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Design and Construction of an Emergency Rechargeable Lamp Incorporated with a Battery Overcharging Preventer Circuit

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Abstract: The analysis, design and construction of an emergency rechargeable lamp with a battery overcharging preventer circuit for illumination purpose has been undertaken in this research. The approach here is generally discrete components based, making use of an operational amplifier comparator circuit, which compares the voltage level across the battery thereby preventing overcharging. Also, a low power transistor was used to generate pulses, which was connected in push-pull mode for signal amplification. A transformer was used to step up the A.C. voltage generated to 220 V required to light the 18 watts A.C. bulb. Following the design, a prototype of the emergency rechargeable lamp with a battery overcharging preventer circuit was constructed.

Key words: Illumination, rechargeable, overcharging, push-pull mode

INTRODUCTION

The emergency rechargeable Lamps that are in circulation today have various defects. The major problem experienced by these lamps is the short life span and damage of the battery due to overcharging and total discharge of the battery and inability to function, while charging. This makes them inadequate for the illumination purpose.

As a result of these, this research was embarked upon to improve the efficiency of the existing rechargeable lamps by incorporating a battery overcharging preventer circuit made up of a comparator and integrated circuits with the lamp circuit. This technique prevents the battery from overcharging (Theraja and Theraja, 1995). Also, the illuminating system was designed to function using the alternating current source to light the bulb and charge the battery simultaneously.

The bulb used for this research is an 18 watt Cata-bulb with the advantage of continuous illumination even when the voltage of the battery drops below the voltage of the comparator used.

CIRCUIT ANALYSIS AND DESIGN

The emergency rechargeable lamp with a battery overcharging preventer consists of four main units as illustrated in Fig. 1, to be able to serve its purpose. These units are analyzed as follows:

Power supply unit: The power unit consists of a step down transformer, which steps the input voltage from 240-9 Va.c. The output voltage is an alternating voltage, which passes through a bridge rectifier that converts it to direct voltage, thereby, producing a full wave rectification. The rectified output passes through an electrolytic capacitor to filter out the ripples. The resistor in this power supply unit was used as a current limiter (i.e. current limiting resistor). Also, an indicator, which is a Light Emitting Diode (LED) was used to indicate the presence of a.c. in the circuit. The power supply unit is shown in Fig. 2.

Charging unit: The charging unit of this system includes the comparator, the relay and also the battery. When the battery is in the discharge state, there is an output voltage at the pin 6 of the comparator due to difference in pin 3 and 2. This output voltage drives the transistor, which energizes the relay and automatically charges the battery (Horowitz and Hill, 1987) as shown in Fig. 3.

To determine the charging current and time, the transformer steps down the 220-9 V a.c, 9 V a.c is taken from the secondary winding. The charging voltage is given by:

$$Vdc = (2Vm - 2Va)/\pi$$

Where:

V_a = Voltage drops across diode = 0.6 a.c.
V_m = Voltage from the secondary winding.
Vdc = Charging voltage.
π = 3.142.

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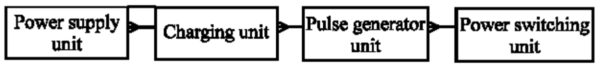

