ITP272 SENSOR TECHNOLOGIES AND PROJECT

L04: Sensors and their Principles

CASE STUDY - SMART PHONE

Analyzing a Smart Phone, what is needed to incorporated these functions ?

- Sense finger touches without buttons
- Detect Knocks
- Read Smart posters
- Get current location

CASE STUDY - SMART PHONE

Finger touches without buttons

- How to know whether finger touches the screen?
  - Pressure sensor

Detect Knocks

- How to know whether there is any knocks on the phone?
  - Vibration sensor

Read Smart Posters

- How to detect a smart card?
  - RFID sensor

Get current location

- How to know where is the current location?
  - Global Positioning System (GPS) Receiver

AGENDA

- Pressure sensors (includes vibration)
- RFID
- GPS

PRESSURE SENSOR

Pressure sensor

D

- A sensor that measures physical force exerted on an object
- Absolute pressure is pressure measured with respect to vacuum (zero pressure)
- Differential pressure is difference in pressure between two pressure sources
- Gauge pressure is a differential pressure compared with atmospheric pressure
- Sometimes being referred to
  - Load sensor
  - Force sensor
  - Vibration / Knock / Collision sensor

PRESSURE SENSOR

Categories

- Mercury Pressure Sensor
- Piezoelectric Sensors (Force and Vibration/knock)
- Piezoresistive Strain Gage Sensors
- Capacitive Pressure Sensor

PRESSURE SENSOR

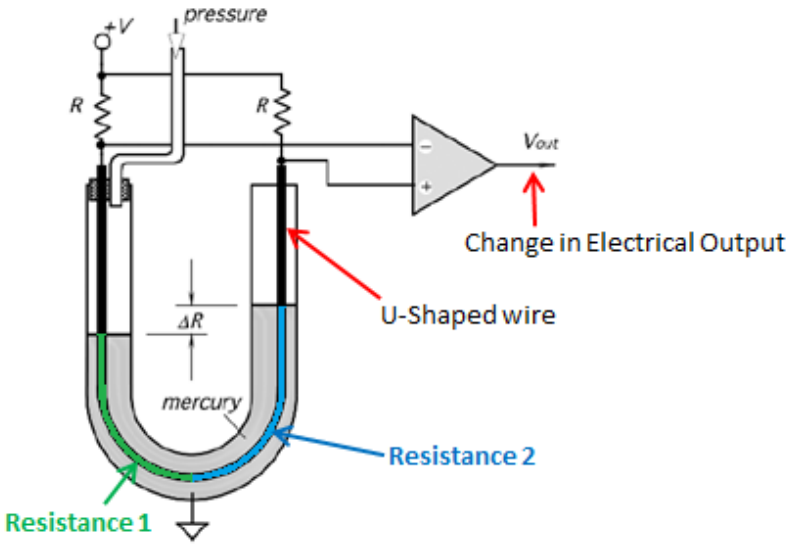
Mercury Pressure Sensor (Manometer)

D

- A sensor that relies on mercury induced variation of resistance to measure air pressure
- A U-shaped wire is immersed into mercury
- Mercury level changes the resistance of wire
- Changes in resistance results in changes in electrical output
- Changes in air pressure alters the mercury level which produces electrical output changes used to measure pressure

PRESSURE SENSOR

Mercury Pressure Sensor (Manometer)



$$V_{out} = V\frac{\Delta R}{R}$$

Air pressure changes -> Mercury level changes

Mercury level changes-> Resistance changes

Resistance changes-> Voltage changes (voltage divider rule)

