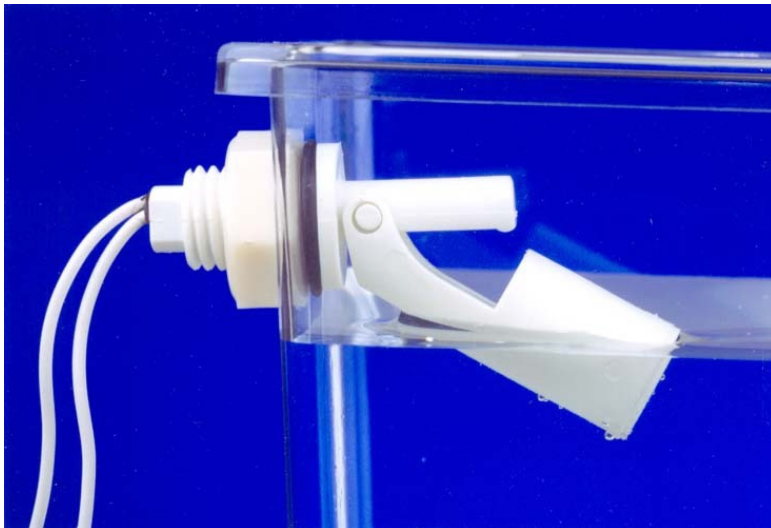
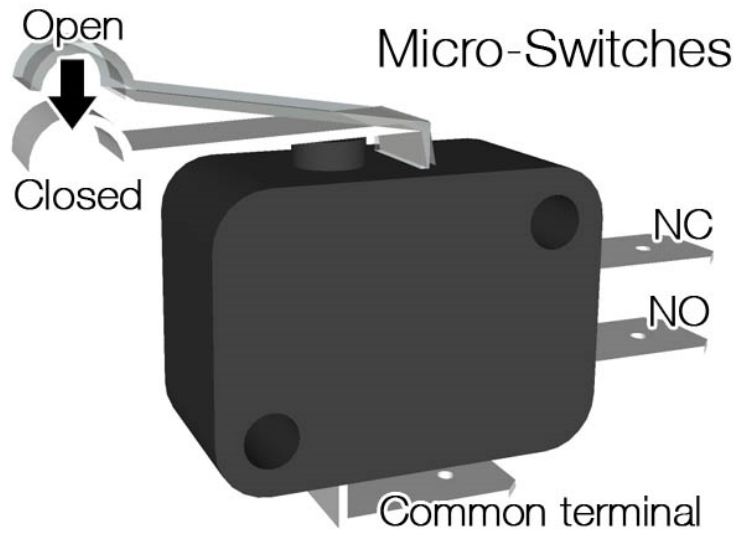


Posisjon, forflytning, nivå



Potensiometre

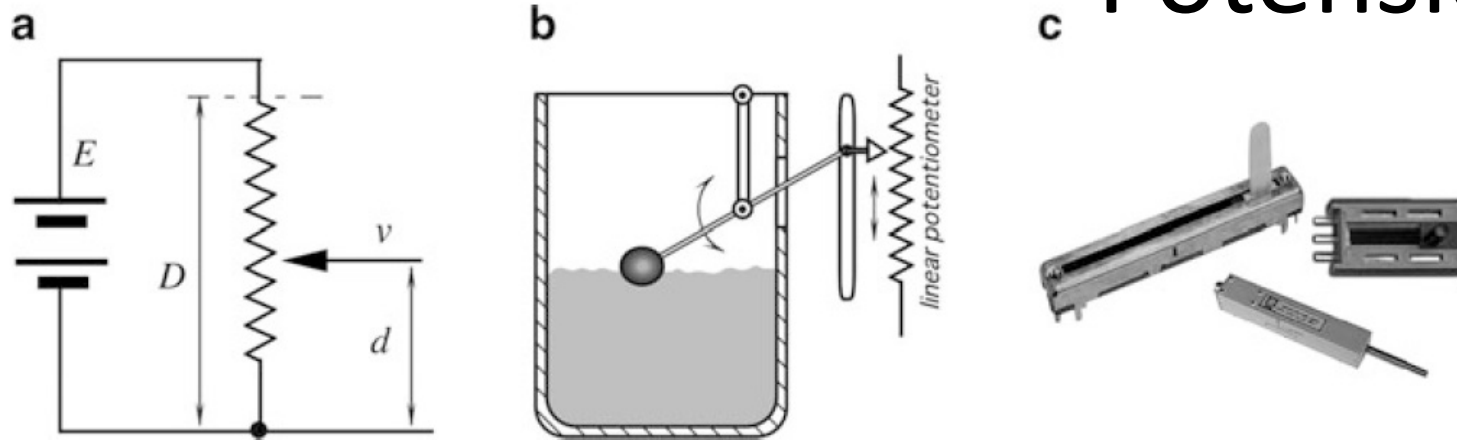
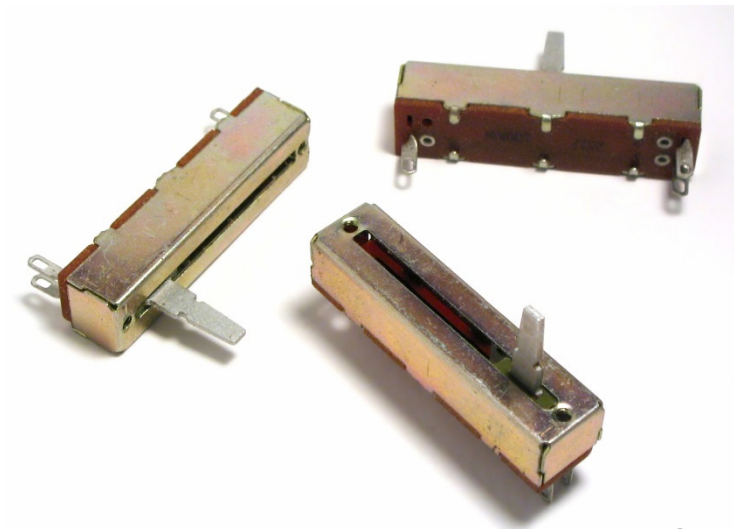


Fig. 7.1 Potentiometer as a position sensor (a); Fluid level sensor with a float (b); linear potentiometers (c)



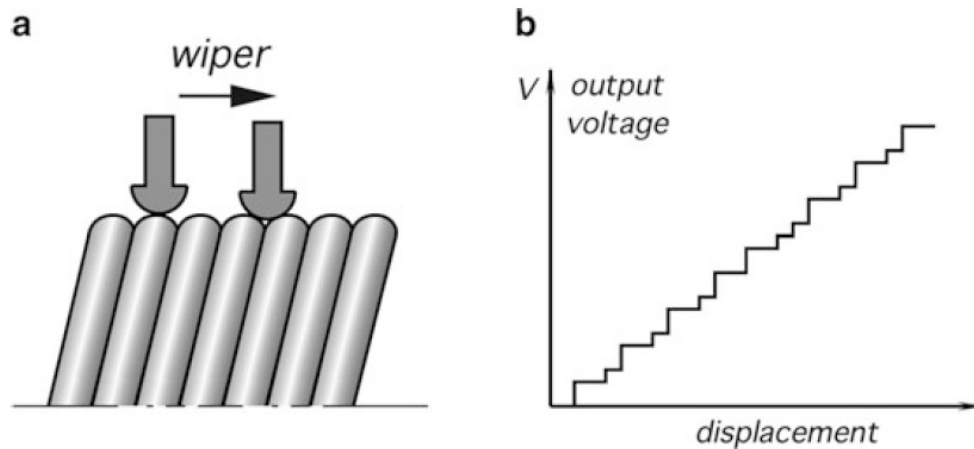


Fig. 7.2 Uncertainty caused by wire-wound potentiometer A wiper may contact one or two wires at a time (a); uneven voltage steps (b)

Gjennomsnittlig oppløsning:

$$n = 100/N\%$$

- Et bra viklet potensiometer kan ha oppløsning på 0,1 % av FS
- Med resistiv film kan man oppnå oppløsning innenfor støygrensen til resten av kretsen
- Multiturn pot med utveksling kan måle vinkler på ca. 10 – 3000 deg.
- Potensiometre med slepekontakter har en del åpenbare svakheter

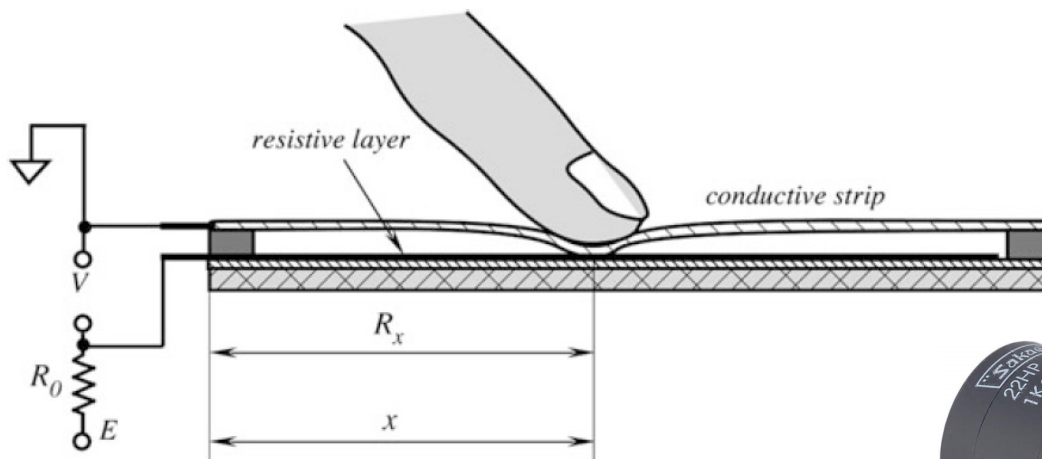
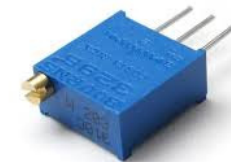


Fig. 7.3 Principle of a pressure-sensitive potentiometric position sensor



Kapasitiv sensor

- Brukes også for å måle kraft, trykk, temperatur, etc.
- Diff-måling med to, eller bromåling med fire kondensatorer

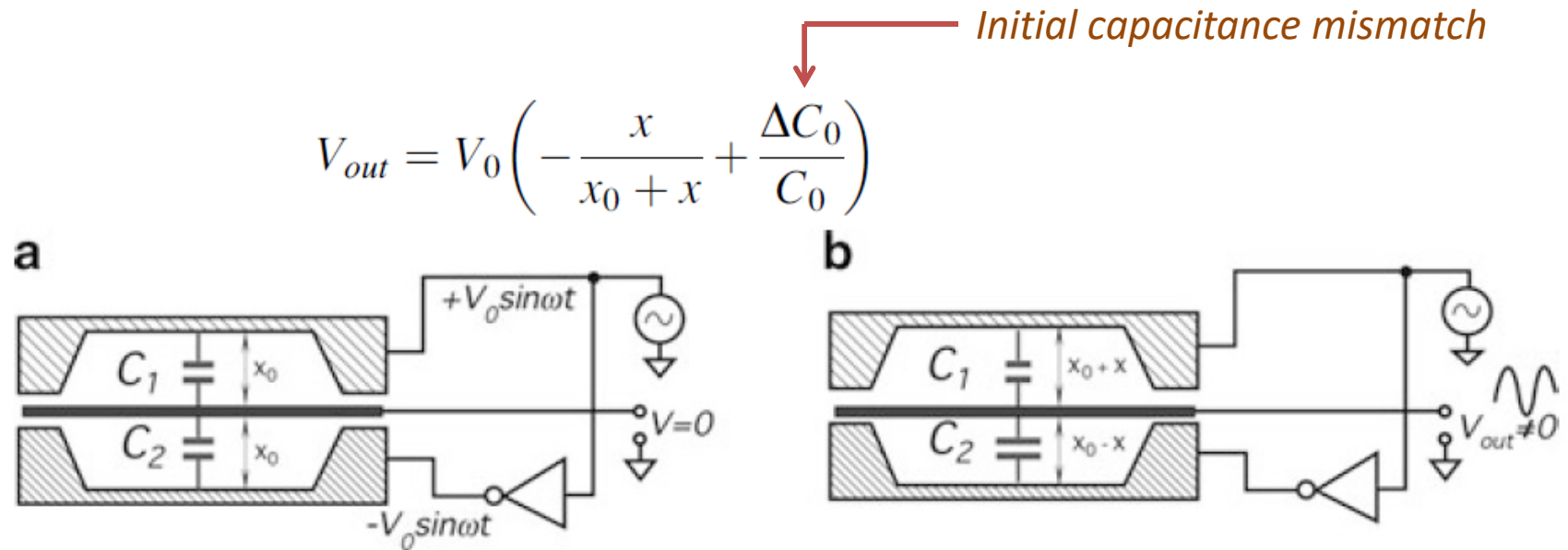
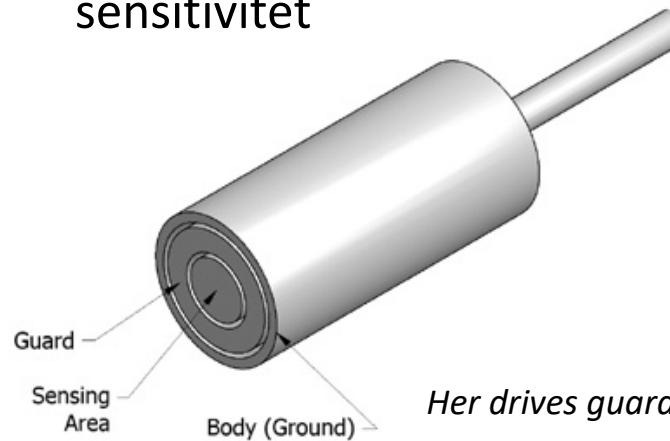


