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Ege Üniversitesi Ege MYO
Mekatronik Programı

BÖLÜM 7

MEMS:

- *Gyroscopes*
- *Accelerometers*
- *Magnetometers*

Gyroscopes

- Intro to Gyroscopes
- Draper Tuning fork Gyroscope
- Piezoelectric Gyroscope
- Absolute Angle Measurement using a Gyroscope
- Optical Gyroscope and limitations
- Applications

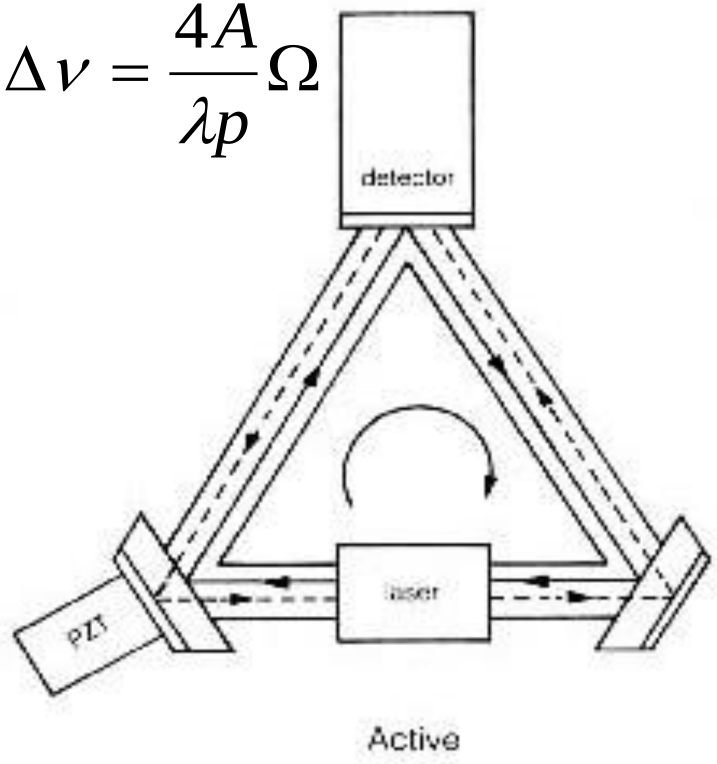
Intro to Gyroscopes

- Traditional Gyroscopes
- Working Principle
- Transition to MEMS
- Types of Gyroscopes
  - Piezoelectric
  - Vibratory
  - Ring Laser

Laser Ring Gyroscopes

- Two signals sent around ring
- Different path lengths create a beat frequency.

