Simulation and Implementation of An Automatic Battery Charger using Silicon Control Rectifier (SCR)

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ABSTRACT-Batteries provide the closekeyforstoringelectricity by putting away electrical energy in form of chemical energy. This paper deals with a partial design, simulation and implementation of an automatic battery chargerusing SCRs. Depending on the charging process requirements some elements of the electronic circuit will be designed. The designed circuit will be simulated using MULTISIM, thenimplementedusing an experimental setup builds in the laboratoryfor verification. The charging progression and the fully charging process realize completely using two SCRs, main and auxiliary. Simulation results and experimental results will be represented and compared.

Keywords: *Automatic battery charger, Simulation, Implementation, Controlled-rectifier, SCR*

INTRODUCTION

Battery chargeris a device used to store energy into a secondary cell or rechargeable battery by forcing an electric current through it.The charging protocol depends on the size and type of the battery being charged. Some battery types have high tolerance for overcharging and can be recharged by connection to a constant voltage source or a constant current source, depending on battery type. Simple chargers of this type must be manually disconnected at the end of the charge cycle, and some battery types absolutely require, or may use a timer, to cut off charging current at some fixed time, approximately when charging is completed. Other battery types cannot withstand over-charging, being damaged, over heating or even exploding. The charger may have temperature or voltage sensing circuits and a microprocessor controller to safely adjust the charging current and voltage, determine the state of charge, and cut off at the end of charge. [1][2]

Battery charging is a complex electrochemical process, in which the discharged electric energymust be refilled from the electric network. The quality of the charging process is critical tothe condition and long life of batteries. A battery charger is an electrical/electronic device that converts the incoming AC line voltageinto a regulated DC voltage to meet the changingneeds of the respective battery.Although today's industrial battery charging market is dominated by ferroresonant and SCR type chargers, which have been in existence for many years, new high frequency battery charging technologies is making headways into the industrial battery charger markets over ferroresonant and SCR types.[3]

After fully charging the battery of the suggested charger by means of a main SCR, charger changes automatically to discharge sequence through another auxiliary SCR and vise-versa.The output DC voltage can be regulated depending on the load specifications.

METHODOLOGY

SYSTEM DESCRIPTION

- **Block Diagram of battery charger using SCRs**

In this work, the illustrative block diagram of the battery charger using SCRs is shown in figure 1. Clearly, the diagram enclosesfundamentally an AC voltage source, single-phase transformer, bridge rectifier, voltage regulator, SCR and chargeable battery. In the following sections, the operation of the suggested charger using SCR will be described.[4]

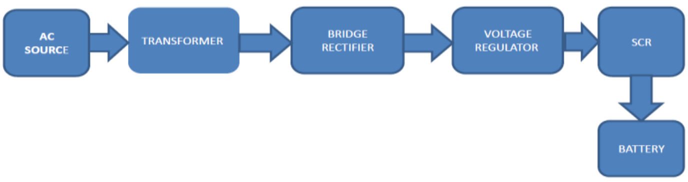

Figure 1: Block diagram of the battery charger using SCRs

- **Battery charger circuit with two SCRs**

The electronic circuit of the automatic battery charger circuit using SCRs is partially designed, simulated and implemented. The circuit can be used to charge batteries with different level of voltages, for instant, 6V, 9V or 12V in choosing appropriate components. As well as, it can be used to power-driven low power loads such as, cell phone, camera, etc. The circuit operation can be illustrated as follows:

- **Simulation of the charger**

The simulated circuit as shown in figure 2, contains in addition to the main and auxiliary SCR's, two LED's, and many other electronics and power components such, single-phase transformer, single-phase full-wave diode rectifier, voltage regulator, rechargeable battery, diodes , capacitors, and resistors. Each of the pointed out components has its role in the operation of the circuit as it will be illustrated. The main SCR (D_1) uses in the charging process and the second auxiliary SCR (D_2) uses to indicate the ending of the charging process and the fully charging of the battery. The LED in the two cases uses to indicate the operation period of the two SCR's respectively.[5][6]

