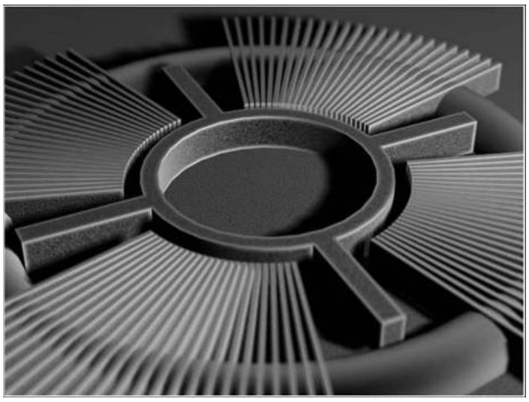
MEMS sensorid

Rait Rand

Sissejuhatus

MEMS

- MEMS : Micro-electromechanical systems
- 1974.a. rõhusensor masstoodangus
- 1988.a. mikromehhaanika ühendati elektroonikaga



Süsteemina

- Sensorsüsteemid
- Aktuaatorsüsteemid

•Mitte-elektrilise suuruse elektriliseks. MEMS puhul siis vaatlen liikumise detekteerimist.

•Mõõdud jäävad mõnest mikromeetrist millimeetriteni

•The first high-volume pressure sensor was marketed by National Semiconductor in 1974. This sensor included a temperature controller for constant-temperature operation.

•Sõõvitustehnoloogiaga saadud õhukesed elemendid suudeti ühendada jootepunktidega nn. vedrude abil

•Generatsioonide kaupa eristatakse:

1. MEMS sensor element mostly based on a silicon structure, sometimes combined with analog amplification on a micro chip.

2. MEMS sensor element combined with analog amplification and analog-to-digital converter on one micro chip.

3. sensor element kokku pandud analog amplification, analog-to-digital converter and digital intelligence for linearization and temperature compensation on the same micro chip.

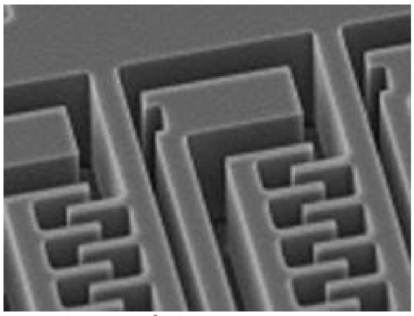
4. Memory cells for calibration- and temperature compensation data are added to the elements of the 3rd MEMS sensor generation.

Sissejuhatus

"Hea" sensor

- Suur tundlikkus mõõdetava suuruse suhtes
- Väike tundlikkus muude suuruste suhtes
- Ei mõjuta mõõdetavat suurust

Võrdlus makrosüsteemidega



- Kiiremad
- Tundlikumad
- Vähene voolutarve
- Mõõtmed
- Odavamad
- Tundlikumad ka muude suuruste suhtes

Ränil põhinevad süsteemil hakkab esinema puudusi 180C juures.
Silindris temperatuur u. 400C

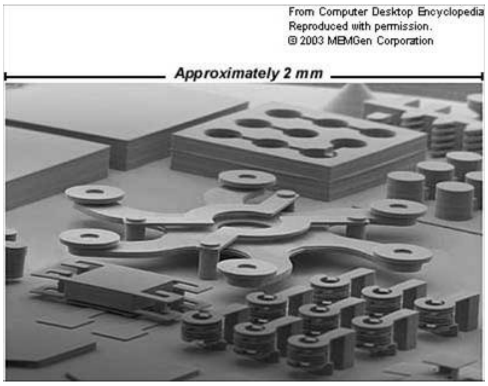
Paljud eelised kaovad kui lisada pikemad juhtmed, ekstra tugev korpus või lisajahutus, samuti mõjutavad need mõõdatevat suurust.

Sensorsüsteemid

- **Kiirendus-sensorid**
- **Güro-sensorid**

Kiirendus-sensorid elektrilise muundamise järgi

- Mahtuvuslikud
- Piesotakistuslikud
- Elektromagnetilised
- Piesoelektrilised
- Ferroelektrilised
- Optilised



capacitive, piezoresistive, electromagnetic, piezoelectric, ferroelectric, optical,

Ferroelectricity is a spontaneous electric polarization of a material that can be reversed by the application of an external electric field.

