

ITP272 SENSOR TECHNOLOGIES AND PROJECT

L04: Sensors and their Principles

AGENDA

- ◉ Motion sensors

MOTION SENSORS

Motion Sensors

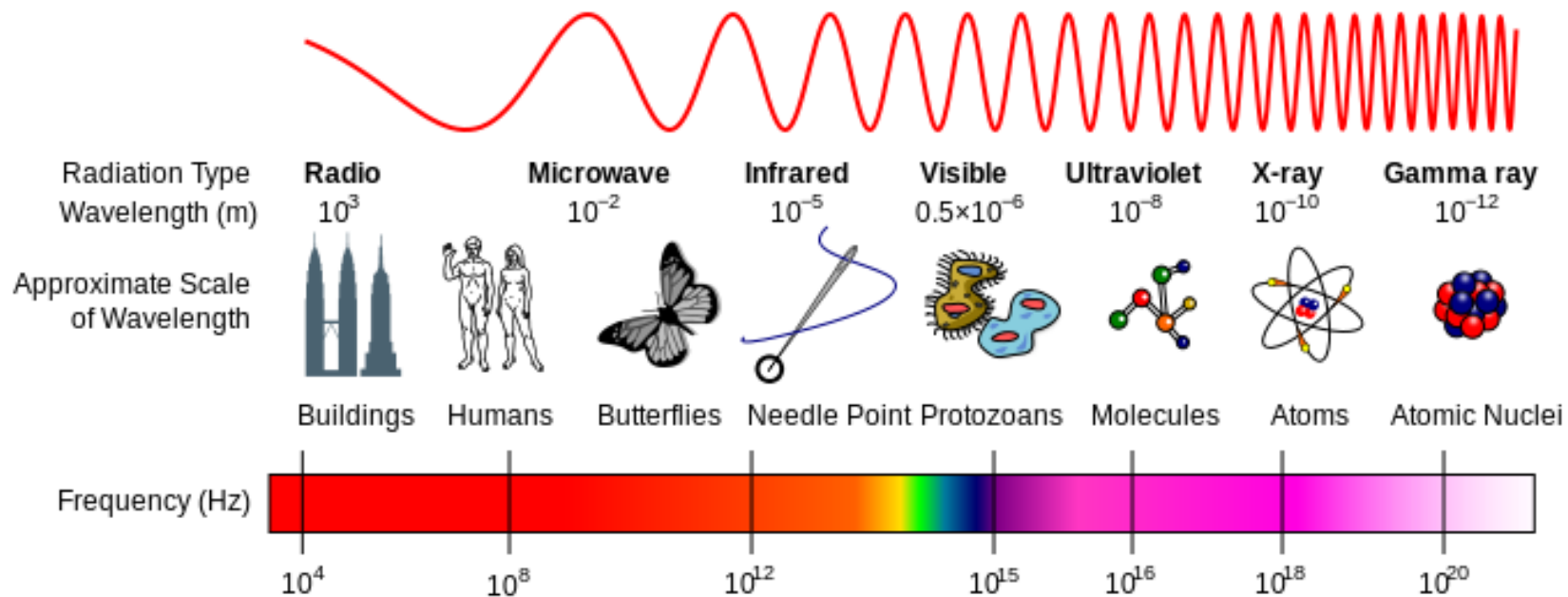
- ◉ A sensor that senses for the movement of object (people, animals or other items) in a monitored area
- ◉ Multiple sensing technologies maybe combined to help reduce false triggering
- ◉ Used in security and automated lighting control

Categories / Types

- ◉ Microwave Motion
- ◉ Ultrasonic Motion
- ◉ Passive infrared sensor (PIR)

MOTION SENSORS

Electromagnetic Spectrum



http://en.wikipedia.org/wiki/Electromagnetic_spectrum

MOTION SENSORS

Microwave Motion detector

D

- ⦿ A sensor that relies on the frequency difference of the reflected microwave (electromagnetic waves) for detecting motion
- ⦿ Microwave travels a lot faster than sound waves (speed of light) and can travel through vacuum
- ⦿ Can operate under more extreme conditions
 - temperature, noise, wind, fog, dust, moisture, and so forth

