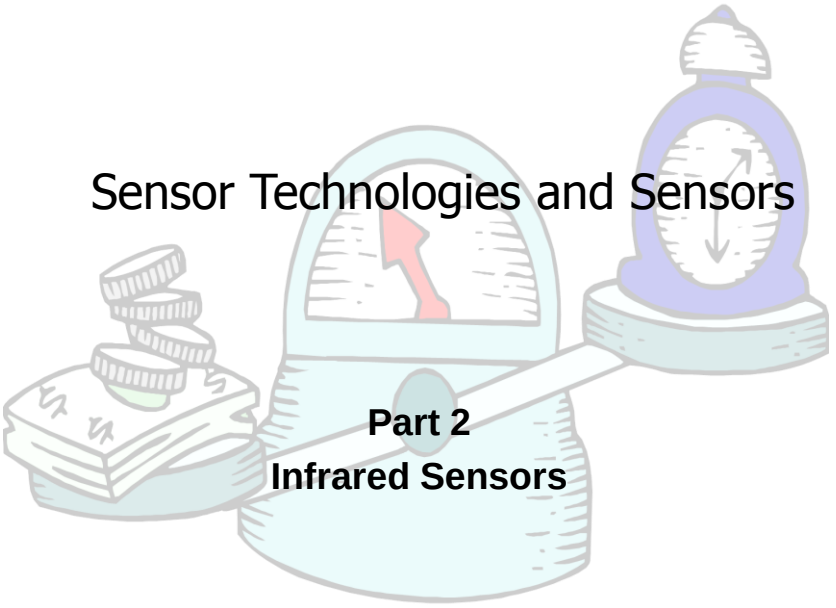
Sensor Technologies and Sensors



Part 2

Infrared Sensors

Infrared Sensor

- An infrared sensor is an electronic instrument that is used to sense certain characteristics of its surroundings by either emitting and/or detecting infrared radiation.
- It is also capable of measuring heat of an object and detecting motion.
- Infrared waves are not visible to the human eye.
- In the electromagnetic spectrum, infrared radiation is the region having wavelengths longer than visible light wavelengths, but shorter than microwaves.
- The infrared region is approximately demarcated from 0.75 to 1000μm.
- The wavelength region from 0.75 to 3μm is termed as near infrared, the region from 3 to 6μm is termed mid-infrared, and the region higher than 6μm is termed as far infrared.

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Infrared Sensor

- Infrared technology is found in many of our everyday products.
- For example, TV has an IR detector for interpreting the signal from the remote control.
- Key benefits of infrared sensors include low power requirements, simple circuitry, and their portable feature.

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Types of Infra-Red Sensors

- Infra-red sensors are broadly classified into two types:
- **Thermal infrared sensors** – These use infrared energy as heat. Their photo sensitivity is independent of wavelength. Thermal detectors do not require cooling; however, they have slow response times and low detection capability.
- **Quantum infrared sensors** – These provide higher detection performance and faster response speed. Their photo sensitivity is dependent on wavelength. Quantum detectors have to be cooled so as to obtain accurate measurements. The only exception is for detectors that are used in the near infrared region.

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Working Principle

- A typical system for detecting infrared radiation using infrared sensors includes the infrared source such as blackbody radiators, tungsten lamps, and silicon carbide.
- In case of active IR sensors, the sources are infrared lasers and LEDs of specific IR wavelengths.
- Next is the transmission medium used for infrared transmission, which includes vacuum, the atmosphere, and optical fibers.

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Working Principle

- Thirdly, optical components such as optical lenses made from quartz, CaF_2, Ge and Si, polyethylene
- Fresnel lenses, and Al or Au mirrors, are used to converge or focus infrared radiation. Likewise, to limit spectral response, band-pass filters are ideal.
- Finally, the infrared detector completes the system for detecting infrared radiation.
- The output from the detector is usually very small, and hence pre-amplifiers coupled with circuitry are added to further process the received signals

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Applications

- Tracking
- Climatology, meteorology, and astronomy
- Thermography, communications, and alcohol testing
- Heating, hyper-spectral imaging, and night vision
- Biological systems, photo-bio-modulation, and plant health
- Gas detectors/gas leak detection
- Water and steel analysis, flame detection
- Anesthesiology testing and spectroscopy
- Petroleum exploration and underground solution
- Rail safety.

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Heat vision

- Heat can be “seen” at a distance.
- Recall temperature = heat/atom.
- At room temp each atom has average energy 6.3 x 10^{-21} J
- Some of this energy is emitted as photons.
- A photon of energy E and frequency f satisfies:

$$E = h f$$

where h is Planck’s constant = 6.63 x 10^{-34} J sec

- Thermal photons have frequency ~ 10^{13} Hz and wavelength ~ 30 μm
- This is in the far infrared range.
- Sensors that respond to those wavelengths can “see” warm objects without other illumination.

Thermal imagers

- Far infrared CCD cameras exist for 10 μm and above, but are much more sophisticated (and expensive) than near-infrared CCDs.
- Generally many $1000s

Thermal sensors

- PIR (Pyroelectric InfraRed) sensors can detect IR heat radiation (7-20 μm typical).
- They are simple, cheap and common. The basis of security system “motion detectors”.
- Most PIR sensors contain two or four sensors with different viewing regions.
- They detect a change in the difference between the signals and give a binary output.

