UNIVERSITY OF MORATUWA
DEPARTMENT OF ELECTRONIC AND TELECOMMUNICATION ENGINEERING
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PIR Sensor Project Report

Name	Index number
D. M. S. S. Dassanayake	190115P
W. A. D. K. De Silva	190128H
J. V. A. P. Dilshan	190144D
A. G. Diron	190149X

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ABSTRACT

The main goal of this project was to create a sensor module that can detect human motion. Mainly filtering and amplification was done to achieve this requirement. User Interface, power supply, sensitivity to light intensity, input block, timer adjustment circuit and the distance adjustment circuit are the main parts of the project. In the final evaluation human motion was successfully detected.

1. INTRODUCTION

The Passive Infra-Red (PIR) sensor module detects IR emitting objects within a certain range. The module consists of an PIR sensor, resistors, capacitors, operational amplifiers, potentiometers, switches, and buzzer and/or lamp. The characteristics of the module heavily depends on the type of the IR sensor chosen for the project i.e. whether the module can detect both objects in motion and motionless objects in the field of detection.

The range of the detection can be increased up to 5m, with increments of 1m. The output of the module is given by the buzzer and/or lamp.

The PIR sensor module has a variety of applications. For example, the module can be used as a security device by placing it suitably near a doorway (or passage, corridor, window, etc.). It will detect if anyone goes through the doorway.

Also, the module can be used as an animal detection device at night time. Especially, farmers can place some sensors in their fields suitably, so the modules may detect if there are animals in the field and emit bright light or give out a repelling sound, which will scare away animals.

2. FUNCTIONALITY

2.1. Components used

- RE200B sensor
- LDR
- 7805, 7905 Voltage regulators
- 50k, 100k potentiometers
- TL074 opamps
- SN74HC08N IC
- Resistors - 100Ω, 220Ω, 1kΩ, 2kΩ, 10kΩ, 47kΩ, 100kΩ, 1MΩ, 2MΩ
- Capacitors - 10nF, 100nF, 10μ F, 47μ F, 100μ F
- BC547, BC557 Transistors
- LED
- Two way switch
- 1N4007 Diodes
- Fresnel Lense

2.1.1. RE200B sensor

RE200B is the PIR sensor used for this project. This sensor can only detect IR emitting objects that are in motion. For the same reason, the PIR sensor module also detects only the IR emitting objects in motion. The RE200B has a detection angle of 138 degrees.

The IR sensors are placed inside a hermetically sealed metal can to improve noise/temperature/humidity immunity. The window made of IR-transmissive material protects the sensing element. There are two balanced sensors behind the window.

Fig. 1. RE200B Sensor

When the sensor is idle, both IR sensors detect the same amount of IR. When a warm body passes by, it first intercepts one half of the PIR sensor, which causes a positive differential change between the two slots. When the warm body leaves, the reverse happens, where the sensor generates a negative differential change. This voltage difference is taken as the output of the PIR sensor. The maximum variation of the output is 20 mV (peak to peak).

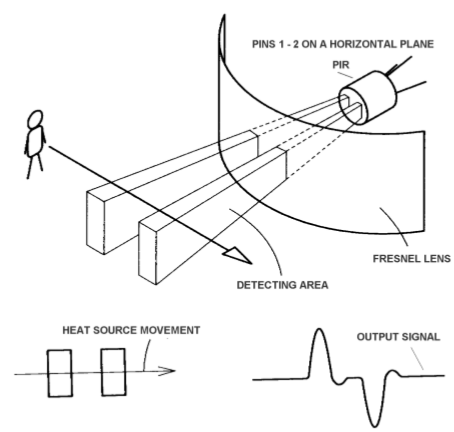


Fig. 2. Output of the sensor

2.1.2. LDR

Light Dependent Resistor (LDR) consists of a semiconductor material that will change its resistance from several thousands of ohms in the dark to a few hundred ohms when exposed to light. Hence this component is used as a lighting switch in the PIR sensor module.

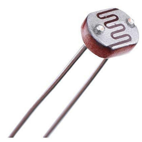


Fig. 3. LDR

2.1.3. *Voltage Regulators*

In order to provide power for the op-amps and the RE200B sensor we need +5V and -5V power supply. To obtain this we use a 7805 voltage regulator together with a 7905 voltage regulator. The 7805 regulator stabilizes a +5V constant voltage output and 7905 stabilizes a constant -5V voltage for a variable input supply.

