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Construction of Sensor Based Human Detector for Lighting Purpose on the Stair Case

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Abstract:
Energy wastage is not ideal in our society because it increases electricity cost and even increase the means of maintaining electricity production. Most frequently, power wastage occurs through the bulbs fitted on the stair case in homes because its light is always ON even when not used. This constant light on the stair case increases electricity costs through non – conserved energy. This report presents the use of sensor based human detector to switch ON the stair case light only when the presence of human motion is detected on the stair case and also switch OFF the staircase light when human motion is not detected thereby increasing effective energy conservation and reduction of electricity cost. Passive Infrared (PIR) sensor, BC547 Transistor, SPDT relay and other electronic components were employed to accomplish the construction of the device. The device was tested and it functioned well.

Keywords: Human motion, Passive Infrared Sensor, Stair-case, Transistor, Relay, Lighting.

1. INTRODUCTION

Staircase lighting (Figure1) is needed to light the way while climbing a staircase. Uncountable accidents have occurred due to poor or no staircase lighting. Several of such accidents have resulted in permanent injuries to people including bone fractures. In some cases, it has led to permanent disability and damages to properties. Staircase lighting ought to be ON only when it is needed. They are of course needed only when necessary, to save energy and energy costs. Staircase lighting is extremely important in terms of safety. Dark spots and shadows along staircases may cause safety risks. For this reason, necessary calculations must be done before the installation of staircase lighting systems. Glare from lighting fixtures and windows should be minimized. There are different classes of lighting schemes, namely, Direct Lighting, Indirect Lighting, semi-direct, semi-indirect and general diffusing Lighting System. A well constructed lighting scheme is the one that provides adequate illumination, avoids glare and hard shadows, and provides sufficient uniform distribution of light all over the working plane (Theraja and Theraja, 2002). The traditional way of controlling the staircase lighting was by use of two-way switching. The modern staircase lighting consists of a simple circuit that makes use of motion/human detector or sensor/ to automatically switch OFF/ON an electrical system such as the staircase lighting. Transistors, light emitting diodes (LEDs), passive infrared (PIR) sensor, etc. can be used to construct a light sensing device that can automatically be switched ON when motion is detected or switch OFF when motion is not detected (Ayush, 2015). A sensor itself is a device used to detect the changes in quantities, events, or actions, and then generates the respective output signals. There are different types of sensors, which include but not limited to analogue, digital sensors. The various types of sensors include temperature sensors, gas sensors, fire sensors, smoke sensors, pyroelectric sensors, passive infrared (PIR) sensors, infrared (IR) sensors, etc. With these sensors, it is possible to design a circuit or power switch, which can be controlled by a motion detector. The constructed staircase lighting system will be automatically controlled as against the old traditional method of using two-way switching circuits. There are two classes of sensor based human detection for the stair case, viz: passive sensors and active sensors. Each uses different technology to detect motion in the stair case. Passive human sensors do not emit energy, but read changes in energy in the staircase. Active sensors emit one of three kinds of energy to identify motion in the staircase: infrared light, microwave radiation, or sound waves (safe wise, 2013).

The list of active sensors used for various automatic staircases lighting system include:

i. Sensor based lighting system using Passive Infrared Resistor

ii. Sensor based lighting systems using microwave (MW)

iii. Sensor based lighting systems using Ultrasonic

iv. Sensor based lighting system using Vibration

These sensor based human detection stair case lighting system differ in their mode of operations in accordance to their nature, either passive or active.

Sapkota (2010) designed dark/light sensor using transistor. Benezeath et al, (2011) presented a vision based system that uses video analysis through static camera to gather information on people activity. Perma et al., (2013) reported a PIR based security system which saves the power consumption and the memory space of the recording system. A way to reduce the standby power consumption of PIR sensor based lighting device was presented by Vijayavarpya et al., 2016. Tao et al, (2018) presented a depth sensor based detection dataset in indoor space and a £D Mean-shift based multi-person detection method. Motion and light sensors can therefore be used and it is the basis of this report, the construction of simple staircase lighting system, using PIR sensor and SPDT relay.