Fig. 7.6 Operating principle of a flat-plate capacitive sensor. Balanced position (a) and disbalanced position (b)

- Probe 3 MHz
- Respons 40 kHz
- Guard ring
- Et objekt i nærheten endrer C mellom elektrode og kapsling
- Driven shield gir økt sensitivitet



Her drives guard-ringen til samme potensial som elektrodene

Fig. 7.8 Capacitive probe with a guard ring cross-sectional view (a); outside view (b)

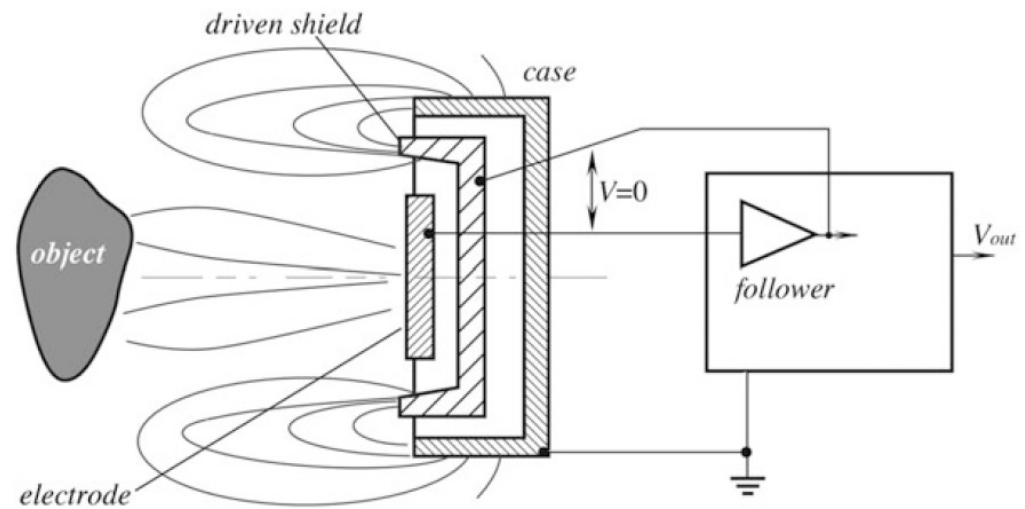
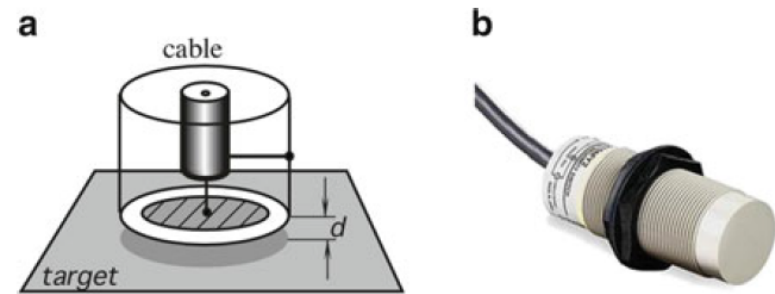


Fig. 7.9 Driven shield around the electrode in a capacitive proximity sensor

Kapasitiv brokoping

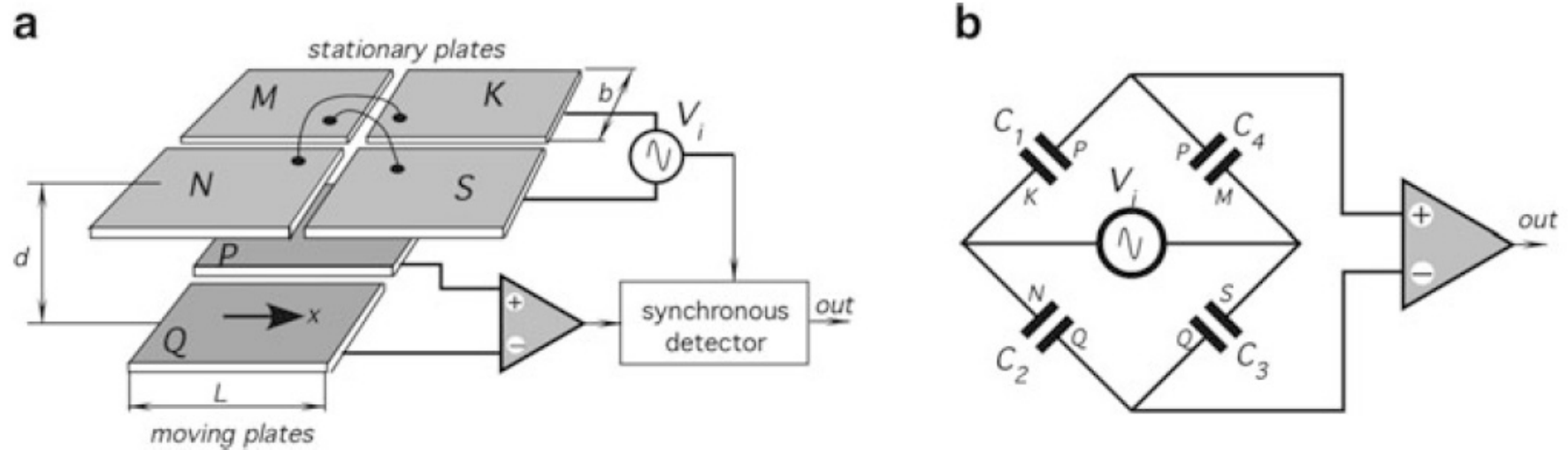
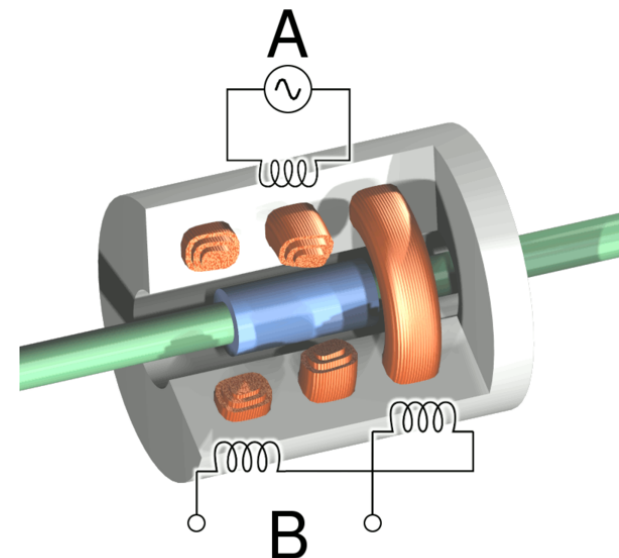
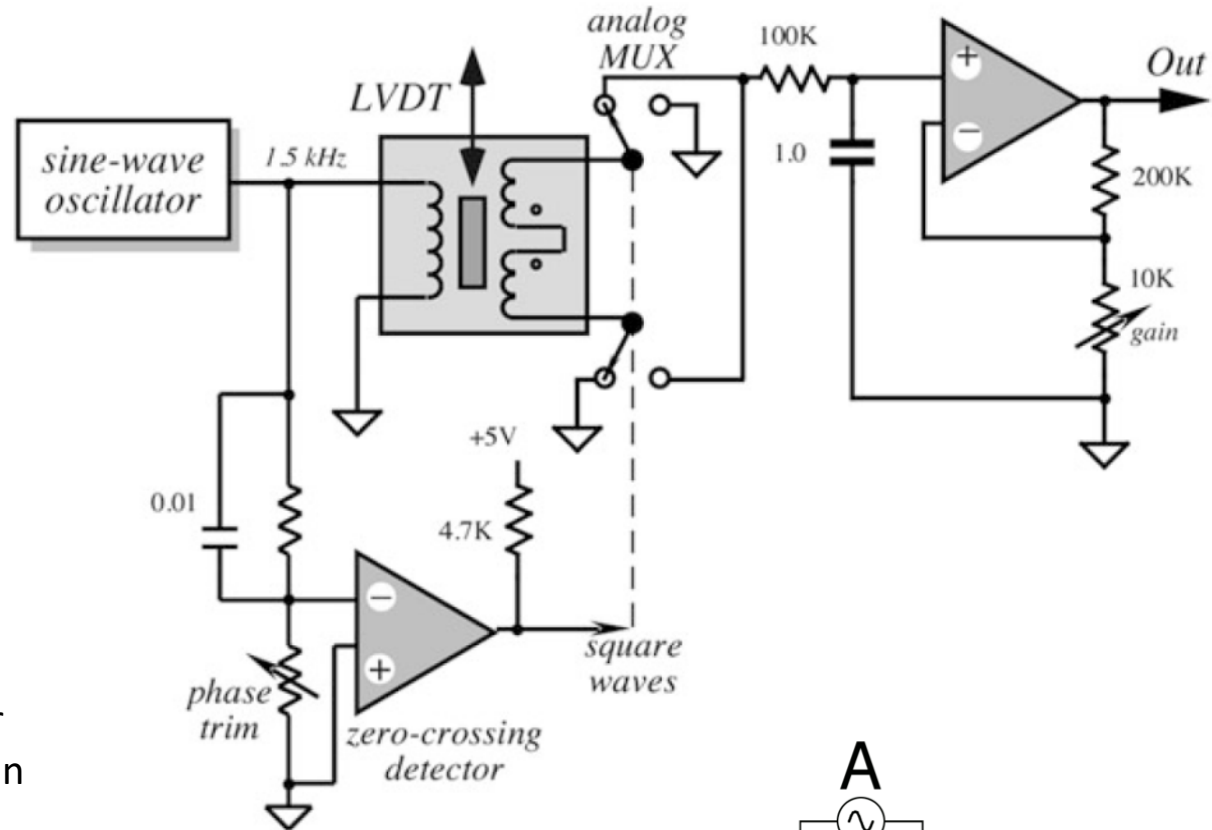


Fig. 7.10 Parallel-plate capacitive bridge sensor plate arrangement (a) and equivalent circuit diagram (b)

- Påtrykker 5 – 50 kHz

Induktive / magnetiske sensorer

- LVDT – Linear Variable Differential Transformer
- De to sekundærspolene er koblet i motfase
- Når kjernen er i sentrum er utgangen balansert og ingen spenning ut
- Retningen på bevegelsen gis av faseforskjellen mellom påtrykk og respons): fortegn på V_{out}
- Liten mekanisk friksjon, lite hysteres, lav utgangsimpedans, støysvak, robust og høy oppløsning



Eddy-strømmer

- Leon Foucault (1851)
- 50 kHz – 10 MHz
- Sensing coil gir Eddy-strømmer i materialet. Disse endrer strømmen i sensing coil og gir ubalanse i fht reference coil
- Materialtykkelse, posisjonering og sprekker

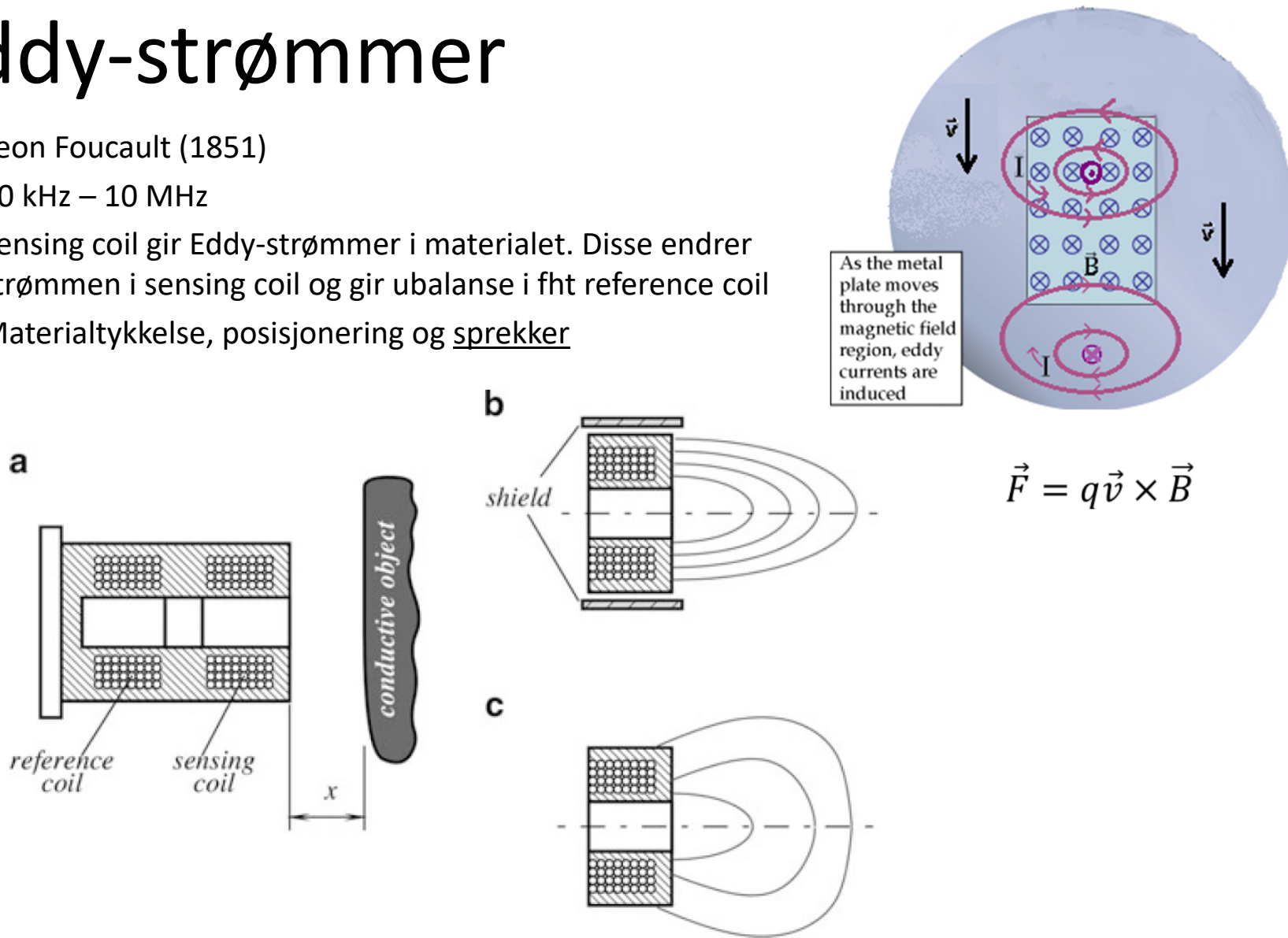


Fig. 7.13 Electromagnetic proximity sensor with eddy currents (a). Sensor with the shielded front end (b); Unshielded sensor (c)