(a) 7805 (b) 7905

Fig. 4. Voltage regulators

2.1.4. *TL074CN*

TL074 IC consists of 4 high-speed JFET input single operational op-amps. This device has high slew rate of 16 V/μs low input bias and offset currents. This op-amps are used in the circuit to obtain a low-pass filter, band-pass filter, comparator circuits and as a buffer circuit.

Fig. 5. TL074CN

2.1.5. *SN74HC08N*

This device contains four independent 2-input AND gates. This IC is used as a buffer when combining the Light sensitivity circuit and timer circuit with the distance adjustment circuit.

Fig. 6. SN74HC08N

2.1.6. *Fresnel Lense*

To collect and focus IR radiation from the field of sensing, a Fresnel lens is used that is made up of IR transmissible material. The advantages of Fresnel lens over typical concave or Plano-concave lens are; low weight, low IR absorption by the lens material, low cost and less space for the lens. Most importantly, the sensitivity of the sensor is increased by the Fresnel lens. If an object is to be detected; the IR rays detected

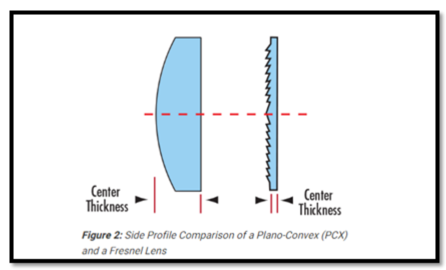


Fig. 7.

by one of these sensor slots should be relatively higher than the other sensor slot. As there are only two sensor slots, an object moving in the non-sensing area (area between the two sensor slots) may not be detected if the motion of the object is such that it does not cross any of the sensor slots. This kind of motion can happen in further distances as the gap between the two sensor slots are increased. In order to avoid such scenarios, the honeycomb structure lens cap is used. Honeycomb structure lens caps split the two sensor fields into many sensor fields, thus reducing non-sensing areas between sensor fields. This special lens cap also increases the sensor angle of the sensor.

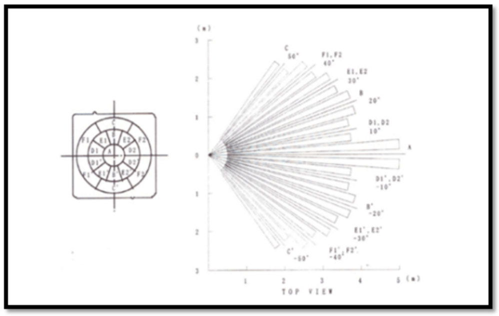


Fig. 8.

2.2. Methodology

2.2.1. Power supply

The sensor is powered from the 230V main supply. A center tapped transformer(24V) is used to step down the voltage. To get a stabilized +5V and -5V, 7805 and 7905 regulators are used. Two heat sinks are used with the regulators to prevent damage at high temperatures.

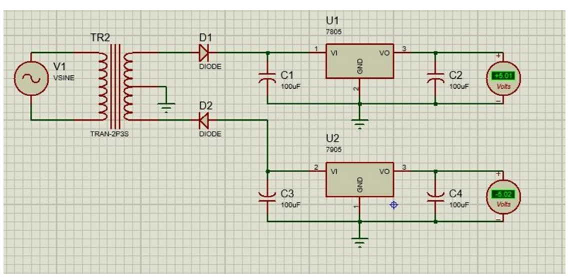


Fig. 9. Power regulation circuit

2.2.2. Light sensitivity Control

The module is designed in a way such that it works only under night/low light conditions. A simple LDR is used to achieve this. LDR has a high resistance of nearly 100 kΩ when it is in dark and has low resistance of nearly 5 kΩ when exposed to light. This simple principle of LDR is used to achieve the sensitivity of the module to light intensity. . An op-amp comparator circuit is used with 10 kΩ as the resistor on the other side for this purpose with the other input terminal of the op-amp is connected to the GND as shown in the figure. This comparator gives +5V as the output in night/low light and -5V as the output in bright light.

