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Construction of Sensor Based Dark Detector for Lighting Purpose on a Stair Case

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Abstract:
Reports on stair case related injuries shows an increasing rate yearly. Investigations have been carried out as to the causes of these staircase hazards and also explored befitting means of preventing the hazards through the use of handrails, staircase safety signs, proper lighting systems, etc. Common staircase lighting consists of a dependent element on staircase and is regarded as an environmental control tool for both direct and indirect elimination of staircase hazards. Due to the importance of staircase lighting systems, most staircase lights are left on even when not needed. Sometimes, due to inefficient operations, they are left on for very long periods leading to waste of electricity and increased electricity bills. This paper therefore reports the construction of a sensor based dark detector to automatically switch ON or switch OFF staircase lighting systems in dark or bright conditions respectively such that the safe use of a staircase is ensured when it is dark, and electricity is conserved when it is bright. The construction was achieved through the use of a Light Dependent Resistor (LDR) as the dark sensing component, a Transistor (BC547) as an amplifier and a Single Pole Double Throw (SPDT) relay as the switch, to switch on or switch off the staircase lighting system. The construction was tested and functioned well.

Keywords: Light Dependent Resistor, Stair-case, Transistor, Relay, Lighting.

1. INTRODUCTION

In this renowned era of science and technology, there are many inventions and innovations to support life, humanity, and day to day activities. The technology is employed so as to be safe, and conserve energy. It is common knowledge that it is a very difficult task and risky to move around in darkness without stumbling. Therefore, light is needed to easily move around when there is darkness. Light is needed to ascend or descend a staircase when it is dark. A stair can be said to be one or more flights of steps, with or without landings or platforms, installed between two or more floors of a building to bridge a vertical distance. The part of the building occupying the stair is known as the staircase. As harmless as staircases may seem, stairways present many chances for accidents to occur. A number of accidents have resulted from no/inadequate staircase lighting. Many of such accidents have resulted in permanent disability, damage to properties and even death. In 2015, the National Safety Council's statistics ranked stairway injuries second only to motor vehicle accidents among the leading causes of accidents. Therefore in the aspect of safety, staircase lighting is needed to safely manoeuvre the way, when staircases are used. Staircase lights however, ought to be ON when necessary. Unfortunately most staircase lights are turned ON and left ON forgetfully, or due to a busy schedule, for very long periods which lead to waste of energy and economic waste as well. It is therefore important to have the staircase lighting ON, only when necessary, to save energy and energy costs. Since manual switches for controlling of lighting are being embedded to history, sensors and detectors can now be used to automatically illuminate our staircase environs and these lights can equally be switched ON/OFF with the aid of these detectors. For better control of the staircase lights, automatic staircase lighting systems can be used. The automatic staircase lighting system is a very simple circuit that could come in different versions. It can be a simple motion/human detector circuit, a light detector circuit, etc. In whatever form, the bottom line is that the staircase lighting system functions to automatically switch ON/OFF the staircase light when and where necessary. Light is a form of electromagnetic radiation within a certain portion of the electromagnetic spectrum. "Electromagnetic" refers to the way the energy travels in wavelengths via electric and magnetic fields. This electromagnetic energy can come in different forms which include radio waves, infrared waves, visible light, ultraviolet light, X-rays, gamma rays. (https:/en.wikipedia.org/wiki/ Light) The word "Light" is usually used to refer to visible light. Visible light is the only type of electromagnetic energy that can be seen with the naked eye, or in other words, can be seen without the aid of a microscope, telescope, or other optical instruments. Although, the sun is earth's main source of visible light, light energy can also be emitted by light bulbs, lanterns, flashlights, and other light emitting devices. Light has long been proposed to have a stimulatory effect on the biological function of both plants and humans. Plants seek out light sources for energy and survival, through processes such as phototropism and photosynthesis which solely depends on the availability of light, since light energy is the spark of these processes. Photosynthesis occurs as plants convert light energy into chemical energy therefore, the resulting production of sugars such as glucose, from the combination of chlorophyll and light, provide plants with food, allowing them to live, grow and reproduce (https://www.hunker.com/13404873/the-importance-of-light-to-a-plant). Light energy also exerts powerful effects on the brain and on our well-being. Light is not only required for vision but is also essential for a wide range of non-visual functions including synchronization of our biological clock to the 24 hour day-night cycle. A research group, Clinical Trials (2014) revealed that in humans, the effects of light can range from increased feelings of activation

