Proteus Based Simulation Design of Portable Charge Controller

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Abstract – This paper describes a study and design of a simulation of portable charge controller based on Proteus software. Proteus is a virtual system modelling and circuit simulation software that is compatible for single or multi mode circuit design and micro-controller based design. The design of this charge controller enables the user to determine whether the battery is already fully charged or under-charged, in order to prevent the battery from being over charging that will shorten the life span of the battery. To ensure that such charge controller practical, it must be compatible with common household socket outlet.

Keywords – Charge controller, Proteus software, Battery-life

1. INTRODUCTION

Nowadays, people are more aware towards their electrical and electronic equipment safety. Many protection devices have been installed to prevent their electrical and electronic equipment from damage such as miniature circuit breaker (MCB), lightning arrestor and surge arrestor.

Charge controller is a device used to prevent battery from damage due to over-charging [1]. The charge controller controls and regulates the supply power and thus prevents the overcharging which can cause loss of electrolyte. This can be achieved by limiting the input current at a predefined charge regulation voltage [2].

Lead-acid battery is widely used in small portable equipment such as headlamp and also in stationary applications such as backup power supplies for telephone and computer centres, grid energy storage, and off-grid household electric power systems [3]. In this project, 12V lead acid battery becomes the subject to be charged.

Since the power supply of this charge controller comes from common household socket outlet that is 230VAC, full wave rectifier circuit is required to convert the alternating current (AC) to direct current (DC) and step down transformers is used to reduce voltage from 230V to 24V, that is the input for the charge controller [4]. To make the DC output from the rectifier is smooth with no ripple, voltage regulator and high energy capacitor are included in the circuit.

2. METHODOLOGY

This project is done by using Proteus software that it is developed by Labcenter Electronics Ltd. Proteus is a virtual system modelling and circuit simulation software that is compatible for single or multi mode circuit design and micro-controller based design. This software consists of several system components where each of the component plays the different role such as ISIS Schematic Capture is the tool for entering design. The electronic diagram or electronic schematic of the designed electronic circuit is created on this ISIS Schematic Capture tool . Another system component is Virtual System Modelling (VSM) that is the circuit simulation tool used to check the integrity of circuit designs and to predict circuit behaviour [5]. Both of this tools are used in this project.

Figure 2.1 shows the process flow for this project. The principle and working mechanism of the charge controller needs to be determined first. Besides, the power supply and capacity of battery need to be charged also need to be considered in order to determine the appropriate electronic devices that could be used in circuit.

