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Department of Electronic and Telecommunication

University of Moratuwa

In19-S3-EN2090 - Laboratory Practice - II

Lab Project Report - Group 27

PIR sensor

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Contents

7**Abstract** : This report deals with how to design a simple PIR sensor capable of motion detection. In this report, we discuss how this measures infrared light radiating from objects, its field of view, how sensitive and accurate the sensor is and its limitations.

***Keywords*—** PIR, Fresnel lens, Sensitivity, Trigger Mode, Re-trigger Mode, Timeout, Lux

1 Introduction

The main application of the PIR sensor is to detect motion and control the level of light in automated controllers. The PIR sensor module is activated based on IR waves radiated from the adjusted field of view. The complete project is based on four circuit parts given as adjusting sensitivity, a timer circuit, trigger and re-trigger modes and an LDR circuit. Combined, these circuits can amplify the signal generated from the sensor module, adjusting the device so that it only works under low light and whether the object is in continuous motion.

At the start of the project, the circuit was implemented using the software, and the parts were tested separately using simulations. ”Circuit-maker” and ”Multisim” were used for the execution. After that, the entire circuit was implemented and tested using both the sensor module and signal generators and finally assembled in the laboratory environment, which proved difficult due to various reasons for handling op-amps.

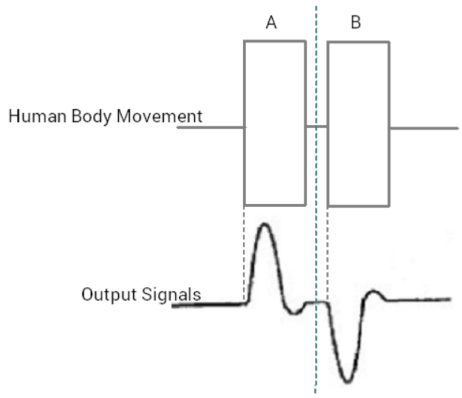

Figure 3: Output of the module when there’s movement of a heat signature

The crystal is split into two and wired together so that the pulses of each sensor cancel out. When one part of the crystal detects a heat signature moment in its field of view, it generates a positive pulse while the other part differentiates it and build a negative pulse. This mechanism is illustrated in Figure 3.

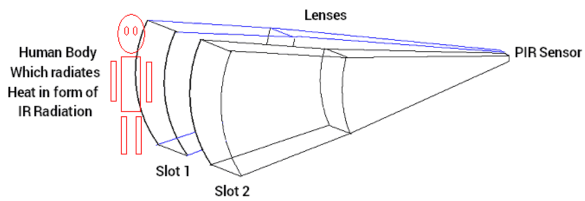

Figure 4: Practical Implementation

2 Methodology

2.1 Mechanism of PIR Sensor [1]

2.1.1 On motion

Indicated by the word Passive, the PIR sensor only detects emitted radiation from objects, which detects the heat signature. This project is built upon the PIR sensor module RE200B, a pyroelectric[1] sensor shown in the rectangular crystals in Figure 1.

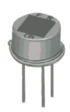

Figure 1: PIR sensor module

Figure 2: Grid Eye Illusion

2.1.2 On Idle

At the idle position, both IR detection slots detect the same signal value of IR radiation. Therefore, the PIR sensor inner circuit, consisting of a differential amplifier, gets the same value per slot. It does not identify an error between two values from the slots. As a result, the circuit output from the PIR sensor is zero.

[1] pyroelectricity - the ability of certain crystals to contain large electric fields due to their natural polarity

2.1.3 Fresnel Lens

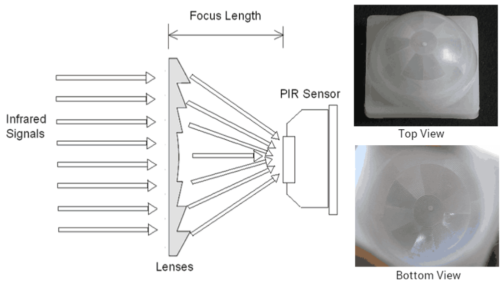

Figure 5: Fresnel Lens views

The PIR sensor's sensitivity depends on the direct IR radiation and the radiation it gets from a wide-angle. Therefore, we need to use a lens to detect more IR radiation to improve sensitivity. Fresnel lens moulded with plastic to reduce the fixed cost of the sensor. This lens condenses the light and provides a wide range of motion detection coverage (Up to 150 degrees) for the circuit [3]. Therefore, this helps to identify even a small signal around the PIR sensor that can activate both slots of the PIR sensor to identify a motion.

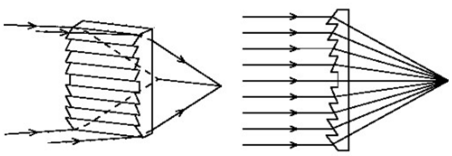

Figure 6: How lens condenses the light

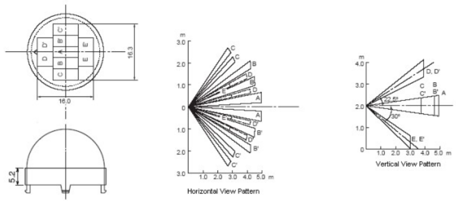

Figure 7: Human Body IR detection form the lens

2.2 Components of the circuit

The circuit described in the following subsections is designed for a 12V Vcc and -Vcc values. LM324 op-amp is used for most of the applications throughout the circuit.Typically, PIR sensor output is around 0.5mV to 1mv in peak-peak. (Vpp) And it has a dc voltage offset of around 0.3V to 1.3V.

2.2.1 Amplifying the PIR output signal and adjusting sensitivity

The drain of the PIR sensor is connected to the supply voltage of 12V. PIR sensor needs a constant Vcc without floating. Therefore, we used a capacitor (C_7) to reduce any ripples (If there were any) in the drain voltage. Then the Ground pin of the PIR sensor is connected to the ground supply directly. The sensor's other pin (pin 02) is the Source pin connected to the first op-amp inverting pin for noise cancellation and first gaining.

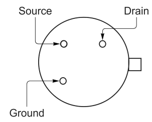

Figure 8: PIR sensor pin-out

Sensitivity Adjusting can be divided into 2 stages.