such as improved alertness, ability to perform or even dizziness. None the less, the mechanism underlying how light positively stimulates these neurobiological system remains to be elucidated (https://clinicaltrials.gov/ct2/show/NCT002 00 8 63). Without sufficient light energy, it becomes difficult to carry out basic activities efficiently. And one of such activities is ascending or descending a staircase safely. It is a risky and slow task to use a staircase in the dark. In order to provide a solution to the problems associated with inefficient lighting systems in homes and beyond, various scholars and academia are carrying out research and works on automated staircase lighting systems. Lighting Automation involves creating automated changes in lighting levels and lighting operations to affect mood, emphasize architecture, illuminate art, influence action, conserve electricity and also improve safety and security of an environment. Therefore, automatic lighting control is one of the more obvious and beautifying applications for incorporating an automation system into a building. An automatic bedside lamp control automatically switches ON lights when the sunlight goes below the visible region of the eyes (Kashyap et al, 2013). This is done by a light dependent resistor (LDR) sensor which senses light like the human eyes. It automatically switches OFF lights whenever the sunlight becomes visible to the eyes and activates the morning alarm.

The light dependent automatic off timer for household electronics provides automatic disconnection of appliances from the alternating current (AC) mains supply, upon the expiration of a pre-set time delay period (Jonathan, 2008). The system works by detecting a transition from light to darkness in a room, which triggers the device into a time-out mode. A key feature of this device is that its operation is light dependent, that is, the device is activated only when it is powered ON in the absence of ambient light or in a sufficiently dark environment making it a light dependent automatic-off timer for electrical appliances. An energy efficient automatic street lighting system, based on a low cost Light dependent resistor (LDR) circuit was proposed. The main objective was to design an energy efficient based controller for controlling the LED street lamps on five levels, proportional to the number of traffic (Mishra et al, 2014). Electronics night lamp controller can be of help and it is a very useful gadget for homes and offices. A sensor controlled automatic switching system that controlled the light bulbs depending on the intensity of the sunlight and/or the detection of human motion and also controlled the fan, depending on the temperature of the room (Bharmal et al, 2017). The purpose of the research work was to design a system for lighting buildings in order to reduce energy consumption, cool the environment when above a preset temperature and increase the lighting efficiency levels. Sudhakar et al, 2013 constructed an automatic and effective street lighting control system, using active and passive electronic components such as LDR, BC547 NPN transistors and 89S52 microcontrollers as a useful tool for the reduction of energy consumption and elimination of manual switching at most up to 100%. An automatic headlight beam controller system was developed for vehicles, as it was observed that the headlight of vehicles pose a great danger during night driving as drivers of most vehicles use high, bright beams while driving at night which causes a discomfort to the person travelling from the opposite direction and therefore experiences a sudden glare for a short period of time (Musthafa et al, 2017). This is caused due to the high intense headlight beam from the other vehicle coming towards the one from the opposite direction. In staircase use, staircase lighting systems (Figure 1) are one of the dependent elements of safer stairways, classed as an environmental control tool for both direct and indirect elimination of staircase hazards.

