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Design and Implementation of a 24V/40apolarity-Sensitive Automatic Battery Charger

[1]Makinde Kayode, [2]Amao Enock and [3]Lawal Olawale Kazeem

[1,3]Department of Electrical Engineering, Federal Polytechnic Bida, Niger State, Nigeria
[2]Department of Physics, Federal Polytechnic Bida, Niger State, Nigeria

Abstract: *24V/40A polarity sensitive automatic battery charger is a device that was designed to charge both home and industrial types of batteries. This design aimed to construct a battery charger that can detect a change in battery polarity terminals and also make available a charging unit capable of charging batteries at a faster rate and cutting off supply when the battery is fully charged. The automation was made possible because of the introduction of the microcontroller embedded in the circuit to activate the switching process. This technique would help to save the device from being damaged as a result of a mistake in reversing the battery charger terminals (the positive and negative terminals) and at the same time prolong the lifespan of the batteries, as it will not be overcharged. A 200AH block battery was used to carry out the test; the charger was connected for 6 hours with a constant supply of electricity. At about 5hours 20 minutes the LED screen of the charger displayed 28V and it cuts off charging. This showed that the battery was fully charged, this shows that the aim of the design was achieved*

Keywords: Charger, Polarity, Automation, LED

I. INTRODUCTION

Batteries provided the earliest source of electricity before the development of electric generators and electrical grids towards the end of the 19th century. Successive improvements in battery technology, facilitated major electrical advances, from early scientific studies to the rise of telegraphs and telephones, and eventually led to portable computers, mobile phones, electric cars, and, many other electrical devices. Scientists and engineers developed several commercially important types of batteries."Wet cells" were open containers that held liquid electrolytes and metallic electrodes. When the electrodes were completely used up, the wet cell was restored by replacing the electrodes and electrolyte. Open containers are unsuitable for mobile or portable use; early electric cars used semi-scaled wet cells. Primary or main batteries could produce current as soon as they are out together, but once the active elements were consumed, they could not be electrically recharged. The development of the Lead-acid battery and subsequent "Secondary" or "Rechargeable" types allowed energy to be restored to the cells, extending the life of permanently assembled cells (Decker, 2005). This design is primarily aimed at designing a charger that can sense the polarity reversal of any battery once it is wrongly connected. The functionality of the charger depends solely on when the proper polarity is obtained. Without its proper polarity, the charger won't activate its relays for the charging process. This is an excellent technique that can also be adopted for any polarity-sensitive devices such as car wiring systems, DC compressors, DC appliances, and many others. It can save many of these aforementioned devices from being damaged from wrong polarity reversal and couple with its speed of charging batteries. This type of design can conveniently charge a 2x100AH battery connected in a series-parallel within the space of 5 to6hours when supply is made available for the said period.

II. LITERATURE REVIEW

Rechargeable batteries tend to have a lower start voltage and shorter usage cycle, however, these make up the difference by being reusable. Batteries can last up to 500-700 charge/discharge cycles. Nickel-cadmium battery is recharged before it is fully discharged, the recharge process can create a layer of bubbles in the battery which will eventually prevent the battery from discharging beyond that point. To avoid this problem, a recommendation is made that Nickel-cadmium batteries must be fully discharged before recharging (Charles, 1992).

A simple charger requires manual disconnection at the end of the charge cycle or may have a timer to cut off current at a fixed time. Other battery types cannot withstand a high rate of over-charging; the charger may have a temperature or voltage sensing circuit and a microprocessor controller to adjust the charging, providing a relatively small amount of current, only enough to counter self-discharge of a battery that is idle for a long time. Slow battery chargers may restore most capacity within minutes or less than an hour, but generally requires monitoring of the battery to protect it from overcharging (Donnelly, 1985).Although battery chargers have been in existence, the design and implementation of a 24V/40A polarity-sensitive automatic battery charge is rare.

