

Design and Implementation of an Automatic Street Light Control System

Isah Abdulazeez Watson¹, Oshomah Abdulai Braimah², Alexander Omoregie³

Department of Electrical/Electronic Engineering, Auchi Polytechnic, Auchi, Nigeria

Abstract-- This Paper discusses “The Design and Implementation of an automatic street light control system”. The project is based on UA741 operational amplifier which is configured as a Schmitt trigger and a light dependent resistor (LDR). During the day the LDR senses enough illumination and the security light goes OFF. And when darkness comes resistance of the LDR increases tremendously and causes the light to come “ON”. Also, a transistor switching a 12V Relay is deployed to provide the switching mechanism to activate the street lights connected in parallel. The need for manual operation of the security lights is completely eliminated and much energy is saved that would have been otherwise wasted if the user were to forget to power “OFF” the light at any point in time. This work was successfully designed, implemented and commissioned for use.

Keywords: Operational amplifier, Schmitt trigger, light dependent resistor (LDR)

I. INTRODUCTION

Street lighting is a key public service provided and sustained by public authorities at the local, state and even federal levels. Efficient lighting is paramount and vital for road safety, human safety and urban beautification. The first street lighting system was brought in to focus in the Arab Empire from the 9th to the 10th century in Cordoba, Spain and lamps filled with vegetable oil were used [1]. The oil lamps were operated by special slaves who have to ensure the oil is never exhausted in the lamps. Most street lights today are manually operated despite several street lighting control technologies that have been developed [3]. [2] Proposed a cost effective automated street lighting control system which depends on a microcontroller based intelligent management of the lamp posts activities of pedestrians, automotive traffic and ambient light conditions. [3] Developed a street light control system featuring two sensors-a light sensor and a photoelectric sensor, and uses a PIC microcontroller to operate the lamps.

[4] Proposed a Gsm-Based RFID approach to automatic street lighting system. In this paper, we have designed an automatic street light control system using a simple light dependent resistor (LDR). The system uses one sensor and does not require a microcontroller and as such it is simple but efficient in regulating the state of the street lights. The LDR and the 100K variable resistor form a voltage divider. When it is dark, the voltage across the variable resistor is small as most of the voltage is dropped across the LDR and as such the voltage across the inverting terminal (pin2) of UA 741 Operational Amplifier is lower than the reference voltage V_{ref} at the non-inverting terminal (pin3). The operational amplifier will produce a positive voltage of 12Volts at the output terminal (pin 6). The voltage is fed through a voltage divider network comprising R5 and R6 which drives the bipolar transistor, C945 to switch the Relay that activates the street lamps.

II. SYSTEM ANALYSIS AND DESIGN

This Automatic street light control system consists of four main units as shown in figure 1. These parts are discussed and elucidated as follows:

A. Power supply unit

The power supply consists of a 12V step down transformer, a bridge rectifier I.C, a 50V/2200uf capacitor and 12V voltage regulator. The step down transformer transforms the alternating current voltage from 220V to 12V a.c. The bridge rectifier I.C comprises of four rectifier diode internally and converts the a.c Voltage to d.c Voltage. The 50V/2000uf capacitor filters the output d.c voltage from the rectifier i.c in to a pure d.c Voltage while the 12V i.c voltage regulator ensures that the voltage is stabilized at 12Volts. Figure 2 shows the circuit of the power supply unit.

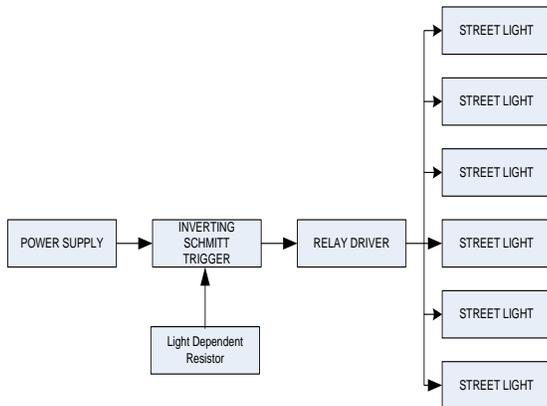


Figure 1: Block diagram of the circuit

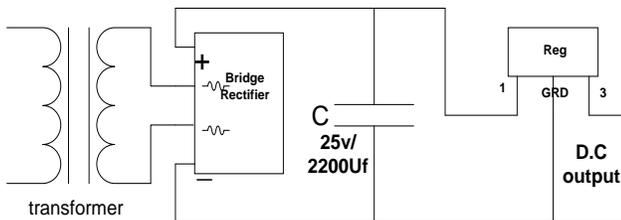


Figure 2.: power supply unit

The rectified output d.c voltage can be obtained as;