Stage 01

PIR sensor is made by using an inbuilt Mosfet. Therefore, we need to add a large resistor to remove charges from the gate pin of the MOSFET. For that, we use a 47kresistor (R_2) in between the source pin of the PIR sensor and the ground. Also, it ensures quick switching when objects move fast above the sensor range. Then we connect a capacitor with the value of 33nF (C_3) to remove the offset voltage of the signal. Then the adjusted signal is connected to the op-amp for noise cancellation. PIR sensor output is around 1mV (peak to peak). Therefore, the signal is corrupted by the noise. This can lead to false detection. Such that we used the noise cancellation technique to get the original signal. Noise is generally in the high-frequency range. Therefore, we used a low pass filter with a 4.82 Hz cutoff frequency and a high pass filter with Hz to get the original signal.

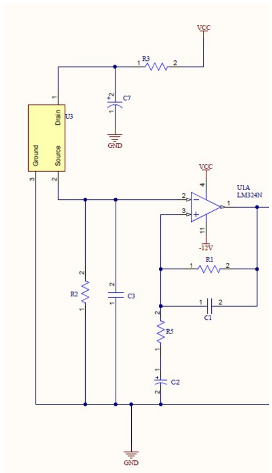

Figure 9: Amplification Circuit

Stage 01 Gain We have to gain the signal high enough for the next stage (around 100 times with the initial) but not too high because it can drive the signal into the saturation level of the op amp.

Stage 01 Calculation

$$f_{high} = \frac{1}{2\pi R_1 C_1} = \frac{1}{2\pi 1 \times 10^6 \times 33 \times 10^{-9}}$$
$$= 4.82Hz \tag{1}$$

$$f_{low} = \frac{1}{2\pi R_5 C_2} = \frac{1}{2\pi 10 \times 10^3 \times 47 \times 10^{-6}}$$
$$= 0.34Hz \tag{2}$$

Stage 1 gain

$$Gain = 1 + \frac{R_1}{R_5} = 1 + \frac{2 \times 10^6}{10 \times 10^3}$$
$$= 101 \tag{3}$$

Stage 02

In the second stage, we have to adjust the sensitivity according to user requirements. For that, we used a 100k resistor to adjust the sensitivity by changing the signal's voltage. Then in the next op Amp, we gain the signal and further remove the noise. We set the low cut-off frequency in the low pass filter to 4.83Hz and the high pass filter cut-off frequency to 0.16 Hz to get a better signal. The signal output wave is as follows.

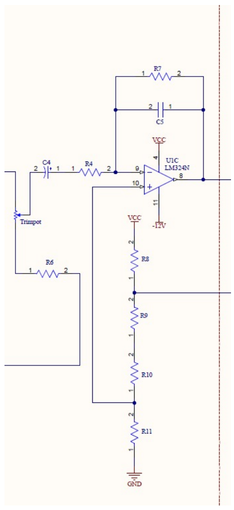

Figure 10: Second Stage Amplifier Circuit

Stage 02 Gain In stage 02, we gain the signal 100 times more than in stage 02 to get a proper output after adjusting the sensitivity of the signal. Then we keep the standard mode voltage of the signal as 4.09 V (34% of the Vcc) to clip the peaks of the signal intentionally.

Stage 02 Calculation

$$f_{high} = \frac{1}{2\pi R_7 C_5} = \frac{1}{2\pi 1 \times 10^6 \times 33 \times 10^{-9}}$$
$$= 4.82Hz \tag{4}$$

$$f_{low} = \frac{1}{2\pi R_4 C_4} = \frac{1}{2\pi 10 \times 10^4 \times 10 \times 10^{-6}}$$
$$= 1.59Hz \tag{5}$$

Stage 2 gain

$$\text{Gain} = -\frac{R_7}{R_4} = -\frac{1 \times 10^6}{10 \times 10^3}$$
$$= 100 \tag{6}$$

$$\begin{aligned} \text{Ordinary Mode Voltage} &= \frac{12V}{R_8 + R_9 + R_{10} + R_{11}} \times R_{11} \\ &= \frac{12V}{120 + 120 + 56 + 56} \\ &= 4.09V \end{aligned} \tag{7}$$

Figure 11: Output from the amplifier with the Sensitivity adjust.

2.2.2 Comparator circuit

In the previous stage, we got an A/C pulse signal. Now we need to compare the signal to get a square wave because it is easy to handle a square wave rather than a sine pulse signal. Moreover, in the following parts, the timer and Lux circuits need a constant Voltage pulse as an input to handle the circuit. Then we add a diode to ensure that the pulse only goes in one direction and block the interference to each circuit block from other blocks. After the comparator circuit user can decide the trigger mode by using the switch. Input for the next stage of the timer will depend on selecting the trigger mode. Output from the comparator is as below.

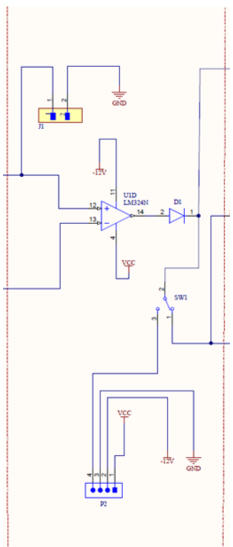

Figure 12: Comparator Circuit

Stage 03 Calculation Comparator Voltage Reference

$$
\begin{aligned}
V_{High} &= \frac{Vcc}{R_8 + R_9 + R_{10} + R_{11}} \times (R_9 + R_{10} + R_{11}) \\
&= \frac{12V}{120 + 120 + 56 + 56} \times (120 + 56 + 56) \\
&= 7.9V
\end{aligned} \tag{8}
$$

$$
\begin{aligned}
\text{Original Signal Comparator Voltage} &= 7.9V - \text{offset added} \\
&= 7.9V - 4.09V \\
&= 3.82V
\end{aligned} \tag{9}
$$

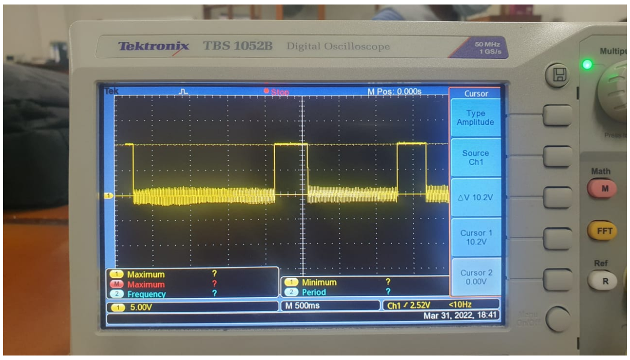

Figure 13: Comparator Circuit Output

2.2.3 Timer Circuit

After selecting the triggering mode signal will enter the timing adjustment part. For that, we used the LM741 timer circuit [4]. We used a diode at the signal collected op-amp non-inverting pin to block the interference that can happen by the capacitor to other circuits.