Several authors have worked on different types of battery chargers and some of these are summarised as follows;

Odia, (2017) worked on the Design and Implementation of a Microcontroller-Based Adjustable Voltage Automatic Battery Charger. This device was used to charge 6V, 9V,and 12V batteries respectively. This design cannot charge a high-capacity battery of 12V/100AH battery because of its low current delivery. The design is not a polarity-sensitive type. All of these limitations were taken care of, as the implementation of the 24V/40A made provisions for the entire author's limitation

Solomon, (2018) reviewed work on the Design and Construction of a 12V Battery Charger. His work was purely a review as there was no construction indicated whatsoever.

Ebeye, (2013) designed and constructed a 24V/36V automatic battery charger with a high voltage. The device was meant to charge batteries between 24V and 36V respectively but it was later discovered that the battery charger had a problem with feedback.

III. MATERIALS AND METHOD

A battery charger circuit can be of distinct types depending on battery size and power rating. However, the essential blocks are almost the same for each battery charger circuit. Every battery charger circuit relies on a power source higher than the battery voltage. This power is then delivered to the battery via a switching device. The block diagram for the design and implementation of a 24Vpolarity-sensitiveautomatic battery charger is shown in figure 1.

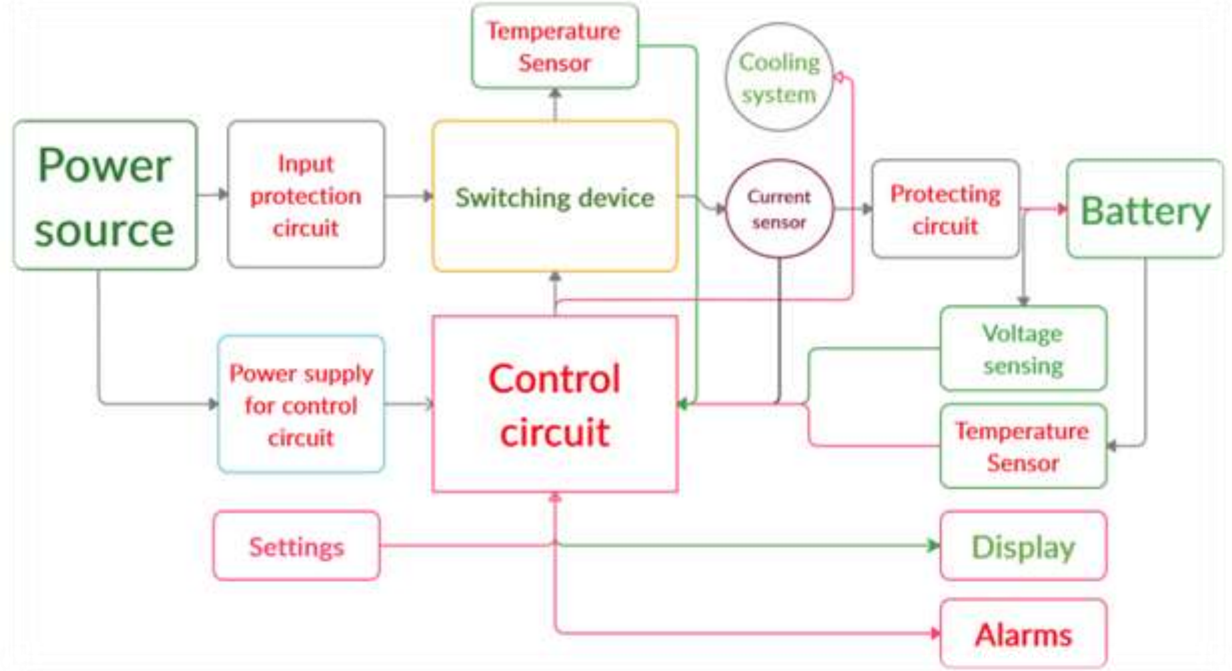


Figure 1: 24V/40A Polarity Sensitive Automatic Battery Charger

A. The Power Source

This unit comprises the transformer, the power switch, the rectifiers, and the voltage regulator.