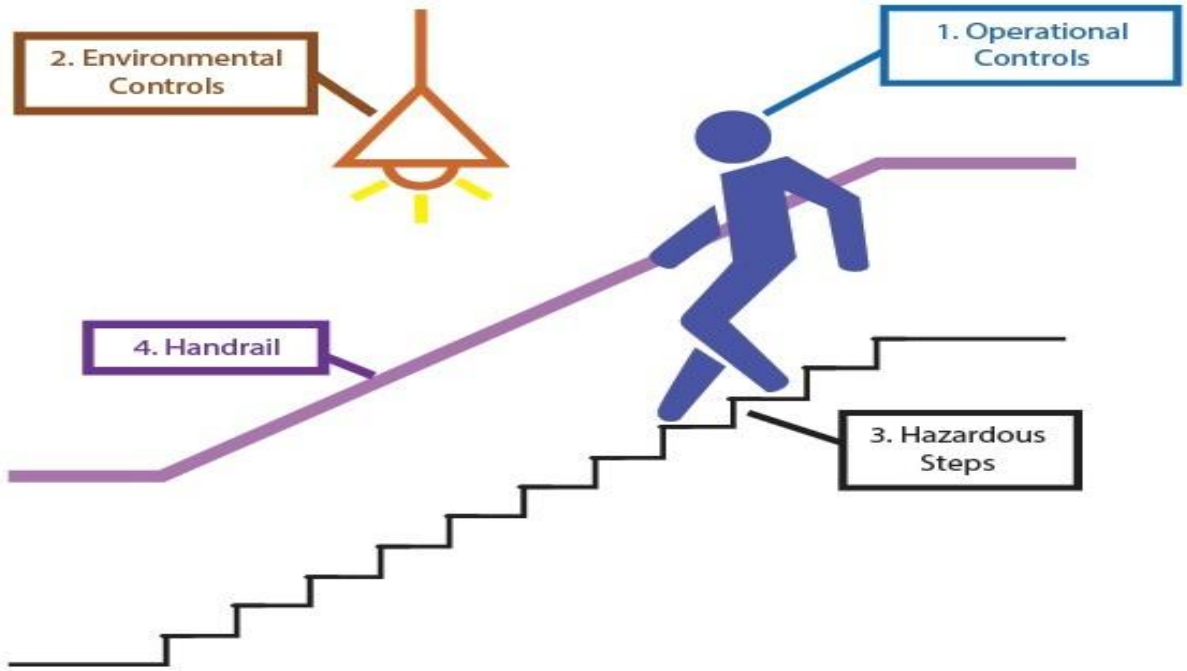


Figure.1. Dependent elements on safer stairs and steps.

A stair (Figure 2) comprises of various parts which includes:

i. **TREAD**: The horizontal surface which people walk on. Tread material can be timber, steel, glass, acrylic, panel product or tiling.

ii. **RISER**: The vertical component in between each tread.

iii. **GOING**: The horizontal distance between each riser face.

iv. **NOSING**: The rounded projected end of the stair treads.

v. **HANDRAILS**: A rail to provide support and assistance with the movement of a person.

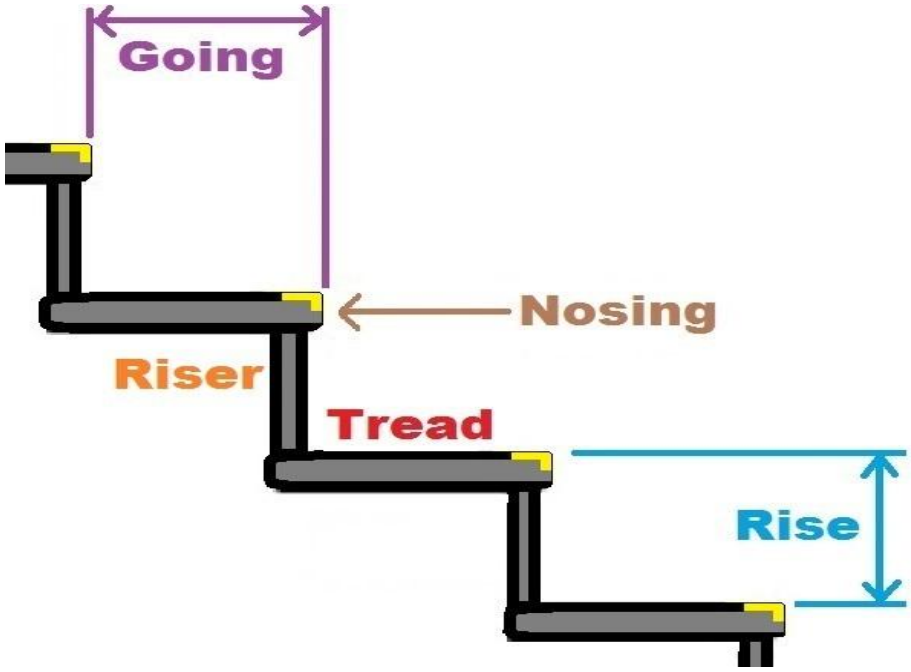


Figure.2. Parts of a stair.

Because stairs are a common feature of homes and buildings, staircases are taken for granted and are assumed to be safe to use. However, this assumption isn't always true, and the unwary user could get involved in a staircase accident. Common staircase hazards that can cause accidents in low lighting conditions on a staircase include:

i. **SLIPPERY STEPS**: Steps that do not have enough grips especially at the step edge/nosing. Wet or slippery surfaces are a major cause of slips. Highly polished floors such as marble, terrazzo, or ceramic tiles can be extremely slippery even when dry and definitely increase the potential for a slip when spills are present.

ii. **SURPRISE STEPS:** A surprise step is not clearly visible or expected. It could be at the bottom of a flight or a single unexpected step.

iii. **IRREGULAR STEPS:** An irregular step is a step which is longer or shorter than the other steps in a flight.

iv. **SHORT STEPS:** A short step does not provide adequate support for the ball of the foot for a safe forward ascent or descent.