The comparator output is fed to an AND gate with the other terminal of the gate given a fixed value of +5V. This AND gate is used as a buffer circuit to supply power to the sensor circuit. The functionality of the AND gate is shown in the below table.

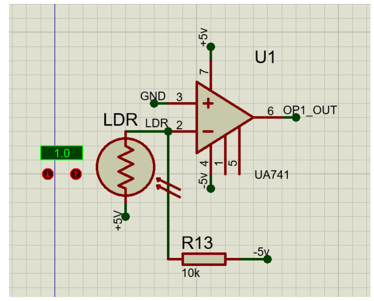


Fig. 10. Light sensitivity Control circuit

Condition	**AND gate Inputs**	**Status**
Bright	+5V +5V	ON
Low	-5V +5V	OFF

As in the table the sensor module works only in night/low light conditions.

2.2.3. Taking the input from PIR sensor

The voltage output of the RE200B sensor is fed through a active low pass filter to cancel out the noise.

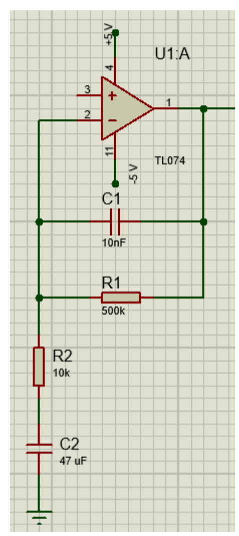


Fig. 11. Low Pass filter

$$Cutoff\ frequency = \frac{1}{2\pi R_1 C_1}$$
$$F_1 = \frac{1}{2\pi * 500k\Omega * 100nF} = 31.8309Hz \tag{1}$$

The filter has a gain of:

$$Gain = \frac{R_2}{R_1}$$
$$G_1 = \frac{500k\Omega}{10k\Omega} \tag{2}$$
$$= 50$$

Then output of the low pass filter is fed through a bandpass filter.

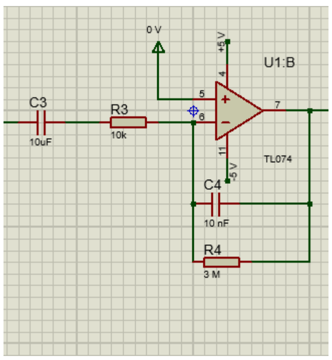


Fig. 12. Band Pass filter

$$High\ cutoff\ frequency = \frac{1}{2\pi R_4 C_4}$$
$$F_H = \frac{1}{2\pi * 3M\Omega * 10nF} \tag{3}$$
$$= 5.3051Hz$$

$$Low\ cutoff\ frequency = \frac{1}{2\pi R_3 C_3}$$
$$F_L = \frac{1}{2\pi * 10k\Omega * 10\mu F} \tag{4}$$
$$= 1.5915Hz$$

The filter has a fixed gain of:

$$Gain = \frac{R_4}{R_3}$$
$$G_1 = \frac{3M\Omega}{10k\Omega} \tag{5}$$
$$= 300$$

Total gain of the circuit is 50*300 = 15000

2.2.4. *Range adjustment*

Range is achieved by controlling the gain of the 4^{th} amplifier used in the module. Higher the gain, higher will be the range. This is because, with higher gain, the slightest variation in the output of RE200B is amplified enough to get detected resulting increase in range, and with lower gain, those slight changes are too insignificant to get detected resulting decrease in range. Gain controlling is achieved with a suitable potentiometer. By trial and error method, the appropriate gain values for various ranges up to 5m with 1m increments are found. It is done by controlling the resistance of the potentiometer which then controls the gain.

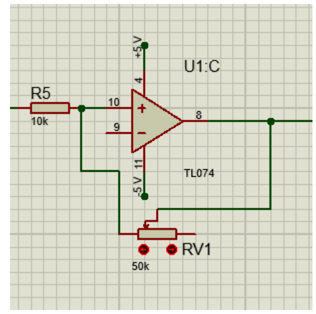


Fig. 13. Range adjustment

The potentiometer resistance values corresponding to the maximum sensing distance is shown in the below table.

