

User Detection Sensors

Design Team 5

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Agenda

Sensing Technologies

- Infrared
- Ultrasonic
- Capacitive
- Pressure
- Video Image



Key Points

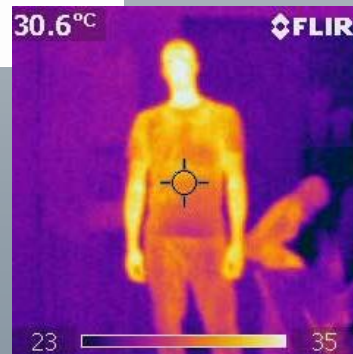
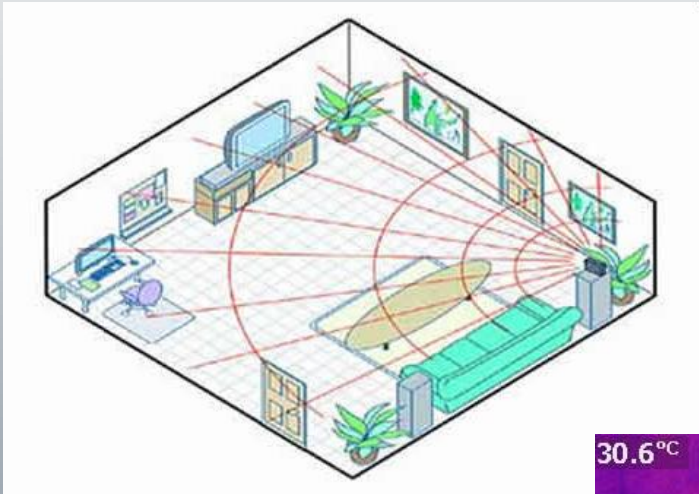
- Theory of Operation
- Advantages
- Limitations
- Power Consumption & Cost
- Common Applications

Infrared Detection

Overview

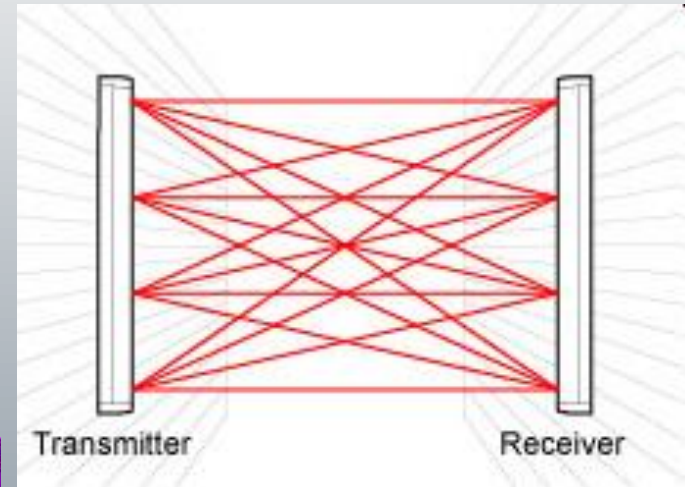
Passive Infrared (PIR)

