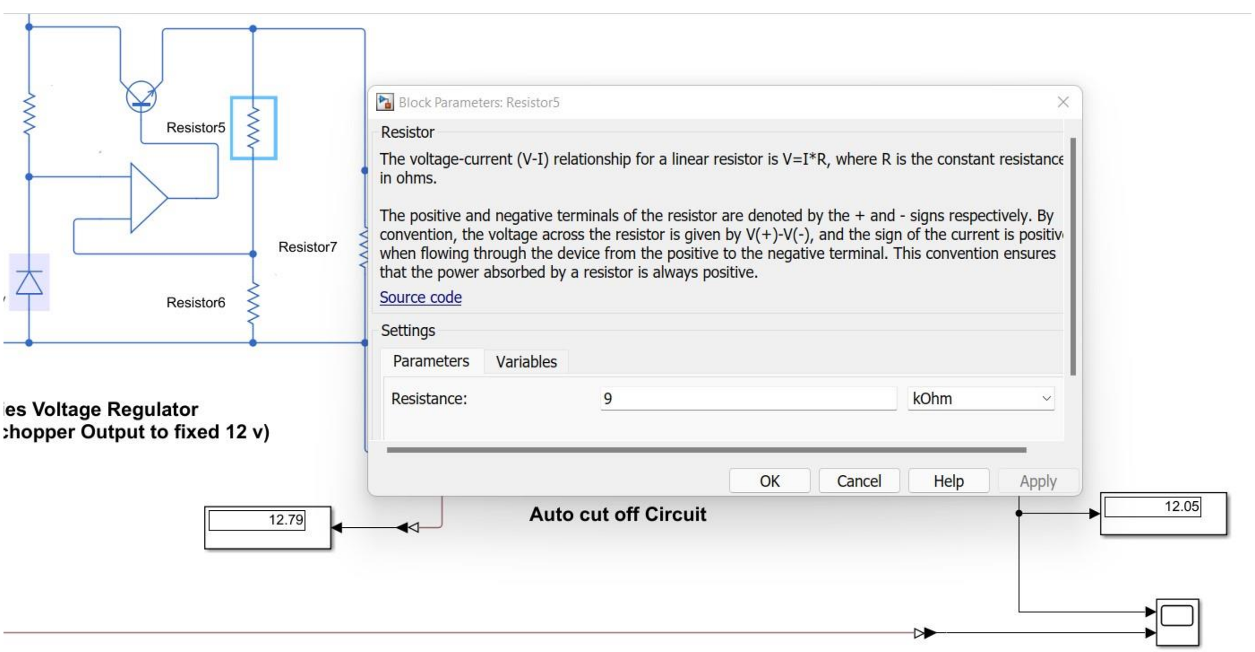
Result:

We can simply change the resistor5 according to the calculation and can get different output voltage to charge different types of battery such as 6V, 9V, 12V etc. Here, some examples are given below:

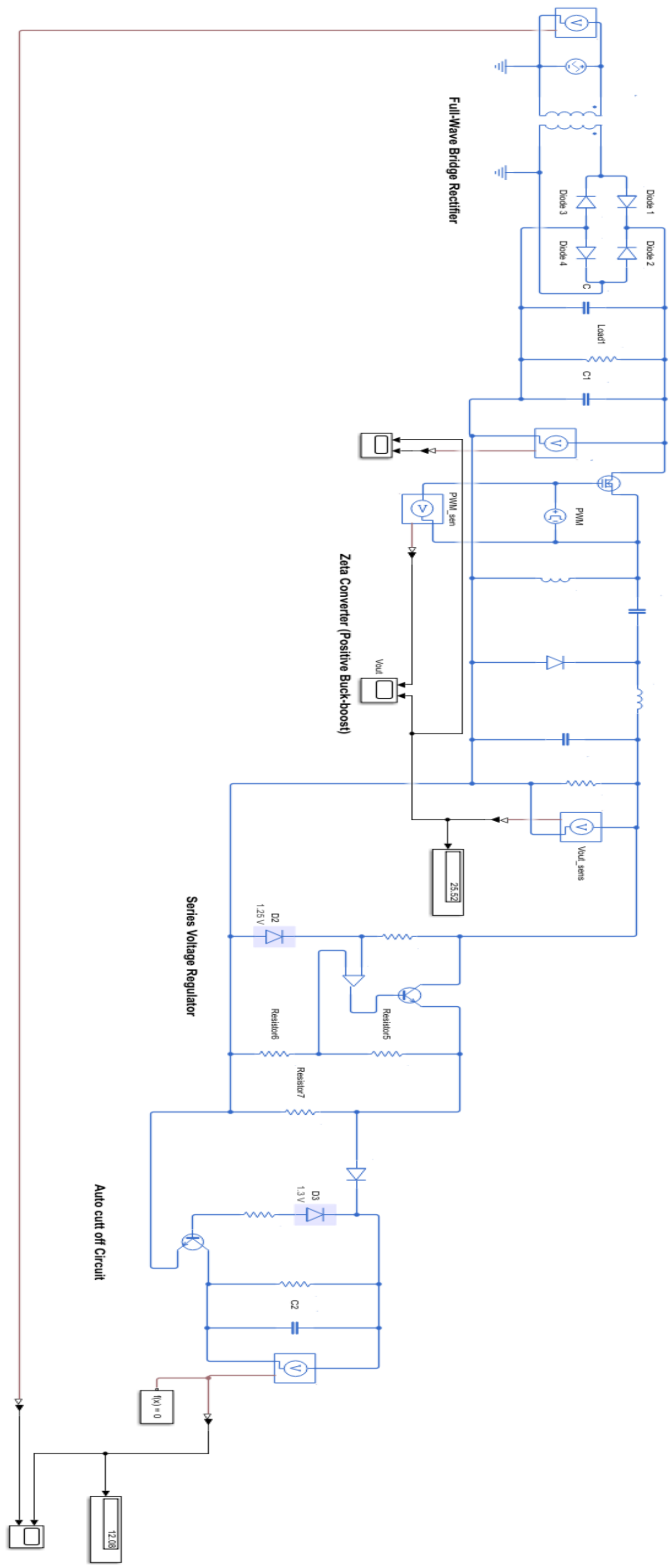
For 6V battery:



For 12V battery:

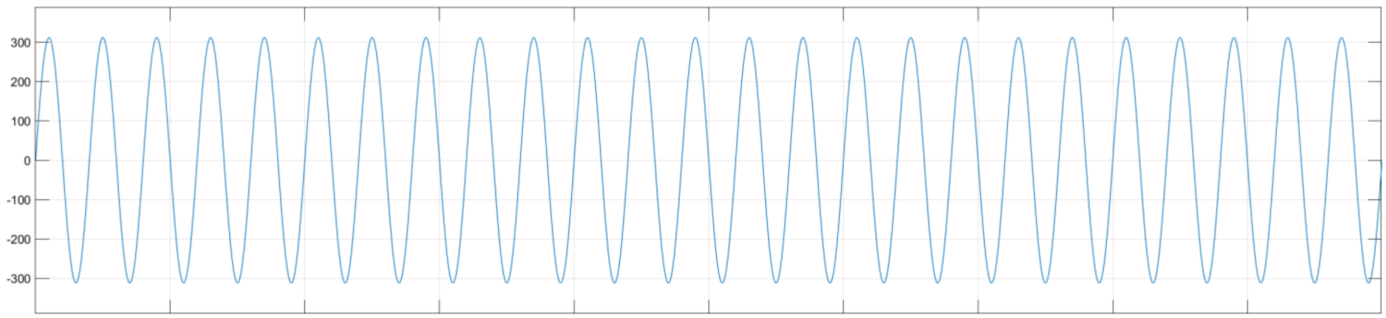


Overall Simulink Model:

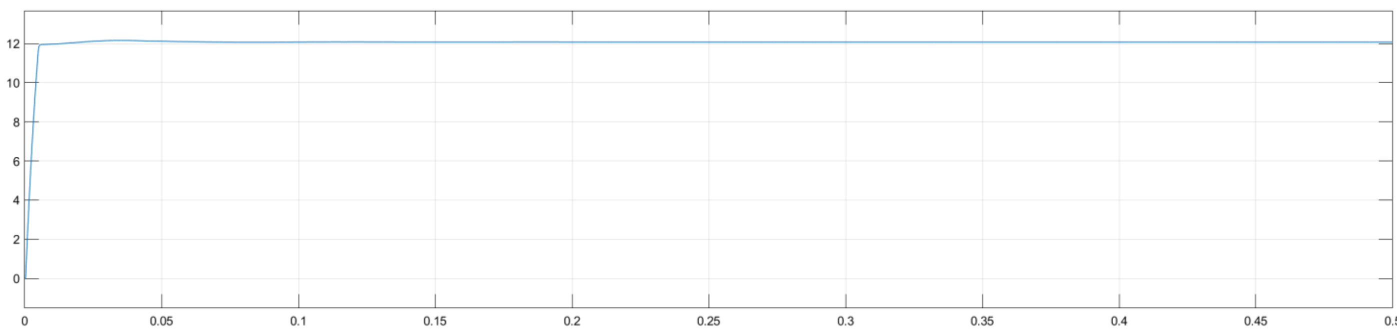


Input and Output Graph:

Input:



Output:



Conclusion:

The automatic battery charger was successfully modelled in the Simulink MATLAB. This battery charger works on the constant voltage method of battery charging. Initially, when a discharged battery is connected to the charger, the charger charges with the battery with constant voltage, until the battery is fully charged. When the battery is fully charged, the charging voltage ceases. Here, series voltage regulator is the brain of the circuit. Because it can regulate any voltage in our desired values. The charger will maintain the float voltage of the battery when it is connected to the charger to compensate for the self-discharge. Although this charger is for 12V batteries, we can charge other batteries also such as 6V, 9V etc. by changing the reference voltage. For the safety of the regulator IC, a heatsink to dissipate the excess heat because of voltage drop on the LM317 regulator is required. This model can be further enhanced by using the constant voltage constant current charging method as it is best suitable method for less charging time and less damage to battery. We are using linear voltage regulator to step-down the voltage which decreases the voltage by dissipating the difference between input and output voltage as heat, which is highly inefficient. We can use switching regulator instead of using linear so that very little energy is wasted. Because of pandemic situation the practical implementation was hard to get ready. But we tried our best to model it in Simulink model. In future we will try to implement it in hardware level which will help to get experience how errors can be solved in practical circuits.