DESIGN AND IMPLEMENTATION OF INTELLIGENT ENERGY-SAVING STREETLIGHT SYSTEM USING ONE SHOT PULSE GENERATOR

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Abstract: Street lights are very crucial devices that enable vision especially during dark hours. Electrical energy lighting makes up the largest part of power consumption in the world particularly through the use of lamps. These lamps are mainly controlled using ordinary switches that are manually operated. Most of these are left on by individuals which leads to wastage of electrical power and increase in payment of such services hence the need for efficient power management. This gave rise to the development of various lighting control technology to increase energy efficiency and minimise cost. This paper discusses an intelligent energy-saving streetlight which is capable of minimizing energy consumption to as low as 30% by switching on the lamps at specific periods. The design inculcates random logic with the LDR acting as input sensors installed at strategic points for maximum efficiency. For a very busy road at night, the vehicles light hitting the light dependent resistor consistently for 90 seconds will trigger the dim state of the streetlight. The streetlight remains in this state until the light dependent resistor stops receiving lights after a period of 60 seconds before the streetlight returns to a fully on state. The sequence of operation of the light is controlled by respective one-shot pulse generator while the switching is done by electromagnetic relays. The system was evaluated using light from car headlamp at full on state on the streetlight.The result of the evaluation shows that the system response minimizes the energy consumption of the street light.

Keywords: Energy-saving, intelligent, LCD, LDR, pulse generator, streetlight

Introduction

The energy crisis is one of the major problems that the world needs to resolve for sustainable economic development. Electrical energy lighting makes up the largest part of power consumption in the world particularly through the use of lamps (Matta *et al*., 2010). These lamps are mainly controlled using ordinary switches that are manually operated. Due to busy schedule and competitive world, human beings cannot spare time to perform their daily activities manually. This leads to wastage of electrical power and an increase in the payment for such services hence the need of some power management to save energy. The importance of electrical energy is increasing everyday with the impact of technological advancements (Gunturkun, 2003). Energy efficiency systems have thus been a subject of interest to many researchers. Many of these researchers have made great attempts in automating the energy efficiency systems to be independent of human support.

Street lighting provides a safe night time environment for all road users including pedestrian. Research indicates that night-time vehicular accidents are significantly reduced by provision of street lighting. It also helps to reduce the fear of crime, and encourages social inclusion by providing an environment in which people feel they can walk in hours of darkness. Providing street lighting is one of the most important and expensive responsibilities of a city. Lighting can account for 10-38% of the total energy bill in typical cities worldwide. Street lighting is a particularly critical concern for public authorities in developing countries because of its strategic importance for economic and social stability. Inefficient lighting wastes significant financial resources each year, and poor lighting creates unsafe conditions. Energy efficient technologies and design can cut street lighting costs dramatically (often by 25-60%).

The main consideration in the present field technologies are Automation, Power consumption and cost effectiveness. Automation is intended to reduce man power with the help of intelligent systems, while power saving is the main consideration using a light dependent resistor as a supporting device. Saving this power automatically instead of doing manual will reduce cost implication. This saved power can be used in some other cases. Most streetlight control systems are based on this traditional strategy in which readings of a sensor of the daylight of the environment are used to regulate the system, yielding an active streetlight depending on these set parameters. One challenge of this control strategy is that it regulates the daylight intensity at particular periods and does not take into consideration the energy savings that could be achieved. Research has shown that huge amount of energy is been expended and wasted in many strategic areas in operation of appliances such as streetlight due to the fact that it might remain in operation whether there is alternative light source or not. In view of the above, we have proposed the use of an automatic control system for a streetlight energy management that is different from the traditional control system, the proposed design makes use of daylight and car headlamps as control variable of the system instead of manual set-point , thus ensuring energy saving at all time. This technique also ensures that the streetlight works by the dictates of car headlamps, thereby making the streetlight operational only at instances when it is needed to satisfy the user's visibility requirement, and eliminating any excessive operation and waste of energy.