$$\Delta \nu = \frac{4A}{\lambda p}\Omega$$

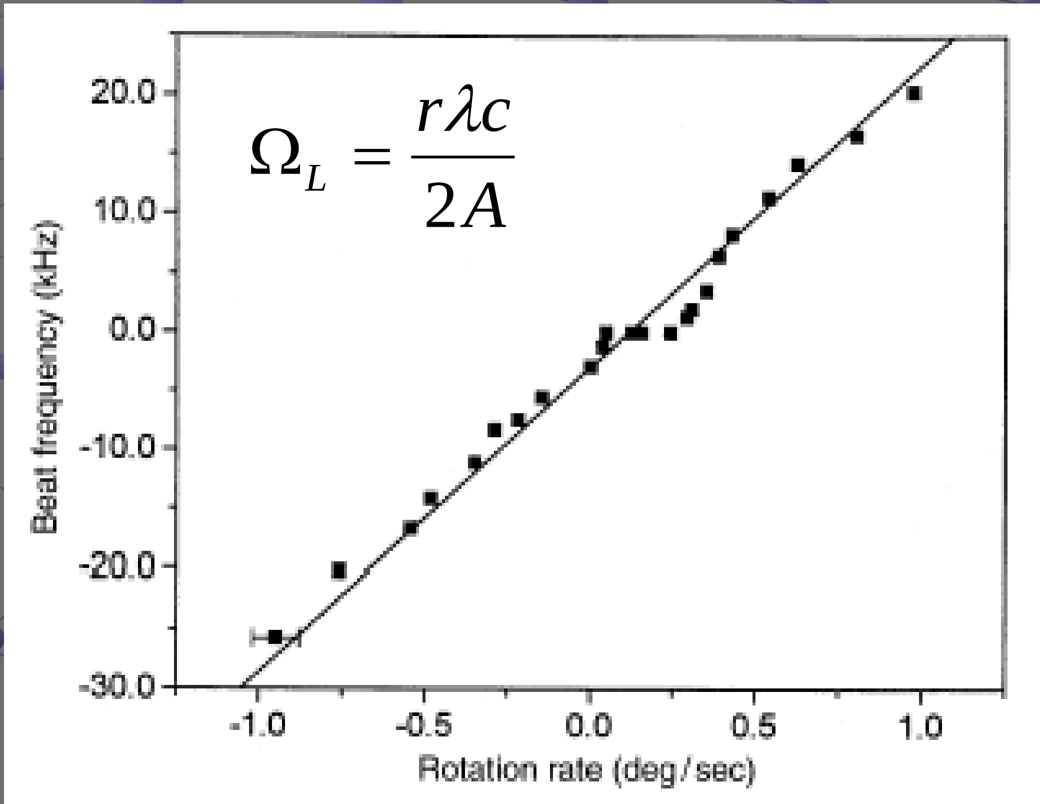


A – area of ring

P – perimeter of ring

Dead Band

- Dead Band -No change in beat frequency for small rotation rates
- Due to frequency “lock-in”



r- backscattering amplitude

Scaling Difficulties

- Derived Equation for Laser Gyroscope

$$\frac{\psi}{2\pi} = \nu_{\text{bias}} + \frac{\mathscr{R}\Omega}{2\pi} - \frac{c}{2\pi P}\left\langle \frac{r_1(\tau)\mathscr{E}_1}{\mathscr{E}_2}\sin(\psi - \varepsilon_1) + \frac{r_2(\tau)\mathscr{E}_2}{\mathscr{E}_1}\sin(\psi + \varepsilon_2)\right\rangle.$$

Beat Freq = (M) Angular Velocity - 1/M

Dead Band = 1/M^2

M = Scaling Factor

Scaling Difficulties

M = 10^{-4}

-Dead Band = 10^{8} times bigger

-Time varying term larger

-Slope of response lower

$$\frac{\dot{\psi}}{2\pi} = \nu_{\text{bias}} + \frac{\mathscr{R}\Omega}{2\pi} - \frac{c}{2\pi P}\left\langle \frac{r_1(\tau)\mathscr{E}_1}{\mathscr{E}_2}\sin(\psi - \varepsilon_1) + \frac{r_2(\tau)\mathscr{E}_2}{\mathscr{E}_1}\sin(\psi + \varepsilon_2)\right\rangle .$$

