Acceleration-velocity-position

Outline

- Accelerometers
- Velocity
- Position + Misc!!

Material from

- Fraden chap. 7
- Fraden chap. 8
- Wikipedia
- Web
  - Analog Devices
  - MEMSIC
  - Chipworks
- SINTEF

Position – velocity - acceleration

Oscillatory motion

$$\omega = 2\pi f$$

- Position $x(t) = x_0 e^{j\omega t}, \quad x_0 \cos(\omega t)$
- Velocity $v(t) = \frac{d}{dt} x_0 e^{j\omega t} = j\omega x_0 e^{j\omega t} \quad , \quad -x_0 \omega \sin(\omega t)$
- Acceleration $a(t) = \frac{d^2}{dt^2} x_0 e^{j\omega t} = -\omega^2 x_0 e^{j\omega t} \quad , -\omega^2 x_0 \cos(\omega t)$

Consequence 1:

low frequency -> measure position or velocity

high frequency -> measure acceleration

Consequence 2

- Plotting position amplitude emphasizes low frequencies
- Plotting acceleration emphasizes high frequencies

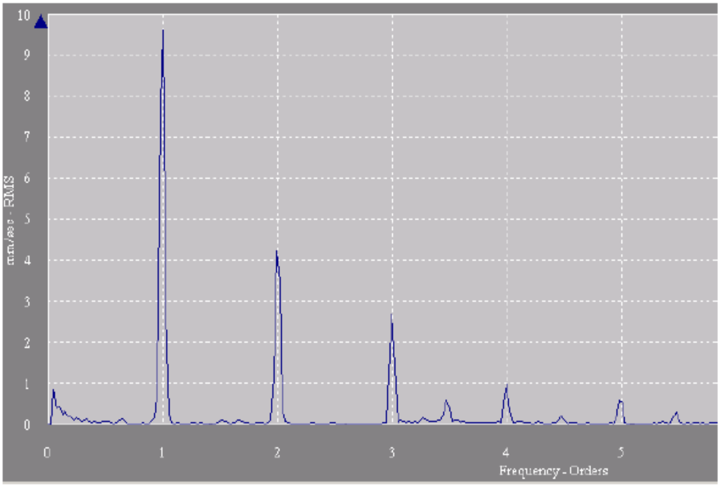


Fig 2: Misalignment

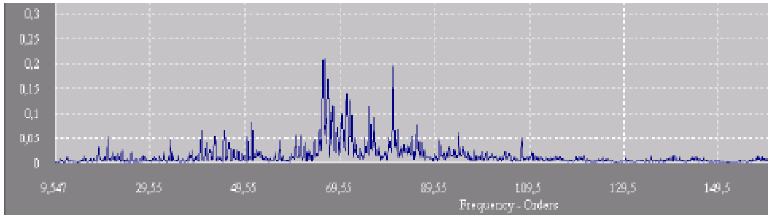


Fig 3: Bearing damage

Velocity is the usual compromise

Acceleration -> Position

- Acceleration is independent of inertial system
- Can be measured without reference
- Can be measured in a closed container

Position can be found by integrating twice:

$$x(t) = \iint a(t)\,dt\,dt$$

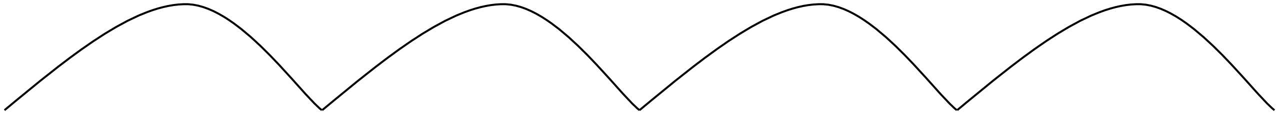
BUT

$$x_{measured}(t) = \iint a_{measured}(t)dtdt = \iint (a_{true}(t) + offset + \text{other errors})\, dtdt =$$

$$x_{true}(t) + \frac{1}{2} \times offset \times t^2 + \text{other errors}$$

=> Measure position if you can

Or, get a grip on your errors



Accelerometer approaches

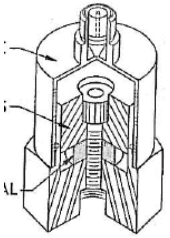
$$ma = F$$

Stress/force based

Measure F
- Compression
- Bending

Piezoelectric

Piezoresistive



$$F = kx$$

$$v = \frac{dx}{dt}$$

Measure v

Inductive

Measure x

Capacitive

Parallell plate

Comb

AC

DC

(Optical)

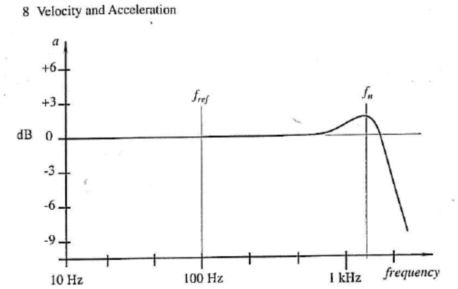
FP

Cantilever

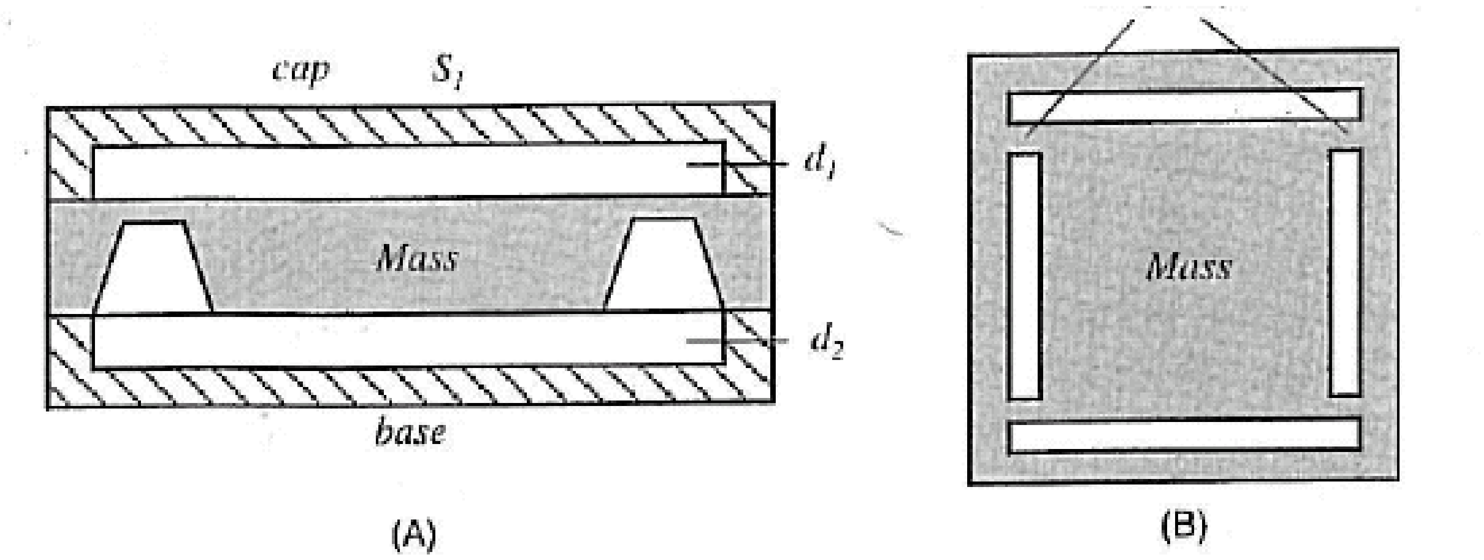
Fiber

(Magnetic)

Thermal



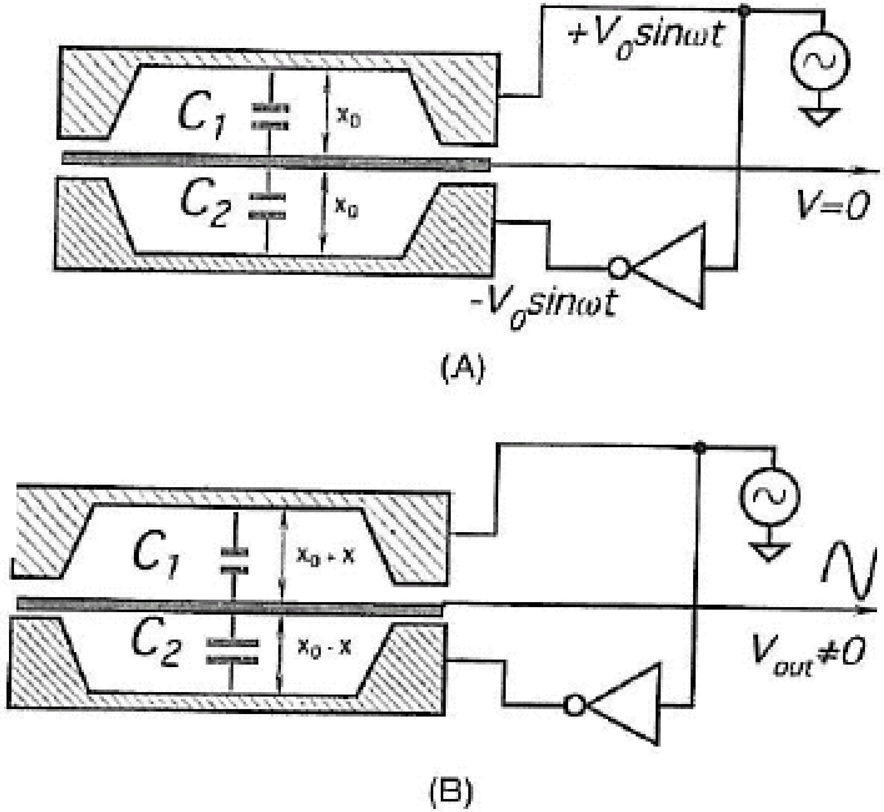
Capacitive spring based



ig. 8.3. Capacitive accelerometer with a differential capacitor: (A) side cross-sectional view;
3) top view of a seismic mass supported by four silicon springs.