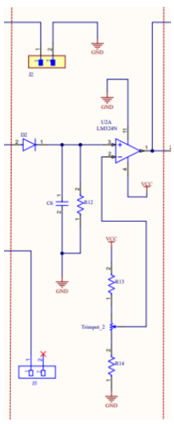

Figure 14: Timer Circuit

Then we used a capacitor in between the non-inverting pin and the ground. The purpose of this capacitor (C_6) is to adjust the pulse width of the signal. The potentiometer is connected to the inverting pin of the op-amp. According to the voltage level, we adjust the potentiometer used to reference the non-inverting pin. When motion is detected, the comparator gives a 12V voltage pulse. From that capacitor will be charged. Then it will be starting discharged. Up to the reference voltage point, the circuit gives an output of 12V Vcc. When the discharging signal drops below the reference level, the op-amp produces the output of 0V, which is the voltage of -Vcc in the op-amp. We used a resistor (R_{12}) parallel with the capacitor to discharge the capacitor gradually. Calculations and the output wave-forms are as follows.

Timing Calculation Assume preset resistance is set to the value of R.

$$
\begin{aligned}
\text{V in inverting Pin} &= \frac{Vcc}{R_{13} + R_{Trim-pot_2} + R_{14}} \times (R_{14} \times R) \\
&= \frac{12V}{100 + 100 + 10} \times (10 + R) \\
&= \frac{12(10 + R)}{210} V
\end{aligned} \tag{10}
$$

$$
\text{Discharge Equation} = V_c = V_{in} e^{-\frac{t}{RC}}
$$

$$
\begin{aligned}
V_1 &= 12e^{\frac{t}{2.2\times10^6\times10\times10^{-6}}} \\
&= 12e^{-\frac{t}{22}}
\end{aligned} \tag{11}
$$

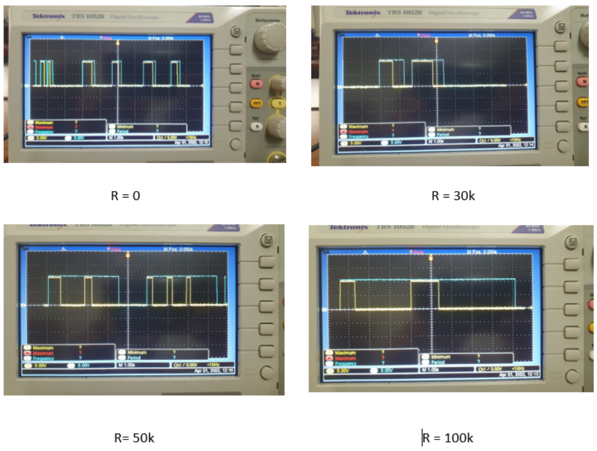

Figure 15: Time-Out Circuit Output

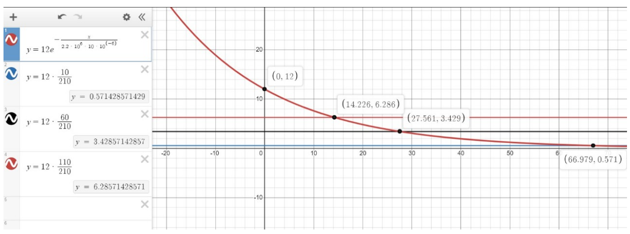

Figure 16: Time adjustment according capacitor discharging graph

2.2.4 LDR circuit [2]

After adjusting the timeout signal entered into the lux adjust circuit. Op amp non-inverting pin connected to the output signal of the timer circuit. We add a potentiometer to the inverting pin to adjust the reference voltage of the pins of the op amp. LDR is connected to the Signal pin to adjust the voltage level according to the light intensity of the signal. The simulation of the circuit is as follows.

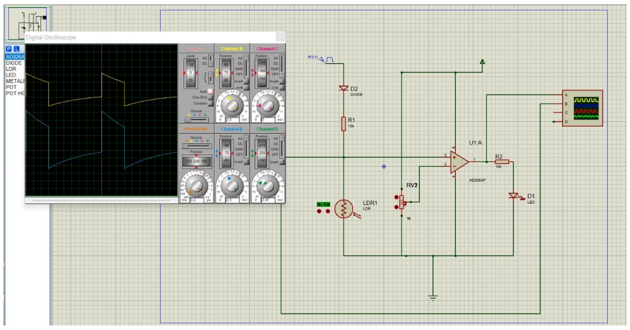

Figure 17: Time adjustment according capacitor discharging graph

- Yellow color signal – Output of the lux circuit.
- Blue color signal – Input voltage pulse changes according to the LDR intensity.

2.2.5 Trigger Mode

Users can change the switch according to the requirement. In trigger mode output will be 12V when the object is detected, then it will go to 0V in a defined specific period which is adjusted in the timeout circuit. Then it stays on low for a small time period and again it goes to 12V if motion is detected. For this mechanism, we used a triggering property of the MOSFET. We get the output from the timeout circuit and inverted the signal by using TL071cp op amp. Then we keep the reference voltage at -6V and got the inverted pulse of the timeout pulse. This is because we need to get the signal for the next stage from the comparator when the output is low. Then we triggered the MOSFET by giving this inverted output into the gate. We connected the comparator output to the drain to get the pulse input to the MOSFET. After the process, we compare the signal with a reference voltage of 8 V and output the signal for time adjustment. We used diodes for this circuit to block the interference from the other blocks to the circuit. The simulation and results are as follows.