$$\Omega_L = \frac{r\lambda c}{2A}$$

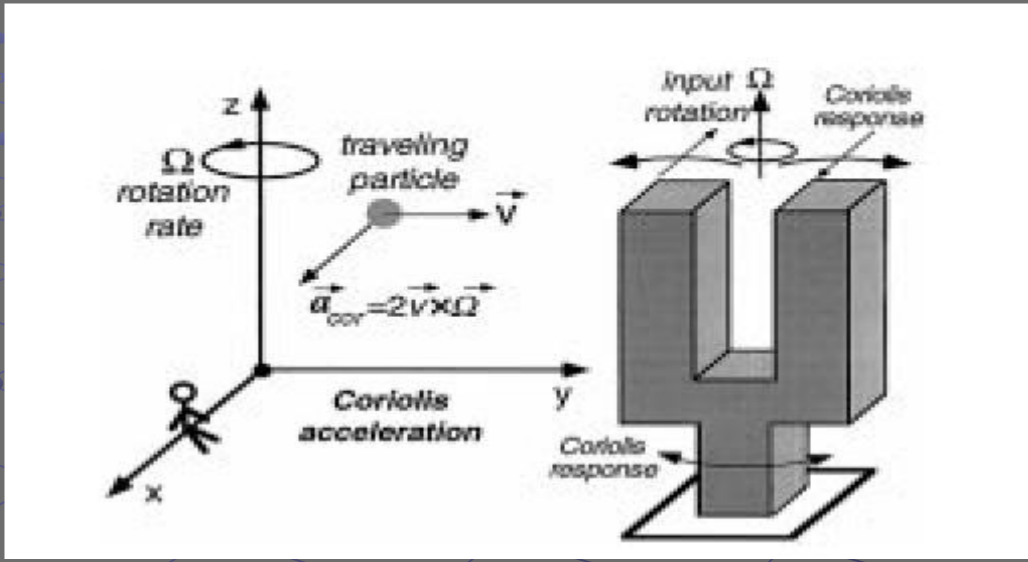
Change Bandwidth

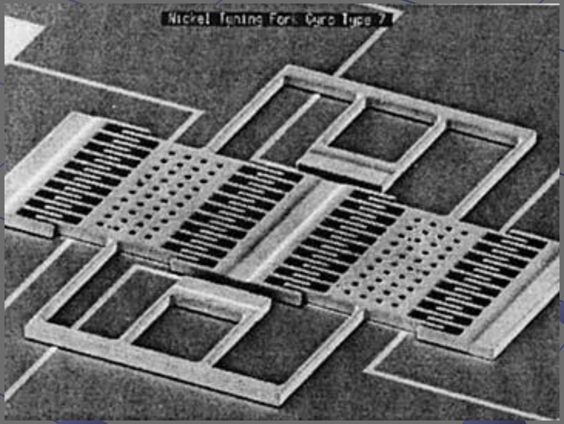
To lower Dead Band, wavelength could be decreased.

Lower slope – Decreased Sensitivity

Draper Tuning Fork Gyro

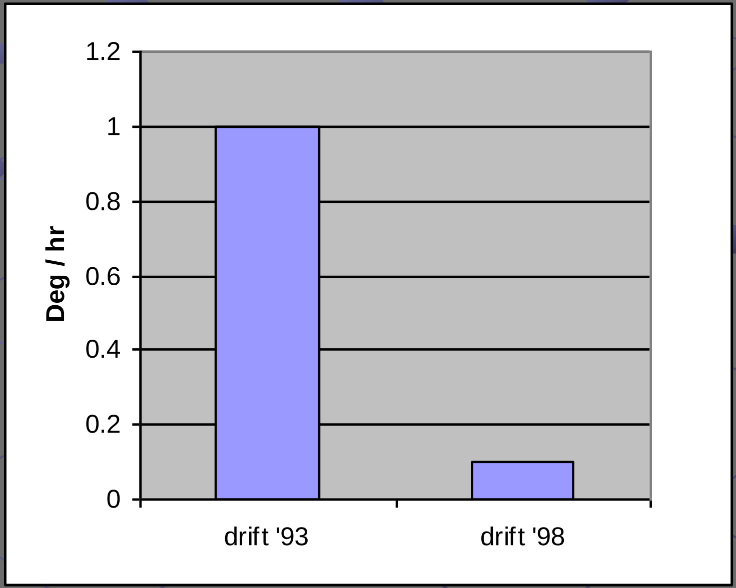
- The rotation of tines causes the Coriolis Force
- Forces detected through either electrostatic, electromagnetic or piezoelectric.
- Displacements are measured in the Comb drive