Absorbs surrounding infrared radiation

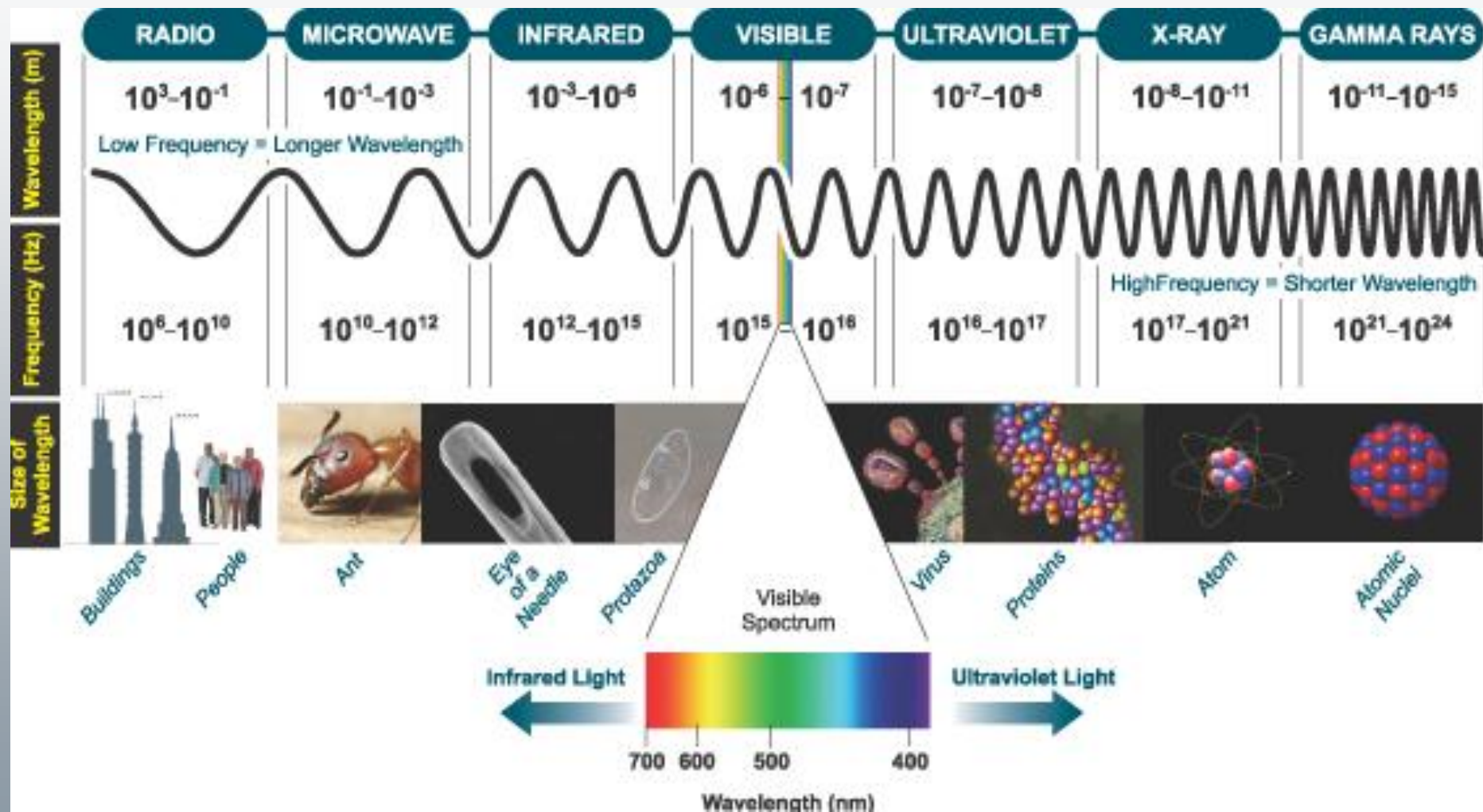


Active Infrared (IR)

Emits infrared beam to be reflected



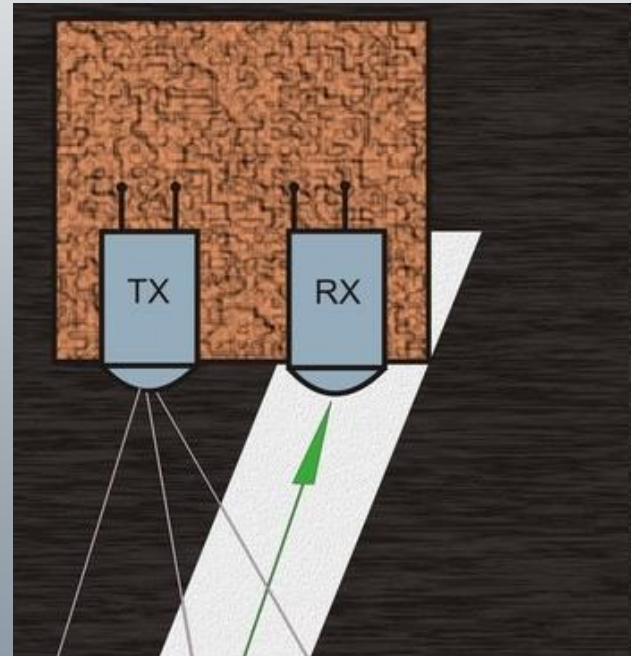
Electromagnetic Spectrum



Infrared Detection

IR - Theory of Operation

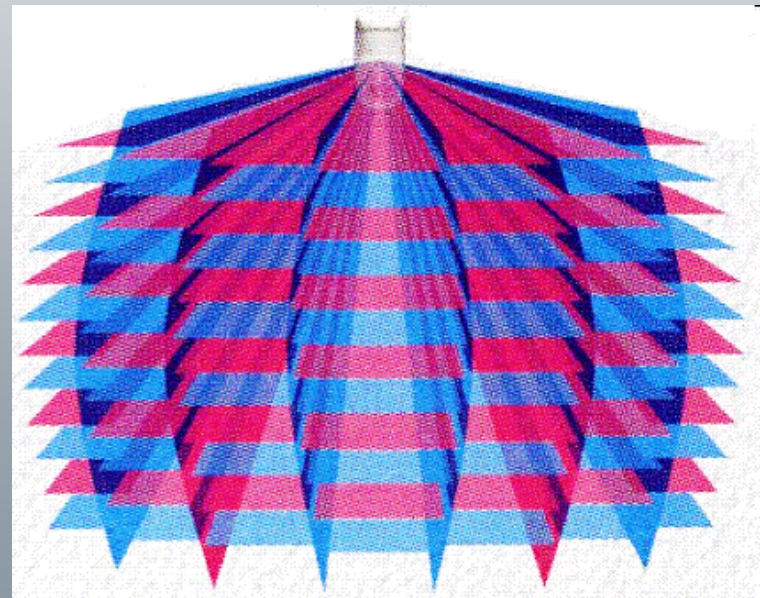
- Transmitter emits an infrared light that travels into field of view
 - No object present – light is never reflected
 - Object present – light will reflect back to receiver
- Tx: Infrared LED
- Rx: Photo-diode, photo-transistor
- Advanced models all for distance approximation with added circuitry