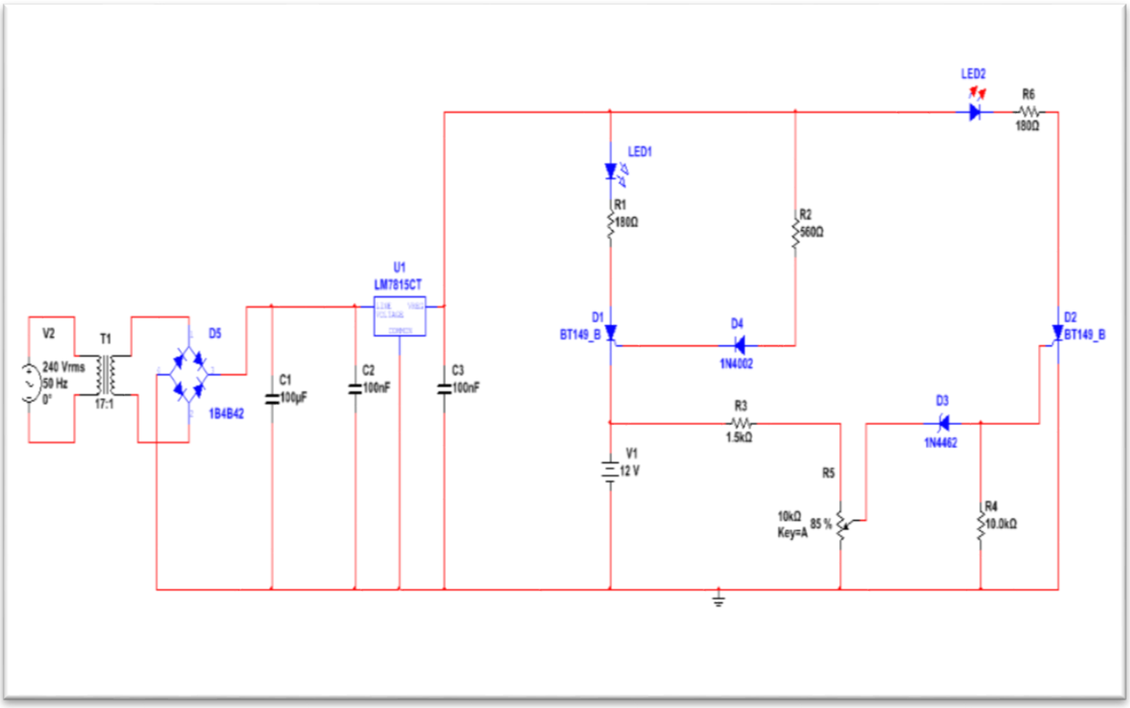

Figure 2: Diagram of the simulated circuit

The battery charger elements are listed in Table 1.

Table 1: Elements used in Battery charger circuit with two SCRs:

NO	Component's Name	Component's Type	Value or code
1	Voltage source	AC voltage source	240V(rams), 50HZ
2	Transformer	Step down transformer	240/14 V
3	Battery charger	Lead acid battery charger	12V
4	Diode 1, D_1	Silicon controlled rectifier	BT149-B
5	Diode 2, D_2	Silicon controlled rectifier	BT149-B
6	Diode3, D_3	Zener diode	1N4462
7	Diode4, D_4	Single Standard Switching Diode	1N4002
8	Bridge rectifier, D_5	Full wave rectifier	1B4B42
9	Voltage regulator	IC	LM7815CT
10	Capacitor ,C_1	Aluminum electrolytic capacitor	100 uF
11	Capacitor, C_2	Ceramic	100 nF
12	Capacitor , C_3	Ceramic	100 nF
13	Resistor 1, R_1	Ceramic	1.2 kΩ
14	Resistor 2, R_2	Ceramic	560Ω
15	Resistor 3, R_3	Ceramic	1.5 KΩ
16	Resistor 4, R_4	Ceramic	10 kΩ
17	Resistor 5, R_5	Potentiometer	10 kΩ
18	Resistor 6, R_6	Ceramic	2.2KΩ
19	LED_1	Green LED	-
20	LED_2	Red LED	-