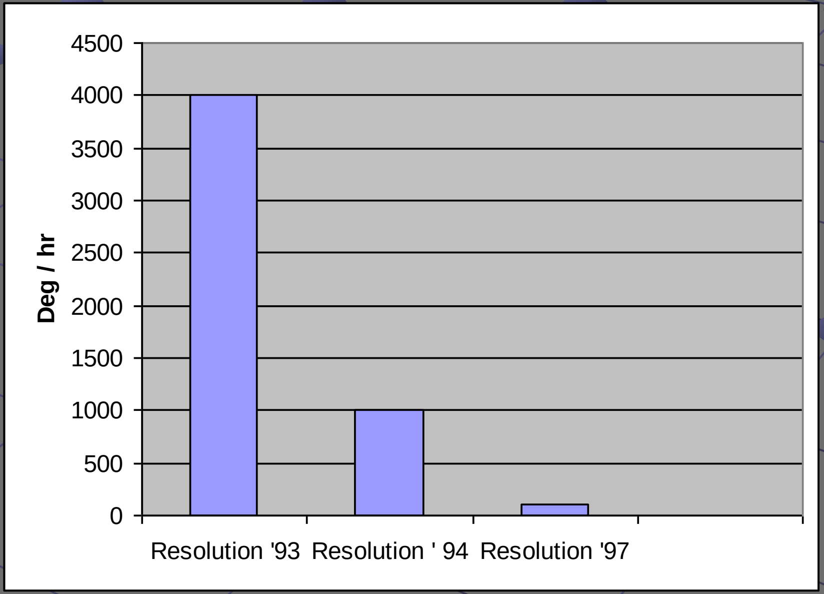




Advancements

- Improvement of drift
- Improvement of resolution



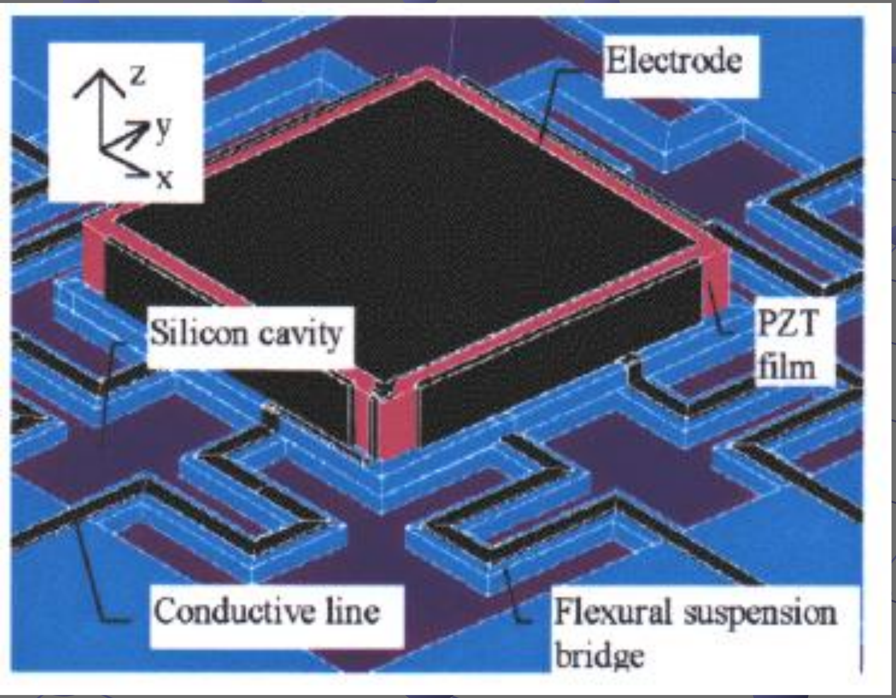


Performance Advantages

- No change in performance due to temperature
- Lower voltage noise
  - Stronger signal to noise ratio
  - Better communication with external devices
  - Higher sensitivity

Piezoelectric Gyroscopes

- Basic Principles
  - Piezoelectric plate with vibrating thickness
  - Coriolis effect causes a voltage form the material
  - Very simple design and geometry



Piezoelectric Gyroscope

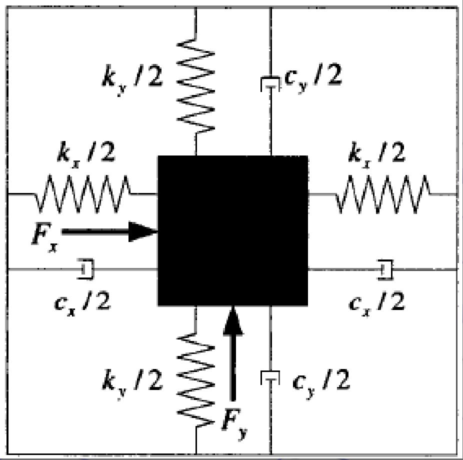
- Advantages
  - Lower input voltage than vibrating mass
  - Measures rotation in two directions with a single device
  - Adjusting orientation electronically is possible
- Disadvantages
  - Less sensitive
  - Output is large when $\Omega = 0$

