Corso di Laurea Magistrale in Informatica

Corso di Robotica

Sensori per la robotica

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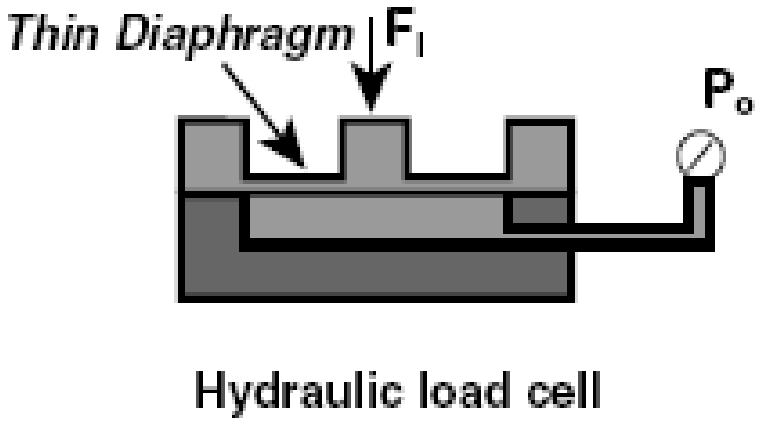
Sensori di forza

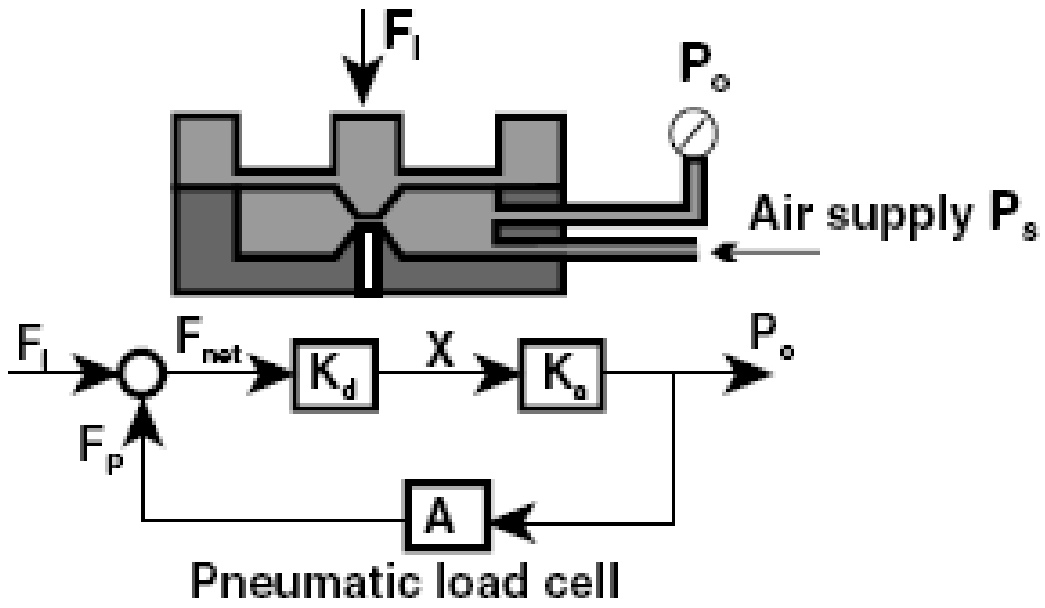
Strain gauge e sensori di forza/coppia

Strutture a celle di carico

- Struttura esterna rigida
- Mezzo per misurare la forza applicata
- Elemento misuratore



