INS:
Inertial Navigation Systems

An overview of 4 sensors

What is an INS?

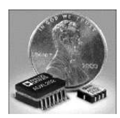
- Position (dead reckoning)
- Orientation (roll, pitch, yaw)
- Velocities
- Accelerations

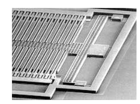
Sampling of INS Applications



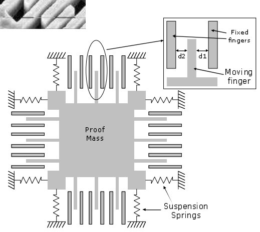


Accelerometers





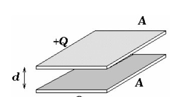
Accelerometers

- F = ma
  (Newton's 2nd Law)
- F = kx
  (Hooke's Law)

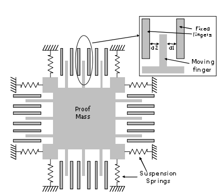
Accelerometers

- $C = \varepsilon_0 A/d$
  (parallel-plate capacitor)
  - ε_0 = permitivity constant
- Q = CV

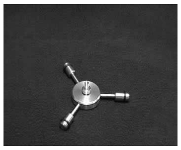


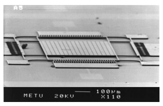
Voltage → Capacitance → Surface Area and distance → Spring displacement → Force → Acceleration

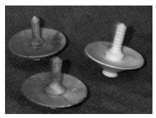
Integrate to get velocity and displacement



Gyroscopes



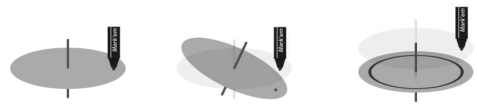




Gyroscopes

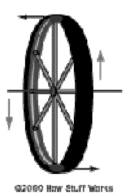
How does it maintain angular orientation?

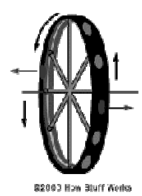
Disk on an axis | Disk stationary | Disk rotating



Red pen indicates applied force

Gyroscopes – Precession





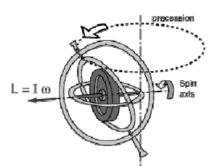
As green force is applied to axis of rotation, red points will attempt to move in blue directions

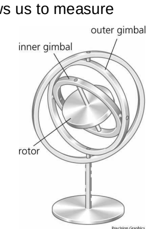
These points rotate and continue to want to move in the same direction causing precession

Rotating around red axis, apply a moment around axis coming out of paper on red axis

Gyroscopes – Gimbaled

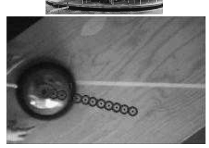
- Rotor Axle wants to keep pointing in the same direction
- Mounting in a set of gimbals allows us to measure the rotation of the body

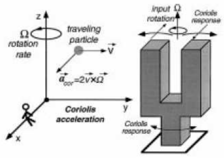


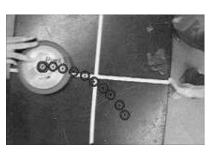


Gyroscopes – MEMS

- Coriolis effect – "fictitious force" that acts upon a freely moving object as observed from a rotating frame of reference

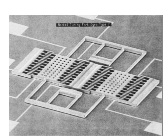




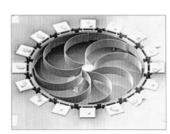


Gyroscopes – MEMS

- Comb drive fingers can be actuated by applying voltage
- Coriolis effect induces motion based on rotation
- Capacitive sensors (similar to accelerometers) detect the magnitude of this effect and therefore the rotation

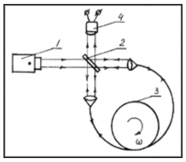


Tuning Fork Gyroscope



Vibrating Ring Gyroscope

Fiber Optic Gyroscope (FOG)



ω = attitude rate, 1 = laser light source, 2 = beamsplitter, 3 = wound optical fiber, 4 = photosensor.

