

CONSTRUCTION OF AN INTELLIGENT AND EFFICIENT LIGHT CONTROL SYSTEM

USIKALU MOJISOLA R, SHITTU ANUOLUWAPO. H &
OBAFEMI LEKE. N

Department of Physics, Covenant University, Ota, Ogun, Nigeria

ABSTRACT

A Lighting control system is an intelligent connection of lighting that controls the amount of light in a given space. It provides interaction between systems in order to regulate light. It is mostly used in public buildings in order to save energy maximally from the lighting system, to satisfy codes of buildings. The problem of expensive cost in the lighting system, increase in energy consumption bills and energy wastage led to the introduction of smart lighting. Therefore, an intelligent and efficient light control system that saves energy and cost of energy consumption of light in our day to day activities for rooms was assembled. Passive infrared sensor combined with the light dependent resistor was used to control the luminous intensity of LED from the comparator (ATMEGA328) comparing the values gotten from the two sensors as input such that when the value of luminous intensity gotten from the light dependent resistor is higher than the required intensity, then the LED remains off and when the value of luminous intensity gotten from the light dependent resistor is lower than the required intensity, the LED supplies light that will make up for the missing intensity. It was deduced that, as the intensity of light increases, the resistance of the light dependent resistor decreases. It was also observed that the luminous intensity increases as the time of the day increase i.e. as the laboratory light intensity decreased. Thus, the system function efficiently as the energy was considerably conserved.

KEYWORDS: *Efficient, Light Control, LED, Energy Saving & Light Dependent Resistor*

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1. INTRODUCTION

Light is very important in our daily activity. Light is the brightness that comes naturally from the sun or artificially from electrical devices, and that allows things to be seen. Light is the natural agent that stimulates sight and makes things visible. It is connected with our daily activities such as reading, working etc. Proper lighting improves the beauty of indoor space and provides illumination for tasks and activities to be done. It also ensures safety. The invention of electric lighting has revolutionized the way we perform various activities, how we live and how we carry out various aspects of social life. An efficient lighting strategy provides a proper level of illumination and also reduces the cost of energy (Aniruddha *et al.*, 2017; Nwoye *et al.*, 2017). Thirty percent (30%) of European total energy consumption is on lighting only (European Commission, 2012). The evolution of the new lighting system will help the energy efficiency in the European country. The Energy Information Administration (EIA, 2018) in the US reported that the cost of electricity for lighting in public buildings like banks, schools etc. tripled the cost of electricity for ventilation.

The Chartered Institution of Building Services Engineering (CIBSE) stated that the intensity of light required for a good environment to work comfortably is different in various areas. With the proper control system,

both artificial lightings and natural illumination can be used in order to reduce the energy consumption. Researchers have reported some research efforts on effective light control framework using Passive Infrared Sensor drives the circuit to recognize luminance (Jingwei and Ziqi, 2014; Nwoye *et al.*, 2017). Sindhu *et al.* (2016) used Arduino to design light controlled system and observed that there is a decrease in energy measure when streetlight was off when there is no vehicular movement. Arun and Vuttaradi (2013) used Light Dependent Resistor (LDR) to control streetlight to show a day/evening and the photoelectric sensors to identify day and night for the development in the city. Ying-Wen and Yi-Te (2008) utilized a robotization automatic idea to control the lights in the house.

Electricity is getting more expensive and neither is the consumption reducing but increasing. In order to reduce the consumption of electricity in building especially public buildings, there is a need for an effective lighting system. Artificial lighting contributed immensely to the electrical energy consumption worldwide. One of the problems is the erratic supply of light in Nigeria so power is gotten from diesel or petrol generators which call for the reduction of the consumption rate of electricity in buildings especially public buildings (Ayara *et al.*, 2017). Providing light into an already bright room leads to over-illumination which brings about waste of energy and an increase in the cost of electricity bills. In a situation due to rushing, the light in the house may not be switched off. The introduction of the intelligent and efficient lighting system to the world has made things easier. It has helped in the reduction of waste of energy. This system will help us to keep the working environment in a pleasant and comfortable manner. An efficient and intelligent lighting system will be needed in public buildings to help in saving up to 40% energy consumption for lighting. It helps also in the reduction of the emission of global carbon oxide (CO₂) to a substantial amount, the lower the CO₂ the healthier the environment and the populace (Usikalu, 2009; Akinyemi and Usikalu, 2011; Akinyemi *et al.*, 2016). Hence, there is a need to design an efficient and intelligent lighting system that uses the daylighting of the room and an automatic occupancy system to shut-off when nobody is inside the room. Figure 1 shows the block diagram of the proposed system and how it can be implemented.