PRESSURE SENSOR

Piezoelectric Sensors

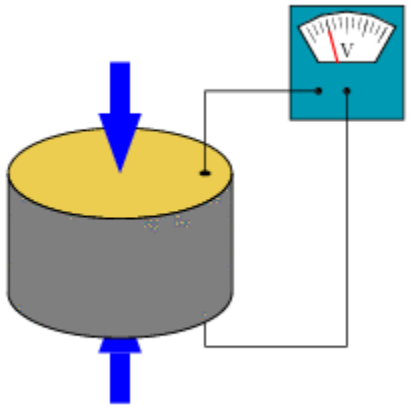
D

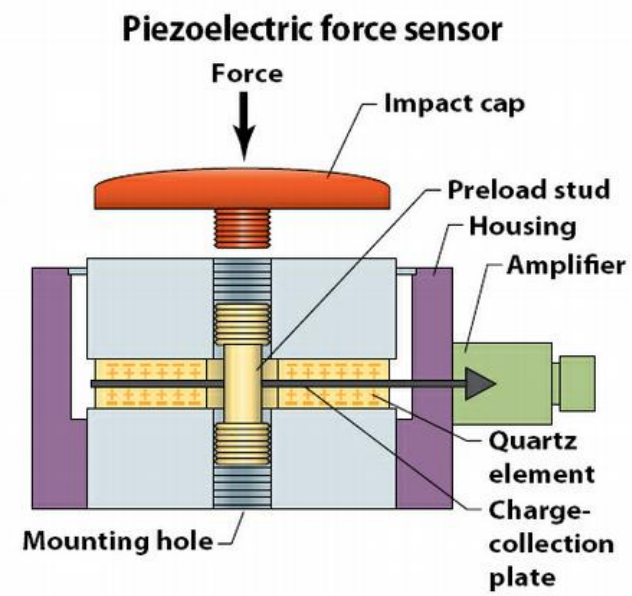
- A sensor that relies on applied electrostatic charge to measure force or vibration
- Force exerted/removed on piezoelectric material generates an electrostatic charge which is processed to generate required electrical output
- Quartz crystals are often used as the piezoelectric element within
- Piezo comes from the Greek word “piezein,” which means “squeeze” or “apply some pressure
- piezoelectric effect is merely the result of stressing a piezo element—crystal, ceramic, or biological matter—to generate a charge or voltage

PRESSURE SENSOR

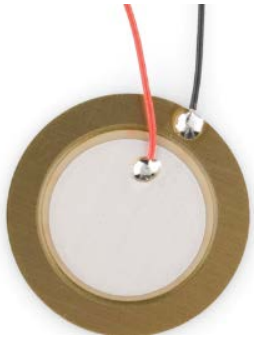
Piezoelectric Sensors

- Force sensor
  - Force applied
  - Piezo element compressed
  - Electrostatic charge generated
  - Electrical voltage changes created



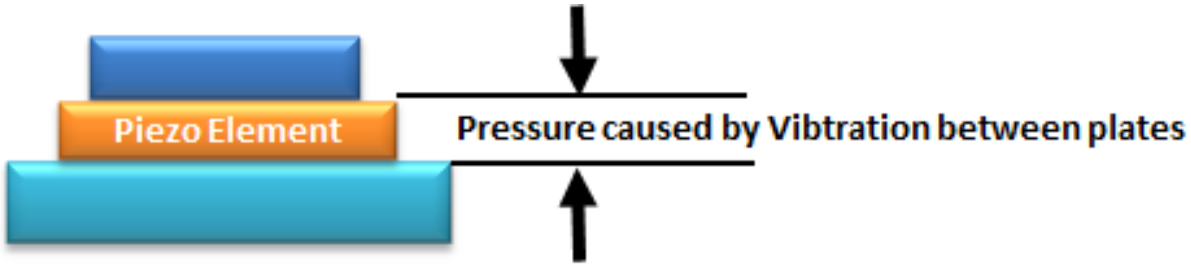


PRESSURE SENSOR



Piezoelectric Sensors

- Vibration (Knock) sensor
  - Piezo element is placed between conducting plates
  - Vibration cause conducting plates to also vibrate
  - Vibration between plates creates pressure on piezo elements
  - Electrostatic charge generated
  - Electrical voltage changes created