Capacitive displacement sensing 3

7.3 Capacitive Sensors 259



$$V = \frac{Q}{C} = \frac{\int i\,dt}{C} = \frac{i}{j\omega C}$$

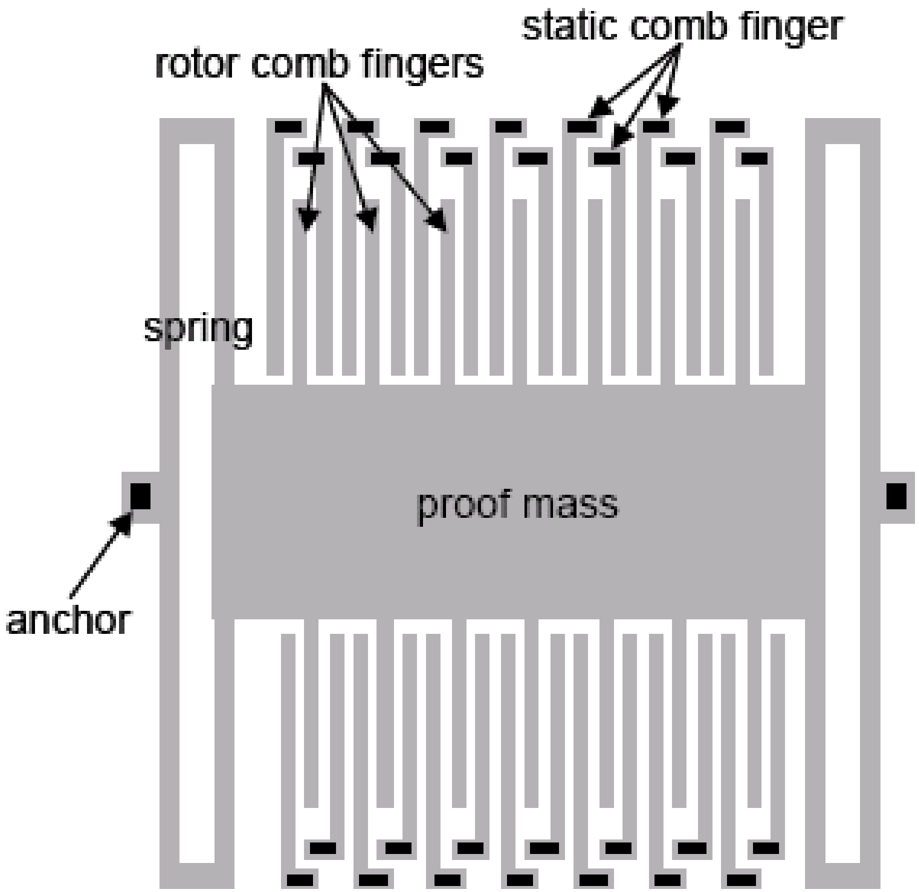
$$C_1 = \frac{\varepsilon A}{x_0 + x}$$

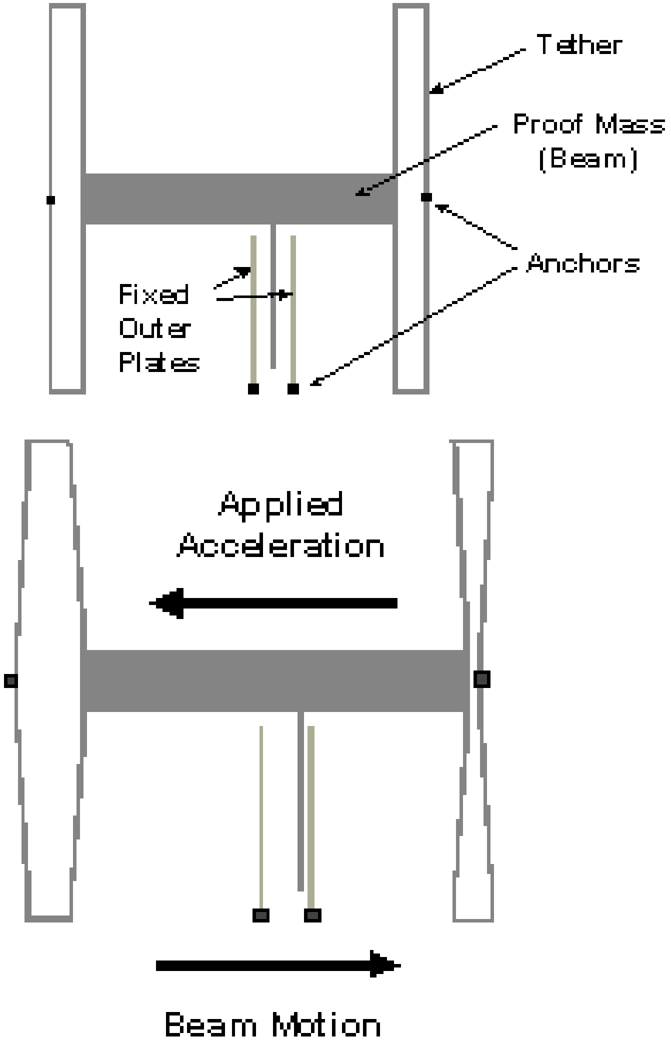
$$C_2 = \frac{\varepsilon A}{x_0 - x},$$

