MOTION SENSOR FOR DETECTION OF WILD LIFE

Navod Marasinghe
Electrical and Electronics Department
University of Peradeniya
Sri Lanka
e18217@eng.pdn.ac.lk

Sadeepa Wijekoon
Electrical and Electronics Department
University of Peradeniya
Sri Lanka
e18396@eng.pdn.ac.lk

Tharindi Rathnayake
Electrical and Electronics Department
University of Peradeniya
Sri Lanka
e18299@eng.pdn.ac.lk

***Abstract*—This paper describes about the motion sensor designed for EE251, Principles of Electrical Measurements. This sensor is based on a PIR sensor and can be used to detect the presence of wild life and to prevent them from entering in to cultivations. This paper focuses on the basic technology, design, additional functions etc.**

Keywords—motion, PIR sensor, wild life

I. INTRODUCTION

Motion sensor is a device that is designed to detect motion. Motion sensors are used primarily in home and business security systems, but they can also be found in phones, paper towel dispensers, game consoles, and virtual reality systems. Here, this project is designed specifically to detect wildlife. Since wildlife has been a major threat to agriculture, a motion sensor is believed to play a major role in protecting crops from wildlife. This sensor consists of a PIR sensor which will detect the presence of wild animals such as cows, goats, pigs, civets and monkeys in the plantation area and will notify the user by switching on an alarm. This report includes the methodology used in designing the sensor, results, Additional functions, specifications and more.

II. INITIAL SPECIFICATIONS

Field of view: 360 motion detection up to 10 m Diameter range

Detectable Volume : 4000 m^3 (approximately)

Response time : less than 1 min

Functioning voltage: 4.5 V to 10 V

Indicator: Alarm

Operating temperature: - 15 °C to 70 °C

Detectable varieties: Birds, mammals, reptiles

III. METHODOLOGY

A. Technology

The functionality of our motion-detecting sensor heavily depends on the PIR sensor. So the PIR sensor plays a vital role in our application. A PIR sensor can detect changes in the amount of infrared radiation impinging upon it, which varies depending on the temperature and surface characteristics of the objects in front of the sensor. The PIR sensor consists of three terminals. One is grounded and the other one is connected to a voltage source. The remaining terminal is the one that gives an output voltage which leads to triggering an awareness signal.

Typically pairs of pyroelectric sensor elements are wired so that two of them are covering slightly different fields of view. Moreover, those two sensing elements are configured in such a way that they will produce directionally opposite waveforms once the same object is passing through each of their fields of view as given in the figure 1[1]. That means, as long as both halves see the same amount of infrared radiation, the sensor has not detected any movement. But if one of these two halves sees a different IR level than the other, the sensor’s output will go either high or low. This method becomes handy to cancel out the effect of the ambient temperature which may cause to create false triggering.

Usually, the Fresnel multi-lens is placed in the arrangement in order to beef up the detection range. The amplification and the filtering stages are used to optimize the output AC voltage form to get an explicit detection of the motion.

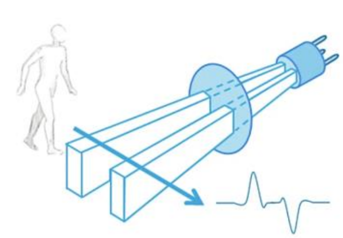

Figure 1: PIR sensor detecting a moving object

B. Design

When an object with a different temperature than the ambient temperature, moves across the field of detection of the PIR sensor, the sensor emits a signal which contains both AC and DC signals. The DC signal is emitted due to the presence of the object with a higher temperature (animal) in its field and the AC signal is emitted due to the motion of the object. As we are designing this sensor to detect both the presence and the motion of the animal, we designed this sensor under two sections to get more accuracy level.