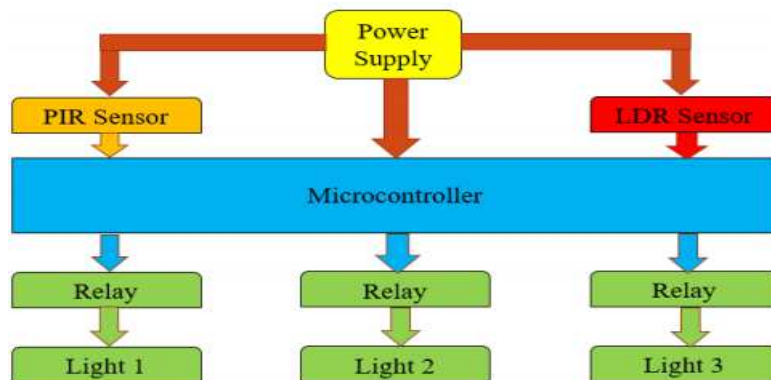


Figure 1: Block Diagram of the Efficient Lighting System
(Modified after, Jingwei and Ziqi, 2014)

2. BASIC THEORY

Several essential parts are required for the implementation of this project. It is thereby divided into several subprojects so as to make the testing, troubleshooting, and implementation of the whole system easy. It will be described briefly under the following parts namely: Passive infrared sensor, light dependent transistor, Microcontroller (Arduino Uno), Relay.

2.1. Passive Infrared Sensor

A passive infrared sensor (parallax 555-28027) is an electronic sensor. It measures infrared light from objects in its field of view. It detects the infra-red radiation from people within its range such that in the presence of a human body an output of high voltage drives the comparator to start working. A passive infrared sensor is used to sense motion in the room. The passive infrared sensor has three pins: the GND is the ground of the sensor and it is connected to the ground, the V_{cc} is the voltage supply which ranges from 3.3 V to 6 V and the OUT is the output terminal. The output of a PIR is similar to the voltage supply such that it is HIGH (1) when motion is detected and LOW (0) when motion is undetected. The human body radiates infrared of 12 μm to 15 μm wavelength so the PIR reacts in the wavelength between 5.5 μm to 14 μm . The size of objects, the thermal objects around, the environment condition like ambient light and light source can affect a passive infrared sensor. The PIR sensor has a jumper on-board that allows the user to choose between normal operation and reduced sensitivity. In the reduced sensitivity mode, the PIR detects object half the distance (i.e. 15 feet) and 30 feet normal mode. The range of a PIR sensor is affected by the sensitivity of the jumper, the size and heat properties of the object in view, ambient temperature and light source (Kadman *et al.*, 2016; Somaesekhar and Umakanth, 2014).

2.2. Light Dependent Sensor

A light dependent resistor is a type of light sensor. It is made from an exposed piece of a semiconductor-like cadmium sulphide that changes resistance to electrical current from several thousand ohms in the absence of light to hundred ohms when light falls on it thereby creating hole-electron pairs that allow the flow of current in the material. This light-dependent resistor has a spectral response of about 610 nm in the yellow to orange region of light. In Figure 2, it is shown that the light dependent resistor is made up of two terminals and one cadmium sulfide track. When light falls on the light dependent resistor, the light energy triggers the release of carriers of extra charge on the track, thus, there is a fall in the resistance and an increase in the level of illumination. LDR is made up of photosensitive semi-conductive material such that when light falls on the material, there is an absorption of energy which excites the electrons and thus frees them. The free electrons carry electricity and therefore the internal resistance decreases. The more electricity, the lower the internal resistance. In the absence of light, the resistance to light is very high (1 M Ω) thereby the level of illumination is decreased rapidly. When there is an absence of light, the electrons are not excited so they do not carry electricity thereby increasing the internal resistance. The light dependent resistor when active will determine the level of lighting in the room when compared to the reference lighting for the room by the comparator which is the microcontroller. The light dependent resistor (LDR) can sense the variation of the illumination intensity, as its internal resistance change linearly with the intensity of light (Usikalu *et al.*, 2011). The output voltage of the circuit was determined using equation 1.

$$V_o = \frac{R_{LDR}}{R_{LDR} + R} \times V_{in} \quad (1)$$

where V_o is the output voltage, R_{LDR} is the resistance of the light dependent resistor, R is the reference light, V_{IN} is the input voltage