Whether looking to improve safety, reduce wastage of electrical power or simply take aesthetics to a higher level, LDR switching methods for staircase lights really can make all the difference. LDR make the perfect choice for staircases for a variety of reasons. Along with being unique and easy to install, LDR activated lights on stairs are also incredibly durable and efficient. Furthermore, when it comes to practicality, safety and minimal energy consumption, nothing beats automatic switching lighting system for stairs. Sensor switches are reliable systems that can be trusted to automatically initiate ON/OFF modes of a lighting system. It is an outstanding option for use in public buildings, not to mention all types of homes and businesses across the board. This paper thus reports the construction of the automatic staircase lighting control, using the Light Dependent Resistor (LDR), as the light sensor. The operation of the staircase lighting system relies basically on the operations of the Light Dependent Resistor (LDR).

2. MATERIALS AND METHOD

The materials used in the construction of the sensor based dark detector (Table 1) basically include:

Table.1. Materials used in the construction of sensor based dark detector.

COMPONENTS	QUANTITY
Light dependent resistor (LDR)	1
Transistor (BC547)	1
Resistor (10KΩ, 330Ω)	2
Diode (IN4001)	1
Relay (SPDT 12V)	1
Battery (9 VOLTS)	1

The light dependent resistor (Figure 3) is also called photo resistor or photo controlled variable resistor. It is a two terminal device in which its resistance decreases with increasing incident light intensity. A photo resistor is made of a high resistance semiconductor which in dark conditions, its resistance may go as high as several mega Ohms while in bright conditions; it has a resistance as low as a few hundred Ohms. The photo resistor was used as a sensor for the staircase lighting control system to ensure that the system is in the ON state when it is dark, and be in the OFF state when light falls on the LDR. In that way, the photo resistor can be used to switch OFF/ON the staircase lights.

(a) Image **(b) Circuit symbol**

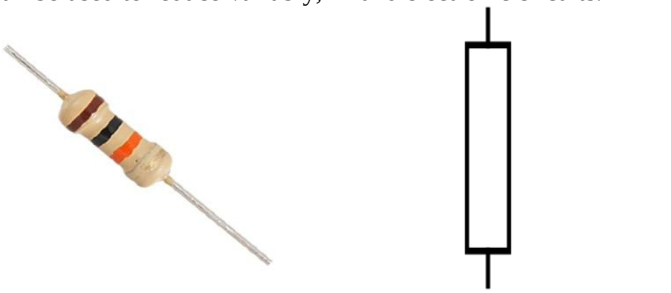
Figure.3. Image and circuit symbol of an LDR.

A transistor (Figure 4) is a semiconductor device used to amplify or switch electronic signals and electrical power. It is composed of semiconductor material usually with at least three terminals (Collector, Base & Emitter) for connection to a circuit. As a Transistor is a three terminal device, there are basically three possible ways to connect it within an electronic circuit with one terminal being common to both the input and output. Some of the most powerful transistor applications involve amplification i.e. turning a low power signal into one of higher power.

(a) Image. **(b) Circuit symbol.**

Figure.4. Image and circuit symbol of a transistor.

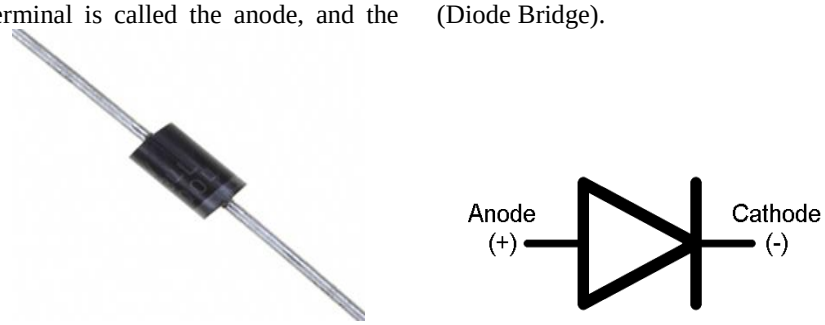
A resistor (Figure 5) is a two way passive electrical component made for the express purpose of creating a precise quantity of resistance for insertion into a circuit, and its value of resistance is measured in Ohms. Resistors can be used to reduce variably, or divide voltage to provide specific voltage for active devices such as a transistor. Resistors are widely used electrical components and can be found in almost all electrical networks and electronic circuits.