Max. distance (m)	Resistance (kΩ) (±0.7)
1	3.78
2	10.33
3	13.6
4	20.3
5	24.7

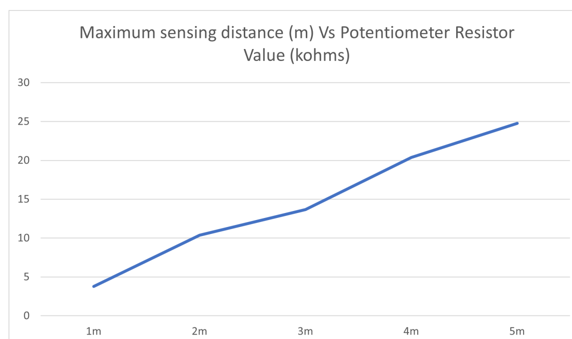


Fig. 14. Range calibration

2.2.5. *Taking the digital output*

The digital output is obtained by using two comparator circuits and a simple OR gate (build using 1N4007 diodes). The threshold values are set to +1.25V and -1.25V. Therefore whenever the voltage value goes beyond the threshold values the comparator circuit outputs +5V. This is connected to the timer circuit through an AND gate similar to the connection of light sensitivity circuit and sensor circuit. The threshold values are selected in order to increase the probability of detecting a motion and avoid unwanted reaction of the sensor module.

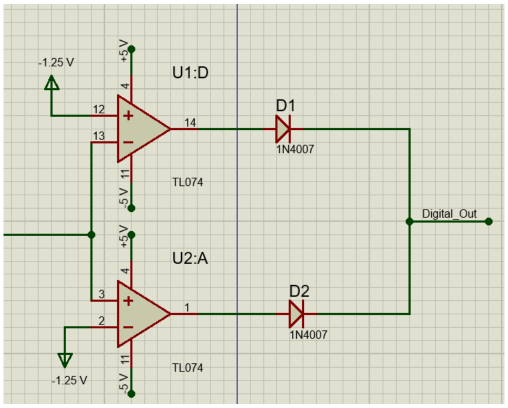


Fig. 15. Digital output

2.2.6. *Timer adjustments*

The module can work under two modes

- Single Trigger mode
- Repeat Trigger mode

These modes can be changed using a switch.

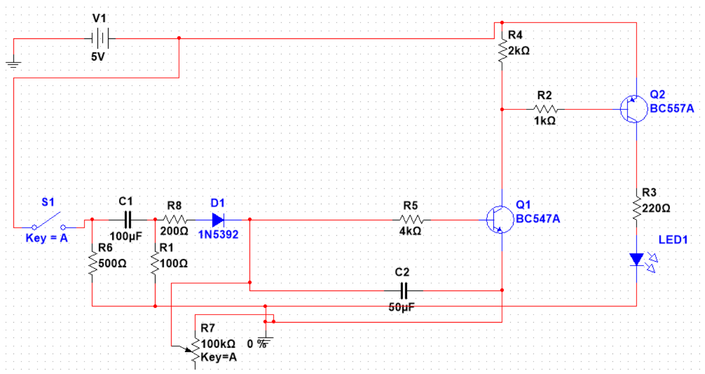


Fig. 16. Timer circuit

Single Trigger mode

In this mode the LED lights up when motion is detected. After a specific delay the LED goes off even if the object is in motion. The specific delay can be changed using a potentiometer.

This mode can be achieved by switching S1 down. After activating this mode, both capacitors C1 and C2 begin to charge. The R1 (100 Ω) resistor helps the C1 capacitor to charge quickly. When capacitor C1 is fully charged (when the voltage across capacitor C1 becomes 5V), the current flowing through the circuit stops. At this point the C2 capacitor is charged to a level that can forward bias the BE junction of the Q1 transistor. It moves the Q1 transistor to the saturation mode. The V_{CE} of Q1 decreases and it makes the BE junction of Q2 transistor forward bias and it saturates Q2. It illuminates the LED. Once C1 is fully charged, C2 capacitor begins to discharge through the variable resistor R7. Diode D1 blocks the discharging current flowing through the left side of the circuit. Transistor Q1 goes to cut off mode when the voltage drop across capacitor C2. It cuts off the Q2 transistor and turns off the LED. The specific delay of the single trigger mode can be changed by changing the discharge time of the C2 capacitor. This can be achieved by changing the R7 resistance.