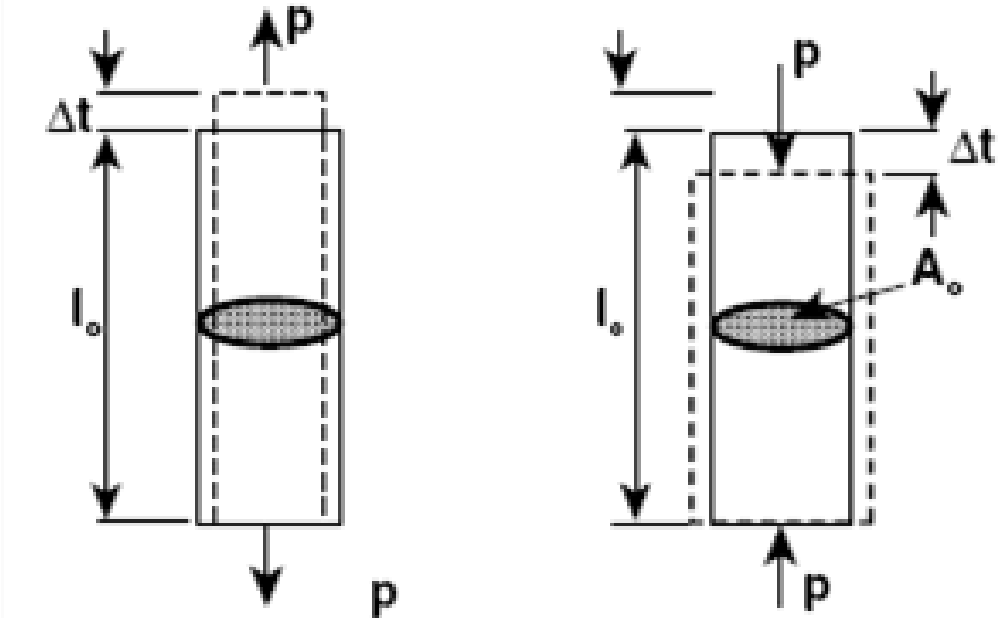
Hydraulic load cell



Pneumatic load cell

Richiami di comportamento meccanico dei materiali

Un materiale sottoposto a uno sforzo si deforma con comportamento elastico fino a una soglia dello sforzo (limite elastico), oltre la quale si deforma plasticamente



sforzo

$$\sigma = {p}/{A_0}$$

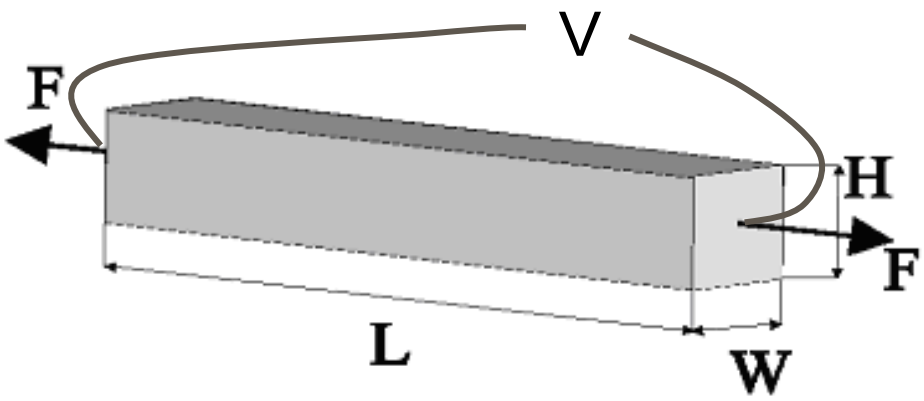
deformazione

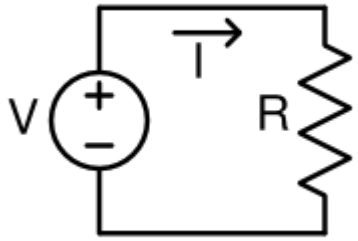
$$\varepsilon = {\Delta l}/{l_0}$$

Rapporto di Poisson: $\nu = -\dfrac{{\delta A}/{A_0}}{\varepsilon}$ Modulo di elasticità: $E = \dfrac{\sigma}{\varepsilon}$

Effetto piezoresistivo

Ogni materiale varia la propria resistenza elettrica in funzione della **deformazione**