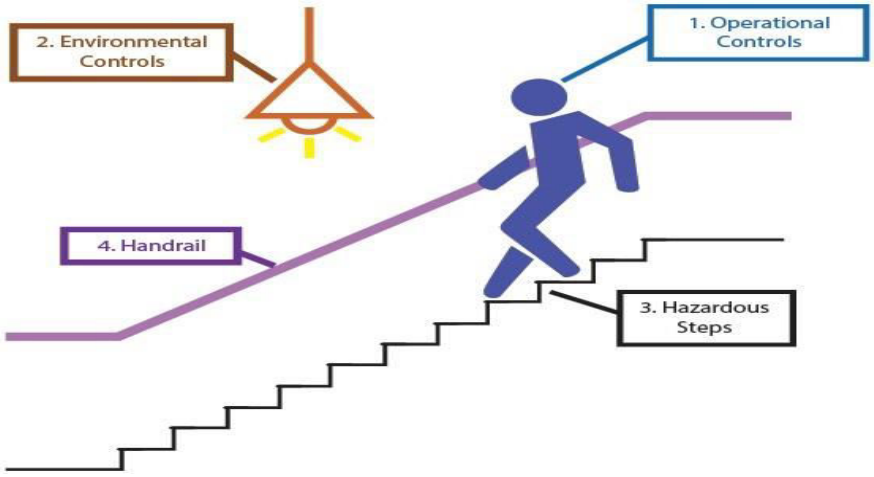

Figure.1. Dependent elements on safer stairs and steps

2. MATERIALS AND METHOD

Materials: Materials used in the construction of the sensor based human detector for lighting purpose on the stair case is shown in Table 1.

Table .1. Table Showing Materials Used.

S/N	COMPONENTS	QUANTITY	VALUE
1.	Passive Infrared Sensor	1	2m
2.	Resistor	1	1KΩ
3.	Transistor	1	BC547
4.	Diode	1	1N4007
5.	Relay	1	7volts
6.	Battery	1	9 volts

The prototype and the block diagram are shown in Figures 2 and Figure 3 respectively.