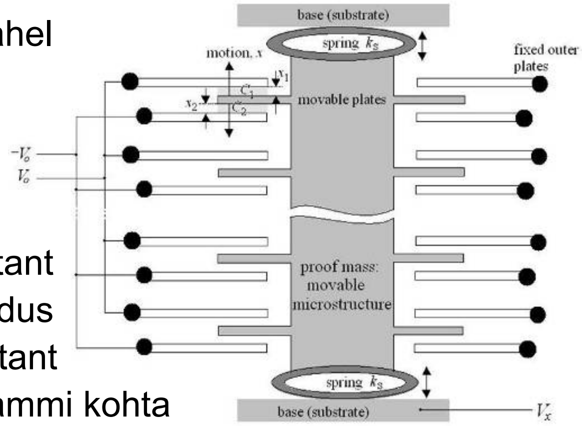
The **piezoresistive effect** describes the changing electrical resistance of a material due to applied mechanical stress.

Piezoelectricity is the ability of some materials (notably crystals and certain ceramics, including bone) to generate an electric field or electric potential[1] in response to applied mechanical stress.

The most successful types are based on capacitive transduction; the reasons are the simplicity of the sensor element itself, no requirement for exotic materials, low power consumption, and good stability over temperature. Although many capacitive transducers have a nonlinear capacitance vs. displacement characteristic, feedback is commonly used to convert the signal to a linear output.

Kiirendus-sensorid

- Kuidas siduda omavahel elektriline ja mehhaaniline ühik?



$$d_g = \frac{Mg}{k_{sp}} = \frac{g}{\omega_0^2}$$

k_{sp} – seadme vedru konstant

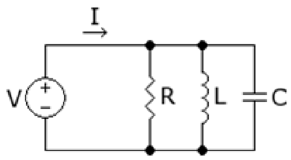
w_0 – resonants nurksagedus

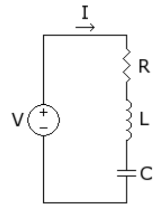
M – seadme massi konstant

d_g – asukoha muutus grammi kohta

g – raskuskiirendus

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$





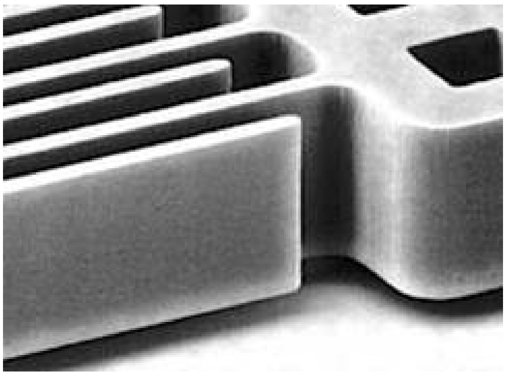
There is a minimum in the frequency response at the resonance frequency .

A parallel RLC circuit is an example of a band-stop circuit response that can be used as a filter to block frequencies at the resonance frequency but allow others to pass.

PILDIL:Accelerometer structure. Proof mass is attached through springs (kS: spring constant) at substrate. It

can move only up and down. Movable and fixed plates construct capacitors [4].

Kiirendus-sensorid



Parameetrid

- Digitaal või analoog väljund
- Temperatuuri vahemik
- Mõõtevahemik (raskuskiirenduses)
- Tundlikkus (mV/g)
- Mõõdetavate telgede arv (x,y,z)
- Elektroonika komponendi standard parameetrid (voolutarve, toitepinge, pakend jne.)

A 1:5g accelerometer will be more than enough for

gravity measurements, 2g to measure the motion of a car and at least 5g or more for a project

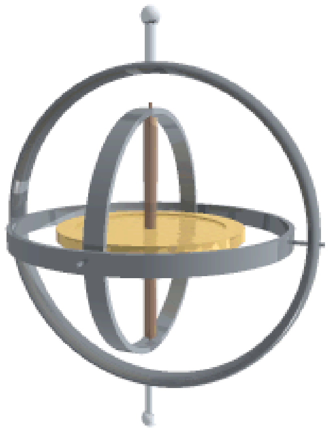
that experiences very sudden starts or stops.