Transvers inductiv sensor

Måler forflytning av ferromagnetisk materiale

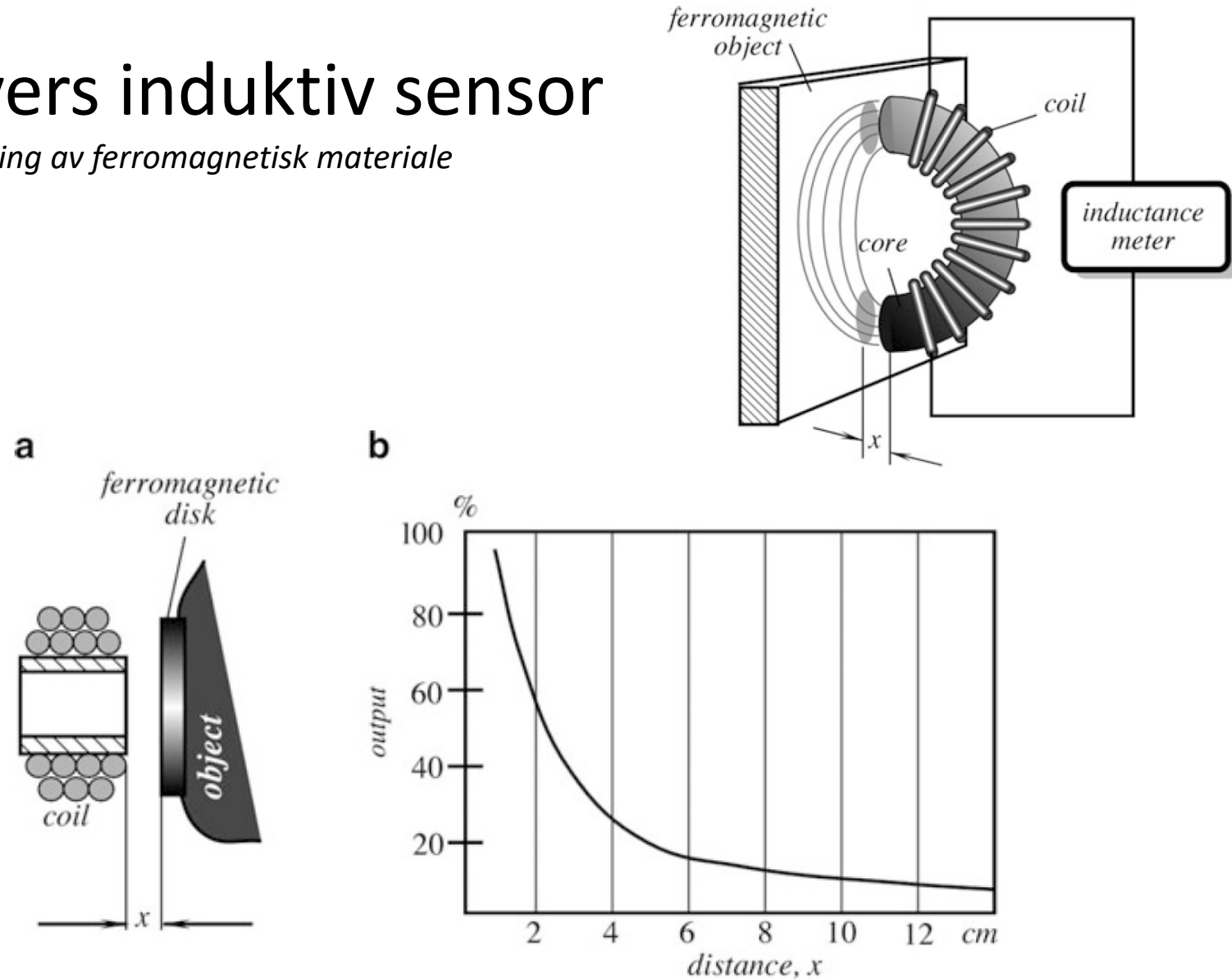


Fig. 7.15 Transverse sensor with an auxiliary ferromagnetic disc (a) and the output signal as function of distance (b)

Hall-effekt sensor

For måling av magnetfelt

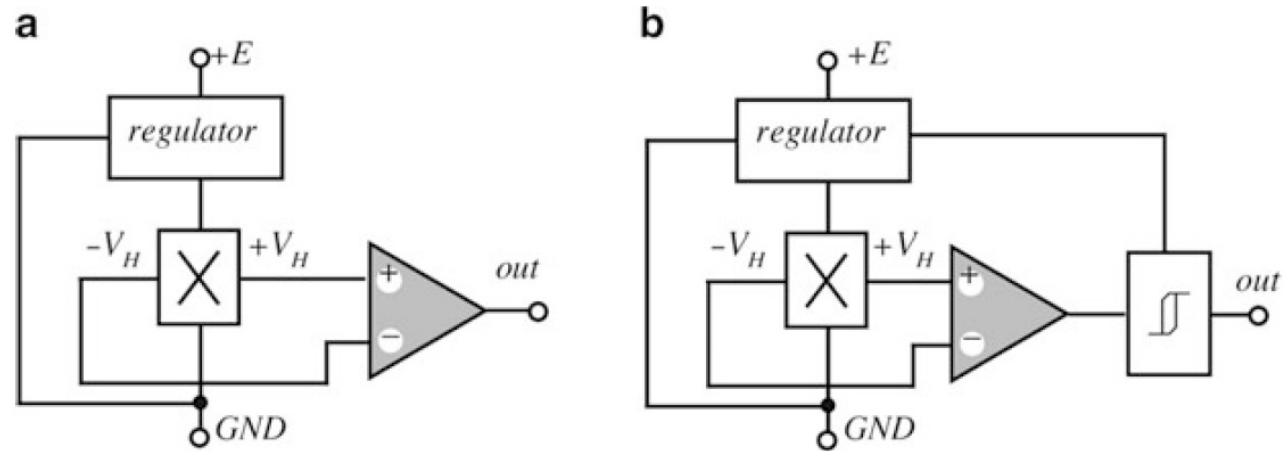


Fig. 7.16 Circuit diagrams of a linear (a) and threshold (b) Hall effect sensors

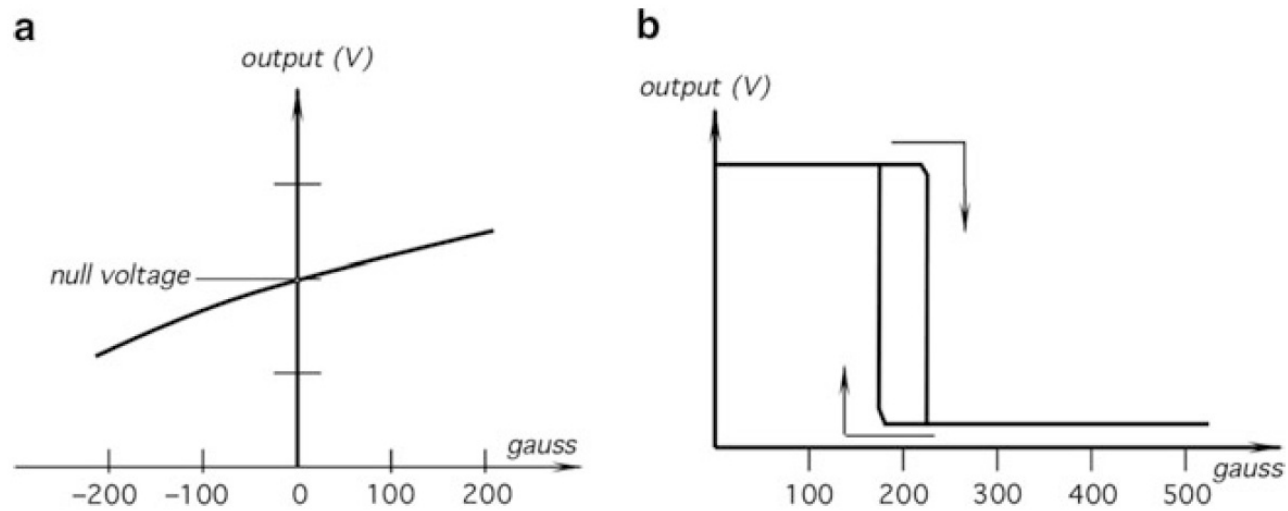
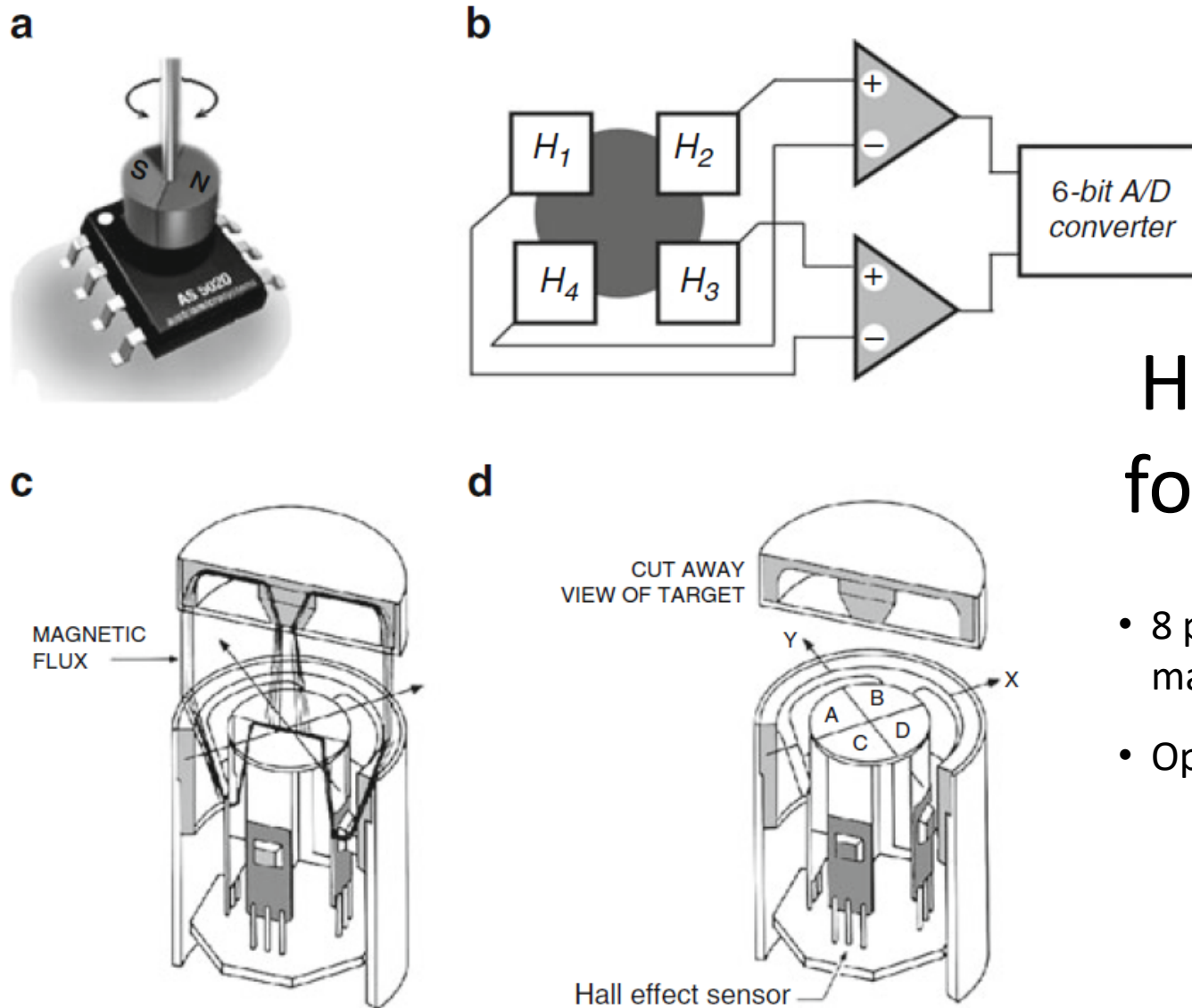


Fig. 7.17 Transfer functions of a linear (a) and a threshold (b) Hall effect sensors

Hall-basert nivåsensor





Hall-sensor for rotasjon

- 8 pins chip med magnet over
- Opp til 30.000 rpm

Fig. 7.20 Angular Hall-sensor bridge (a) and the internal sensor interface (b) (courtesy of Austria Micro Systems).