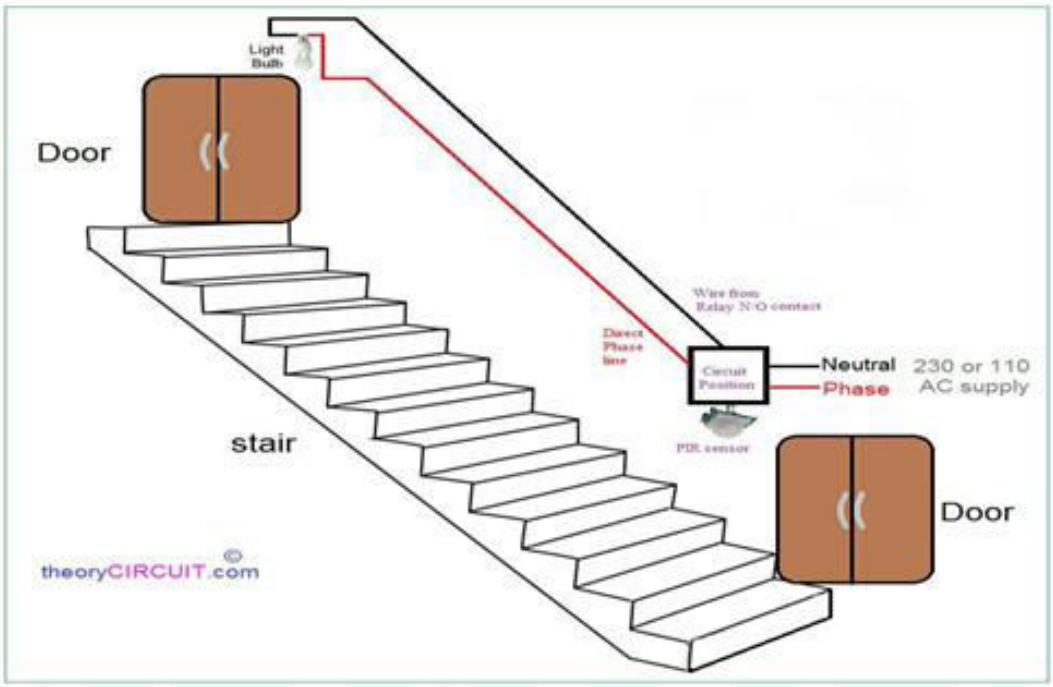

Figure.2. Prototype of sensor based human detector for lighting purpose

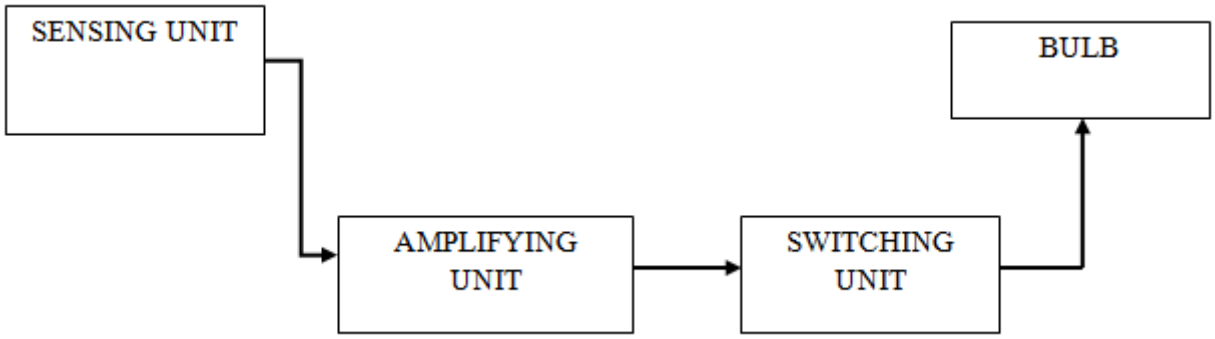

Figure.3. Block Diagram of sensor based human detector for lighting purposes

Methods: The DC supply is given to the PIR sensor. If there is any movement in the range of the sensor, then 5V is given as output. The resistor which is connected between the sensor and transistor acts as the current limiting device. The transistor is connected in order to prevent the back flow of the current. The temperature difference is sensed by the PIR sensor and the output is given to the transistor and then to relay. The relay circuit acts as switch. It has two terminals, normally closed and normally open. The common of the relay gets connected to normally open and circuit gets closed and the fluorescent lamp is ON. When there is no movement there is no input to the PIR sensor hence the output is 0V and common of the relay remains connected to normally closed, so circuit remains open and fluorescent lamp is OFF. Thus the power is saved when not in use.

Circuit Layout: Using the listed components and circuit elements, the sensor based human detector for lighting purpose on the stair case was constructed. These components were first laid out on the bread board to ascertain its workability. The circuit layout of the sensor based human detector for lighting purpose on the stair case is shown in Figure 4