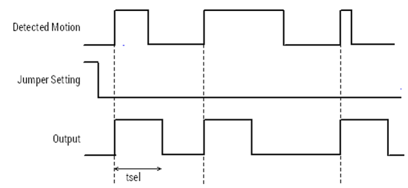


Fig. 17. Single Trigger mode

Repeat Trigger mode

In this mode, the LED lights up when motion is detected. The LED is ON until the object is in motion. When an object stops motion, or disappears from the sensing area, the LED stays ON for some specific delay. The specific delay can be changed using a potentiometer.

This mode can be achieved by switching S1 up. After activating this mode, C2 begins to charge. This drives the Q1 transistor to saturation. As in the previous mode the Q2 transistor becomes saturated and the LED lights up. When an object stops motion, or disappears from the sensing area, the C2 capacitor begins to discharge through the variable resistor R7. During the discharge time (until Q2 becomes cut off) the LED stays ON for some specific delay. In here Diode D1 separates the left side and the right side of the circuit. As in the previous mode the transistor Q1 goes to cut off when the voltage drops across capacitor C2. It cuts off the Q2 transistor and turns off the LED. The specific delay of the repeat trigger mode can be changed by changing the discharge time of the C2 capacitor. This can be achieved by changing the R7 resistance.

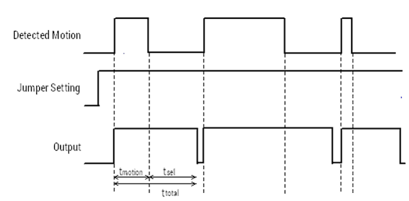


Fig. 18. Repeat Trigger mode

2.2.7. Indicating the output

The output of the module is shown using a LED attached to the enclosure. The indicator can be replaced with a buzzer circuit as well as per the wish, since the indicator is connected using a connector to the PCB. According to the preference of the user the indication can be given as light through a LED or as sound using a buzzer circuit as well.

3. RESULT

3.1. Prototype Description

The prototype is supposed to detect any motion in its sensing range in night/low light conditions and give an LED output. Its maximum sensing distance can be changed using a potentiometer. The built prototype was tested inside the laboratory manually under several circumstances and performed as expected.

3.2. PCB Design

PCB for the project was designed using the Altium Designer software version 21.3.1. The PCB designed for the project is a double layer PCB of dimension 98.806mm x 62.484mm. The PCB was manufactured by a local manufacturer. The normal traces are 0.8mm and +5V, -5V traces are 1mm in width. The GND is the copper plane. The clearance between traces is 0.8mm. The design of the PCB is shown below.

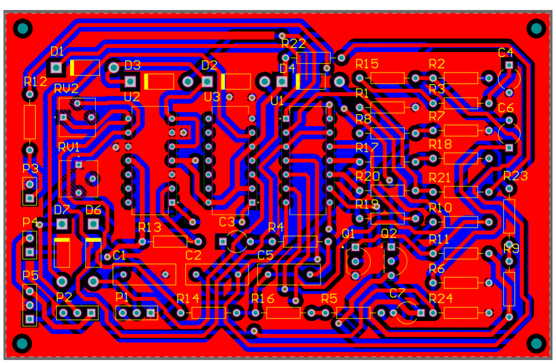


Fig. 19. PCB design

3.3. Enclosure design

The enclosure was designed using dark gray high gloss plastic. The RE200B sensor is placed inside a fresnel lens. Two plastic knobs are attached to the enclosure to control the two potentiometers. A toggle switch is used to switch between the timing modes.

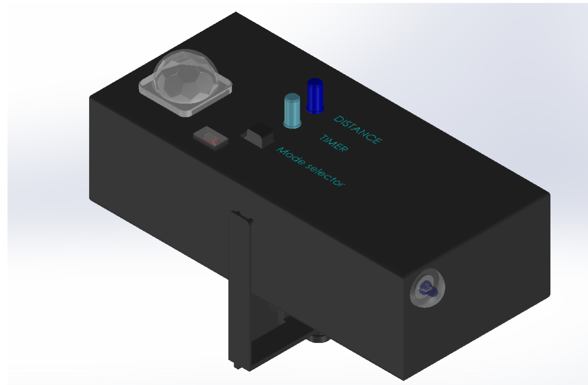


Fig. 20. Enclosure design

4. DISCUSSION

4.1. PCB Manufacturing and soldering

Designing the PCB was a bit challenging as it is required to route all the pins of the ICs in the same layer in order to make soldering of the IC easier. To meet that requirement many vias were used.