Fig. 1: Block diagram of the circuit

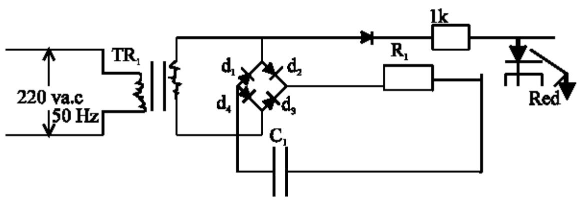

Fig. 2: Power supply unit

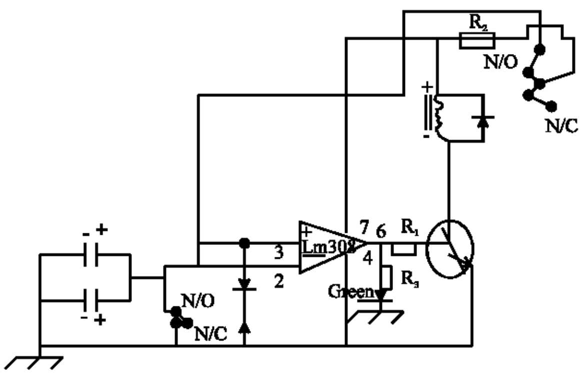

Fig. 3: Charging unit

Therefore, Vdc = (2×9 - 2×0.6)/π

= 5.347V a.c.

Vdc≈5.35V a.c.

Charging current is determined by applying Ohm's law.

i.e., V = IR

$$I = \frac{V}{R} = \frac{5.35}{10} = 0.54\,A$$

To calculate the time it will take to charge up battery.
Assume 4.0 Ah battery
Current × charging time = 4.0 Ah

$$\text{Charging time} = \frac{4.0Ah}{0.54} = 7.41$$

Charging time = 7 h 24 min

Pulse generator: The pulse generator consists of the 555 timer and the dual D type flip-flop. The 555 timer was used to generate a square wave of accurate and stable frequency. The external capacitor charges through R_A and

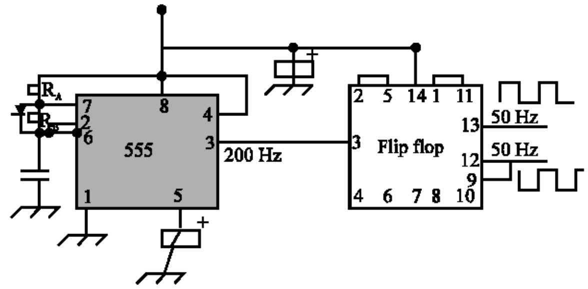

Fig. 4: Pulse generator unit

R_b and the frequency is independent of the supply voltage (Carpenter, 1993) as shown in Fig. 4.

The 555 timer generates a square wave with a frequency of 200 HZ. Form the equation $T = t_{high} + t_{low}$

$$\text{Recall that } t = 0.7\,(R_A + 2R_B)\,C_1 \tag{3.2}$$

Since, t high is the time the external capacitor C1 charges from 1/3-2/3 Vcc through resistor R_A then

$$2/3\ Vcc = 1/3\ Vcc\ \frac{1^{-e\text{-}t\ high}}{(R_A C_1)} \tag{3.3}$$

$$2.0 = \frac{1^{-e\text{-}t\ high}}{R_A C_1}$$

Taking natural logarithm of both sides,

$$In\ 2 = \frac{t\ high}{R_A C_1}$$

$$t_{high} = 0.7RAC_1 \tag{3.4}$$

t = Low is the time the capacitor.
C_1 = Charges from 2/3-1/3 Vcc through RB.

$$\text{Then } 1/3 = 2/3Vcc\ \frac{e^{-t\ low}}{R_B C_1} \tag{3.5}$$

$$0.5 = \frac{e^{-t\ low}}{R_B C_1} \text{ taking the } l_n \text{ of both side}$$

$$In\ 0.5 = \frac{-tlow}{R_B C_1}$$

Then

$$t\ low = 0.7\ R_B C_1 \tag{3.6}$$

$$T = 0.7\ (RA + RB)\ C_1$$

Where:
T = The total period of oscillation

$$F = \frac{1}{T}$$

$$= \frac{1.44}{(RA + RB)C_1}$$

The pin 8 of the 555 timer was connected to the positive of the 6 V supply, while the output pin 3 was connected to the input of the flop, which divides the frequency generated by 200 Hz\2^n where n = 1 = no of flip flop (Meadows, 1990). This results to 100 Hz, which bifurcates into 2 channels to give the required frequency of 50 Hz each as shown in the flip-flop component in Fig. 4 and 5.