Infrared Detection

PIR - Theory of Operation

- Sensing unit is a pyroelectric device
 - Generates an electric potential when temperature change is experienced
- Circuitry settles into a quiescent state after power up
 - Change in potential triggers circuit
- Most use a fresnel lens for uniform sensitivity and reduce false triggers



Infrared Detection

Advantages

IR

- Simple circuitry
- Not sensitive to electrical noise
- Low cost
- Widely available – many options

PIR

- Low power consumption
- Single sensor capable of monitoring an entire room
- Very popular – hundreds of options

Infrared Detection

Limitations

IR

- Cannot distinguish between objects
- Short detection range
- Not ideal for distance calculations

PIR

- Cannot easily distinguish between humans and other objects such as animals
- Susceptible to “dead spots”
- Cannot detect motion behind barriers
- Ambient temperature changes

Infrared Detection

Power Consumption & Cost

Power Consumption

- Ideal solution when power consumption is an issue
 - PIR especially

Cost

- Relatively low cost
- Can buy the individual sensors in bulk for pennies
 - Can purchase with circuitry for low prices
- High tech units more costly (~\$100+)

Infrared Detection

Common Applications

- Alarm systems
- Automatic Doors
- Request to Exit
- Robotics
- Thermometers
- Remote Controls



Ultrasonic Detection

Overview

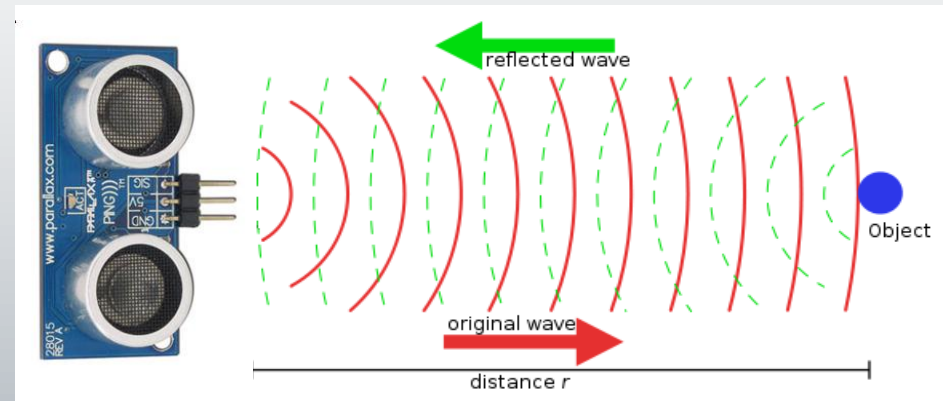
- Detects motion using sonar
 - Emit sounds at ultrasonic frequencies (beyond the capacity of human hearing)
- Active Sensors
 - Send & receive sounds
- Passive Sensors
 - Only listen for sounds



Ultrasonic Detection

Theory of Operation

- Trigger a pulse to emit a sonic burst
- Sound wave (typ. 40-50kHz range) emitted from quartz-crystal transducer
- Transducer – transforms electrical energy into sound and vice versa
- When movement occurs, the sound wave is disrupted and related back to receiver
- Control unit determines if signal disruption indicates inordinate movement



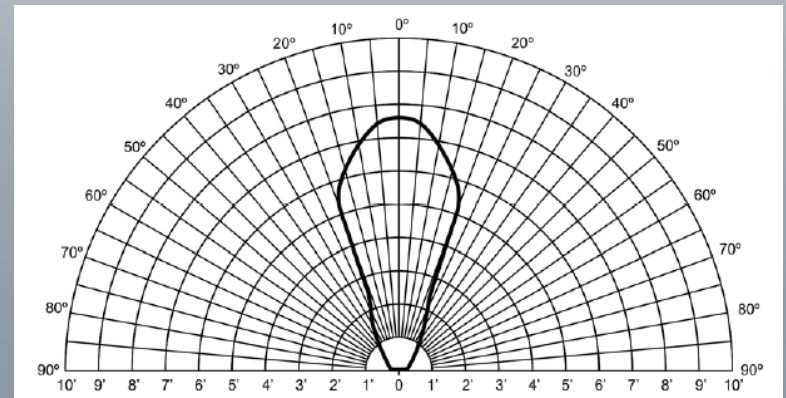
$$Distance = \frac{elapsed\ time \times speed\ of\ sound}{2}$$

Medium: Air → Speed of sound: 340.29 m/s

Ultrasonic Detection

Advantages

- Easy to calculate distance
- Large detection range
 - Maximum detection up to 40 ft
 - Detection cone up to 60° wide
- Relatively inexpensive
- Can operate with narrow beam widths
- Extremely sensitive



Ultrasonic Detection

Limitations

- Extremely sensitive
- Precise movements may not trigger sensor
- Cannot penetrate solid objects
- Another type of sensor may be needed to compliment ultrasonic