V=RI

In un parallelepipedo metallico: $R = \rho \frac{L}{WH}$

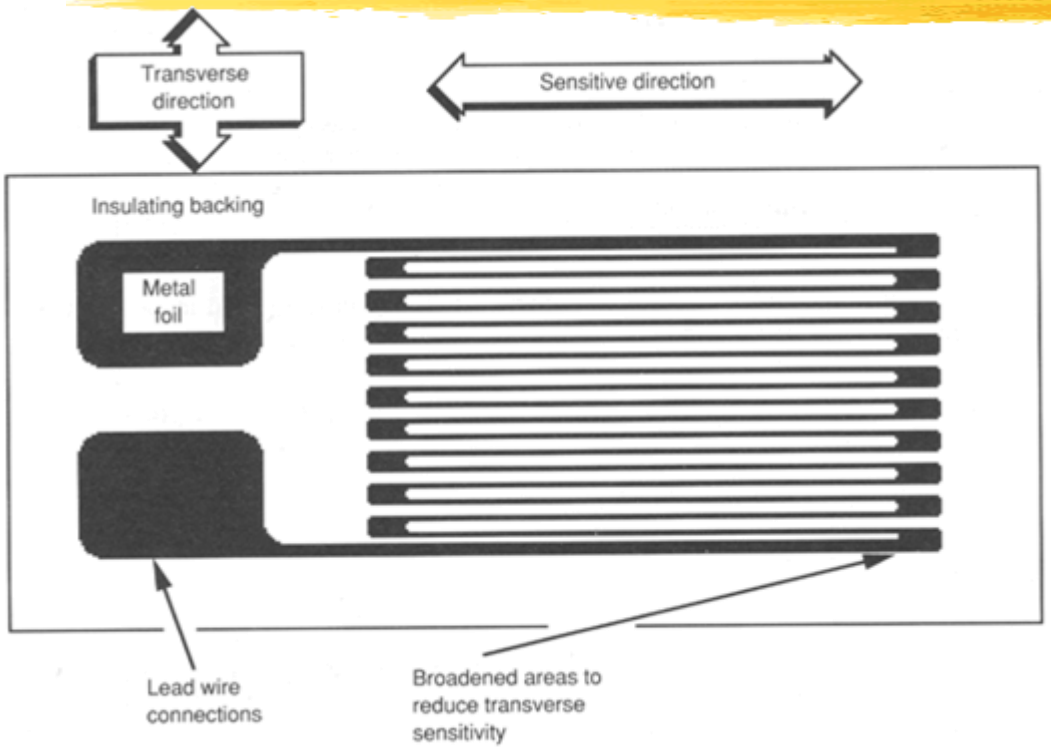
con ρ = resistività del materiale,

L, W, H = dimensioni del parallelepipedo

$$\frac{\Delta R}{R} = \varepsilon + 2\nu\varepsilon + \frac{\Delta\rho}{\rho}$$

v = rapporto di Poisson del materiale

Strain gauge

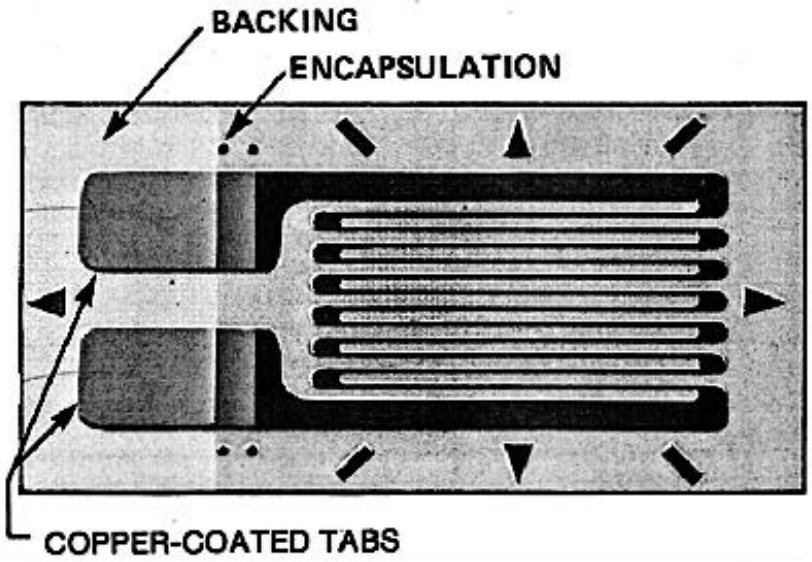


La forma del sensore serve a renderlo più sensibile in una direzione che nell'altra

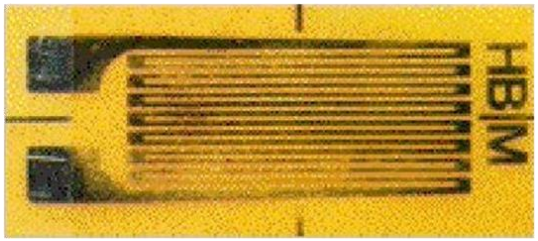
Fattore di Gauge: $$G = \frac{\Delta R/R}{\varepsilon} = 1 + 2\nu + \frac{\Delta\rho/\rho}{\varepsilon}$$