PRESSURE SENSOR

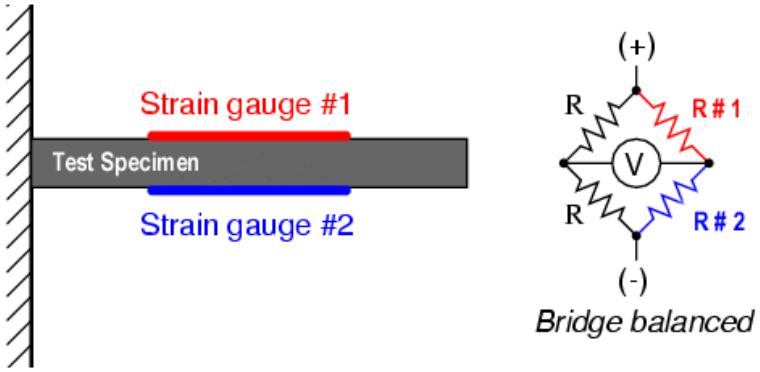
Piezoresistive Strain Gage Sensors

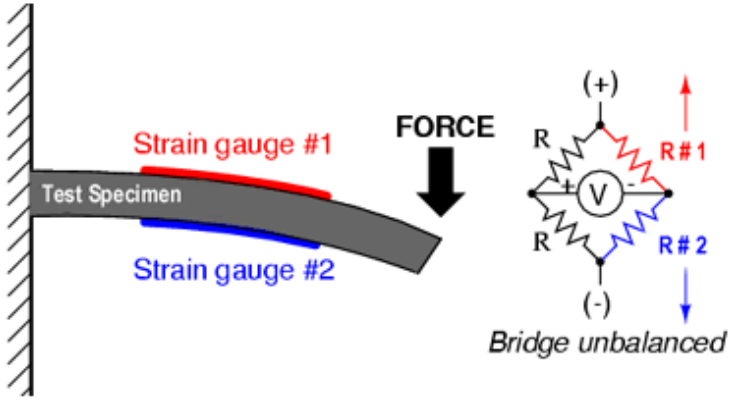
D

- A sensor that relies on deformation (strain) caused by object to measure its load
- The resistive elastic gage, also known as a load cell, alters its resistance according to the magnitude of deformation
- Load applied on load cell creates strain which results in resistance changes
- The strain gages are connected in a four-arm Wheatstone bridge configuration to generate electrical output

PRESSURE SENSOR

Piezoresistive Strain Gage Sensors



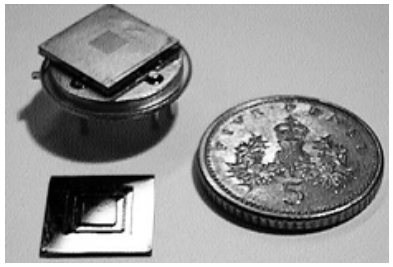


PRESSURE SENSOR

Capacitive Pressure Sensor

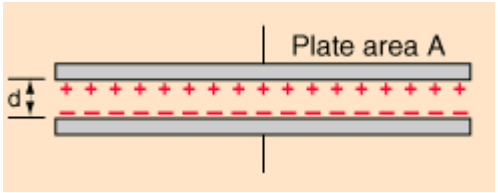
D

- A sensor that relies on changes of capacitance to measure pressure
- Consist of metal diaphragm and a fixed metal plate that forms a fixed capacitance
- Pressure cause metal diaphragm to deflect changing the capacitance between the two plates
- The capacitance change is used to measure pressure

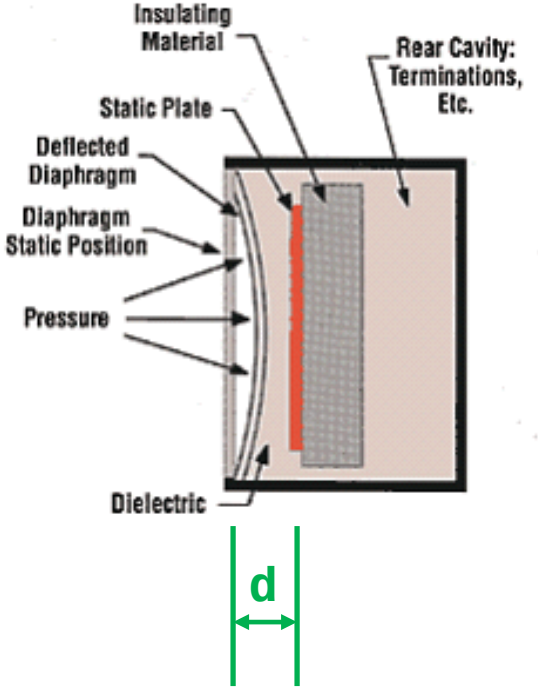


PRESSURE SENSOR

Capacitive Pressure Sensor



$$C = \varepsilon_r \varepsilon_0 \frac{A}{d}$$



C - the capacitance

A - the area of overlap of the two plates

ε_r - the relative static permittivity sometimes called the dielectric constant) of the material between the plates (for a vacuum, εr = 1)

ε_0 - the electric constant (ε0 ≈ 8.854×10−12 F m−1)

d - the separation between the plates.