A cutaway view (c) of the sensor with the target and the probe shows the magnetic flux paths. A cut-away view (d) shows four Hall effect sensors with four flux return path

Magnetoresistive sensorer

Pga. avbøyning – Lorentz-kraft): Hall-effekt

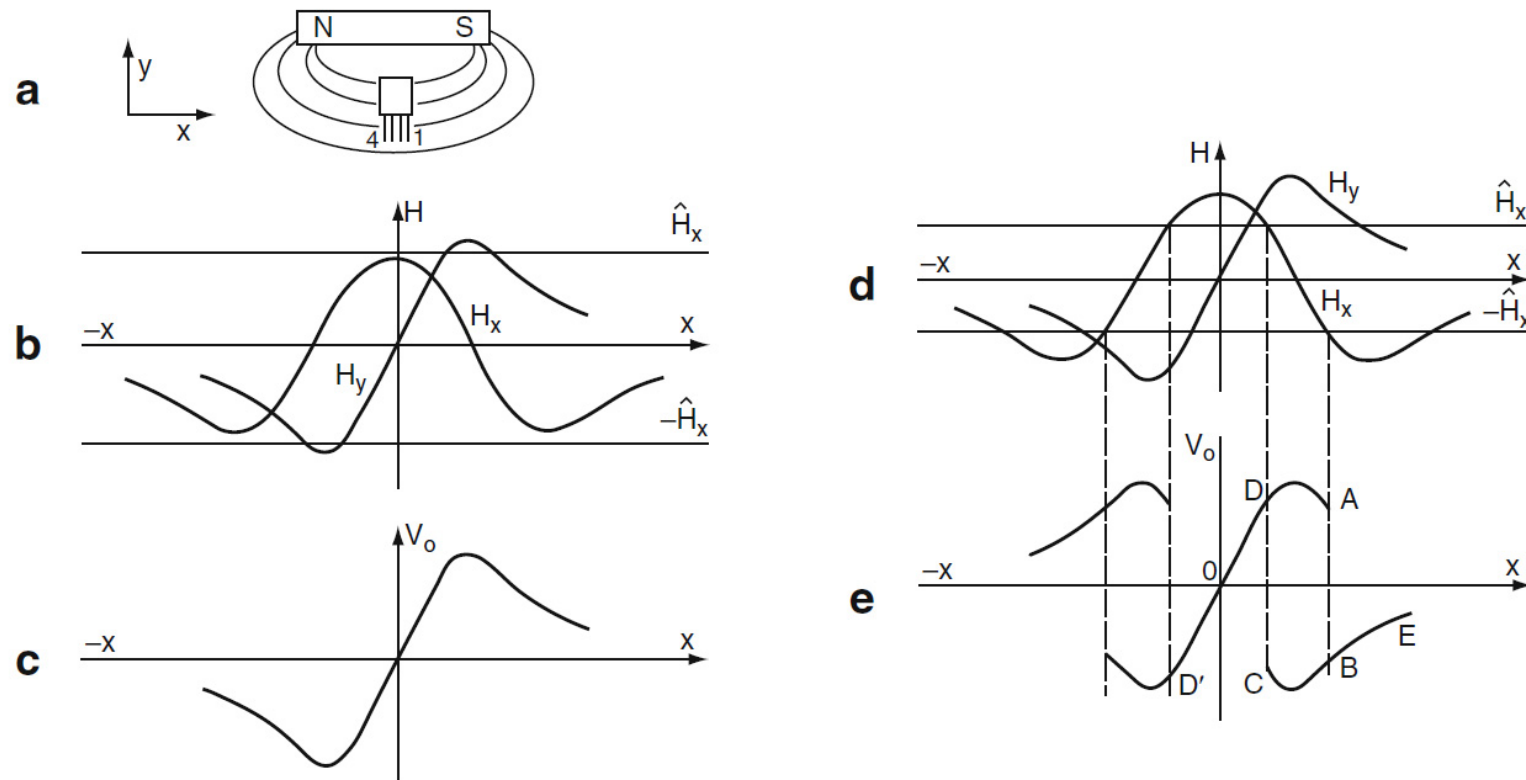


Fig. 7.22 Magnetoresistive sensor output in the field of a permanent magnet as a function of its displacement x parallel to the magnetic axis (a–c). The magnet provides both the axillary and transverse fields. Reversal of the sensor relative to the magnet will reverse the characteristic. Sensor output with a too strong magnetic field (d and e)

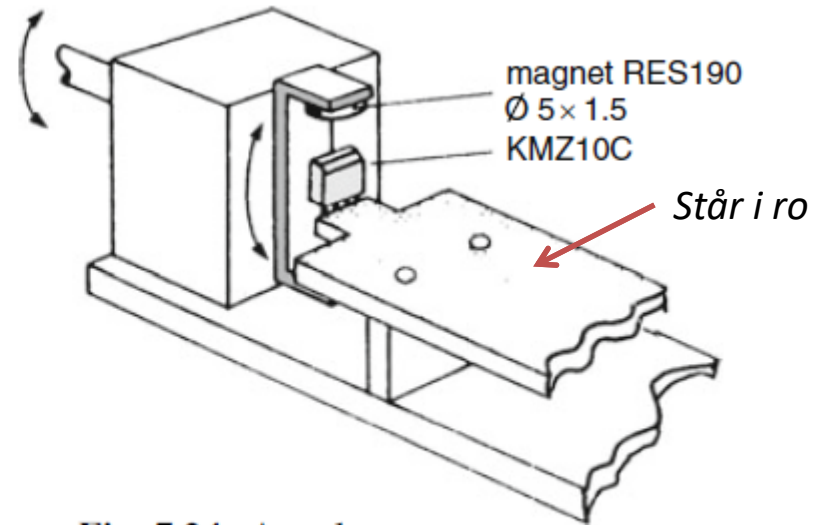
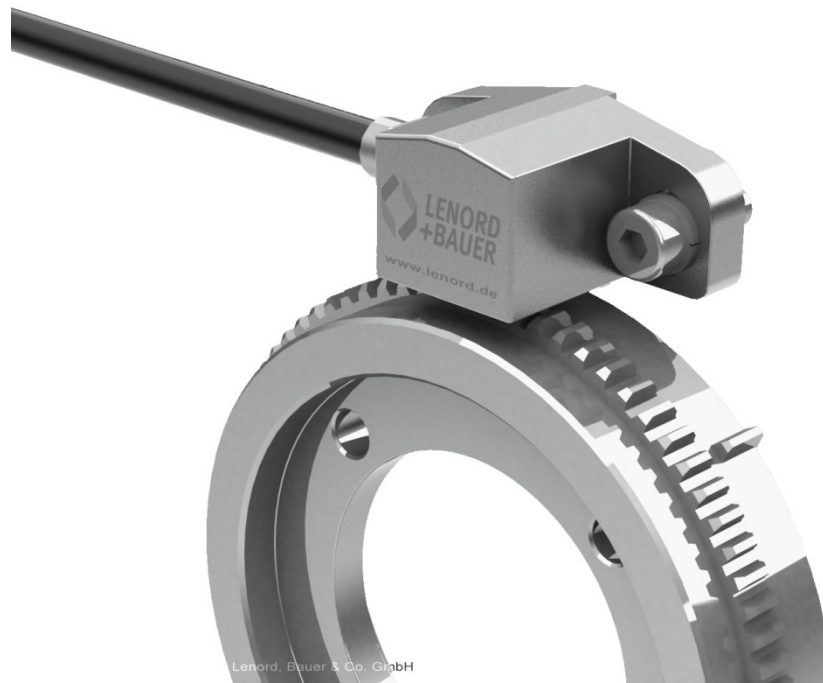


Fig. 7.24 Angular measurement with the KMZ10 sensor

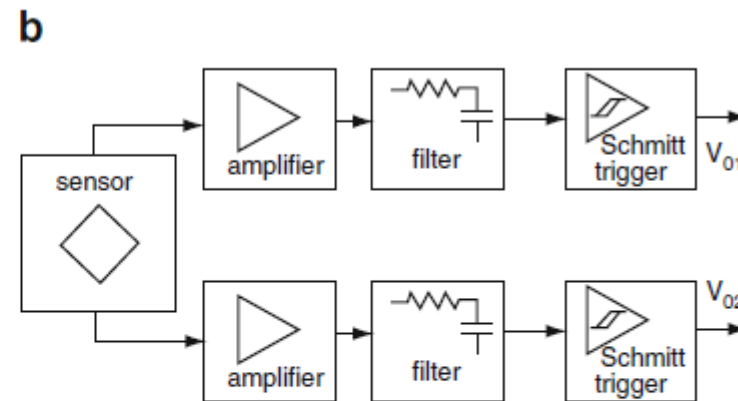
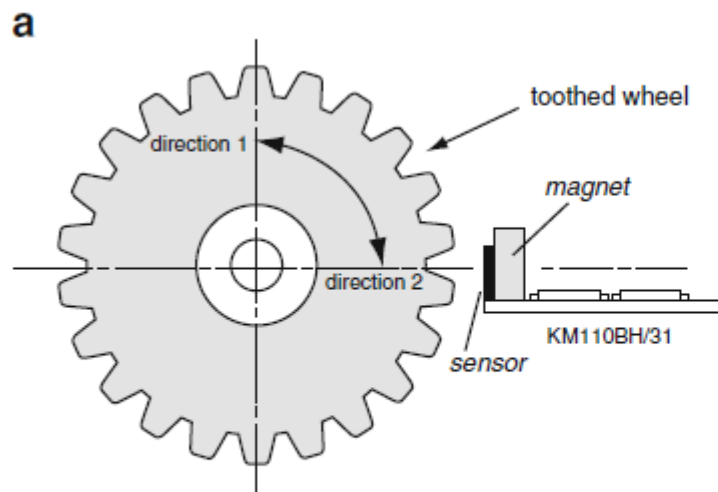


Fig. 7.25 Optimum operating position of a magnetoresistive module (a). Note a permanent magnet positioned behind the sensor. Block diagram of the module circuit (b)

Optiske sensorer

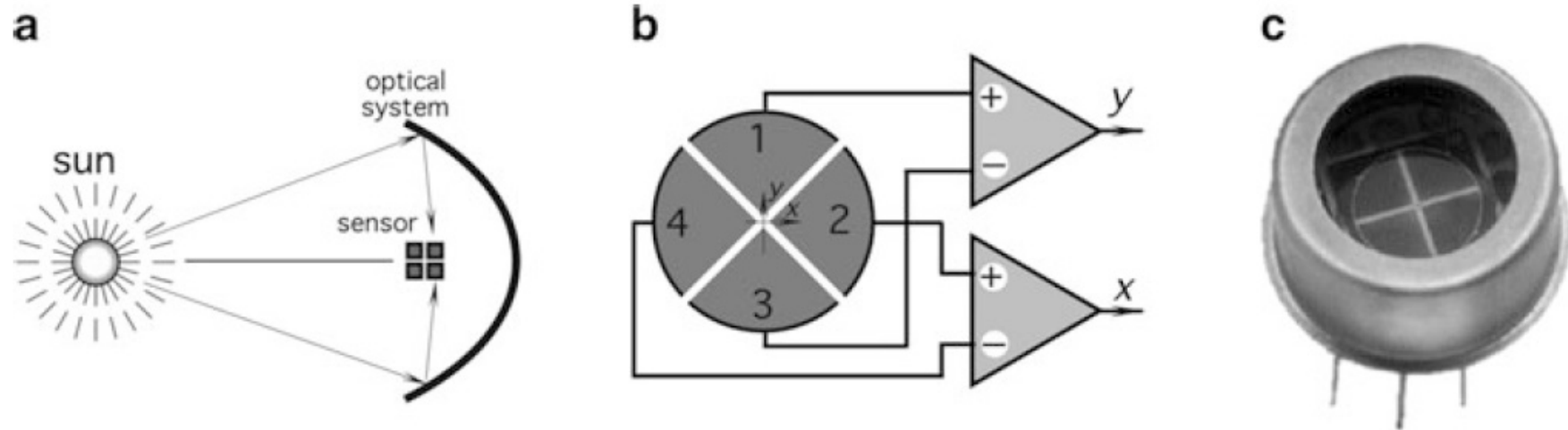


Fig. 7.28 Four-quadrant photodetector. Focusing an object on the sensor (a). Connection of the sensing elements to difference amplifiers (b). Packaging of the sensor (c) (from Advanced Photonix, Inc. Camarillo, CA)

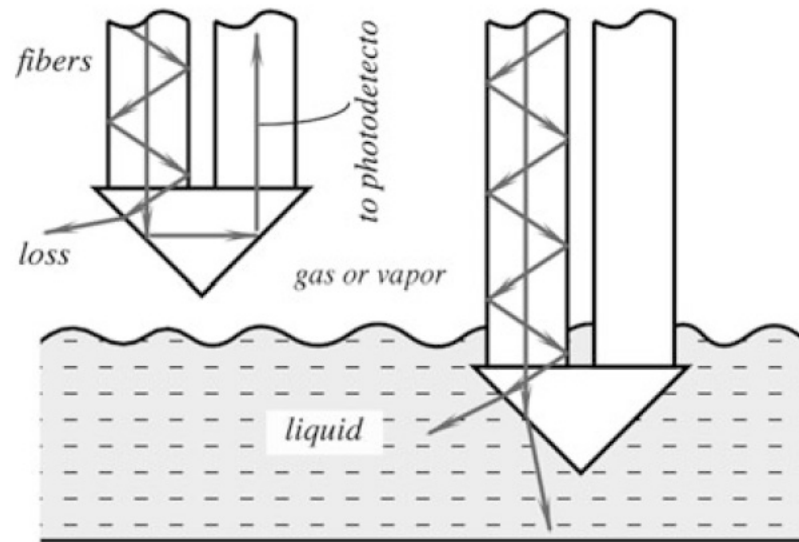
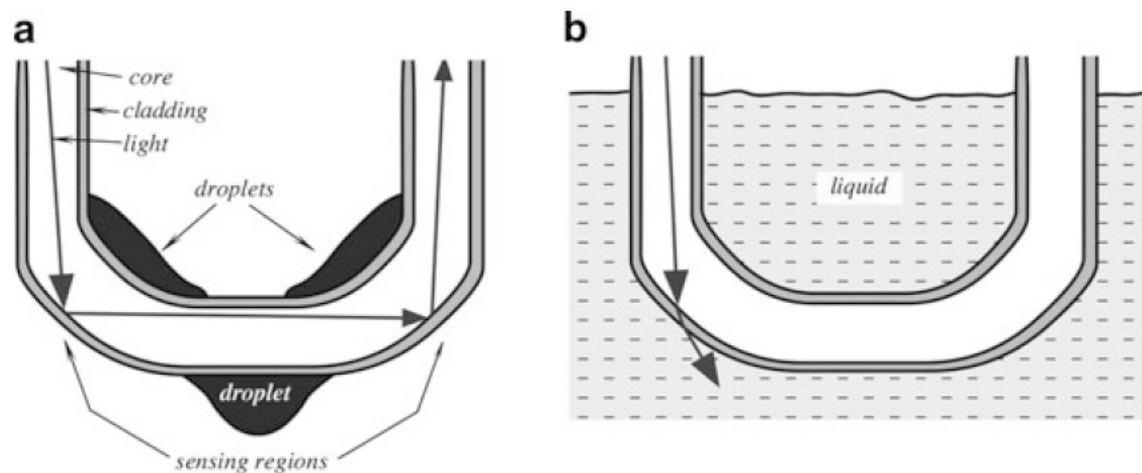