Sensor part 1:

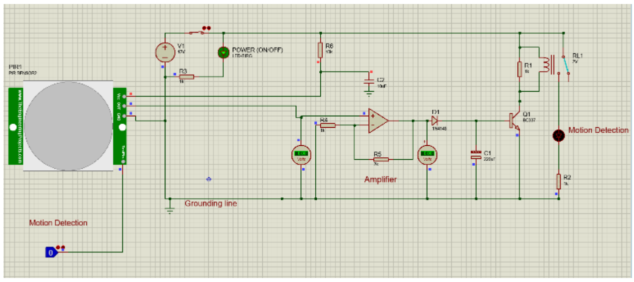

Figure. 2: The sensor Designed to detect the presence of the animal (Circuit 1).

In this section, the aim is to detect only the presence of the wild animal in the field. As shown in the Figure 2, the design is consisted of a PIR sensor, Op-Amp, transistor(BC337), diode (1N4148), resistors (1 kΩ,2 kΩ), capacitors (220uF), LEDs and a relay switch (2V).

When a signal from the PIR sensor module comes to the circuit, it is a 5V peak voltage. Then, this voltage is amplified using an operational amplifier and two resistors (1 kΩ,2 kΩ) as shown in the Figure 3.

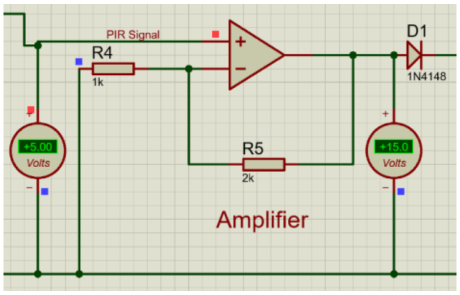

Figure. 3. Amplifying process of the circuit 1

After the amplification process, this voltage flows to the base of the transistor. When PIR runs, it emits a short signal. Therefore, a capacitor is included to keep this voltage for couple of seconds. And a diode is used to protect discharge voltage of the capacitor, not reverse to PIR sensor. After the transistor runs, the current can flow from the 12V to relay switch. Therefore, the switch turns ON and the LED will glow up and indicate the presence of the animal as shown in Figure 4.

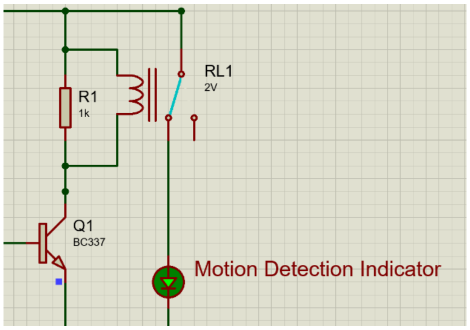

Figure. 4: Relay switch turning on when the transistor is on

Since Using a battery with a shorter battery life is not effective and efficient, a transformer circuit is designed to connect the above circuit directly to the AC power source. This circuit is consisted with a transformer (2p2s), diodes (1N4007), Capacitor (1000uF) as shown in the Figure 5.

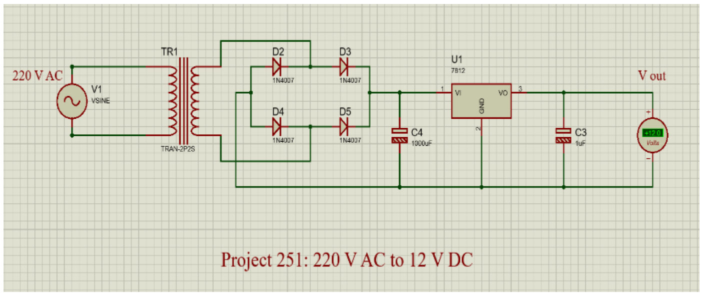

Figure. 5: 220V AC to 12V DC converter circuit

Sensor part 2:

Since all the important characteristic information of the motion such as speed, distance and direction are contained in the AC signal, it is mandatory to cancel the DC part of the signal and to amplify only the AC part.

