(1)

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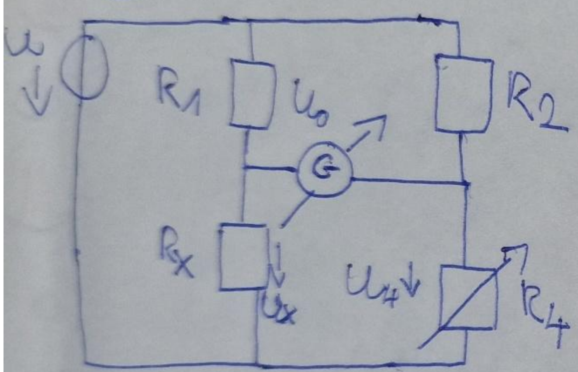


Balanced bridge

$U_0 = 0 \Rightarrow U_x - U_4 = 0$

$U_x = U_4$

$$U_0 = U\left(\frac{R_x}{R_1+R_x} - \frac{R_4}{R_2+R_4}\right) = 0$$

$$U_x = U \cdot \frac{R_x}{R_1+R_x}$$

$$U_4 = U \cdot \frac{R_4}{R_2+R_4}$$

(2)

1. Definition

A **strain gauge** is a sensor that measures **mechanical strain** (deformation) by converting it into an **electrical resistance change**.

2. Mechanical ↔ Electrical Relationship

Mechanical Input: Strain (ε) = $\Delta L / L$ (relative length change)

Electrical Output: $\Delta R / R$ = Gauge Factor (GF) × ε
where:

ΔR = Change in resistance

R = Original resistance

GF = Gauge Factor

3. Working Principle

Piezoresistive Effect: When the gauge is stretched or compressed:

Its **resistive foil/wire** deforms, altering its cross-section and length.

This changes its **electrical resistance** (ΔR).

Wheatstone Bridge Circuit: Used to measure small resistance changes accurately.

4. Applications

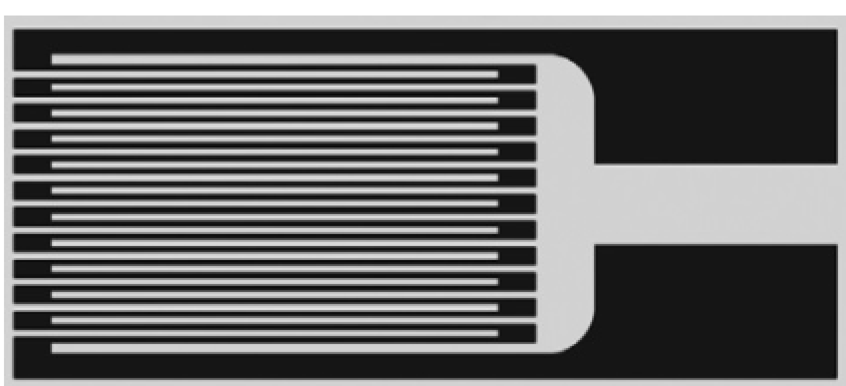
Load cells (force measurement)

Structural health monitoring (e.g., bridges, aircraft)

Pressure sensors

Key Formula:

$$\frac{\Delta R}{R} = GF \cdot \epsilon$$



(3)

③ $I_n = 3A$, $U_n = 300V$

$\cos\varphi_n = 1$, scale rate 150°, $\alpha_1 = 60^\circ$

$\alpha_2 = 72^\circ$ $p_0 = 0,2$

a) It can be used in a symmetric system without a neutral wire

$P = P_1 + P_2$

~~(A23A)~~

$P_n = U_n \cdot I_n \cdot \cos\varphi = 300 \cdot 3 \cdot 1 = 900 [W]$

$C = \frac{P_n}{\alpha_{max}} = \frac{900}{150} = 6 \left[\frac{W}{^\circ}\right]$

$P_1 = C \cdot \alpha_1 = 6 \frac{W}{^\circ} \cdot 60^\circ = 360 [W]$
$P_2 = C \cdot \alpha_2 = 6 \frac{W}{^\circ} \cdot 72^\circ = 432 [W]$ } $792 [W]$