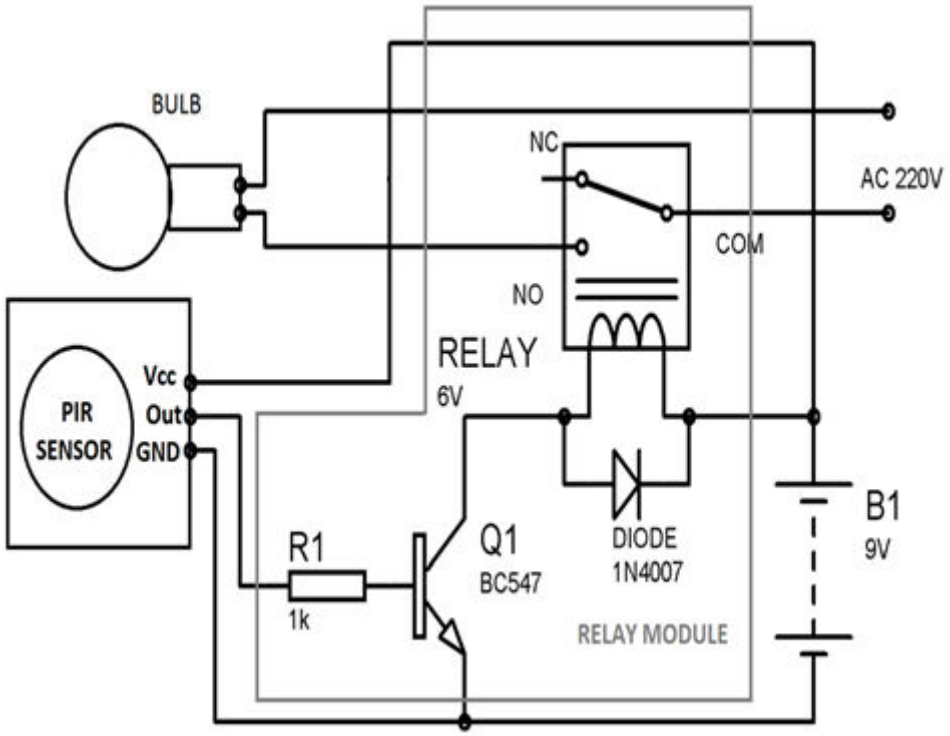

Figure.4. Circuit layout of the sensor based human detector for lighting purpose on the stair case.

The circuit is divided into stages. These are:

The Sensing Stage: The Passive Infrared Sensor is used to sense the heat produced by humans and uses the signal generated to trigger the circuit using the output pin which is connected to the base of the transistor through a resistor. In this construction, the PIR sensor has been used to detect human motion within 2 meters range. It's +DC VOLTAGE terminal is connected to the POSITIVE (+V) supply VOLTAGE (Vcc). The output pin is connected to the base of the transistor through a 1k resistor. The ground terminal is connected to the circuit ground. The principle of operation is that whenever there is a body movement around the sensor, it detects a signal which is converted into electrical signal. This signal VOLTAGE is then applied to the base of the transistor to forward bias the base emitter Junction so that the transistor conducts. PIR sensor has variable resistors to vary its Sensitivity and distance of coverage. PIR sensor consists of a Fresnel lens, an infrared detector and supporting detection circuitry. The lens on the sensor focuses any infrared radiation/wavelengths present around it towards the infrared detector. It offers a tentative range of detection of about 2 m and is highly sensitive generating infrared heat and as a result this gets picked up by the motion sensor. The sensor outputs, a 5V signal for a period. The output from the sensor (5V) is used to trigger a transistor BC547. The transistor then switches on a 7V SPDT relay. The relay correspondingly switches the stair case light ON. Figures 5 and 6 show the internal and external views of the Passive Infrared Sensor respectively.

