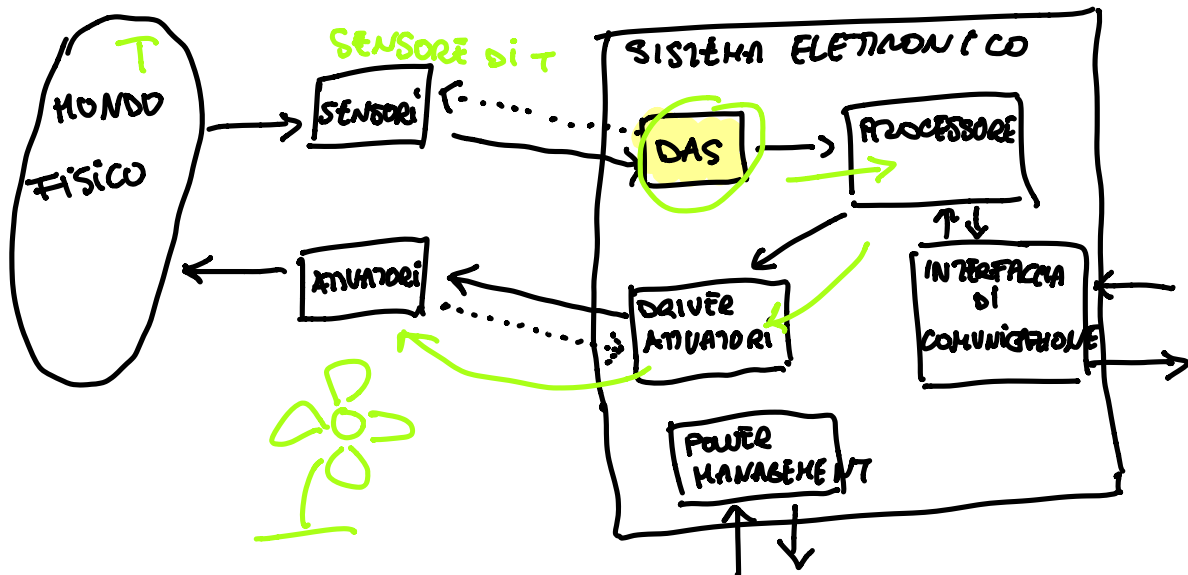
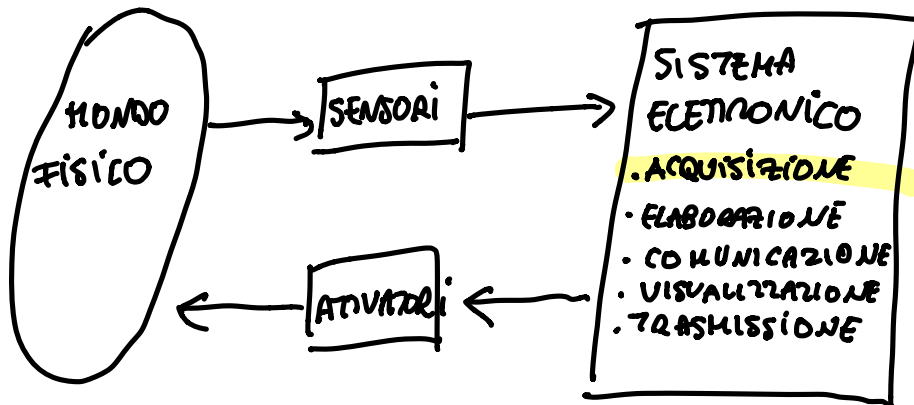
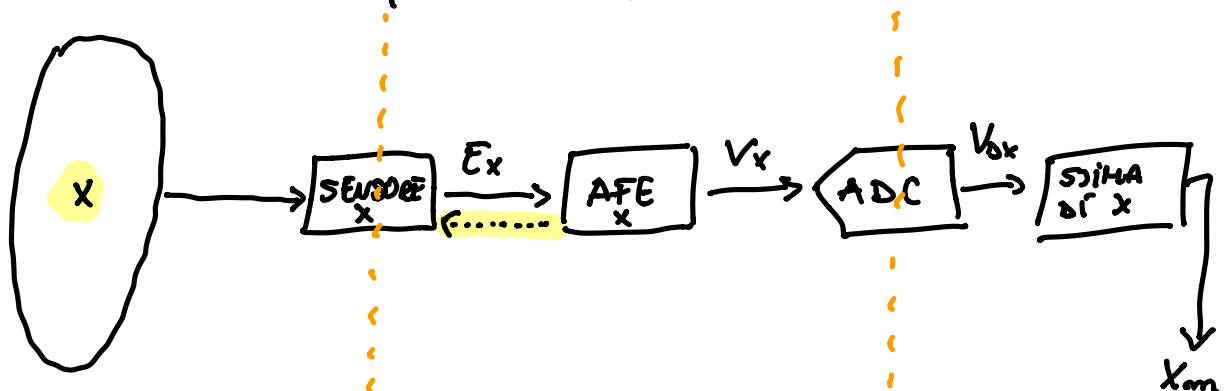