The AC signal emitted by the sensor is in the range of 1 mV. Since this signal is disturbed by the environment, noise filtering is highly recommended. Therefore, as shown in the Figure 6 PM1008GP operational amplifier is used to amplify and filter this signal.

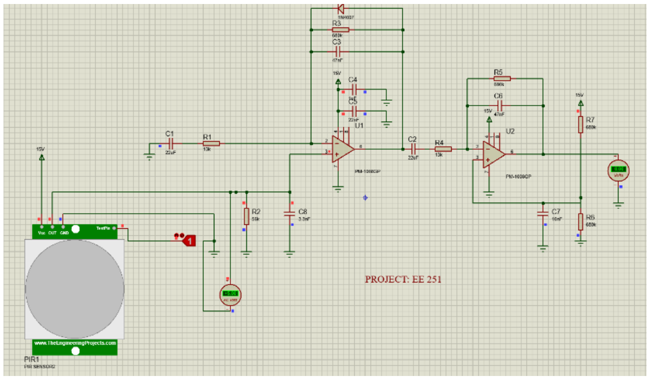

Figure. 6. The sensor designed for detect motion (Circuit 2)

The AC signal which is emitted by the PIR sensor, is amplified under two stages as shown in the Figure 7 and Figure 8 and the DC signal is canceled out.

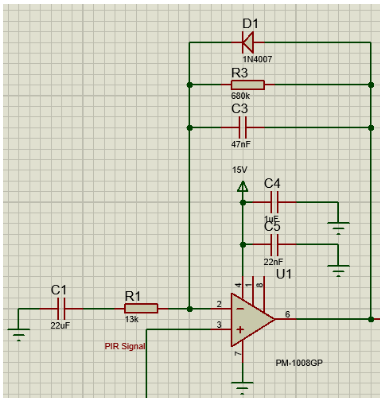

Figure 7: Stage 1

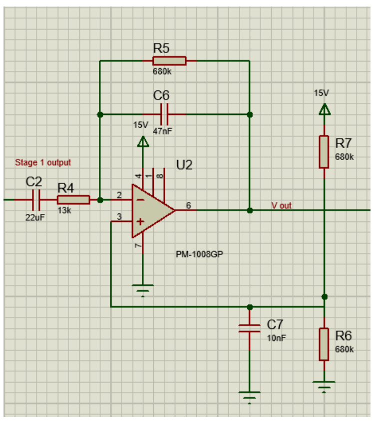

Figure 8: Stage 2

C. Calibration

a. Calibration of the sensor circuit 1

Since the PIR sensor gives an output of digital level, the result of the sensitivity measurements shows that the voltage of the sensor to various wild animals is the same value of V_{max} (usually 3.3V). As shown in the table. 1 [2], the range reaches the object indicating that the PIR sensor can still detect at a distance of 5m for all types animal tested.

	PIR sensor voltage based on distance(V)						
Animal	1m	2m	3m	4m	5m	6m	7m
Cow	3.3	3.3	3.3	3.3	3.3	0	0
Goat	3.3	3.3	3.3	3.3	3.3	0	0
Monkey	3.3	3.3	3.3	3.3	3.3	0	0
Civet	3.3	3.3	3.3	3.3	3.3	0	0

Table. 1. PIR sensor Output voltage to animal detection distance

b. Calibration of the sensor circuit 2

The calibration process can be done under several methods.

Method 1:
From changing the distance between the animal and the sensor and observing the amplitude of the amplified waveform as shown in Figure 9.

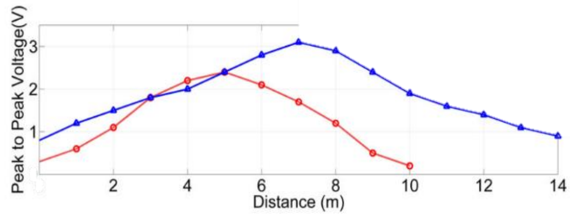

Figure 9: Peak to peak voltage of the output signals for two movements at different distances with same gain and speed set to 4 kmph

Method 2:
From changing the speed of the motion and observe the amplitude change as shown in figure. 10.