The switch is meant to make or break the transformer circuit, the transformer itself is used to step down the primary source of AC from 240V to 24VAC and then get rectified by the diodes (rectifier circuit) and then the regulator stabilizes the voltage at 26VDC.There are three different DC voltages rating for the circuit. Each is used in a different part of the circuit. Voltage rating in the circuit is 24Vdc, 15Vdc, and 5Vdc. The 24Vdc is used to charge the battery as soon as the controller activates the relay responsible for charging. The 5 Vdc is used in Vcc to enable ICs responsible for the LED display and also the microcontroller. The 15V is used to power the 12Vdc relays (Figure 2).

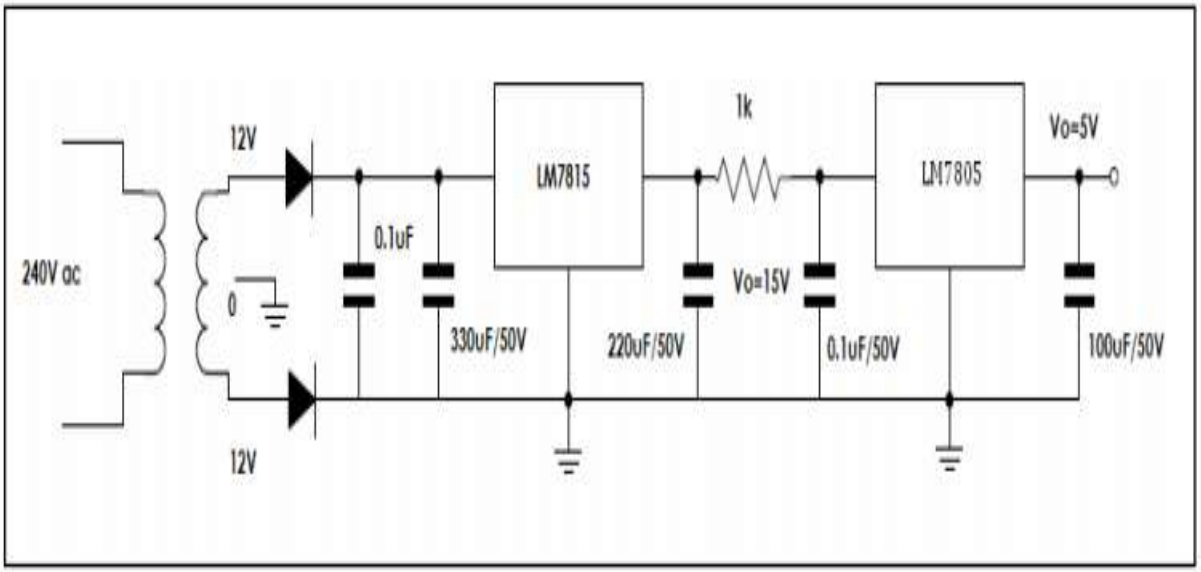


Figure 2:Power Supply 5V, 15V

1. Transformer Design Specification

The following are the assumed design parameters for the transformer;

Power rating (Kilowatts output) 9500VA (9.5KVA)
Stacking Factor = 0.9
Primary (Input) Voltage = 230V
Secondary (Output) Voltage = 24V
Frequency = 50Hz
Efficiency = 90%
B_m 1.1 tesla
Required dimensions
Centre limb - 3.5cm
Window Width - 2.7cm
Window Height - 8.1cm
Overall Height - 10.8cm
Thickness of each lamination – 0.05cm
Stack width = number of lamination x thickness
= 106 x 0.05 = 5.3cm
Core area = stack width x centre limb
= 5.3 x 3.5
= 18.55cm

Net core area Ai = $\frac{corearea}{corestacking}$

Therefore, Ai = $\frac{18.55}{0.9}$ = 20.61cm^2

Using $E = 4.44B_mA_iNFS$
N_1= 507turns so that N_2 =52turns

B. Automatic and Protection section

This section is made up of the microcontroller and its related components. This part is responsible for the switching and the control of the whole circuitry. The input and the output protection circuit are also embedded in this section as well as their settings. The controller compares the design temperature for the device and the temperature produced during charging and switch on the cooling part of the system to normalise the temperature. At the out, a diode is connected to a relay that will be triggered as soon as the polarity is normalised. In turn, the relays transfer the current to the positive terminal of the battery ready to be charged. This output protection circuit is used for battery terminals for the wrong polarity; the current sensing circuit was used herein between the switching device and the battery to sense the charging current. A voltage sensing circuit was also used to sense the battery voltage. All of these are done to protect the charging circuit itself as well as the battery. The schematic diagram is shown in figure 3.