- **Operation of the charger**

The circuit operation starts in supplying 240 V from AC voltage source to the circuit passing through a single-phase transformer 240/14 V and a single-phase full-wave diode rectifier to rectify the AC-to-DC voltage that is needed for battery charging. By the way, the capacitors C_1-C_3 use for DC voltage smoothing and the voltage regulator uses for controlling the output DC voltage at a value of 15 V as show in figure 3 that is appropriate for charging process.Initially, the main SCR_1, (D_1) starts conducting at the instant of receiving the required gating signal through R_2 and D_4. In the conducting period, green LED_1 which is connected in series turns ON, to ensure the starting period of battery charging.During this period the output of the voltage regulator, 15V DC will apply across the serial combination of (D_1, resistor R_1 =180Ω, and the battery to be charged). The charging current will flow through the battery and the charging process will start till the fully charging of the battery approximately equal to 12 V. At this instant, the charging current will be less than the holding current, I_H which is the minimumneeded current to keep the SCR in its On-state and the conduction will be ended and the SCR_1state will be changed to Off-state.When the main SCR_1 stops conducting and the battery is fully charged, the auxiliary SCR_2 conducting period is started at the instant of the battery 12 V applied across the combination of $R_3$and R_5 and a current will flow through this combination and a part of the voltage across the variable resistor of 10 kΩ, reaches to a value of 7.5 V that is necessary for letting the Zener diode (D_3) to be in On-state and a triggering gating current by applied to SCR_2 (D_2) changing its state from Off to On-state, and the red LED_2 which is connected in series with SCR_2 (D_2) will be in the On-state indicating the ending of the charging period.