Sensitivity is the output voltage produced by a certain force measured in g's. Accelerometers typically fall into two categories - producing either 10 mV/g or 100 mV/g. The frequency of the AC output voltage will match the frequency of the vibrations. The output level will be proportional to the amplitude of the vibrations. Low output accelerometers are used to measure high vibrational levels while high output accelerometers are used to measure low level vibrations.

Pildil: this MEMS accelerometer features a 20 micron thick single-crystal comb structure whose precision and flatness provide high performance while the glass substrate ensures very low stray capacitance. Low stray capacitance is essential to achieving low noise, high sensitivity, and high dynamic range. The structure was fabricated by the dissolved wafer process.

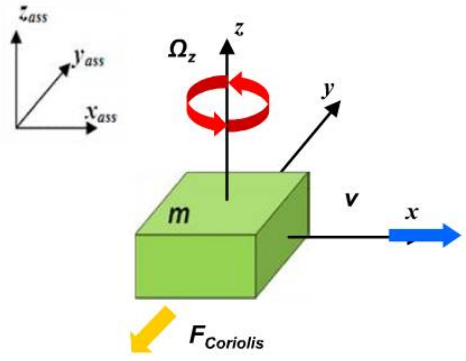
Küroskoop-sensorid

- Mõõdavad nurga nihet (kiirendus sensorid lineaarset nihet)
- MEMS tehnoloogiad ning mehhaanilise ühiku saamine elektriliseks samad mis kiirendus anduritel (Näiteks: Mahtuvuslik)
- Liikuva keha nurga muutumise detekteerimiseks kasutatakse Coriolise effekti



Küroskoop-sensorid

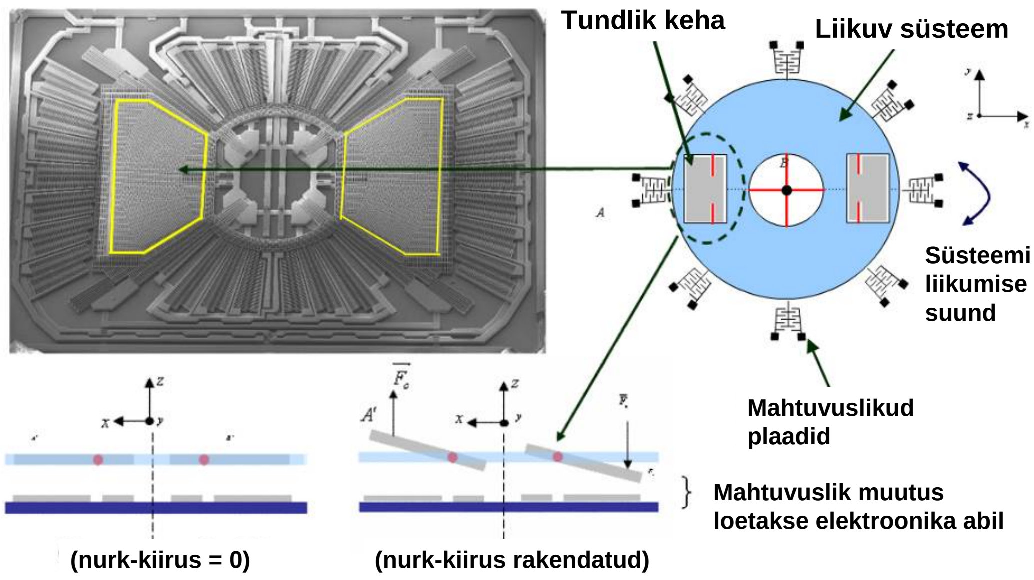
- Coriolise effekt
  $F=2mv\circ\Omega$
  m – mass
  v – kiirus (lineaarne)
  Ω - nurkkiirus



- Reaalses sensoris kasutatakse kahte teineteisest eemale liikuvat massi, mis on pidevas liikumises.