Ultrasonic Detection

Power Consumption & Cost

Power Consumption

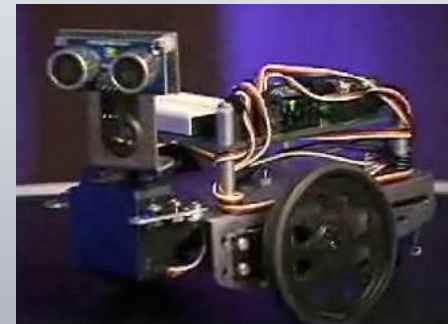
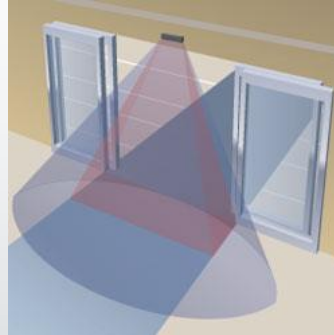
- Operates at +5VDC
- Current draw: 2 – 30 mA
- Serial signal (0 – V_{cc})

- Relatively inexpensive

Ultrasonic Detection

Common Applications

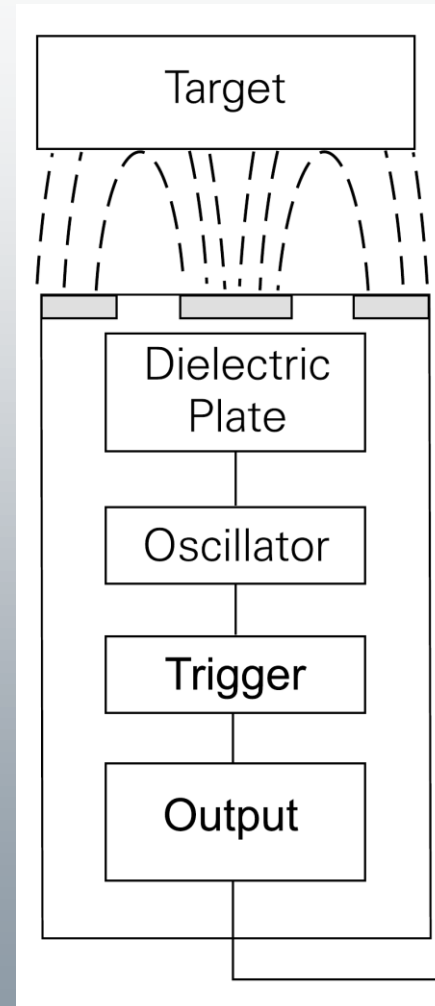
- Security Systems
- Robotics
- Lighting
- Automatic Door Openers
- Parking Aid Systems
- Industrial
- Medical



Capacitive Detection

Overview

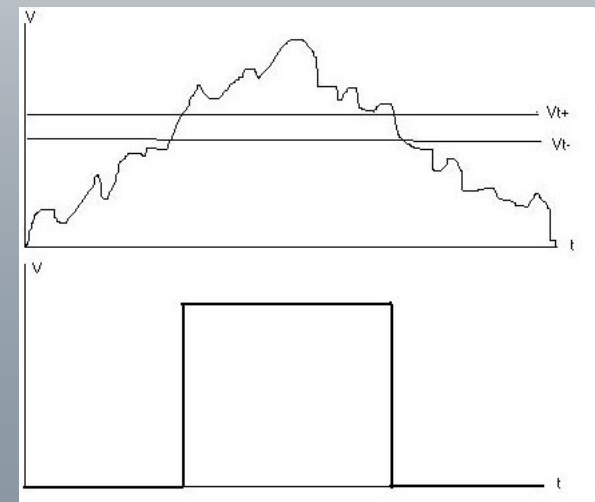
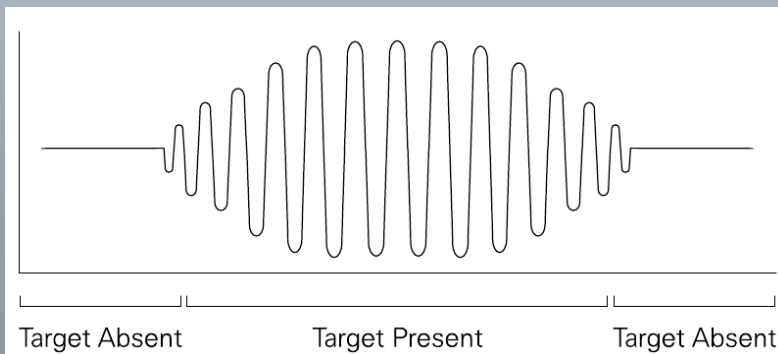
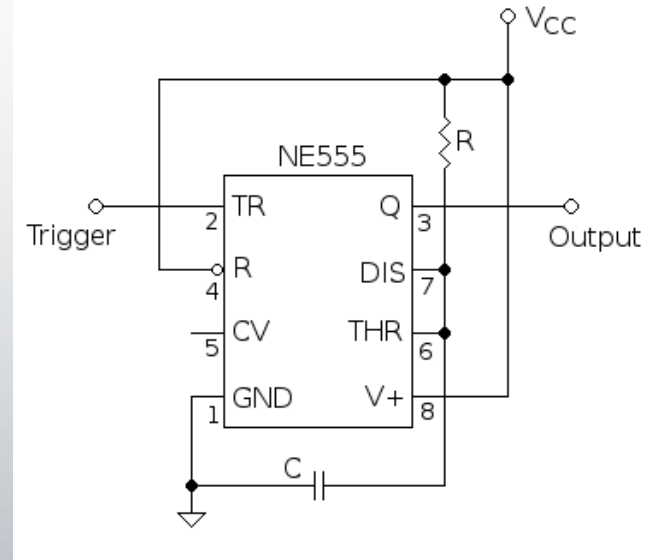
- Diagram shows one type
- Second type, object is the other plate
- How it works
 - Capacitance changes properties of an oscillator circuit



