Available online at www.journal.gvu.edu.ng

GVU Science-Tech Journal

A scientific publication of the College of Basic and Applied Sciences, Glorious Vision University, Ogwa, Edo State, Nigeria.

p - ISSN: 2536 – 6866
e - ISSN: 2659 - 1529

Vol. 8(1), 2023:153-162

DESIGN AND CONSTRUCTION OF A DARK-ACTIVATED EMERGENCY MAINS FAILURE TORCH

Dada, J. B.[1*] and Lawal, Y. B.[2]

[1]Department of Physical and Chemical Sciences, Elizade University, Ilara-Mokin. Ondo State, Nigeria
[2]Department of Physics, University of Africa, Toru-Orua, Bayelsa State, Nigeria

*Corresponding author e-mail: babatunde.dada@elizadeuniversity.edu.ng**

Abstract

This paper presents the design and construction of a dark-activated emergency mains failure (DAEMF) torch mounted on a printed circuit board (PCB). The battery-powered torch called a DAEMF is intended to automatically light up a home and its surroundings in the dark, but it will turn off if it detects the presence of a power source, even if the lighting system is not on. The charging, switching, and lighting sections comprise the three main sections. During the dark period, the switching circuit was switched ON by a voltage of 1.7 volts, and a current of 0.006 mA measured across the light-dependent resistor (LDR) at the switching section. The charging section uses a linear Integrated Circuit (IC) LM 317 as the main electronic component to charge the battery with about 0.65A load current. The high-voltage transformer (HVT) at the lighting unit inverts and converts a 12 Volts direct current (DC) to approximately 100 Volts alternating current (AC) to drive the 6 watts 12 volts fluorescent tube in the lighting section to illuminate the household and its surrounding for 10.5 hours of continuous use

Keywords: *Light-dependent resistor; Transformer; Torch; Dark sensor; Fluorescent tube*

INTRODUCTION

The torchlight comes in different handy designs; however, most of it comes in manually operated ways. The purpose of a torch in daily activities is to illuminate a dark region (room) and to assist a user with better vision at night. The emergency needs for a torch and its automatic operation (ON and OFF), when the power (mains) supply fails, is

essential to avoid any domestic accident in the dark region, along with the torch's brightness are essential. The fluorescent bulb produces between 50 and 100 lumens per watt, which is four times more than the light produced by incandescent bulbs and makes it relatively close to 130 lumens produced by light-emitting diodes (LED) (https://actionservicesgroup.com/blog/led-vs-fluorescent-tubes/). Fluorescence requires more power, which can be provided by a high-voltage transformer, to maintain the same level of lighting. Fluorescent lights emit light in a full 360 °(omnidirectional) around the bulb itself, which

* Corresponding author email: babatunde.dada@elizadeuniversity.edu.ng

makes the coverage area larger than that of the LED, which emits light in a focused 110° area (one-directional).

Automation of a lighting system can be achieved using an electronic design. In this fast-developing society, one of the fastest-growing areas of today's high-tech and education is ELECTRONICS. Electronics have been the bedrock of many machines and a wide range of electrical equipment such as radio, television, computers, and other domestic equipment. In electronic circuits, some components perform their predefined functions while they are combined for various purposes. Among the electronic components, transistors are solid-state devices used in electronic circuits as amplifiers or switches and have three electrical terminals: base, collector, and emitter. The base controls the voltage or current between the collector and emitter. The transistor operates as a closed switch when it attains its saturation point when the input base-emitter voltage is around 0.7 volts and above for the NPN silicon transistor (Akinsanmi et al., 2015; Choudhary, 2017). Two transistors can be connected in Darlington Pair to operate as a single transistor for high current gain (hfe) with high impedance (Motayed and Mohammad, 2001; Wijesekara et al., 2021), in which approximately 1.4 volts is required at the base to operate as a switch. The Darlington pair requires a very small current in its base terminal to switch to a much greater current at its collector circuit (Hu et al., 2018). Transistors are only slightly more than 76 years old, right from the year of the invention in 1947 by John Bardeen and Walter Brattain at Bell Telephone Laboratories, U.S.A (Baedeen, 1957).