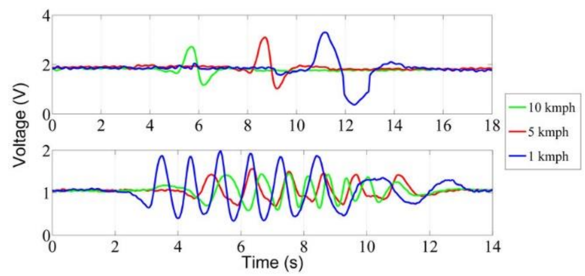

Figure 10: Plots showing the output signals at different speeds while keeping the gain and distance constant.

Method 3:
By keeping different objects with different temperatures and observe the amplified peak to peak output voltage of the sensor as shown in figure. 11.

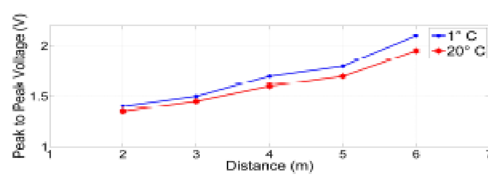

Figure 11: Peak to peak voltage of the output signals for movements at different temperatures and different distances with same gain and speed

Note:
Since an oscilloscope is required to observe the amplitude changes and the simulation software does not provide the facility of inserting multiple inputs or motion inputs, the calibration process of the sensor could not be done virtually. Therefore, the above figures (Figure. 9, Figure. 10, Figure. 11) were extracted from the [3].

IV. RESULTS

A. Final circuit

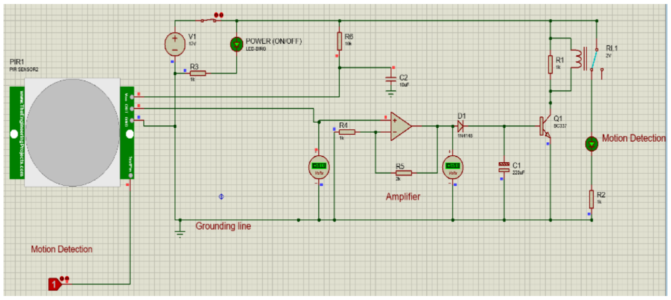

Figure 12: LED (Motion detector) turns ON when the logical input of the PIR sensor is "1"

B. Output graphs

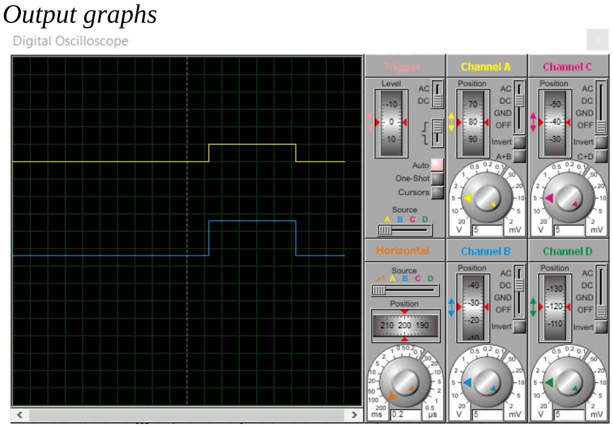

Figure 13: Amplification of the output voltage in sensor

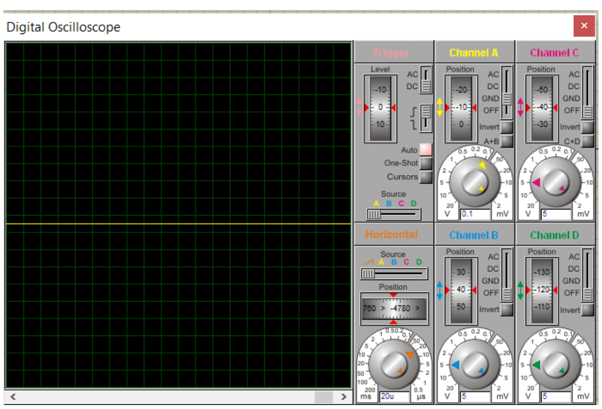

Figure 14: The 0V output voltage after canceling the DC signal and amplifying the AC signal in sensor 2