MOTION SENSORS

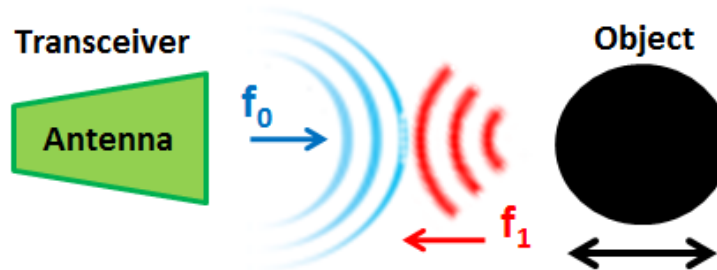
Microwave Motion detector

- ◉ Unable to penetrate metal
 - large metal objects in the area of detection shield the area behind them
- ◉ Extremely sensitive to motion
 - Can be triggered by objects blowing in wind
 - Can detect motion behind walls
- ◉ Two types of Microwave motion detector
 - Monostatic
 - Transmitter and receiver are housed in the same unit
 - Bistatic
 - Transmitter and receiver are house in separate unit

MOTION SENSORS

How Microwave Motion detector works

- ◉ Microwave are sent at known frequency
- ◉ Frequency of reflected waves are measured
- ◉ Difference in frequency between sent and reflected waves are used to detect motion
 - Frequency increases when object is moving closer
 - Frequency decreases when object is moving further
- ◉ This changes in frequency is known as Doppler effect



Doppler Effect more sensitive to Forward Motion !

MOTION SENSORS

Doppler effect on sound waves

- ◉ An ambulance sounding off its siren in constant frequency
- ◉ When the ambulance is moving closer, the siren sounded higher in pitch
- ◉ When the ambulance is moving away, the siren sounded lower in pitch
- ◉ The differences in frequency due to motion is caused by the doppler effect



http://en.wikipedia.org/wiki/Doppler_effect

MOTION SENSORS

Doppler effect

- ⦿ An antenna transmit a signal at a frequency of f_0 , this signal is having wavelength of λ_0 as calculated below

$$f_0 = \frac{c_0}{\lambda_0}$$

- ⦿ c_0 is the speed of light = 3×10^8 m/s
- ⦿ One common frequency of microwave is 10.525 GHz (X –band)
- ⦿ Thus its wavelength,
 - $\lambda_0 = 3 \times 10^8 / (10.525 \times 10^9) \sim 0.03\text{m}$

MOTION SENSORS

Doppler effect

- ◉ The difference in frequency caused by the doppler effect is known as the doppler frequency (Δf) as calculated below

$$\Delta f = \frac{v}{\lambda_0}$$

- ◉ v is velocity of the moving target
- ◉ λ_0 is the wavelength of the transmitted signal
- ◉ Positive value of Δf implies increase in frequency which means target is moving closer
- ◉ Negative value of Δf implies decrease in frequency which means target is moving away from

MOTION SENSORS

Doppler effect

- Assume a person walking at 0.6 m/s towards a X-band microwave detector
- X-band wavelength, λ_0 , as found in previous slides = 0.03 m
- $v = 0.6$ m/s

$$\Delta f = \frac{v}{\lambda_0}$$

- Doppler frequency, $\Delta f = 0.6 / 0.03 = 20$ Hz
- The reflected signal's frequency is having a higher frequency of 20 Hz

MOTION SENSORS

Ultrasonic Motion detector

D

- ◉ A sensor that relies on frequency difference of reflected acoustic (sound) waves signal for detecting motion
- ◉ Motion detection measured based on Doppler effect (similar to explanation for microwave)
- ◉ Operate at frequencies that are above human sensitivity (20 kHz).
 - Typical operating frequencies are 25, 30, and 40 kHz
- ◉ Not suitable areas with unusual amount of noise such as an airport, industrial area or construction area