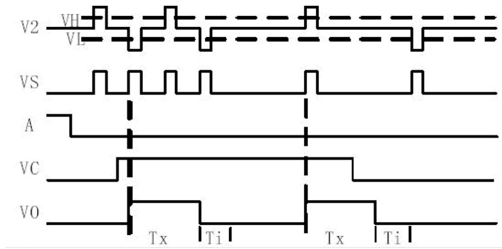

Figure 18: Trigger Output V0

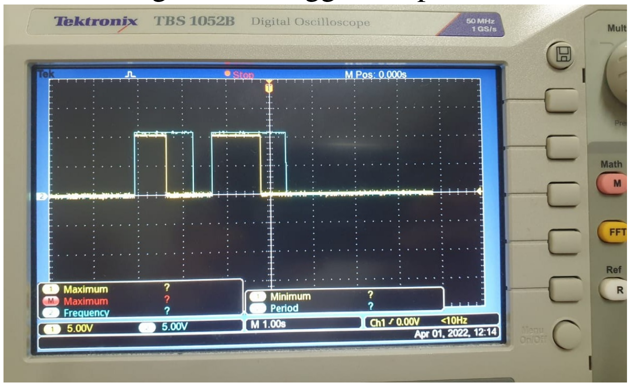

Figure 19: Trigger Output
Blue - Output Signal Yellow - Input Signal

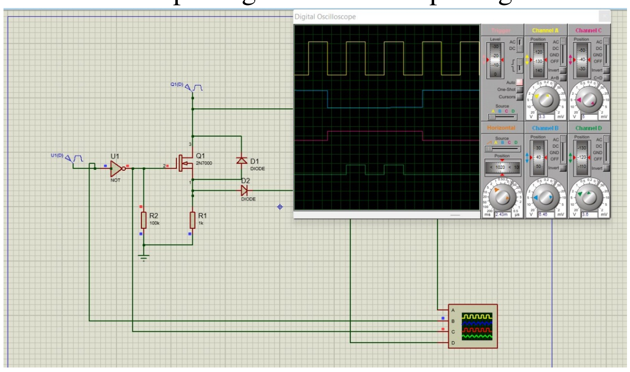

Figure 20: Trigger Simulation

- Comparator Input – Yellow colour signal
- Timer circuit output – Blue colour signal
- Inverted Timer circuit input circuit output as the input to trigger the MOSFET – Red colour signal
- The output of the trigger circuit – Green colour signal

2.2.6 Re-trigger Mode

Re-trigger mode also known as repeat trigger mode is the other mode of the PIR sensor modes. In this mode circuit will remain high until the motion and then the output remain high until the specified delay time which is adjust during the time out circuit. This is the most common method in PIR sensor. If the motion is continuous in covered are of the PIR sensor output will remain high(12V) until it stops the motion. Result signal of the re-trigger mode is as follows.

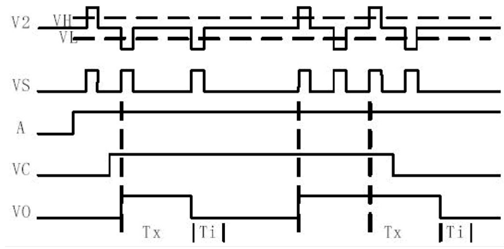

Figure 21: Re-trigger Mode Output - V0

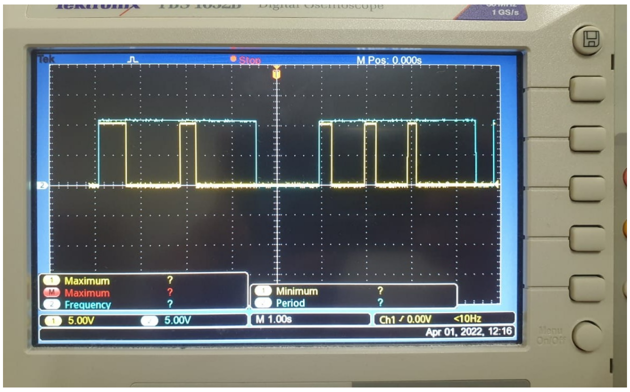

Figure 22: Re-trigger Mode Output Pulse

2.3 PCB layout

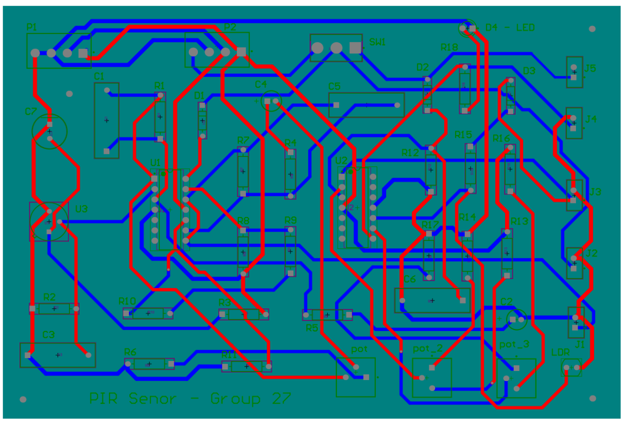

Figure 23: PCB layout

2.4 Solidswork design (Diagrams of each part and of full assembly)

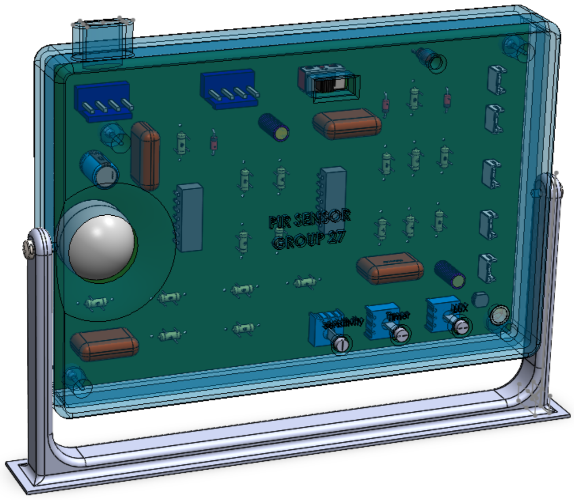

Figure 24: Solid-works Design

3 Results

- The operating voltage of the circuit is 12V.
- Our circuit can handle a sensitivity distance of approximately 6 meters. Sensitivity also depends on the environmental conditions and object size.
- The circuit worked in two modes. They are Trigger mode Retrigger mode.
- We can change the mode by using the switch.
- Trigger mode gives high(12V) output once motion is detected, and the next motion will detect after the output goes to low(0V).
- Retrigger mode gives a high voltage pulse(12V) until motion stops. It continuously detects the motion rather than trigger mode. When the motion stops output remains within a specific timeout period.
- Users can adjust the time-out period. The maximum time that can change is up to 70 seconds, the minimum time is 14 seconds.
- Users can adjust the Lux adjustment. This adjustment defines the light intensity when the light will be on and off.
- Circuit output is visible from the LED.