EB1 - ESERCITAZIONE 1 - 03/20/2020



DAS : Data Acquisition System



DOMINIO
FISICO

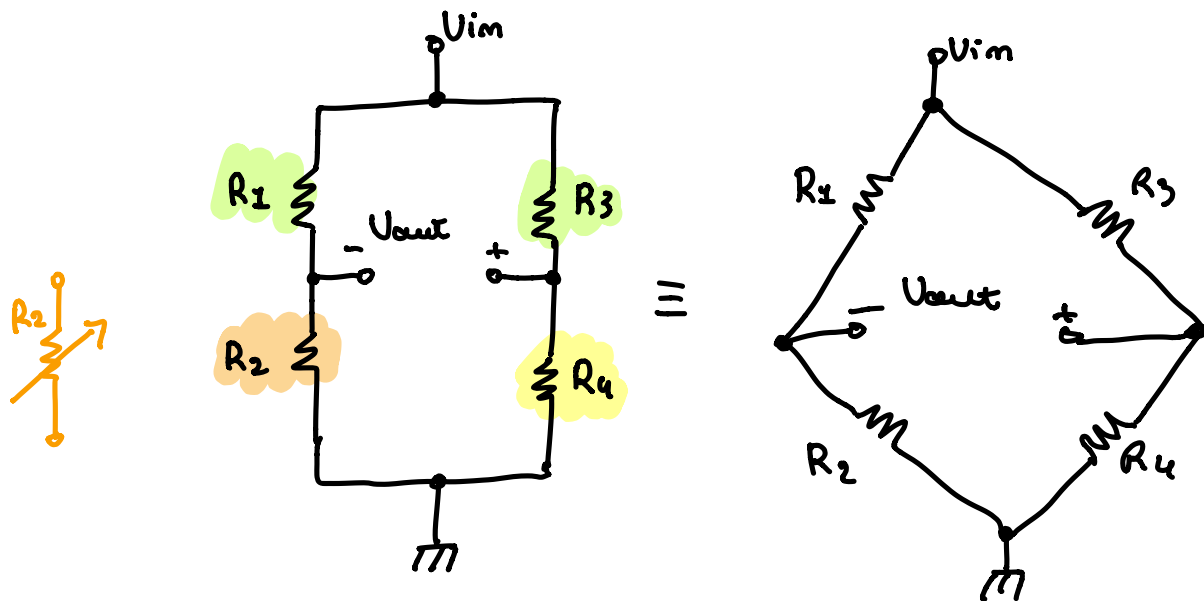
DOMINIO ANALOGICO

DOMINIO
DIGITALE

AFE: Analog Front End

ADC: Analog to Digital Converter

PONTE DI WHEATSTONE



CENNI STORICI: Valutazione del valore di una resistenza incognita.

$$R_x = R_4 \quad (?)$$

$$V_{out} = V_{out+} - V_{out-}$$

$$V_{out-} = V_{im} \cdot \frac{R_2}{R_4 + R_2}$$

$$V_{out+} = V_{im} \cdot \frac{R_4}{R_3 + R_4}$$

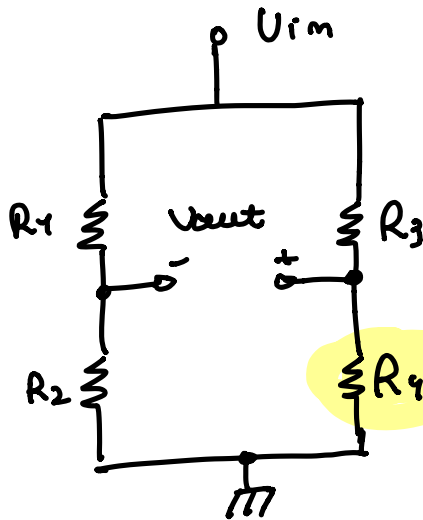
$$V_{out} = V_{im} \left(\frac{R_4}{R_3 + R_4} - \frac{R_2}{R_4 + R_2} \right)$$

