Bab 6. Elemen Pengindera (*Sensing Element*)

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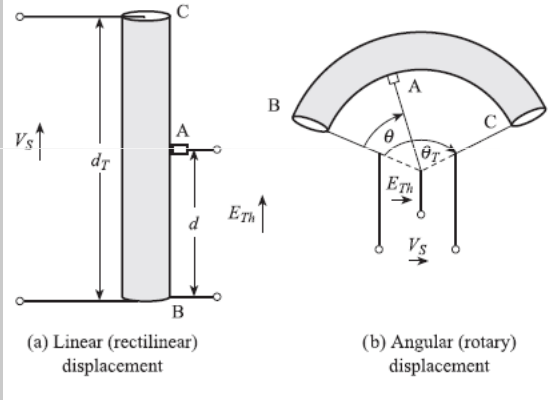
Resistive sensing elements

- Potensiometer Displacement Sensor

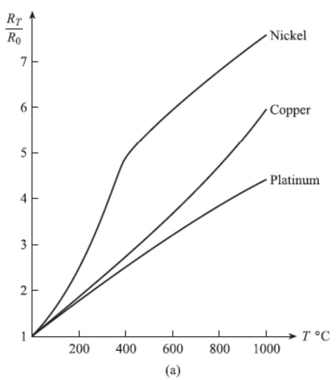


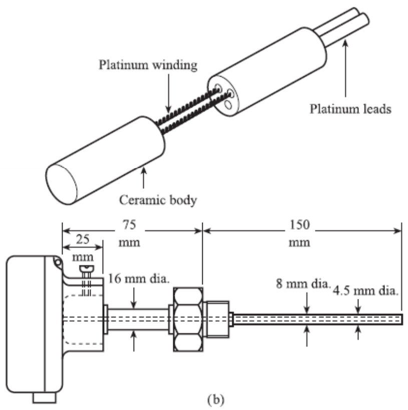
$E_{Th} = V_S x = V_S d/d_T$

$E_{Th} = V_S\theta/\theta_T = V_S x$

Resistive metal and semiconductor sensors for temperature measurement

$$R_T = R_0(1 + \alpha T + \beta T^2 + \gamma T^3 + \ldots)$$



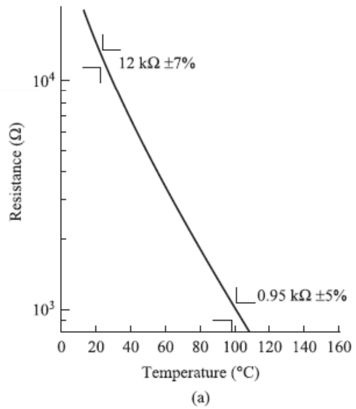


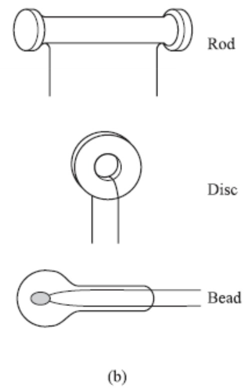
Platinum

- $R_0 = 100.0\ \Omega$, $R_{100} = 138.50\ \Omega$, $R_{200} = 175.83\ \Omega$,
- $\alpha = 3.91 \times 10^{-3}$ °C^{-1} and $\beta = -5.85 \times 10^{-7}$ °C^{-2}.

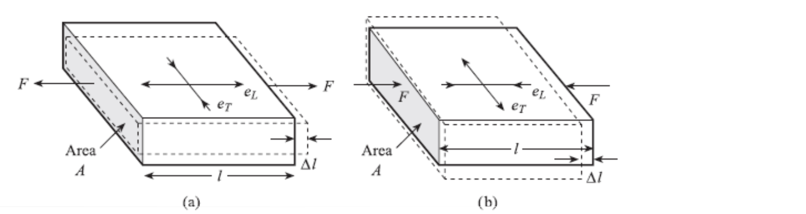
Termistor

$$R_\theta = R_{\theta_1} \exp \beta \left[\frac{1}{\theta} - \frac{1}{\theta_1}\right]$$