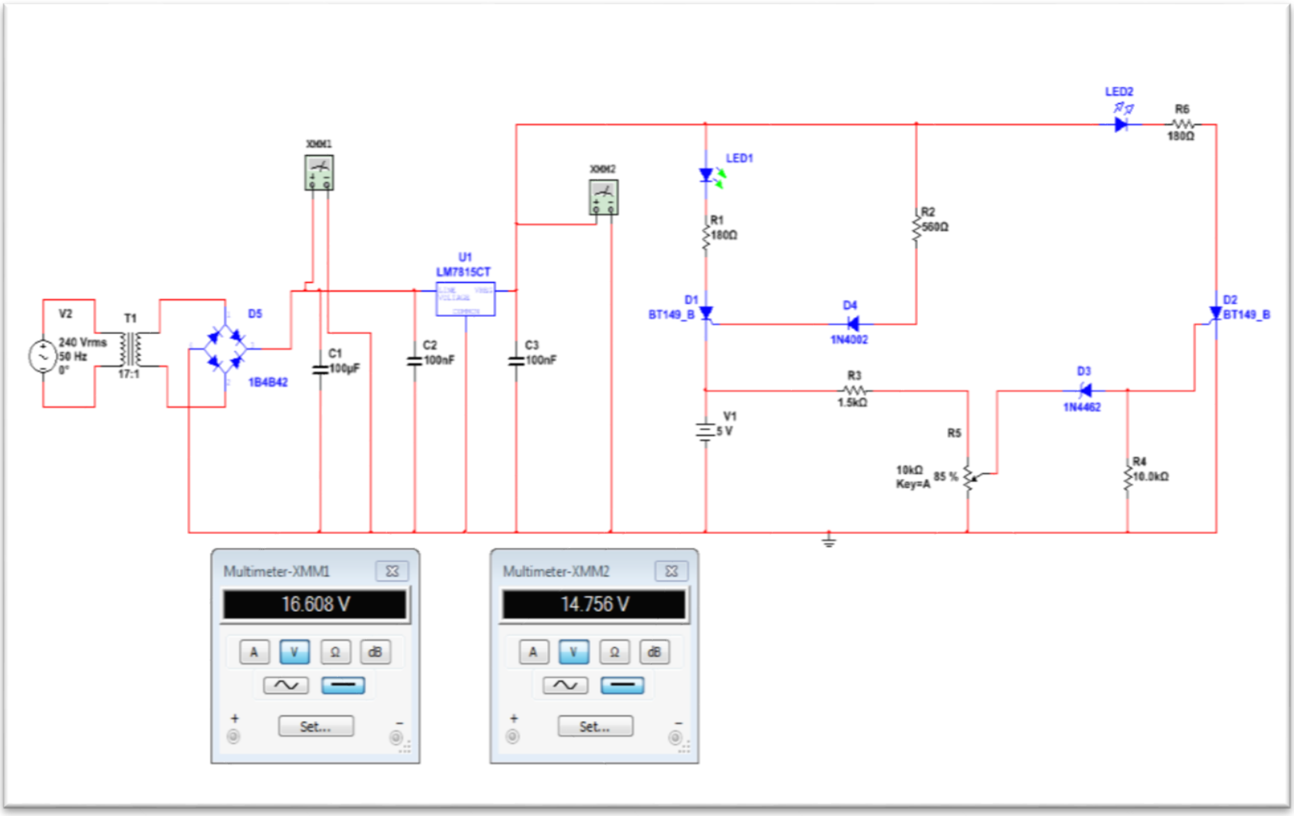

Figure 3: Input and output voltage of the voltage regulator

- **Output of the charger**

Simulation tests were performed using MULTISIM. From the reading of the meters in figure 4, it is clear that during charging process, with abattery voltage of value 5 V, the current flow through the Thyristor SCR_1 has a value of 38.926 mA and through the second Thyristor SCR_2 is 6.523 uA (very small), which mean that the SCR_1 is in On-state and the SCR_2 is in Off-state. While at the fully charging process, and at a value of battery voltage equal to 12 V, it is clear from figure 5 that the current value through the Thyristor SCR_1 is 1.248 mA (smaller than that in the charging process) and through the second Thyristor SCR_2 is 66.955 mA (much larger than that in the charging process). Which means that the SCR_1 is in off- state while the SCR_2 is in On- state.