v = rapporto di Poisson del materiale

Strain gauges



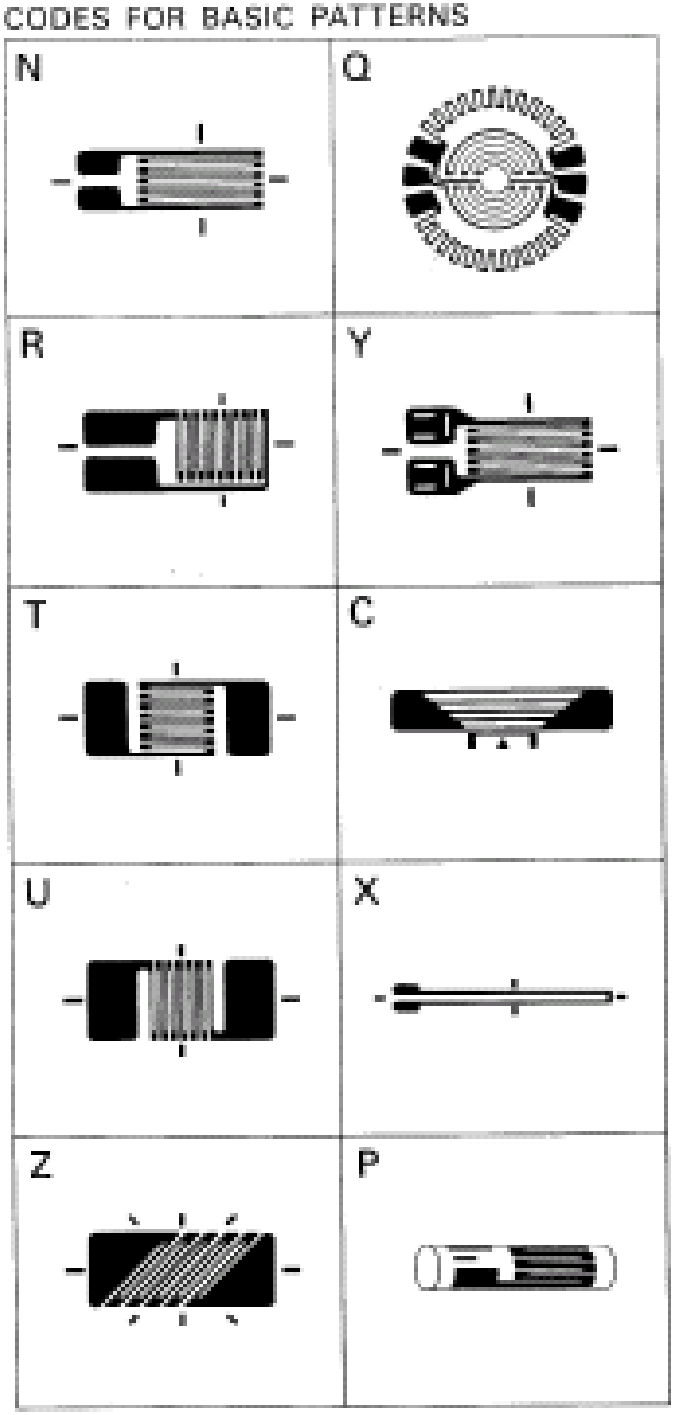
10 mm



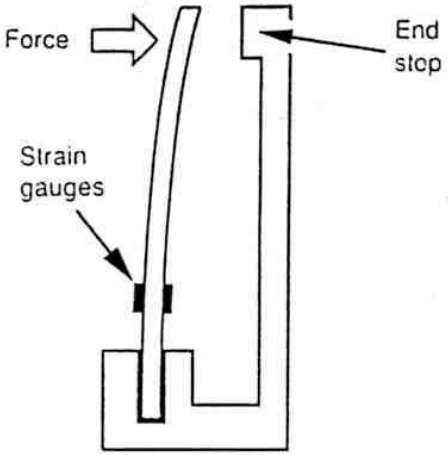
principal measurement axis

$$\text{Gauge-Factor} = GF = \frac{\Delta R/R}{\Delta L/L}$$ strain ε

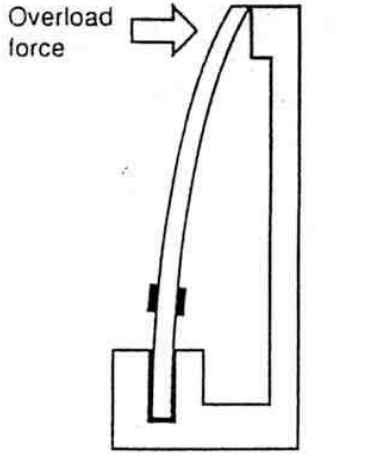
(typically ≈ 2. i.e., small sensitivity)