RFID SENSOR

Radio Frequency Identification sensor

D

- A sensor that uses radio-frequency electromagnetic fields to transfer data
- non-contact and wireless
- It allows data/information to be physically attached to objects. (Information will 'follow' the object wherever it goes)
- Provide a way to extract the data without need of physical contact or line of sight with objects
- Immune to dust, dirt, grease or Spatter
- Read or write product data into RFID tag

RFID SENSOR

RFID Tag Form Factor

- Disk / Coin
  - To withstand higher temperatures, an epoxy resin molding may be used

- Glass or Plastic Housing
  - Animal tracking and identification can be done by injecting these transponders under the animal's skin

RFID SENSOR

RFID Tag Form Factor

- Keys or Key fob
  - Immobilizers (for cars) or door locking applications for high security areas

- Stickers
  - Smart Labels

RFID SENSOR

RFID Tag Form Factor

- Smart Cards
  - Contactless smart cards facilitate transactions without swiping the magnetic stripe

- Wristband
  - To facilitate contactless access control

RFID SENSOR

RFID Tag Types

- There are generally three types of RFID tags
- Active RFID tags, which contain a battery and can transmit signals autonomously
- Passive RFID tags, which have no battery and require an external source to provoke signal transmission
- Battery assisted passive (BAP) tags, which contain a battery but require an external source to wake up. It has significant higher forward link capability providing great read range.

RFID SENSOR

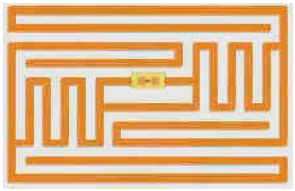
RFID Frequency Range

- Low Frequency
  - 125-134 k Hz
- High Frequency
  - 13.56 M Hz
- Ultra High Frequency
  - 860 – 930 M Hz
- Microwave
  - 2.4 G Hz

RFID Reader

What frequency?

RFID Tag



RFID SENSOR

Comparison across frequencies

Freq	Range	Access speed	Power	Penetration (water, tissues)	Cost
Low	Short < 30 cm	slow	Low	Good	Low
High	Short < 1 m	Mid	Mid	Normal	Mid
Ultra high and Microwave	Long > 1 m	High	High	Weak	High

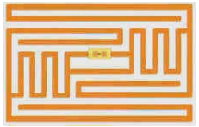
RFID SENSOR

RFID Adoption Challenges

- Cost in implementation – install Tags, readers, devices, software. Cost saving must big enough to cover.
- Requires infrastructure changes which may disrupt business
- Business process changes due to revamp in the administration
- Large volume of acquired data may call for need to upgrade system to handle them which results in higher maintenance cost
- Reliability of scanning which maybe affected by interferences that could cause errors
- Privacy issues that bothers consumers

RFID SENSOR

Comparison between Barcode & RFID



Bar Code	RFID
Line of sight	General vicinity
One at a time	Batch processing identifies unique items.
Tag must be visible or exposed.	Covert
Operator intervention	Automated process
Read only	Read and write
Cost is cheap	More expensive
Bar code easily duplicated	Harder to replicate (security).