2.3. Relay

An SRD-05VDC-SL-C relay is a switch that is operated electrically. It is used to control a circuit using a separate low-power signal or in several circuits that is controlled by one signal. The state of a relay can be controlled using three of the connections and they are DC+: positive electrode. It is connected to 5 V power supply; DC-: negative electrode. It is

connected to the GND; IN: this is the signal connection used to control the relay. The SRD-05VDC-SL-C relay has six pins which are: normally closed (NC), common pin (C), normally open (NO), a ground pin, 5 V pin which is also known as V_{cc} and the signal pin which is connected to the microcontroller in order to control the relay. A relay can be connected in three ways: NC (Normally Close): in this mode of connection, the COM is connected to the NC when there is no trigger in the relay; NO (Normally Open): when NO is connected to the COM, there is a trigger in the relay and COM (Common Connection): this is connected to the power supply. Using a direct current (DC), the COM is connected to the positive of the power supply while using an alternating current (AC), the COM is connected to the hot wire.

2.4. Microcontroller

On the microcontroller board is the ATMEGA328 datasheet. The Arduino Uno board in this project acts as the comparator. It works in such a way that the value of the ambient light given by the light dependent resistor is compared to the reference light so as to determine the luminous intensity of the light given as the output. It has three main categories of the pins on an Arduino Board which are the Digital pins, Analog pins, and the Power pins as shown in Figure 2.

Digital pins

Pins 0 and 1: 0(RX) and 1(TX): Serial I/O (input and output); receives (RX) and transmits (TX) serial data.

Pins 2 and 3: External interrupts. Using the attach interrupt() command function, these pins are programmed to trigger an interruption in a low value or a change in value.

Pins 3-11: PWM; using the analogWrite() command function they provide 8-bit PWM output.

Pin 7: BT reset. This function works only with the BT-Arduino and serves as a connection between the Arduino BT and the Bluetooth module.

Pins 10-13: These pins support Serial Peripheral Interface (SPI) communication.

Pin 13: LED; On the Arduino Diecimila and the LilyPad, there is an onboard LED connected to this pin. At HIGH value, the LED comes on and at a LOW value, the LED is switched off.

Also, digital pins can be used for general purpose input and output using the pinMode(), digitalRead() and digitalWrite() command functions. The maximum current per pin is 40mA and each pin has an internal resistor that can be switched off or on using digitalWrite() if that pin is particularly configured to function as an input.

Analog Pins

Using the analogRead() command function, analog pins aid 10-bit ADC (analog-to-digital) conversions. Most analog inputs can also function as digital pins. Some pins support I²C communications (specifically pins 2 and 3). They serve as input into the Arduino.

Power Pins

VIN (9 V): The input voltage to the board when this is coming from an external power source that is not from the USB connection; A 5 V which is a regulated power supply. It powers the microcontroller board and its components; A 3.3 V power supply from the FTDI chip. It is used only in Arduino Deceimilia; GND which are the ground pins and the Reset pin.

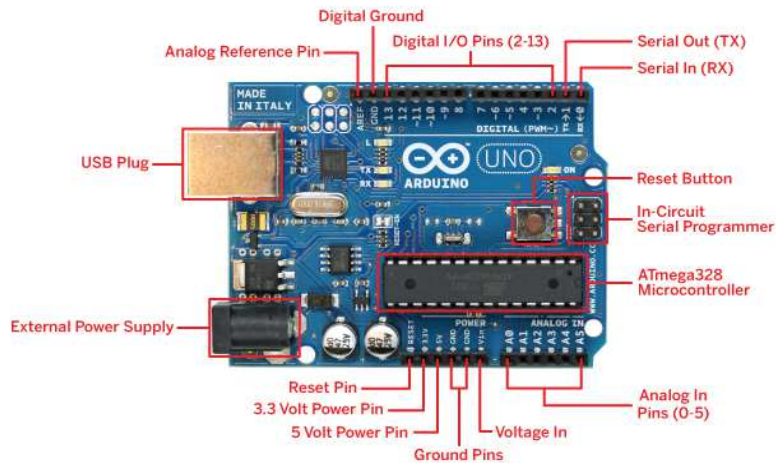


Figure 2: Diagram Showing the Layout and Pins of the Arduino Board

3. CIRCUIT DESIGN

This involves the placing of the components together on the board so as to simulate the circuit as shown in the flow diagram in Figure 3. One leg of the light dependent resistor is connected to the V_{cc} of the Arduino (i.e. the 5 V of the Arduino). The other leg of the light dependent resistor is connected to the A4 pin of Arduino and to one leg of the 10k resistor. The empty leg of the resistor was connected to the GND of the Arduino. The PIR sensor has three pins: V_{CC} , GND, OUT. The PIR sensor is powered by connecting the voltage pin V_{cc} to 5v of the Arduino. The output pin of the PIR sensor is connected to the 8th digital pin of the Arduino and the GND of the PIR sensor to the GND of the Arduino. A relay is connected to control alternating current light since the Arduino cannot control voltage that is high. In connecting the relay to the system, a Normally Closed connection of the relay mode was used. The output pin of the relay is connected to the 8th digital pin of the Arduino Uno while the GND of the relay is wired to the GND of the Arduino and the voltage pin of the relay to the voltage pin of the Arduino.