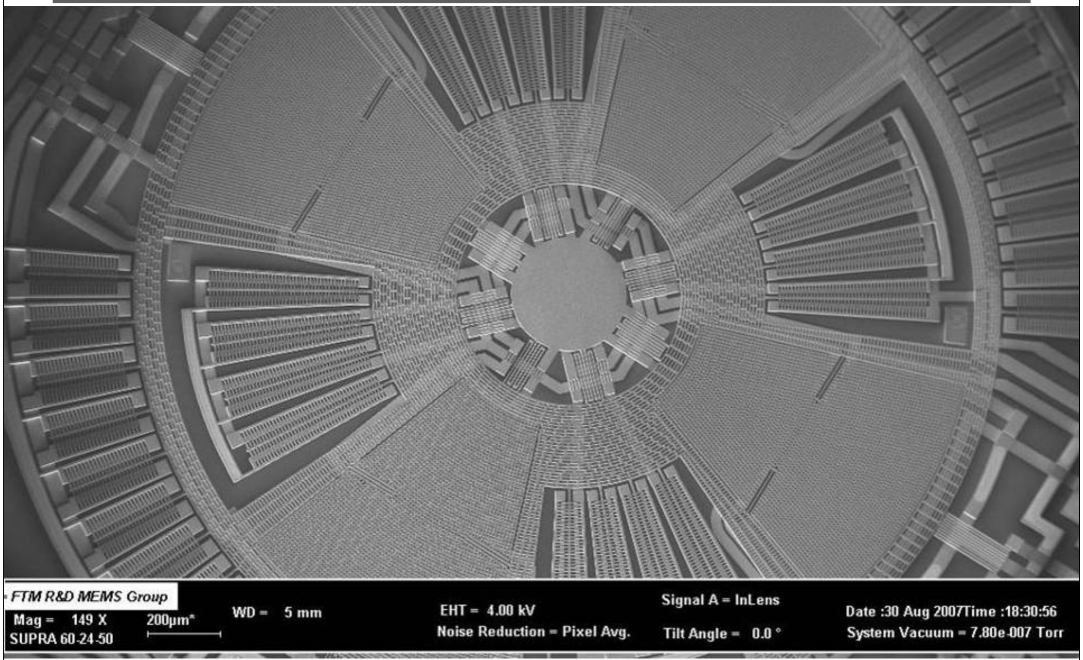
Mass liigub kiirusega v, ning talle rakendada nurk-kiirus

Küroskoop-sensorid



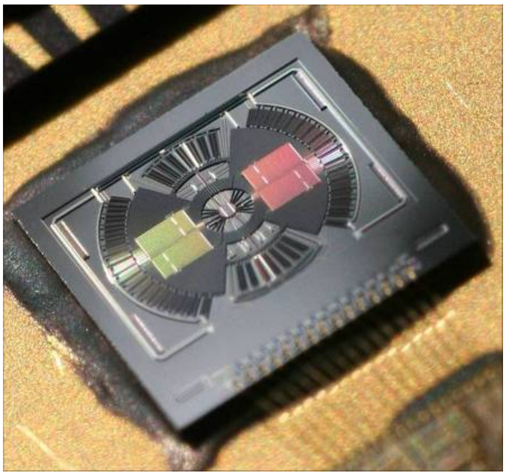
Mass liigub kiirusega v, ning talle rakendada nurk-kiirus

Küroskoop-sensorid



Mass liigub kiirusega v, ning talle rakendada nurk-kiirus

Küroskoop-sensorid

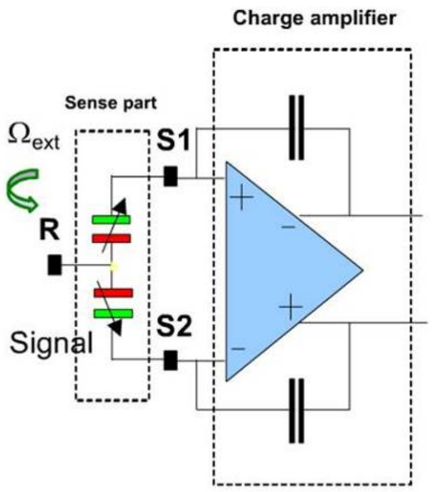


- **Parameetrid**
- Digitaal või analoog väljund
- Tundlikuse muutus temp. ühiku kohta (Näiteks:0,017%/°C)
- Mõõtevahemik (kraadides)
- Tundlikkus (mV/dps)
- Mõõdetavate telgede arv (x,y,z)
- Elektroonika komponendi standard parameetrid (voolutarve, toitepinge, pakend jne.)