- This Circuit also can use to switch on a relay to on or off a bulb is 230V.
- Extremely low power consumption. Approximately max 2mA current need.

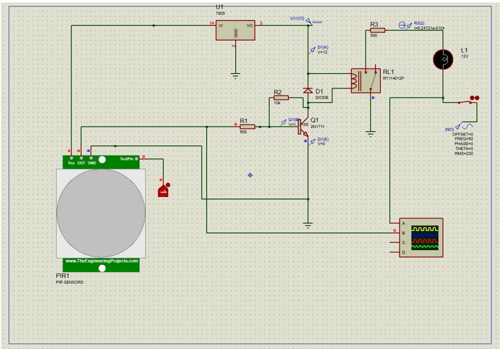

Figure 25: Relay Output

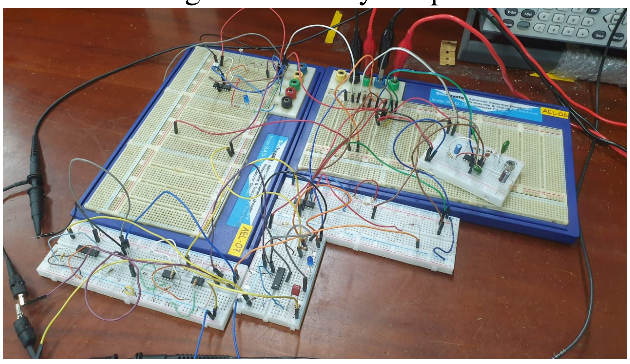

Figure 26: Prototype Design

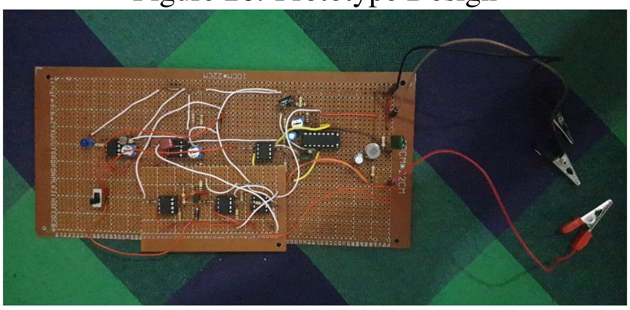

Figure 27: Dot Board Design

4 Conclusion

This project is based on the PIR sensor. PIR sensor is based on the IR radiation of objects. To identify a motion sensor used two slots to generate an A/c signal pulse. PIR sensor output peak-peak voltage is extremely low, and it is corrupted with noise. Therefore, we need to filter the circuit before doing other adjustments. After filtering signal was gained using op amps and compared the signal with the specified reference voltage. Then the operating mode is selected out of trigger mode re-trigger mode. After the mode selection, time-out period adjustment lux adjustment are done in separate circuit blocks. Finally, the output is used to switch on off a LED light according to the motion detection. Dot board design and PCB design were done according to the circuit design. As the final Solidswork design was done to give a fine look for the final product. With a lot of failures, we can be able to build a very user-friendly PIR module with Sensitivity adjustment, Timer adjustment, Lux adjustment, Mode selection with Trigger mode, and Re-trigger mode.

5 Contribution from each member

- Wanshika W.A.R. - Sensitivity, Filtering, Circuit design, PCB design
- Weerasinghe K.N - LDR circuit, Solidswork design, Report
- Wickrama W.M.T.B. - Timer circuit, Soldering, Circuit design

6 Acknowledgement

First and foremost, we would like to express our sincere gratitude to our group coordinator Mr. Thamindu Naveen, assistant lecturer, Electronic and Telecommunication Department, the University of Moratuwa for staying connected with us throughout the entire span of the project and taking countless meetings with us and guiding us in every single step of our project. And also, we would like to thank our evaluation panel, Mr. Bhanuka de Silva, Mewan Wijewaradhana Pasan Dissanayake for advising on upcoming projects.

And we would like to thank all the Senior lecturers, Assistant lecturers, the Electronics and Telecommunication Department, the University of Moratuwa along with all the junior lecturers for conducting sessions based on specific stages of the project and for the knowledge given through the modules.

And we would also like to remember Mr. Ajith Pasquel for conducting sessions on SOLIDWORKS essentials and Altium under the module electronic product design and manufacture.

References

[1] lady ada, "PIR Motion Sensor," https://learn.adafruit.com/

pir-passive-infrared-proximity-motion-sensor/how-pirs-work/, 2008, [Online; accessed 1-May-2022].

[2] terraduino, “Night light with LDR and PIR but no µC,” https://forum.arduino.cc/t/night-light-with-ldr-and-pir-but-no-c/513697/, 2018, [Online; accessed 1-May-2022].

[3] adafruit, “RE200B,” https://cdn-learn.adafruit.com/assets/assets/000/010/134/original/RE200B.pdf, [Online; accessed 1-May-2022].

[4] circuitdiagram.org, “LM741 Timer,” http://www.circuitdiagram.org/lm741-timer.html, [Online; accessed 1-May-2022].