$$V_{dc} = \frac{(2V_m - 2V_a)}{\pi} \quad (1)$$

$$= \frac{(2 \times 12 - 2 \times 0.7)}{3.142} = \frac{22.6}{3.142} = 7.19V$$

Where V_m = Voltage from the secondary winding of transformer

V_a = Voltage drop across each diode

V_{dc} = Rectified d.c voltage

And $\pi = 3.142$

To determine the value of the capacitance, C we must consider the required ripple percent in the output d.c voltage. The capacitor must be able to withstand twice the d.c voltage to avoid been over stressed.

$V_{cap} = 1.5$ to 3times V_{peak}

$$V_{cap} = \frac{3 \times V_m}{2}$$

$V_m = 12V$ as read from the output of the step down transformer

$$V_{cap} = \frac{3 \times 12 \times 1.414}{2} = 25V$$

A capacitor of 25Volts rating was selected

The capacitance is derived from

$$V_r = \frac{I_{d.c}}{2fc} \quad , \text{ Where } V_r = \text{ripple voltage,}$$

$f =$ mains frequency = 50HZ

$C =$ capacitance,

$I_{d.c} =$ load current

Assume a maximum load current of 1Amps, therefore

$$V_r = \frac{1}{2 \times 50 \times C}$$

For a ripple factor of 5percent

$$0.05 = \frac{V_r}{V_{d.c}}$$

$$V_r = 0.05 \times 7.19V = 0.3595V$$

$$C = \frac{1}{2 \times 50 \times 0.3539} = \frac{1}{35.95} = 0.027816 = 27816 \mu f$$

We used 25000 μ f/ 25V capacitor

B. The light dependent resistor (LDR)

The light dependent resistor is a resistor whose value varies on exposure to light. When light falls on it, the resistance reduces and increases when exposed to darkness.

C. Inverting Schmitt Trigger With Reference Voltage

The circuit of the inverting Schmitt trigger uses a uA741 operational amplifier and a positive feedback provided by resistor, R_4 . Pin 2 of the Op-amp is the inverting input while Pin3 is the non-inverting input. Pin6 represents the output terminal while Pin 7 and Pin4 are for $+V_{CC}$ and $-V_{CC}$ respectively. A potential divider provided by R_2 and R_3 determine the reference voltage V_{ref} . The voltage at the non-inverting input terminal (V_+) is determined by V_{ref} and the output voltage, V_o . Figure 3. shows the circuit as described above.

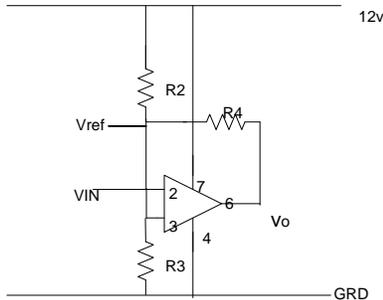


Figure 3: Non-inverting Schmitt trigger circuit

The Thevenine voltage $V_{th} = V_{ref}$ and is determined by setting $R_2 = R_3 = 10K$ and

$$V_{ref} = \frac{V_{CC} \times R_3}{R_2 + R_3} \quad (2)$$

$$V_{ref} = \frac{V_{CC} \times R_3}{R_2 + R_3} = \frac{12 \times 10k}{(10 + 10)k} = \frac{120k}{20k} = 6V$$

Thevenine resistance is

$$R_{TH} = \frac{R_2 \times R_3}{R_2 + R_3} \quad (3)$$

$$R_{TH} = \frac{R_2 \times R_3}{R_2 + R_3} = \frac{10 \times 10}{10 + 10} = \frac{100k}{20} = 5k\Omega$$

R_4 was determined from equation 3 after redrawing the circuit as shown in figure 4.