$$V_{\text{out}} = V_0 \left(-\frac{x}{x_0 + x} + \frac{\Delta C}{C} \right).$$

7.5. Operating principle of a flat plate capacitive sensor A-balanced position; B-disbalanced tion

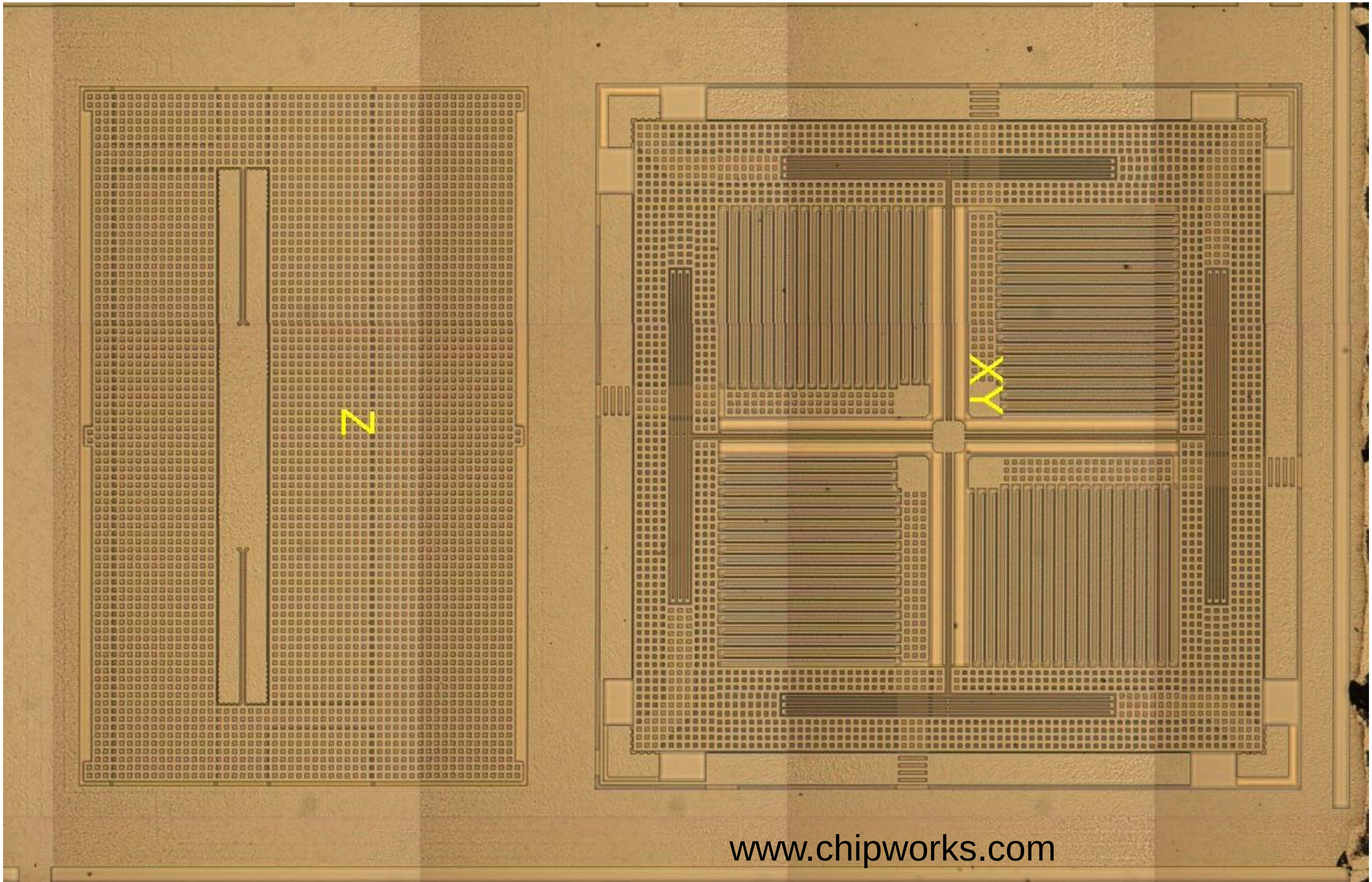
Capacitive finger





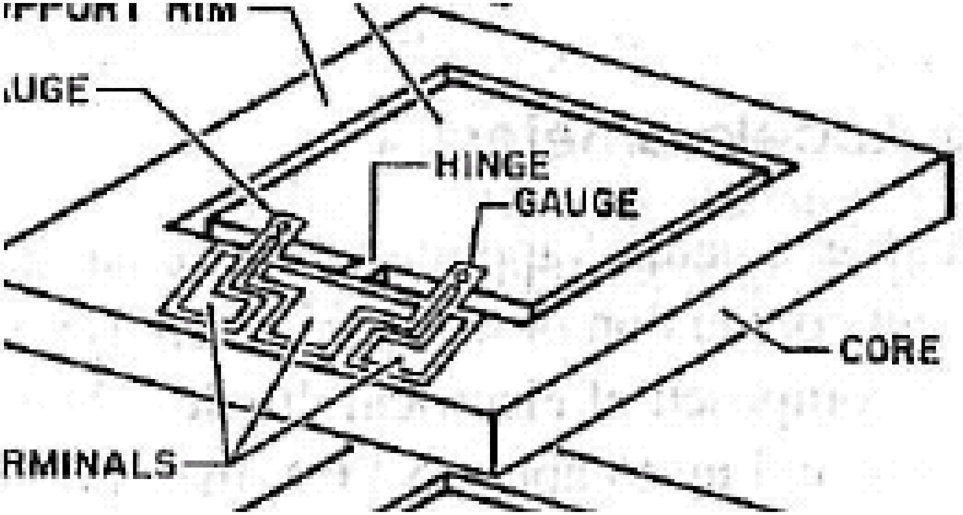
Analog Devices

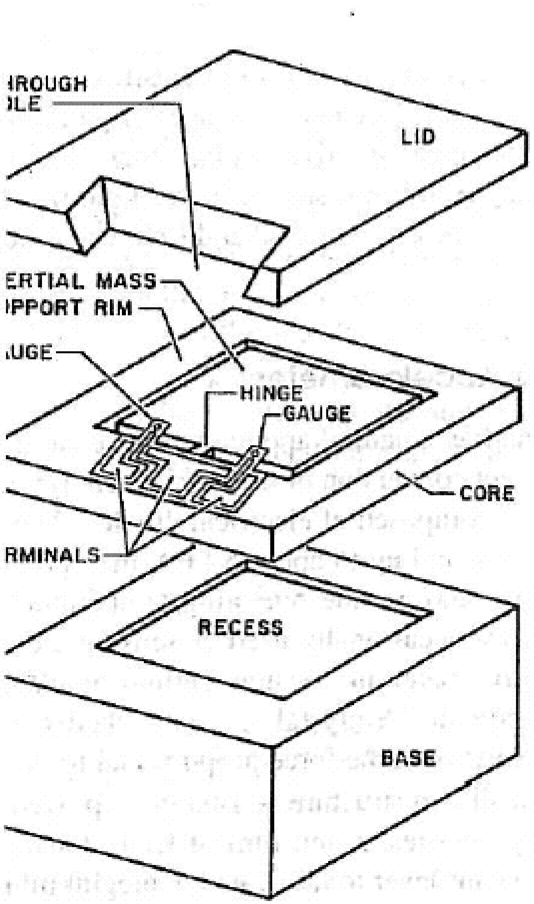
ST-Accelerometer Iphone 4s



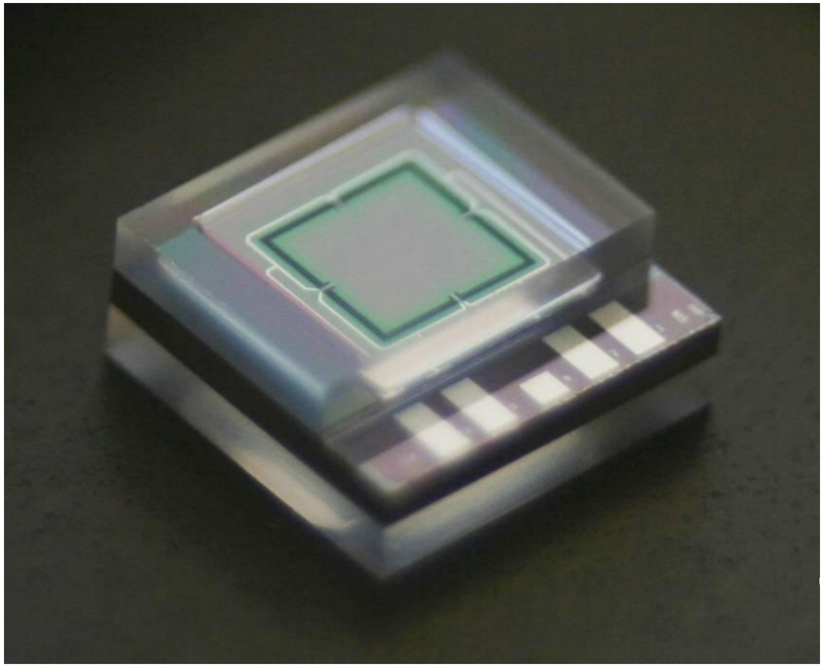
www.chipworks.com

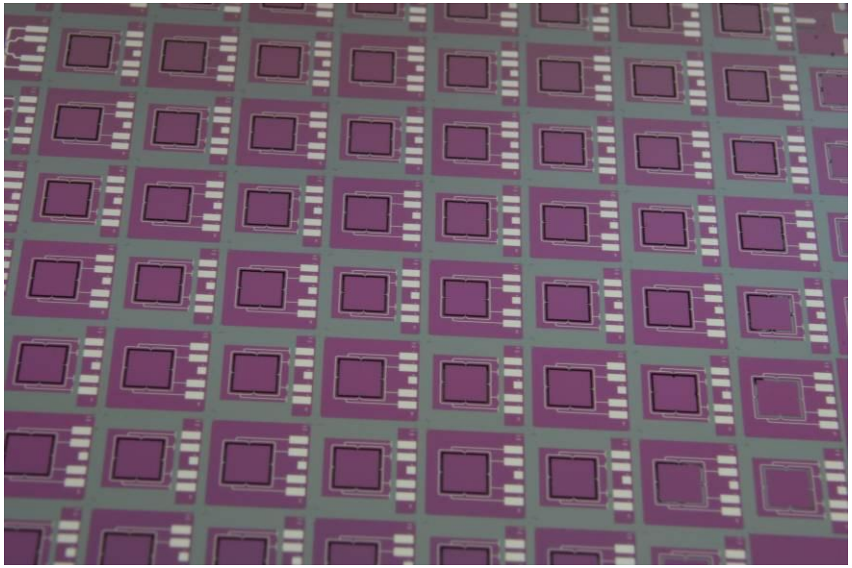
Piezoresistive accelerometer

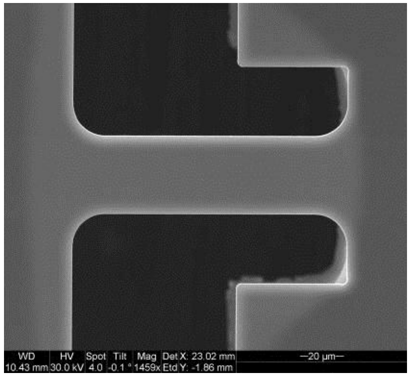


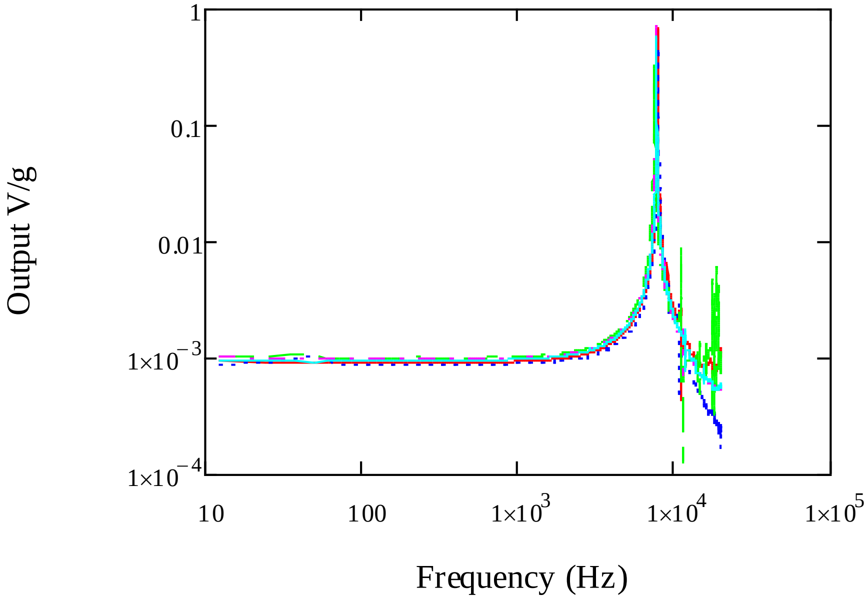


Piezoresistivt akselerometer 2









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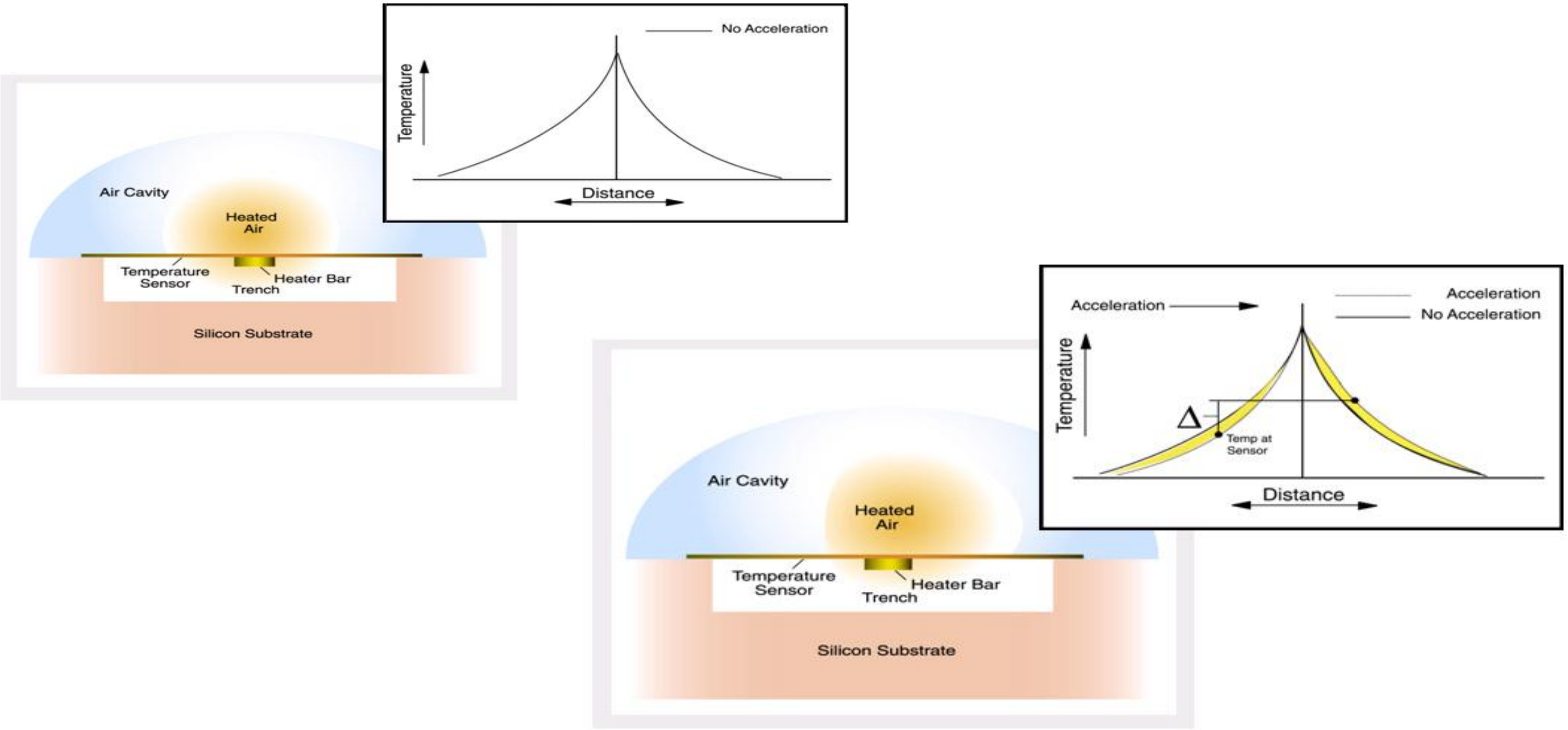
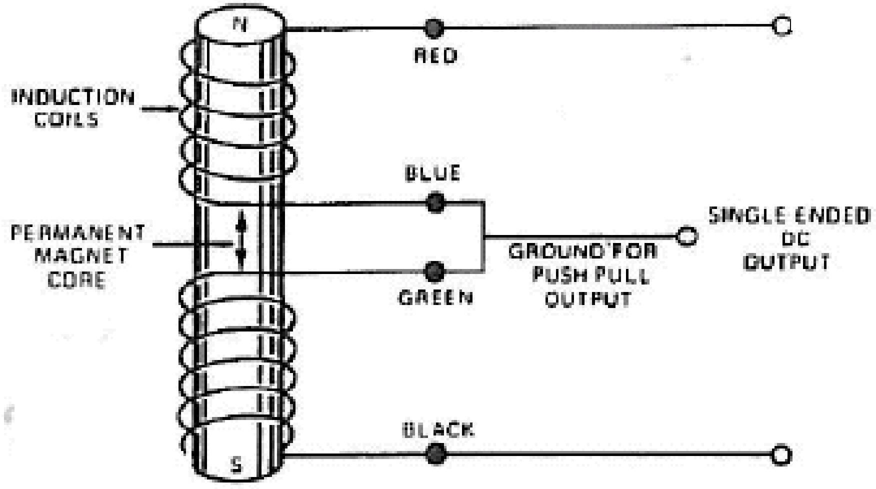


http://www.memsic.com/memsic/products/technology.html

Magnetic velocity measurement

$$V = -N \frac{d\Phi_B}{dt},$$

)2 8 Velocity and Acceleration



g. 8.1. Operating principle of an electromagnetic velocity sensor. (Courtesy of Trans-Tek, c., Ellington, CT.)