(a) Image **(b) Circuit symbol**

Figure 5: Image and circuit symbol of a 10kΩ resistor.

A diode (Figure 6) is an electronic component with two terminals. It allows electricity to go through it only in one direction. The positive terminal is called the anode, and the negative terminal is called the cathode. Diodes can also be used as a gate to convert alternating current to direct current (Diode Bridge).

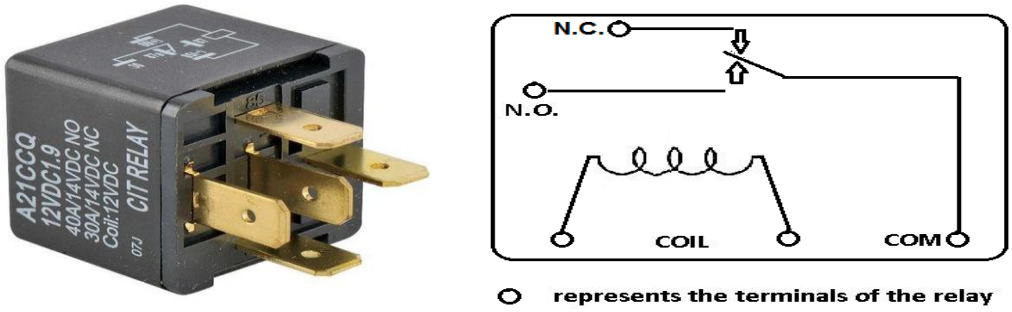


(a) Image. **(b) Circuit symbol.**

Figure .6. Image and circuit symbol of a diode.

A relay (Figure 7) is an electrically operated switch. Many relays use an electromagnet to mechanically carry out switching, but other operating principles are also used such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The Single Pole Double Throw (SPDT) relay is quite useful in certain applications because of its internal configuration. It has one common terminal (COM) and two contacts namely normally

closed (NC) and normally open (NO). So basically, the SPDT relay is a way of switching between two circuits.



(a) Image. **(b) Circuit symbol.**

Figure.7. Image and circuit symbol of a relay.

A battery (Figure 8) is a device consisting of one or more electrochemical cells with external connections provided to power a variety of electrical devices.

(a) Image. **(b) Circuit symbol.**

Figure.8. Image and circuit symbol of a battery.

The circuit diagram of the sensor based dark detector for lighting purpose on the staircase (Figure 9), consists of the sensing unit using (LDR), the amplifying unit (TRANSISTOR), and the switching unit (RELAY).