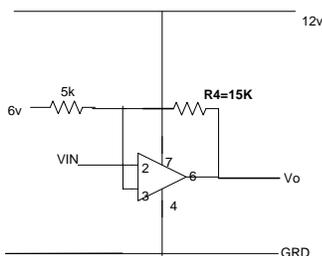


Figure 4: Non-inverting Schmitt trigger circuit re-drawn after thevenizing

The key to analyzing this positive feedback circuits is to assume an initial condition. The possible values that V_o can take are V_H and V_L , where $V_H > V_L$. Also assume that $V_L < 0$. By assuming that the initial state of V_o is V_H then,

$$V_+ = \frac{V_H R_2}{R_2 + R_4} \quad (4)$$

Note that R_2 is now $5k\Omega$ as shown in figure 4 and V_H is the initial output voltage before the switching of the Op. Amp and this is 12V. If we set the voltage at the non-inverting input at 3volts,

$$3 = \frac{12 \times 5k}{5k + R_4}$$

Therefore $R_4 = 15K$

$$\text{And the output is } V_o = A \left(\frac{V_H R_2}{R_2 + R_4} - V_{IN} \right) \quad (5)$$

D. Relay Driving Circuit

The Relay driving circuit is shown in figure 5. It comprises a voltage divider network R_5 , R_6 and a transistor T1. The output voltage from Pin 6 of the op-amp is passed through the voltage divider network to provide the required base bias for the transistor. Any voltage above 0.7v will switch the transistor which causes the Relay to get activated. The Relay on activation closes the normally opened contact while the normally closed contact is opened.

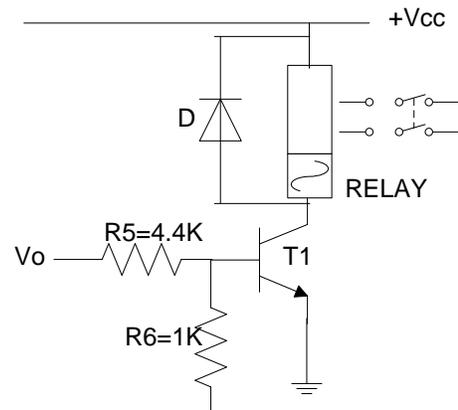


Figure 4: Relay driving circuit

The base voltage is driven by a voltage divider network R_5 and R_6 . Once the base voltage exceeds 0.7V the transistor will switch. We set the base voltage by selecting corresponding resistor values.

$$V_B = \frac{V_o \times R_6}{R_5 + R_6} \quad (6)$$

If $V_b=1.3$ volts and setting $R_5=4.4K$, we can determine R_6

$$V_b = 1.3 = \frac{12 \times R_6}{4.4K + R_6}$$

$$R_6 = \frac{5.72K}{10.7} = 0.535K\Omega$$

A resistor value of 1k was selected.

Figure 5 shows the complete schematic circuit of the Automatic security light controller.

E. Mode of operation of the circuit

The operation of the circuit is elucidated by considering the complete circuit diagram as shown in figure 5. The system utilizes an inverting Schmitt trigger circuit which relies on a light sensitive component called a light dependent resistor (LDR). The amount of light that falls on the LDR determines its resistance. The LDR and the 100K variable resistor form a voltage divider. When it is dark, the voltage across the variable resistor is small as most of the voltage is dropped across the LDR and as such the voltage across the inverting terminal (pin2) of UA 741 Operational Amplifier is lower than the reference voltage V_{ref} at the non-inverting terminal (pin3).

The operational amplifier will produce a positive voltage of 12Volts at the output terminal (pin 6). The voltage is fed through a voltage divider network comprising R_5 and R_6 which drives the bipolar transistor, C945 to switch the Relay. The Double Pole Double Throw (DPDT) Relay makes contact to switch “ON” the two security lights. A flywheel diode is connected across the Relay to protect the contact against “back-emf” generated by the magnetic field of the Relay coil. When light shines on the light dependent resistor, the resistance reduces depending on the amount of light and the voltage across the variable resistor increases. This voltage is applied to the inverting terminal (pin2) of the UA741 operational amplifier configured as a Schmitt trigger. This voltage is higher than the V_{ref} at the non-inverting terminal (pin3) and as such the operational amplifier will switch to ground and the Relay remains unswitched and the two security lights remain in the “OFF” state. The variable resistor is necessary to set the point of illumination at which the switching occurs. In this design, the variable resistor is set to cause the switching at between 0 to 50 lux. When illumination is anything above 50 lux the lights go “OFF” and below 50 lux the lights come “ON”.

