EE C245 – ME C218
Introduction to MEMS Design
Fall 2011

Prof. Clark T.-C. Nguyen

Dept. of Electrical Engineering & Computer Sciences
University of California at Berkeley
Berkeley, CA 94720

Lecture Module 15: Gyros, Noise, & MDS

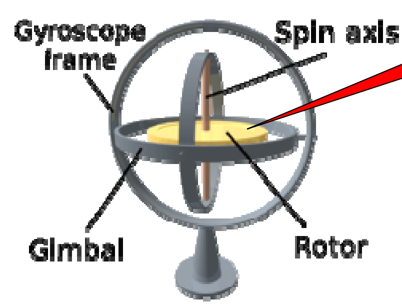
Lecture Outline

- Reading: Senturia, Chpt. 14, Chpt. 16, Chpt. 21
- Lecture Topics:
  - Gyroscopes
  - Gyro Circuit Modeling
  - Minimum Detectable Signal (MDS)
    - Noise
    - Angle Random Walk (ARW)

Gyroscopes

Classic Spinning Gyroscope

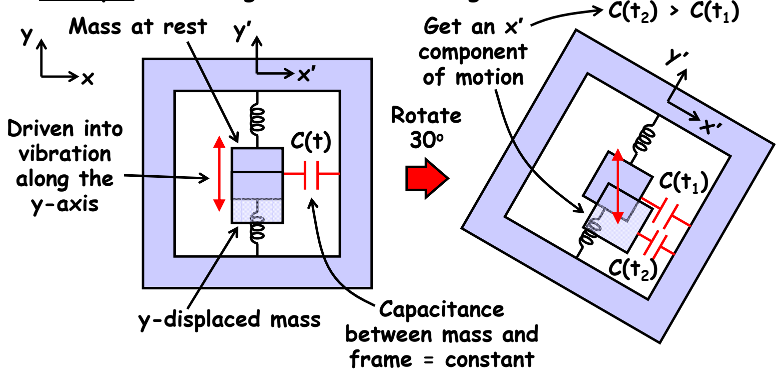
- A gyroscope measures rotation rate, which then gives orientation → very important, of course, for navigation
- Principle of operation based on conservation of momentum
- Example: classic spinning gyroscope



Rotor will preserve its angular momentum (i.e., will maintain its axis of spin) despite rotation of its gimbled chassis

Vibratory Gyroscopes

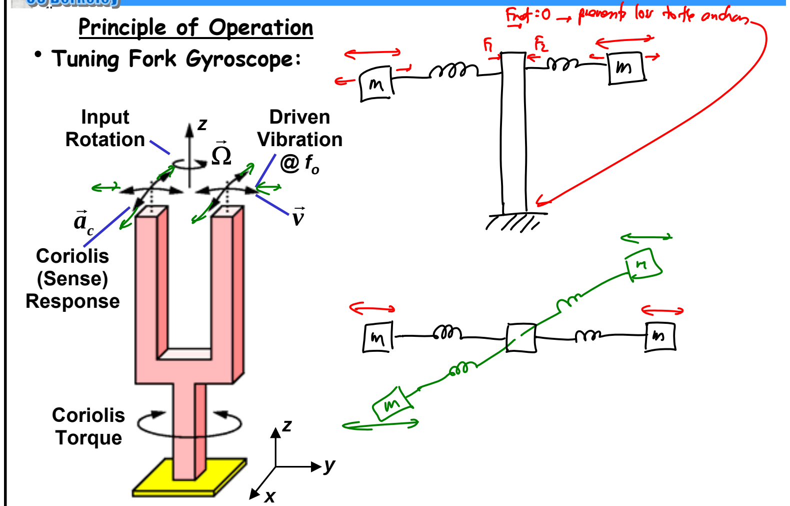
- Generate momentum by vibrating structures
- Again, conservation of momentum leads to mechanisms for measuring rotation rate and orientation
- Example: vibrating mass in a rotating frame



Basic Vibratory Gyroscope Operation

Principle of Operation

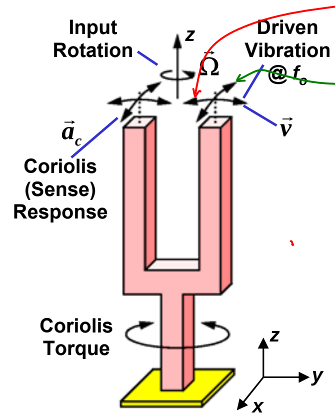
- Tuning Fork Gyroscope:



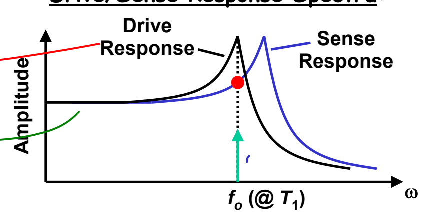
Basic Vibratory Gyroscope Operation

Principle of Operation

- Tuning Fork Gyroscope:



Drive/Sense Response Spectra:



Coriolis Acceleration, Driven Velocity, Rotation Rate:

$$\vec{a}_c = 2\vec{v} \times \vec{\Omega}$$

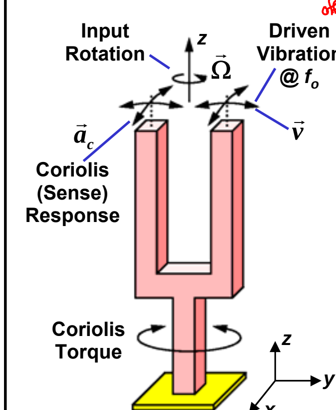
Coriolis Displacement, Coriolis Force, Beam Stiffness, Beam Mass, Sense Frequency:

$$\vec{x} = \frac{\vec{F}_c}{k} = \frac{m\vec{a}_c}{k} = \frac{\vec{a}_c}{\omega_r^2}$$

Vibratory Gyroscope Performance

Principle of Operation

- Tuning Fork Gyroscope:



$$\vec{x} = \frac{\vec{F}_c}{k} = \frac{m\vec{a}_c}{k} = \frac{\vec{a}_c}{\omega_r^2} \qquad \vec{a}_c = 2\vec{v} \times \vec{\Omega}$$

Beam Mass, Beam Stiffness, Sense Frequency, Driven Velocity

- To maximize the output signal x, need:
  - Large sense-axis mass
  - Small sense-axis stiffness
  - (Above together mean low resonance frequency)
  - Large drive amplitude for large driven velocity (so use comb-drive)
  - If can match drive freq. to sense freq., then can amplify output by Q times