Absolute Angle Measurement

- Bias errors cause a drift while integrating
- Angle is measured with respect to the casing
  - The mass is rotated with an initial θ
  - When the gyroscopes rotates the mass continues to rotate in the same direction
- Angular rate is measured by adding a driving frequency ω_d

Design consideration

- Damping needs to be compensated
- Irregularities in manufacturing
- Angular rate measurement



$$F_x = \alpha\left(E - \frac{k_x}{2}x^2 - \frac{m}{2}\dot{x}^2 - \frac{k_y}{2}y^2 - \frac{m}{2}\dot{y}^2\right)\dot{x}$$

$$F_y = \alpha\left(E - \frac{k_x}{2}x^2 - \frac{m}{2}\dot{x}^2 - \frac{k_y}{2}y^2 - \frac{m}{2}\dot{y}^2\right)\dot{y}$$

Compensation force

$$F_x = \alpha\left(E - \frac{\hat{k}_x}{2}x^2 - \frac{m}{2}\dot{x}^2 - \frac{\hat{k}_y}{2}y^2 - \frac{m}{2}\dot{y}^2\right)\dot{x} + F_d \sin(\omega_d t)$$

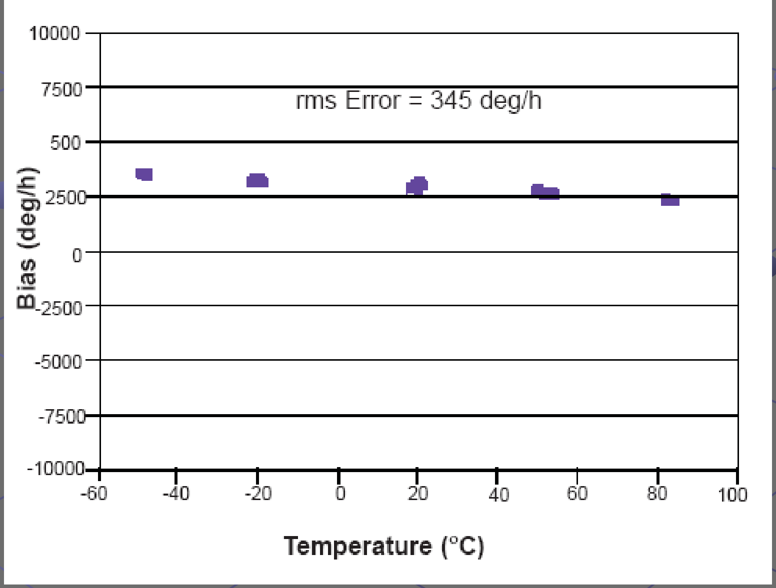
For angular rate measurement

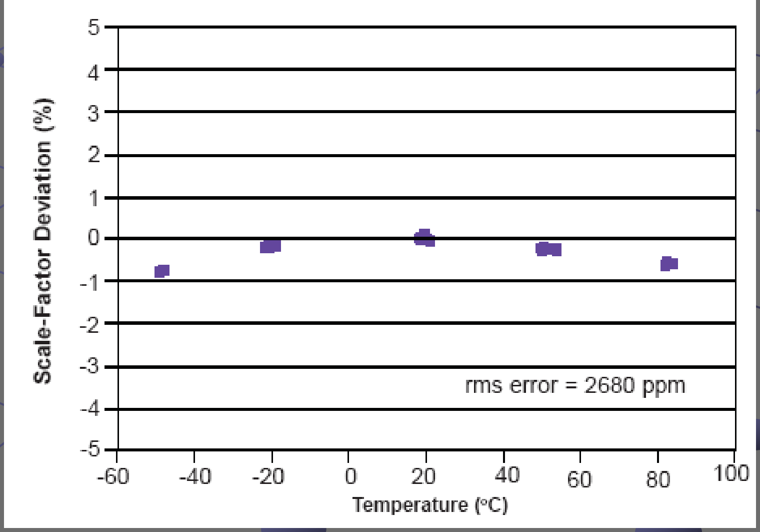
APPLICATIONS

- Anti-Lock Brakes
- Military Munitions
- Inertial Measurement Unit
- Gait-Phase Detection Sensor Embedded in a Shoe Insole