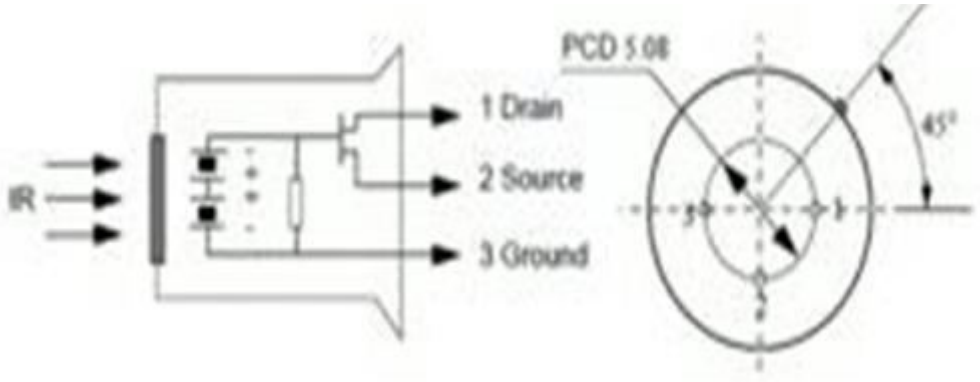

Figure.5. Internal view of Passive Infrared Sensor

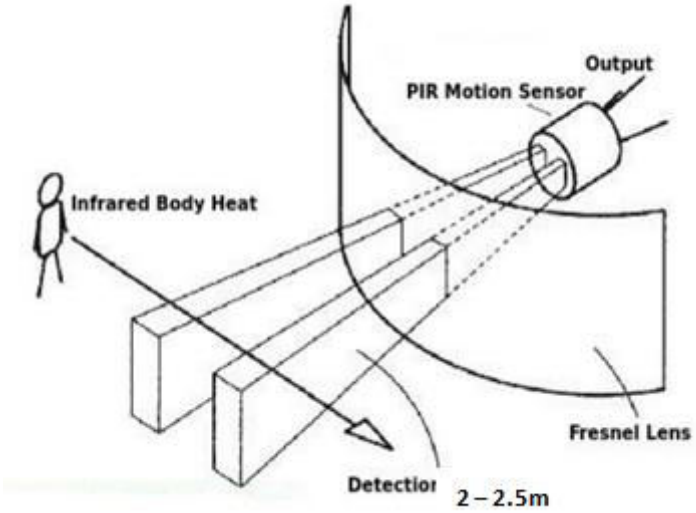

Figure.6. External view of Passive Infrared Sensor

The Amplifying Stage: In the construction of the sensor based human detector for lighting purpose on the stair case, the amplifying stage (figure 7) uses the BC547 NPN Transistor. In addition to amplification of the signal voltage, current and power, the BJT TRANSISTOR in general can be used as a switch or a combination of both switch and amplifier. In this construction, the BC547 NPN Transistor was used for both signal amplification and Switching. Its operation is that it converts electrical signal from the PIR sensor, biases the transistor, thereby setting it into conduction or saturation. When no signal comes from the PIR sensor the transistor remains at the cut off mode. The BC547 TRANSISTOR is connected to the output pin of the PIR SENSOR through a resistor and directs current and voltage stream and goes about as switch or entryway for electronic signs. Transistors comprise of three layers of semiconductor material, each equipped for conveying current. Transistor is used to amplify the current so that full current (from the DC source – 9v battery) can flow through coil to fully energize it. Resistor is used to provide biasing to transistor. And diode is used to prevent reverse current flow, when the transistor is switched OFF. Every Inductor coil produces equal and opposite e.m.f. when switched OFF suddenly, this may cause permanent damage to components, so diode must be used to prevent reverse current. Other component is a RESSISTOR which is connected at the base of the transistor which is a passive element with two terminals that implements electrical resistance as a circuit element. The electronic circuits resistors are used to suppress current flow, adjust signal level, and divide voltage e.t.c.

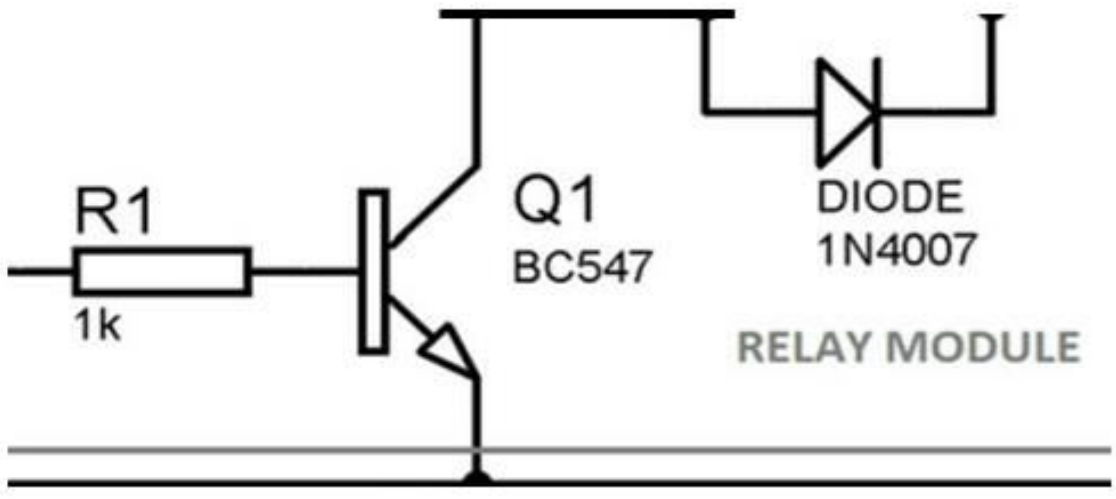

Figure.7. Amplifying stage

The under listed components are embedded inside the PIR:

i. PIR Motion Detection.
ii. Dual Element Sensor with Low Noise and High Sensitivity.
iii. Delay Time Adjustable.
iv. Standard TTL Output.