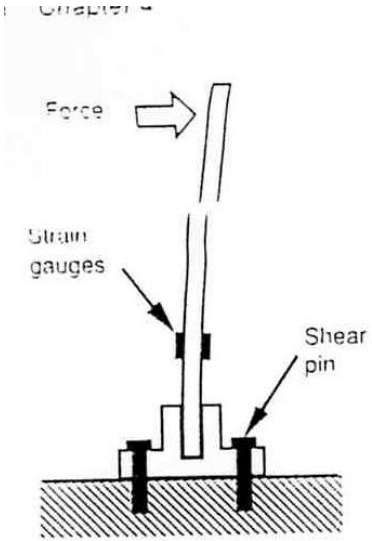
Sensori che usano strain gauge



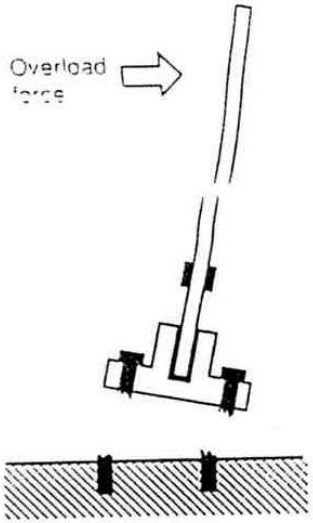
(a) Small applied force



(b) Overload force applied

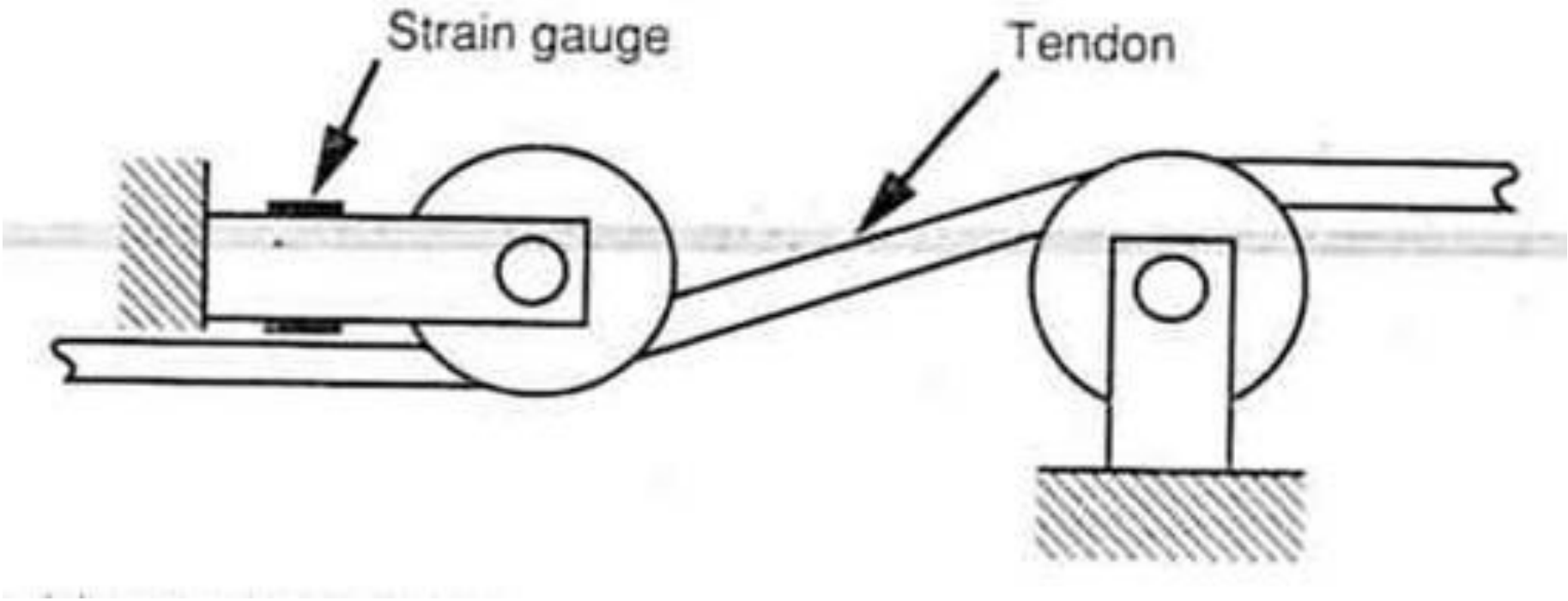


(a) Small applied force

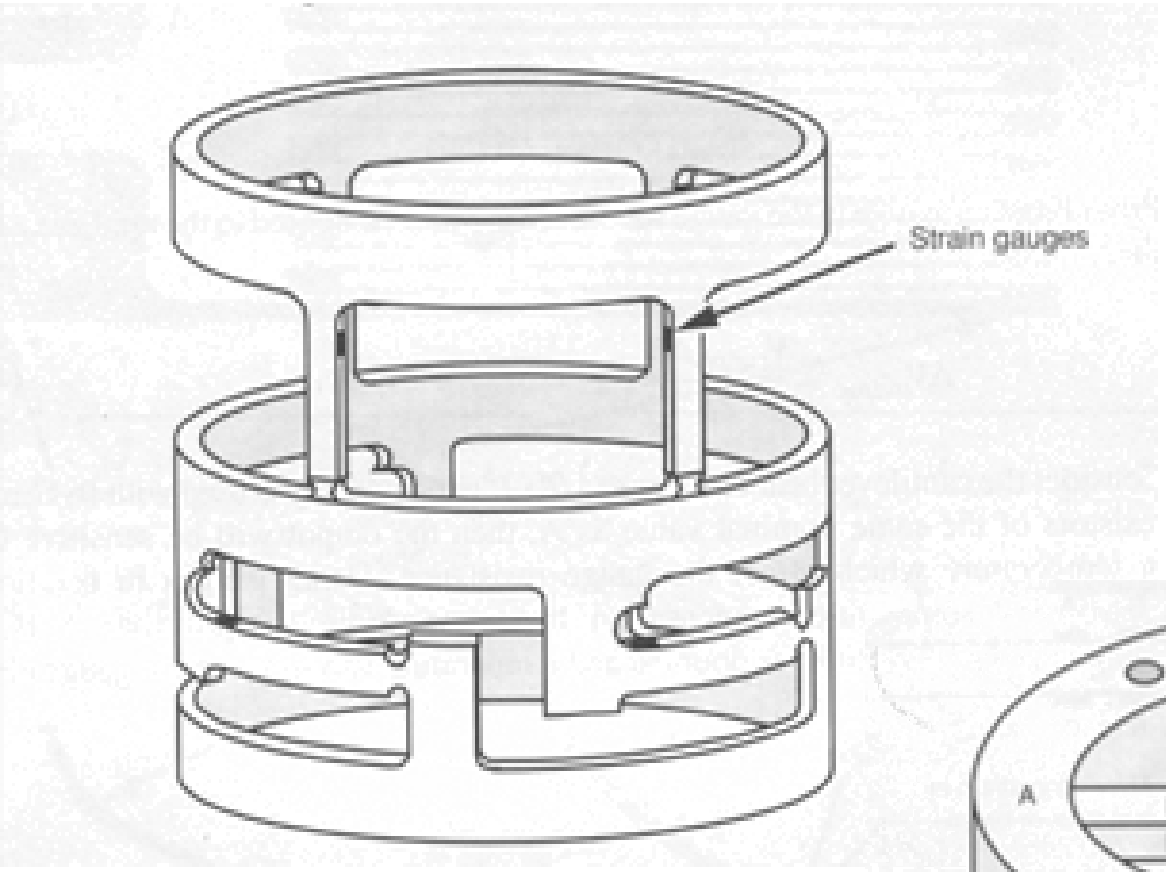


(b) Overload force applied

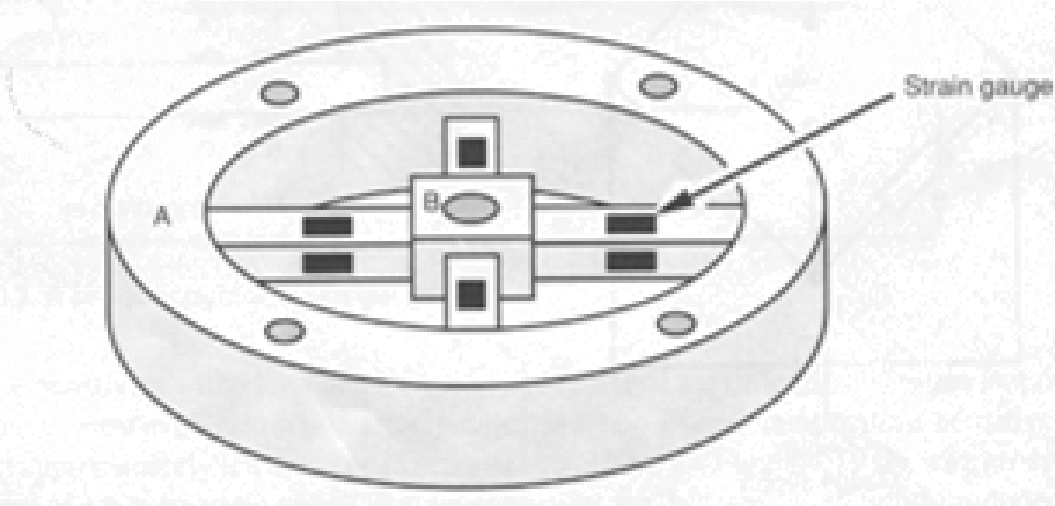