Doppler

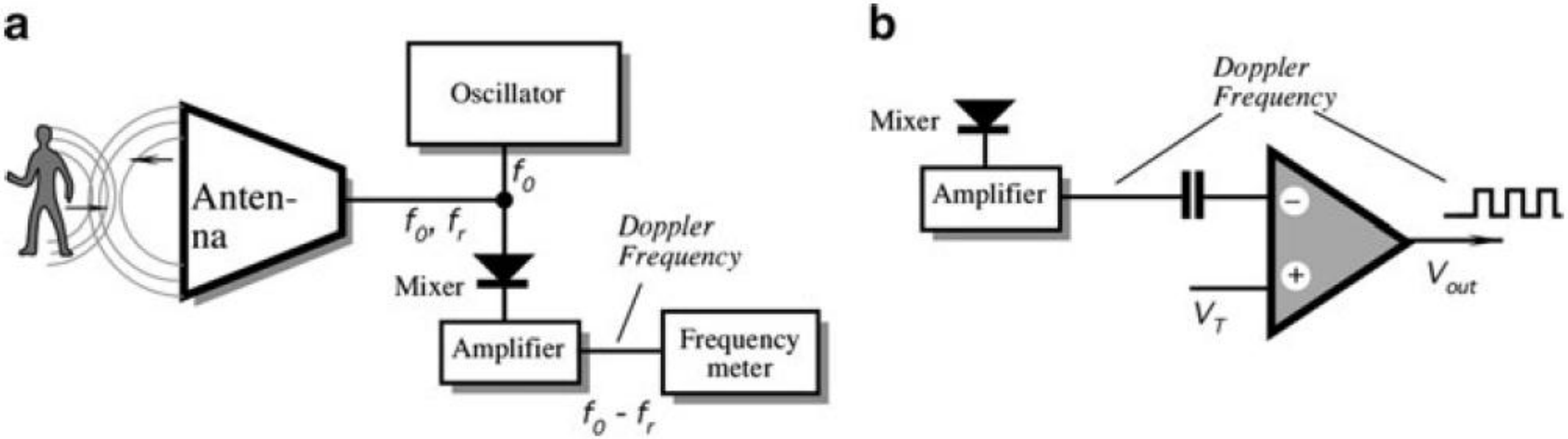
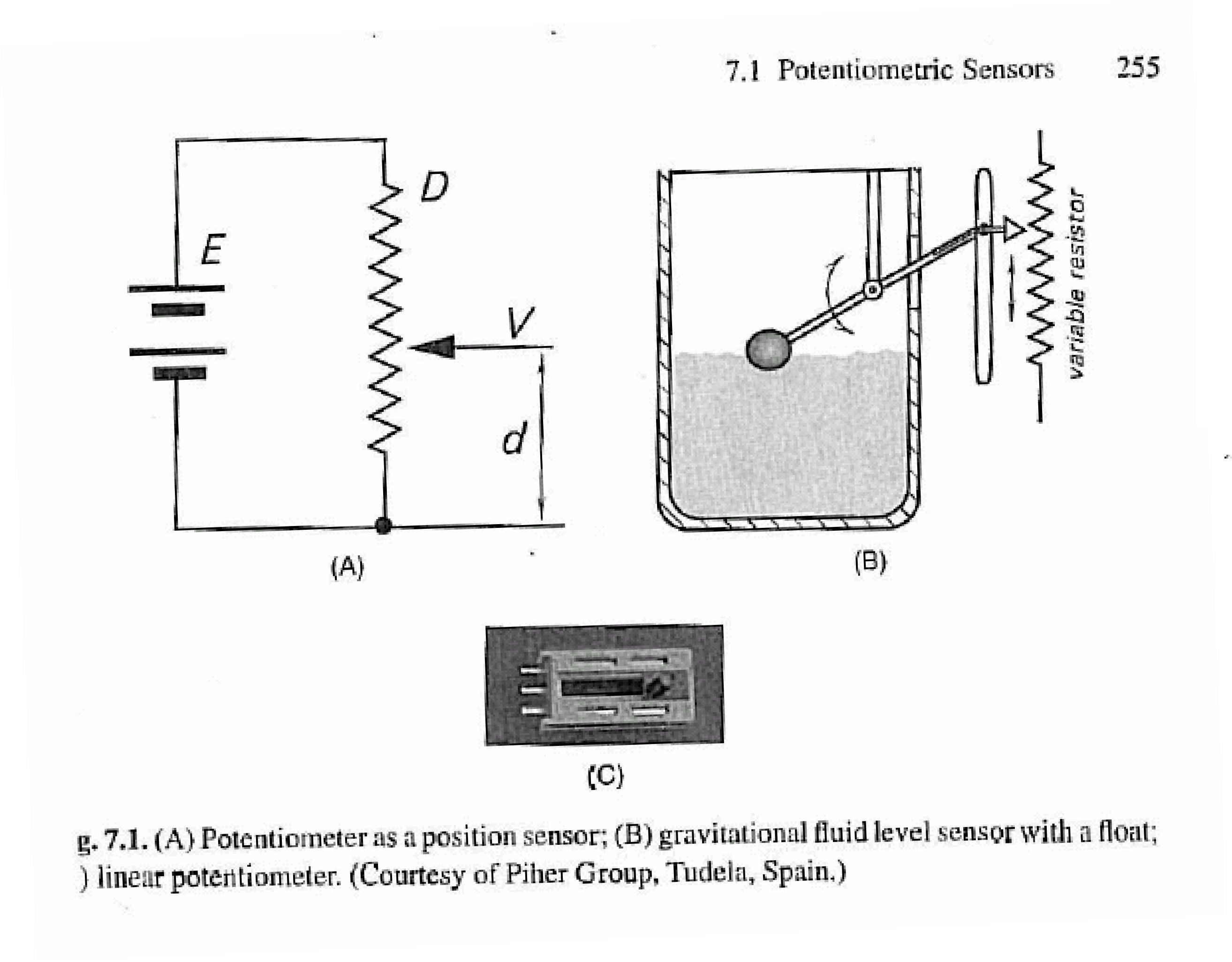


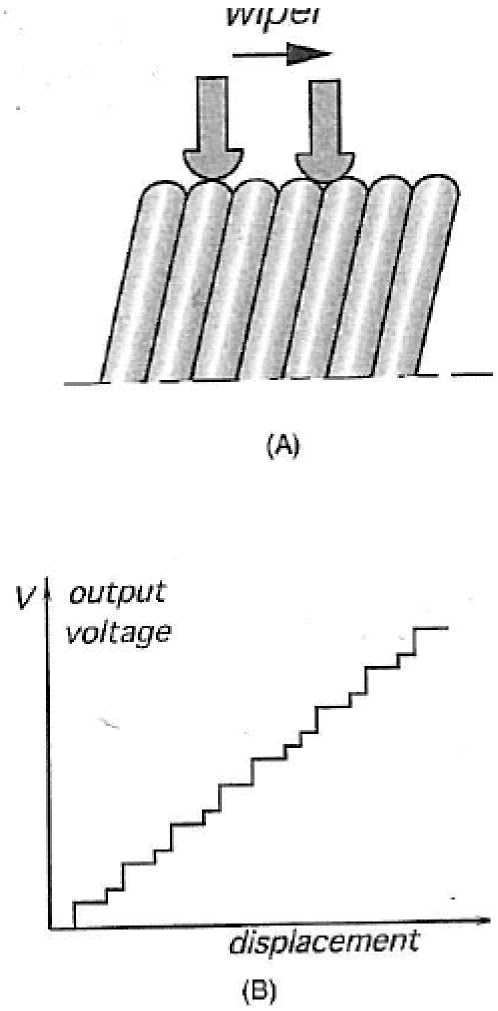
Fig. 6.1 Microwave occupancy detector: a circuit for measuring Doppler frequency (**a**); circuit with a threshold detector (**b**)

Potentiometric level sensor

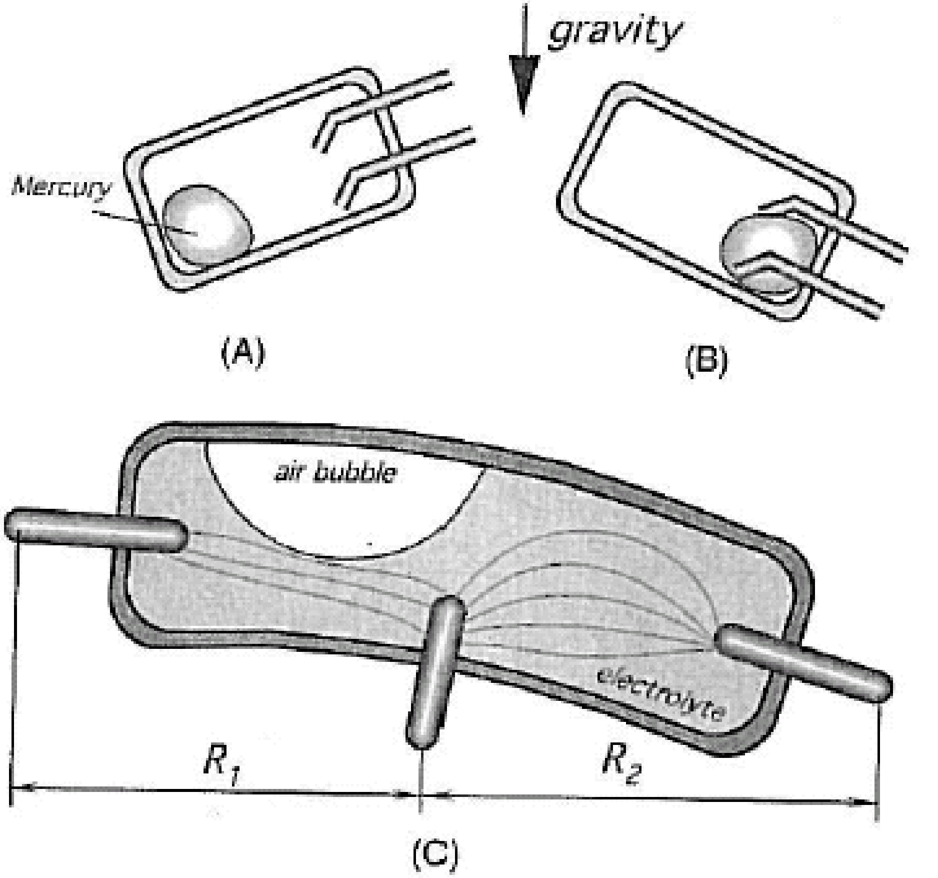


7.1 Potentiometric Sensors 255

g. 7.1. (A) Potentiometer as a position sensor; (B) gravitational fluid level sensor with a float;) linear potentiometer. (Courtesy of Piher Group, Tudela, Spain.)