III. RESULT

The result comprises the successful operation of the automatic street light control system. Figure 6 (a) shows a part of the sensor circuit on bread board. Figure 6 (b) shows the completed sensor circuit while (c) shows one of the lamps controlled by the circuit. The circuit is stationed in a suitable location that is exposed to sunlight so that immediately it is dark the system automatically switches “ON” the lamps and when it is dark or the illumination is above 50 lux the lamps are automatically switched “OFF”.

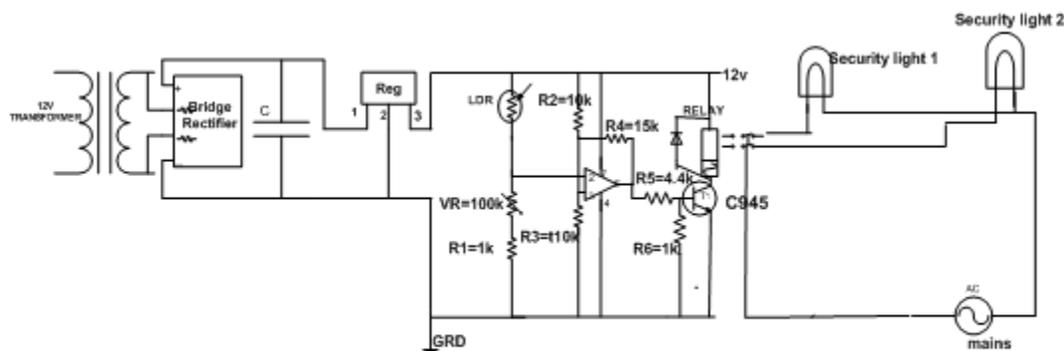


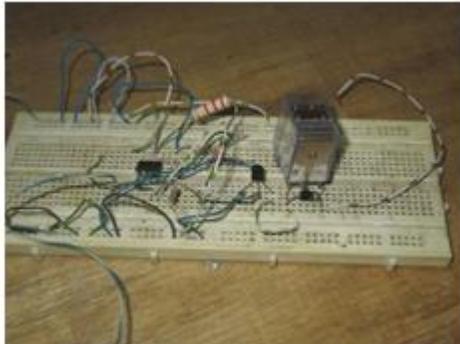
Figure 5: complete circuit diagram of an Automatic security lighting system

IV. CONCLUSION

This paper elucidates the design and implementation of an automatic street light control system. The design works efficiently to turn street lamps ON/OFF. The LDR sensor is the only sensor used in this circuit. The lamps will come “ON” immediately darkness falls and go “OFF” once the illumination exceed 50 lux. With this design, the drawback of the street light system using timer controller is overcome and human intervention is completely eliminated. By this energy consumption and cost are drastically reduced.

REFERENCES

- [1] Wikipedia, “History of Street light,” Available at http://en.wikipedia.org/wiki/street_light/
- [2] Jinwen zhu, Christopher Raison, “Cost Effective Street Lighting Control”, International Journal Of Electrical and Computer Engineering, Vol.4, No.4, pp.637-642, 2014.
- [3] Wazeed, M. A., Nafis, N., Islam, M. T., and Sayem, A. S. M. “Design and Fabrication of Automatic Street Light Control System”, Engineering e-Transaction, Vol. 5, No. 1, pp 27-34, 2010.
- [4] Rubanath, R., and Kavitha, T., “ GSM Based Rfid Approach To Automatic Street Lighting System”, Journal of Theoretical and Applied Information Technology, Vol.38, No.2, pp.202-205, 2012



(a)



(b)



(c)

Figure 6 (a): A part of the Sensor circuit during the bread-board stage, (b) the complete Sensor circuit (c) one of the lamps controlled by the circuit