Cable tension sensor



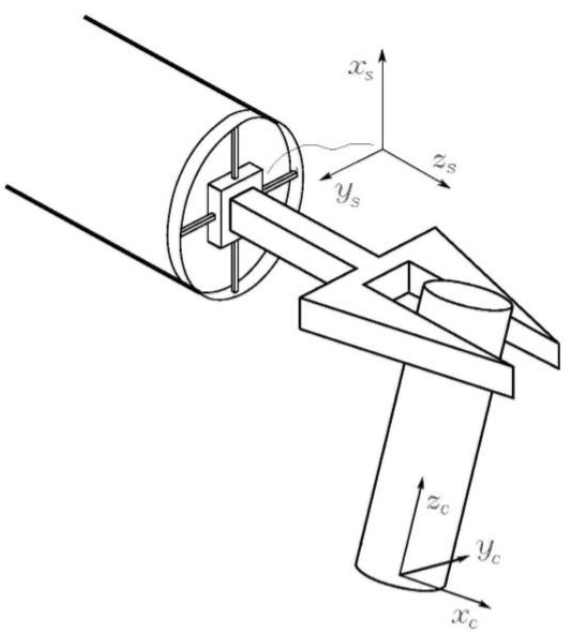
Sensori di forza/coppia a 3 componenti

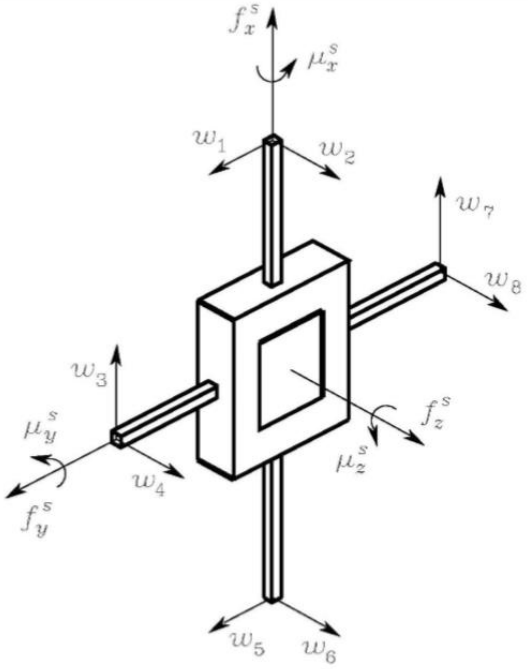


- Strutture meccaniche con direzioni di deformazione preferenziali, date da indebolimenti, su 3 assi
- Strain gauge disposti sugli indebolimenti



Sensore triassiale di forza/coppia a croce di Malta