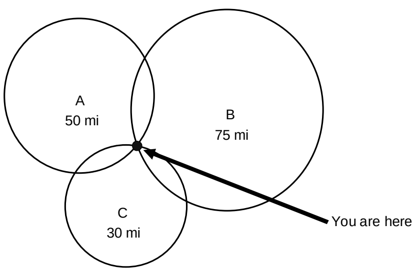
DSP 4000

turret, antenna, and optical stabilization systems

GPS – Global Positioning System

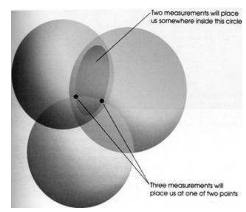
- Constellation 27 satellites in orbit
- Originally developed by U.S. military
- Accuracy ~ 10 m
- 3D Trilateration

GPS – 2D Trilateration



GPS – 3D Trilateration

- Location of at least three satellites (typically 4 or more)
- Distance between receiver and each of those satellites
  - Psudo-random code is sent via radio waves from satellite and receiver
  - Since speed of radio signal is known, the lag time determines distance



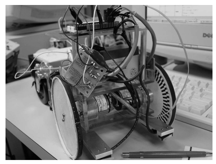
GPS – Improvements

- Some sources of error
  - Earth's atmosphere slows down signal
  - Radio signal can bounce off large objects
  - Misreporting of satellite location
- Differential GPS (DGPS)
  - Station with known location calculates receiver's inaccuracy
  - Broadcasts signal correction information
  - Accuracy ~ 10 m

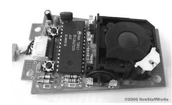
GPS – Improvements

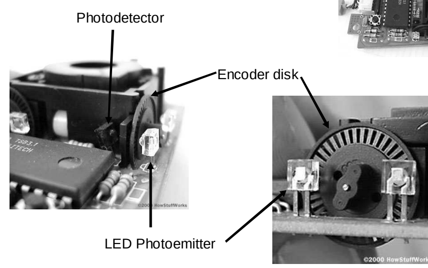
- WAAS (Wide Area Augmentation System)
  - Similar to DGPS
  - Geosynchronous Earth Orbiting satellites instead of land based stations
  - Accuracy ~ 3 m

Encoders

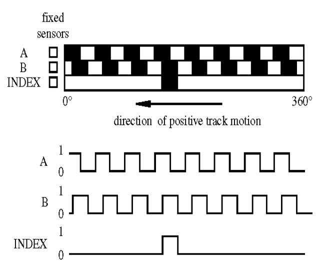


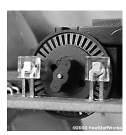
Encoders – Incremental





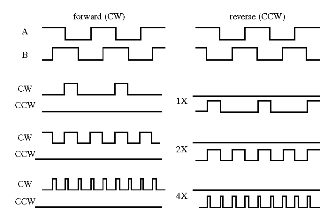
Encoders - Incremental





Encoders - Incremental

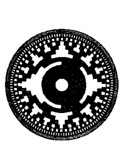
- Quadrature (resolution enhancing)



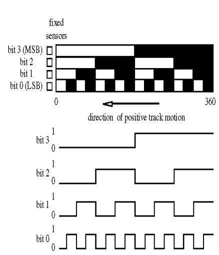
Encoders - Absolute

- More expensive
- Resolution = 360°/ 2^N
  where N is number of tracks

4 Bit Example



(b) actual disk (Courtesy of Parker Compumotor Division, Rohnert Park, CA)



(a) schematic and signals

Pros and Cons

	Pros	Cons
Accelerometer	Inexpensive, small	Integration drift error
Gyroscope	Large selection	Integration drift error
GPS	No drift	Data at 1 Hz
Encoders	Inexpensive	Slip