It has been reported that lighting consumes more than 2000 terawatt-hours of electricity globally and 48% of lighting electricity is attributed to the commercial sector (Rubinstein *et al*., 1997) while It is estimated that about 40% of the supplied energy is being wasted in Nigeria due to misuse of appliances such as streetlights whereas about 60% of Nigerian populace are without electricity (Atkinson, 1995). Various lighting control technologies have been developed for increased energy efficiency, including daylight harvesting, occupancy sensing and light level tuning. The most excellent way of reducing lighting energy wastes while enhancing lighting quality is through the use of controls. Lighting controls have shown to reduce lighting consumption by 50% in existing buildings and by at least 35% in new construction (RLW Analytics, 1999).

Hengyu *et al.* (2010) presented a street light controller system based on the AT89S52 microcontroller as the control core. The product combined the following technologies: a digital clock, a timer, an LCD, a statistics of traffic flowing

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magnitude, a photosensitive induction, an infrared control and alarm function. The system also included a time cut-out function and an automatic control pattern for even more electricity conserving, namely when vehicles passed by, the lights switched on automatically and later switched off. The system implemented traffic flow magnitude statistics without adding any hardware facilitating transportation condition and information collection. The system also had auto-alarm function which switched off if any light was damaged and showed the serial number of the damaged light, thus being easy to be located and replaced. The designed system uses random logic, thereby cutting off the need to program a microcontroller and reducing execution time.

Somasekhar and Umakanth (2014) presents the design and the implementation of a lighting system which is able to detect the approach of the visitors and then turn the lighting onto the normal intensity to let the large scale sectors be bright enough. All lights are equipped with the energy-saving function which will turn itself to the dimming level automatically after the visitors' leaving. PIR (Passive Infrared) sensors are utilized in the system instead of a video camera for the purpose of both cost-down and privacy issue. As it works with PIR sensor, no programming of timings and battery back-up is required. When the light focuses on PIR it sends signal to microcontroller, depending on that signal the lights will be turned off through relays and when PIR detects darkness the street lights will be automatically turned on. There is no need for manual controlling system. This is a simple and very useful system.

Adegoke *et al.* (2015) presented a robust intelligent energy saving system that will efficiently regulate power consumption for domestic use. In its implementation, a microcontroller and series of sensors (e.g PIR, LDR and temperature sensors) have been used to realize the set objective. The design work was initially simulated on an electronic simulator software 'PROTEUS' before being assembled on electronic breadboard and later transferred onto a PCB. When put into test, it was found to perform satisfactorily within expected limit of design.

Bai and Ku (2008) designed a system for light intensity detection and control using both microprocessor and light sensors. In this design, the home light control module (HLCM) made up of four blocks; the Passive Infrared (PIR) sensor circuit, microprocessor and radio frequency module was installed in every light fixture.Okomba *et al*. (2015) worked on the design and prototype implementation of an Arduino microcontroller based liquid crystal display (LCD) system that uses a light dependent resistor (LDR). The Arduino microcontroller was connected (hard-wired) to the pins of an LCD programmed to display a list of names continuously but one at a time. The developed system was tested and found to meet the required specifications.Tien-Shang and Chun-lin (2011) proposed a microprocessor based dimming controller with both analog and digital interfaces to control dimming ballasts through traditional toggleswitches. The dimming ballasts have high efficiency and contributes highly in energy saving.

Lee *et al.* (2006) surveyed various street light control systems and analyzed itscharacteristics. Through these efforts, they found that common drawbacks of most lightcontrol systems were uneasy of handling and difficulty of maintenance. To reduce uneasinesss of handling and difficulty of maintenance on operating light control system, they designed new street light control system by using the Zigbee communication technique.Yue *et al.* (2010) improved street lighting control computer system composition,working principle and function; it could meet the increasing demand of the different holidaysby different control strategies, and strengthen the relevant measures for energy-savingtechnologies, highlight

characteristics such as energy-saving, environmental-protection,controllable etc.Agogino *et al*. (2007) presented a lighting optimization approach for open plan offices capable of tuning lighting to each occupant‟s preference. Each luminaires was dynamically actuated at different levels to realize various lighting configurations without any physical rewiring.