After manufacturing the PCB only, a mistake on the schematic of the circuit is found. So, the mistakes were found and re routed manually using wires. For manufacturing, the PCB is mirrored so the component pins are mismatched in the manufactured PCB. So the pins of some components had to be inverted especially for the ICs to match the correct pins with the footprints. Due to these, soldering the components was challenging. The final manufactured PCB after soldering the components looked like as shown in the below figure.

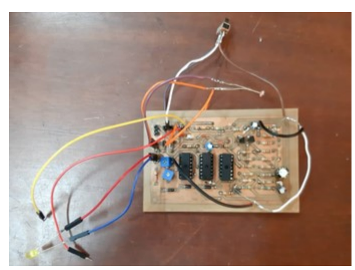


Fig. 21. Final PCB

4.2. Enclosure designing

The LED is placed in such a way that the emitted light is not detected as a bright light condition by the LDR.

4.3. Prototype designing

This project was really helpful to learn how a PIR sensor works. Using the knowledge in the analog electronics the analog output from the PIR sensor was converted as the digital output required to indicate using an LED. As mentioned above soldering the PCB was the most challenging part of the project. Apart from that in the breadboard implementation the circuit sometimes did not work as expected due to some loose connections making it hard to debug the circuit. Therefore we had to debug the circuit many times to get the final prototype as the result.

The skill of using the laboratory equipment and knowledge about some electronic components are improved with the help of this project. Other than that everyone learnt how to work on the project in a given timeline, working as a team and managing the work load of the project together with the other things to do. Overall this experience will help to work on the future projects in a better manner.

5. REFERENES

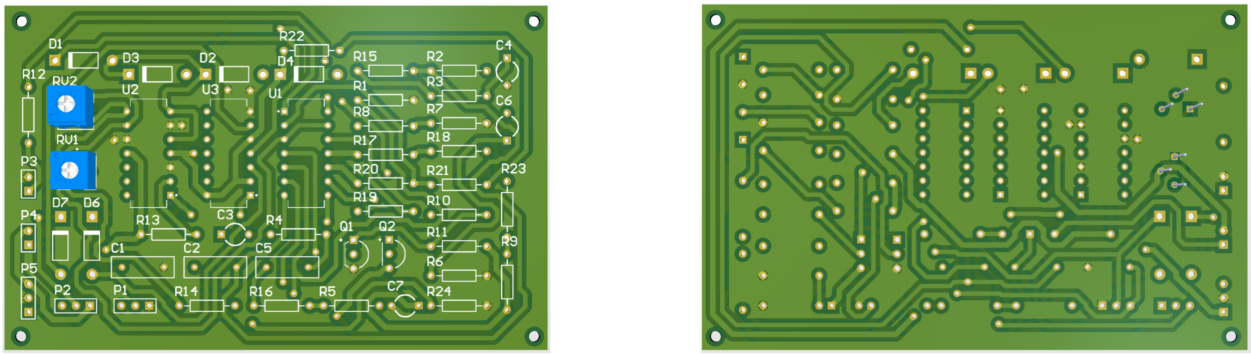
1. PIR sensor module
2. RE200B datasheet
3. Passive Infrared (PIR) Detector Controller
4. TL074CN datasheet
5. SN74HC08N datasheet

6. CONTRIBUTIONS

- 190115P - Distance adjustment, comparator circuit for thresholds
- 190128H - Noise cancellation, Enclosure design
- 190144D - Timer circuit, Voltage regulation
- 190149X - Light intensity circuit, PCB design