Tilt sensors



. 7.3. Conductive gravitational sensors: (A) mercury switch in the open position; (B) mercury tch in the closed position; (C) electrolytic tilt sensor.

2D tilt sensor

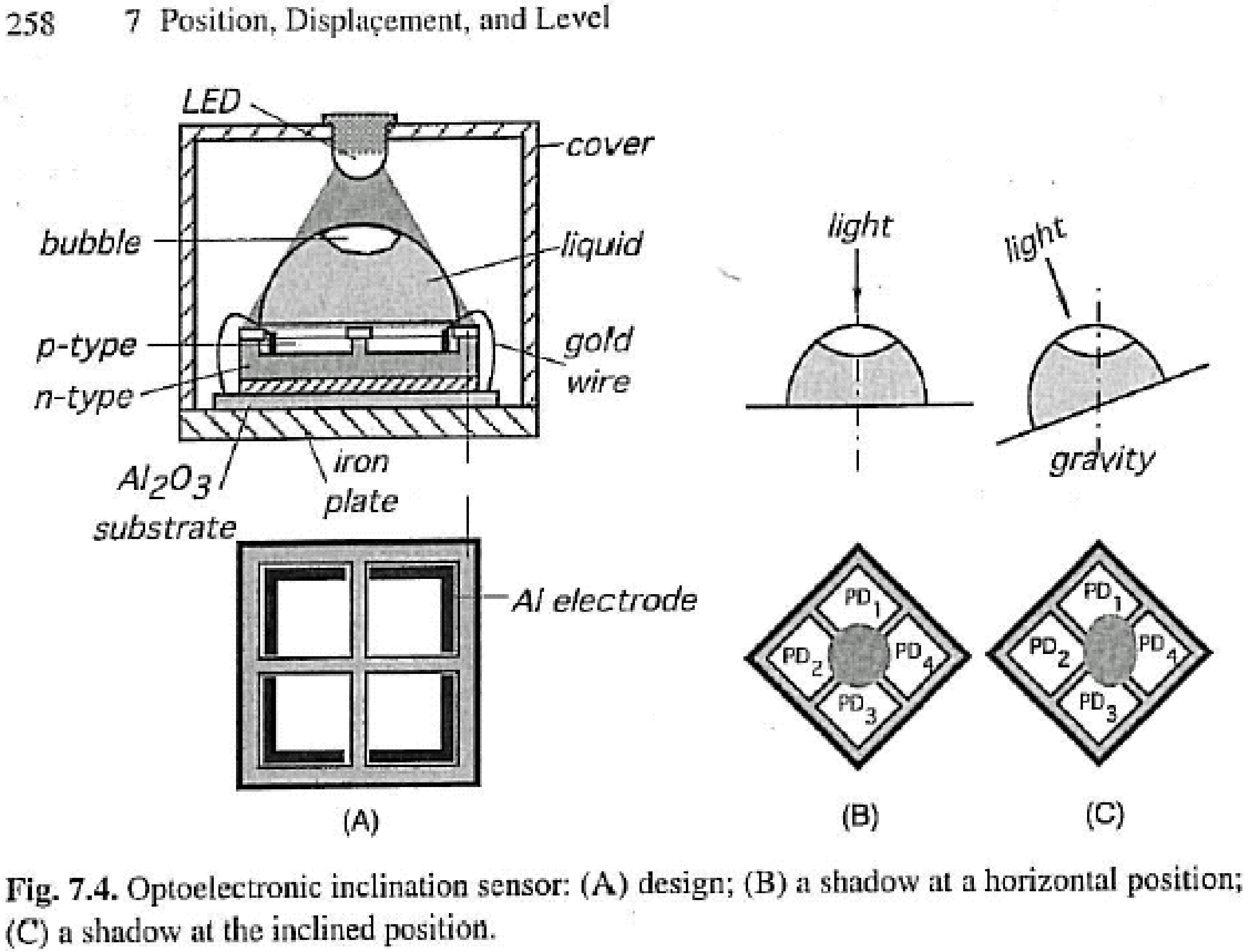


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Fig. 7.4. Optoelectronic inclination sensor: (A) design; (B) a shadow at a horizontal position; (C) a shadow at the inclined position.

Linear variable differential transformer LVDT

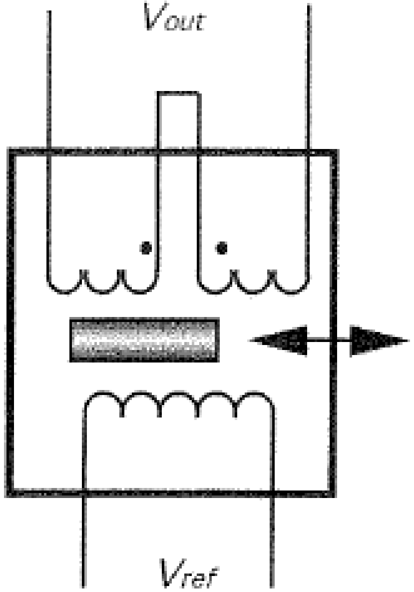
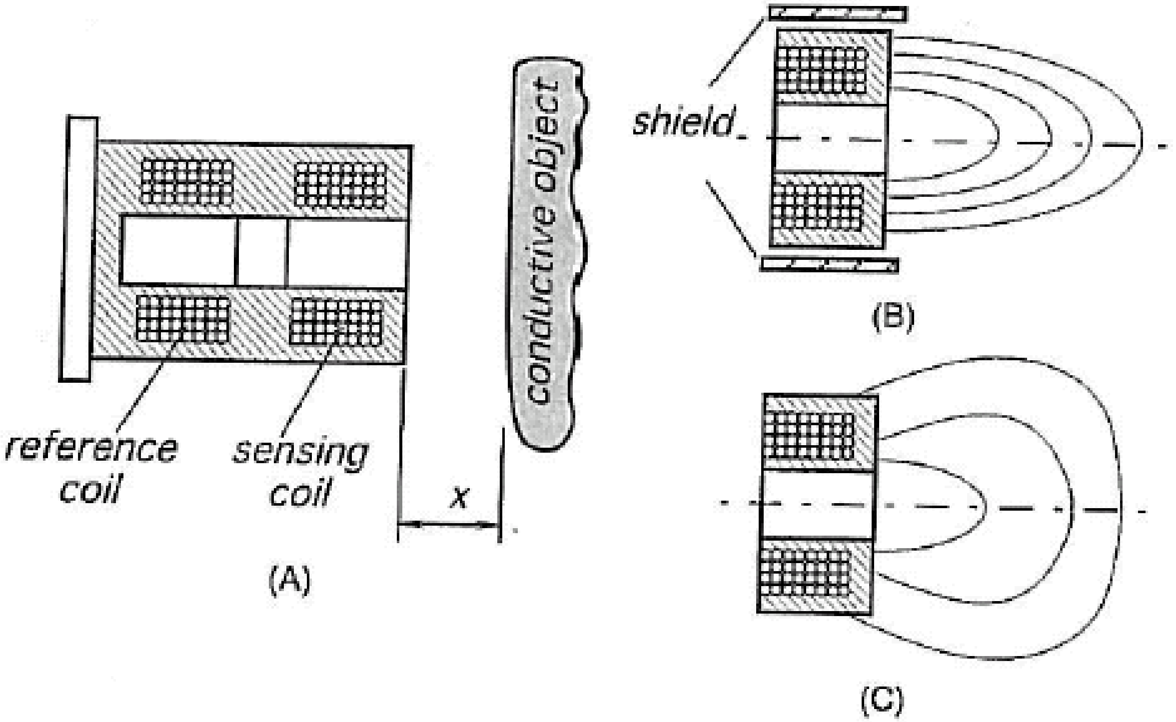


Fig. 7.9.

Eddy current sensor

7.4 Inductive and Magnetic Sensors 26



7.11. (A) Electromagnetic proximity sensor; (B) sensor with the shielded front end; (C) ielded sensor.