Switching Unit: The Single Pole Double Throw(SPDT) relay was used, one terminal of the RELAY coil was connected to a battery of 9V with the COM connected to one terminal of the AC mains (220VAC) and the NO terminal connected to the light to be switched leaving the NC terminal floating. The other terminal of the RELAY coil was connected to the collector of the transistor. When there is no voltage applied to the coil, COM (common) is connected to NC (normally closed contact). When there is some voltage applied to the coil, the electromagnetic field produced, which attract the Armature (lever connected to spring), and COM and NO (normally open contact) gets connected, which allow larger current to flow. 7V operating voltage relay was used to isolate both the controlling and the controlled device. The relay is an electromagnetic device, which consists of solenoid, moving contacts (switch) and restoring spring and consumes comparatively large amount of power. Hence, the relay is used to switch the electrical supply to the appliances. From the figure 8, when the rated voltage across the coil was connected, the back e.m.f. opposed the current flow but after the short time the supplied voltage overcame the back e.m.f. and the current flow through the coil increases. When the current is equal to the activating current of relay, the core is magnetized and it attracts the moving contacts. Now, the moving contact leaves from its initial position denoted "(N/C)" normally closed terminal which is a fixed terminal. The common contact or moving contact establishes the connection with a new terminal which is indicated as a normally open terminal "N/O". The SPDT at applied voltage and when the no voltage is applied are shown in Figure 8.

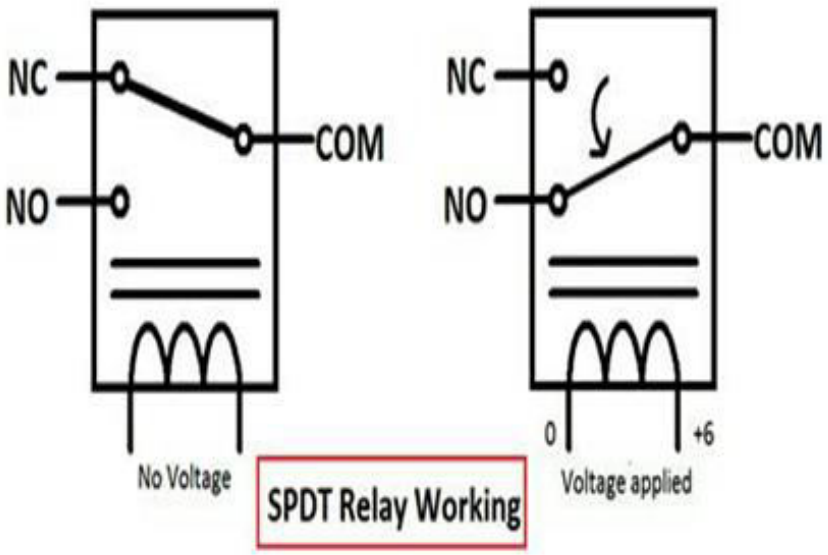

Figure. 8. The switching unit, SPDT in no voltage and applied voltage.

External view of the Constructed device: The PIR sensor is placed within the circuit though it can be external or internal depending on the nature of the stair case. The construction (Figure 9) is enclosed in a plastic casing to avoid short circuitry of the components.