$$R_4 = R_x \quad (?)$$

$$R_1 = R_3 \Rightarrow V_{out} = U_{im} \left(\frac{R_x}{R_1 + R_x} - \frac{R_2}{R_4 + R_2} \right)$$

$$V_{out} = 0 \Rightarrow \frac{R_x}{R_1 + R_x} - \frac{R_2}{R_4 + R_2} = 0$$

$$R_2 = R_x \Rightarrow V_{out} = 0 !$$



$$\begin{aligned} V_{out} &= V_{out+} - V_{out-} \\ &= U_{im} \left(\frac{R_4}{R_3 + R_4} - \frac{R_2}{R_1 + R_2} \right) \\ &= U_{im} \cdot \frac{R_4(R_1 + R_2) - R_2(R_3 + R_4)}{(R_3 + R_4)(R_1 + R_2)} \\ &= U_{im} \cdot \frac{R_4 R_1 + \cancel{R_4 R_2} - R_2 R_3 - \cancel{R_2 R_4}}{(R_3 + R_4)(R_1 + R_2)} \end{aligned}$$

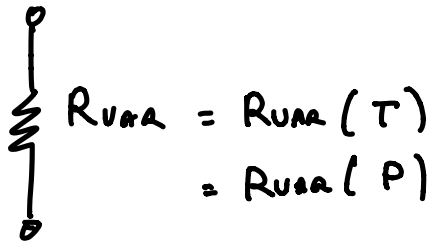
$$= U_{im} \cdot \frac{R_4 R_1 - R_2 R_3}{(R_3 + R_4)(R_1 + R_2)}$$

$$V_{out} = 0 \Rightarrow R_4 R_1 - R_2 R_3 = 0$$

$$R_4 R_1 = R_2 R_3$$

$$\boxed{\frac{R_1}{R_2} = \frac{R_3}{R_4} = K}$$

CONDIZIONE DI
BILANCIAMENTO DEL
PONTE



$$R_{UAA} = R_U$$

$$R_U = R_U(T, P)$$

$$R_U = R_{U0} + \Delta R_U$$

IN PRESENZA DI PICCOLE VARIAZIONI ($\Delta R_4 \neq 0$)

$$R_4 = R_{40} (1+x)$$

$$V_{out} = V_{out+} - V_{out-}$$

$$V_{out-} = V_{im} \cdot \frac{R_2}{R_1 + R_2}$$

$$V_{out+} = V_{im} \cdot \frac{R_4}{R_3 + R_4}$$

$$V_{out-} = V_{im} \cdot \frac{R_2}{R_1 + R_2} = V_{im} \cdot \frac{\frac{R_2}{R_1}}{\frac{R_1 + R_2}{R_1}} =$$

$$= V_{im} \cdot \frac{\frac{R_2}{R_1}}{\frac{R_1}{R_1} + \frac{R_2}{R_1}} = V_{im} \cdot \frac{1/k}{1 + 1/k} = V_{im} \cdot \frac{1}{1+k}$$

$$V_{out+} = V_{im} \cdot \frac{R_4}{R_3 + R_4} = V_{im} \cdot \frac{R_{40}(1+x)}{R_3 + R_{40}(1+x)} =$$

$$= V_{im} \cdot \frac{\frac{R_{40}}{R_3} (1+x)}{\frac{R_3 + R_{40}(1+x)}{R_3}} = V_{im} \cdot \frac{\frac{R_{40}}{R_3} (1+x)}{\frac{R_3}{R_3} + \frac{R_{40}}{R_3} (1+x)}$$

$$= V_{im} \cdot \frac{\frac{1}{k} (1+x)}{1 + \frac{1}{k} (1+x)} = V_{im} \cdot \frac{1+x}{k + (1+x)} =$$

$$= V_{im} \cdot \frac{1+x}{1+x+k} = V_{im} \cdot \frac{\frac{1+x}{1+x}}{\frac{1+x+k}{1+x}} = V_{im} \cdot \frac{1}{1 + \frac{k}{1+x}}$$

$$V_{out} = V_{out+} - V_{out-} =$$

$$= V_{im} \cdot \frac{1}{1 + \frac{k}{1+x}} - V_{im} \cdot \frac{1}{1+k} =$$

$$= V_{im} \left(\frac{1}{1 + \frac{k}{1+x}} - \frac{1}{1+k} \right) = V_{im} \cdot \left(\frac{1+x}{1+x+k} - \frac{1}{1+k} \right)$$