Anti-Lock Brakes

- Use of Draper Tuning Fork Gyroscope
- Yaw Rate Sensor for skid control
- Tested under rigorous temperature conditions



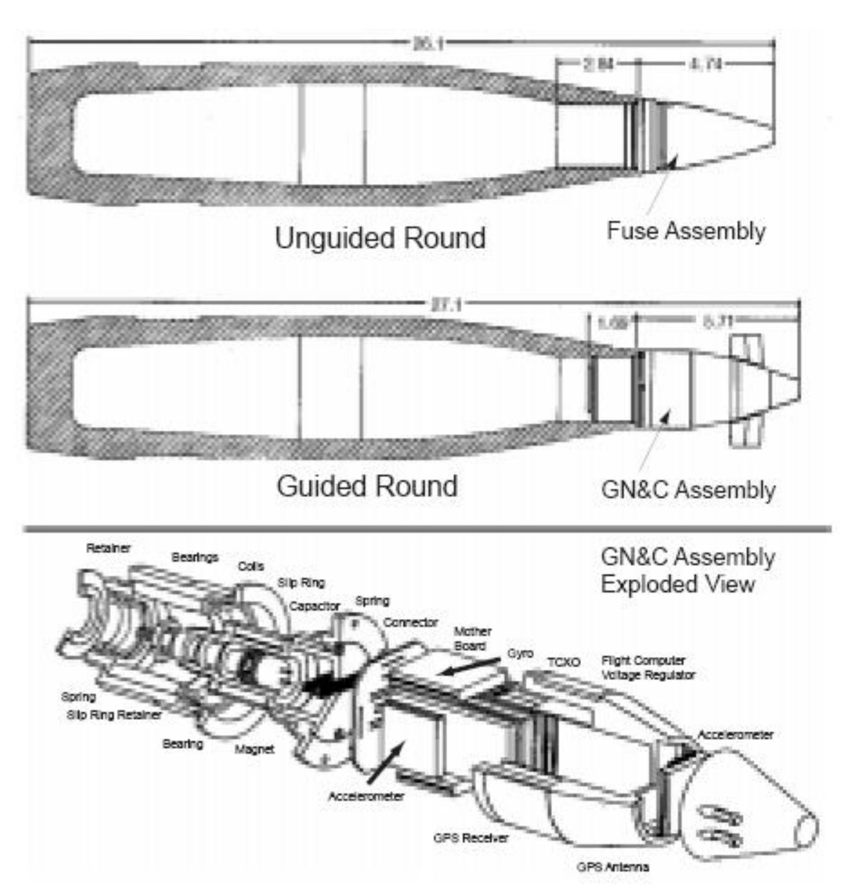


Inertial Measurement Unit

- Honeywell acquired Draper's Tuning Fork technologies
- Replaced Ring Laser Gyro in original design
- Developed a low-cost, micro-device capable of accurately measuring rates and displacements