Fig. 7.31 Optical liquid level detector utilizing a change in the refractive index

Fiberoptisk sensor



Proben er
5 mm i diameter

Fig. 7.32 U-shaped fiber optic liquid level sensor. When the sensor is above the liquid level, the light at the output is strongest (a); When the sensitive regions touch liquid, the light propagated through the fiber drops (b)

Maurice Paul Auguste Charles Fabry



Born June 11, 1867
Died December 11, 1945 (aged 78)
Known for Fabry-Pérot interferometer

Alfred Perot



Born November 3, 1863
Metz, France
Died November 28, 1925
(aged 62)

Fabry-Perot -sensorer

- Lys fra f.eks. LED eller lyspære inne i kaviteten med speil
- Noen gitte frekvenser slipper ut, avhengig av kavitets lengde:

$$\Delta\nu = \frac{c}{2L}$$

- Brukes bl.a. til måling av trykk og temperatur

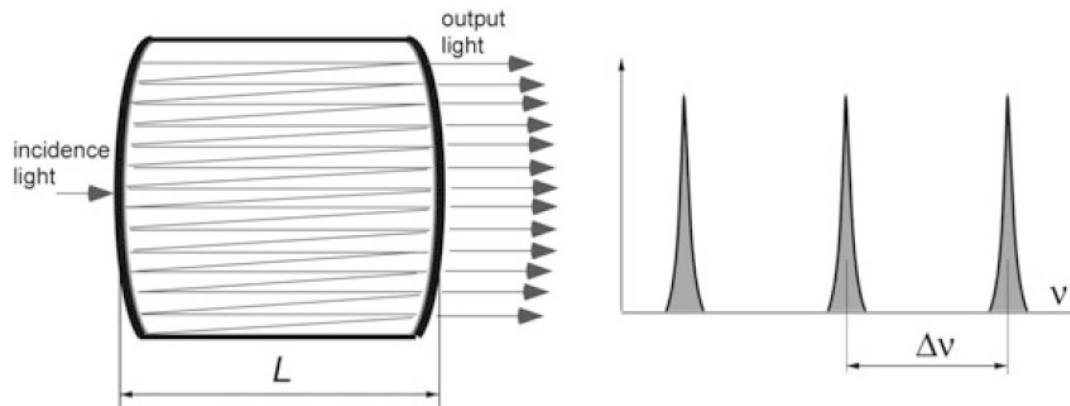


Fig. 7.33 Multiple-ray interference inside Fabry-Perot cavity (a). Transmitted frequencies of light (b)

Praktisk målesystem

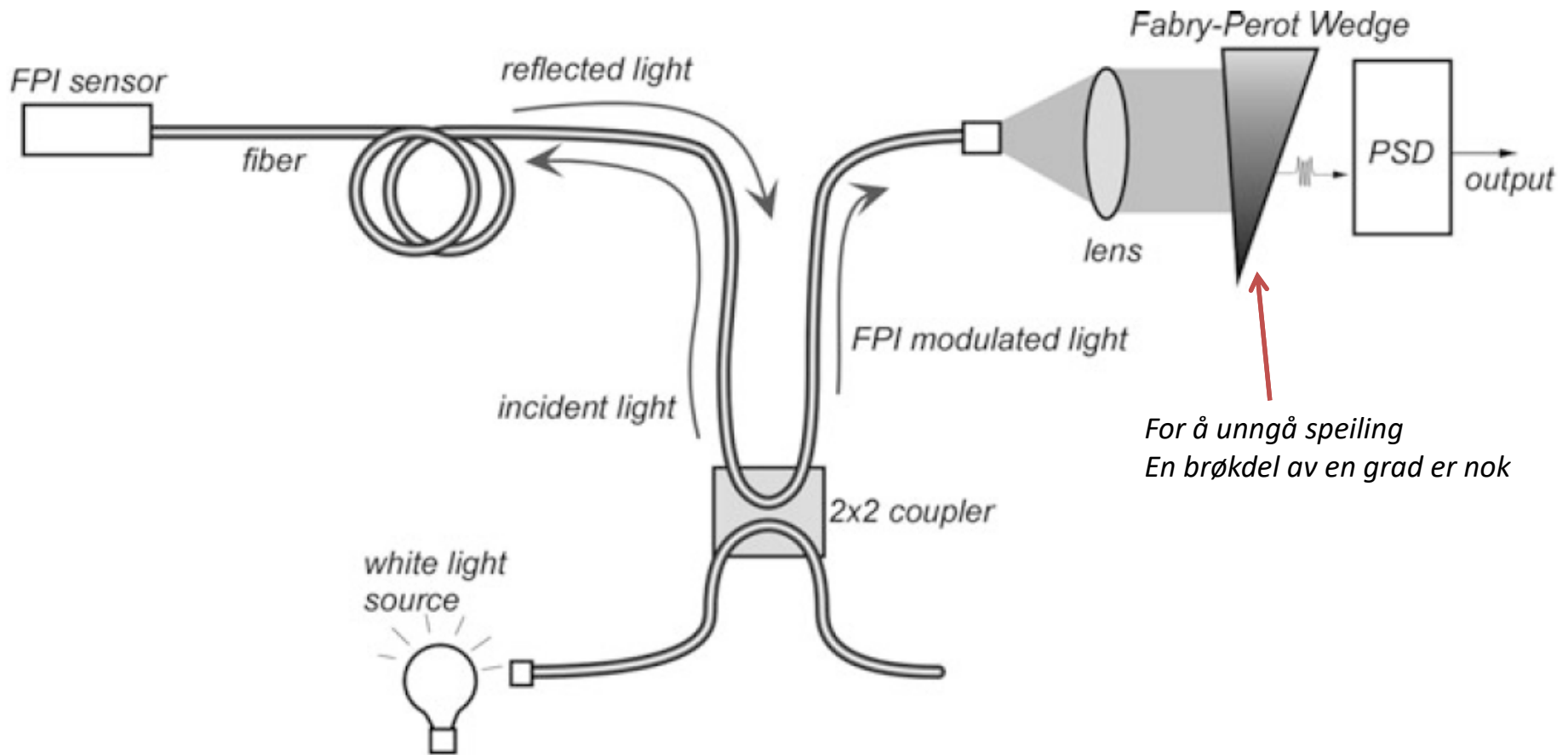


Fig. 7.35 Measuring system for the Fabry-Perot sensor (courtesy of Roctest. www.roctest.com)

Rist-sensor

- To overlappende rister
- Full scale = bredden på et element i risten
- Liten bredde \rightarrow høy følsomet
- Stor bredde \rightarrow stort måleområde

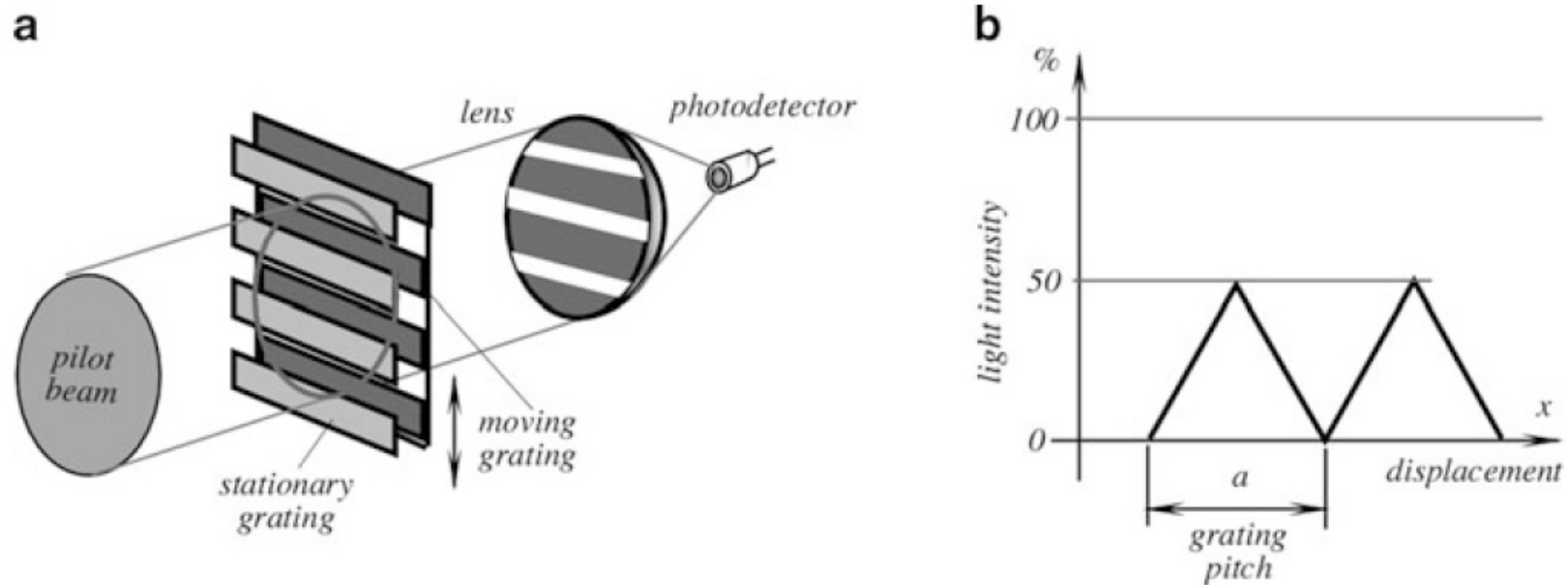
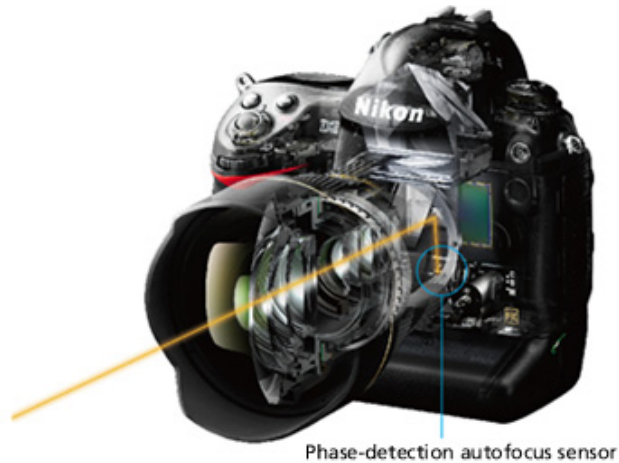


Fig. 7.36 Optical displacement sensor with grating light modulator. Schematic (a); transfer function (b)

Lineær optisk sensor

- Autofokus i kameraer
- Aktiv med NIR-LED
- 0.7 ms puls



Phase-detection autofocus sensor

$$P = \frac{D}{x} - 1$$

$$L_0 = f \frac{L_B}{D} (P + 1) = k(P + 1)$$

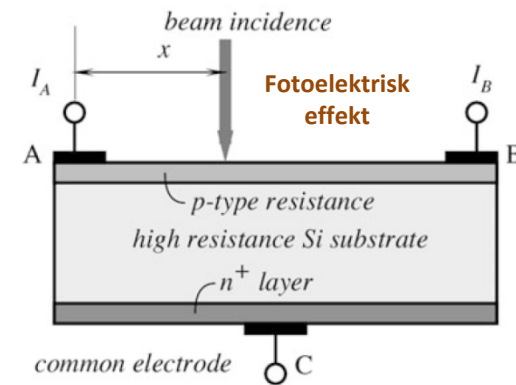
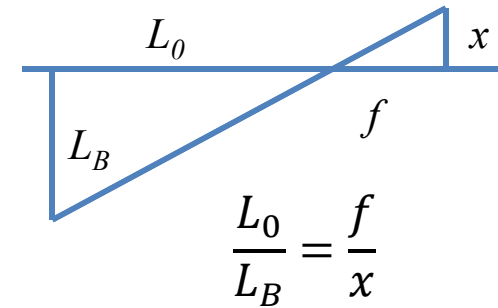
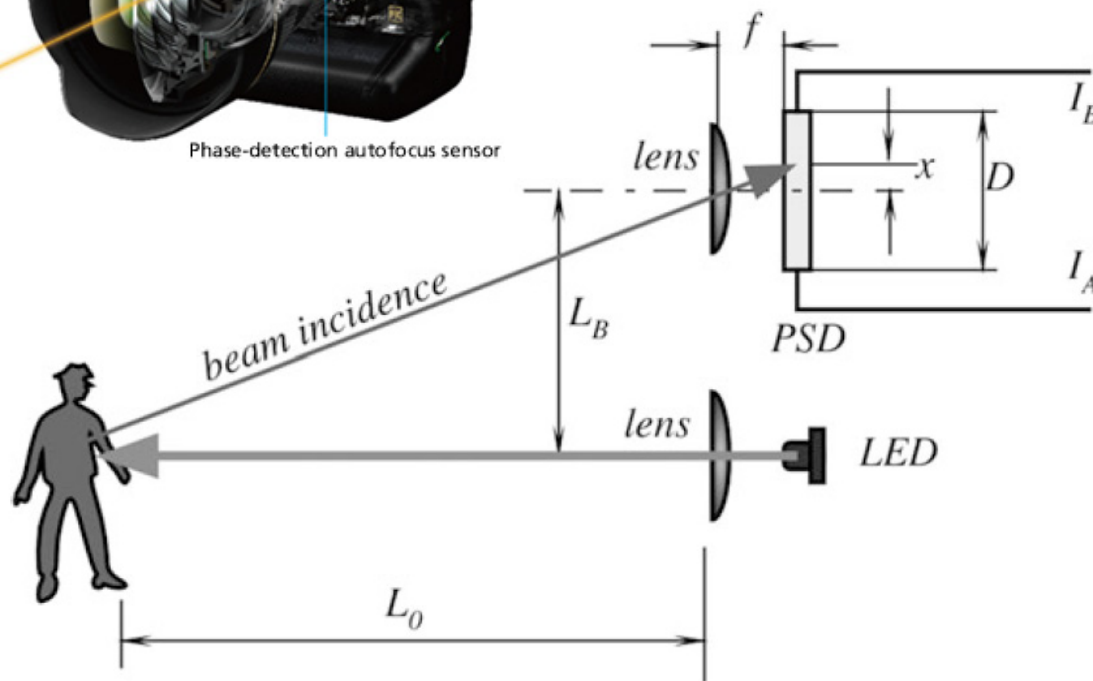


