

MEMS Inteligentné senzory a aktuátory

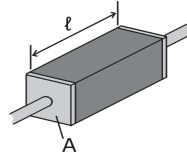
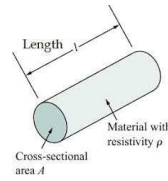
Ing. Richard Balogh

Odporové snímače



Elektrický odpor

$$R = \rho \frac{l}{A}$$



Závislosť od

1. geometrické rozmery
2. teploty

$$R = R_0(1 + \alpha \Delta t)$$

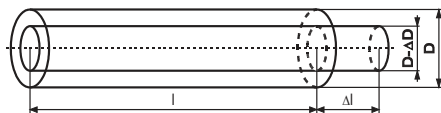
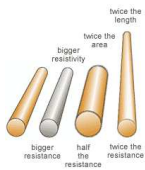
kovy: PTC

polovodiče a oxidy: NTC

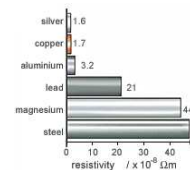
$$l = l_0(1 + \gamma \Delta t)$$

3. piezorezistívny jav
4. vlhkosť

Elektrický odpor

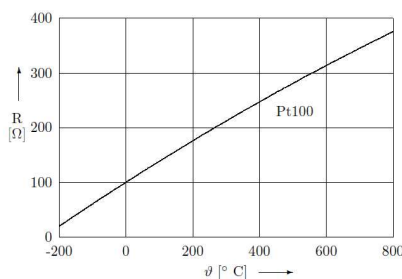


Elektrický odpor - tabuľky

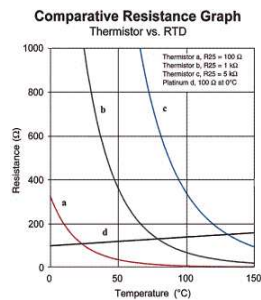


- ◆ Strain Gages: 120Ω, 350Ω, 3500Ω
- ◆ Weigh-Scale Load Cells: 350Ω - 3500Ω
- ◆ Pressure Sensors: 350Ω - 3500Ω
- ◆ Relative Humidity: 100kΩ - 10MΩ
- ◆ Resistance Temperature Devices (RTDs): 100Ω, 1000Ω
- ◆ Thermistors: 100Ω - 10MΩ

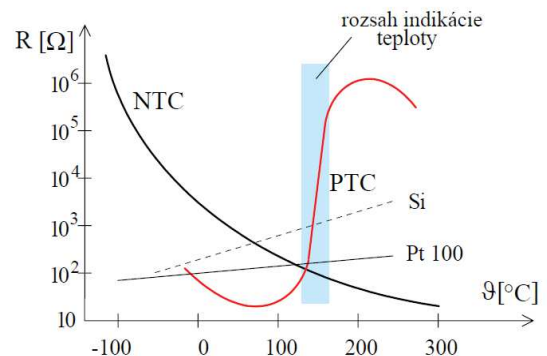
Elektrický odpor Závislosť od teploty



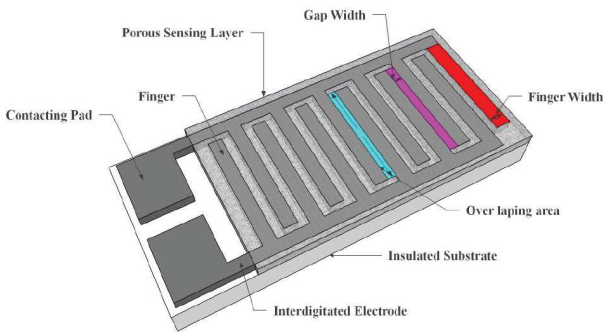
Obr. 33: Prevodová charakteristika Pt100.



Elektrický odpor Závislosť od teploty



Elektrický odpor Závislosť od vlhkosti



Elektrický odpor Závislosť od deformácie

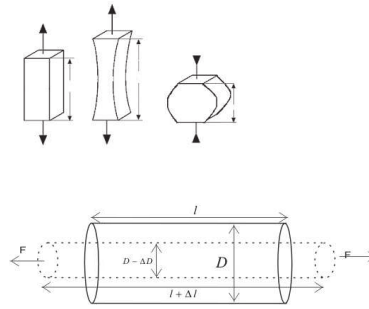


Figure 4.