Wayne and Steve (2007) studied digital systems and noted that they can perform the same lighting automation functions that independent, stand-alone systems perform. They can override the set schedule to match the changes in operating schedules and monitor occupancy patterns in an area and adjust the operation of the lighting system as required. Yandan *et al.* (2008) designed an intelligent lighting control system with adjustable illuminance, uniformity, correlated color temperature (CCT) and duration and transition of different modes, whose control strategy is based on ergonomic research. It is verified by ergonomic experiments (study of designing equipment and devices that fit human body, its movements and cognitive abilities) to be a suitable adjustable system to meet different situation of human needs. Jinsoo *et al.* (2008) proposed and designed an automatic standby power cutoff outlet and a zigbee controller with Infra-Red code learning functionality. The proposed power outlet monitored the power consumption for the predetermined time and completely cut off the power supply when the monitored power was below the threshold. Based on the zigbee controller, it plays a role of switches for the power outlet and dimming lights.

Ranjit *et al.* (2010) used an infrared door sensor based on electronic combinational logic circuit technology to develop an automatic light switching system. The system was developed with safety environment when switching `ON` or `OFF` the light during the room occupancy or unoccupancy. Apart from the safety environment, it also comprises manual switching in case user needs to have light during the day. Haskew *et al.* (2010) proposed an optimal control strategy for a high voltage dc light system using a direct current vector control method for different HVdc control requirements, such as active power, reactive power and grid voltage support control. A limitation of the conventional control mechanism was analyzed through a theoretical study and computer simulation. In this study, closed-loop control evaluation demonstrated that the proposed approach works well for HVdc light system control both within and beyond the physical constraints of the system, such as rated power and saturation of pulse width modulation (PWM). The evaluation showed that the conventional control technique could result in over-voltage and system oscillation.

Changhong *et al.* (2010) designed a smart streetlamp controller with dual functions including timing control and automatic photoelectric control. The waste of energy is a result of inefficient use of the electrical energy consumed by artificial light devices such as light bulbs. Matta *et al*., (2010) presented a system for saving electrical energy by controlling the intensity of artificial light to a satisfactory level was designed and took into account the use of the day light when possible with the best effort for energy saving. An improvement to daylight harvesting and controlled dimming systems was introduced while counting for over illumination cases. The idea behind was to count the venetian blinds or curtains in such a way to make use of the daylight if available. Otherwise it uses the artificial internal building light.

In this traditional control strategy, the streetlight activation is supplied manually via a remote control unit. The system applying traditional control method also senses the environmental visibility and regulates the streetlight using it. In this case, streetlight operates continuously until the system is turned off, which poses a challenge of electric power

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wastage, which we want to address. The proposed system allowed street lamps to be automatically lit in the evening for a very busy road the vehicles light hitting the light dependent resistor consistently for 90 seconds will trigger the dim state of the streetlight. The streetlight remains in this state until the light dependent resistor stops receiving lights after a period of 60 seconds before the streetlight returns to a fully on state.

Materials and Methods
The street light control systempresented by Hengyu *et al.* (2010) is based on the AT89S52 microcontroller as the control core which is programmed to manage the entire system activities on its program execution. The response time of the program execution is quite slow and a limitation compared to hardwired random logic. This research is aimed at designing and implementation of a random logic based energy saving street light system. To achieve this, sensors that produced digital output on light sensing techniques were employed.This method encompasses ordered steps in form of sensing organ that senses the daylight, an approaching car headlamp and the control device that implement control strategy's based on this sensed variable. The streetlight sensor is expected to sense the instantaneous value of the car headlamps continuously for a period of 90 seconds and automatically dims the streetlight and switches to a one shot pulse generator which allows the light dimming to last for a time frame of 60 seconds after the vehicle headlamps seizes to hit on the sensors and return back to full light state. The system automatically triggers the streetlight on during the night and off during the day. Modular approach of design has been adopted in this work so as to simplify it. The design is broken down into five (5) major subunits as shown in the functional block diagram of the system in Fig. 1; namely, the power supply unit, the day/night control unit, the headlamp sensing unit, transistor static switchesand the resetting unit
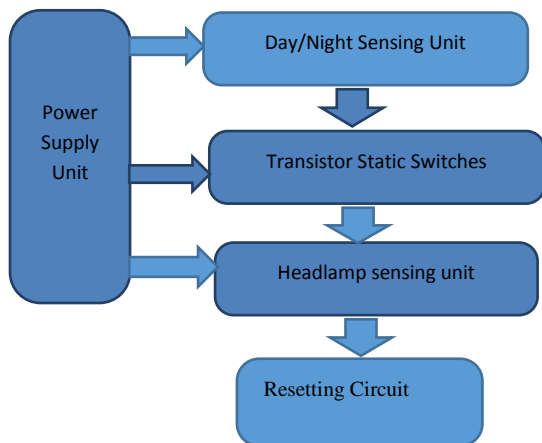