MOTION SENSORS



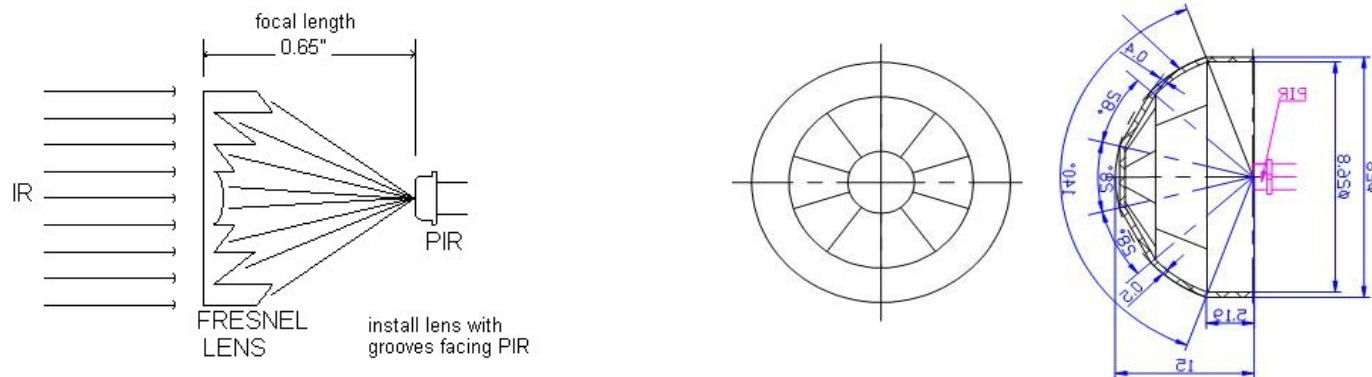
Passive Infrared (PIR) Sensor

- ④ A sensor that relies on detection of far-infrared (300 GHz to 30 THz) radiation emanated from the surface of a object to detect for motion
- ④ It is passive detection because it does not generate or send out any kind of beam for detection purposes but rely on detecting far-infrared radiation from surrounding.
- ④ It works on concept that all objects above absolute zero emit heat energy in the form of infrared radiation

MOTION SENSORS

Passive Infrared (PIR) Sensor

- Use Fresnel lens to focus infrared radiation onto internal pyroelectric element



- Pyroelectric elements are capable of generating electrical charge in response to infrared radiation
- Constant infrared radiation causes pyroelectric element to produce stable electrical output

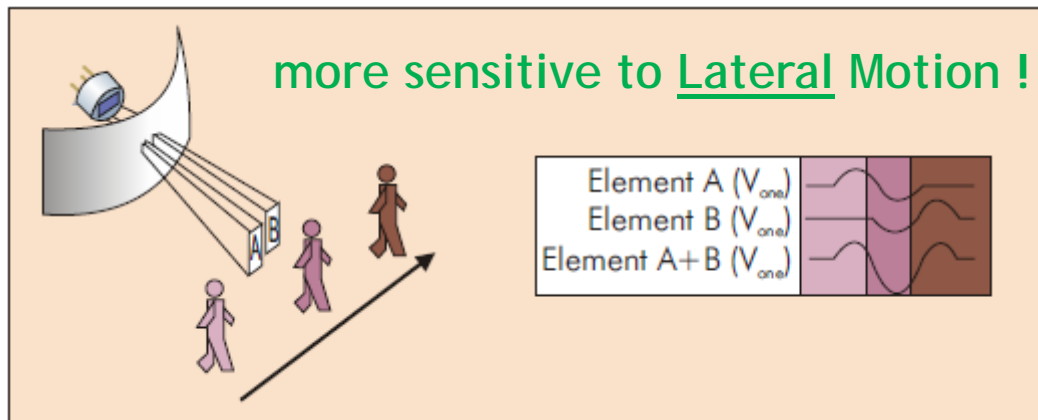
MOTION SENSORS

Passive Infrared (PIR) Sensor

- ◉ Interferences like abrupt changes in surrounding temperature may cause sensing element to produce variation in electrical output causing false positive
- ◉ Uses differential detection to prevent false positive
- ◉ Differential detection operation
 - 2 sensing element are used
 - They were used to detect different segments
 - They are connected out of phase (output in different polarity)
 - Their electrical output are summed up
 - Both sensing element will pick up interferences at the same time and cancel out each other's output