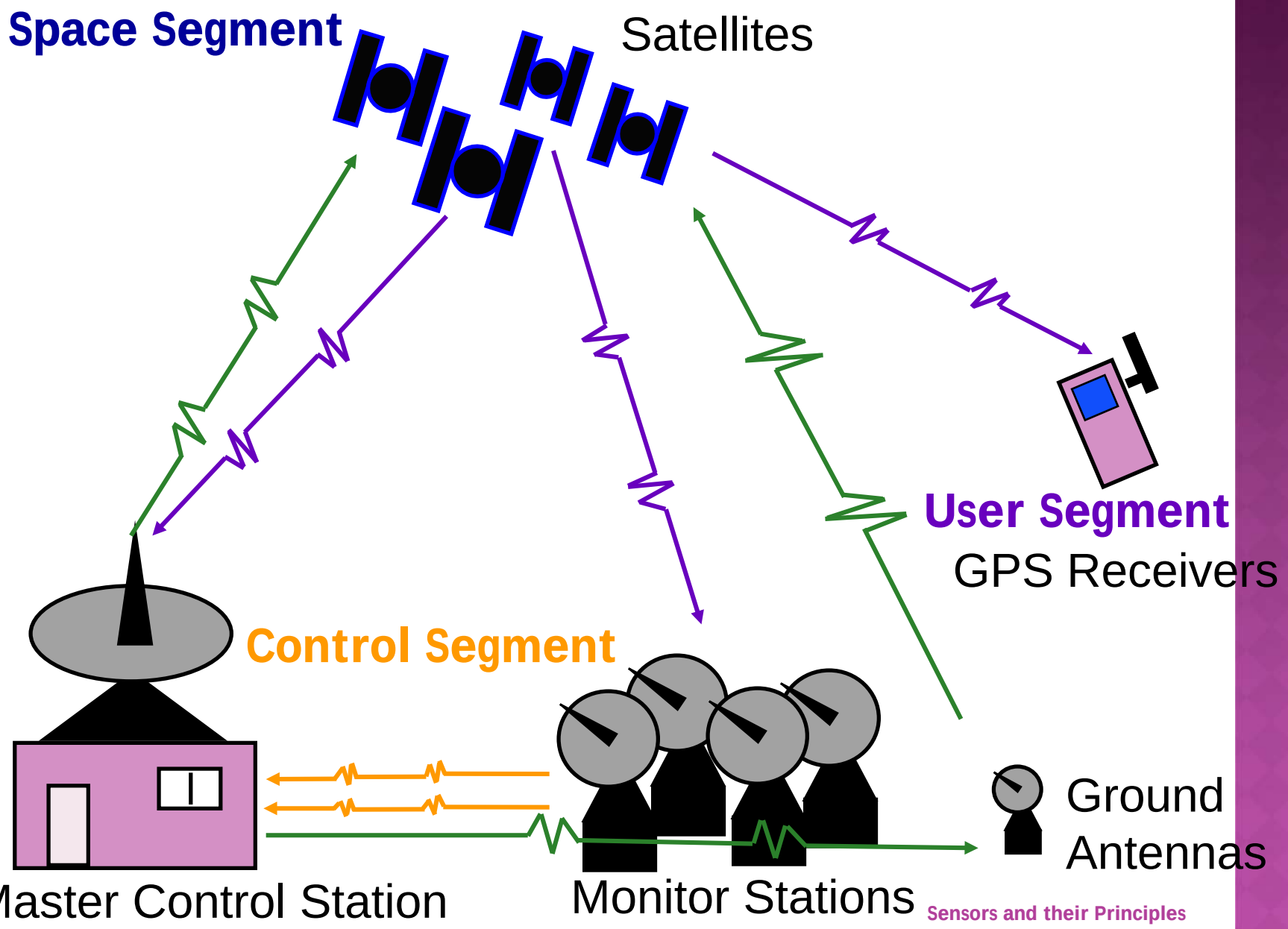
GPS SENSOR

Global Positioning System sensor

D

- A sensor that uses Trilateration of multiple satellites signals to estimate positioning
- Provides 3D location (longitude, latitude & altitude) and time
- Requires an unobstructed line of sight to multiple GPS satellites
- GPS System are made of 3 segments
  - Space Segment (SS)
  - Control Segment (CS)
  - User Segment (US)