Capacitive Detection

Theory of Operation

- Presence of object will vary capacitance
- Oscillator meets criteria, then trigger
- Schmitt Trigger
 - Hi/Low threshold
 - Small change in analog input, binary output
 - Common and cheap
- Output
 - +5V or 0V
 - 3-wire switch output



Capacitive Detection

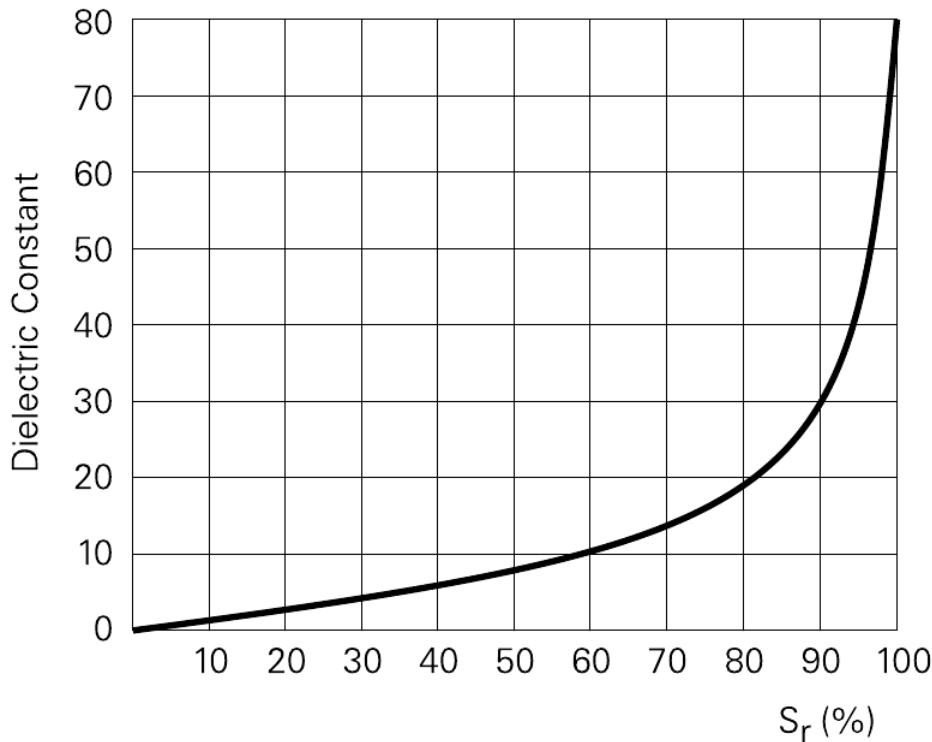
Advantages

- Large range of sizes
 - On chip, too large
- Small sensors normally for touch input
- Large sensors normally for precision measurement or material presence



Capacitive Detection

Limitations



- Relatively short range
- Permittivity of material changes range
 - In range alters the change in capacitance; it is the dielectric for the “capacitor”
- Small capacitances subject to interference
- If you know material and can limit noise – good sensor for short range

Capacitive Detection

Power Consumption & Cost

- Power consumption varies dramatically since sensors can vary
 - Approx. $20\mu\text{W}$ – 3.5 W
- Typical 10mm stand alone sensor: 20mW
- Wide cost range
 - Small scale sensors less than a dollar in bulk
 - Stand alone sensors \$100+, but cheaper in bulk
 - Nanometer precision sensors in thousands



Capacitive Detection

Common Applications

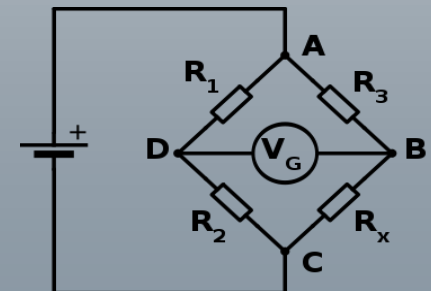
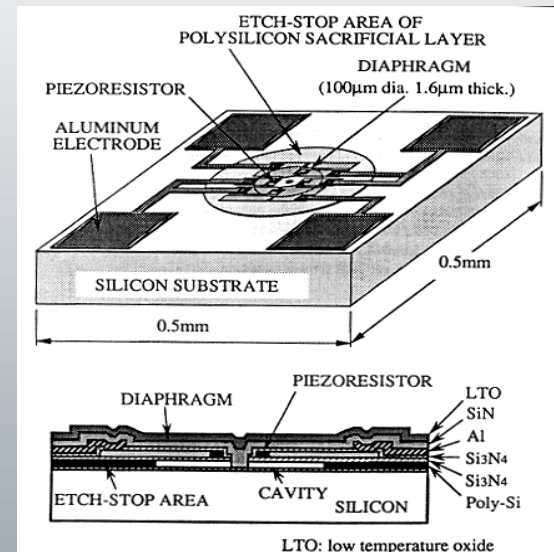
- Proximity Sensing
- Precision Measurement
- See through objects
 - Large silos
 - Cupcake factory