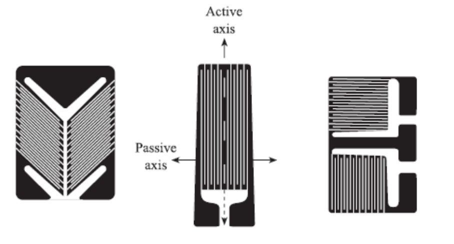




Metal and semiconductor resistive strain gauges (Piezoelectric Effect)



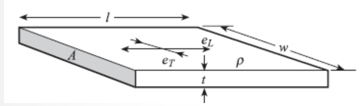
Stress and strain:
(a) Effect of tensile stress
(b) Effect of compressive stress.



Gauge factor 2.0 to 2.2
Unstrained resistance 120 ± 1 Ω
Linearity within ±0.3%
Maximum tensile strain $+2 \times 10^{-2}$
Maximum compressive strain -1×10^{-2}
Maximum operating temperature 150 °C.

Perhitungan Straingauge

$$\Delta R = \left(\frac{\partial R}{\partial l}\right)\Delta l + \left(\frac{\partial R}{\partial A}\right)\Delta A + \left(\frac{\partial R}{\partial \rho}\right)\Delta \rho$$



Gauge Factor :

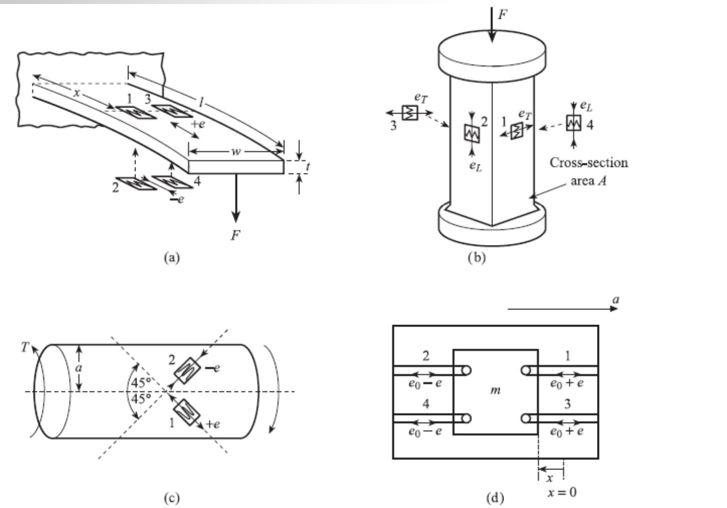
$$G = 1 + 2v + \frac{1}{e}\frac{\Delta\rho}{\rho}$$

V=poisson ratio (0,25-0,44)
e= elastisitas
ρ = tahanan dalam

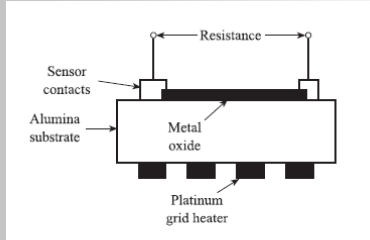
$$\frac{\Delta R}{R_0} = Ge$$

Practical elastic sensing elements using strain gauges

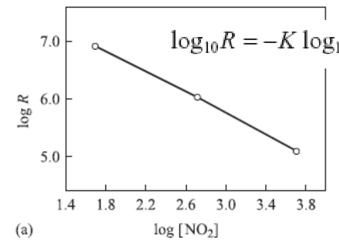
Figure 8.20 Practical elastic sensing elements using strain gauges:
(a) Cantilever load cell
(b) Pillar load cell
(c) Torque sensor
(d) Unbonded strain gauge accelerometer.