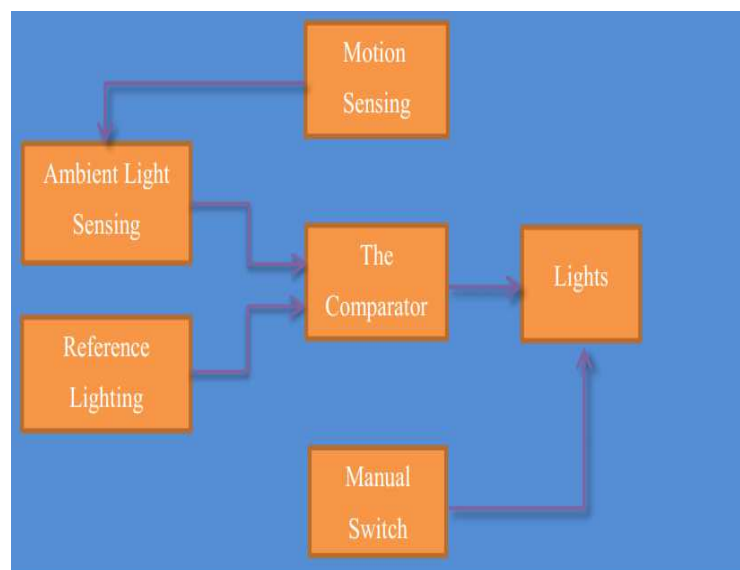


Figure 3: Flow Chart of the Light Efficient System

4. RESULTS AND DISCUSSIONS

Having completed the coupling of the system, it was tested to ascertain the functionality of the system. The compilation of the hardware and the software was done successfully as it gave a very good result. Figure 4 was the picture of the system obtained in the absence of the human body in the room and Figure 5 was obtained when there is a presence of human body but not enough luminous intensity in the room during the day. Figure 6 was obtained in the presence of human body but there is no sufficient light in the room during the day and Figure 7 displayed the system at night such that there is no daylight at all. Table 1 is the measured luminous intensity of the light dependent resistor and the measured resistance of the light dependent resistor at the different time of the day. It was deduced that, as the intensity of light increases, the resistance of the light dependent resistor decreases. It is also observed that the luminous intensity increases as the time of the day increases. The observation in Figure 8 is in consonance with the report of Nwoye *et al.*, (2017) and Jingwei and Ziqi, (2014), the resistance decrease with the rise to the intensity of light that falls on the light dependent resistor.

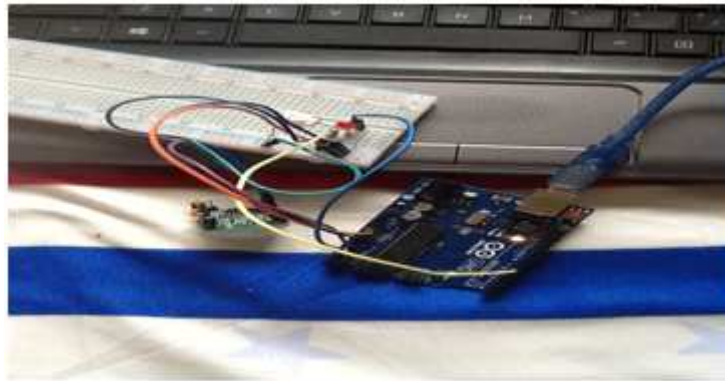


Figure 4: Circuit in the Absence of the Human Bod

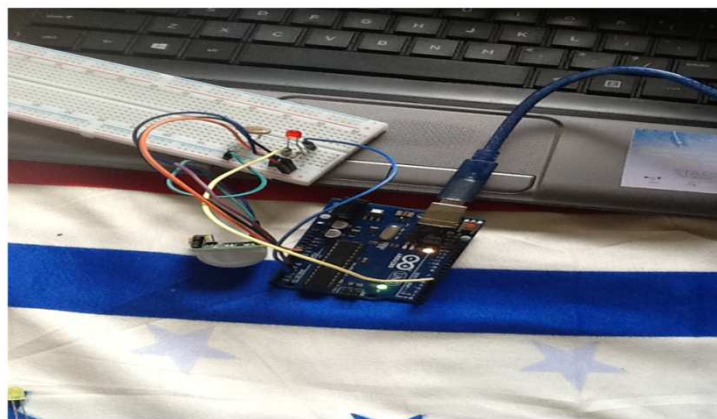


Figure 5: Circuit in the Presence of the Human Body with Sufficient Luminous Intensity