Pressure Detection

Theory of Operation

- Pressure measurement for gases and liquids
- High impedance for low power application
- Conversion of mechanical force to analog electrical signal
- Stainless steel media isolated and Silicon Sensors
- Piezoelectric effect: electrical charge displacement due to lattice deflection in quartz crystal
- Wheatstone bridge strain gauge circuits convert mechanical stress into an electrical output signal



Pressure Detection

Advantages

Optimum stress isolation,
broad pressure range

Easy to install, maintain and
calibrate

Compatible with all the
HVAC systems

Communication capability with
computerized systems

Low power consumption
high dynamic response
and high resolution

Analog/ Digital output
no interface card for PC

Pressure
Temperature
Flow of Steam
Gases
Liquids

Chemical
Pharmaceutical
Food
Oil and Gas
Energy generation



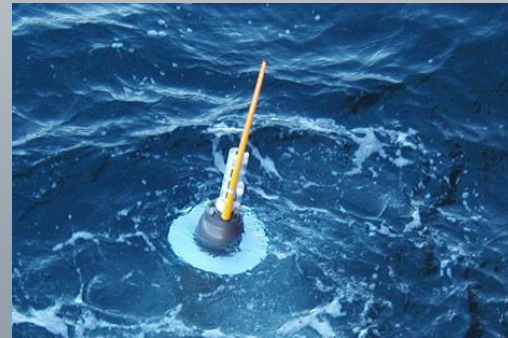
Pressure Detection

Limitations



- Corrosion or fouling with direct exposure to environmental changes
- Long-term drift after a long service time for industrial purposes

- Lifetime, sensitivity and response time is degraded by environmental conditions
 - i.e. temperature, weather
- chemical substance usage in home appliances damaging sensor's body
- electrical noise in the circuit



Pressure Detection

Common Applications

Pressure Sensing:

- Heavy machinery
- Automotive industry
- Medical industry

$$p = \frac{F}{A} \text{ or } p = \frac{dF}{dA}$$

Altitude Sensing:

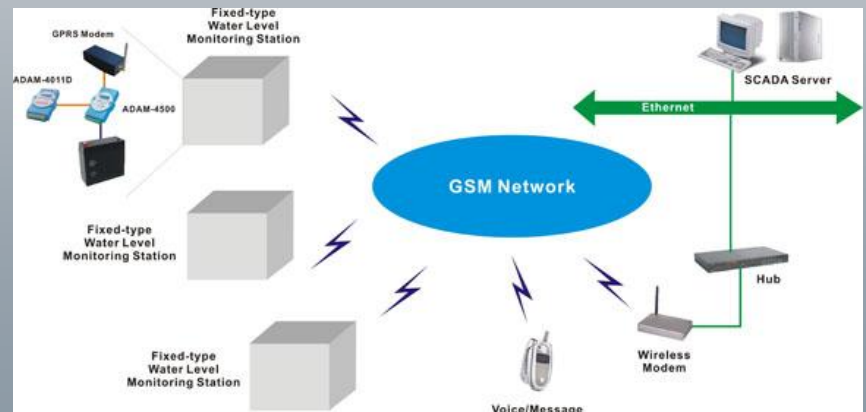
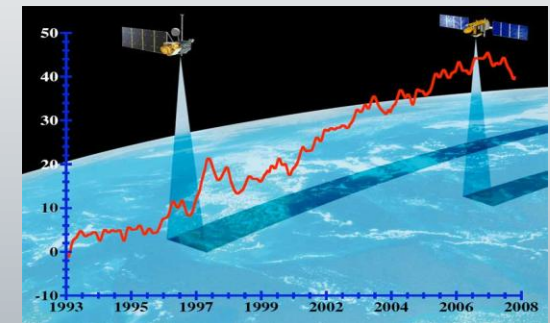
- Barometry
- Satellite, GPS Navigation
- Rocket industry
- Aircraft (i.e. altimeter)

$$h = \frac{(1 - (P/P_{ref})^{0.19026}) \times 288.15}{0.00198122}$$

Level Sensing:

- Medical instruments
- Subsea oceanology
- Environmental water monitoring

$$P = p * g * h$$



Pressure Detection

Specifications

- 1 PSI = 0.0689476 bar

1 PSI = 68.9476 mbar

- 1 PSI = 6894.76 N/m²

1 PSI = 6894.76 Pa

Output Voltage:

0.5 - 4.5V (at 5Vdc) 4 – 20mA (at 9 – 32 Vdc)

