Sensor Mekanik

SISTEM PENGUKURAN

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SISTEM PENGUKURAN

SENSOR MEKANIK



SENSOR MEKANIK:

Pressure Sensors
- Mercury Pressure Sensor
- Piezoresistive Sensors
- Capacitive Sensors
- VRP Sensors
- Optoelectronic Sensors
- Vacuum Sensors
  - Pirani Gauge
  - Ionization Gauges
  - Gas Drag Gauge

Velocity and Acceleration
- Capacitive Accelerometers
- Piezoresistive Accelerometers
- Piezoelectric Accelerometers
- Thermal Accelerometers
  - Heated-Plate Accelerometer
  - Heated-Gas Accelerometer
- Gyroscopes
  - Rotor Gyroscope
  - Monolithic Silicon Gyroscopes
  - Optical Gyroscopes

Force, Strain, and Tactile Sensors
- Strain Gauges
- Tactile Sensors .
- Piezoelectric Force Sensors

SENSOR MEKANIK:

Flow Sensors
- Thermal Transport Sensors
- Ultrasonic Sensors
- Electromagnetic Sensors
- Microflow Sensors
- Breeze Sensor
- Coriolis Mass Flow Sensors
- Drag Force Flow Sensors

Acoustic Sensors
- Resistive Microphones
- Condenser Microphones
- Fiber-Optic Microphone
- Piezoelectric Microphones
- Electret Microphones
- Solid-State Acoustic Detectors

SENSOR MEKANIK:

Occupancy and Motion Detectors
- Ultrasonic Sensors
- Microwave Motion Detectors
- Capacitive Occupancy Detectors
- Triboelectric Detectors
- Optoelectronic Motion Detectors
  - Visible and Near-Infrared Light Motion Detectors & Far-IR Motion Detectors

Position, Displacement, and Level
- Potentiometric Sensors
- Gravitational Sensors
- Capacitive Sensors
- Inductive and Magnetic Sensors
  - LVDT and RVDT
  - Eddy Current Sensors & Transverse Inductive Sensor
  - Hall Effect Sensors & Magnetoresistive Sensors
- Optical Sensors
  - Optical Bridge & Proximity Detector with Polarized Light
  - Fiber-Optic Sensors & Fabry–Perot Sensors
  - Grating Sensors & Linear Optical Sensors (PSD)
- Ultrasonic Sensors
- Radar Sensors : Micropower Impulse Radar & Ground-Penetrating Radar
- Thickness and Level Sensors : Ablation & Thin-Film & Liquid-Level Sensors

SENSOR TEKANAN (PRESSURE SENSOR):

Definisi *makroskopis* Tekanan (P) = Gaya mengenai permukaan / Satuan luas

$$P = F/A$$

Definisi *mikroskopis* Tekanan (P) berdasar teori kinetik gas =
"Total energi kinetik molekul gas mengenai permukaan persatuan volume"

$$P = 2/3\ (E_k/V) = NRT$$

Ek = energi kinetik molekul gas
V = volume gas
N = jumlah molekul gas
R = konstanta gas
T = temperatur gas

Satuan tekanan (P):

1 Pa=1.45×10.4 lb/in^2 =9.869×10.6 atm=7.5×10.4 cm Hg.

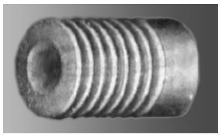
1 atm=760 torr=101,325 Pa.