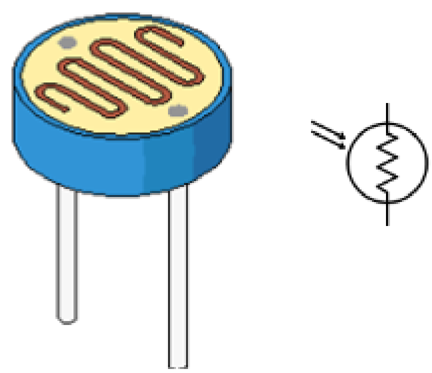

Fig. 1: Light-Dependent Resistor (LDR)

A resistor is a component that tends to prevent the current flow in an electric circuit. Photoresistors are also known as photoconductors or light-dependent resistors (LDR) (Fig. 1). The three classes of photoresistors are visible-light photoresistors, infrared photoresistors, and ultraviolet photoresistors.

* Corresponding author email: babatunde.dada@elizadeuniversity.edu.ng

The LDR is a photoelectric conversion component, and its operation is based on its internal photoelectric effect. The default resistance of LDR is in a range above 1 Mega Ohm but dramatically drops once light rays fall on it (Pratik et al., 2019). The numerous applications of electronics have made them more important in the industry with the help of electronic components such as transistors, resistors, and diodes. Various functions of the electronic components include rectification, such as the conversion of Alternating Current (A.C) to Direct Current (D.C), amplification (a process of raising and strengthening weak signals), inversion (conversion of D. C. power to A. C. power of any frequency), control (used in automatic control, for example, speed of motor utilized in television by conversion of electricity into light), and photoelectricity (conversion of light into electricity). Considering the control and photoelectricity aspect of the application of electronics, we built a device called the dark-activated emergency mains failure (DAEMF) torch.

MATERIALS AND METHODS

In this work, the transistor was used as a switch to switch electromagnetic relay, LDR as the light sensor to detect darkness and to activate the ON/OFF switching of the transistor, High voltage transformer (HVT) to drive the fluorescent tube which in turned illuminate the dark room, 3.2v Zener diode as power supply (mains) sensor to switch OFF the transistor once the mains are available which turns OFF the fluorescent tube (6 Watt 12 Volts). A linear transformer, bridge rectifier, and adjustable voltage regulator (LM317) are used to recharge the DC source that powers the circuit. The battery used as a direct current source to power the torch is rated at 12V 7Ah, this makes the torch last for approximately 10.5 hours.

CIRCUITS DESIGN AND DESCRIPTION

Considering the aforementioned combinational operation, the DAEMF circuit consists of three major sections (Fig. 2).

i. Charging section
ii. Switching section
iii. Lighting section

* Corresponding author email: babatunde.dada@elizadeuniversity.edu.ng

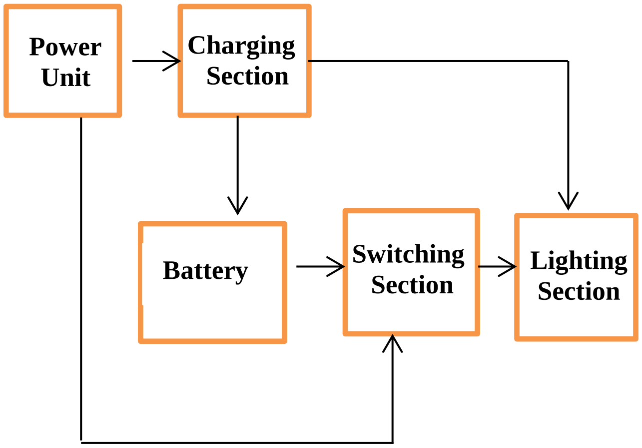

Fig. 2: Block diagram of the designed torch

The Charging Section

The circuit diagram of the charging section is displayed in Fig 3. After the AC signal exits the linear transformer (12v 1A), the full wave bridge rectifier circuit which is made of four power