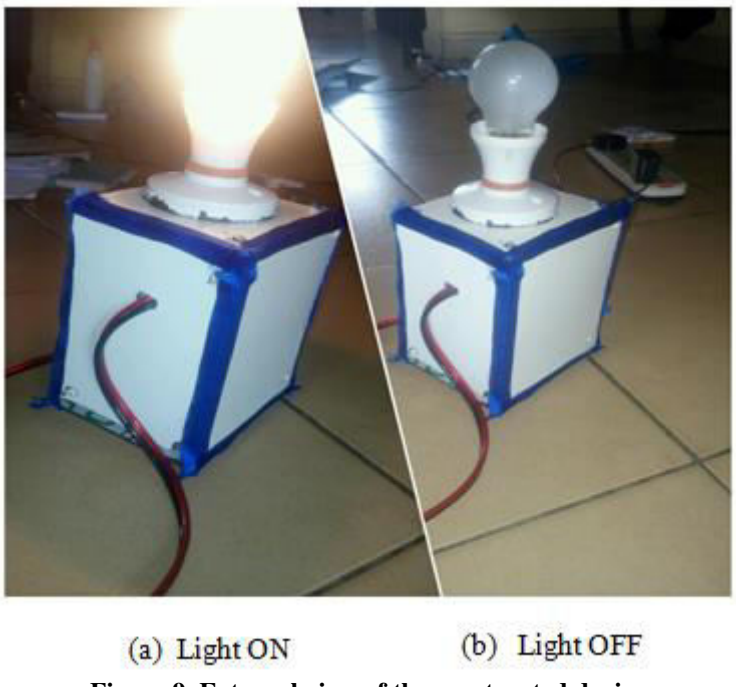

Figure.9. External view of the constructed device.

3. TESTS AND RESULTS

With the Digital Multimeter set to DC voltage mode, the base voltage before the lamp came ON and when it was OFF was read and recorded. Similarly, the collector outputs voltages for the lamp or bulb ON/OFF condition were also read and recorded. With the variable resistors provided on the sensor circuit for the sensitivity and distance of coverage of the sensor were adjusted and observations read and recorded accordingly. The various tests carried out on the bread board before soldering were then repeated to confirm the functionality of the circuit. Human motion was introduced in front of the sensor, it was observed that at a certain distance before the sensor, the relay bridged and the lamp came ON. The distance at which this occurred was measured and recorded. Furthermore, it was observed that after some time the motion has gone out of the sensing range of the sensor, the light went OFF.

The sensor based human detector for lighting purpose on the stair case works in both bright and dark areas. The results obtained from the test carried out on the system as a whole is shown in Table 2.

Table.2. Measured Parameters and Units

S/N	Parameter	Expected	Measured	Unit
1	battery voltage	9	8.8	Volts
2	Sensor distance	2	2-3	meters
3	Lamp duration	26	27	Seconds
4	PIR output	5	4.8	Volts
5	Transistor output	7	6.8	Volts
6	Base-bias with motion	7	7	Volts

4. DISCUSSIONS

From Table 2, it was observed that the d.c battery voltage in the construction was 9V while the measured voltage was 8.8V, which is still enough to power the circuit. Also, the expected output voltage from the PIR sensor is 5V although a 4.8V was actually measured. This slight difference in the voltage is negligible as the circuit is able to work properly on the measured voltage. Similarly, the duration of time for the lamp to be ON as expected from the construction is 26 seconds but the actual measured time it took the lamp to go OFF is 27 seconds 40 milliseconds which is almost the expected time and also enough for any human to climb up or climb down the stair case. The measured distance from which the lamp comes ON was 2. 5 meters compared to the expected distance of 2 meters. This little difference in the detection range gives flexibility. The 2.5 meters from which the PIR sensor detects human and automatically switching the lamp ON is more economical, more efficient and more smart as compared to the manual switches. From the calculations and comparison for power consumption, LED LIGHT without PIR sensor consumes more than the device with PIR sensor.

5. CONCLUSION

The constructed sensor based human detector for lighting purpose presents one of the simplest and effective ways of saving energy automatically in any room of a building or organization. This was achieved by the application of the Passive Infra-red sensor and the relay as the major building blocks. A randomly selected test for duration of 3 hours using the module showed a 15% saving in the energy consumption. This is based on the premise that the manual control switches are operated with 50% accuracy. In this PIR Sensor Based human detector for lighting purpose on the stair case System, low power, low cost PIR sensor that are easy to interface with other components was used . By using this system, power consumption was reduced and finally it can also be used in car parking lots and in Street lighting system.

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