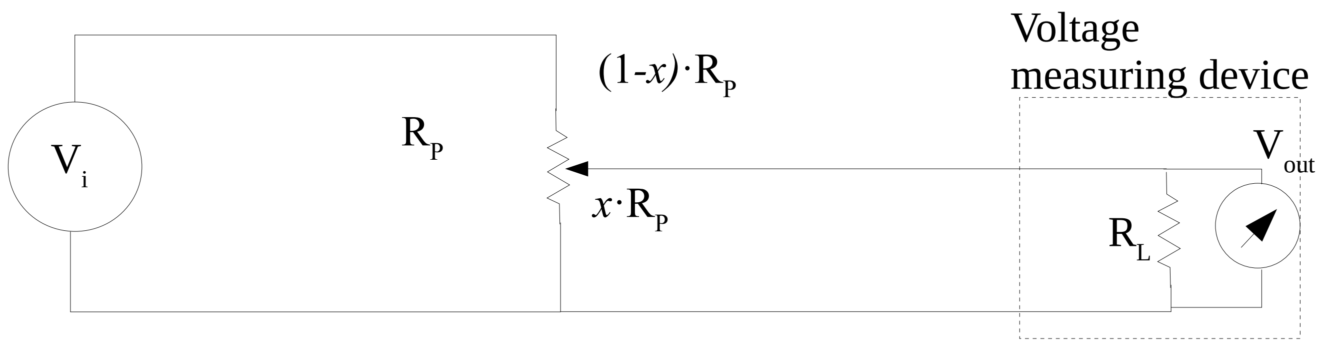
Resistive Transduction

Suresh Devasahayam
Department of Bioengineering
Christian Medical College, Vellore

Lecture - Outline

- Variable Resistance Potentiometer as Transducer
- Power and Error in Potentiometer measurement
- Measuring Small Resistance Changes
  - Bridge Measurement
  - Single Active Arm Bridge
- Temperature compensation
  - Two and Four Active Arm bridge

Displacement measurement with a potentiometer



Simple case

$$V_{out} = \frac{V_i}{R_P} \cdot x R_P$$

$$\frac{V_{out}}{V_i} = x$$

Simple case:

- If $R_L >> R_P$:

$$V_{out} = \frac{V_i}{R_P} \cdot x R_P \qquad \frac{V_{out}}{V_i} = x$$

- Current drawn by R_p :

$$I_P = \frac{V_i}{R_P}$$

- Power dissipated:

$$Power_P = \frac{V_i^2}{R_P}$$

- To minimize power dissipated in the potentiometer, the value of R_P **should be large.**

Considering the value of the measuring instrument

- R_P is large :

$$V_{out} = I_{R_L} \cdot R_L = \frac{V_i}{\left((1-x) R_P + \dfrac{x R_P R_L}{x R_P + R_L} \right)} \cdot \left(\frac{x R_P}{x R_P + R_L} \right) R_L$$

$$\frac{V_{out}}{V_i} = \frac{x R_L}{x R_P (1-x) + R_L}$$

- R_L and R_P are large:

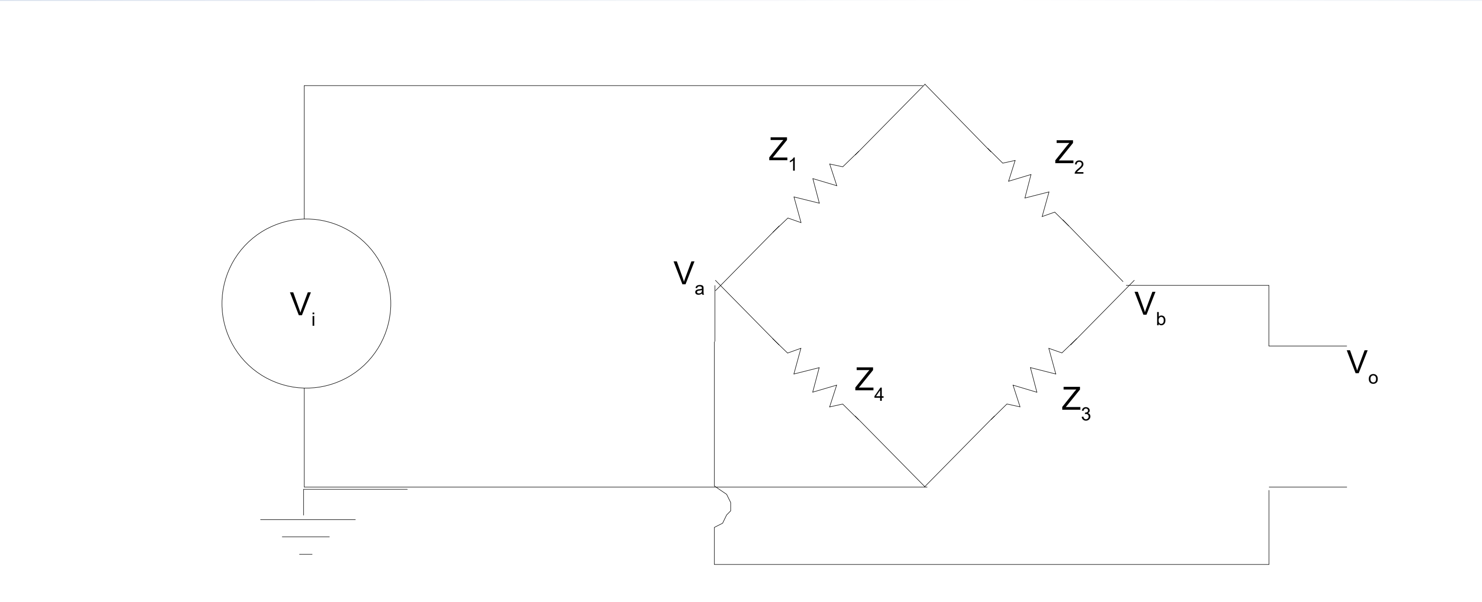
$$\alpha = \frac{R_L}{R_P} \qquad \frac{V_{out}}{V_{\%in}} = \frac{x\alpha}{x(1-x)+\alpha}$$