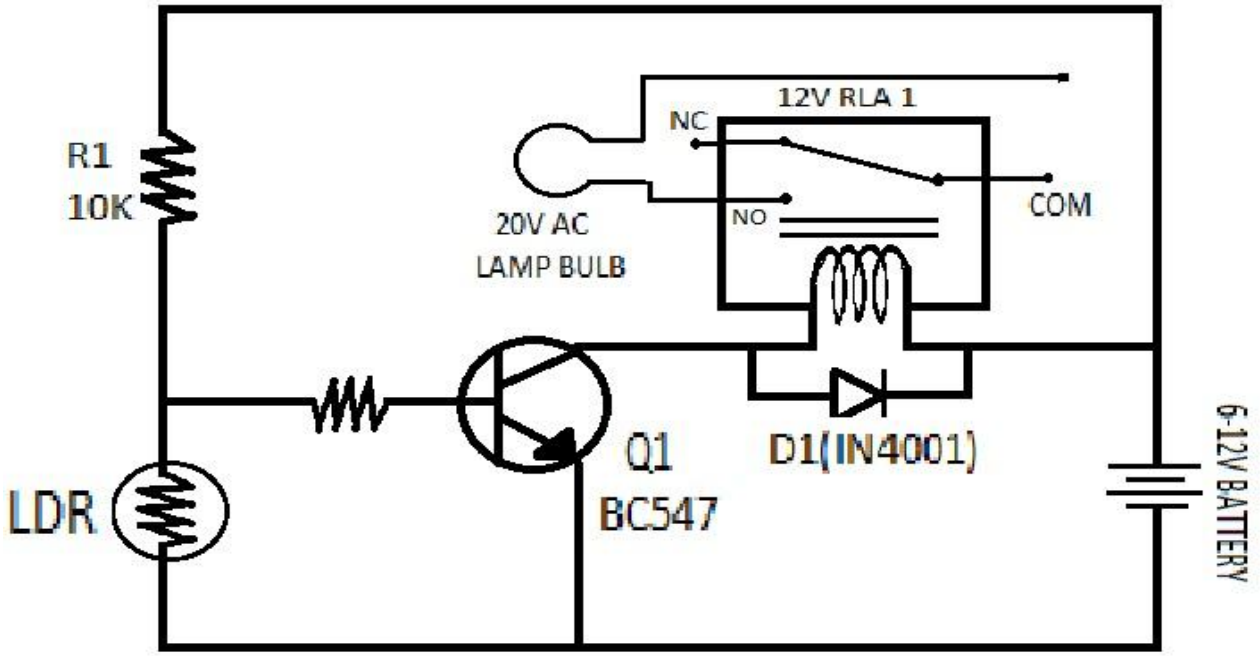


Figure .9. Circuit layout of LDR based dark detector.

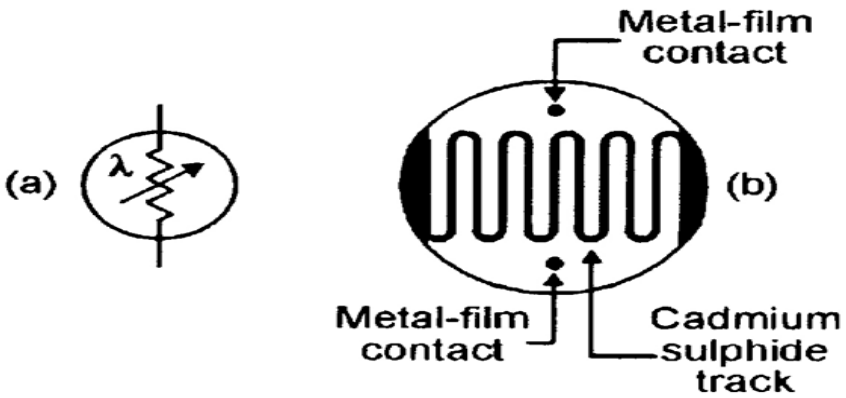
The circuit is divided into three stages which are; the sensing stage, amplifying stage and switching stage for easy understanding of the construction and operation of the dark detector.

- **Sensing Stage**

i. One terminal of the Light dependent resistor (LDR) was connected to one terminal of a 10kΩ resistor (R1) and the second terminal of R1 was connected to the battery.

ii. The second terminal of the LDR was connected to ground.

R1 reduces the voltage entering the LDR to protect it from damage when its resistance becomes Low. The LDR consists of a Cadmium Sulphide track (Figure 10) and its operation relies on the fact that the conductive resistance of the track of Cadmium Sulphide (CdS) varies with the intensity of light falling on the face of the cover film. Its resistance is very high under dark conditions and low under bright conditions. The LDR in this case, acts as a photo sensor to detect between night and day time, for the purpose of staircase lighting.



(a) Symbol of a variable resistor. (b) Parts of a variable resistor.

Figure.10. Schematic of an LDR.

- **Amplifying Stage**

i. One terminal of the second 330Ω resistor (R2) was connected to the junction of the LDR and R1.

ii. The second terminal of R2 was connected to the base of the BN547 transistor and the emitter was grounded. The transistor was used in the common emitter configuration, to amplify the base voltage to a larger output voltage for triggering the relay.

The common emitter configuration (Figure 11) is one of the popular transistor arrangements. In this circuit the emitter was joined to the voltage common (ground) for both the base and collector. The base became the signal input terminal, and the collector became the output terminal.