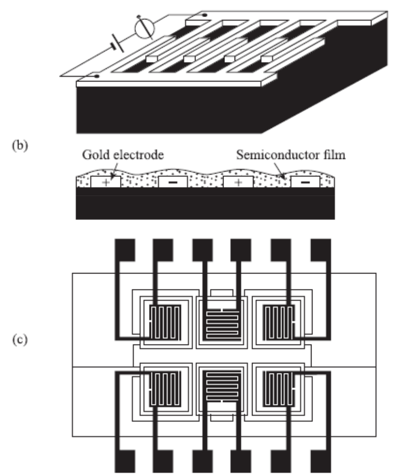
Semiconductor resistive gas sensors (HCl, NO_2, H_2S)



Untuk NO_2

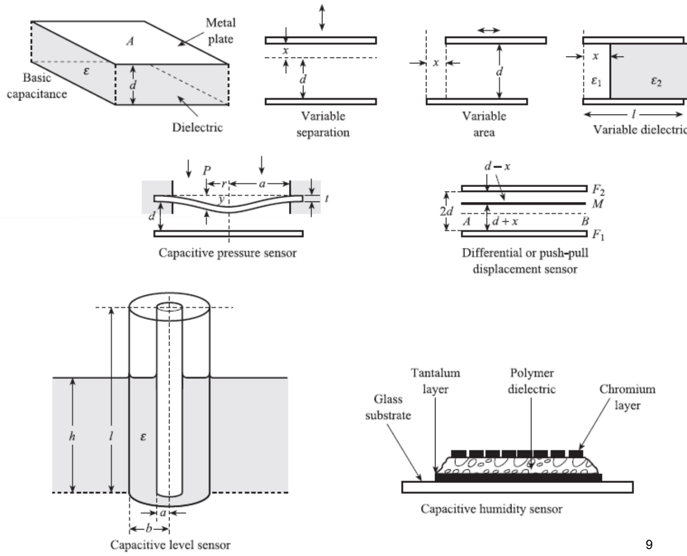


$$\log_{10} R = -K \log_{10}[NO_2] + a$$



Capacitive sensing elements

$$C = \frac{\varepsilon_0 \varepsilon A}{d}$$



Capacitive sensing elements

$$C = \frac{\varepsilon_0 \varepsilon A}{d}$$

$$C = \frac{\varepsilon_0 \varepsilon A}{d + x}$$ *Variable separation displacement sensor*

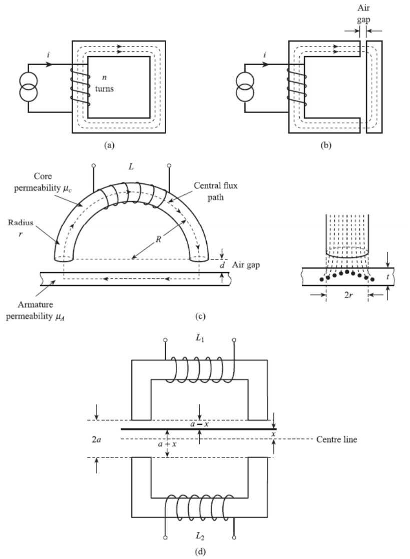
$$C = 375 + 1.7\ \mathrm{RH}\ \mathrm{pF}$$ *Capacitive Humidity sensor*

$$\frac{\Delta C}{C} = \frac{(1 - \nu^2)a^4}{16Edt^3}P$$ *Capacitive pressure sensor*

$$C_h = \frac{2\pi\varepsilon_0}{\log_e\left(\frac{b}{a}\right)}[l + (\varepsilon - 1)h]$$ *Capacitive level sensor*