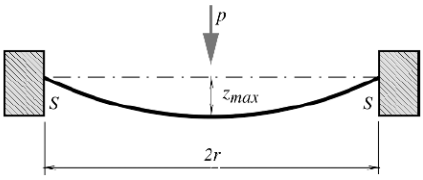
1 psi=6.89×103Pa=0.0703 atm.*(sistem US)*

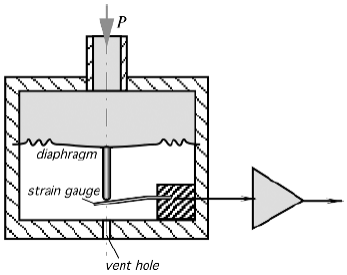
SISTEM PENGUKURAN

PRINSIP DASAR

Bellow & Membran Strain-gage Pressure Sensor



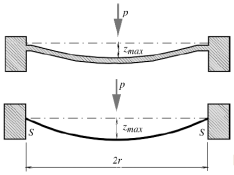




$$z_{\max} = \frac{r^2 p}{4S},$$

$$\sigma_{\max} \approx \frac{S}{g},$$

Z : defleksi
r : jari-jari membran
S : tensi pada membran
g : tebal membran
σ : stress pada membran



plat tipis

membran

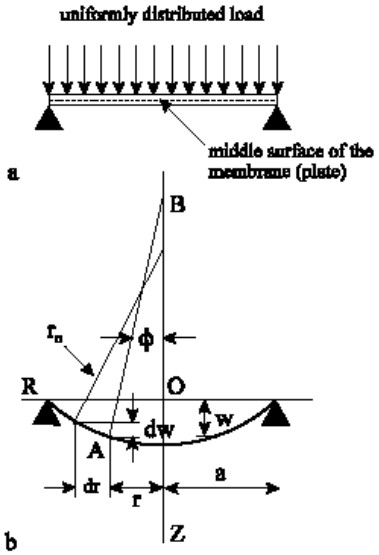
Untuk plat : $z_{\max} = \frac{3(1-v^2)r^4 p}{16Eg^3}$,

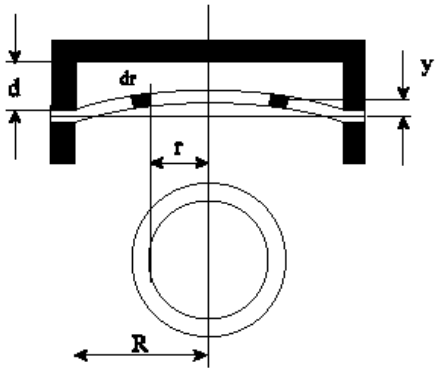
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SISTEM PENGUKURAN

PRINSIP DASAR

Membran/diaprahm Pressure Sensor





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PRINSIP DASAR

Membran/diaprahm Pressure Sensor

Defleksi yang kecil ditengah-tengah membran ➔ jari-jari membran r_n berubah

$$\frac{1}{r_n} = -\frac{\frac{d^2w}{dr^2}}{[1+(\frac{dw}{dr})^2]^{\frac{3}{2}}} \approx -\frac{d^2w}{dr^2} = \frac{d\phi}{dr}$$

Untuk $\frac{dw}{dr} < 1$ ➔ $\frac{d}{dr}[\frac{1}{r}\frac{d}{dr}(r\frac{dw}{dr})] = \frac{qr}{2D}$

dimana $\frac{1}{D} = \frac{12(1-\nu^2)}{Eh^3}$ $\qquad w = \frac{q}{64D}(a^2-r^2)^2$

$R = a,$
$y(r) = w$
$P = q$

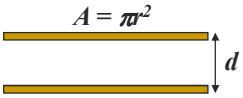
$$y(r) = P\frac{3(1-\nu^2)}{16Eh^3}(R^2-r^2)^2$$

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PRINSIP DASAR

Capacitive Transduction

Bagaimana transduksi P ➔ C ?



$$C = \varepsilon_o\varepsilon_r\frac{A}{d}$$



$$y(r) = P\frac{3(1-\nu^2)}{16Eh^3}(R^2-r^2)$$

Maka: $C = 2\pi\varepsilon_o\varepsilon_r\int_0^R \frac{r}{d-y(r)}dr = \frac{2\pi\varepsilon_o\varepsilon_r}{d}\int_0^R \frac{rdr}{1-\frac{y(r)}{d}}$