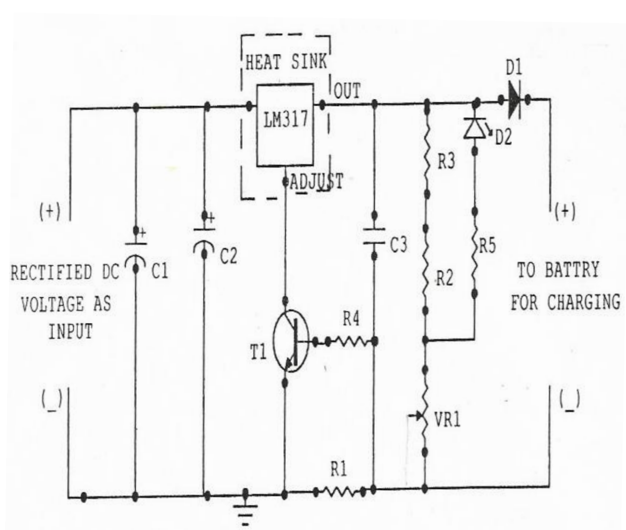

Fig. 3: Charging Circuit

diodes converts the AC to DC. The pulsating DC signal is smoothened by the capacitors C_1 and C_2 connected in parallel to the rectifier. The combination of the linear transformer, rectifiers, and capacitor constitutes the power unit (Fig. 6). The DC from the power unit is fed into the input terminal of the voltage-regulator transistor (LM317). LM317 controls the voltage at its output terminal to a stable value of 12 volts and approximately 0.65 A to recharge the rechargeable battery (12V 7Ah) which acts as the power source for the torch. Once the battery is fully charged by 1/10th of the battery current rating (7Ah) which is equivalent to the voltage and current required by the lighting unit, the current to the battery is reduced with the help of the transistor (T_1) in the circuit, whereby it operates as a switch, and changes in the amount of current T_1 received switch the output to the battery ON and OFF (trickle charging mode), which is much faster than a mechanical switch. The charging process continues once the voltage value on the battery drops, and the lighting section continues to receive power supply as long as the battery is capable of supplying the required voltage. The charging voltage can be determined by

$$V_{out} = 1.25\left(\frac{R_2}{R_1} + 1\right)$$

Therefore, the charging voltage at VR_1= 2kΩ is:

* Corresponding author email: babatunde.dada@elizadeuniversity.edu.ng

$$V_{out} = 1.25\left((VR_1 + \frac{R_2}{R_1}) + 1\right)$$

$$V_{out} = 1.25\left((2000 + \frac{1000}{300}) + 1\right)$$

$$V_{out} = 1.25\left(\frac{3000}{300} + 1\right)$$

V_{out} = 1.25 (10 + 1)

V_{out} = 13.75v

Switching Section

Fig. 4 shows the circuit diagram of the switching section of the DAEMF torch. T_1 and T_4 are combinations of two NPN transistors (T_A and T_B), each in series, that behaves like a single transistor (Darlington). The VR_1 and LDR are combined to form a potential divider, through which the switching circuit can operate as a dark-operated switch circuit (Merev and Kalenderli, 2009; Aladeniyi et al., 2013).

The value of VR_1 was selected to control the sensitivity of the dark and light resistance to the LDR. Once darkness falls on the LDR, its resistance rises to approximately 20 megaohms and 12.23 volts flow across it leaving only 0.02 volts across VR_1. The base-emitter junction of T_1 connected to the potential divider junction received little current (around 0.006 mA) and a total voltage of about 1.70 volts which in turn switches to send a low signal as input to T_2 which in turn inverted the signal with no signal from T_3. This signal reaches the base of T_4 through D_5 and R_2 as a high signal and bias T_4. Immediately T_4 gets biased, it switches on and gives