$$n\Phi_B = Li,$$

$$v = -\frac{d(n\Phi_B)}{dt} = -L\frac{di}{dt}.$$

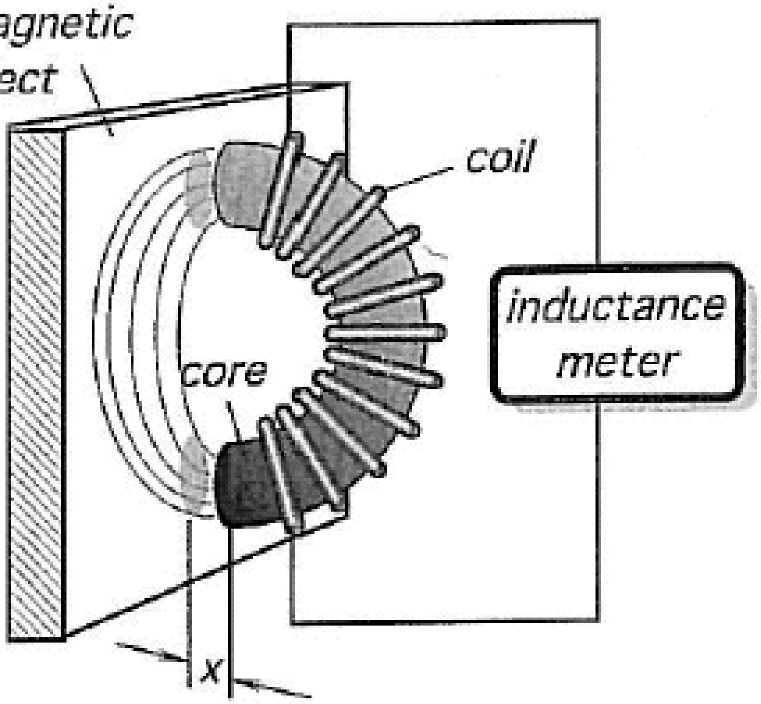
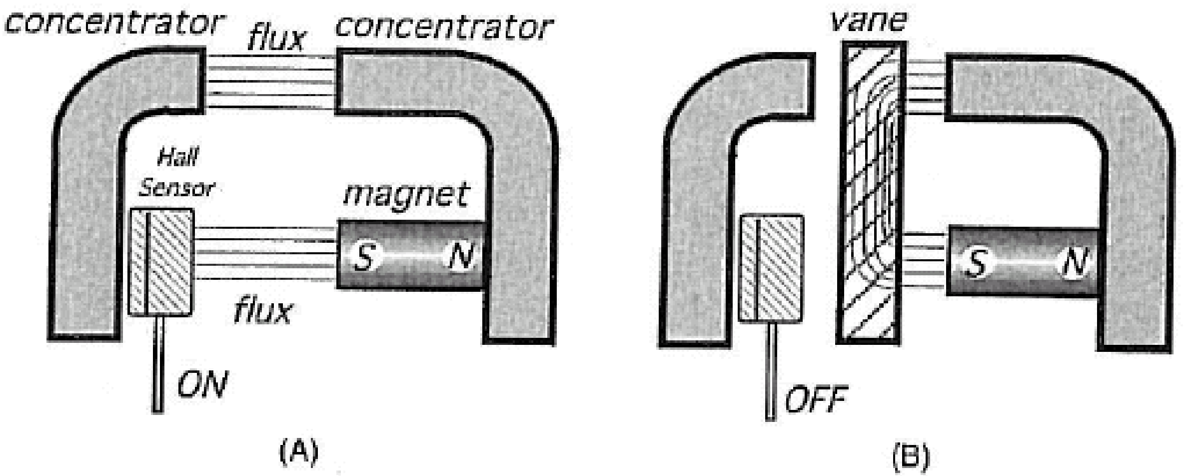
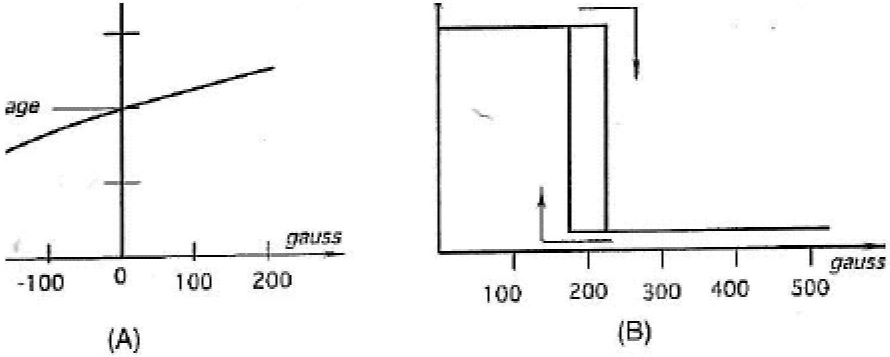


Fig. 7.12. A transverse inductive proximity sensor.

Permanant magnet - Hall sensor

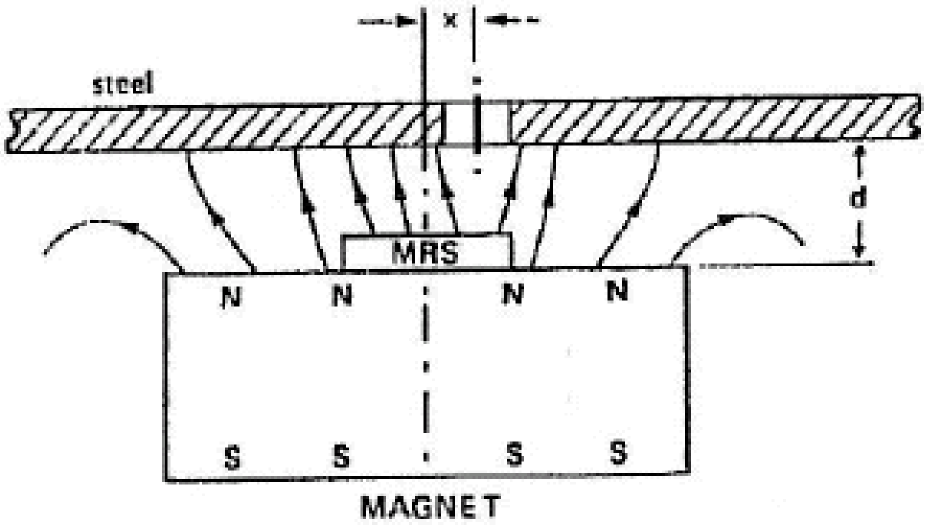


. 7.16. The Hall effect sensor in the interrupter switching mode: (A) the magnetic flux turns sensor on; (B) the magnetic flux is shunted by a vane. (After Ref. [6].)

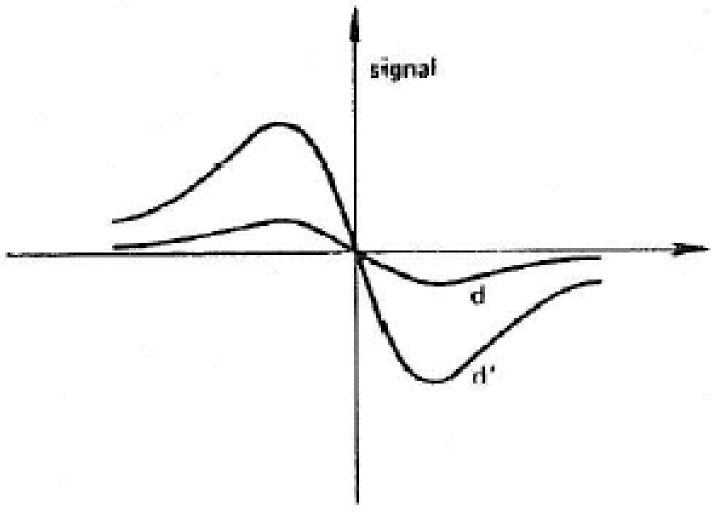


. Transfer functions of a linear (A) and a threshold (B) Hall effect sensor.

Permanent field 1

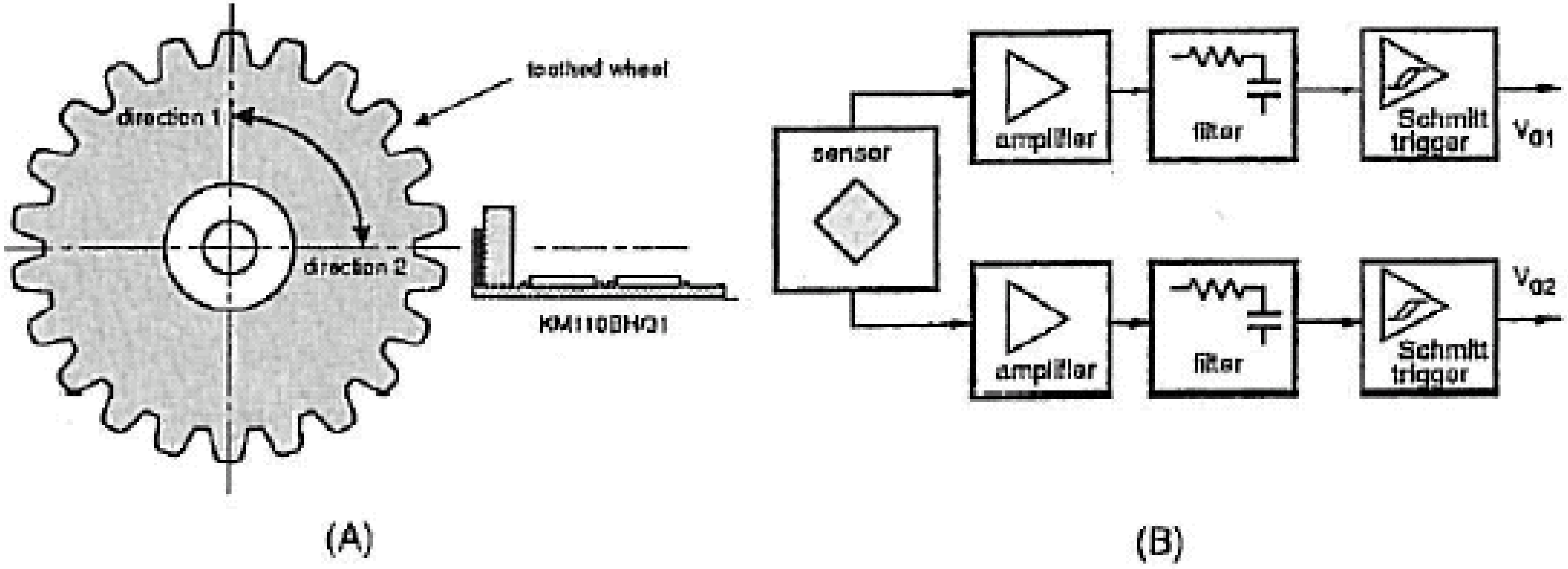


(A)



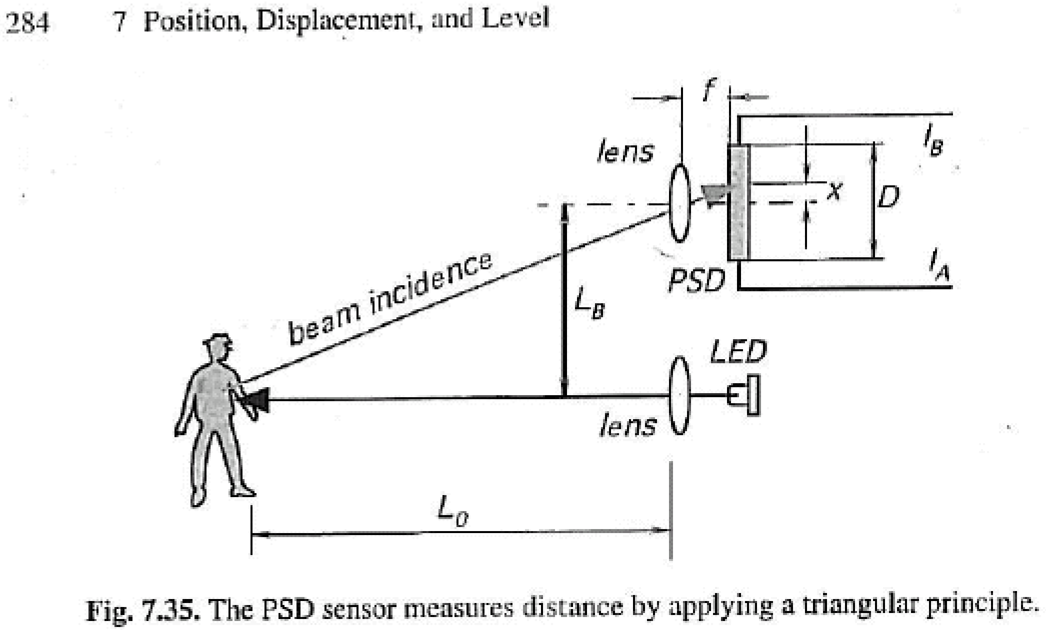
(B)