Note:

Since this circuit is simulated in the "Proteus 8.10", it is impossible to give a motion signal to the PIR sensor without physically implementing the sensor. Therefore, in the simulation, there is no AC signal from the PIR sensor. Therefore, the simulation as shown in Figure 14, the output voltage can be seen as 0V (Because there is no AC signal and the DC part has been canceled out).

C. Final Specifications

In order to achieve the expected specifications, we chose the "SKU 113990020" PIR sensor from[4].

The specifications of the above mentioned sensor is given in the Table 2.

Item	Value
Input Voltage	DC 4.5V ~ 20V
Static Current	<50uA
Output Signal	0V / 3V (Output high when motion detected)
Sensing Range	7 meters (120 degree cone)
Delay time	8s ~ 200s (adjustable)
Operating Temperature	-15℃ ~ +70℃
Dimensions	24mm*32mm*25mm(Height with lens)
Weight	6.6g

Table 2: Specifications of the PIR sensor

By using the above sensor, we achieved the following specifications.

Field of view: 360 motion detection up to 7 m Diameter range
Response time: less than 1 min
Functioning voltage: 4.5 V to approximately 20 V
Indicator: Alarm
Operating temperature: - 15 °C to 70 °C

V. ADDITIONAL FUNTIONALITIES

There are additional functionalities apart from detecting motion. Some of them are detecting the kind of animal, the direction of motion, the distance of the object or possibly the size of the individual/animal and the speed of motion.

PIR sensors are based on Wien's displacement law, which states that black body radiation curve for different temperature will peak at different wavelengths that are inversely proportional to the temperature. That is, objects of different temperature will radiate different levels of energy as shown in the Figure 15[5]. Hence, using the PIR sensor we can identify specifically which animal has entered the cultivation to take necessary measures.

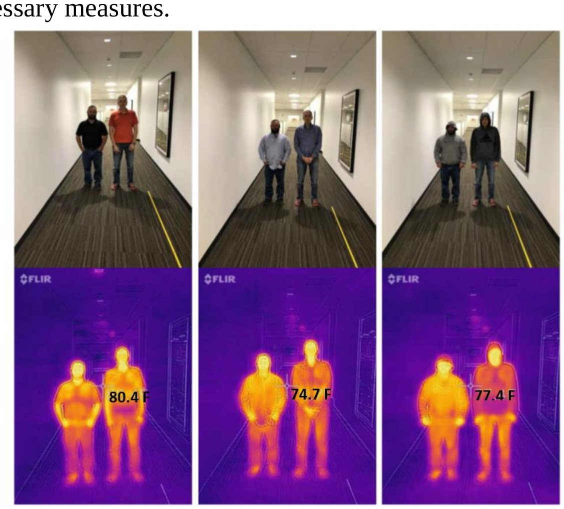

Figure 15 : Energy radiated by different people

The PIR motion detectors typically generally only have only two sensing elements, as seen in Figure 16[5]. These two sensing elements will be physically offset from each other, giving each of them slightly different fields of view (FOV). Each sensor will respond to general changes in temperature in its FOV.

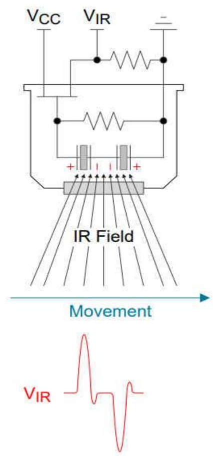

Figure 16: The two sensing elements of the PIR sensor

As a person moves across both fields of view, the sensor will output a wave form from the sensing elements as the person passes from one sensor element's FOV through the next one. As seen in Figure 17[5], the direction of motion can be detected using the direction of this signal.