Fig. 1: System block diagram

A. Power circuit unit

The power circuit unit serves as the only power source for the entire system. The power supply unit provides of +5V, by converting 240V of the wall plug to a value, which is required by the microcontroller unit and other circuitry in the design. The power circuit unit consists of Step down transformer, Rectifier circuit, Filter circuit, Voltage regulator and an isolating capacitor shown in Fig. 2. The transformer is 230 V/12V step down transformer. This 12V AC supply from the transformer is converted by the rectifier into direct current (DC) voltage. The output of the rectifier is smoothened of its ripples by a 4700 µF capacitor while the 7805 regulator is used to regulate the output voltage to a fixed value of +5V. To isolate the final output voltage from any noise and further ensure more filtration of the output +5V, a100 µF Capacitor is
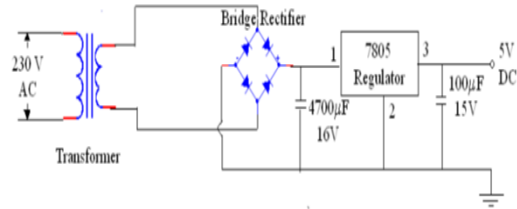
added.

Fig. 2: Power circuit unit (circuitstune.com)

B. The day/night sensing unit

This unit is responsible for the intelligent feature of this project. It makes sure the streetlights are only switched ON at night and OFF in the day time automatically. The circuit of the day/night sensing unit is shown in Fig. 3.
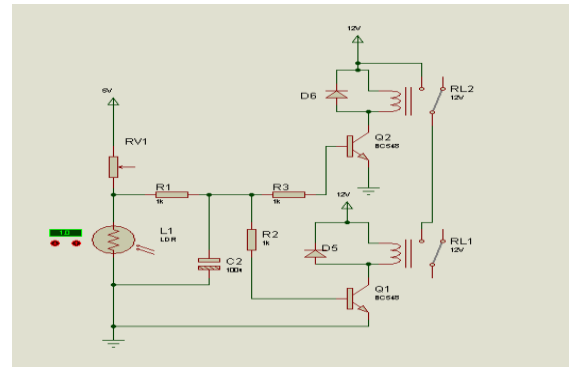

Fig. 3: Circuit of the day/night control unit

The variable resistor Rv_1 and LDR L_1 formed a voltage divider network for the circuit which determines the logic input of the circuit at a particular period of time. Resistor R_1 and capacitor C_2 form an RC network to prevent flickering or circuit bounce. R_2 and R_3 are current limiting resistors for transistor Q_1 and Q_2 respectively, while RL_1 and RL_2 are electromagnetic relays that switches the streetlights from off to on state and vice versa for day and night periods, respectively. Diode D_5 and D_6 are connected in a reverse bias to relay RL_1 and RL_2, respectively to prevent backward flow of current in the relays. This circuit unit is powered with a 5V whiles the relays operate with a 12V, all being supplied directly from the power supply unit.