OVERVIEW OF GPS

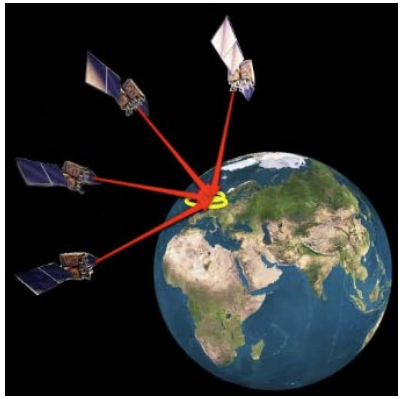


GPS SENSOR

Trilateration

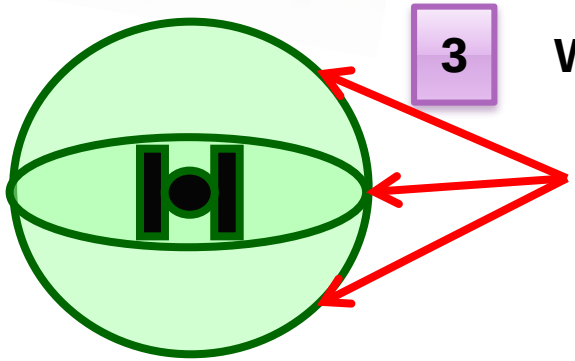
D

- The process of estimating receiver position based on the intersection of sphere surfaces from the satellites distances
- It results in 2 points of intersection of the 3 spheres
- For more precise location, 1 of these 2 points will intersect with the 4th sphere to get a unique receiver position
- Thus usually a minimum of 4 satellites are required

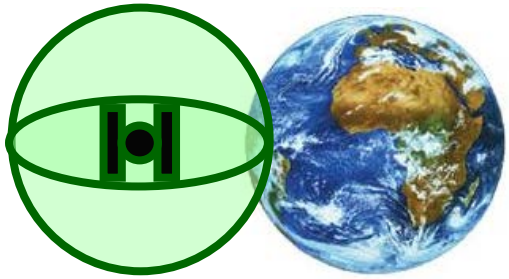


DISTANCE TO LOCATION

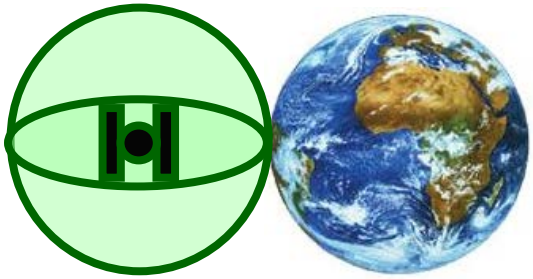
1. Location of satellite known from GPS signal
2. Distance from satellite calculated
3. What can we gather from 1 satellite?



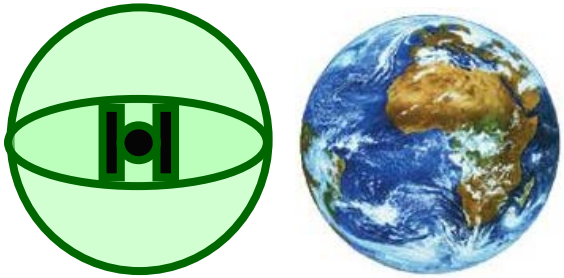
Receiver is anywhere on the surface of this sphere around the satellite



under water ?



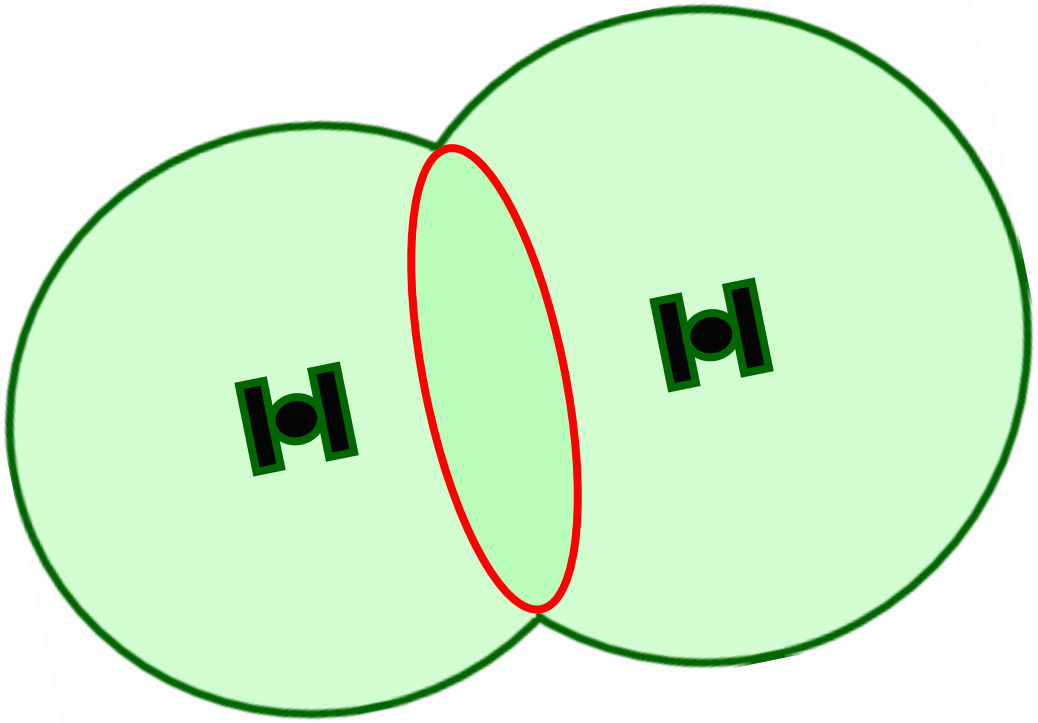
On surface ?