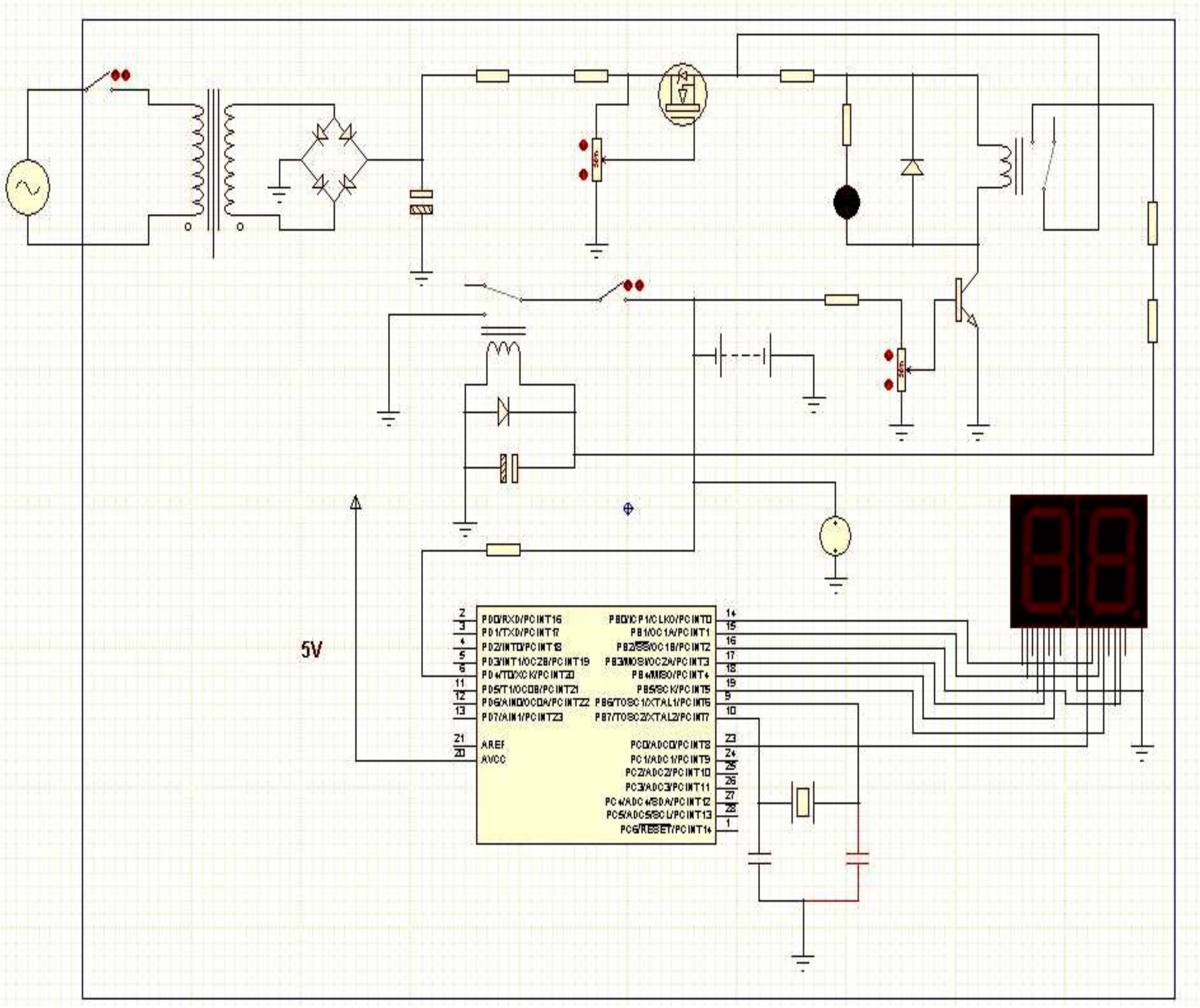


Figure 3: Schematic Diagram 24V/40A Automatic Battery Charger with Polarity Reversal