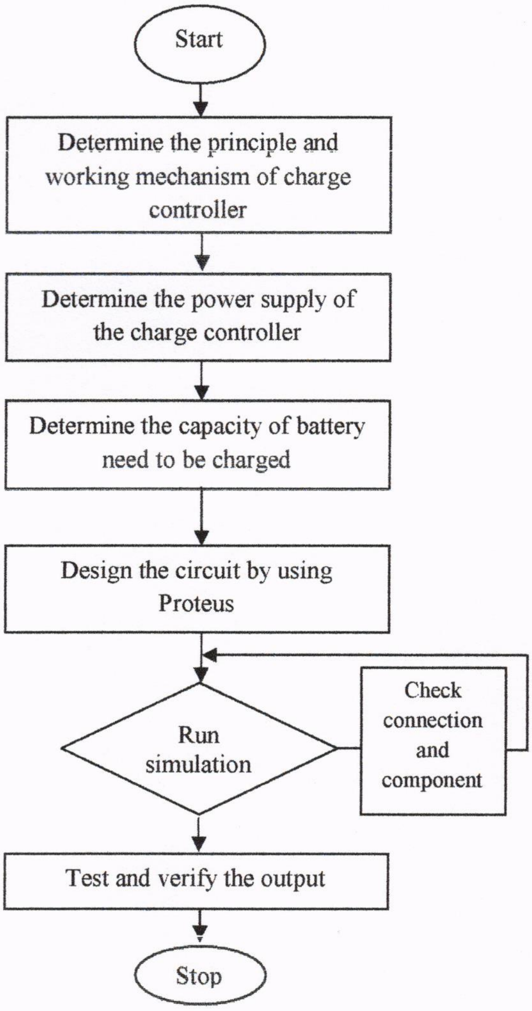

Figure 2.1: Flowchart process of the project

In this project, since the power supply of this charge controller comes from common household socket outlet that is 230VAC, full wave rectifier circuit is required to convert the alternating current (AC) to direct current (DC) and step down transformers is used to reduce voltage from 230V to 24V, that is the input for the charge controller [6]. This household outlet is selected as power supply for the charge controller is because to make this charge controller portable and practical to be used anywhere. The flow of the circuit is shown on Figure 2.2.

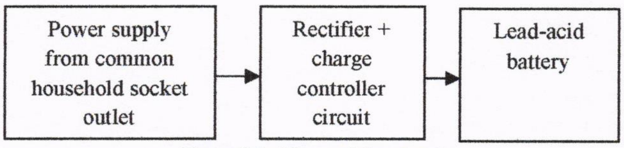

Figure2.2: Flow of the circuit

The design of this project is separated into two parts:

- 2.1 Rectifier circuit
  - 2.1.1 Improve rectification wave
- 2.2 Charge controller circuit

2.1 Rectifier Circuit

A rectifier is used to convert the alternating current (AC) to direct current (DC). This process is known as rectification. Before rectification process took place, supply voltage need to be lowered to make its value suitable for the components used in rectifier and for the charge controller as well. Step-down transformer is used to reduce the 230V supply voltage from household socket outlet to 24V. Figure 2.3 shows the circuit of rectifier.

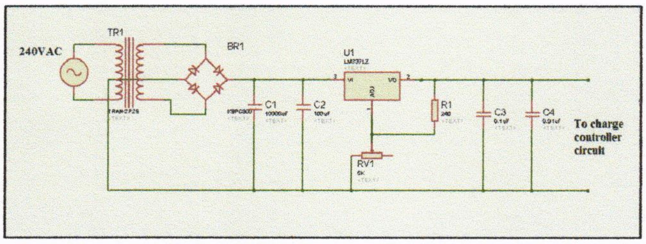

Figure 2.3: Figure of rectifier circuit

2.1.1 Improve Rectification Wave

Bridge rectifier, as shown in Figure 2.4, is used to produce full wave positive output, whereby the whole input waveform had been rectified to one constant positive wave as its output. The waveform is shown in Figure 2.5.

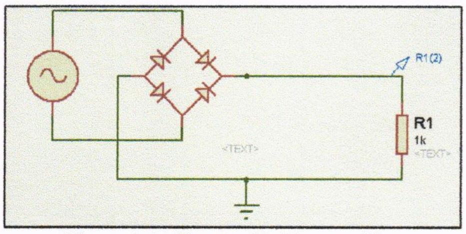

Figure 2.4: Circuit of bridge rectifier

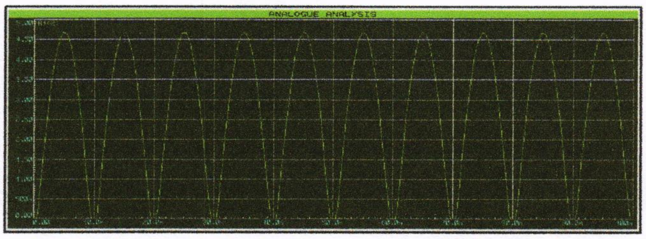

Figure 2.5: Graph of voltage across R1 for bridge rectifier circuit

To make the output of the rectifier smoother, large value of the electrolytic capacitor is connected across the rectified wave to act as a reservoir, supplying current to the output when the varying DC voltage from the rectifier is falling [7]. Circuit of bridge rectifier with electrolytic capacitor and output of this circuit are shown in Figure 2.6 and Figure 2.7 below.