On Air?

DISTANCE TO LOCATION

1. When 2 satellites distances are gathered
2. 2 spheres of possible locations intersect
3. Possible locations are reduced to circumference of circle

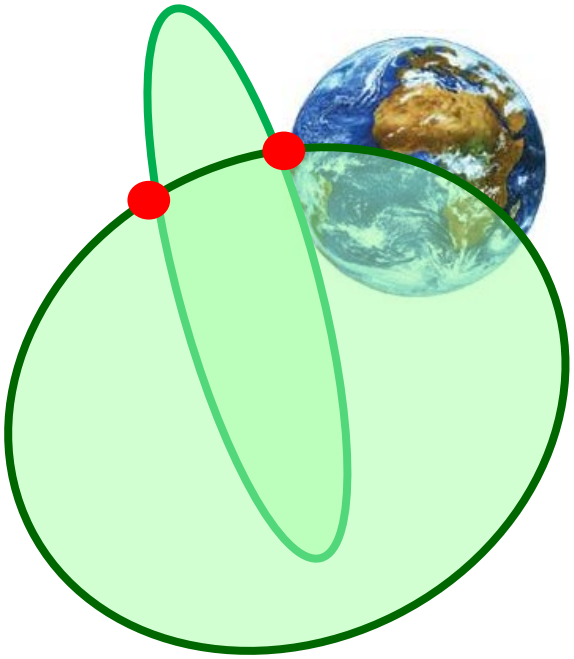


DISTANCE TO LOCATION

1. When 3 satellites distances are gathered

2. Circumference of circle and 1 sphere of possible locations intersect

3. Possible locations are reduced to 2 points



4. The 4th satellite are used to intersect one of the 2 points get a unique location

REVIEW QUESTIONS

REVIEW QUESTION

List down 5 comparisons between Barcode & Radio Frequency Identification (RFID)?

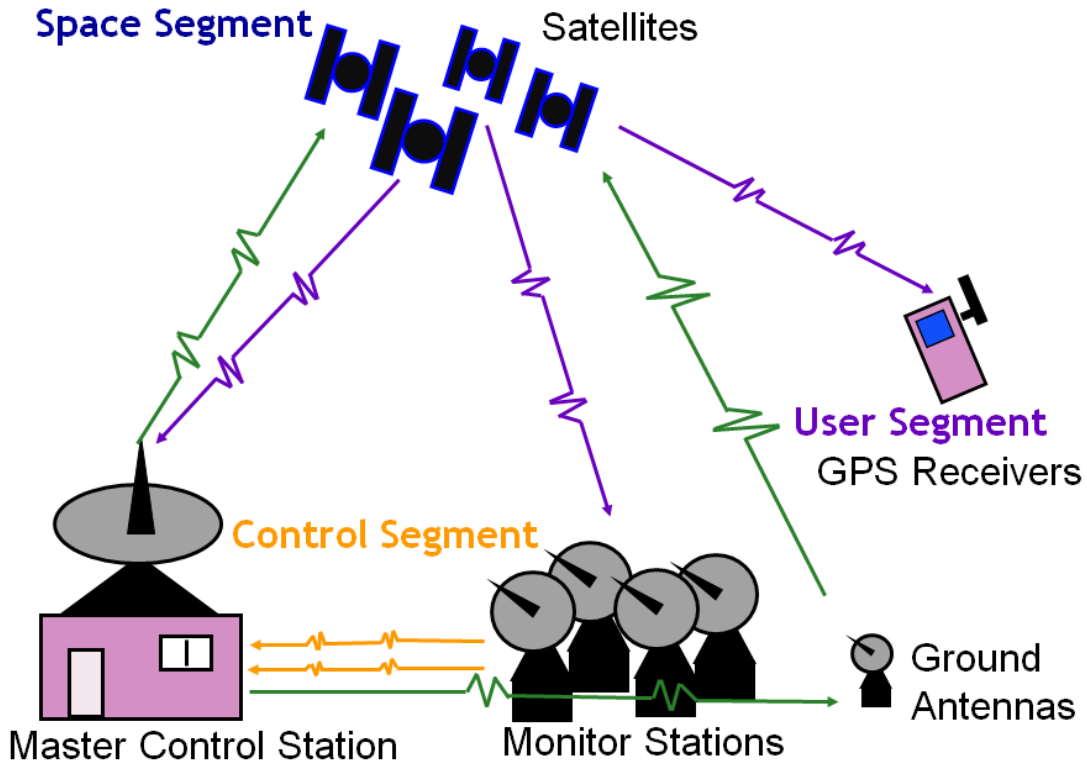
Answer: (Any 5 of the below)