MOTION SENSORS

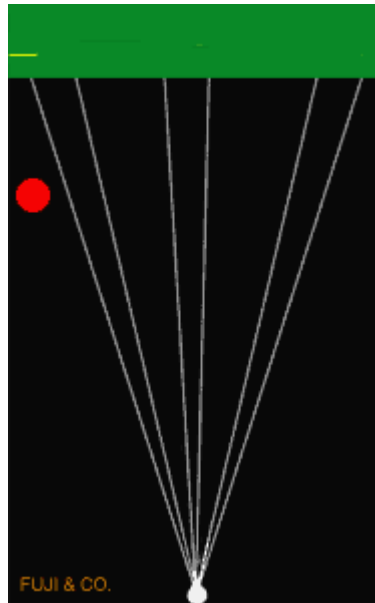
Passive Infrared (PIR) Sensor



- Detection of human movement
 - 2 sensing element are used
 - They were used to detect different segments
 - Human movement will trigger infrared changes in different detection segments
 - Different segments pick up changes at different point of time
 - Variations in combined electrical output are used to detect motion

MOTION SENSORS

Passive Infrared (PIR) Sensor



- ⦿ Electrical output cause by human movement

MOTION SENSORS

Criteria for selection

- ⦿ Sensing principle
- ⦿ Sensing Range
- ⦿ Sensing Speed
- ⦿ Direction of motion

MOTION SENSORS

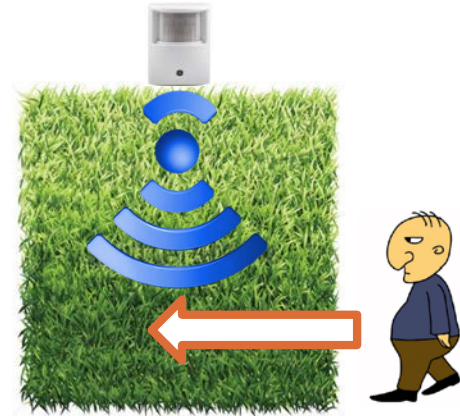
Criteria for selection

	Sensing Principle	Range	Speed	Direction of Motion
Ultrasonic	Acoustic wave	Long	Fast	Forward
Microwave	Microwaves	Long	Very fast	Forward
PIR	Infra-red (heat)	Short	Fast	Lateral

CASE STUDY

HAS – Smart Light requirements

- “Smart Light” system that can turn only the garden lights during when someone walks (laterally) across the garden and there is insufficient light



Requirement

- Need to detect for presence of human
 - Reliable indication of human
- There is no requirement to detect distance
 - So do not need position sensor
- Need to be in the vicinity (nearby)
 - Means sensing short range
- Lateral movement

CASE STUDY

Smart Light

- ◉ Sensing principle

- Need to detect for movement of human reliably => heat (infra red)

- ◉ Sensing Range

- Need to be in the vicinity which means short range

- ◉ Sensing Speed

- To on lighting for human => Need not be very fast

- ◉ Direction of motion

- Need to detect lateral movement across the garden

CASE STUDY

Smart Light : Lateral movement

	Sensing Principle	Range	Speed	Direction of Motion
Ultrasonic	 See #			 See *
Microwave	 See #			 See *
PIR				

Both Ultrasonic and Microwave may detect movement of other objects like plants swaying and thus are not suitable.