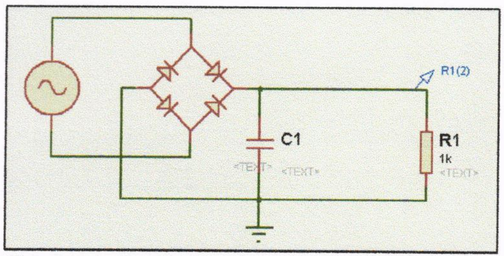

Figure 2.6: Circuit of bridge rectifier with electrolytic capacitor connected across DC supply

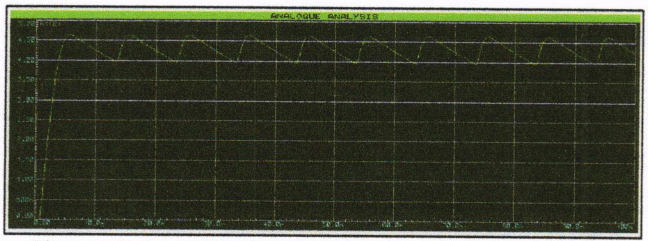

Figure 2.7: Graph of voltage across R1 for bridge rectifier with electrolytic capacitor connected across DC supply circuit

Refer to the Figure 2.7, the waveform of the voltage across the resistor R1 is still not completely smooth. To make the voltage smoother with no ripple, voltage regulator is installed on the circuit. This is because of the ability of voltage regulator to maintain the voltage of a power source within acceptable limits [8]. The connection of the voltage regulator on the circuit is shown in Figure 2.8.

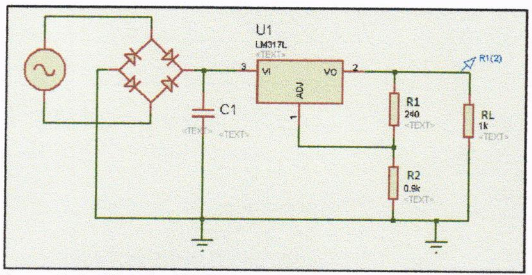

Figure 2.8: Circuit of bridge rectifier with voltage regulator

The improved waveform of the output after the installation of the voltage regulator is shown in Figure 2.9.

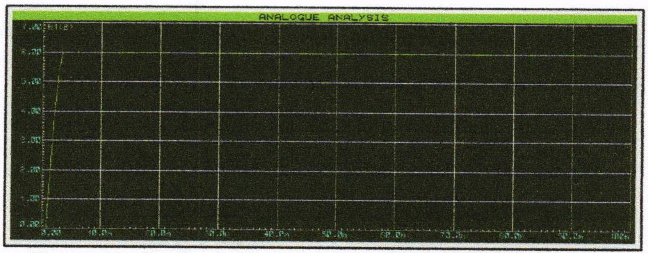

Figure 2.9: Graph of voltage across R1 for bridge rectifier with voltage regulator circuit

The voltage regulator is needed to keep voltages within the prescribed range [9]. The connection of the voltage regulator is shown in Figure 2.10.

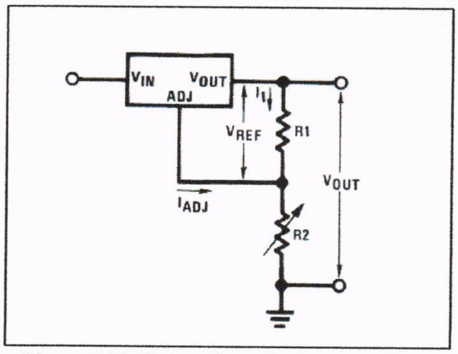

Figure 2.10: Connection of voltage regulator

In order to get the desired output voltage, resistor have to be added which their values is based on this formula:

$$V_{OUT} = V_{REF}(1 + R2/R1) + I_{ADJ}\,R2$$

Based on the datasheet of LM317 3-terminal positive adjustable regulator, this voltage regulator develops 1.25V of V_{REF} and the value of I_{ADJ} is below 100μA, thus I_{ADJ} is assumed as 70μA and R_1 is fixed as 240Ω [10]. The output voltage (V_{OUT}) is set to 6V. All those values are listed below:

V_{REF} = 1.25V
I_{ADJ} = 70μA (assumed)
R_1 = 240Ω (fixed)
V_{OUT} = 6V (set)

In order to find the value of R2, the formula stated above is applied,

$$V_{OUT} = V_{REF}(1 + R2/R1) + I_{ADJ}\,R2$$

$$6 = 1.25(1 + R2/240) + 70\mu\,(R2)$$

$$R2 = 900\Omega$$

2.2 Charge Controller Circuit

This charge controller circuit consists of voltage regulator, silicon NPN low power bipolar transistor, operational amplifier and other common electronic components. This circuit is designed to charge 12V of lead-acid battery. The schematic diagram of the charge controller is shown in Figure 2.11 below.

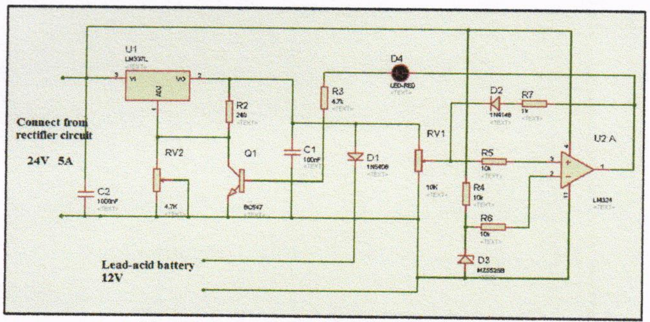

Figure 2.11: circuit of charge controller

The system of this charge controller is shown as Figure 2.12:

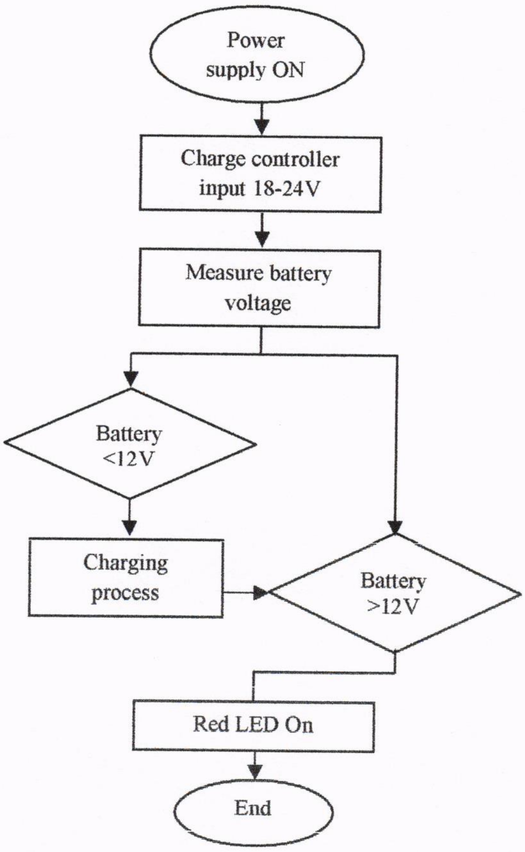

Figure 2.12: Block diagram of charge controller system

The flow starts with power generated from AC power outlet and need to be step down and rectified first before it sent to charge controller. Lead-acid battery with voltage rating of 12V must be connected in parallel with charge controller and then recent voltage value of battery is measured. The operational amplitude (op-amp) read the value of battery voltage and determined the further process. There are two possible conditions that might be occurred:

a) Battery voltage value is lower than 12V, charging the battery. When battery voltage value is greater than 12V, red LED on

b) Battery voltage value is more than 12V, red LED on

The role of IC LM324 operational amplifier in this circuit is acting as a comparator [9]. The inverting input of the IC 324 is clamped at a fixed reference voltage of 6 via a 10kΩ resistor. With reference to this voltage, the tripping point is set via the 10kΩ preset connected across the non inverting input of the IC. The output supply from the IC LM 338 goes to the battery positive for charging it. This voltage also acts as the sensor as well as the operating voltage for the IC 324. The connection of IC 324 operational amplifier in this charge controller circuit is shown in Figure 2.13 below.