Fig. 7.38 The PSD sensor measures distance by applying a triangular principle

Ultralydsensorer

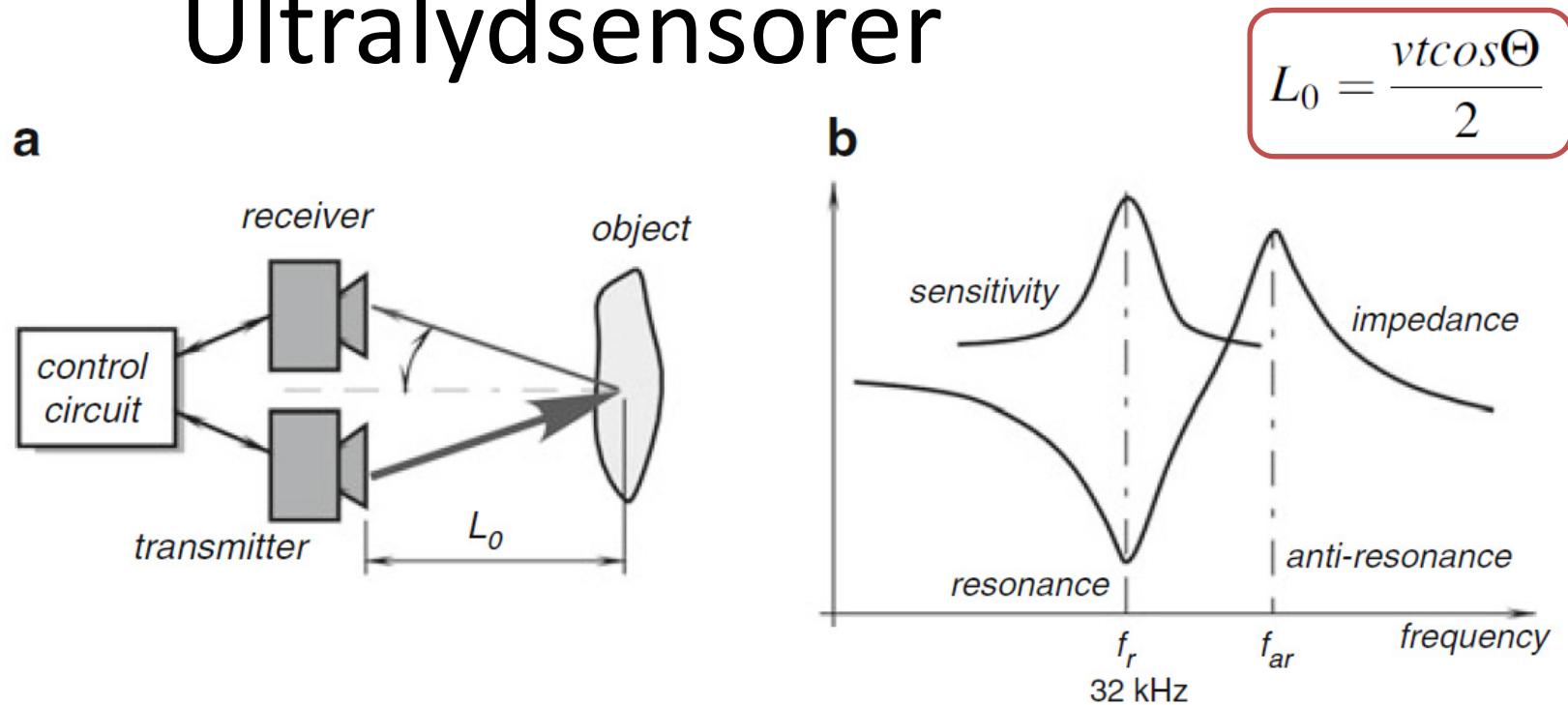


Fig. 7.42 Ultrasonic distance measurement: basic arrangement (a); impedance characteristic of a piezoelectric transducer (b)

- Avstand og fart (Doppler-effekt)
- Lavere hastighet enn EM-bølger og dermed enklere å måle
- Piezo-elektrisk element kan brukes i både sender og mottaker
- Kan være samme element ved *pulsed mode*





Kateter med ablasjon for behandling av atrieflimmer

Ablasjonssensorer

- Brukes her om smelting/fordamping av et beskyttende lag på romfartøyer for å redusere temperatur
- Måler hvor mye av tykkelsen som er igjen

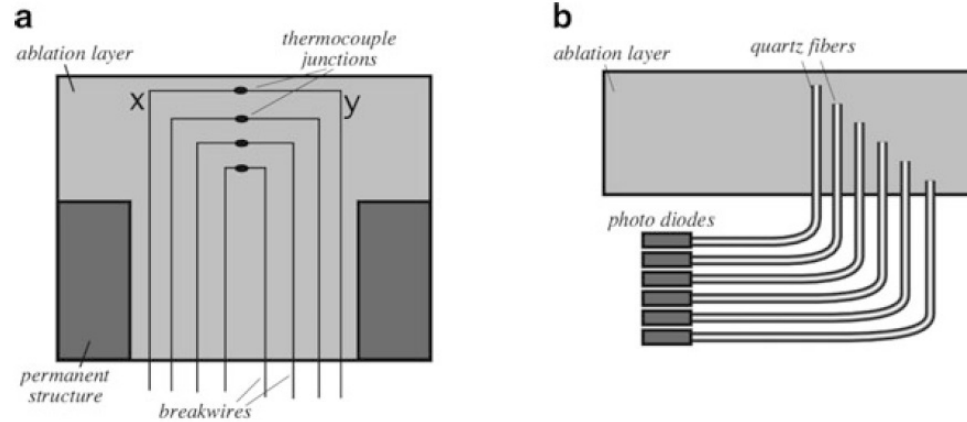


Fig. 7.49 A breakwire concept with thermocouples consisting of metals x and y (a), and a light pipe concept (b)

- Resonans ved:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$
- Kan bruke auto-tuning til å finne resonansfrekvensen og dermed C

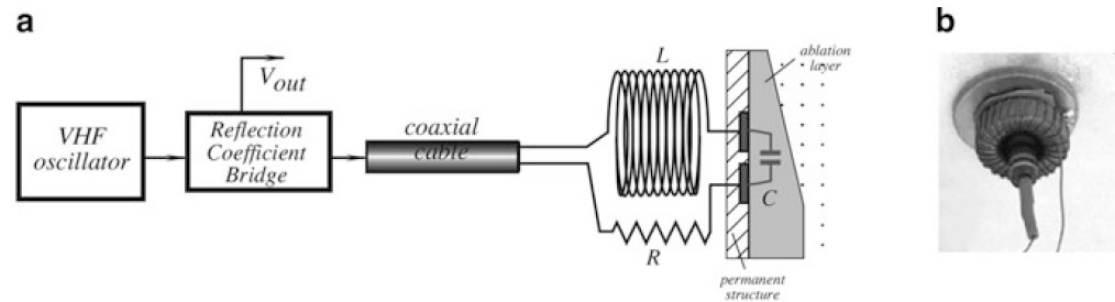


Fig. 7.50 Block diagram of resonant ablation gauge (a) and a prototype sensor (b)

Optisk PC-mus

- Rød eller IR LED eller laserdiode
- Eks. 1.512 fps
- 18 × 18 pixler
- 6 bit gråskala (64 gråtoner)

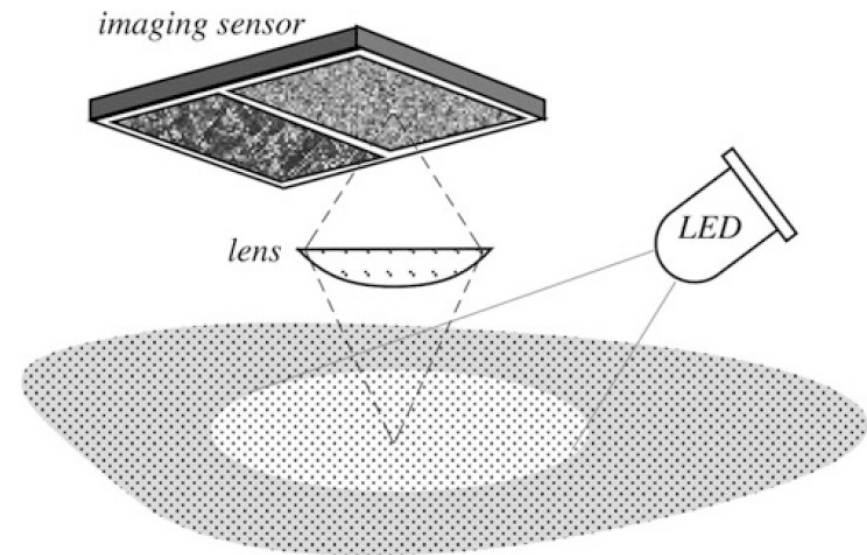


Fig. 7.54 Concept of optical pointing device

Hastighetsensorer

EM-sensor (Faradays induksjonslov)

- Passiv sensor i motsetning til LVDT sensoren
- Begge ender av magneten er inne i spolen
- Må splitte spolen for at ikke de to endene skal kansellere hverandre

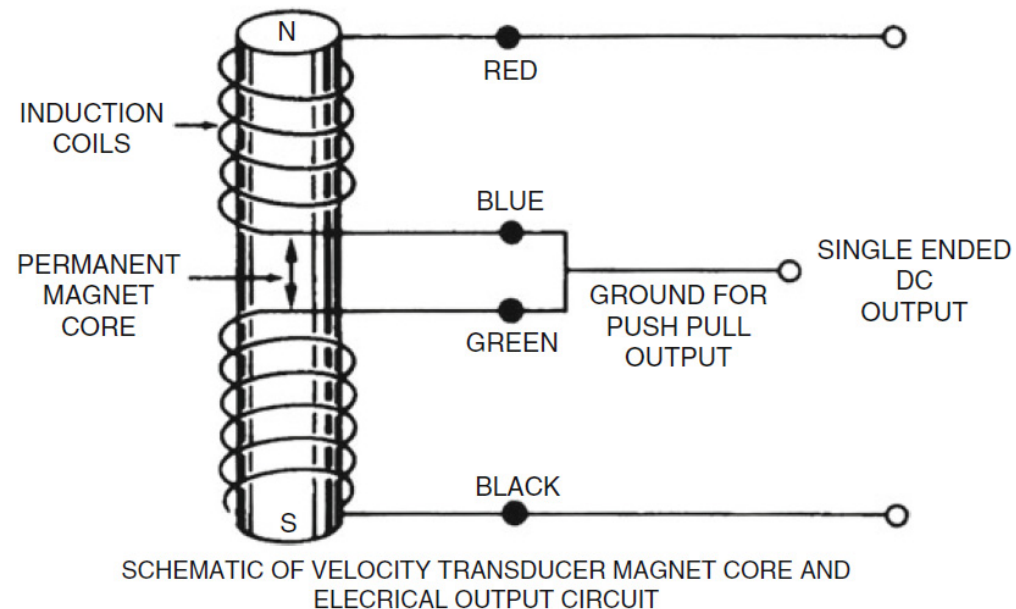
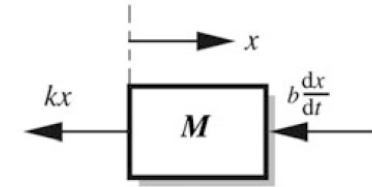
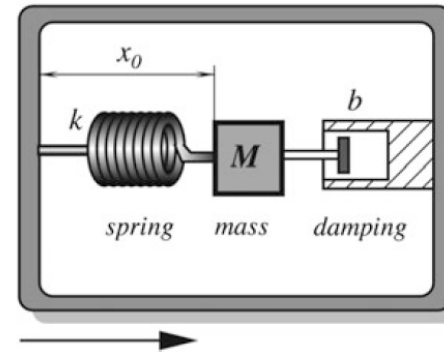


Fig. 8.1 Operating principle of an electromagnetic velocity sensor (Courtesy of Trans-Tek, Inc., Ellington, CT)