* Both Ultrasonic and Microwave uses Doppler effect which is more sensitive to forward movement

PIR sensor is suitable as there is no requirement for long range and high speed. It is more sensitive the lateral motion and it can rely on the heat emitted by human to reduce false alarm

REVIEW QUESTIONS



REVIEW QUESTION

Explain how Doppler effect is used to detect motion

Answer: (state the 5 points below)

- ⦿ Electromagnetic or Acoustic waves sent at known frequency
- ⦿ Frequency of reflected waves are measured
- ⦿ Difference in frequency between sent and reflected waves are used to detect motion
 - Frequency increases when object is moving closer
 - Frequency decreases when object is moving further

REVIEW QUESTION

What is the element used by PIR to detect far-infrared radiation and how are the radiation concentrated on this element

Answer:

- It uses pyroelectric element to generate electrical charge in response to infrared radiation detected
- It uses Fresnel lens to focus infrared radiation onto internal pyroelectric element

REVIEW QUESTION

Explain the Differential detection in Passive Infrared (PIR) Sensor.

Answer: (state these 5 points)

- ⊙ Differential detection operation
 - 2 sensing element are used
 - They were used to detect different segments
 - They are connected out of phase (output in different polarity)
 - Their electrical output are summed up
 - Both sensing element will pick up interferences at the same time and cancel out each other's output

REVIEW QUESTION

Explain the operating principle of a Passive Infrared (PIR) Sensor to detect human.

Answer: (state the 5 points below)

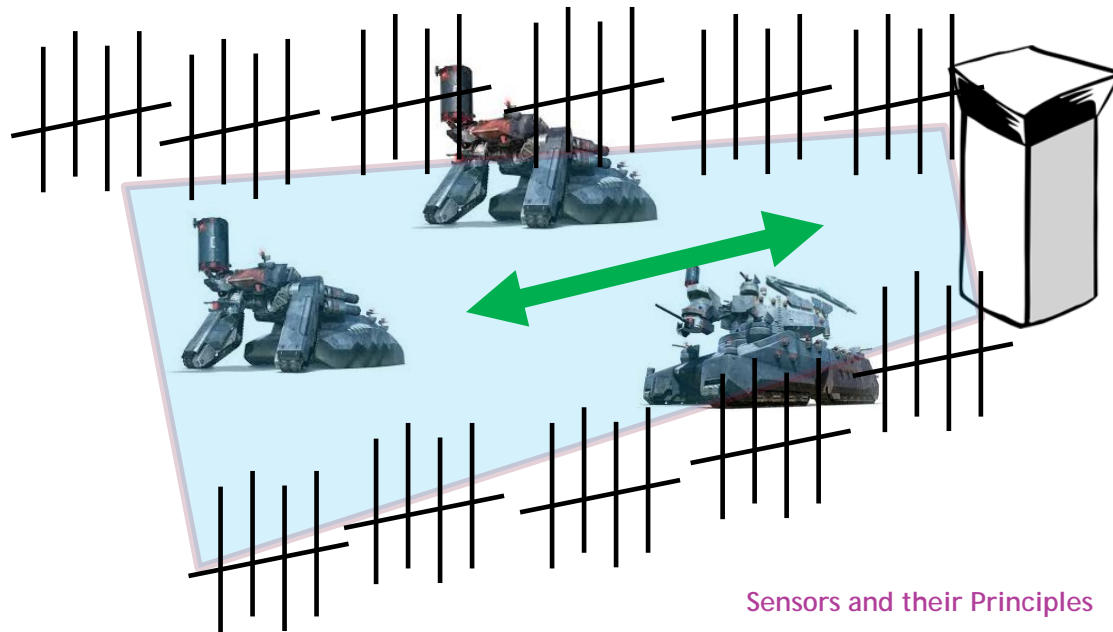
- ⦿ Detection of human movement
 - 2 sensing element are used
 - They were used to detect different segments
 - Human movement will trigger infrared changes in different detection segments
 - Different segments pick up changes at different point of time
 - Variations in combined electrical output are used to detect motion

REVIEW QUESTION

Steel Defense Pte Ltd is building a monitoring system. It is supposed to detect at long range for any movement towards the isolated control tower. The fenced area of surveillance are fortified with many large metal structures.