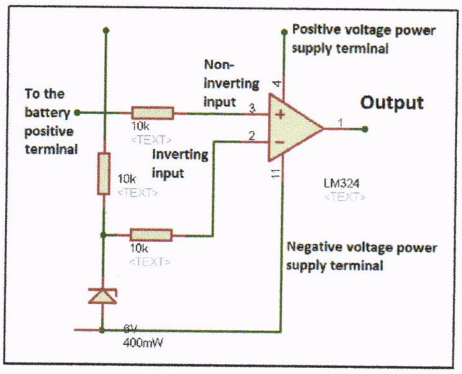

Figure 2.13: Connection of IC 324 operational amplifier

As the setting of the 10kΩ preset when the battery voltage during the charging process reaches or crosses the threshold, the output of the IC 324 goes high and it make voltage passes through the LED and reaches the base of the transistor which in turn conducts and switches off the IC LM 338. The illuminated LED at the output indicates the fully charged condition of the battery.

3 RESULT AND DISCUSSION

The objective of this project is to observe whether the charge controller can determine whether the lead-acid battery is fully charged or not. The other objective is to ensure the output of charge controller is always maintained between 12V to 13.5V.

The battery is considered as fully charged when the voltage measured across the battery is more than 12V. When this occurs, IC LM324 operational amplifier becomes saturated and makes voltage pass through LED [11]-[12]. To make sure this circuit really works as desired, the value of output current of the IC LM324 operational amplifier is measured. The sufficient current that come out from this operational amplifier will light up the red led, that indicates the battery is fully charged. The value of current flow through output of LM324 operational amplifier in different value of battery voltage is shown in Figure 3.1

Battery Voltage (V)	Current at LM324 output (mA)	LED emitted
1	3.0690×10^{-6}	No
2	3.0667×10^{-6}	No
3	3.0658×10^{-6}	No
4	3.0650×10^{-6}	No
5	3.0642×10^{-6}	No
6	3.0634×10^{-6}	No
7	3.0624×10^{-6}	No
8	3.0619×10^{-6}	No
9	3.0611×10^{-6}	No
10	3.0604×10^{-6}	No
11	3.0597×10^{-6}	No
12	6.97	Yes
13	6.98	Yes

Figure 3.1: Table of current flow through output of LM324 operational amplifier in different value of battery voltage

Figure 3.2 and Figure 3.3 show the diagram of charge controller when the battery is at 9V (under-charged) and 12V (fully-charged). When the battery is under-charged condition, red LED is turn off but while the battery is fully-charged, red LED is turned on.

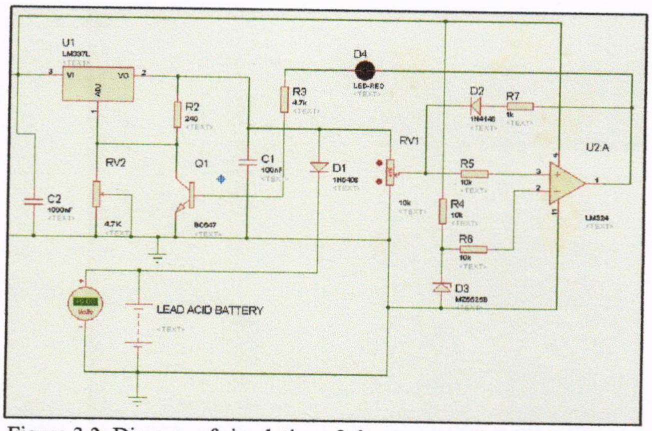

Figure 3.2: Diagram of simulation of charge controller when voltage of the lead-acid battery is 9V (not fully charged)