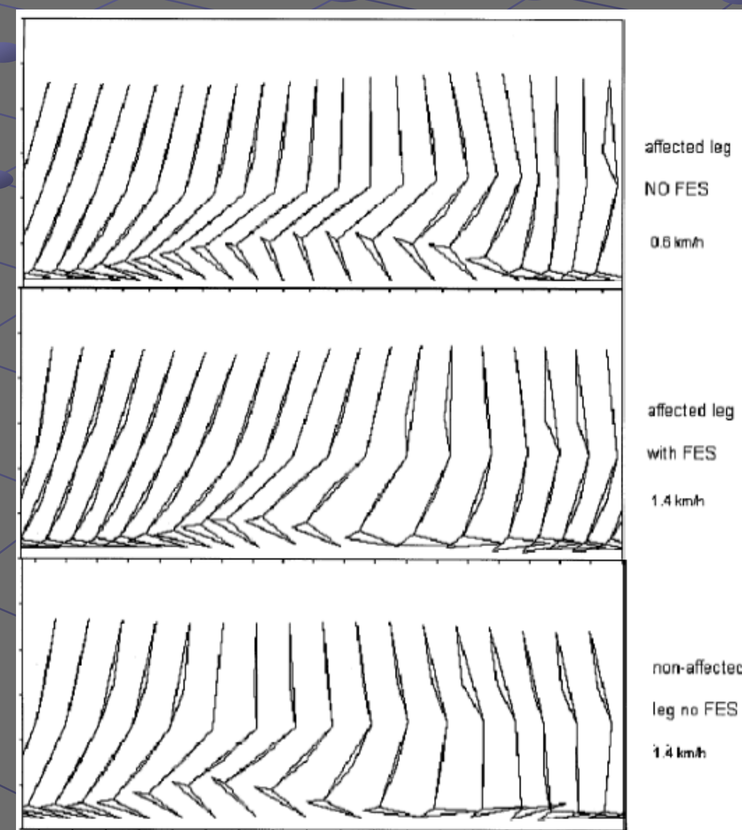
Munitions Controls

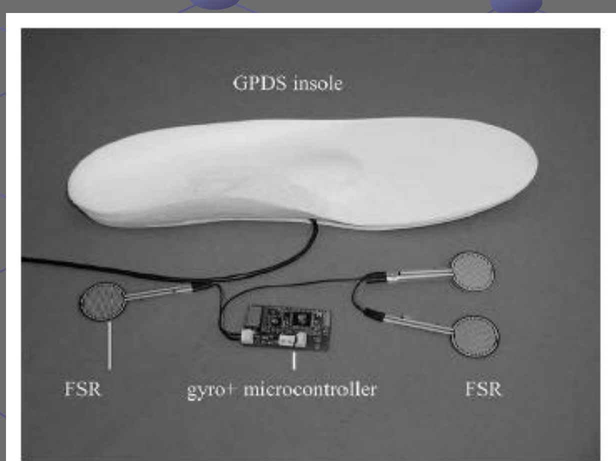
- Draper Laboratories working with Office of Naval Research to develop countermeasure-proof munitions
- Tuning Fork Gyroscope used for positioning and rates of displacement
- Gyro allows for inertial movement, bypassing countermeasures



Gait-Phase Detection sensor Embedded in a Shoe Insole

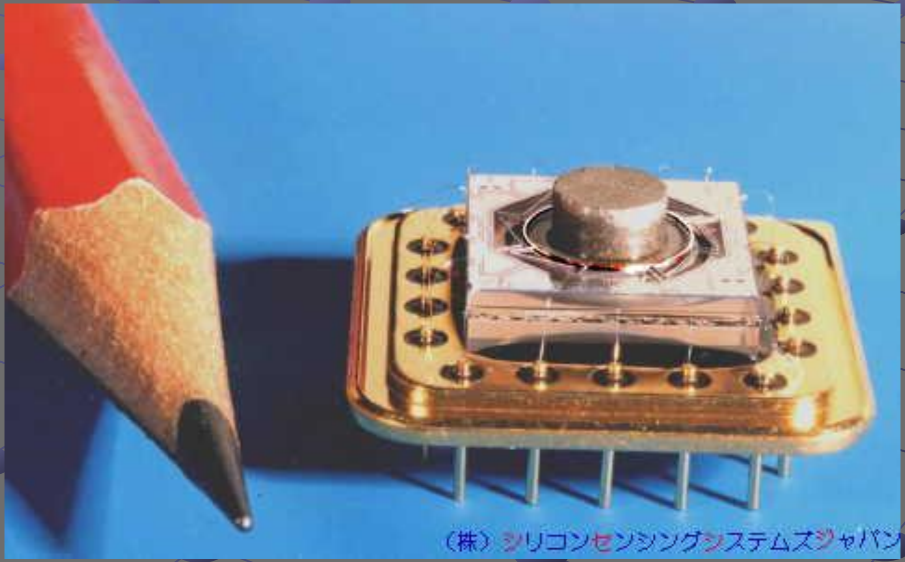
- Measures the angular velocity of the foot
- Used to activate a functional electrical stimulator attached to the foot.
- Over 96% accuracy





Conclusion


Gyro Frame
or Gimbal
Spin Axis
Gimbal
Rotor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