Source:
John P. Bentley
Principles of Measurement System

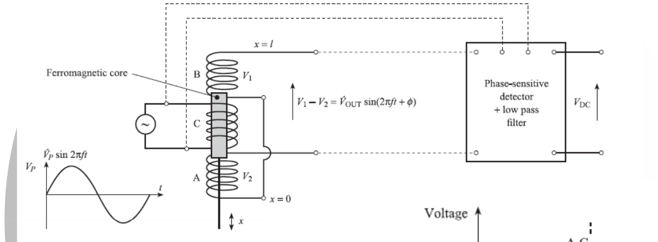
Inductive sensing elements

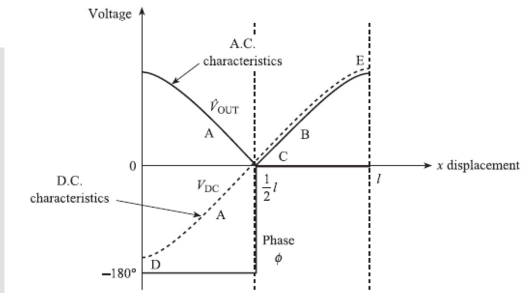


$$L = \frac{N}{i} = \frac{n^2}{\mathcal{R}}$$

L = Induktansi
N = Total Fluks
i = Arus
n = jumlah lilitan
R = Reluktansi

Linear Variable Differential Transformer (LVDT) displacement sensor





Electromagnetic sensing elements

$$E = -\frac{dN}{dt}$$

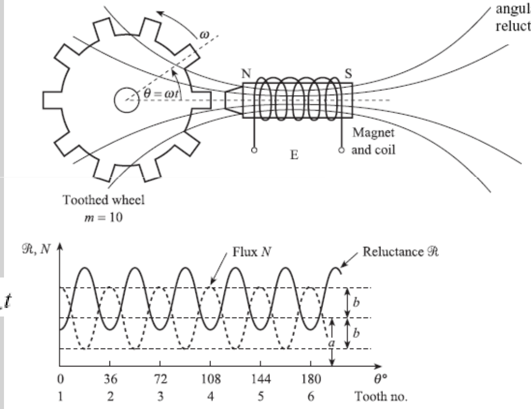


Figure 8.15 Variable reluctance tachogenerator, angular variations in reluctance and flux.

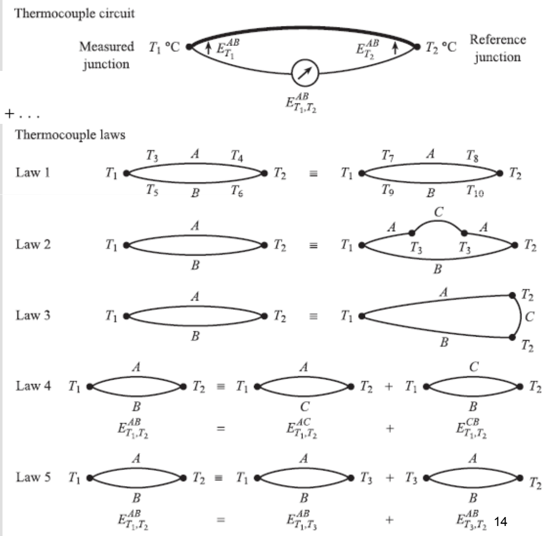
$$E = bm\omega_r \sin m\omega_r t$$

m = nomor gigi

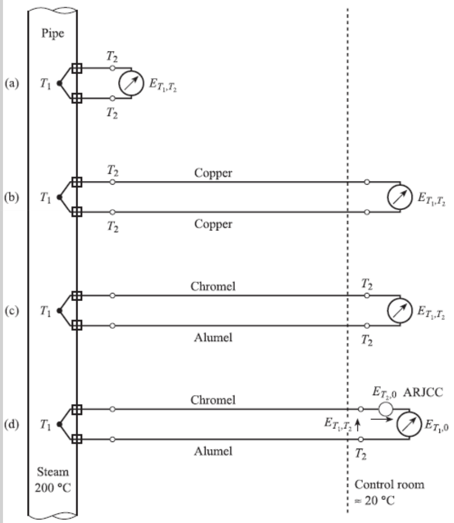
Thermoelectric sensing elements

Figure 8.16 Thermocouple principles.

$$E^{AB}_{T_1,T_2} = E^{AB}_{T_1} - E^{AB}_{T_2}$$
$$= a_1(T_1 - T_2) + a_2(T_1^2 - T_2^2) + a_3(T_1^3 - T_2^3) + \ldots$$