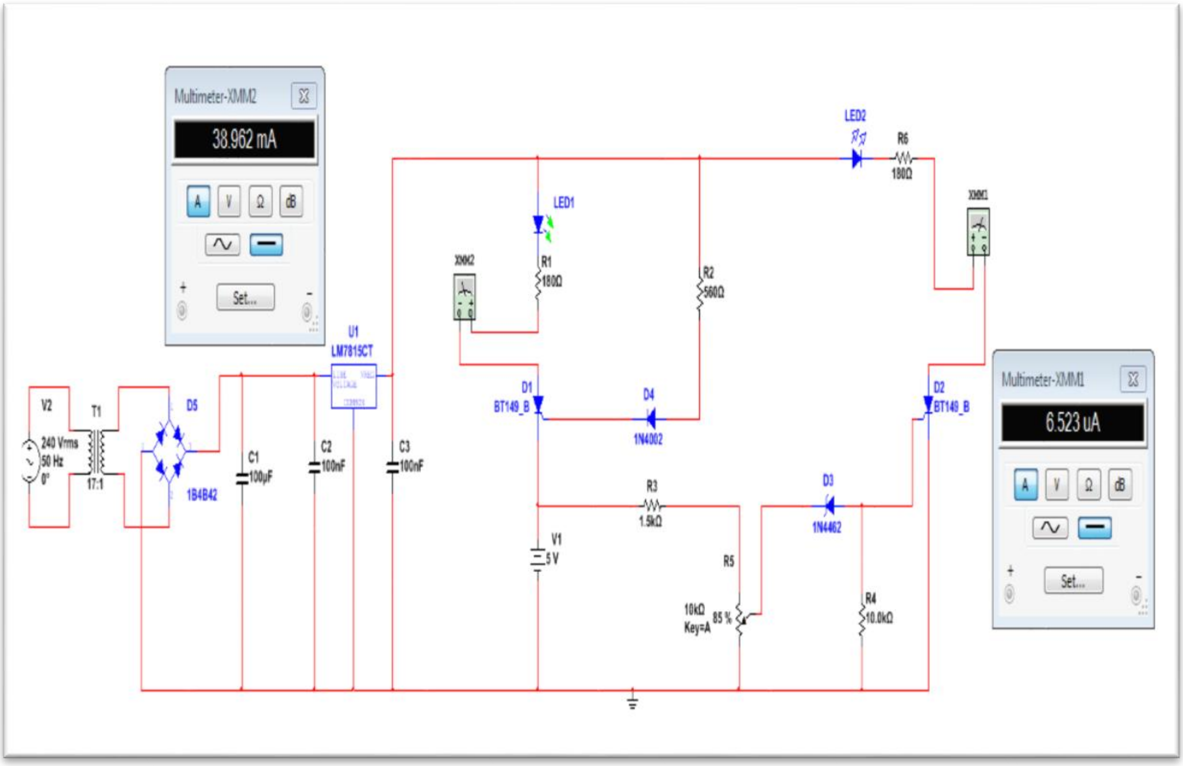

Figure 4: The current values at charging process

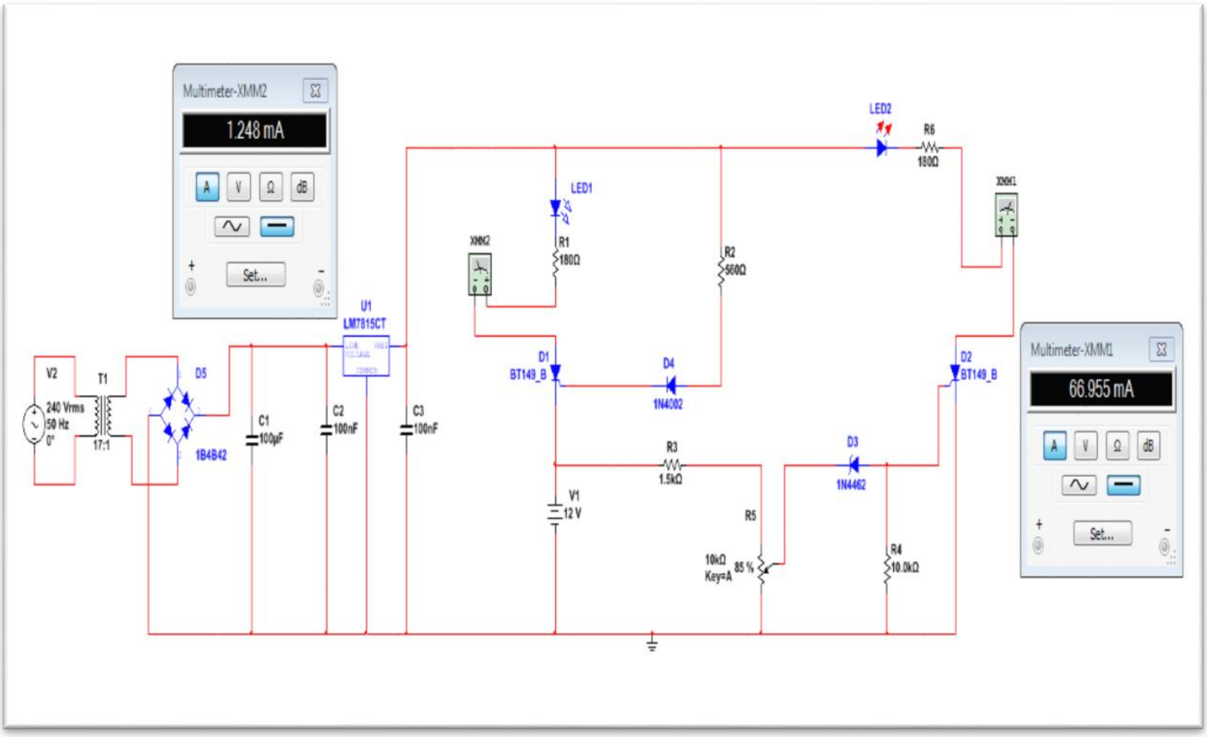

Figure 5: The current values at fully charging process

From figure 6,the potentiometer voltageat charging process is 3.695 V which is not enough for turning on the Zener diode and the SCR_2 is not triggering so it stays in Off- state and red LED is Off. While at the fully charging period, the voltage at the potentiometer is reached to 8.064 V which is enough for letting the Zener diode to be in On-state and letting current flows to the SCR_2 and turn it On and at the same time, turning the red LED on as shown in figure 7.