- Measurement error:

$$Error = \frac{Actual\ value - Desired\ value}{Desired\ value} = \frac{\left(\dfrac{x\alpha}{x(1-x)+\alpha} \right) - x}{x} = \frac{-x(1-x)}{\alpha + x(1-x)}$$

Bridge Measurement

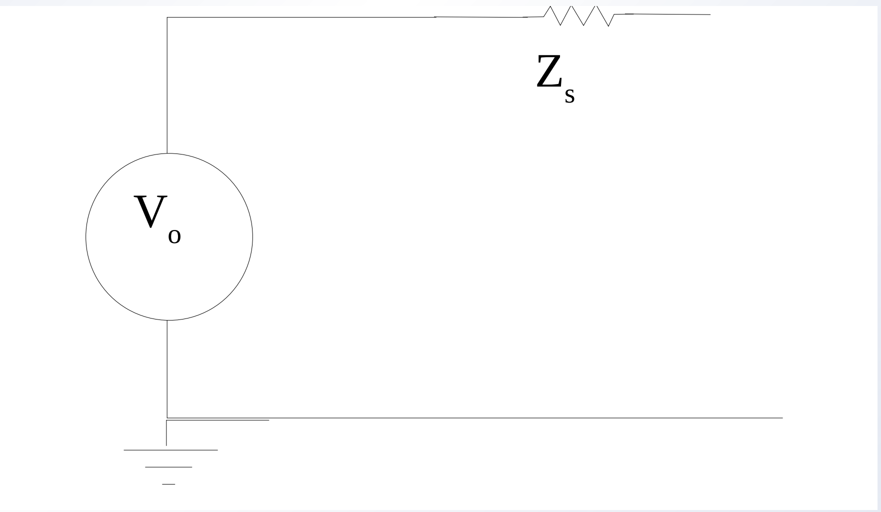
Measuring small resistance ***change***



$$V_o = V_a - V_b = V_i\left(\frac{Z_4}{Z_1 + Z_4} - \frac{Z_3}{Z_2 + Z_3}\right)$$

Measuring the bridge output

- Thevenin equivalent of the bridge



- Output impedance or source impedance =
  OC voltage/SC current

$$Z_s = \frac{Z_1 Z_2}{Z_1 + Z_2} + \frac{Z_3 Z_4}{Z_3 + Z_4}$$

One Active Arm Bridge

- A resistive transducer's resistance varies around a "no signal" value of "R"

$$Z_4 = R \pm \Delta R = R(1 \pm \Delta), \quad Z_1 = Z_2 = Z_3 = R$$

$$V_o = V_i \frac{\Delta}{4+2\Delta} \approx V_i \frac{\Delta}{4} \quad , \quad Z_s = R \frac{(4+3\Delta)}{(4+2\Delta)} \approx R$$

Two active arm bridge

- Resistance also has a temperature dependence
- If transduction can yield complementary resistance change, then we can use a two active arm bridge:

$$Z_4 = R(1+\Delta_s+\Delta_T), \quad Z_3 = R(1-\Delta_s+\Delta_T), \quad Z_1 = Z_2 = R$$

$$V_o = V_i \left\{ \frac{R(1+\Delta)}{R(2+\Delta)} - \frac{R(1-\Delta)}{R(2-\Delta)} \right\}$$

$$V_o = V_i \left\{ \frac{(1+\Delta)(2-\Delta)-(1-\Delta)(2+\Delta)}{(4-\Delta^2)} \right\} =$$

$$V_o \approx V_i \frac{\Delta}{2}, \quad Z_s = R\left(1-\frac{\Delta^2}{2}\right)$$