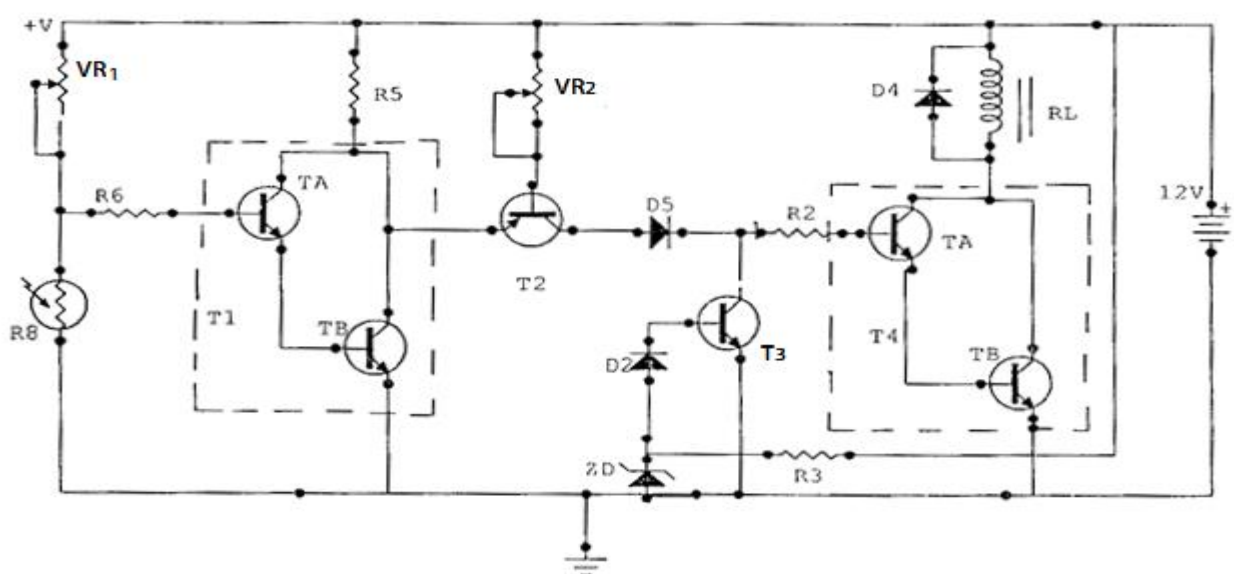

Fig. 4: Switching Circuit

* Corresponding author email: babatunde.dada@elizadeuniversity.edu.ng

a high current as an output to energize the relay "RL," which then allowed positive voltage to the lighting section.

Once there is a power supply at the power unit, T_3 senses it through a Zener diode (ZD) of 3.2 volts. ZD allows 3.2 volts to pass through to bias T_3 and switch it ON, thereby making the signal through R_2 as the input voltage to T_4 a low signal. This allows a high signal as the output, where T_4 is in the OFF state, preventing the relay from being energized, and no signal was sent to the lighting section. This shows that once the power unit is plugged into the power socket, and if the power supply is available, the lighting section will not function.

The Lighting Section

The unit consists of a fluorescent bulb (Fig. 5) that performs the illumination, a transistor, BD711 (TR_1), which acts as an open and closed switch to induce a high voltage across a coil of the HVT, which operates as an inverter and amplifier by generating several hundred volts, enough to strike the fluorescent tube.

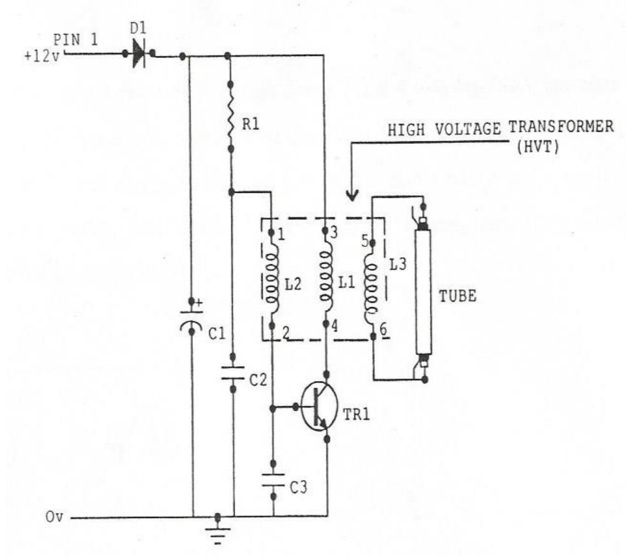

Fig. 5: Lighting Circuit

COMPONENT LIST

(A) ***RESISTORS***

R_1 = 1.5k

R_2 = 1K

R_3 = 10K

R_4 = 10K

R_5= 100K

VR_1 = 500K

VR_2 = 100K

VR_3 = 2K

(B) ***CAPACITORS***

C_1 = 4.7nf

C_2 = 10nf

C_3 = 100µf

C_4 = 0.22µf

* Corresponding author email: babatunde.dada@elizadeuniversity.edu.ng

C_5 = 100µf

(C) ***TRANSISTORS***

T_1 = BD 711

$T_A = T_B = T_3$ = C945

T_6 = A733

T_5 = BC 140

(D) ***DIODES***

D_1 = IN4001

$D_2 = D_3 = D_5$ = IN4007

D_4 = Light Emitted diode (LED)

Zener Diode = 3.2v

IC = LM 317

PRECAUTION

Fig. 6 shows a complete circuit diagram of the torch. Care was taken when mounting and soldering the component on the printed circuit board (PCB) to avoid short-circuiting on the board. The heat sink was used with the LM 317 and T_1 to increase their surface area for heat dissipation, for a maximum power output of the LM 317, and for the proper functioning of T_1. The protecting Diode, D_5, prevents the battery from discharging during the rest state of the circuit (Fig. 6). D_1 prevents T_2 from possible feedback current from the relay coil, while D_1 in Fig. 5 prevents damage to both T_1 and the battery in the case of the reversed polarity of the battery during the circuit test.