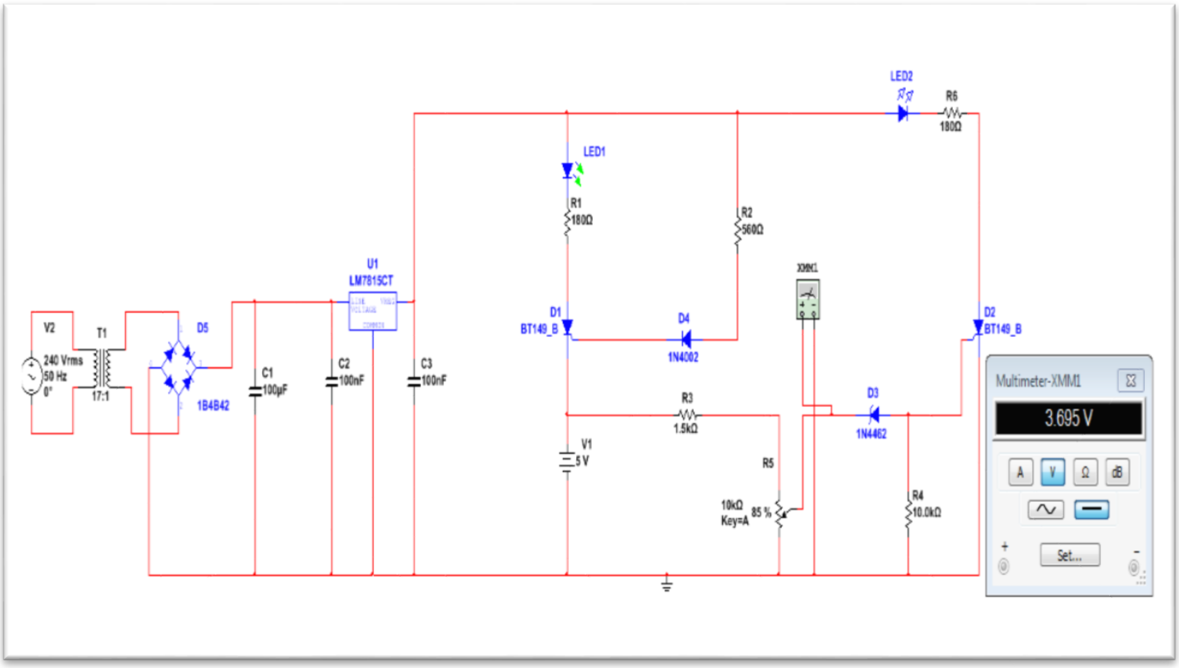

Figure 6: The potentiometer voltage at charging process

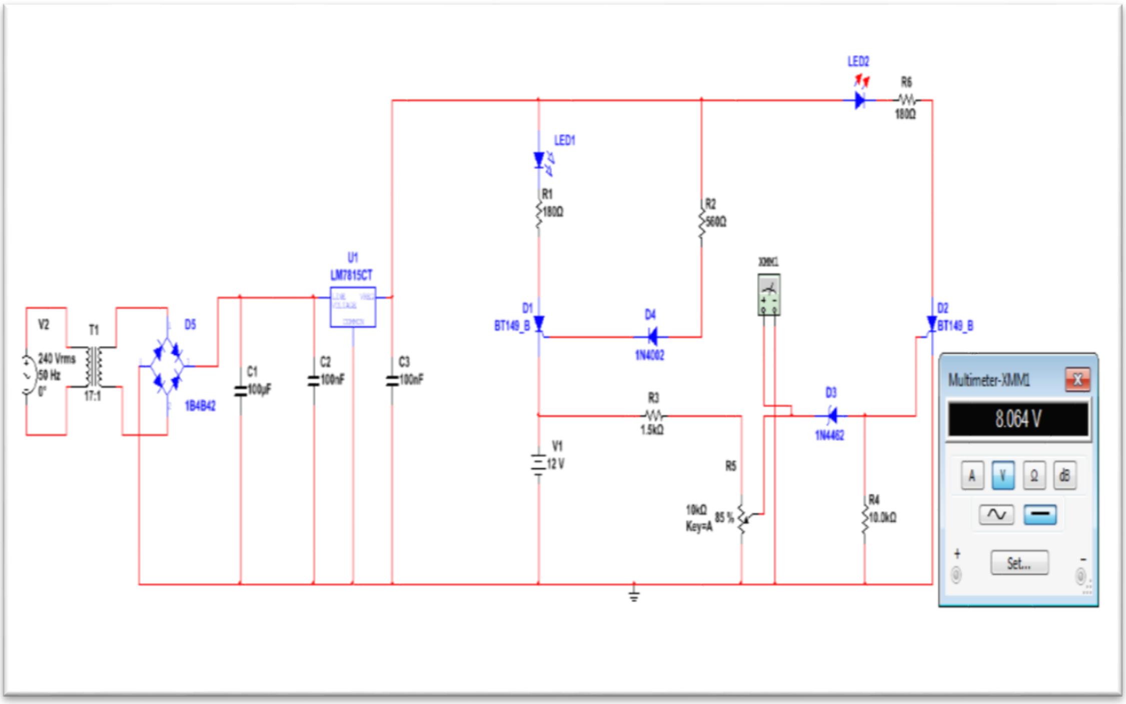

Figure 7: The potentiometer voltage at fully charge process

EXPERIMENTAL SETUP, RESULTS AND DISCUSSION

The electronic circuit is built in the laboratory as shown in figure 8.