7. APPENDICES

7.1. PCB Design



(a) Top layer (b) Bottom layer

Fig. 22. PCB design

7.2. Schematic diagram

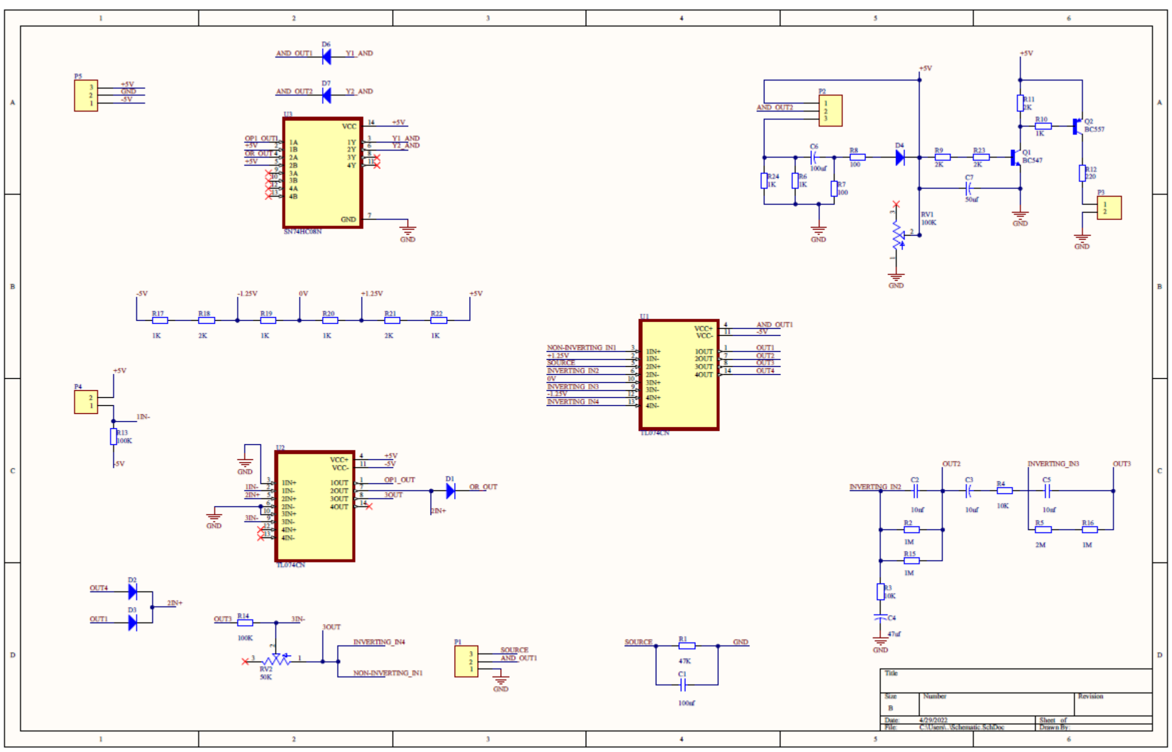
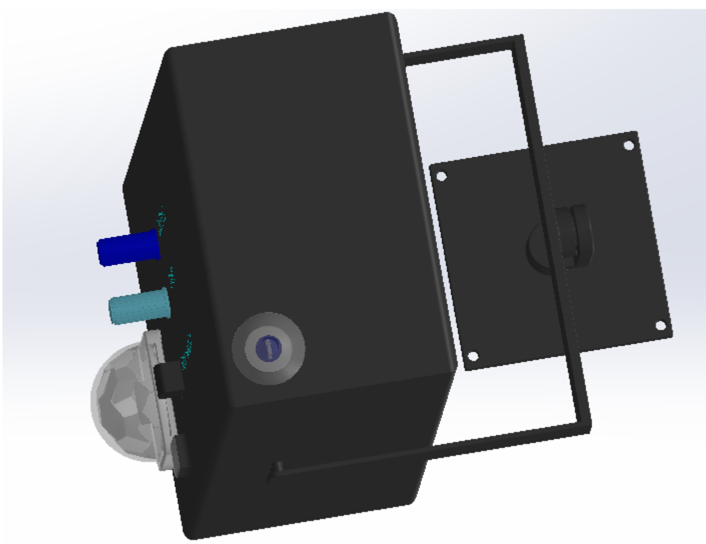