A First Appendix - Full Circuit

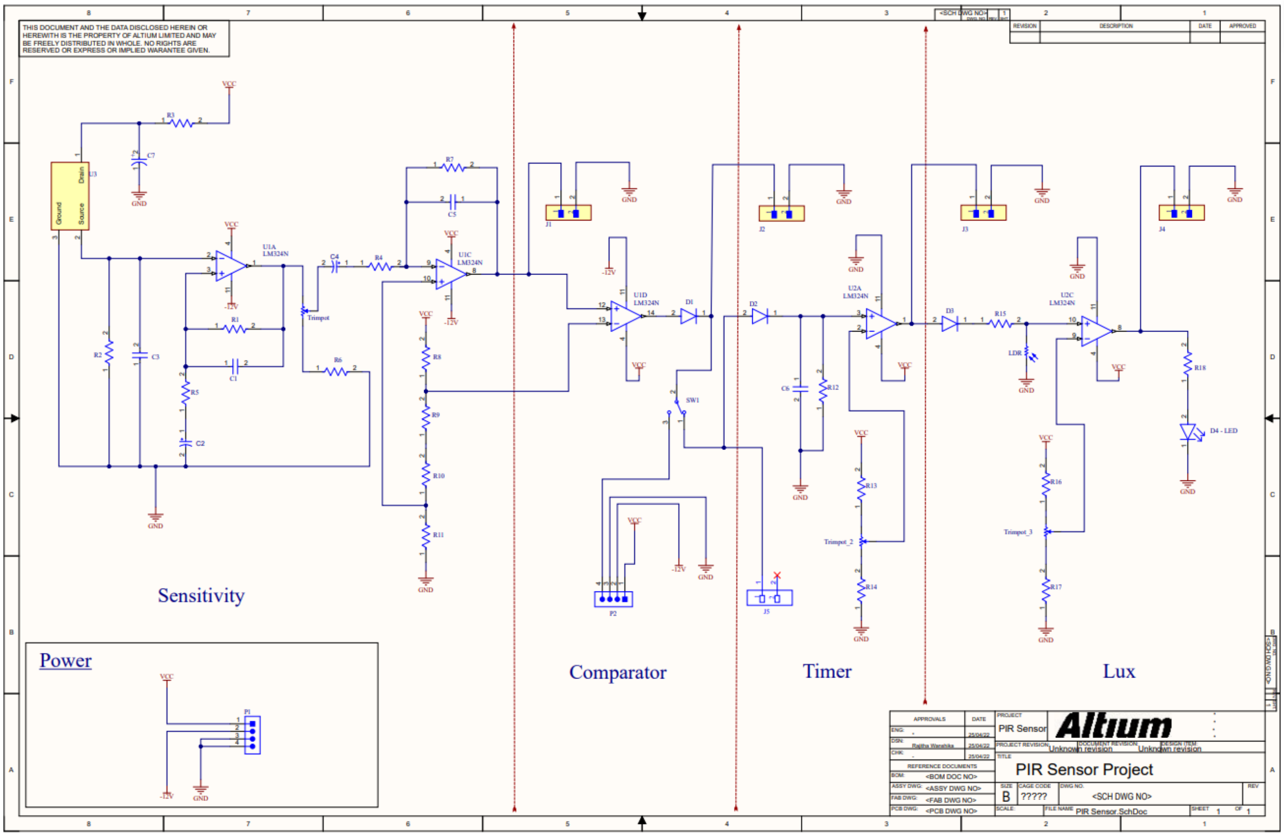

Figure 28: Complete Schematic Diagram

B Second Appendix - Trigger Circuit

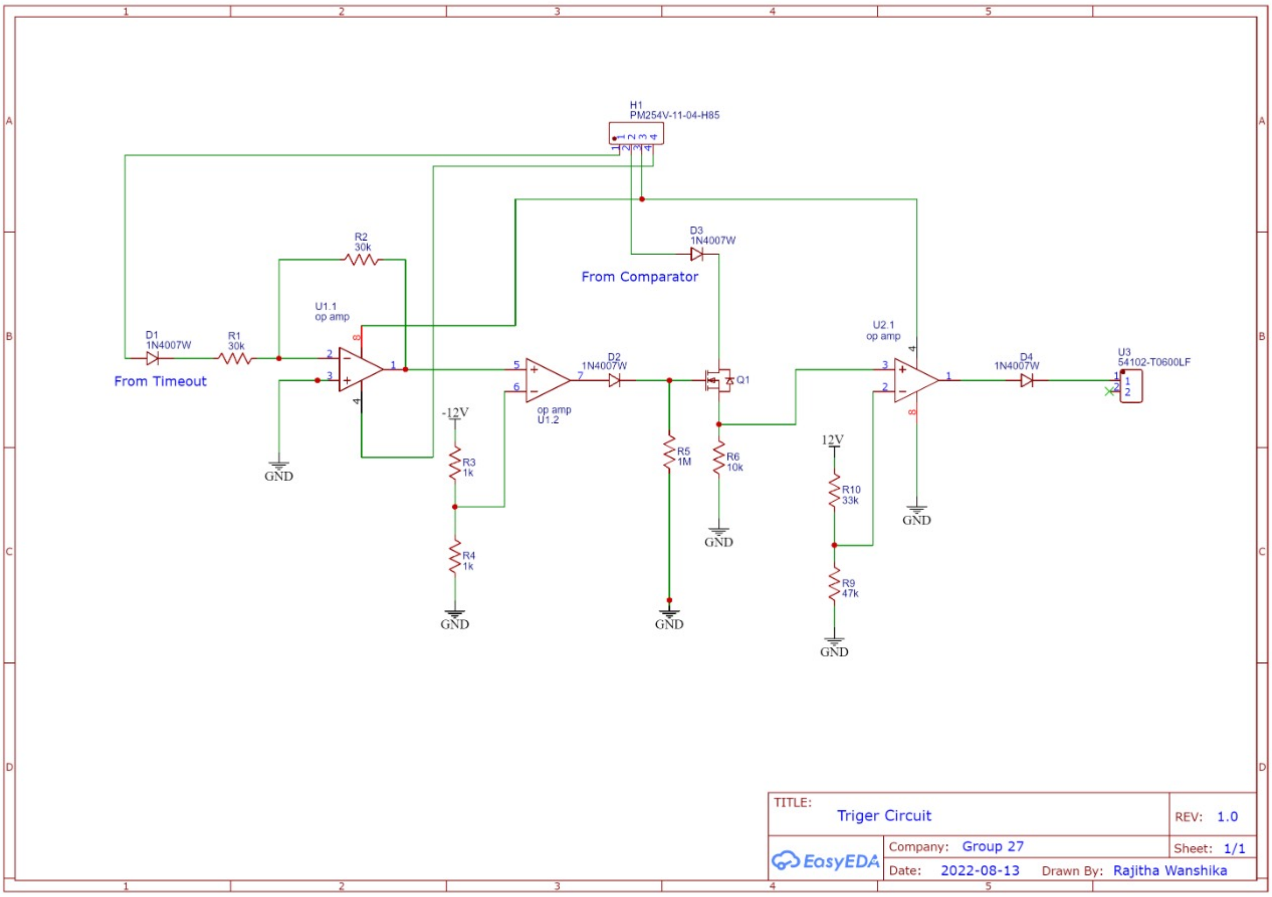

Figure 29: PIR Trigger Mode

C Third Appendix - Block Diagram

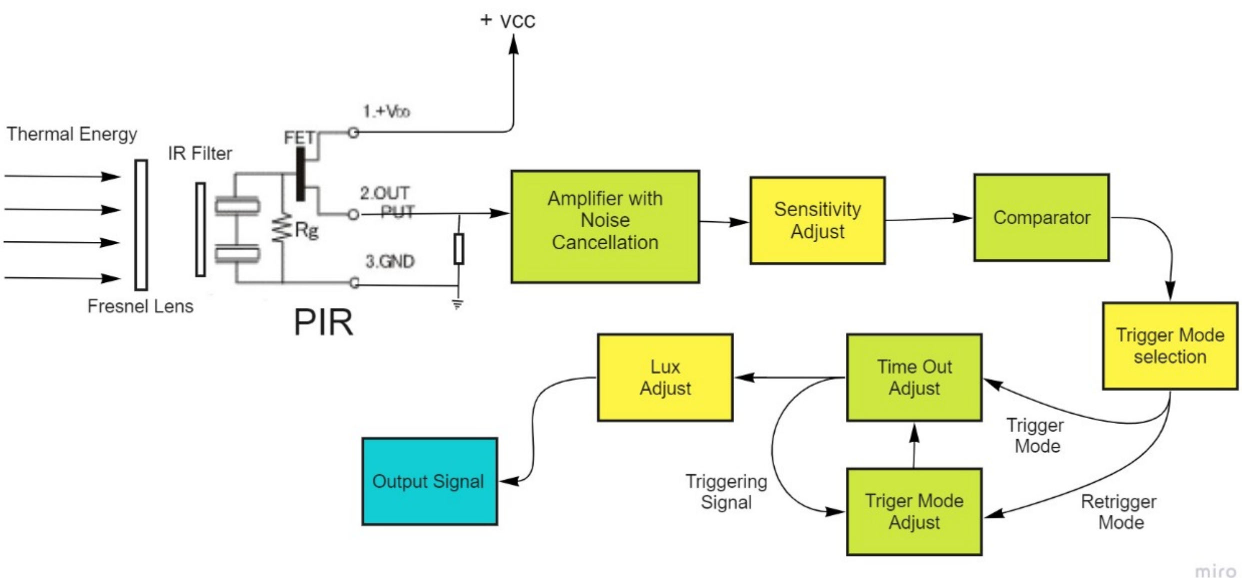

Figure 30: Block Diagram of the circuit

D Forth Appendix - 3D Layout Main Circuit

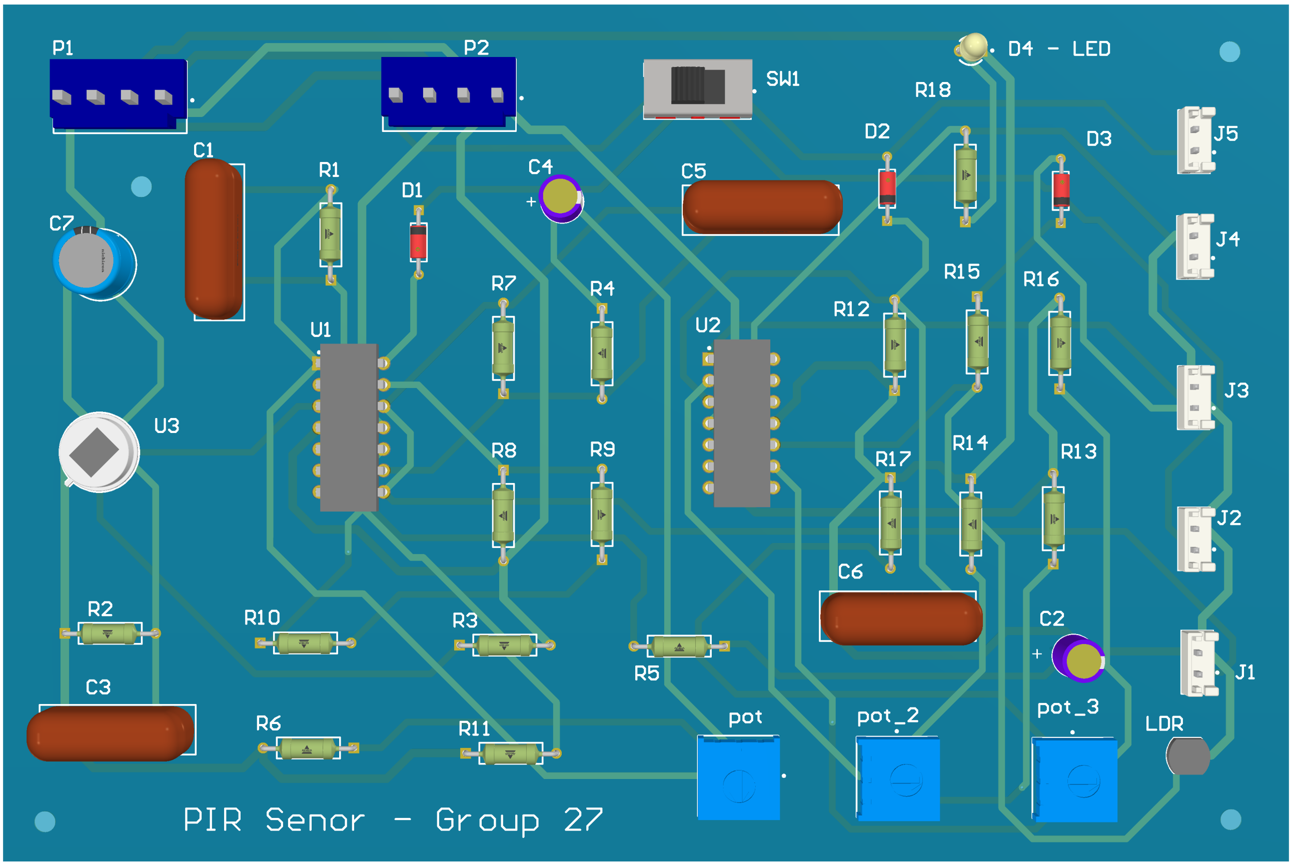

Figure 31: 3D Layout of main circuit

E Forth Appendix - 3D Layout Trigger Circuit

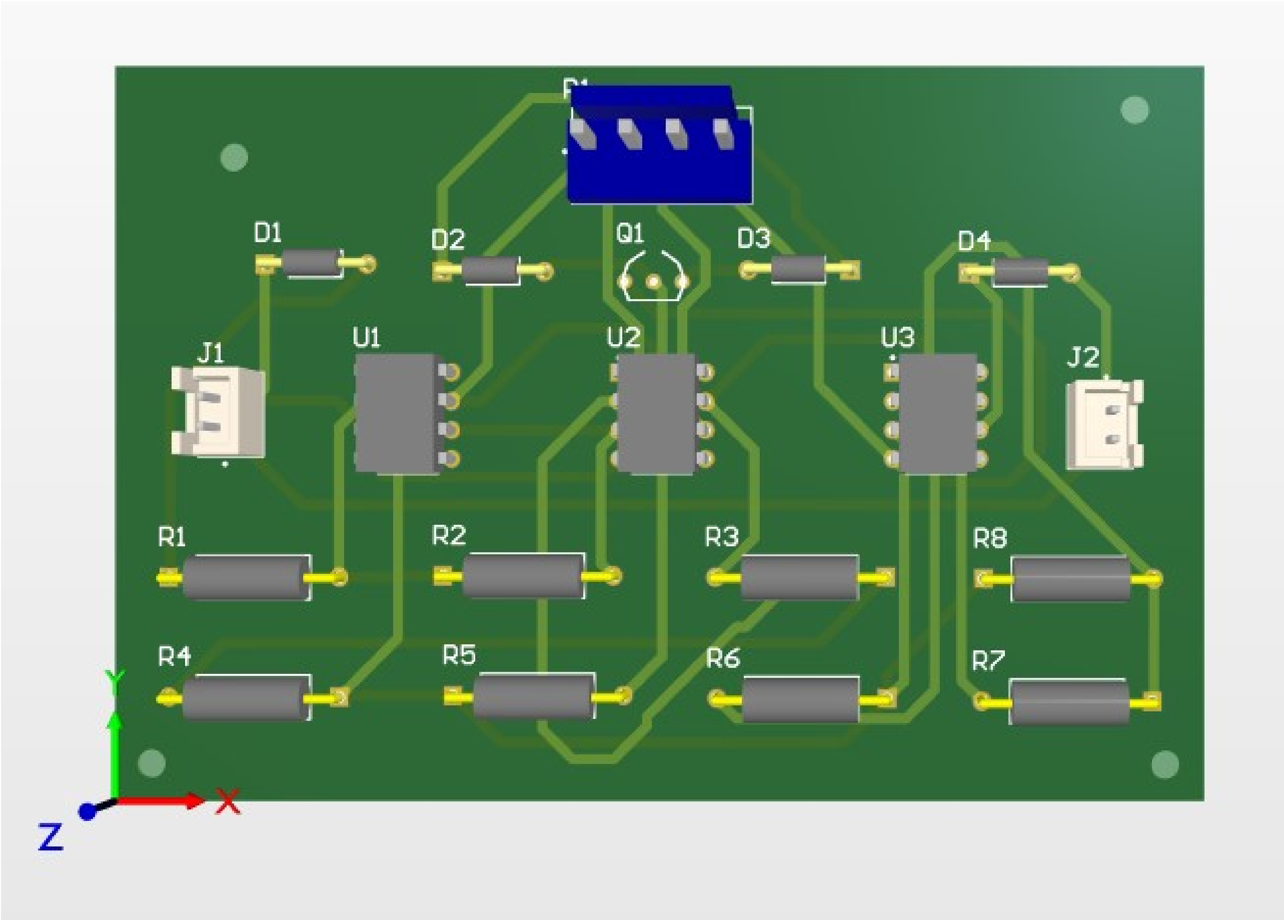

Figure 32: 3D Layout of trigger circuit