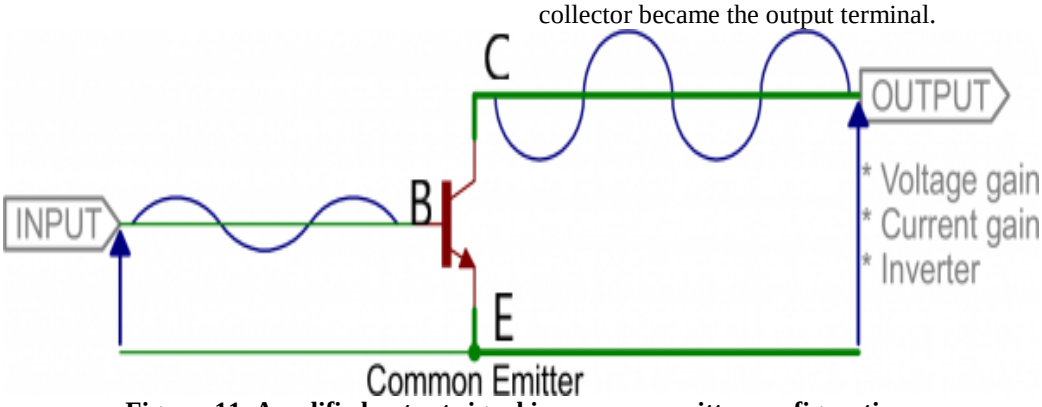


Figure .11. Amplified output signal in common emitter configuration.

The common emitter circuit is popular because it is well-suited for voltage amplification, especially at low frequencies.

- **Switching Stage**

i. The collector terminal of the transistor was connected to one of the coil terminals of the SPDT relay.

ii. The second terminal of the coil was connected to the battery.

iii. The common (COM) terminal of the relay was connected to AC.

iv. The normally open (NO) terminal was connected to the light bulb.

v. The IN4001 diode was looped from the junction of the transistor and the relay to the junction of the relay and the battery.

vi. The second terminal of R1 was connected to the battery to power ON the dark detector circuit (Figure 9).

When an amplified voltage from the transistor reaches the relay, the core starts to create an electromagnetic field around it and acts as a magnet (Figure 12). The relay also has two pins namely normally closed and normally opened (NC and NO). The normally closed pin was connected to the armature or the common terminal whereas the normally opened pin was left free (when the coil was not energized). When the coil is energized the armature gets attracted to the normally opened contact (NO). When it is de-energized, the common contact is de-magnetized and it goes back to its initial position (NC).

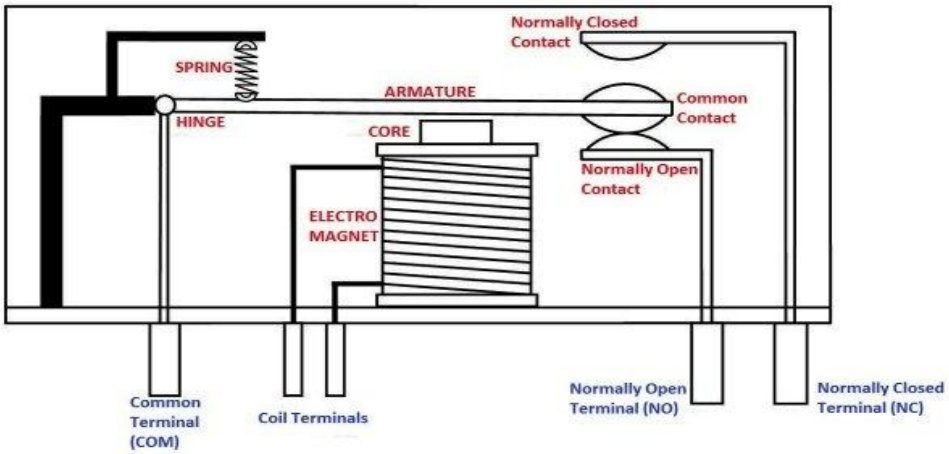


Figure.12. Internal structure of a relay.

- **Operations**

The operation of the sensor based dark detector (Figure 13) is as follows;

i. 9V battery supplies the source DC biasing voltage needed to bias the transistor.

ii. With the battery connected, when light falls on the LDR its resistance reduces. The supply voltage is connected to ground through 330Ω resistor. No voltage gets to the transistors and they remain at cut-off region.

iii. Consequently, no output voltage to the relay and the bulbs / staircase light remains off.

iv. During the dark, the resistance of the LDR goes very high.

v. The current then takes the path of low resistance (330Ω).

vi. The output voltage energizes the relay which subsequently switches ON the staircase light (Figure 14).

Figure.13. Image of constructed sensor based dark detector.