Termocouple Instalation



Elastic sensing elements

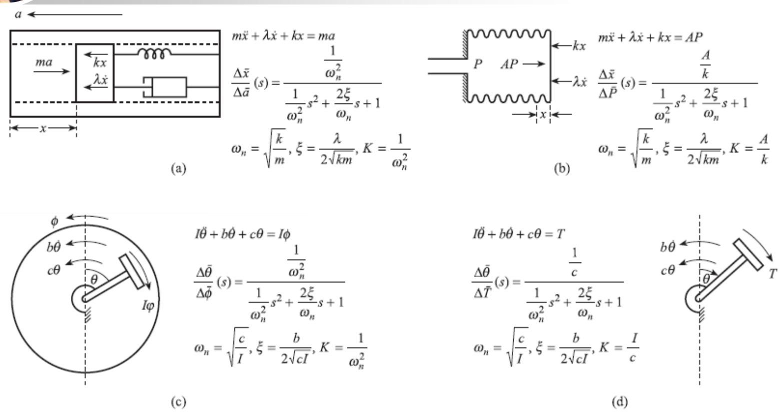
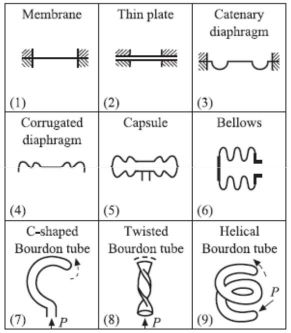
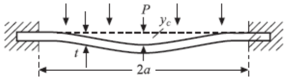


Figure 8.19 Dynamic models of elastic elements:
(a) Linear accelerometer
(b) Pressure sensor
(c) Angular accelerometer
(d) Torque sensor.



(a)



$$P = \frac{16\,Et^3}{3a^4(1-\nu^2)}\,y_c\left[1 + 0.5\left(\frac{y_c}{t}\right)^2\right]$$ Accurate steady-state relation

if $\left(\frac{y_c}{t}\right) \ll 1$ then

Steady-state sensitivity $K = \frac{y_c}{P} \approx \frac{3a^4(1-\nu^2)}{16Et^3} = \frac{1}{16t\gamma}$

and

Natural frequency $f_n = \frac{2.56}{\pi}\sqrt{\frac{Et^2}{3a^4(1-\nu^2)\rho}} = \frac{2.56}{\pi}\sqrt{\frac{\gamma}{\rho}}$ Hz

E = Young's modulus
ν = Poisson's ratio
ρ = density
$\gamma = \frac{Et^2}{3a^4(1-\nu^2)}$

(b)

Figure 8.21 Elastic pressure sensing elements:
(a) Different types (after Neubert[12])
(b) Flat circular diaphragm.

Ion selective electrodes

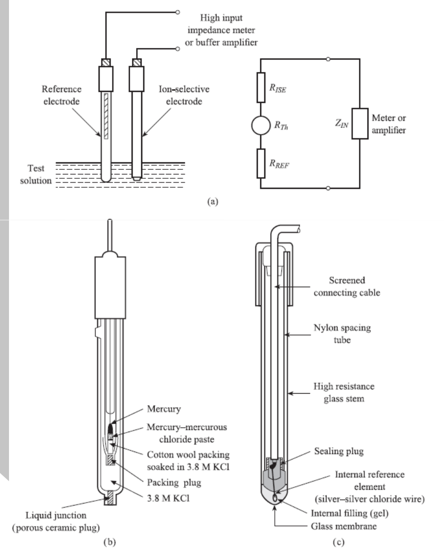


Figure 8.25
Ion-selective electrodes:
(a) Basic system for ion concentration measure and equivalent circuit
(b) Calomel reference electrode (after Bailey[17], © P. L. Bailey 1980. Reprinted by permission of John Wiley & Sons Ltd)
(c) Practical pH sensor (after Thompson[18]).