$$= V_{im} \cdot \frac{(1+x)(1+k) - (1+x+k)}{(1+x+k)(1+k)} =$$

$$= V_{im} \cdot \frac{\cancel{1} + \cancel{k} + \cancel{x} + kx - \cancel{1} - \cancel{x} - \cancel{k}}{(1+x+k)(1+k)} =$$

$$= V_{im} \cdot \frac{kx}{(1+x+k)(1+k)}$$

$(x \ll 1)$ DENOMINATORE di $V_{out} = (1+x+k)(1+k)$

$$(1+x+k)(1+k) = 1 + k + k + kx + k^2 =$$

$$(1+k)^2 = 1 + k^2 + 2k$$

$$= (1+k)^2 + x(1+k)$$

$$(1+k) > 1 \Rightarrow (1+k)^2 > (1+k)$$

$$\underline{\underline{x \ll 1}} \Rightarrow (1+k)^2 \gg x(1+k)$$

$(k > 0)$

$$(1+x+k)(1+k) \sim (1+k)^2$$

$$V_{\text{aut}} = U_{\text{im}} \cdot \frac{x \cdot k}{(1+k)^2} = x \cdot U_{\text{im}} \cdot \underbrace{\frac{k}{(1+k)^2}}_{\alpha}$$

$$V_{\text{aut}} = \alpha \cdot x$$

$$x = \Delta R_4 / R_{40}$$

$$V_{\text{aut}} = \underbrace{\left(\frac{\alpha}{R_{40}} \right)}_{\beta} \cdot \Delta R_4 = \beta \cdot \Delta R_4$$

RICORDIAMO : Se $x \ll 1$
 IN CONDIZIONE di
 BILANCIAMENTO
 $\frac{R_1}{R_2} = \frac{R_3}{R_{40}} = k$

$$\rightarrow V_{\text{aut}} = \beta \cdot \Delta R_4$$

$$V_{\text{aut}} = V_{\text{aut}_{\text{diff}}} = V_{\text{aut}+} - V_{\text{aut}-}$$

$$V_{outc} = \frac{V_{out+} + V_{out-}}{2}$$

CONDIZIONI DI RIPOSO :

$$\Delta R_4 = \phi$$

$$R_4 = R_{40}$$

$$V_{out+} = V_{im} \cdot \frac{R_{40}}{R_3 + R_{40}} = V_{im} \cdot \frac{1}{\frac{R_3}{R_{40}} + 1} = V_{im} \cdot \frac{1}{1+K}$$

$$V_{out-} = V_{im} \cdot \frac{R_2}{R_1 + R_2} = V_{im} \cdot \frac{1}{\frac{R_1}{R_2} + 1} = V_{im} \cdot \frac{1}{1+K}$$

$$\begin{aligned} V_{outc} &= \frac{V_{out+} + V_{out-}}{2} = \frac{1}{2} \cdot \cancel{2} \cdot V_{im} \cdot \frac{1}{1+K} \\ &= V_{im} \cdot \frac{1}{1+K} \end{aligned}$$

$$\Delta R_4 \neq \phi$$

$$R_4 = R_{40}(1+x)$$

$$V_{out-} = V_{im} \cdot \frac{1}{1+K}$$

$$V_{out+} = V_{im} \cdot \frac{1}{1 + \frac{K}{1+x}}$$

$$V_{out_c} = \frac{V_{out+} + V_{out-}}{2} =$$

$$= \frac{1}{2} \cdot V_{im} \left(\frac{1}{1 + \frac{k}{1+k}} + \frac{1}{1+k} \right) = \frac{V_{im}}{2} \cdot \left(\frac{1+k}{1+x+k} + \frac{1}{1+k} \right)$$