C. Design of the Electronic Section

1. Voltage regulator

$$Vout = Vref\ (1 + \frac{R2}{R1}) + Iadj \times R_2$$

Where Vout=?,Vref = 4.7V, R_1= 470Ω, R_2 = 0Ω andIadj = Regulator Current = 0.25A

Substituting into the formula

$$Vout = 4.7\ (1+\frac{0}{470}) + 0.25 \times\ 0$$

4.7 x 1 + 0 = 4.7V

The required voltage for the controlled circuit is 4.7V.

2. Diode IN4007 Regulator

For Diode IN4007, the formula is given by

$$R = (\frac{Vin-Vz}{Iz})$$

Where R= 3.3Ω, V_Z= 7V, Iz = 1 x 10 $^{-2}$A

But Vin = Vz + IzR

Vin = 7 + 1 x 10 $^{-2}$ x 3.3 = 7.033V

The voltage of the diode should not exceed 7V, and practically a Diode IN4007 was used.

3. Rectification unit

To rectify 24V

From the formula

$$i = C\ \frac{dv}{dt}$$

Allowable ripple factor of 20% was set and peak voltage of rms value Vp= Vrms x $\sqrt{2}$

Where Vrms = 24V

Vp = 24$\sqrt{2}$ = 33.94V

dt = 0.2 x 33.94 = 6.788s

dv = $\frac{1}{50}$ = 0.02 for half cycle

$$C=\frac{Q}{V}$$

C=4700 x 10 $^{-6}$/50

C=9.4 x 10 $^{-5}$F

Therefore, from equation 3.11,

$$i=9.4 \times 10^{-5} \times \frac{0.02}{6.788}$$

i=2.7696 x 10 $^{-7}$A

dt = 6.788s and Vp = 33.94V at Vrms = 24V

Substituting into the equation

$$C = 2.7696 \times 10^{-7} \times \frac{6.788}{0.02} = 9.4 \times 10^{-5}F = 0.094mF$$

Practically 4700µF was used.

For voltage k = $\frac{V2}{V1}$Where V_1 = 230V AC, V_2= 24V

$\therefore$ K = $\frac{24}{230}$ = 0.1

Peak full wave rectified voltage at full input,
Vp = 33.94V, but practically 40A was used

V = IR R = $\frac{V}{I}$

Where V = 230V, I = 40A

R= $\frac{230}{55.56}$ =5.7Ω

The circuit diagram for this battery charger is shown in figure 4

For two 12V = 24V, since conventional nominal voltage for 12V = 13.8V, for a fully charged battery with 90% to 100% efficiency.

I = $\frac{24}{5.7}$ = 4.2A

For 24V two 12V – 200AH is 5.797A

Where V = 230V, I = 40A

P = 40 x 230 = 9200VA as the power of constructed automatic battery charger at V = 230V the current is 40A.