Permanent field 2



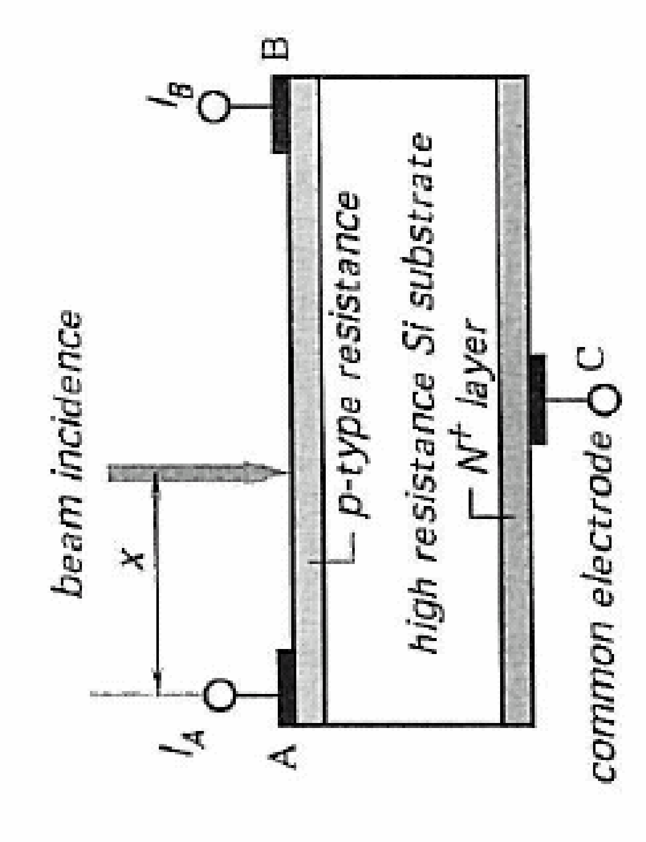
. **7.22.** (A) Optimum operating position of a magnetoresistive module. Note a permanent gnet positioned behind the sensor. (B) Block diagram of the module circuit.

Position sensitive detector



284 7 Position, Displacement, and Level

Fig. 7.35. The PSD sensor measures distance by applying a triangular principle.



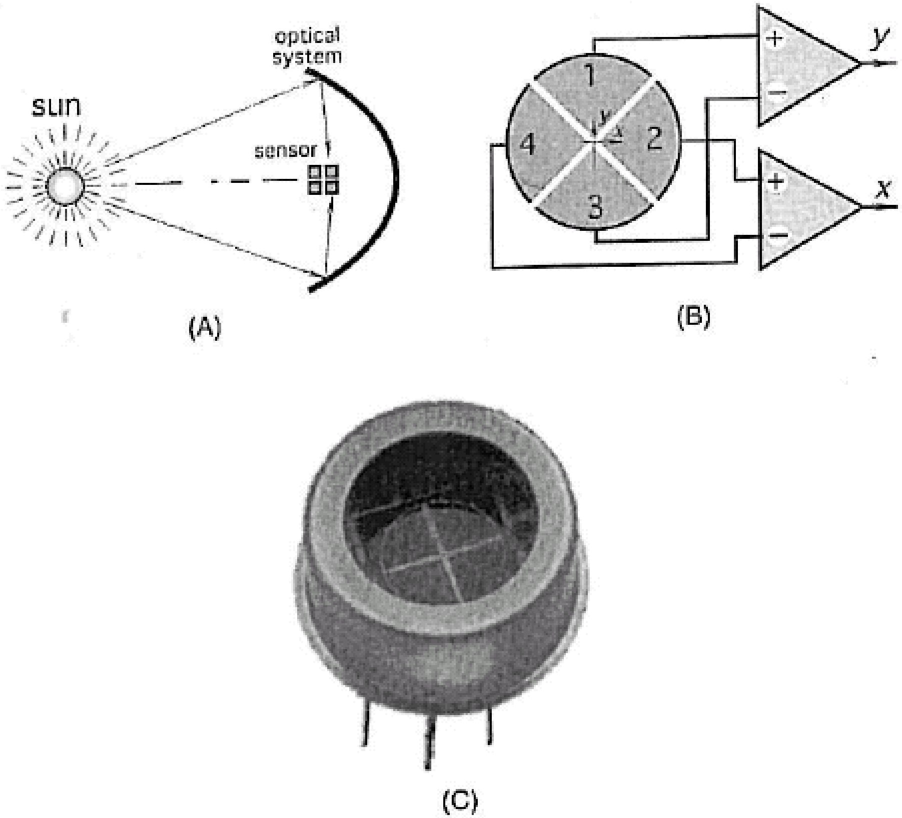


Fig. 7.25. Four-quadrant photodetector: (A) focusing an object on the sensor; (B) connection of the sensing elements to difference amplifiers; (C) sensor in a packaging. (From Advanced Photonix, Inc. Camarillo, CA.)

Linear -> Rotary

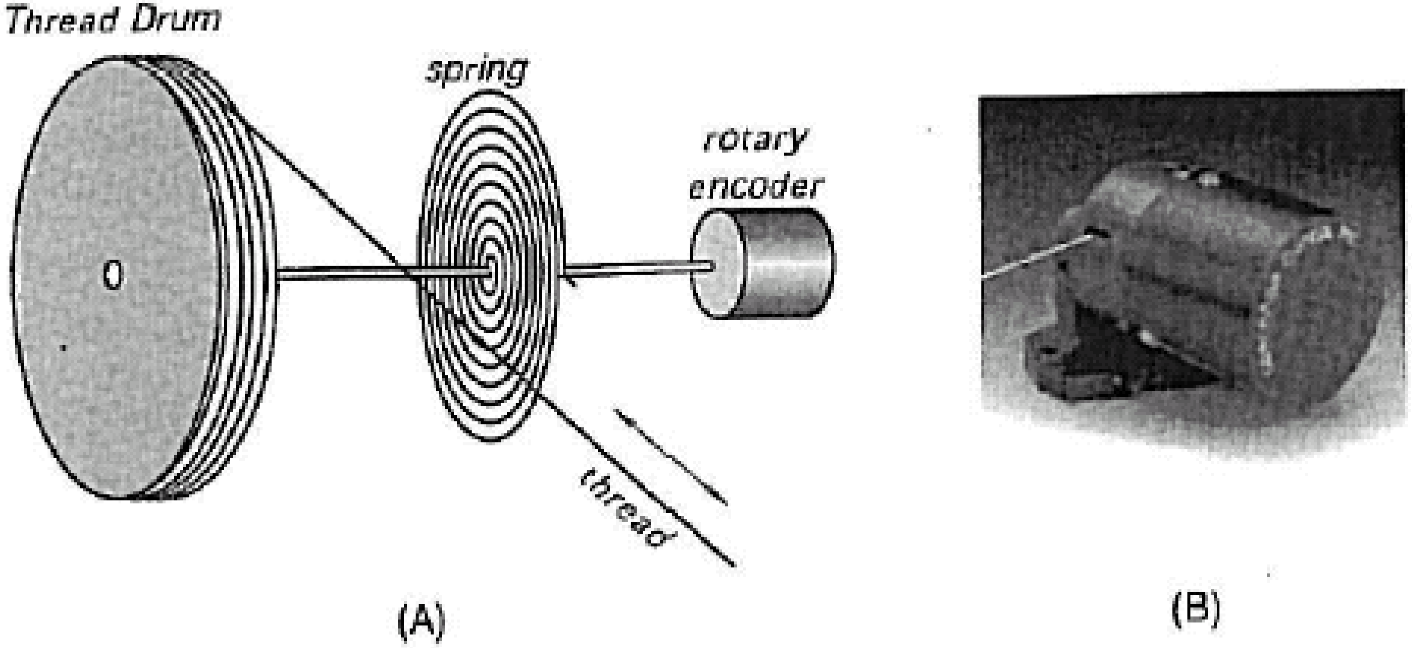
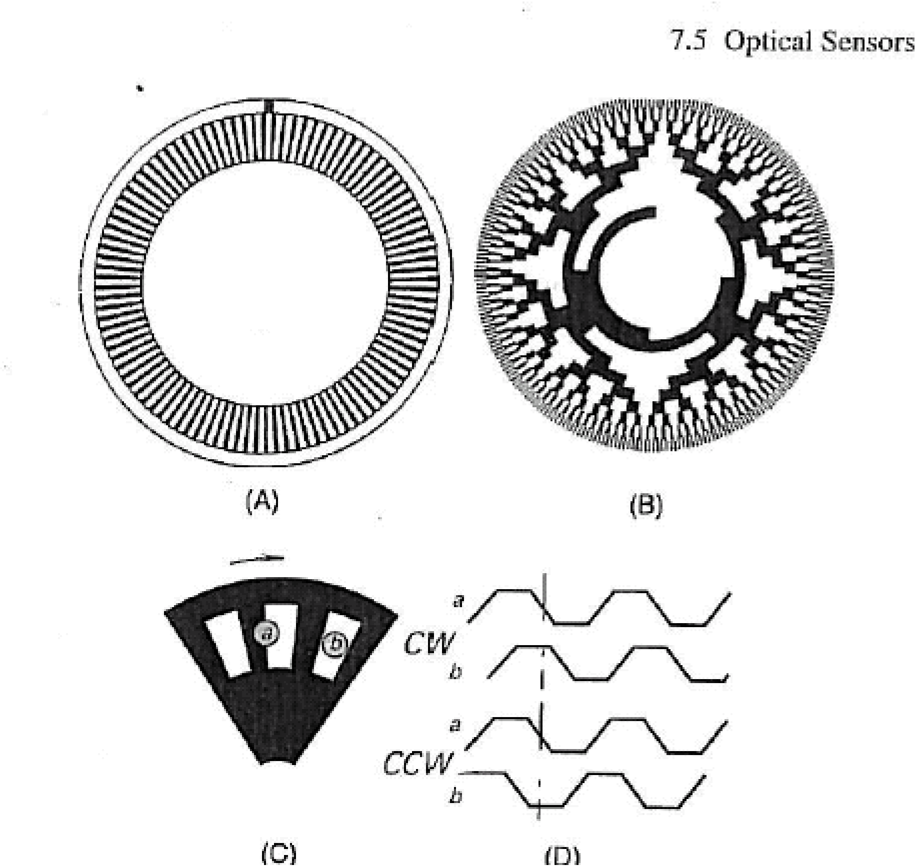
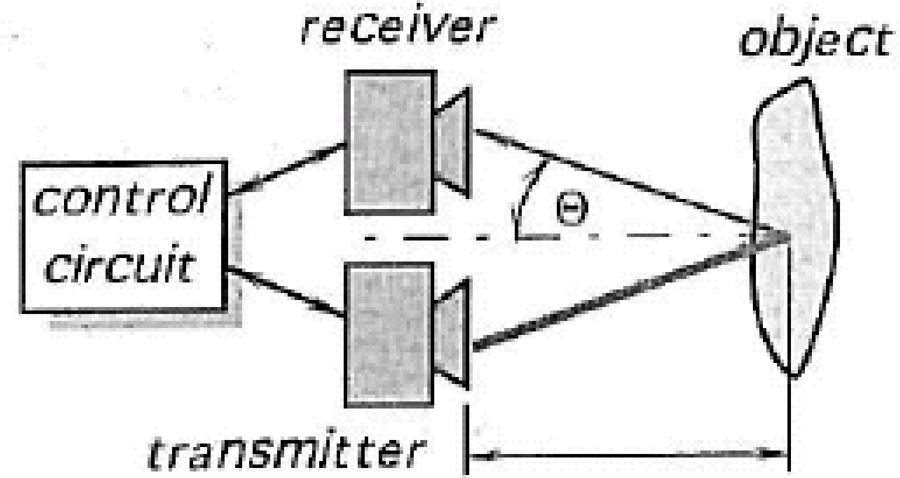


Fig. 7.18. Conversion of a linear displacement (length of a thread or cable) into a rotary motion (A) and cable position sensor (B). (Courtesy of Space Age Control, Inc.)