Akselerometre

Deteksjon av en masses forskyvning i fht innkapslingen



Karakteristiske egenskaper:

- Sensitivitet (i V/g ved 160 Hz, hvor $g = 9.8 \text{ m/s}^2$)
- Frekvensrespons (vibrasjonsmåling)
- Resonansfrekvens
- Nullverdi (pga gravitasjon)
- Linearitet

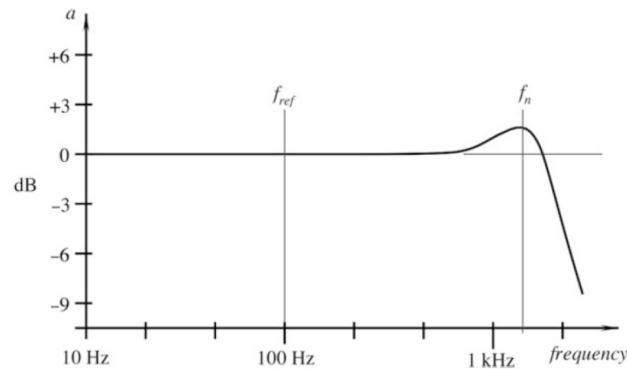
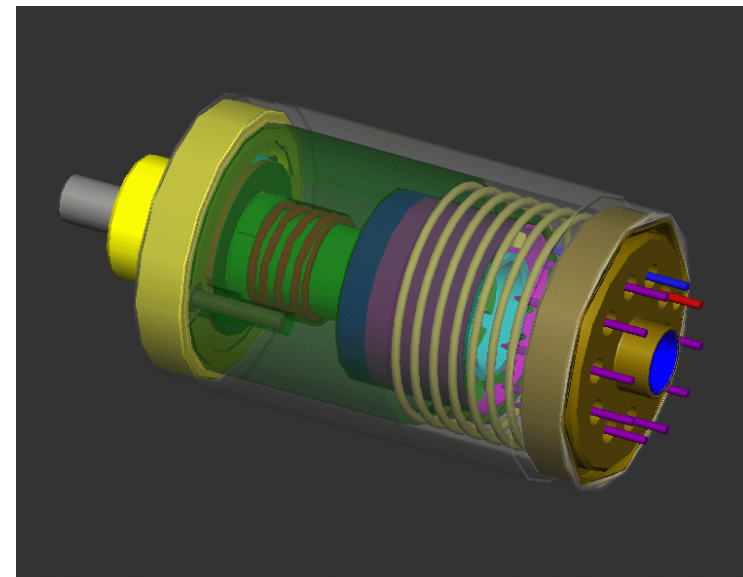


Fig. 8.2 A frequency response of an accelerometer. f_n is a natural frequency; f_{ref} is the reference frequency



Kapasitivt akselerometer

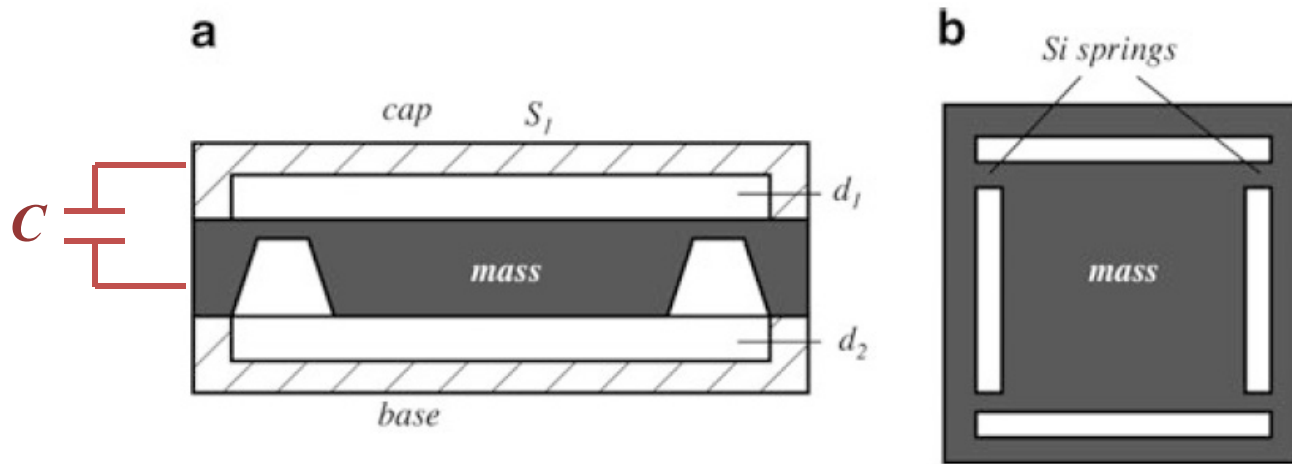
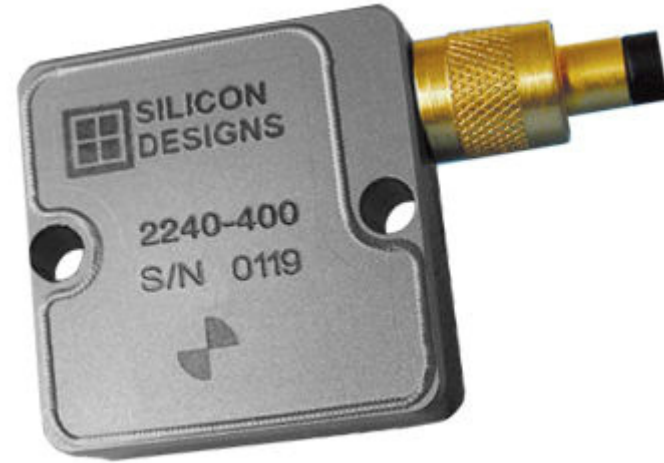


Fig. 8.3 Capacitive accelerometer with a differential capacitor side cross-sectional view (a); top view of a seismic mass supported by four silicon springs (b)

Varmeplateakselerometer

- Temperaturen som måles på opphenget er avhengig av avstanden fra varmeplata til kjøleplatene over og under

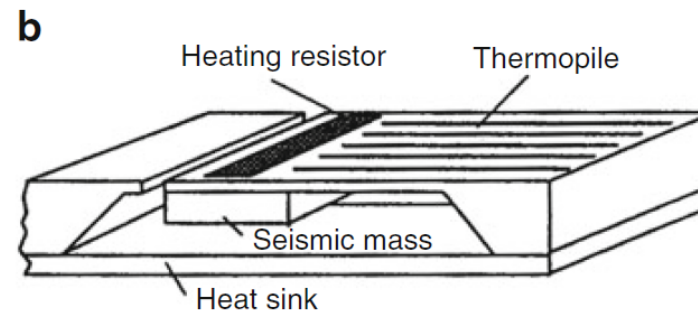
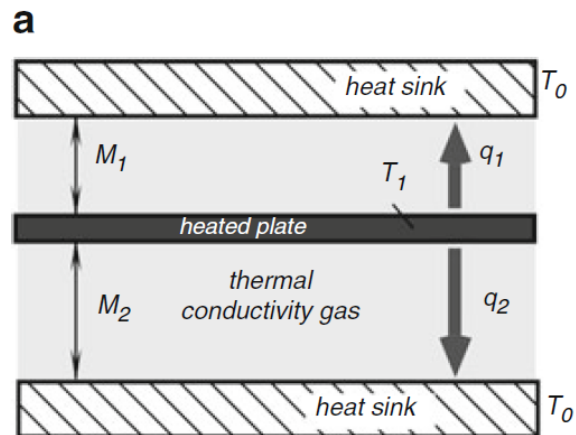
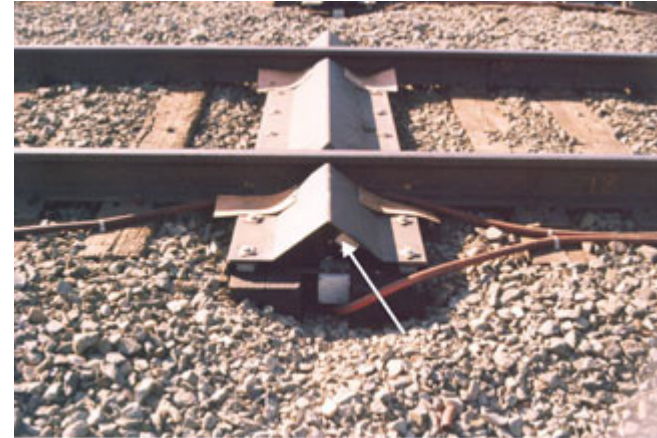
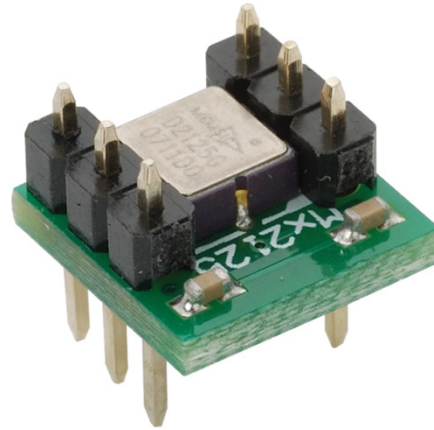


Fig. 8.7 Thermal accelerometer.

(a) A cross-section of the heated part; (b) an accelerometer design shown without the roof (adapted from [5])

Varmgass-akselerometer



- Gass i stedet for masse
- Tåler dermed sjokk på 50.000 g
- Fire temperatur-sensorer
- Varmes til ca. 200 °C
- To-akse

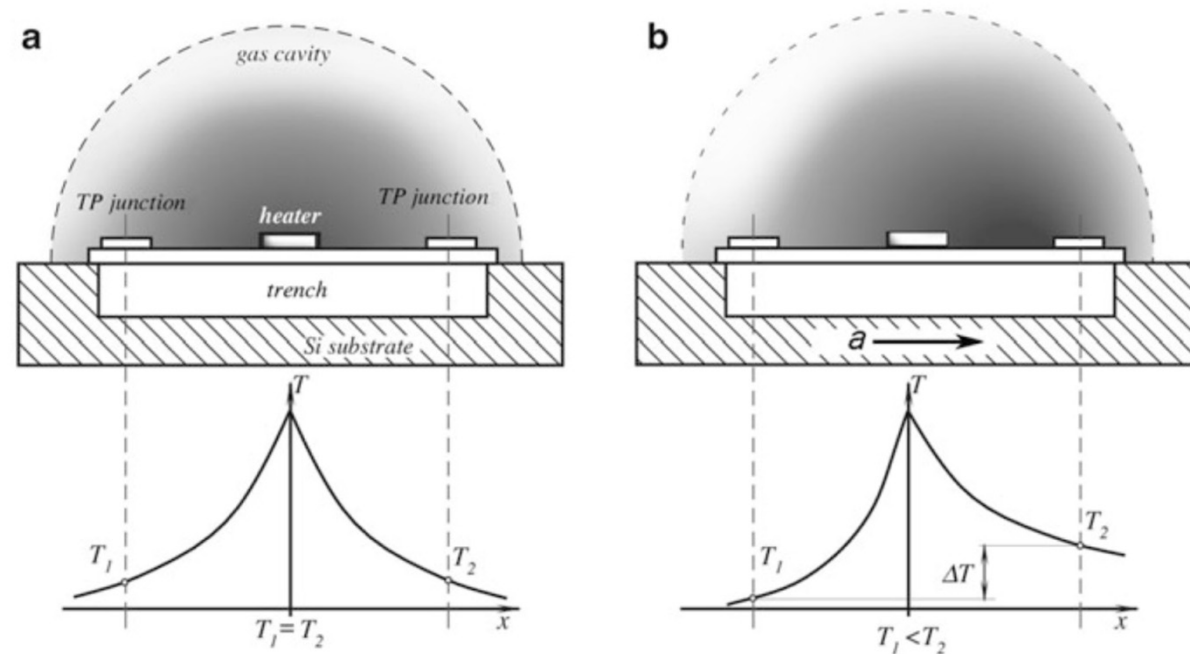


Fig. 9.26 Cross-sectional view of HGA sensor along x -axis (a). Heated gas is symmetrical around the heater (b). Acceleration causes heated gas to shift to right, resulting in temperature gradient

Gyroskop

- Brukt til navigasjon før GPS
- Bevaring av spinn: Spinnaksen er fast i rommet hvis ingen krefter virker på hjulet
- Hvis plattformen dreies rundt input-aksen vil det skapes et dreiemoment rundt output-aksen
- Johann Bohnenberger 1817
- En eller to frihetsgrader
- For å redusere friksjon kan gyroen flyte i fluorkarbon-væske eller holdes svevende i et elektrisk- eller magnetfelt

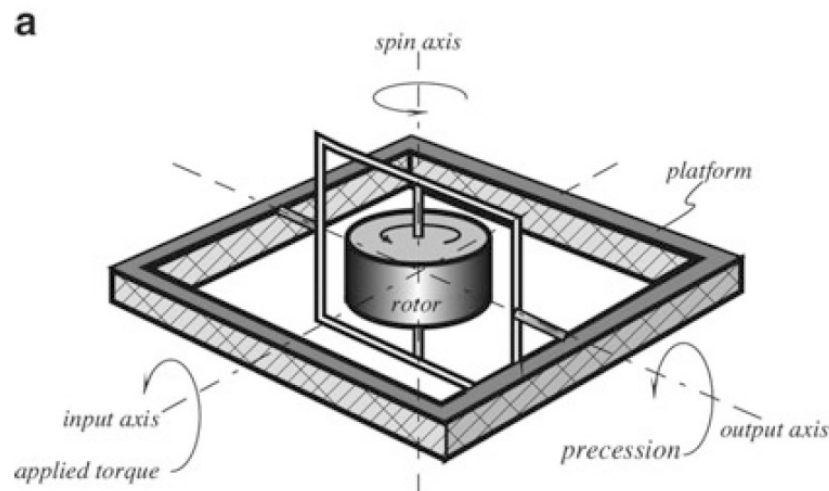


Fig. 8.10 Mechanical gyroscope with a single degree-of-freedom (a) and early auto-pilot gyroscope (b)