Ingat pendekatan $\frac{1}{1-x} = 1+x+\ldots \Rightarrow \frac{rdr}{1-\frac{y(r)}{d}} = \left(1+\frac{y(r)}{d}\right)rdr+\ldots$

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Capacitive Transduction

Sehingga:

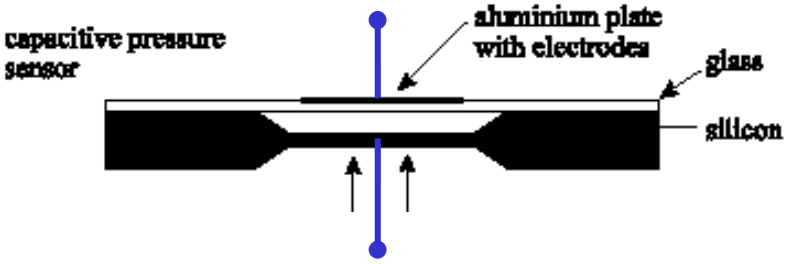
$$C = 2\pi\varepsilon_o\varepsilon_r \int_0^R \frac{rdr}{1-\frac{y(r)}{d}} = \frac{2\pi\varepsilon_o\varepsilon_r}{d}\int_0^R \left(1-\frac{y(r)}{d}\right) rdr$$

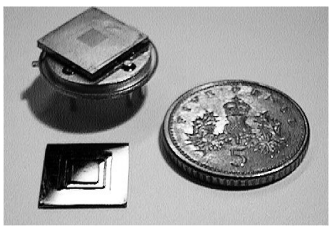
$$C = \frac{2\pi\varepsilon_o\varepsilon_r}{d}\left[\int_0^R rdr + \frac{1}{d}\int_0^R y(r)rdr\right] = \frac{2\pi\varepsilon_o\varepsilon_r}{d}\left[\frac{R^2}{2} + \frac{(1-\nu^2)R^6}{16Edh^3}P\right]$$

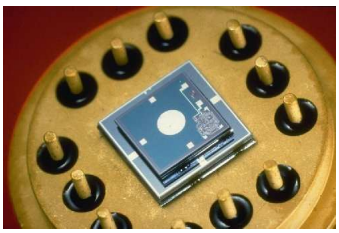
atau

$$C(P) = \frac{\pi\varepsilon_o\varepsilon_r R^2}{d} + \frac{\pi\varepsilon_o\varepsilon_r(1-\nu^2)R^6}{16Ed^2h^3}P$$