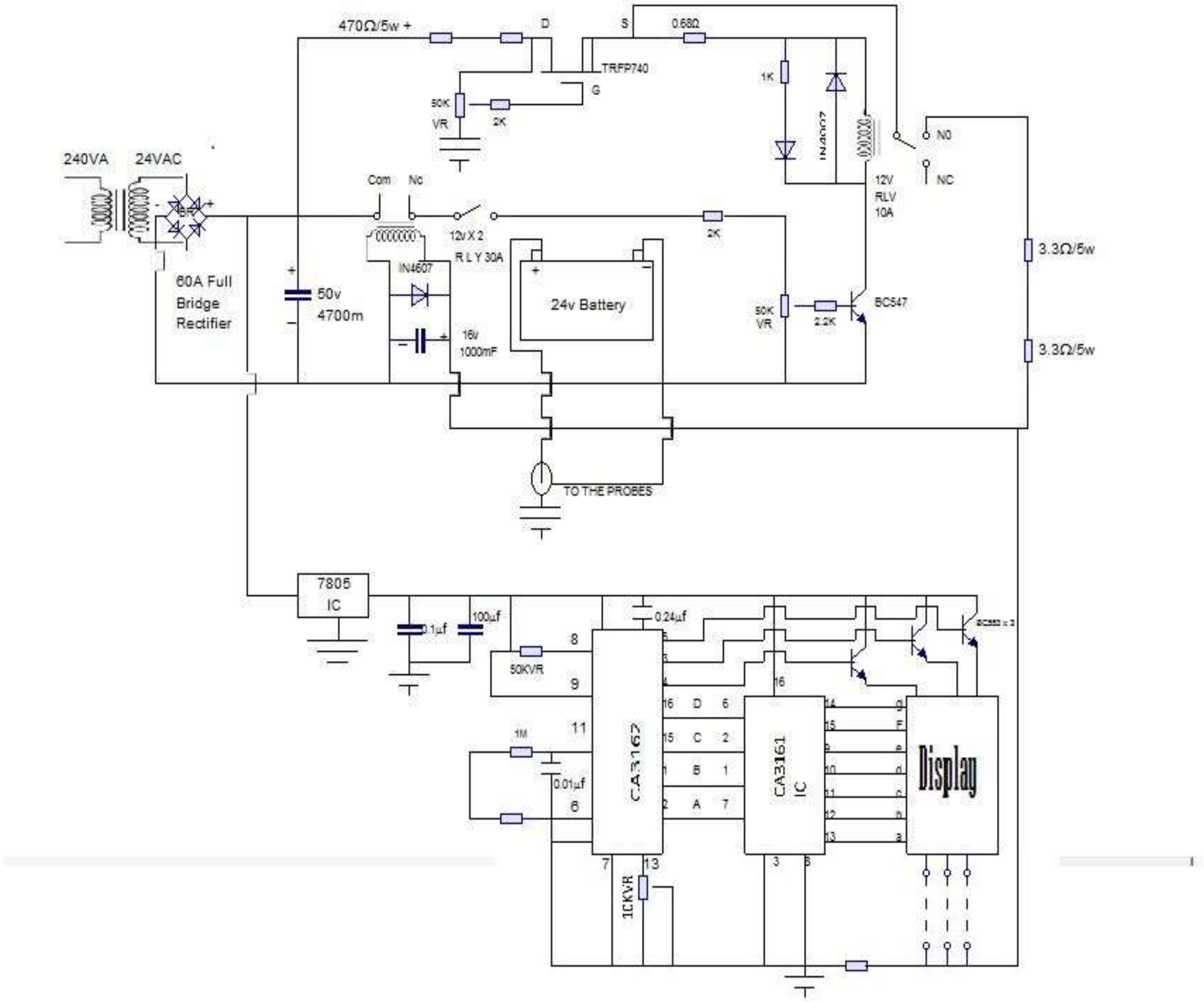
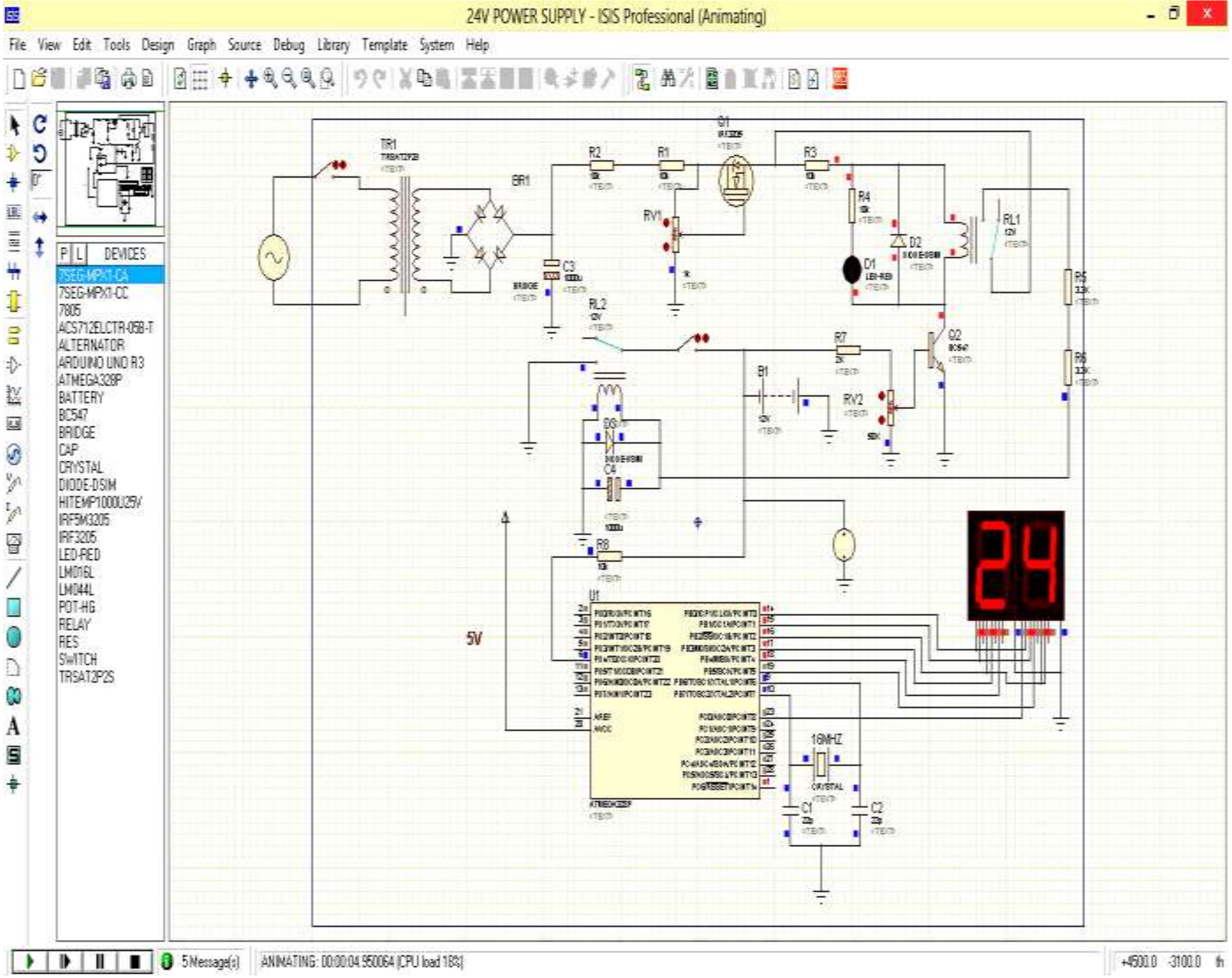