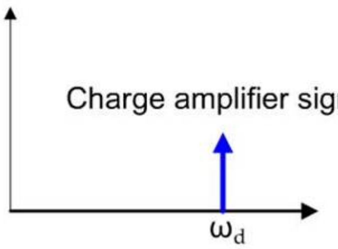
MEMS kiirendus sensorid ja küroskoop sensorid kokku ühendades saab moodustada nn. IMU (Inertial measurement unit)

Küroskoop-sensorid

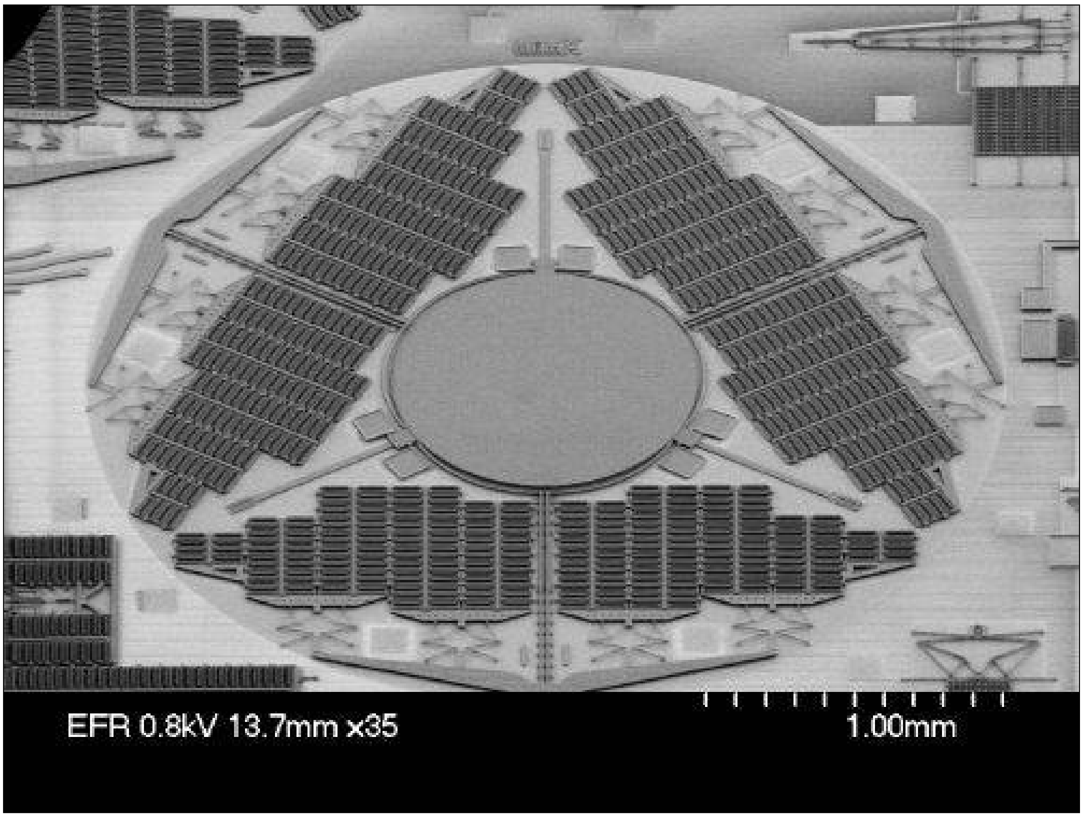
Charge amplifier signal is modulated at drive frequency ω_{drive}



$$V_{out}(t) = V_{\Omega_{EXT}}(t) \cdot \sin(\omega_d t)$$



Mass liigub kiirusega v, ning talle rakendada nurk-kiirus



Aktuaator süsteem, mis lülitab peeglite abil ümber optilisi signaale.