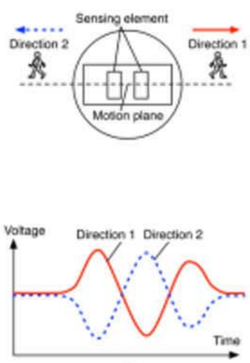

Figure 17: The effect of direction of motion on the signal

As in Figure 18[5], the amplitude of the signal can indicate the distance of the object or possibly the size of the individual/animal.

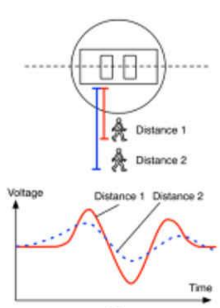

Figure 18: The effect of distance to the signal

Furthermore, the speed of motion can be detected by observing the speed of the waveform as shown in the Figure 19[5]. In a given hallway, a walking person will have a different signature than a running person. An adult will have a different signature than that of a child or pet.

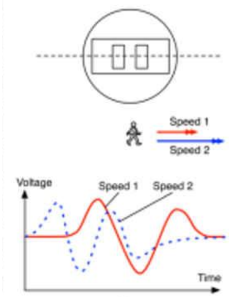

Figure 19: The effect of the speed of motion on the signal

VI. DISCUSSION

A. *Difficulties and solutions*

The motion detecting sensor is developed using a lot of electronic and mechanical theories which we are not really familiar with. Therefore, there were a lot of difficulties to overcome and a lot of things to research. Since this sensor is not practically implemented, a simulation software called "Proteus 8.10" has been used to do the simulations and check faults. When using this software, there was a constant error message appeared due to the complexity of our sensor design. It showed that "The CPU is over loaded". To overcome this error, we had to reduce the components used in this sensor and make it more simple. Therefore, this circuit design is mostly constructed base on basic electronic and electrical components.

The next challenge was that there was a significant difference between the theoretical calculation results and the practical simulation results. To overcome this challenge, the "Try and error" method was used to choose the values of capacitors, resistors and etc.

Since this sensor is targeted on detecting the wild life, the requirement of a constant power supply was a bit of a concern. The idea of using a 12 V DC battery was not really helpful. Therefore, a 220V AC to 12 V DC converter was designed and added to this circuit to overcome this challenge.

PIR sensors usually emit a short signal and sometimes it is really hard to get noticed. Then, it gives a small window to some animals with high speed to not get detected and enter to the field. Since this could be a huge threat, it should not be neglected. Therefore, a capacitor is being used in the sensor circuit to hold that signal for a couple of seconds.

Last but not least, PIR sensors emit a signal proportional to the motion and sometimes when the signal is small, it is also hard to get noticed. To overcome this problem, we used a non-inverting operational amplifier to amplify this signal to a detectable range.

B. *Strengths*

The motion sensor we designed to detect wild life can detect motion reliably indoors as well as in day or dark. Since we have used multi Fresnel lens arrangement, an extensive detection range can be acquired. As the PIR sensor consumes less energy and the required voltage has been supplied through the rectifier circuit from the household electrical system, seamless functionality of the PIR sensor can be achieved.

We took measures to analyze the output wavelet via an oscilloscope. It enables us to get some idea about the size, temperature, and speed of the object/animal and the distance from the sensor to the object/animal. Since this circuit has been designed using basic electronic components the cost was low comparatively to the other similar sensors that are in the market.

Furthermore, by using three PIR sensors, the angle of view has been expanded up to 360°.

C. *Weaknesses*

The motion sensor we designed have several weaknesses. Fluttering leaves, irregular heat cycles, and other environmental changes may cause false triggering. The detection and the sensitivity will drop considerably when the body temperature of the animal is close to the ambient temperature.