MEMS-gyroskop

- Basert på Coriolis-effekt (Gustave-Gaspard Coriolis, 1835):
- Treghetskraft vil virke til høyre for bevegelsesretningen hvis referansesystemet dreies mot klokka (og motsatt)
- Roterende disk er erstattet av et vibrerende element

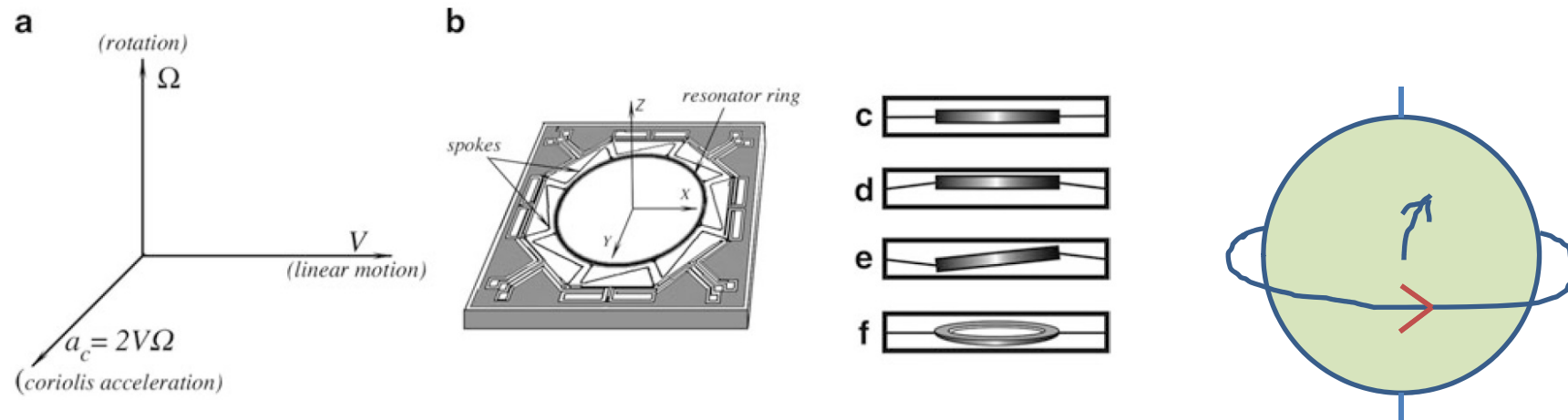
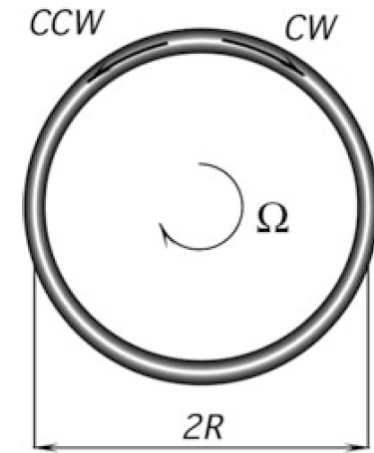
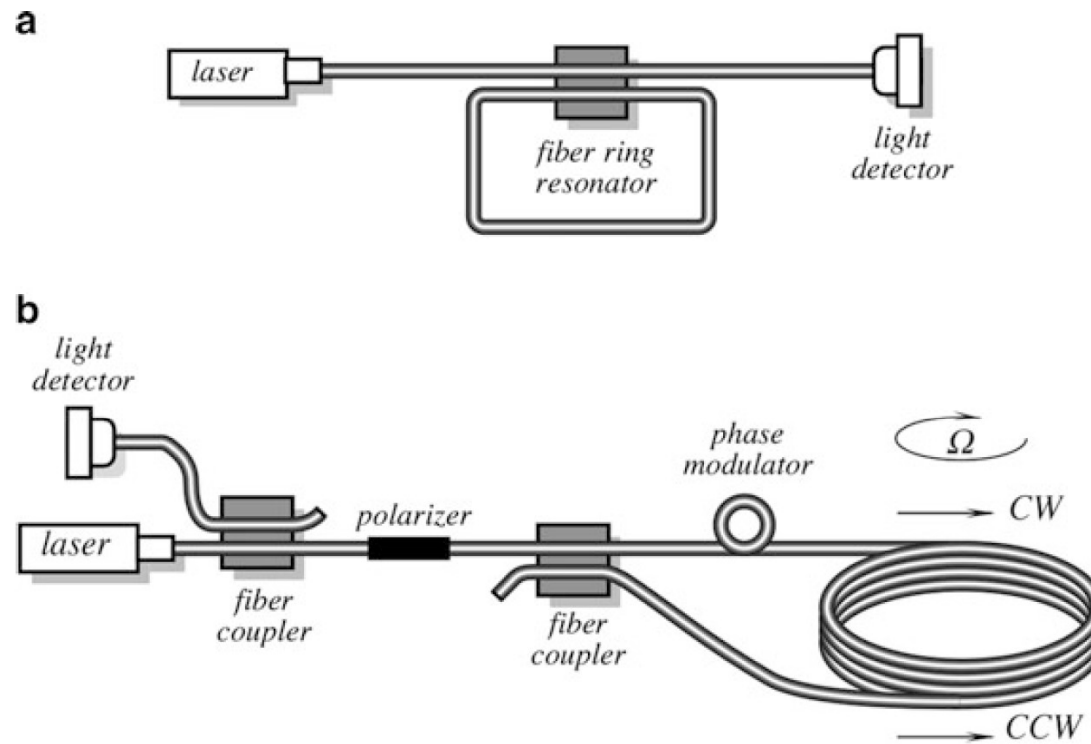


Fig. 8.12 Coriolis acceleration (a). Vibrating ring micromachined structure (b); effects of acceleration on the vibrating modes of the ring (c–f)

Optisk (laser) gyro

- Robuste – tåler tøffe omgivelser



$$l_{cw} = 2\pi R + \Omega R \Delta t$$

$$l_{ccw} = 2\pi R - \Omega R \Delta t$$

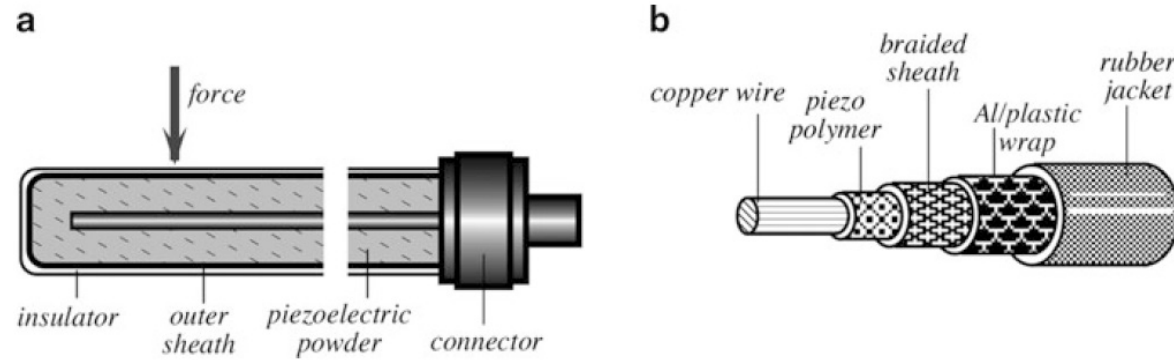
$$\Delta l = \frac{4\pi\Omega R^2}{nc}$$

$$\Delta t = 2\pi R / nc$$



Fig. 8.14 Fiber optic ring resonator (a); fiber optic analog coil gyro (b) (adapted from [9])

Piezo-elektrisk kabel



- For å måle vibrasjon

Fig. 8.15 Piezoelectric cable sensors. Construction of *Vibracoax* (a); polymer film as a voltage generating component (b) (adapted from [13])

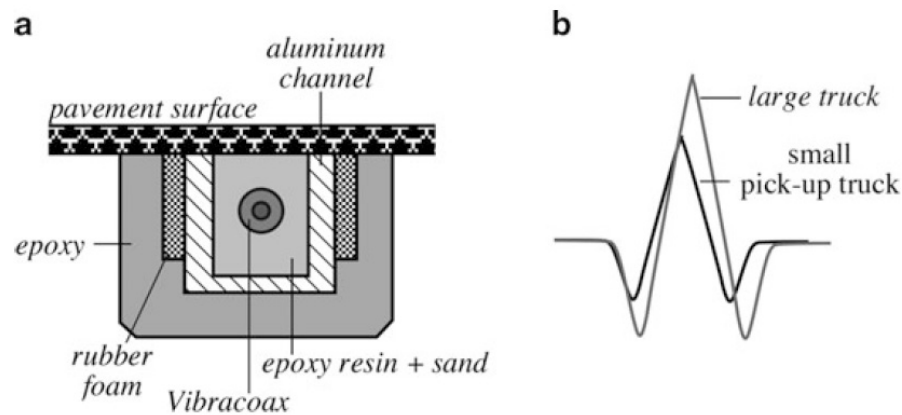


Fig. 8.16 Application of the piezoelectric cables in highway monitoring. Sensor installation in the pavement (a); shape of electrical response (b)

I vesten på TKD utøvere i OL



Gravitasjon – vinkelmålere

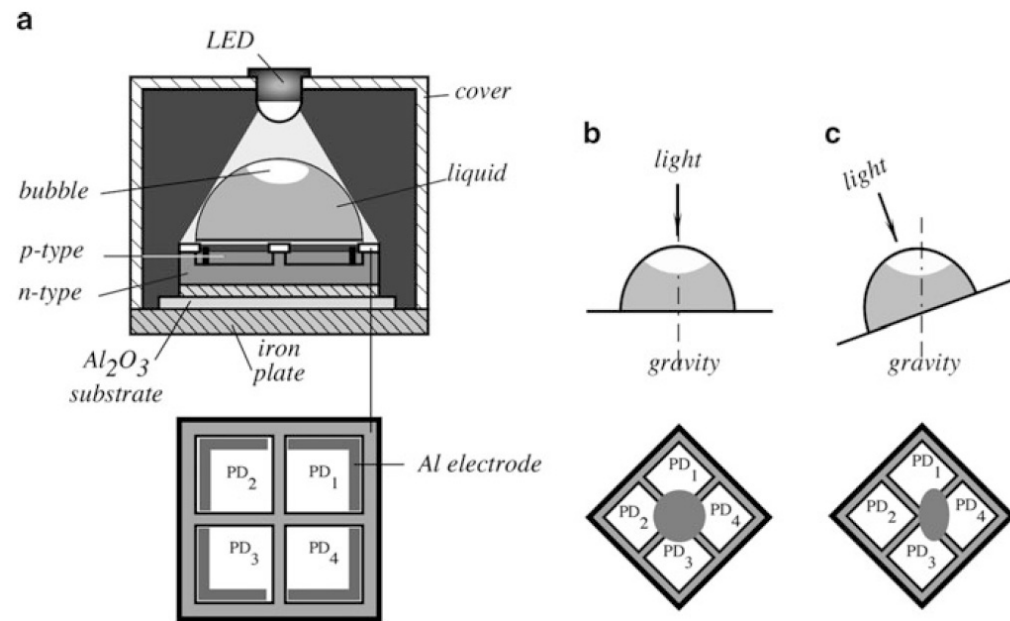


Fig. 8.19 Optoelectronic inclination sensor design (a); shadow at a horizontal position (b); shadow at the inclined position (c)

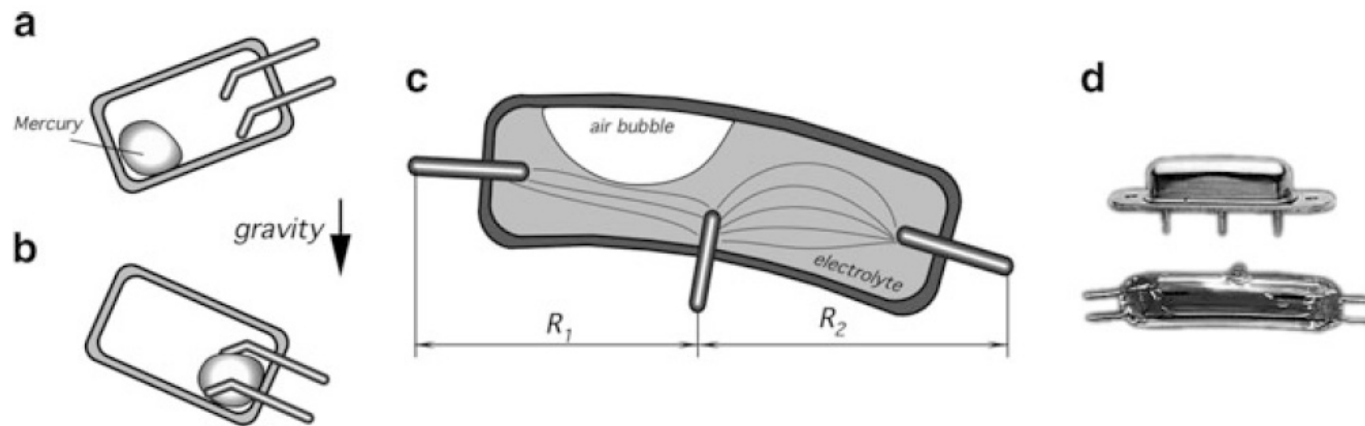


Fig. 8.18 Conductive gravitational sensors.

Mercury switch in the open position (a) and closed (b) positions; electrolytic tilt sensor (c) and electrolytic sensor housings (d)