Power switching unit: The power switching unit consists of the power transistors connected in push-pull mode with the MOSFET. The transistors act as a switch to connect the d.c. voltage source to the primary of the transformer. The transistor amplifies the output voltage that gets to the MOSFET, since the MOSFET requires high voltage and lesser or little current for its operation (Bishop *et al*., 2002). This voltage generated is not enough to drive the gate of the MOSFET. Thus, the transistor acts as a buffer amplifier. With this, it separates the low power signal generator unit from the power-switching unit. The required 6 V is passed through the MOSFET to the center type 6-0-6 V transformer, which steps up the voltage to the required voltage (150-220 V a.c) to light the 18 watts bulb as shown in Fig. 6.

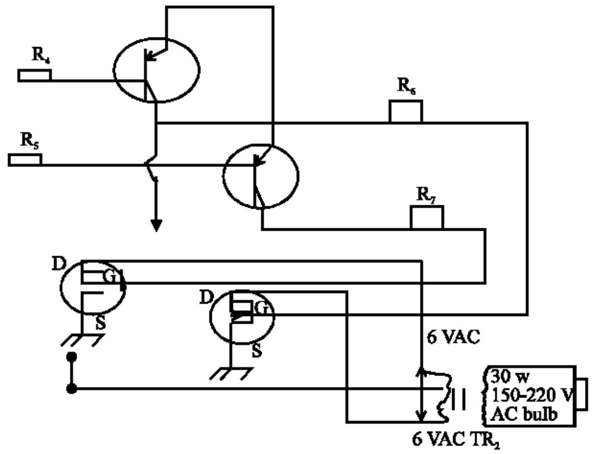

Fig. 5: Power switching unit

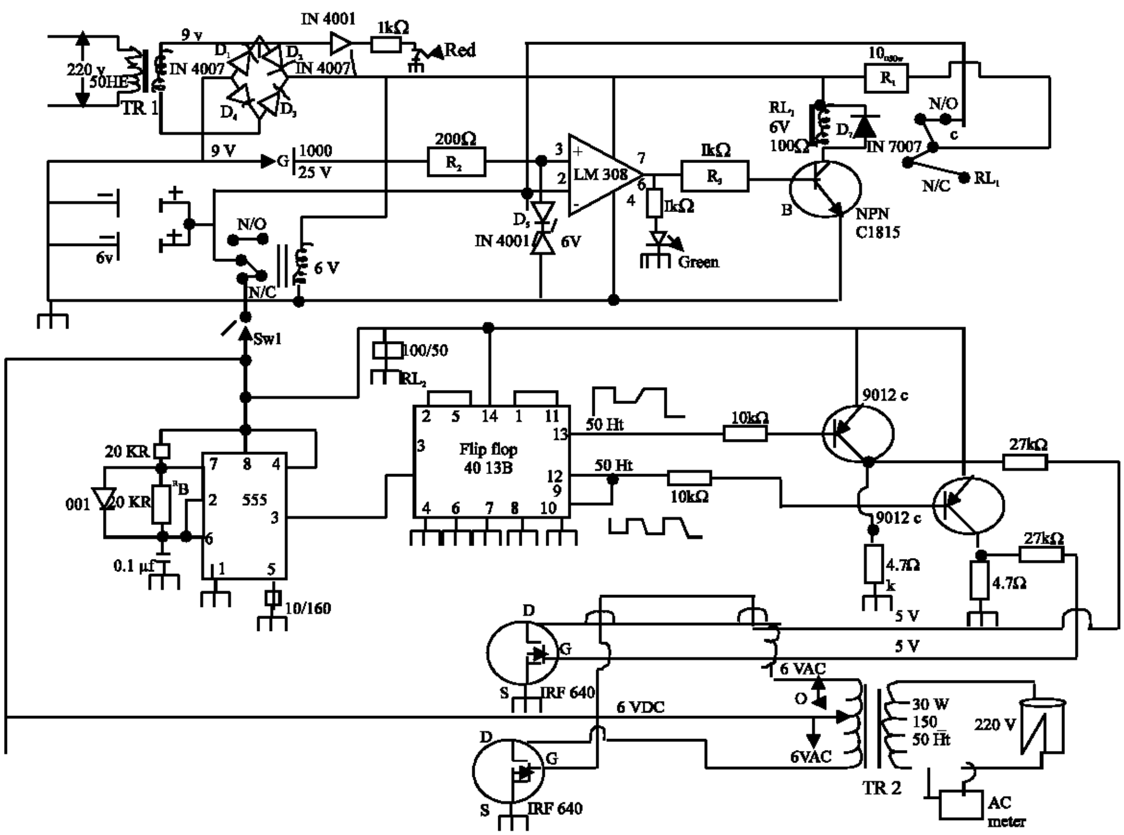

Fig. 6: Schematic circuit diagram showing how the circuit stages or units are connected

Mode of operation of the circuit system: The Operation of the lamp circuit is analysed as follows by considering the complete circuit diagram in Fig. 5. The incoming voltage from mains supply is 220 V a.c., which is stepped down to 9 V a.c. by TR_1, step down transformer. The output of TR_1 is fed into full wave bridge rectifier, which converts the signal from a.c. to d.c., thereby producing full wave rectification. The output obtained from rectification is not a pure d.c., so it is then passed through an electrolytic capacitor to filter out the ripples resulting from a 6 V d.c. with little or no ripples.

The 6 V d.c. is supplied to the two relays and the Integrated Circuit (IC), which act as a comparator of voltage levels. When the battery is in a discharge state, it is sensed by the comparator as a result of the difference between the voltage levels at pins 2 and 3, which produces an output voltage at the end of the pin 6. The transistor amplifies the output voltage, which energizes the relay. The driving of the transistor completes the relay circuit making the common terminal switches to Normally Open (N/O) allowing the 6 V d.c. to pass straight to the battery and also the comparator through pin 2.