C. Transistor static switch

Transistor switches are used for a wide variety of applications such as interfacing large current or high voltage devices like motors, relays or lamps to low voltage digital logic IC's or gates like AND gates or OR gates. Here, the output from a digital logic gate is only +5v but the device to be controlled may require a 12 or even 24 volts supply. Or the load such as a DC Motor may need to have its speed controlled using a series of pulses (Pulse Width Modulation). Transistor switches will allow us to do this faster and more easily than with conventional mechanical switches. Fig. 4shows a transistor used as a simple electronic switch or digital inverter. Its base is driven (via R_b) by a digital input that is at either zero volts or at a positive value, and load R_L is connected between the collector and the positive supply rail. When the input voltage is zero, the transistor is cut off and zero current flows through the load, so the full supply voltage appears between the collector and emitter. When the input is high, the transistor switch is driven fully on (saturated) and maximum current flows in the load, and only a few hundred millivolts are developed between the collector and emitter. The output voltage is thus an inverted form of the input signal
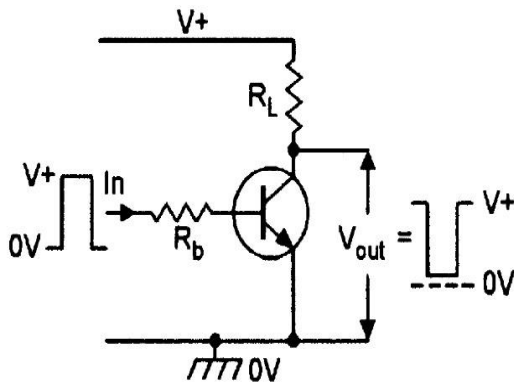
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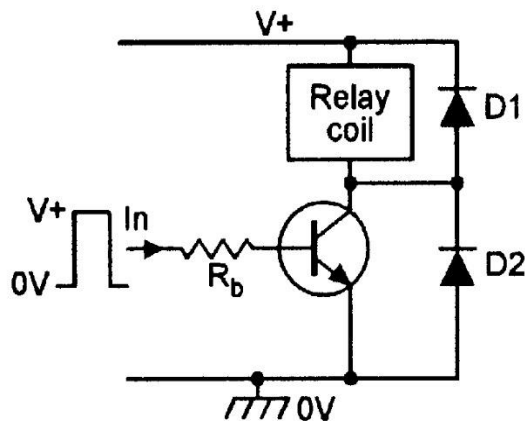**Fig. 4: Transistor switch (nutsvolts.com)**

Fig. 5: Transistor switch driving a relay coil (nutsvolts.com)

The basic Fig. 4 circuit is intended for use as a simple digital switch or inverter, driving a purely resistive load. It can be used as an electronic switch that drives a relay coil or other highly inductive load (such as a DC motor) by connecting it as shown in Fig. 5, in which diodes D1 and D2 protect the transistor from high-value switch-off-induced back EMFs from the inductive load at the moment of power switch-off.

D. Head lamp sensing unit
A headlamp sensing circuit is developed such that when this circuit senses light from a vehicle headlamp, it thereafter activates the sensing unit, and takes care of the dimming of the streetlights. The headlamp sensing circuit is shown in Fig. 6.
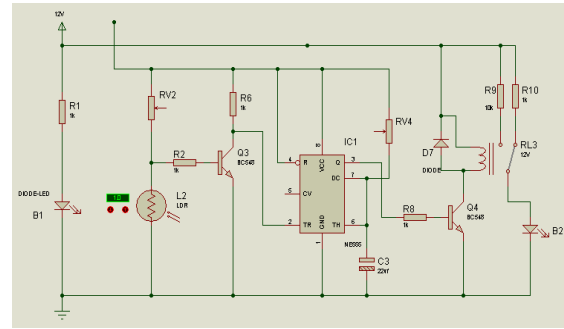

Fig. 6: The headlamp sensing unit

A voltage divider network is formed using a variable resistor Rv_2 and an LDR L_2 to determine the input logic to be fed to transistor Q_3 at any given time. IC_1 is a Ne555 timer configured in mono-stable mode to generate a one shot pulse (delay) for the lights. This delay for each light is simply the time range each light spends in its dim state before returning back to its bright state. To actualize this required delay, the capacitor C_3 with a capacitance of 22 uf and a variable resistor Rv_4 is connected between the pin 6 and pin 7 of the Ne555 timer IC1. This variable resistor was later adjusted to obtain the required delay.