Position encoders



Ultrasound time of flight



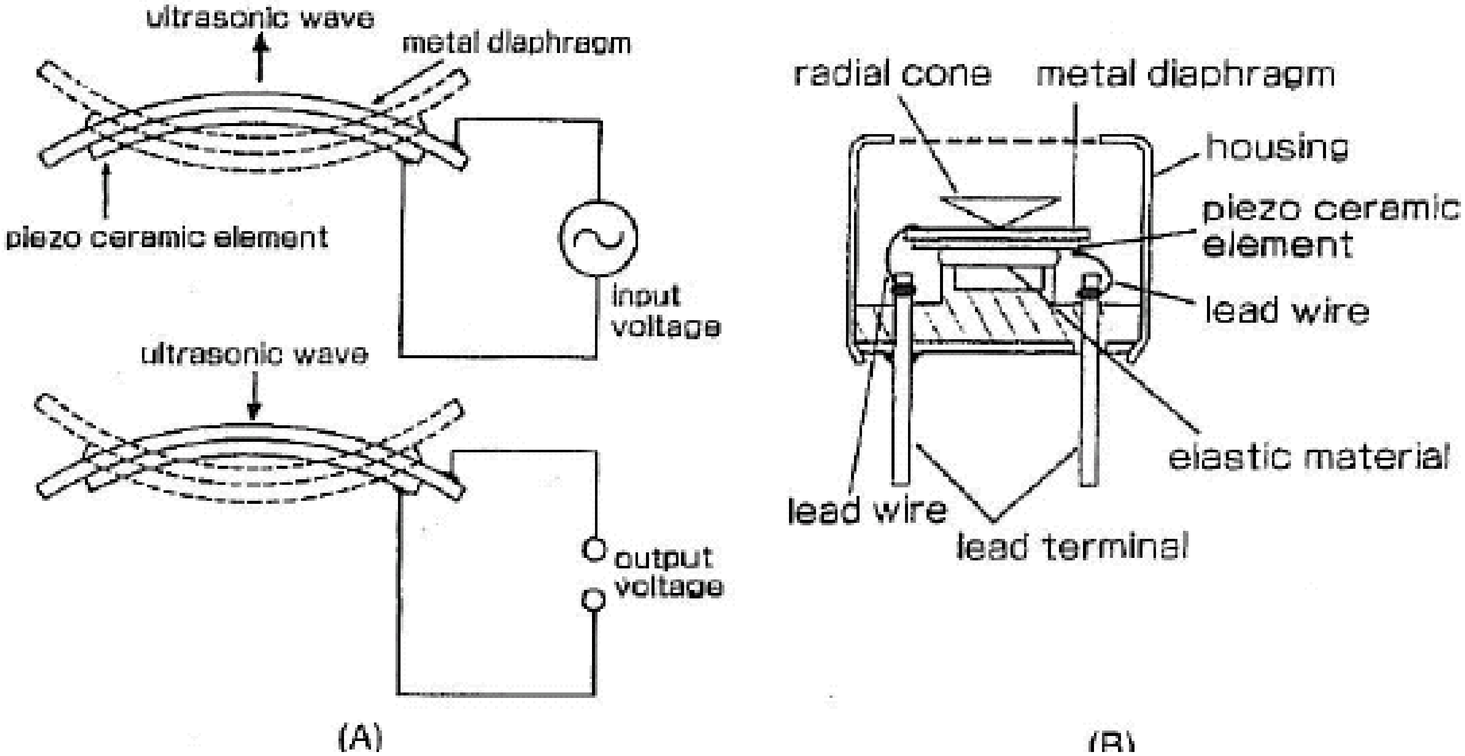
$$L_0 = \frac{vt \cos \Theta}{2},$$

(A)

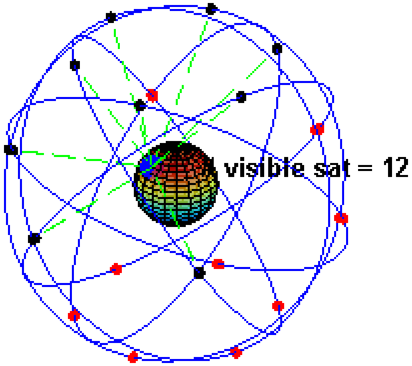
7.42

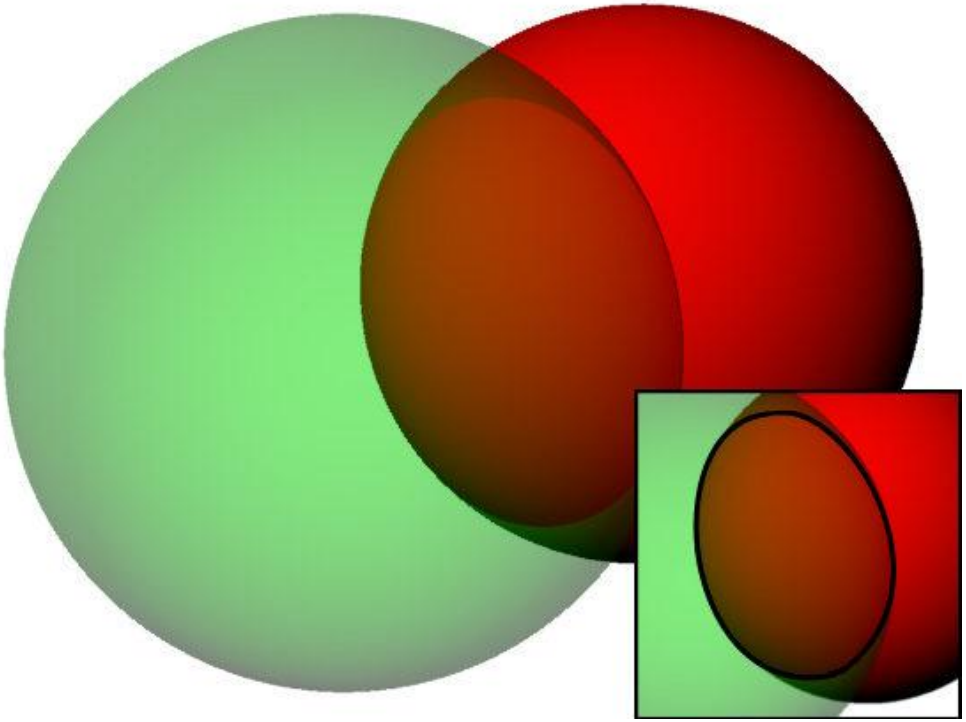
Fig. 7.39. Ultrasonic distance measurement:
istic of a piezoelectric transducer.

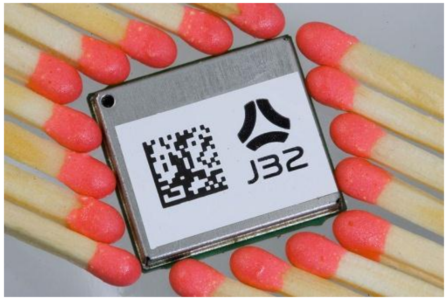
Impedance matching



Triangulering - GPS







Wikipedia

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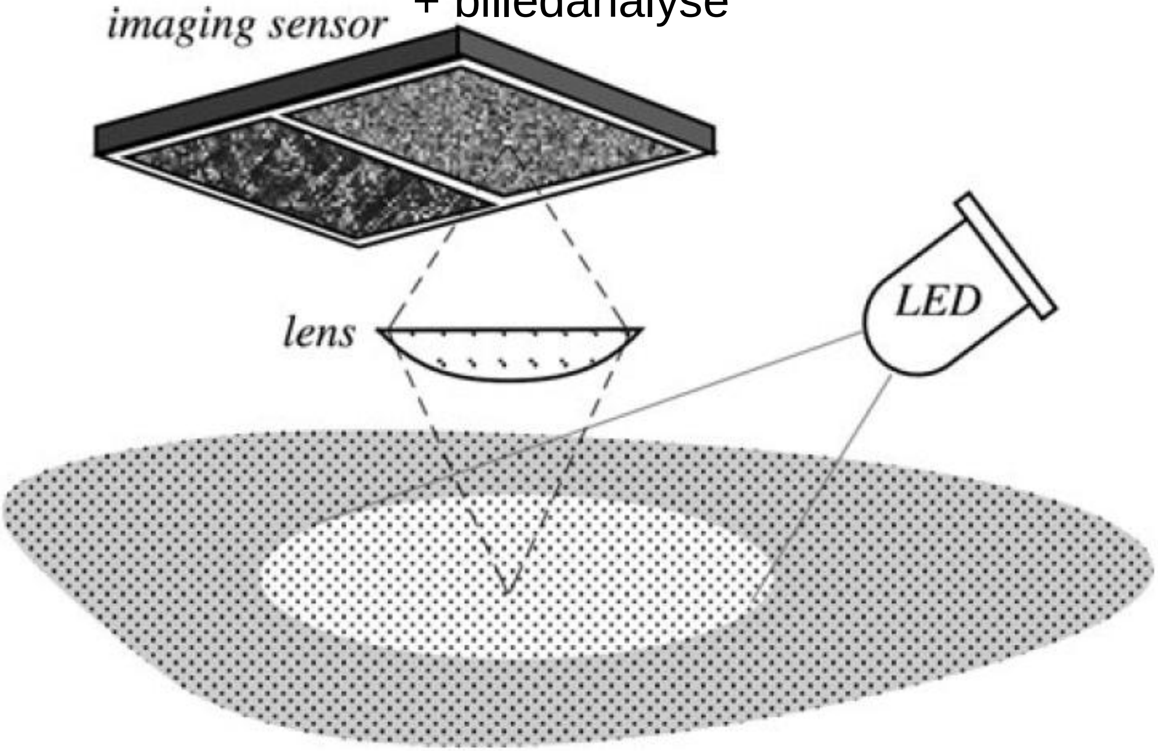

+ billedanalyse

Fig. 7.54 Concept of optical pointing device