Thermal sensors

- A few component PIR sensors are available that provide the PIR analog signals directly.
- Eltec two-element sensor, shown with matching fresnel IR lens and mounting:
- NAIS ultra-compact PIR sensor

- Note: PIR sensors are slow with time constants ~ 1 sec

What is a Passive Infrared (PIR) Sensor?

- Used to detect motion
- Basically made up of pyroelectric sensors
  - Detect levels of infrared radiation
- Does not emit any radiation, only detects, hence passive

Major applications

- Motion Detection
  - Lighting Systems
  - Security Systems
  - Automation (doors, air conditioning, etc.)
- Measuring Temperature Differentials
  - Measure temperatures of remote objects
- Automatic doors
- Interactive Rooms
  - Activate when person enters room
- Remote triggered cameras
  - Take photos/start recording when person enters room

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How It Works – Theory

- Infrared radiation exists in the EM spectrum
  - Can't be seen, but can be detected
- Objects that generate heat also generate IR radiation
- PIR sensor consists of two sensing elements
  - One gives a frame of reference and the other detects the change
  - Can only detect the difference in temperatures between the two sensors

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How It Works – Theory (cont.)

- **For example:** A PIR sensor is pointed into a room. An animal, with a temperature greater than the wall, walks into the room.
- As the animal crosses the first sensor, a positive pulse is produced.
- When the animal is in front of both sensors, there is no sensed change.
- As it crosses the second sensor, a negative pulse is emitted. These pulses are what is detected.
- An illustration of this example is shown on the next slide

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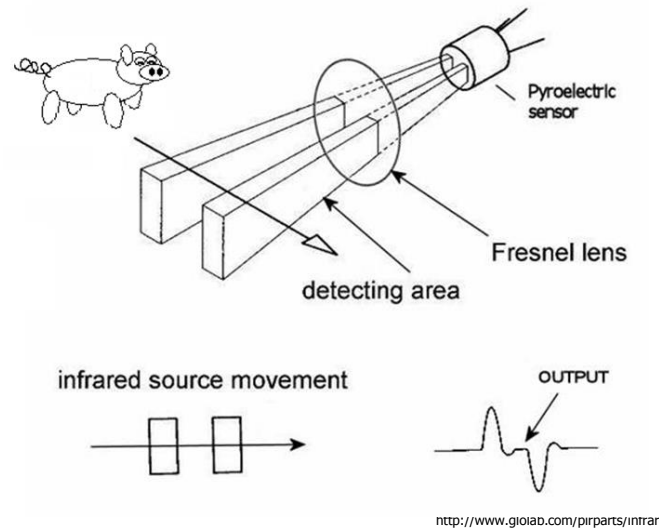
How It Works – Theory (cont.)



http://www.glolab.com/pirparts/infrared.html

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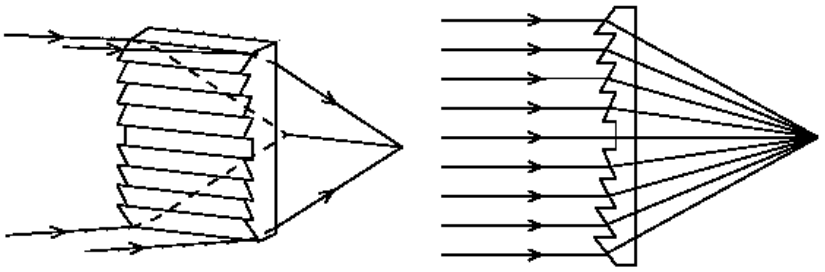
How It Works – Fresnel Lens

- Captures more IR radiation
- Focuses the radiation into a smaller point
- Condenses the light and provides a larger range of IR to the sensor



http://www.ladyada.net/learn/sensors/pir.html

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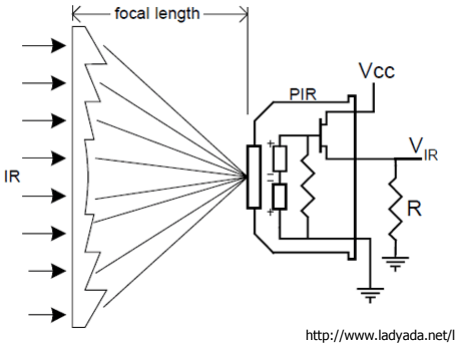
How It Works – Fresnel Lens (cont.)

- Focal point moves across the sensor as the IR source moves, exposing one element at a time
- Grooved side usually face the PIR sensor



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How It Works – Fresnel Lens (cont.)

- Usually thin and flexible
  - About 0.015 inches thick
- Made of material opaque to visible light
  - Materials that pass visible light will not pass infrared radiation (e.g. glass, plastic, etc.)

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How It Works – Summary

- Fresnel lens directs IR radiation at two pyroelectric sensors
- Impulse gives the difference in temperature between two sensors
- Motion is detected when a body with different temperature than the surroundings enters the frame of the sensor

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Major Specifications

- Power requirements
- Communication (Output)
  - Single bit high/low output
- Dimensions
- Operating Temperature
- Range
- Detection Angle

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Limitations

- Sensing can be confused
  - Motion too close to sensor
  - Motion is not passed through sensor one at a time
  - Cannot detect slow moving or stationary objects
  - Sensor is approached straight on
- Limited range in most sensors
- Temperature sensitive

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