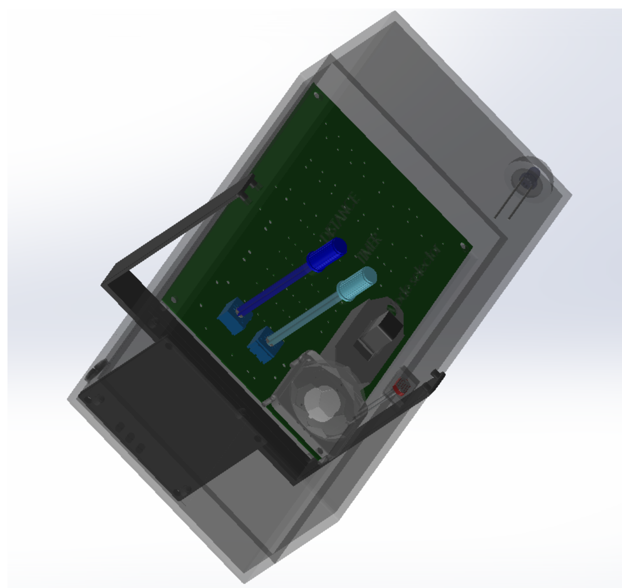
Fig. 23. Schematic diagram

7.3. Enclosure design

(a) Top view



(b) Side view



(c) Transparent view

Fig. 24. Enclosure design

7.4. Datasheet

DATASHEET

PIR Sensor Module

The PIR sensor detects motion in its sensing range and gives a voltage signal as the output. In this project the PIR sensor was used to build a module which gives digital output in different modes, and it can be indicated using an LED or a buzzer as per user wish. Also, the sensitivity can be manually changed to change the sensing range of the sensor module. The module also detects the light intensity of the environment and designed to work only in the dark light conditions.

1. WORKING MODES

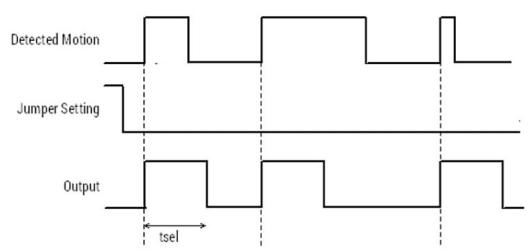
The module can work under two modes:

- Single Trigger mode
- Repeat Trigger mode

These modes can be changed using the switch.

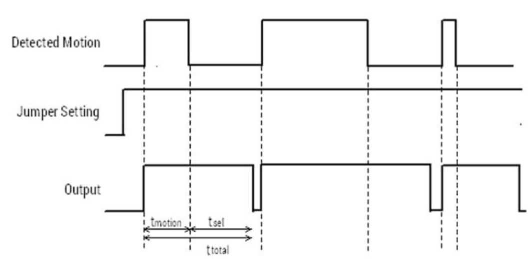
1.1 Single Trigger mode

In this mode the LED lights up when motion is detected. After a specific delay the LED goes off even if the object is in motion. The specific delay can be changed using a potentiometer.



1.2 Repeat Trigger mode

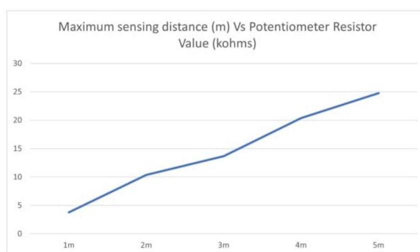
In this mode, the LED lights up when motion is detected. The LED is ON until the object is in motion. When an object stops motion, or disappears from the sensor area, the LED stays ON to some specific delay. The specific delay can be changed using a potentiometer.



2. SENSITIVITY CONTROL

The maximum sensing distance can be changed using a potentiometer. The recommended sensing distance is from 1 metre to 5 metres. Because as the distance increases the intensity of the receiving signal decreases resulting the accuracy of the module decreases. Anyhow the sensing angle cannot be changed. It is a fixed angle of 1350. The potentiometer resistance values corresponding to the maximum sensing distance is shown in the below table.

Maximum sensing distance (in metres)	**Potentiometer resistance value (in kohms) (±0.7 k)**
1	3.78
2	10.33
3	13.6
4	20.3
5	24.7



3. PRECAUTIONS

- Do not use in a high temperature area
- Keep the sensor and LDR facing the environment the module wants to detect
- Do not keep any bright lights in the sensing environment of the module. (The module might not work in bright lights)