Bar Code	RFID
Line of sight	General vicinity
One at a time	Batch processing identifies unique items.
Tag must be visible or exposed.	Covert
Operator intervention	Automated process
Read only	Read and write
Cost is cheap	More expensive
Bar code easily duplicated	Harder to replicate (security).

REVIEW QUESTION

Draw an overview diagram of the GPS showing various segments and the entities in them. You will also need to include the direction of transmission?

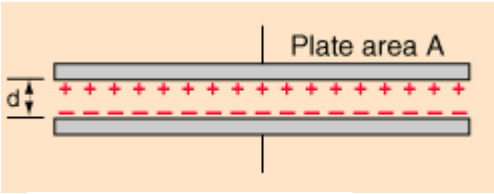
Answers:



REVIEW QUESTION

The capacitance changes of a Capacitive Pressure Sensor is <u>not</u> affected by which of the following?

A. The amount of vacuum between the two capacitor plates
B. Area of the overlap between the two capacitor plates
C. Relative static permittivity of the material between the two capacitor plates
D. Separation distance between the two capacitor plates



$$C = \varepsilon_r \varepsilon_0 \frac{A}{d}$$

Answers => A

REVIEW QUESTION

What is the similarity between a Strain Gage and a Mercury Pressure Sensor?

A. They have a piezoelectric element to generate electric signal
B. They have a metal diaphragm within
C. They rely on the concept of capacitance changes
D. They rely on the concept of resistance changes

Answers => D

REVIEW QUESTION

Which of the following sensors is used to detect intensity of knock or vibration?

A. Ultrasonic sensor
B. Manometer
C. Piezoelectric sensor
D. Passive Infrared (PIR) sensor

Answers => C

REVIEW QUESTION

What of the following is not true about a Radio Frequency Identification (RFID) sensor?

A. It is immune to dust, dirt and grease
B. It requires line of sight to work
C. It performs contactless reading and writing of data
D. The RFID Tags can active, passive or Battery Assisted Passive types

Answers => B

REVIEW QUESTION

What of the following is an advantage of Radio Frequency Identification (RFID) sensor over Bar Code?

A. It is read only
B. It does not require tags to be exposed
C. It can be easily duplicated
D. It is cheaper to implement

Answers => B

REVIEW QUESTION

Which of the following is not a segment within the Global Positioning System (GPS)?

A. Space Segment
B. Control Segment
C. User Segment
D. Device Segment

Answers => D

REVIEW QUESTION

Which of the following does not belong to the Control Segment of the Global Positioning System (GPS)?

A. Master Control Station
B. GPS Receivers
C. Monitor Station
D. Ground Antennas

Answers => B

REVIEW QUESTION

The Global Positioning System (GPS) receivers resides in which segment of the GPS?

A. Space Segment
B. Device Segment
C. User Segment
D. Control Segment

Answers => C

REVIEW QUESTION

A Global Positioning System (GPS) receiver requires signals from a minimum number of _____ satellites to compute its current location?

A. 3
B. 4
C. 6
D. 8

Answers => B

REVIEW QUESTION

What is the process used by Global Positioning System (GPS) to estimate receiver position?

A. Trilateration
B. Interpolation
C. Doppleration
D. Triangulation

Answers => A