F Fifth Appendix - Data Sheet

Datasheet

Essential data points are as follows.

Ratings	Condition	Units
1. Sensor Model	RE200B	
2. Spectral response	5-14	um
3. Sensor fields of view – (X-X)	138	degree
4. Sensor fields of view – (Y-Y)	123	degree
5. Input offset voltage	0.3 – 1.4	V
6. Op-amp model	LM324, TL071	-
7. Operating Voltage (Ideal)	12	V
8. Operating max current	3	mA
9. Operating perfect current	1.5	mA
10. Output pulse voltage	12	V
11. Output drive current	25	uA
12. Noise(Vpk-pk)	<70	mV
13. Comparator high tip level voltage	3.82	V
14. Reference voltage for 1st amplifier	4.09	V
15. DC gain 1st stage	101	-
16. DC gain 2nd stage	100	-
17. Frequency range 1 st stage	0.34 – 4.82	Hz
18. Frequency range 2nd stage	1.59 – 4.83	Hz
19. Maximum timeout duration (Per round)	66.98	S
20. Minimum timeout duration (per round)	14.22	S
21. Maximum Sensitivity	6	Meters
22. Operating Temperature	-	-
23. Modes of operations	Trigger mode, Re-trigger mode	
24. Adjustments	Sensitivity, Lux, Timeout	
25. Applications	Motion detection, Security Alarm systems, Energy saving applications, Instruction alarming, Battery operations	

Figure 33: Data Sheet of the circuit