HARDWARE IMPLEMENTATION AND TESTING,

The constructed DAEMF touch circuit was tested using a battery to supply the required DC voltage to the LDR and Darlington pair to activate the entire switching circuit, energizing the relay to send a signal to the lighting unit, where the fluorescent tube switched ON and OFF. The charging circuit was tested with and without connecting the battery. Each section works well, and the fluorescent tube glow, as expected.

RESULT AND DISCUSSION

The power unit was connected to a power source socket. The charging voltage and current of 13.5 volts and 0.65 A are measured across the output terminal of the charging circuit without the battery and when the battery was connected respectively. In the darkness, the relay (RL) at the switching circuit immediately energizes, and a positive voltage is sent to the lighting section. The section operates in its normal condition in which the fluorescent tube lights up.

* Corresponding author email: babatunde.dada@elizadeuniversity.edu.ng

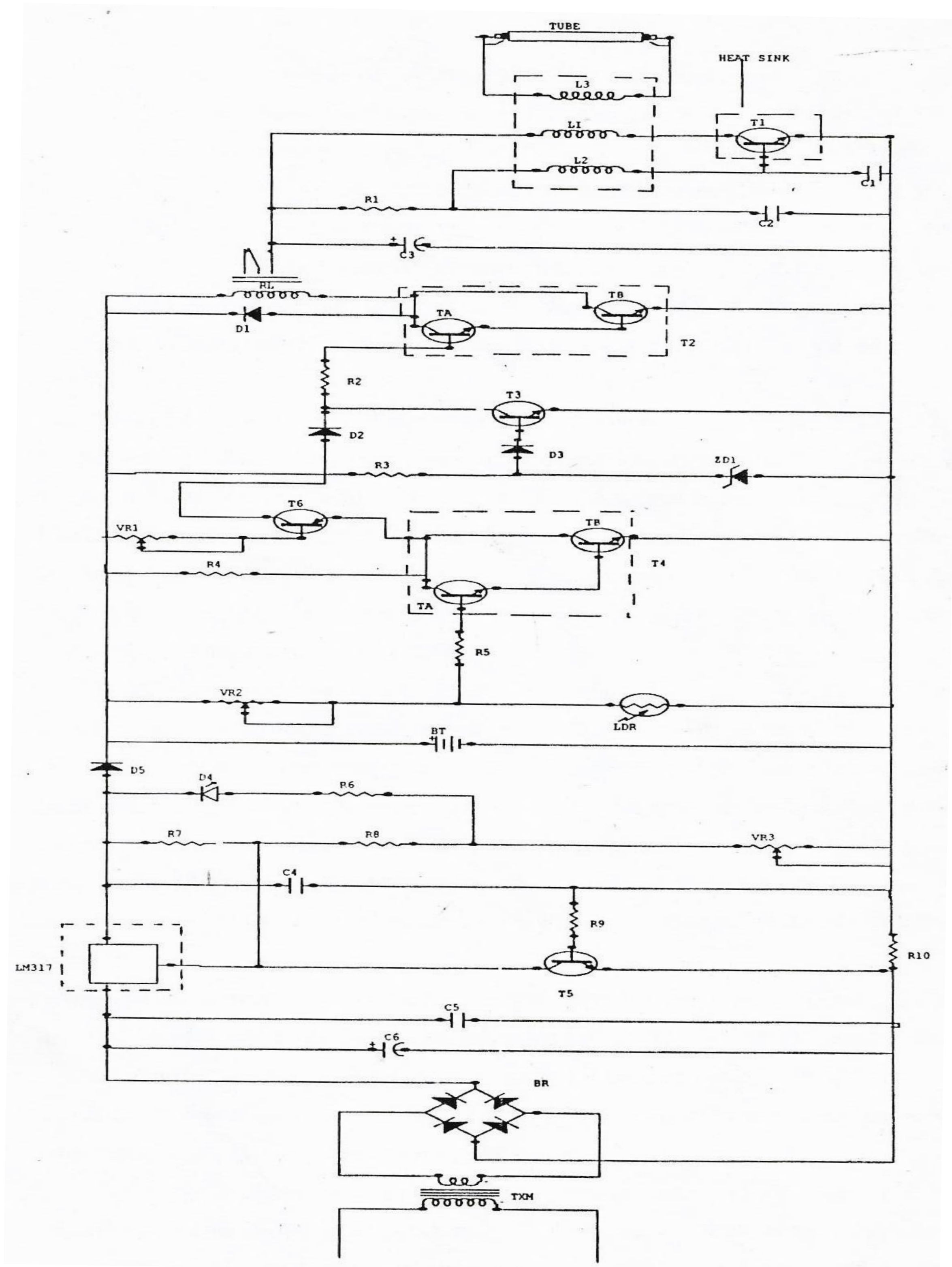

Fig. 6: The circuit diagram of the DAEMF Torch

* Corresponding author email: babatunde.dada@elizadeuniversity.edu.ng

Under this normal load running conditions, a 50 kHz square wave at 250 volts is across pins 5 and 6, meanwhile, the current at pin 1 relative to the 0 V pin (Fig. 5) is between 0.4 A to 0.5 A. It can be seen that the voltage and current supplied by the charging unit without a battery are sufficient for both the switching and lighting sections.

CONCLUSION

The DAEMF torch circuit was tested and found working perfectly well. Precisely, only 0.7 Volts measured across the LDR will switch on the switching section which switches to 'ON' the fluorescent tube in the lighting section due to the LDR's high resistance in the dark. Inside a glass tube, flowing electron produced by the battery through a coil in the HVT strikes the gas atoms, energising them. The excited atoms release invisible ultraviolet rays which bombard the phosphorus used in coating the tube. The Phosphorus absorbs these rays and radiates them as visible white light.