2 – 10mV (at 3 – 15Vdc)

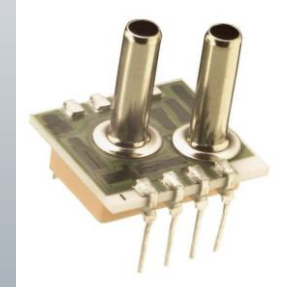
- Pressure Range: 0 – 450psi

- Nominal Temperature: -55 – 125 Fahrenheit

- Serial peripheral Interface (SPI) or
Inter-integrated (I²C) Serial Interface

- Weight: 6.5 oz. Size: 30 x 60 x 16 mm

- Price Range: \$25 - \$450



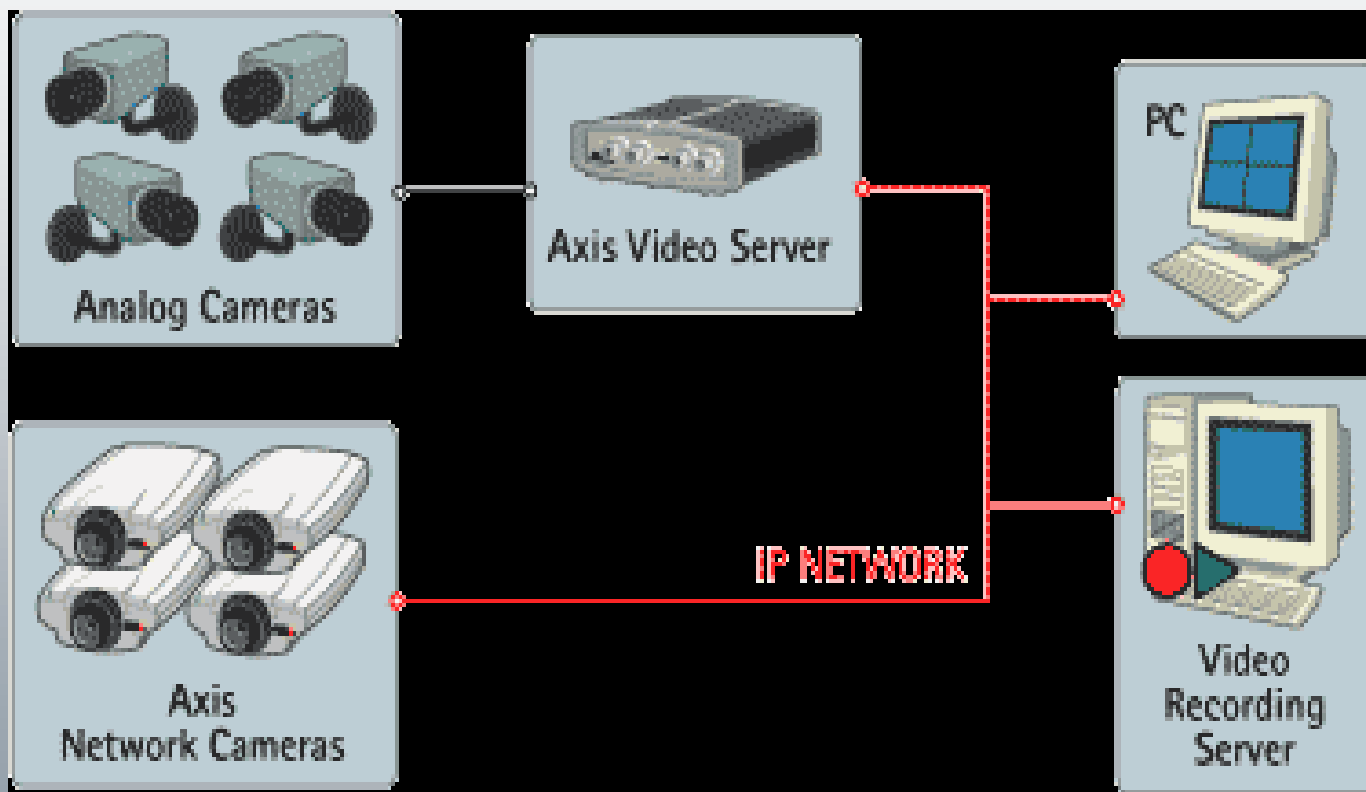
Video Image Detection

Overview

- Utilizes Cameras to analyze data
- Data is analyzed through a series of images
- Differences in images or frames are compared and distinguished
- Can be networked or localized

Video Image Detection

Theory of Operation



Video Image Detection

Theory of Operation

- Algorithms for frame comparison:
 - Current frame with previous one



Video Image Detection

Theory of Operation

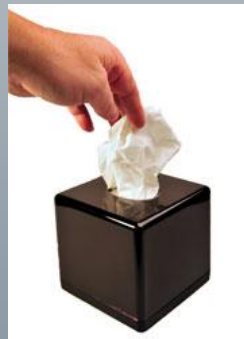
- Algorithms for frame comparison:
 - Current frame with background



Video Image Detection

Advantages

- Integrates well into varied environments
- Wired or wireless networks available
- Use of the IP network easily allows large scale intelligent systems
- Ideal for high cost, high accuracy detection
- Cameras can be nearly imperceptible