$$= \frac{V_{im}}{2} \cdot \frac{(1+x)(1+k) + (1+x+k)}{(1+x+k)(1+k)} =$$

$$= \frac{V_{im}}{2} \cdot \frac{1+k+x+xk+1+x+k}{(1+x+k)(1+k)} =$$

$$\sim \frac{V_{im}}{2} \cdot \frac{2(1+k) + x(2+k)}{(1+k)^2} \sim$$

$\uparrow$
 $(k \ll 1)$

$$2(1+k) = 2+2k > 2+k \quad (k > 0)$$

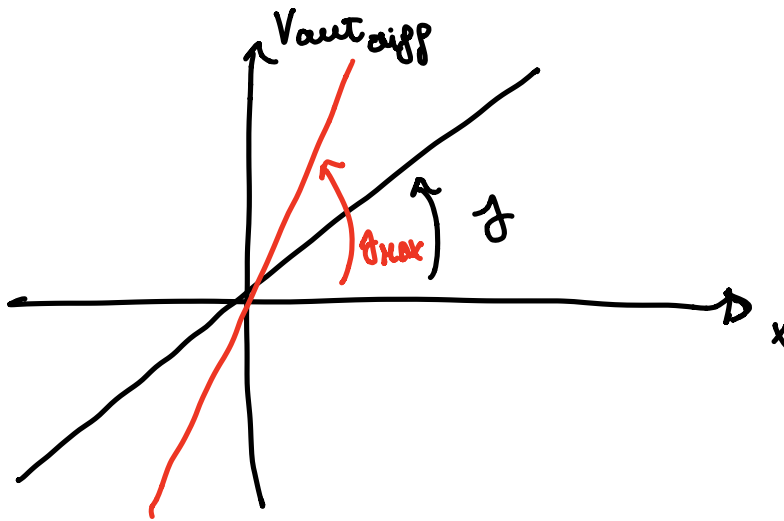
$$(2+2k) \gg x(2+k)$$

$\uparrow$
 $x \ll 1$

$$\sim \frac{V_{im}}{2} \cdot \frac{2\cancel{(1+k)}}{(\cancel{1+k})^2} = \frac{V_{im}}{\cancel{2}} \cdot \frac{\cancel{2}}{1+k} = V_{im} \cdot \frac{1}{1+k}$$

$$V_{out_c} = \frac{V_{im}}{1+k} \quad \text{sempre se } x \ll 1!$$

MAX SENSIBILITÀ DEL PONTE DI WHEATSTONE



$$V_{outdiff} = U_{im} \cdot x \cdot \frac{K}{(1+K)^2}$$

$$\theta = \frac{d}{dx} V_{outdiff} = U_{im} \cdot \frac{K}{(1+K)^2}$$

θ_{max} ?

$$\frac{d\theta}{dK} = U_{im} \cdot \frac{1(1+K)^{-2} - K(1+K)^{-2} \cdot 2}{(1+K)^3} =$$

$$= U_{im} \cdot \frac{1+K-2K}{(1+K)^3} = U_{im} \cdot \frac{1-K}{(1+K)^3}$$

$$\frac{d\theta}{dK} = 0 \rightarrow U_{im} \cdot \frac{1-K}{(1+K)^3} = 0 \Leftrightarrow 1-K = 0$$

$$K = 1$$

$$K = \frac{R_1}{R_2} = \frac{R_3}{R_4} = 1$$

$$R_1 = R_2 = R_3 = R_4$$

$$\delta_{MAX} = \delta / (K=1) = U_{im} \cdot \frac{1}{(1+1)^2} = U_{im} \cdot \frac{1}{4}$$

$$V_{out_diff} = \frac{U_{im}}{a} \cdot x = \frac{U_{im}}{a} \cdot \frac{1}{R_{40}} \cdot \Delta R_4$$

RICAPITOLANDO:

Se : • $x \ll 1$ (PICCOLE VARIAZIONI)

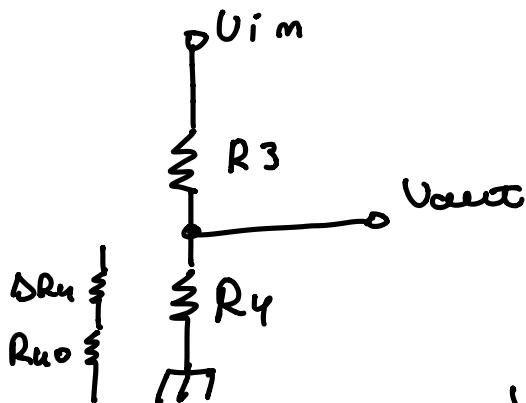
• $K = \frac{R_1}{R_2} = \frac{R_3}{R_{40}}$ (PONTE È BILANCIATO)

• $K=1$ (δ_{MAX})

$$V_{out_diff} = \frac{U_{im}}{a} \cdot \frac{1}{R_{40}} \cdot \Delta R_4$$

$$V_{out_c} = \frac{U_{im}}{2}$$

DIFFERENZA CON PARTITORE RESISTIVO



$$V_{out} = U_{im} \cdot \frac{R_4}{R_3 + R_4}$$

$$R_4 = R_{40}(1+x)$$

$$V_{out} = U_{im} \cdot \frac{R_{40}(1+x)}{R_3 + R_{40}(1+x)}$$

$$= \lim_{x \ll 1} \frac{1}{1 + \frac{k}{1+x}}$$