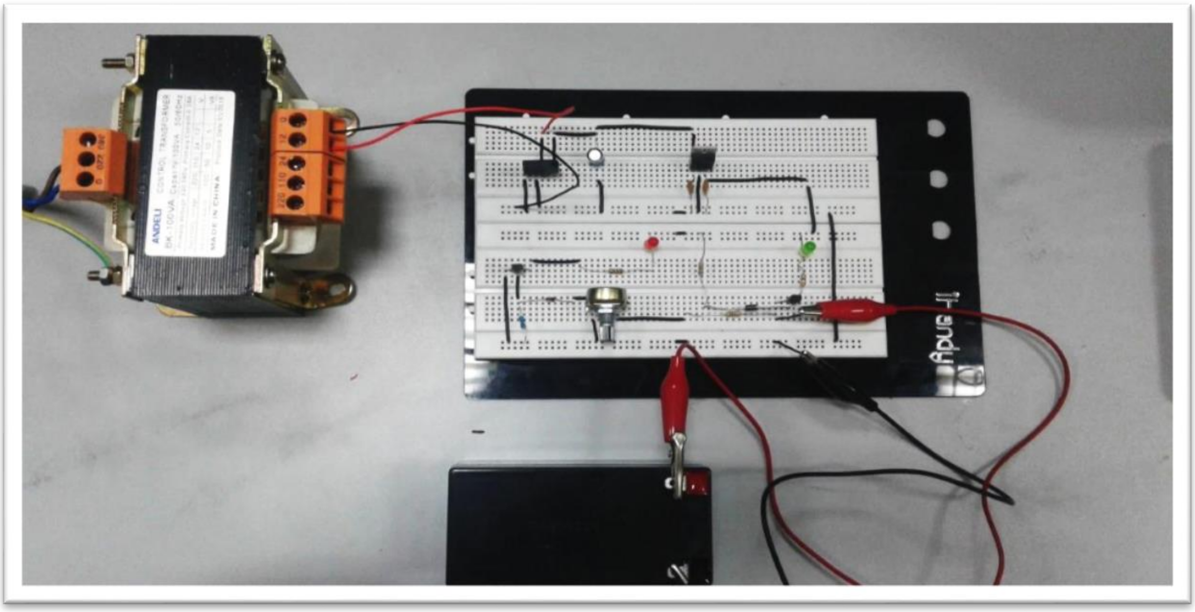

Figure 8: Experimental set up of the project

When the circuit connects to the AC power supply, as shown in figure 9 the necessary getting current for SCR_1 triggering it and its state changes to ON indicating the starting of the charging period. At the same time, the green LED becomes ON indicating the starting of charging period and the charging current flows to the battery for charging.