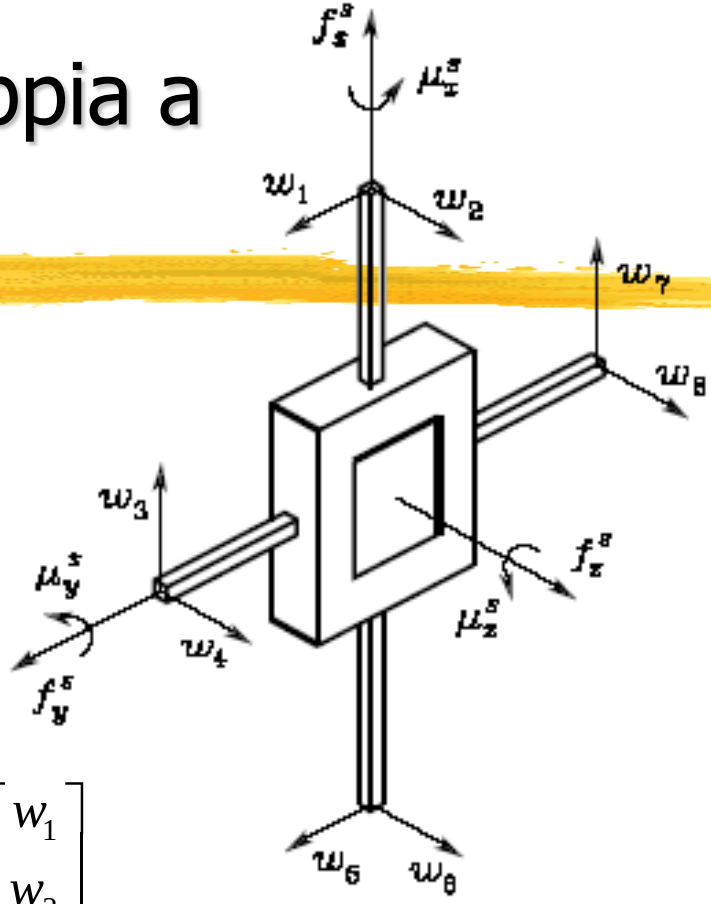




- diameter ≈ 10 cm
- height ≈ 5 cm
- 50÷500 N (resolution 0.1%)
- 5÷70 Nm (resolution 0.05%)
- sample frequency ≈ 1 KHz

- 4 deformable elements
- two pair of strain gauges are mounted on opposite sides of each element (8 pairs)
- the two gauges of each pair are placed adjacent on the same Wheatstone bridge