The sensing effect could be interfered by Radio frequency radiation. Since IR rays do not penetrate through the object, some obstacles in the environment might confine the responsiveness of the sensor.

D. *Comparison with similar sensors in the market*

The motion sensor we designed uses pyroelectric as the sensing element. our Sensor detects animals in a larger range of distance and a field of view compared to other similar sensors in the market. The designed sensor uses Analog signals whereas most of the similar sensors in the market uses digital signals. Furthermore, this sensor can be considered cost effective.
A comparison between the designed sensor and similar sensors available in the market is given below in the Table 3.

Parameters	Our sensor	Grid eye sensor	Melexis sensor	Microwave sensor
Sensing Element	Pyroelectric	Thermopile	Thermopile	microwave detector
Sensing property	senses the difference of received IR flux by two sensing elements	Direct indication of the incident IR flux	Direct indication of the incident IR flux	Analyzing the changes of reflected electromagnetic radiation onto the receiver
Sensing range	5-12 m	5 m	<10 cm	2-16 m
Power consumption	0.8 - 1 W	22.5 mW	6 mW	1.1 - 1.5 W
Signal type	Analog	Digital	Digital	Digital
Detection	Both static and moving objects	Both static and moving objects	Both static and moving objects	Moving objects only
Field of view	120° (with the Fresnel lens)	60° conical	90° conical	75°
costs	Low in cost	Costly	Bit pricey	Low in cost(But slightly costlier compare to PIR sensors)

Table 3: The comparison between the designed sensor and the similar sensors in the market

E. *Difficulities in physical implementation*

We did not implement the sensor physically due to several reasons with the main reason being the current pandemic situation of the country. As the three of our team members live in three different districts it was difficult to get us into one place. Furthermore, we found it difficult to purchase some of the devices such as a Voltmeter and an oscilloscope. Also we acknowledged that we do not have enough resources to practically implement the setup. Hence we decided to design a simulation using the software proteus 8.10.

VII. CONCLUSION

As per the results obtained from the calibration process and simulation part, there were significant distinctions in the output wavelets due to the distance that the object/animal persists and the inherent properties that the particular object/animal has. Like speed, body temperature, size, etc. Assuming the same animal/object has taken place with maintaining the same speed, according to the empirical results we can conclude that when the distance from the sensor to object/animal is increasing the amplitude of the out wavelet will be decreasing.
Likewise, as per the observations, it can be further concluded that the size and the body temperature of the object/animal have proportionally affected to the output wavelet's amplitude whereas the speed of the object/animal will be inversely proportional to the wavelet's amplitude.

Since we are using two offset sensing elements and those two are producing the wavelets which are opposite in direction, the ranging/formation of the wavelet enables us to identify the exact direction in which the animal/object is moving.

On the other hand, utilization of Fresnel multi-lens has enhanced the productivity as well as efficiency of the detection process.

Thus, by referring to the output wavelet (maybe an amplified one) some important inferences can be assessed regarding the nature of the motion.

VIII. ACKNOWLEDGMENT

We would like to express our sincere gratitude to the resource persons of this project, Prof. Manjula Fernando, Dr. Ruwan Ranaweera and Dr. Nimal Ratnayake for giving us an invaluable guidance throughout this project. It was a great privilege and honor to work and study under their guidance.

IX. REFERENCES

[1] [Online]. Available: https://sosteneslekule.blogspot.com/2016/08/signal-conditioning-for-pyroelectric.html

[2] [Online]. Available: https://www.emerald.com/insight/content/doi/10.1108/978-1-78756-793-1-00042/full/html

[3] [Online]. Available: https://www.researchgate.net/publication/289446262_PIR_sensors

[4] [Online]. Available: www.seeedstudio.com

[5] [Online]. Available: https://www.ti.com/lit/an/slaae30/slaae30.pdf?ts=1634016689855&ref_url=https%253A%252F%252Fwww.google.com%252F