You are required to select a suitable motion sensor for this system.

(a) List down the selection criteria for this sensor



REVIEW QUESTION

(b) You are asked to select between Microwave sensor, Ultrasonic sensor and Passive Infrared (PIR) sensor.







- ⦿ Justify how the selected sensor meets all requirements
- ⦿ List down why other sensors are not suitable

ANSWER

Criteria for selection

- ⊙ Sensing principle
 - Must be able to function with large metal structures around
- ⊙ Sensing Range
 - Long
- ⊙ Sensing Speed
 - No requirement
- ⊙ Direction of motion
 - Sense for movement towards => Forward motion

ANSWER

	Sensing Principle	Range	Speed	Direction of Motion
Ultrasonic				
Microwave	 See #			
PIR				 See *

Microwave motion sensor is unable to penetrate metal structure and thus is not suitable for this system.

*Passive Infrared (PIR) sensor is more sensitive to lateral motion and thus is not suitable to sense movement towards the control tower.

Ultrasonic sensor is suitable as it can sense long range as required. It can sense motion of target by measuring frequency difference of the reflected acoustic waves. It is also sensitive to forward motion.

REVIEW QUESTION

Which type of Microwave motion detector house the transmitter and receiver in the same unit?

- A. Continuous Transmission
- B. Monostatic
- C. Pulse
- D. Bistatic

Answers => B

REVIEW QUESTION

Which type of Microwave motion detector house the transmitter and receiver in separate unit?

- A. Continuous Transmission
- B. Monostatic
- C. Pulse
- D. Bistatic

Answers => D

REVIEW QUESTION

What is the similarity between Microwave and Ultrasonic motion detector?

- A. They relies on timed reception of the reflected electromagnetic waves to function
- B. They relies on frequency difference of reflected electromagnetic waves to function
- C. They relies on Hall effect to function
- D. They relies on Doppler effect to function

Answers => D

REVIEW QUESTION

Which of the following is true about Doppler effect?

- A. It is more sensitive to lateral motion
- B. It uses difference in frequency between sent and reflected waves to work
- C. It is only used in Microwave motion detection
- D. It states that voltage is generated when a current-carrying conductor is placed into a magnetic field

Answers => B

REVIEW QUESTION

Large metal objects in the area of detection will affect which type of motion sensor?

- A. Microwave
- B. Photoelectric
- C. Passive Infrared (PIR)
- D. Ultrasonic

Answers => A

REVIEW QUESTION

Unusual amount of noise such as an airport, industrial area or construction area will affect which type of motion sensor?

- A. Microwave
- B. Photoelectric
- C. Passive Infrared (PIR)
- D. Ultrasonic

Answers => D

REVIEW QUESTION

Passive Infrared (PIR) Sensor makes use of _____ element to generate electrical charge in response to infrared radiation?

- A. Hall
- B. Piezoelectric
- C. Pyroelectric
- D. Fresnel

Answers => C

REVIEW QUESTION

Which motion sensor uses Differential detection to prevent false positive?

- A. Microwave
- B. Photoelectric
- C. Passive Infrared (PIR)
- D. Ultrasonic

Answers => C

REVIEW QUESTION

Which of the following is not true about Differential detection in Passive Infrared (PIR) Sensor?

- A. It uses two piezoelectric sensing elements
- B. The two sensing elements detect different segments
- C. Connection of the two sensing elements are out of phase
- D. Interferences picked up by both sensing elements at the same time will cancel out each other's output

Answers => A

REVIEW QUESTION

How does Passive Infrared (PIR) sensor focus infrared radiation onto its internal element?

- A. It uses Pyroelectric lens
- B. It uses Fresnel lens
- C. It uses photoelectric lens
- D. It uses Passive lens

Answers => B