Video Image Detection

Limitations

- Very Few limitations
 - High Complexity
 - Limited Perception
 - High Power Consumption
 - High Cost

Video Image Detection

Power Consumption & Cost

Low Complexity Systems

- Single Cameras
- Connected Straight to DVR or PC

- 2 – 3 W
- 3.7 – 9 V
- \$25 - \$480

High Complexity Systems

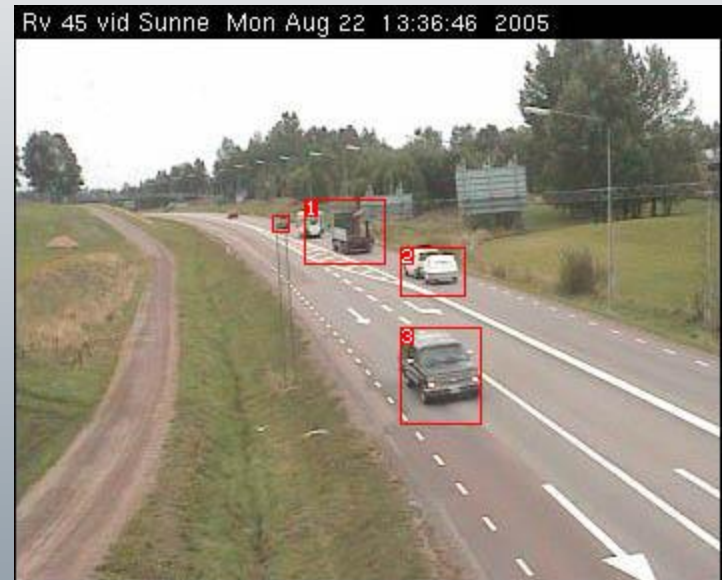
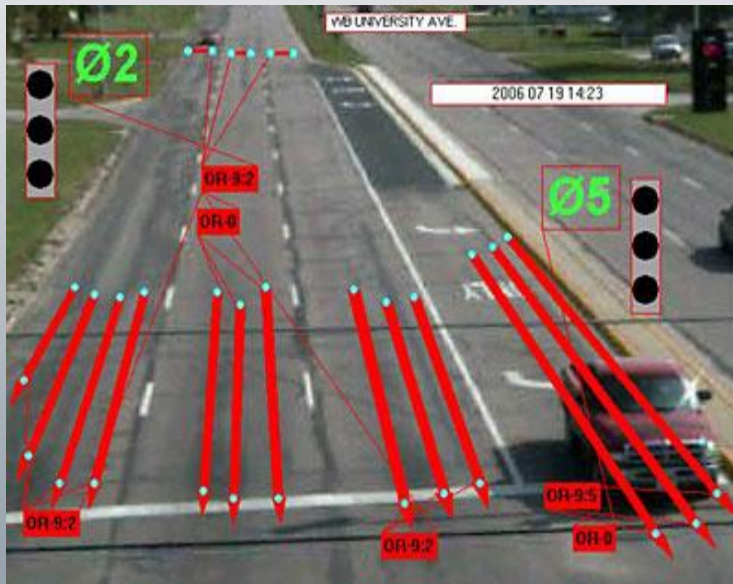
- Networked Cameras
- On Data Hub or Server

- 6 – 60 W
- PoE
- \$99 - \$4000

Video Image Detection

Common Applications

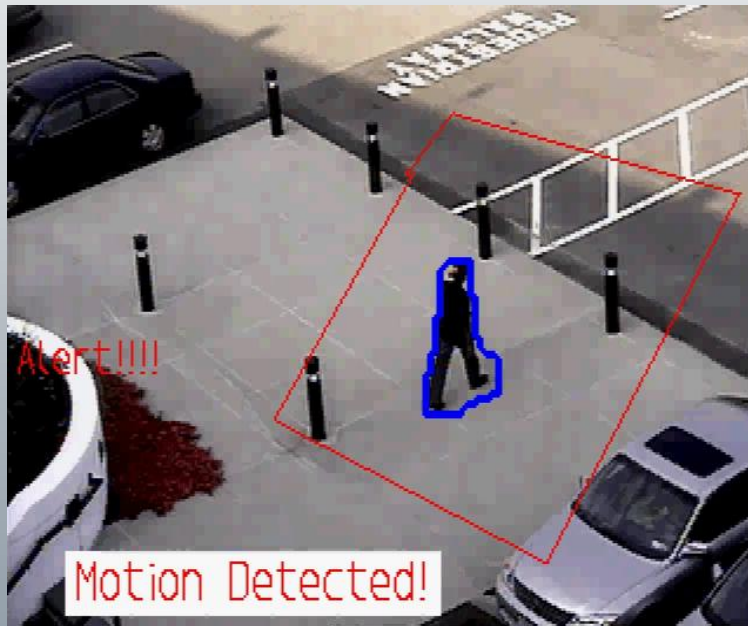
- Traffic Surveillance



Video Image Detection

Common Applications

- Security and Safety



Any Questions??