Figure 4: Automatic Battery Charger Circuit Diagram

IV. RESULT AND DISCUSSION

The simulation result helps to show the behaviour of the design on the oscilloscope as shown in figure 5



ANIMATING: 00:00:04.950064 (CPU load 18%)

Figure 5: Simulation Results

The battery charging status was displayed on the LED as shown in figure 5. After 5 hours, the voltage increases to 27.5V showing that the charging was at its float value. and the charge cuts off at 28VDC. This result showed that the battery was fully charged. It was observed that when the mains were less than 220V the charging time increases from 5 hours to about 8 hours. That means if the supply is not at 230V, the charging process will not be fast as expected.

V. CONCLUSION

The design and implementation of a 24V/40A automatic battery charger with polarity reversal was designed to charge both home and industrial types of batteries of different Ampere hour (AH) batteries at a very fast rate and cut off automatically when the battery is fully charged. The digital display helps to indicate each charging voltage at a particular level of the battery. This design was done to charge only a 24V battery, the input voltage ranges from 200-230V and the current is 40A.

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Solomon A. (2018) Design and Construction Of 12v Battery Charger Enugu State University of Science & Technology

APPENDICES

The designed assembly is as below:

The wounded Transformer in its square bobbin

The wounded transformer in its laminated sheet

Laminating sheets

The Battery Charger completely Assembled