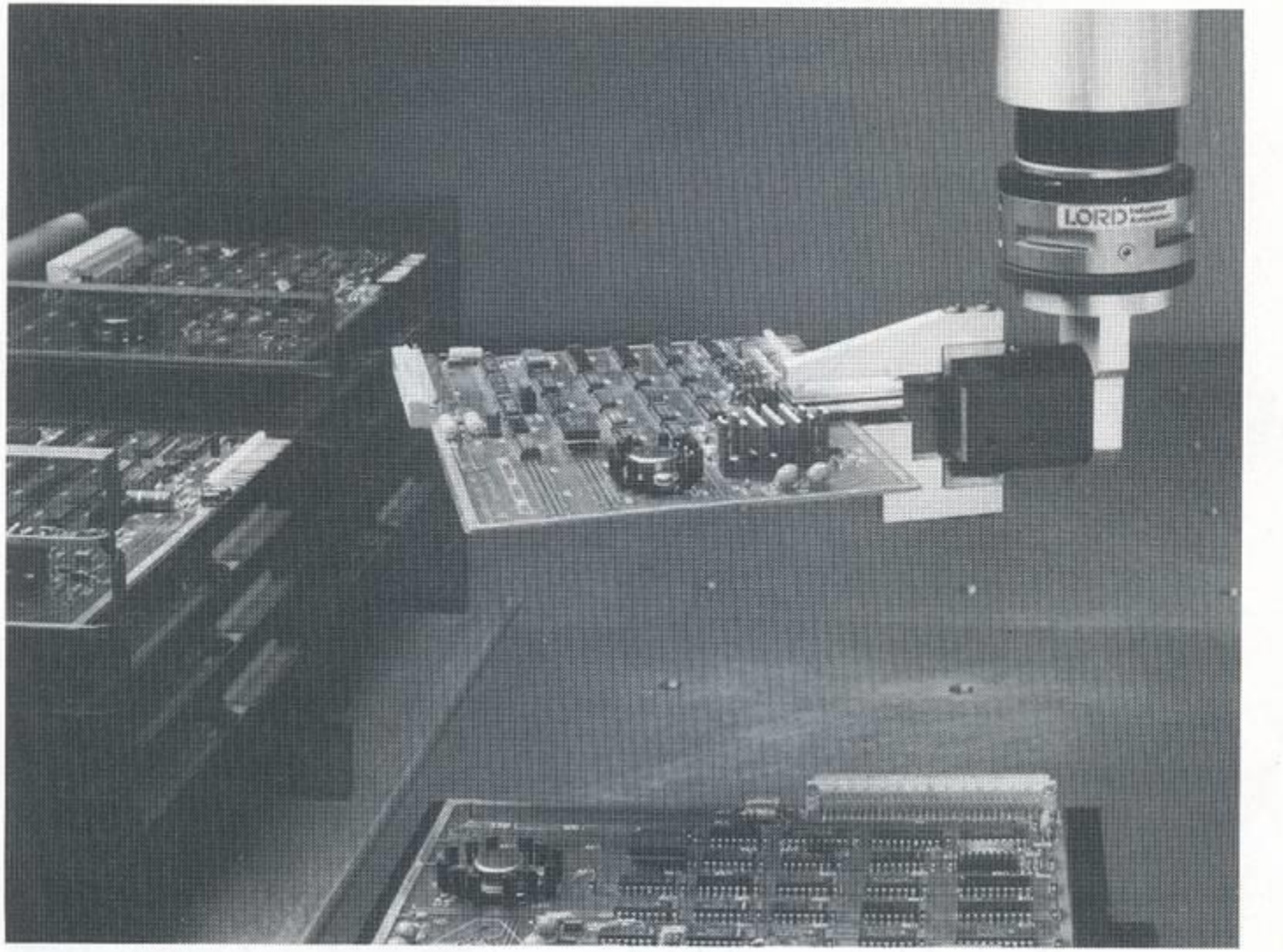
Sensore triassiale di forza/coppia a croce di Malta



- Le forze e le coppie vengono misurate a partire dalle misure delle variazioni di resistenza degli strain gauge, moltiplicandole per una matrice di coefficienti tipica del sensore
- La matrice dei coefficienti si costruisce con una procedura di calibrazione in cui si applicano forze note

$$\begin{bmatrix} f_x^s \\ f_y^s \\ f_z^s \\ \mu_x^s \\ \mu_y^s \\ \mu_z^s \end{bmatrix} = \begin{bmatrix} 0 & 0 & c_{13} & 0 & 0 & 0 & c_{17} & 0 \\ c_{21} & 0 & 0 & 0 & c_{25} & 0 & 0 & 0 \\ 0 & c_{32} & 0 & c_{34} & 0 & c_{36} & 0 & c_{38} \\ 0 & 0 & 0 & c_{44} & 0 & 0 & 0 & c_{48} \\ 0 & c_{52} & 0 & 0 & 0 & c_{56} & 0 & 0 \\ c_{61} & 0 & c_{63} & 0 & c_{65} & 0 & c_{67} & 0 \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \\ w_6 \\ w_7 \\ w_8 \end{bmatrix}$$

Sensori di Forza: applicazione



Sensori di Forza: applicazione