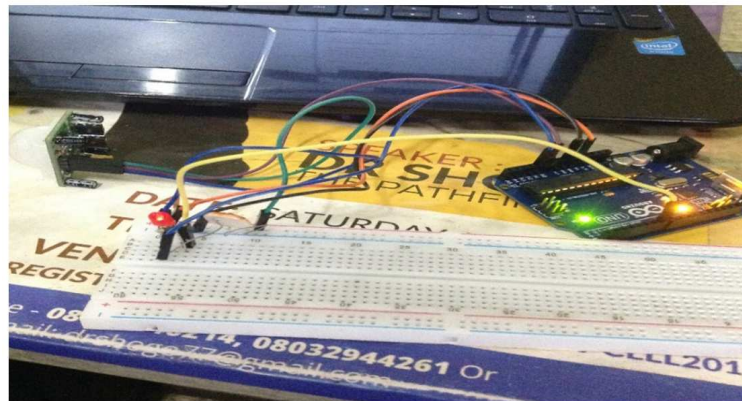


Figure 6: The Circuit in the Presence of the Human Body with Insufficient Luminous Intensity

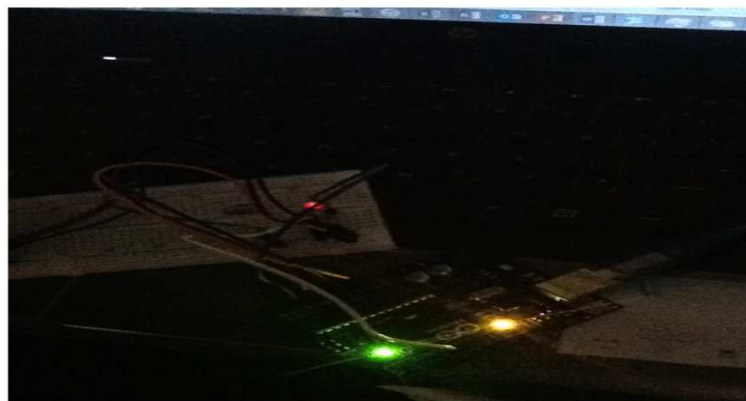


Figure 7: Circuit in the Presence of the Human Body with No Luminous Intensity at Night Time

Table 1: Mean Luminance and Resistance of a Light Dependent Resistor at the Different Time of the Day

Luminous Intensity (lux)	Resistance (K Ω)	Time of the Day (AM/PM)
7	100	11:30 AM
60	50	7:30 AM
110	30	2:30 PM
247	10	10:30 PM

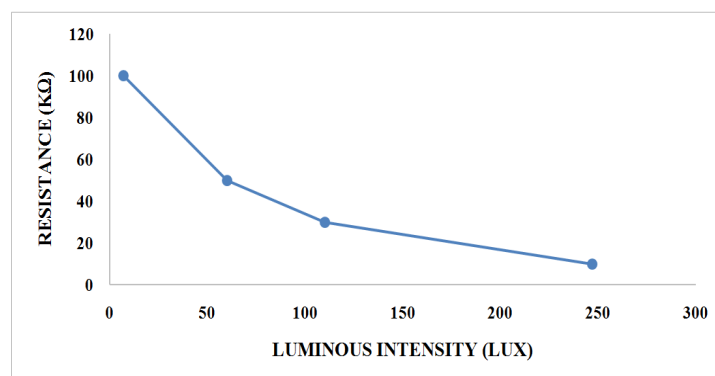


Figure 8: Variation of Resistance with Luminous Intensity

5. CONCLUSIONS

Smart light system was developed which used a motion sensor to detect the presence of human body, a light dependent resistor that sense the luminous intensity in the room, a microcontroller (Arduino Uno) that takes in the value of the motion sensor and the value of the intensity of light detected by the light sensor and compare it to the required intensity of light in the room so as to give an output as programmed in the microcontroller. This project has shown how to minimize the use of electricity and it also successfully controlled the brightness of light according to its environment and surroundings. Thus, implementing the intelligent and efficient light has helped to avoid wastage and minimize the cost of electricity. Future research is recommended by implementing the system in a real environment not just for a room. Also, research can be done by adding other functions in order to control other electrical appliances like the fan, air conditioner etc. in the room.

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