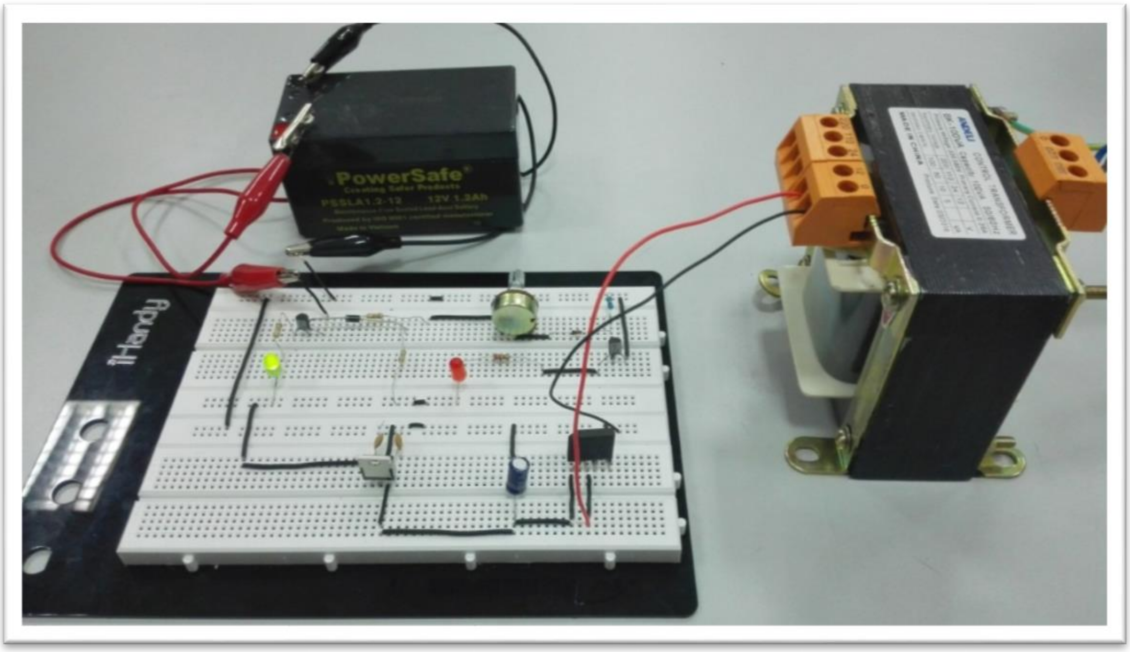

Figure 9: The charging process

After 7 to 8 hours, the SCR_1 automatically stops conducting and becomes in Off-state. While the SCR_2 starts conducting after triggering by the Zener diode by which the charging process is stopped and the red LED is turning ON as shown in figure 10.

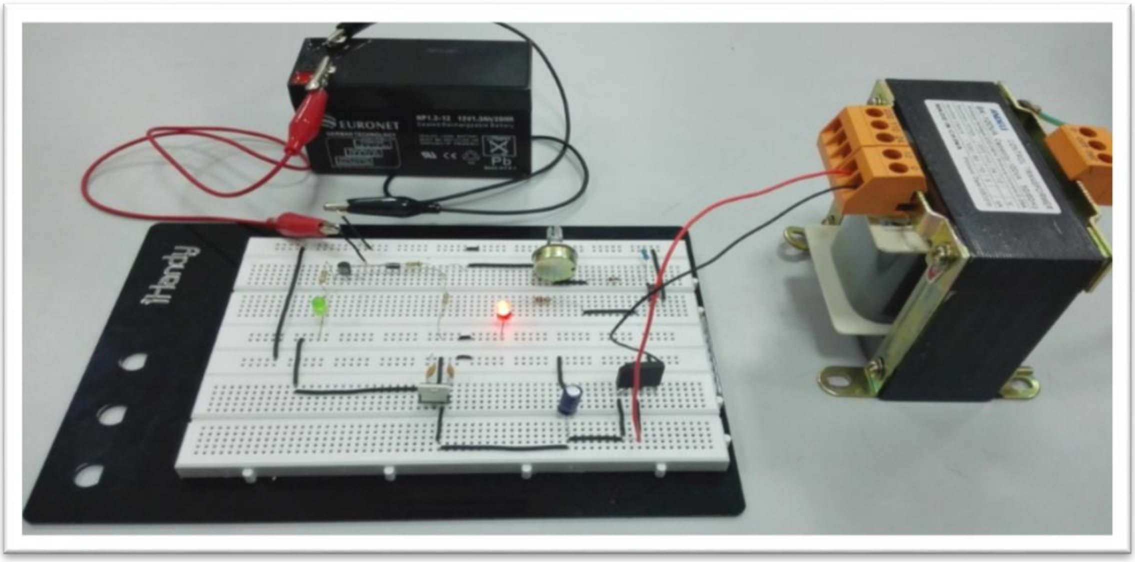

Figure 10: Fully charging process

CONCLUSSION

The paper presentedan automatic battery charger using two SCRs, main for charging course and auxiliary for discharge course. Depending on the charging process requirement some electronic elements of the charger have been designed. The designed circuit has been simulated using MULTISIM, constructed in the laboratory and then tested for verification. The simulated and experimental results were compared and they found to be in match and satisfy the main goal of the suggested charger

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