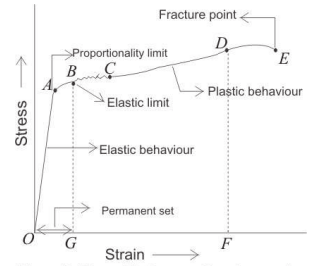
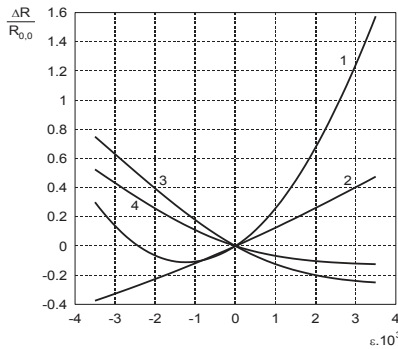


Figure 5. Stress-Strain curve for a bar or wire

Elektrický odpor Závislosť od deformácie



Závislosť relatívnej zmeny odporu od relatívnej deformácie pre kremík:

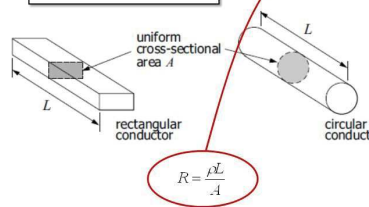
- (1) P-typ s $\rho > 10^{-3} \Omega\text{m}$
- (2) P-typ s $\rho = 2 \cdot 10^{-4} \Omega\text{m}$
- (3) N-typ s $\rho > 10^{-3} \Omega\text{m}$
- (4) N-typ s $\rho = 3,1 \cdot 10^{-4} \Omega\text{m}$

Elektrický odpor

Gage factors and the piezoresistive effect

What is the relation between deformation and resistance?

$$\text{Gage factor: } F = \frac{\Delta R/R}{\epsilon_L}$$



$$\Delta R = \frac{\partial R}{\partial \rho} \Delta \rho + \frac{\partial R}{\partial L} \Delta L + \frac{\partial R}{\partial A} \Delta A + \text{higher order terms}$$

$$\frac{\Delta R}{R} = \frac{\Delta \rho}{\rho} + \frac{\Delta L}{L} - \frac{\Delta A}{A}$$

Metals	Semiconductors
Changes in geometry dominate	Changes in resistivity dominate
$\frac{\Delta R}{R} = \frac{\Delta L}{L} - \frac{\Delta A}{A}$	$\frac{\Delta R}{R} = \frac{\Delta \rho}{\rho}^*$

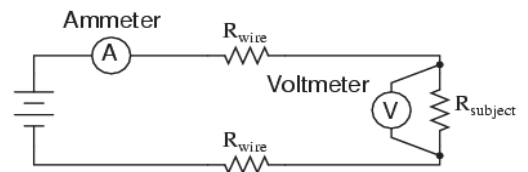
* Strain causes differences in atomic spacing, which in turn causes changes in band gaps and thus ρ .

Meranie odporu

- meranie U a I
- meranie U (konšt. I)
- prevod na frekvenciu
- mostíkové zapojenia

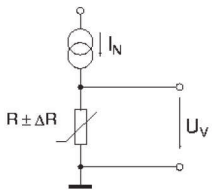


Meranie odporu Meranie napätia a prúdu

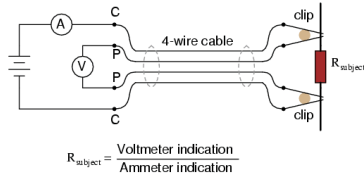


$$R_{\text{subject}} = \frac{\text{Voltmeter indication}}{\text{Ammeter indication}}$$

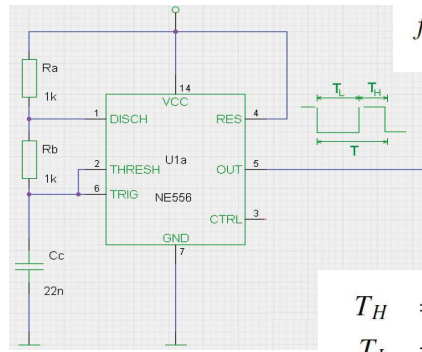
Meranie odporu Meranie napätia



$$U_v = I_N (R \pm \Delta R)$$



Meranie odporu Prevod na frekvenciu

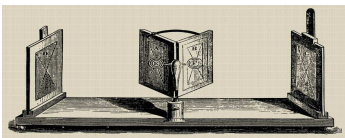


$$f = \frac{1,429}{C_c(R_a + 2R_b)}$$

$$T_H = 0,7(R_a + R_b)C_c$$

$$T_L = 0,7R_b C_c$$

Mostíkové zapojenia Wheatstonov mostík



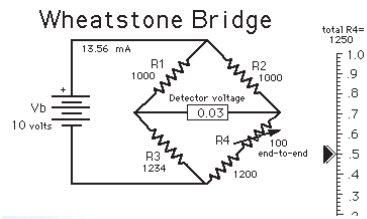
Charles Wheatstone
(1802-75)