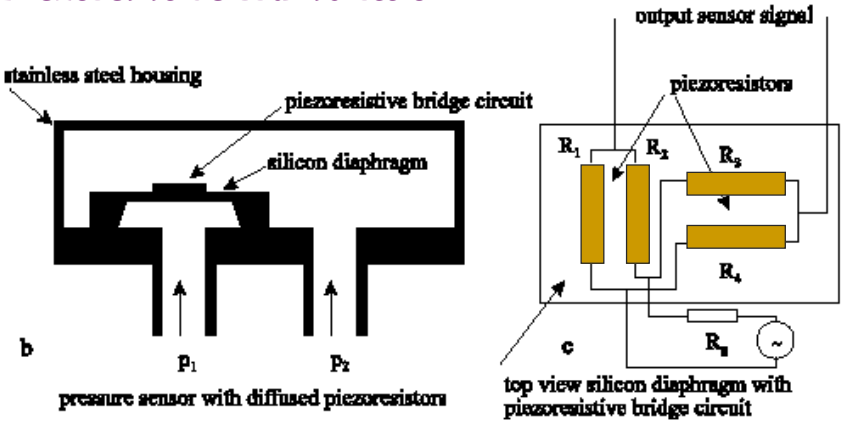
Capacitive Pressure Sensor



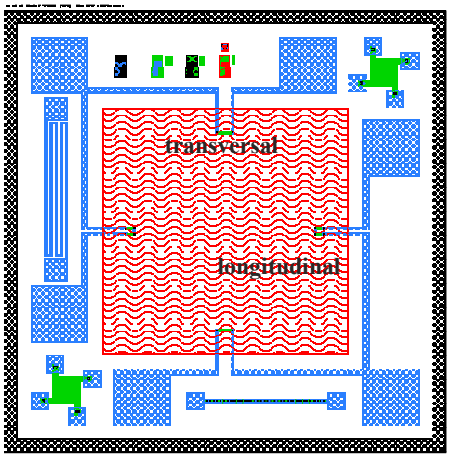




Piezoresistive Transduction



Piezoresistive Transduction



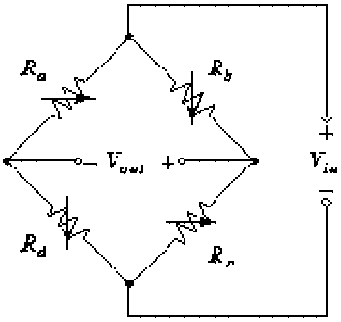
$$\left(\frac{\Delta R}{R}\right)_{||} = \pi_{||}\sigma_{||} + \pi_{\perp}\sigma_{\perp}$$

$$\left(\frac{\Delta R}{R}\right)_{\perp} = \pi_{||}\sigma_{\perp} + \pi_{\perp}\sigma_{||}$$

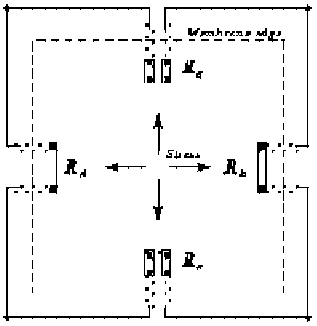
$\sigma_{\perp}$ and $\sigma_{||}$ are the perpendicular/transversal and parallel/longitudinal components of stress

$\pi_{\perp}$ and $\pi_{||}$ are the perpendicular and parallel piezoresistive coefficients

Piezoresistive Transduction - Circuit



Wheatstone Bridge circuit

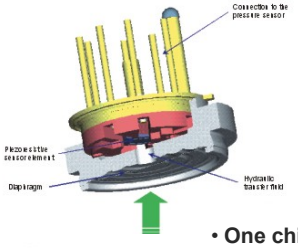


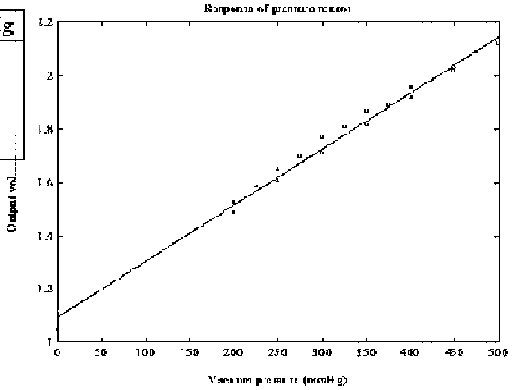
R_a & R_c // stress
R_b & R_d ⊥ stress

$$V_{out} = V_{in}\left(\frac{R_c}{R_b + R_c} - \frac{R_d}{R_a + R_d}\right).$$

Piezoresistive Transduction - Circuit

Resistor	R at STP	R at 500 mmHg
R_a	151.8	153.8
R_b	148.7	147.7
R_c	151.4	152.4
R_d	151.1	150.9







- One chip Si-Piezoresistive sensor and signal conditioning
- Pressure range: up to 5,2 bar Absolute
- Operating temperature: -40 to 125 °C
- Supply voltage: 5 V ± 0.25 V
- Transfer function: linear, ratiometric
- Accuracy over full-scale: 1 % full span (10 to 85 °C)