E. The resetting circuit
As a vehicle passes any of the lights, it dims, delays for a few set seconds, then returns to its original bright state. This process continues for all the lights as the vehicle passes. Now, assuming another vehicle is set to use the road after the first one has left, there is need to reset all the lights to the original state to get them ready to sense the next incoming vehicle. To achieve this, the circuit of the last light is built to have a resetting feature. Hence, the resetting circuit acts as a feedback to the headlamp unit and the vehicle sensing unit. In design, the resetting circuit is much similar to the vehicle sensing circuit, but in resetting circuit, a connection is made from the output of the first transistor to the pin 4 (the resetting pin) of the Ne555 timer IC_2. When a vehicle light passes after a period of 60 seconds, the logic 0 which is fed into pin 2 as input to the Ne555 timer also returns to the pin 4 of the Ne555 timer IC_2 in the headlamp unit, and resets it, thereby de-energizing the relay RL_4 which in turn returns all the lamps to their original bright state.

Implementation and Results
The system design and implementation of intelligent energy-saving streetlight is realized in different functional modules, all combined/cascaded to form one functional system. On plugging the system to the MAINS, the voltage is stepped down to 12V by the step-down transformer. This voltage is rectified by the bridge rectifier which consists of four (4) IN4007 diodes D1, D2, D3 and D4. This voltage is further filtered using a 3300uf capacitor to remove any ripples in the voltage signal. Then, two different regulators are used, a 7812 to provide a +12V for the relays and a 7805 for supplying a +5V to other parts of the circuit. The complete circuit diagram for the system is shown in Fig. 7.
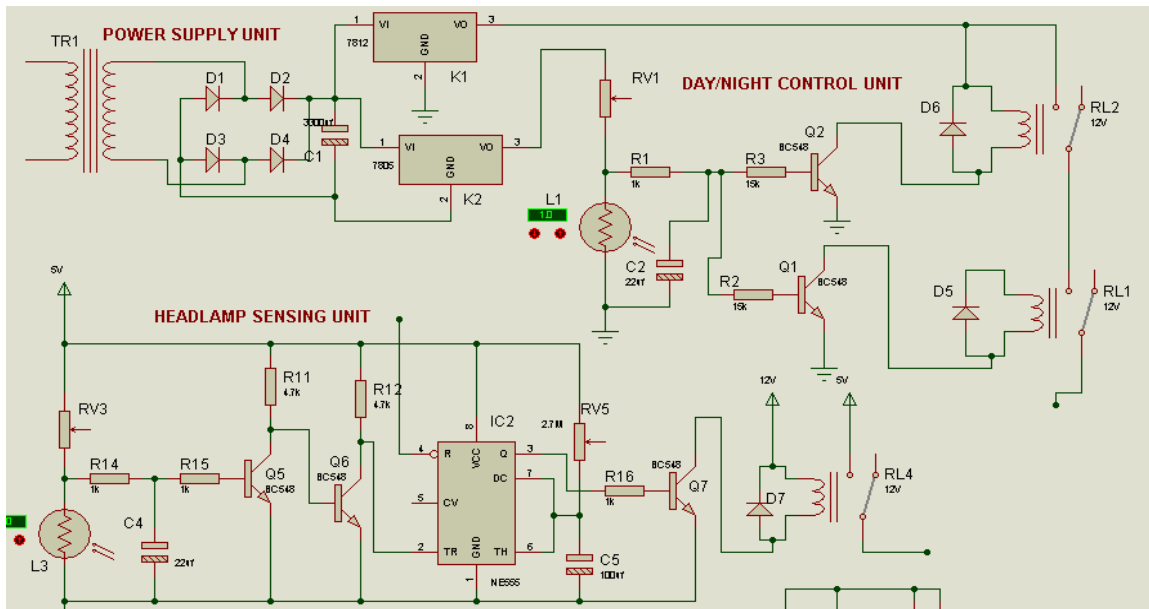
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Fig. 7: The complete circuit diagram of the system