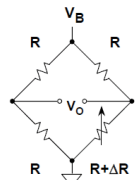
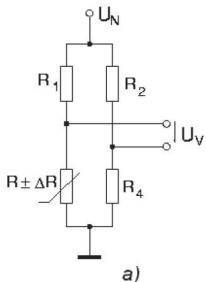
Mostíkové zapojenia Wheatstonov mostík The Differential Resistance Measurer



Samuel Hunter Christie



Meranie odporu Mostíkové zapojenia



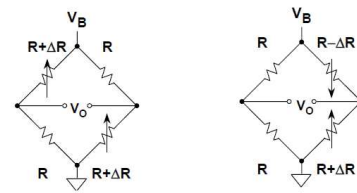
$$V_o = \frac{V_B}{4} \left[\frac{\Delta R}{R + \frac{\Delta R}{2}} \right]$$

Linearity Error: 0.5%/%

(A) Single-Element Varying

$$U_v = U_N \left(\frac{R \pm \Delta R}{2R \pm \Delta R} - \frac{1}{2} \right)$$

Meranie odporu Mostíkové zapojenia



$$\frac{V_B}{2} \left[\frac{\Delta R}{R + \frac{\Delta R}{2}} \right]$$

0.5%/%

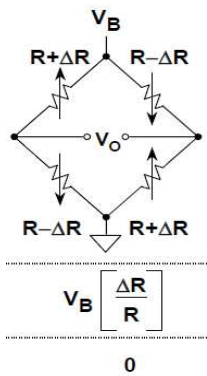
(B) Two-Element Varying (1)

$$\frac{V_B}{2} \left[\frac{\Delta R}{R} \right]$$

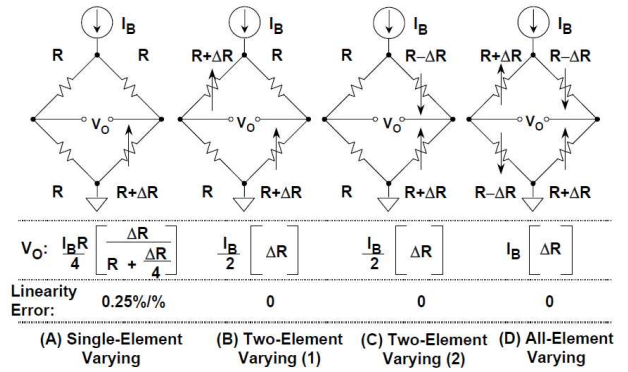
0

(C) Two-Element Varying (2)

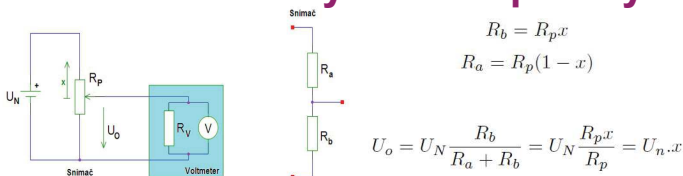
Meranie odporu Mostíkové zapojenia



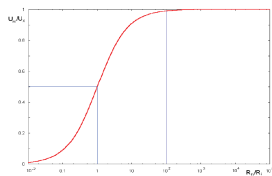
Meranie odporu Mostíkové zapojenia



Meranie odporu Potenciometrický snímač polohy



Obr. 1. Lineárny potenciometrický snímač.



Obr. 2. Impedancné prispôsobenie zosilňovača.

Meranie odporu Mostíkové zapojenia - vyhodnotenie

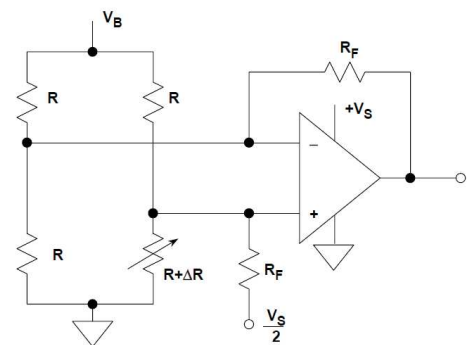


Figure 4-9: Using a single op amp as a bridge amplifier

Meranie odporu Mostíkové zapojenia - vyhodnotenie

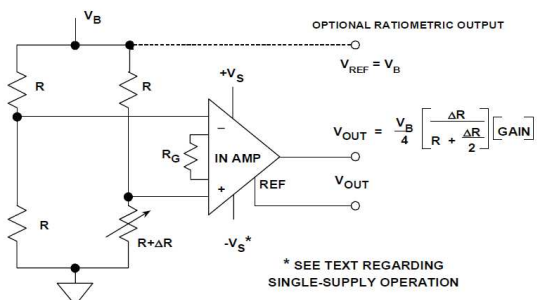
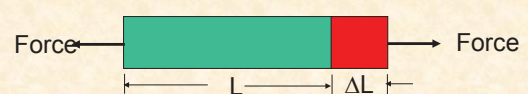