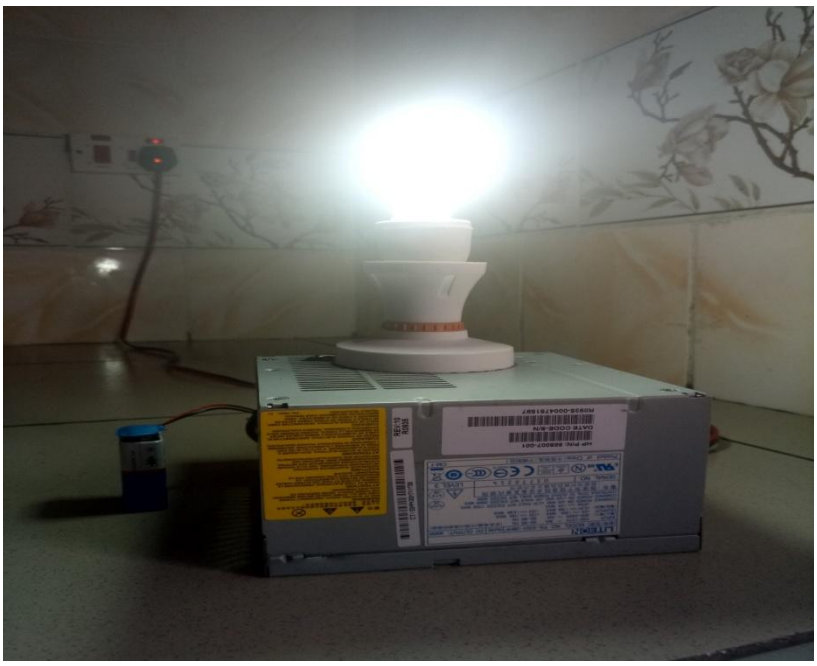


Figure.14. Constructed Sensor based dark detector in an ON state in poor lighting condition.

3.0 Tests and Results

The constructed circuit (Figure 9) was subjected to various tests and measurements on both Bread and Vero boards to confirm functionality between day and night time. The results of the tests / measurements and observations made were recorded.

3.1 Tests

I. When light was shone on the LDR (to simulate day).

i. The base voltage of transistor was measured.

ii. Output (collector) voltage of transistor was measured.

iii. AC output across relay was measured.

iv. State of bulb if in ON or OFF condition.

II. When LDR was covered with a black cloth (to simulate night)

i. The base voltage of transistor was measured.

ii. Output (collector) voltage of transistor was measured.

iii. AC output across relay was measured.

iv. State of bulb if in ON or OFF condition.

3.2 Results

The results of the measurements carried out on the circuitry are tabulated in Table 2 and Table 3.

Table.2. When light was shone on the LDR.

BASE VOLTAGE OF TRANSISTOR	0V
OUTPUT COLLECTOR VOLTAGE	0V
AC OUTPUT ACROSS RELAY	0V
STATE OF LAMP/BULB	OFF

Table.3. When LDR was covered to provide darkness.

BASE VOLTAGE OF TRANSISTOR	0.6V
OUTPUT COLLECTOR VOLTAGE	7.0V
AC OUTPUT ACROSS RELAY	230V
STATE OF LAMP/BULB	ON

4. DISCUSSION

Results from the measurements carried out on the circuit showed that the system was able to detect between light and dark to trigger the relay via the Light Dependent Resistor (LDR). Similarly, tests carried out on the system also showed the system was able to switch OFF or switch ON a 60 watt bulb when light rays were incident or shaded from the LDR respectively. The control of the unit is automatic and needs no manual intervention. Furthermore, the resistance of R1 (Figure 9) can also control the sensitivity of the LDR to suit various lighting conditions on a desired staircase i.e. reduction in the resistance of R1 (Figure 9) increases the sensitivity of the Light Dependent Resistor, and an increase in the resistance of R1 reduces the sensitivity of the LDR. The advantages of the model construction are:

i. It is easy to set up.
ii. It is easy to maintain.
iii. It has faster response.
iv. The dark detector automatically controls the switch OFF/ON.
v. LDRs are small enough to fit into virtually any electronic device.
vi. LDRs are sensitive, inexpensive and readily available devices that have good power and voltage handling capabilities similar to those of a conventional resistor.

5. CONCLUSION

In order to improve efficiency lighting systems, as to improve safety and reduce unwanted electricity utility cost due to inefficiency in the operation of staircase lighting, there is the need for modern automatic switching control units. The given Light or Dark detector system is implemented and tested successfully. It could detect between day and night to switch OFF or switch ON a lighting system automatically. Such an amenity is suitable for places which include homes, schools, malls, hospitals, hotels, libraries, offices, where staircases are frequently used irrespective of the time of the day to conveniently control their staircase lighting system making it independent of manual switching. So. Stair-case lights are only turned on when necessary to ensure safety and also save electricity costs.

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