The construction of the system is carried out in different phases according to the circuit diagram. Firstly, the components were assembled and tested to ensure they are in good working condition, using digital multimeter (DMM) set to the appropriate point. *The power supply unit* consist of a transformer that steps down the voltage from 220/240V to 12V, four (4) diodes D_1, D_2, D_3 an D_4 connected in bridge to rectify the 12V voltage, a 3300 uf capacitor for filtering the signal and two regulators 7805 and 7812 to output a +5V and +12V for use by the system. *The day/night control module has* the light dependent resistor (L_1) connected from GND, through a variable resistor to Vcc (5V). In between the sensor and preset resistor, the transistors Q_1 and Q_2 are biased through 1K resistors. Two electromagnetic relays are interfaced to the collectors of the transistors to enable switching ON and OFF the system in the day and night hours, respectively. The headlamp sensor is connected in the same manner like the daytime sensor using L_3 as the light dependent resistor. The voltage divider formed with 1mega-ohms pre-set resistor is wired to the base of a transistor static switch whose collectoris connected to pin 2 one-shot pulse generators. Pin 3 of this one-shot is connected to another transistor Q_7 that energizes the relay. This relay is meant to switch the lamps (light) from fully-ON state to dim state.

The newly applied control strategy for the streetlight control using car headlamps for signal inputs as described in the methodology was designed using light dependent resistors and power up one shot design for circuit development and it is as presented in Fig. 7. The design consists of all the circuitries as earlier described. The design exercise of this work utilizes the circuit diagram development.Hardware prototype of the units ware developed in one casing using breadboard component mounting and pins' jump-wire interconnections. The basic principle of this device is that when light falls on LDR electrons jumps from valance band to conduction band and the value of resistance decreases, and in darkness the value increases as the gap between valance band and conduction increases; and when there appears a current flow in base of BJT connected to LED, the circuit completes and LED starts glowingThe prototype of the controller based design of this work is presented in Fig. 8, showing the residents hands on the table where the sensors are placed.
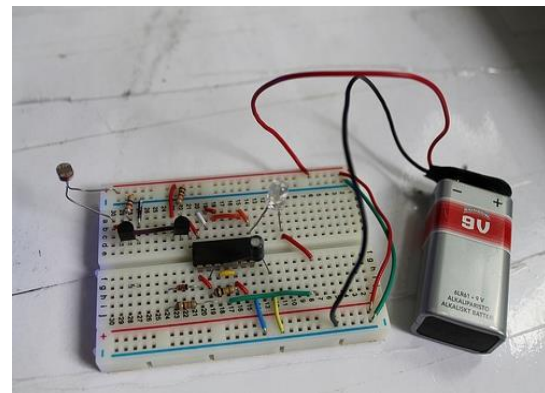

Fig. 8: The prototype of intelligent energy saving streetlight

In order to evaluate the performance of the system and ascertain its responses speed to changes in car headlamp or daylight condition, the light emitting diode output signal at different environmental and car headlamp conditions were sampled. The readings were classified as full headlamp, dimmed headlamp, no light, daylight and night intervals, which was obtained by subjecting the system headlamp sensing unit to some rigorous activity to increase, reduce and minus light intensity on the light dependent resistor. The results obtained are presented in Table 1.

Table 1: System performance

Inputs	Sensor State LED	Dim state LED	LED state
Full headlamp	1	1	1
Dimmed headlamp	0	0	0
No light	0	0	0
Daylight	1	0	1
Night	1	0	0

The system is tested by observing the performance of light emitting diode (LED) indicators to specify the on and off state in case of daylight or consisted full light car headlamp. The automatic control of the streetlight diming process is tested by

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observing the LED indicator at its on and off state, were the LED comes on when the headlamp sensor receives adequate light from a car headlamp and off otherwise.

Conclusion

The intelligentenergy saving street lighting system is developed and successfully implemented using light dependent resistors, transistor switches and an Ne555 timer that generate one pulse shot delay. From the design and implementation, around 77% - 85% of power consumption can be reduced by using this system. The minimum components produce better saving in terms of cost and its automatic activation eliminates the manual process of powering on the streetlight. The random logic hardwired electronic circuitry eliminates the time constraint in designing with programmable microcontrollers. The streetlights transit from fully-ON to Dim state and back to fully-ON after a while. The daytime sensor and headlamp sensor were working as expected. The system is powered by a regulated 12V dc power supply unit.

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