Figure 4-10: A generally preferred method of bridge amplification employs an instrumentation amplifier for stable gain and high CMR

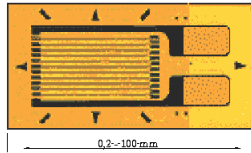
Tenzometer Strain Gauge

Definition of strain, ϵ

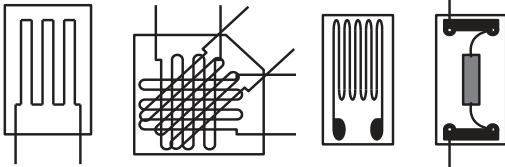


$$\epsilon = \frac{\Delta L}{L}$$

Tenzometre



a



Tenzometre

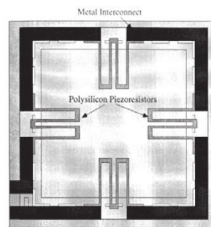
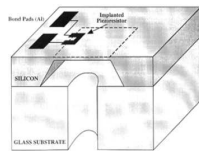
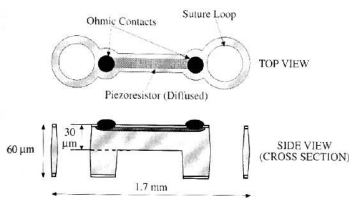
Tab.1 Prehľad vlastností nalepených tenzometrov

Tenzometre	Fólové	Polovodičový	
Typ	KFC-2-D1-23 (R_{SC})	KFC-5-350-C1-23 (R_{SA}, R_{SB}, R_{SE})	KSP-2-E3 (R_{SD})
Odpor R [Ω]	119.9±0.4	350±0.6	110±2%
Súčiniteľ deformácie citlivosti K	2.11	2.1±1%	124±3%
Teplotný súčiniteľ deformácie citlivosti $\alpha_{d,0}$ [$1/^\circ C$]	≈ 0	≈ 0	0.14%
Teplotný súčiniteľ elektrického odporu $\alpha_{R,0}$ [$\mu m/m/^\circ C$, tj. $^\circ C$]	1.8	1.8	13.8
Súčiniteľ teplotnej rozťažnosti materiálu tenzometra α_s [$\mu m/m/^\circ C$]	≈ 0	≈ 0	7±22
Výrobca	Kyowa Tokyo	Kyowa Tokyo	Kyowa Tokyo
Max. relatívne predĺženie ϵ [$\mu m/m$]	±3000	±3000	±2000
Dĺžka aktívnej mriežky [mm]	2	5	2
Poznámka	tepelná kompenzácia pre namáhaný materiál-hliník (23 $\mu m/m/^\circ C$)	tepelná kompenzácia pre namáhaný materiál-hliník (23 $\mu m/m/^\circ C$)	

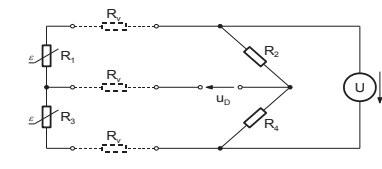
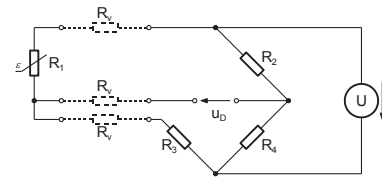
Membrane type gauges: typical pressure sensor

MEMS Tenzometre

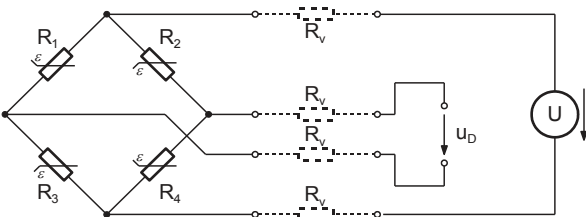
Implantable strain gauge



Tenzometre



Tenzometre



Využitie tenzometrov Sila

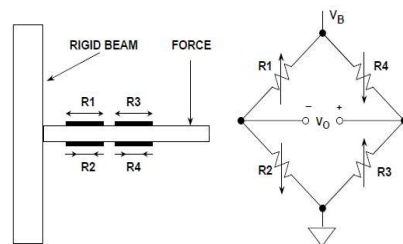


Figure 3.83: A beam force sensor using a strain gage bridge

Využitie tenzometrov

Váženie