$k_{P1} = \frac{P_1}{P_1 + P_2} = \frac{360}{792} = 0,45$

$k_{P2} = \frac{P_2}{P_1 + P_2} = 0,545$

$\delta_{P1} = \frac{P_n}{P_1} \cdot p_0 = \frac{900}{360} \cdot 0,2 = 0,5$

$\delta_{P2} = \frac{P_n}{P_2} \cdot p_0 = \frac{900}{432} \cdot 0,2 = 0,42$

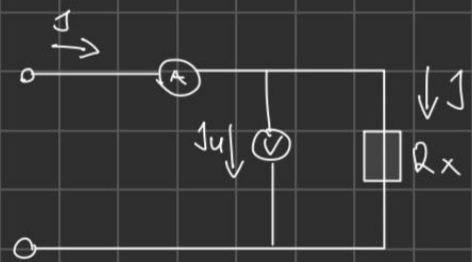
$\delta_P = \sqrt{(k_{P1} \cdot \delta_{P1})^2 + (k_{P2} \cdot \delta_{P2})^2} =$
$= \sqrt{(0,45 \cdot 0,5)^2 + (0,545 \cdot 0,42)^2}$
$= 0,32\%$

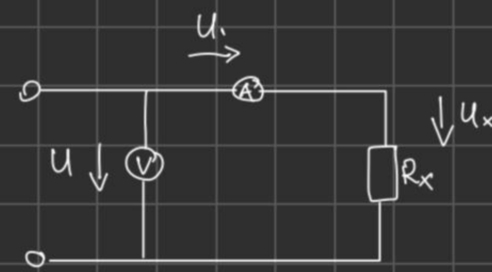
$Q = \sqrt{3}(P_2 - P_1) = \sqrt{3}(432 - 360) =$
$= 124,7 [VAr]$

$S = \sqrt{P^2 + Q^2} = \sqrt{792^2 + 124,7^2} = 801,76 [VA]$

(4)

$I = 0{,}8$; $U = 24$; $R_u = 2000$; $U_{mk} = 50$; $I_{mk} = 1{,}5$; $h_{po} = 0{,}5$; $R_J = 0{,}5$





1. **We calculate it in volts (V)**

a) $$I = \frac{U}{R_u} + \frac{U}{R_x}$$

$$0{,}8 = \frac{24}{2000} + \frac{24}{R_x}$$

$$0{,}8 = 0{,}012 + \frac{24}{R_x}$$

$$0{,}788 = \frac{24}{R_x}$$

$$R_x = 30{,}45\ \Omega$$

b) $$h = \frac{U_{mk}}{U} \cdot h_{po}$$

$$h = \frac{50V}{24V} \cdot 0{,}5$$

$$h = 1{,}04\%$$

2. **We calculate it in ampere (A)**

a) $$R_x = \frac{U}{I} - R_1$$

$$R_x = \frac{24}{0{,}8} - 0{,}5$$

$$R_x = 29{,}5\ \Omega$$

b) $$h = \frac{I_{mk}}{I} \cdot h_{po}$$

$$h = \frac{1{,}5A}{0{,}8A} \cdot 0{,}5$$

$$h = 0{,}9375\%$$

The ammeter has a smaller measurement error.

(5)

a) $h = \frac{U_{mh}}{U_m} \cdot h_{po} = \frac{10V}{3V} \cdot 0{,}5 = 1{,}66\%$

b) $h = \frac{U_{mh}}{U_m} \cdot h_{p_0} = \frac{5}{3} \cdot 1{,}5 = 2{,}5\%$

c) $U_{mh} = 20V \longrightarrow \left.\begin{matrix} 19{,}99 \\ 19{,}97 \end{matrix}\right\}$ 2 digit = 0,02

0,2% 2D

$(19{,}99 \cdot 0{,}002) + 0{,}02 = 0{,}06$

U(measured)

$x_h = 3 - 0{,}06 = 2{,}94V$

U(measured) Absolute error

$H = X_m - x_h = 3 - 2{,}94 = 0{,}06$

Relative error

Deviation

$h = \frac{H}{x_h} = \frac{0{,}06}{2{,}94} = 0{,}02 = 2\%$

(6)

a) **Period (T), Phase angle difference or Phase shift, Frequency**

b) $\sin\varphi = \frac{X_m}{X} = \frac{4,5}{5} = 0,9^\circ \quad / \sin^{-1}$

$\varphi = \underline{\underline{64,16^\circ}}$