This automatically charges the battery as well as the capacitor through pin 3. The method or mode of charging in this research is called Trickle charging method. The battery is fully charge when the capacitor has assumed a voltage of 9 V d.c., which is immediately sensed by the comparator through pin 3 meaning that both pin 2 and 3 are at the same voltage level. There would be no voltage at pin 6, which is the output required to drive the transistor. Thus, the circuit of the relay, RL_1, will be short circuited. Thereby, de-energizes the coil of the relay and common terminal switches to normally close.

Based on this, no amount of voltage supplied by the step down transformer will be passed to the battery. This prevents the battery from being overcharged.

The battery stores electrical energy in chemical form, which is discharged as electrical energy to light the lamp when there is a power outage. The relay, RL_2, acts as a switch, which is energized whenever there is power supply.

When there is a power outage, the coil de-energizes and the common terminal switches to Normally Close terminal (N/C) connecting the battery to the inverter unit and the current flows from the battery to the unit. But when there is power supply, the coil energizes and the common terminal switches to Normally Open (N/O) connecting the circuit to the oscillator stage thereby making use of the power supply from the electric power grid and at the same time charges the battery. Switch 1 turns off and on the lamp. The inverter unit consists of an oscillator, which is made up of 555 timer, flip-flop as its active elements. The basic function of the oscillator stage is the conversion of d.c. to a.c., which is required to light the a.c. bulb.

CONCLUSION

Incorporation of a battery overcharging preventer circuit with the aid of Comparator operational amplifier into the emergency rechargeable lamp circuit has prolonged the lifespan of the battery, which is the main engine behind the rechargeable lamp. This lamp will work continuously, even when the voltage of the battery drops below the voltage of the comparator used. This is due to the low power consumption bulb called 'Cata-Bulb' that was used as an illuminator.

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