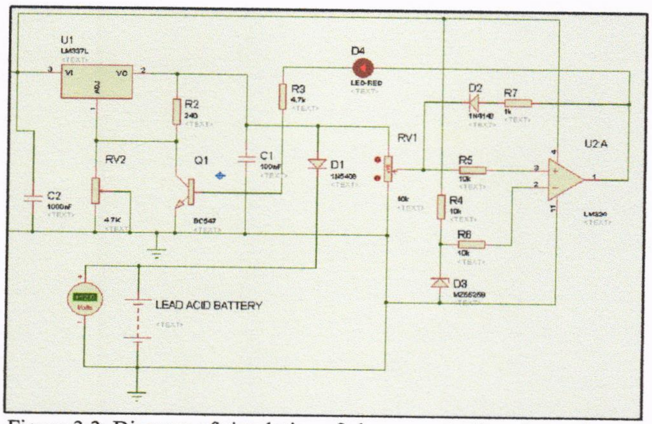

Figure 3.3: Diagram of simulation of charge controller when voltage of the lead-acid battery is 12V (fully charged)

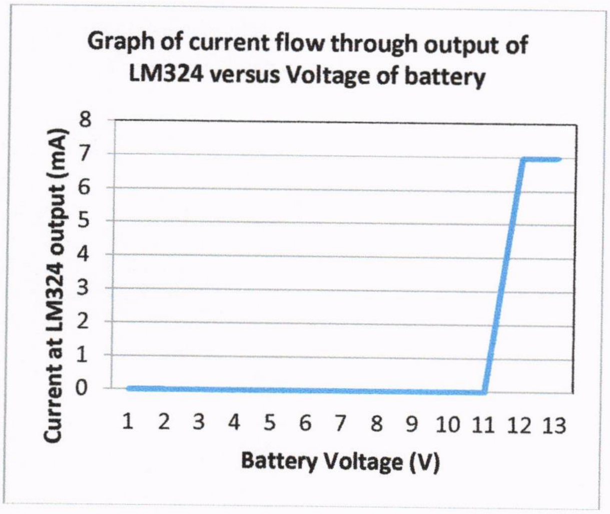

Figure 3.4: Graph of current flow through output of LM324 operational amplifier versus voltage of battery

Figure 3.4 shows the graph of current flow through output of LM324 operational amplifier versus the voltage of lead-acid battery. Based on the graph, the output of the operational amplifier is increase rapidly when the voltage of the battery reaches 12V, that is the maximum capacity of the battery.

In order to measure the stability of the output of the charge controller, DC Voltmeter is connected in parallel with it. The simulation result of this process is shown in Figure 3.5 below.

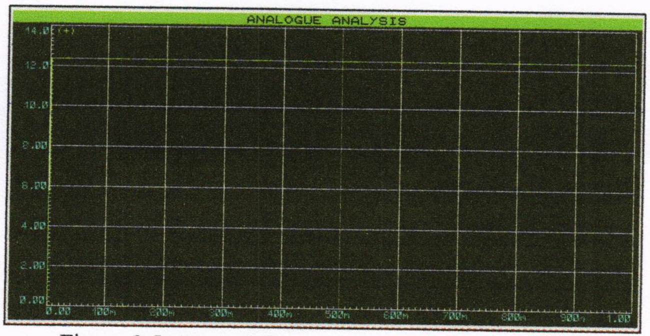

Figure 3.5: Graph of output of charge controller voltage

Based on the graph above, the output voltage of the charge controller is maintained on 12.5V. The objective to maintain the voltage stability is achieved.

4 CONCLUSION

This project is successfully done with all the objectives achieved. The charge controller can determine whether the battery is fully charged or not by indicating it with the luminance of red LED that present in this circuit. Besides, the output of the charge controller also maintained between 12.5V to 13.5V. Recommendation to improve this charge controller is by install the system that capable to determine the condition where the capacity of the battery becomes too low due to discharging process [13]. Another recommendation is Proteus software should include rechargeable battery with various capacity and types as one of their packages of the components to enable the analysis of charging and discharging of battery can be done.

5 ACKNOWLEDGEMENT

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