The charging section, which charges with about 0.65 A load current having a heat sink fixed on the IC LM 317 can recharge the battery and keeps it in good condition, while with the help of other components in the charging circuit, the battery is prevented from discharging during the downtime of the torch. Moreover, the self-wounded HVT can also be used to strike and run 8 watts, 12 volts other than the 6 watts, 12 volts fluorescent tube used in the work.

Additionally, if DEAMT is plugged into a power socket, the function of the power supply sensor (ZD) helps the user to know when the power supply (mains) is available during or in the darkness even if the illuminating system (bulb) is not ON. The torch conserved power usage from the battery compared to the recent solar-powered bulb that is always ON even in the daytime.

REFERENCES

Akinsanmi, O., Ganjang, A. D., & Ezea, H. U. (2015). Design and development of an automatic automobile headlight switching system. *International Journal of Engineering and Applied Sciences, 2*(8), 257837.

Aladeniyi, K., Aponjolosun, J. K., Eniafe, S. B., & Solanke, S. O. (2013). Automatic Household Electrical Lights Monitoring System. *IOSR Journal of Applied Physics, 4*, 54-58.

Bardeen, J., (1957). "Semiconductor research leading to the point-contact transistor", in Les Prix Nobel en 1956, edited

Choudhary, B. (2017). Study & Application of Bipolar Junction Transistor.

* Corresponding author email: babatunde.dada@elizadeuniversity.edu.ng

https://actionservicesgroup.com/blog/led-vs-fluorescent-tubes/

Hu, S.,Yu, S., Hu, Y., Wang, Z., Zhou, B., Cai, Z., & Guo, Y. (2018). A 0.2-6 GHz linear Darlington-cascode broadband power amplifier. *IEICE Electronics Express*, *15*(8), 20180298. https://doi.org/10.1587/elex.15.20180298

MAPLIN MAGAZINE. (2006), Maplin-Projects-Book-06 tube driver.

Merev, A., & Kalenderli, Ö. (2009). The construction of a DC high voltage precision divider. *Journal of Electrostatics*, *67*(5), 741-745.

Motayed, A., & Mohammad, S. N. (2001). Tuned performance of small-signal BJT Darlington pair. *Solid-State Electronics*, *45*(2), 369-371.

Pratik D. S.,Gaurav J. M. and Mahure K. P., (2019), Implementation of Automatic Street Light Control System, *IJRESM*, *2*, 643-645.

Wijesekara, R. T., Gunapala, S. D., & Premaratne, M. (2021). Darlington pair of quantum thermal transistors. *Physical Review B*, *104*(4), 045405.

Conflict of interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by us.

* Corresponding author email: babatunde.dada@elizadeuniversity.edu.ng