Basic Input Circuits

Prof. Dr. M. Zahurul Haq
zahurul@me.buet.ac.bd
http://teacher.buet.ac.bd/zahurul/

Department of Mechanical Engineering
Bangladesh University of Engineering & Technology

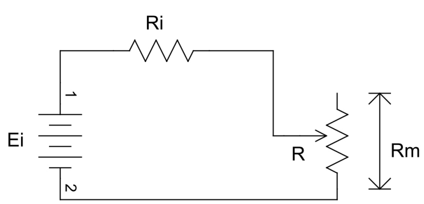
ME 361: Instrumentation & Measurement

Basic Input Circuits

Most common input circuits used in transducer work:

1. Current-sensitive Circuit
2. Voltage-sensitive (ballast) Circuit
3. Voltage-divider Circuit
4. Voltage-balancing Potentiometer Circuit
5. Bridge Circuit
6. Amplifier Circuit

Current-sensitive Input Circuit



$$\longrightarrow \quad i = \frac{E_i}{R + R_i}$$

$$\Rightarrow \boxed{\frac{i}{E_i/R_i} = \frac{1}{1 + (R/R_m)(R_m/R_i)}}$$

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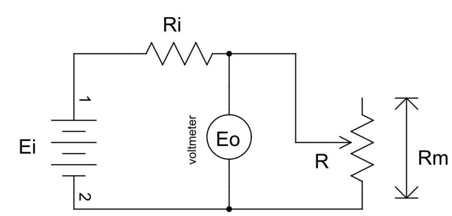
- Current flow through the circuit indicates sensor's resistance R.
- Current flow varies linearly with R for some ranges of operation.

Voltage-sensitive (ballast) Circuit



$$\longrightarrow \quad i = \frac{E_i}{R + R_i}$$

$$\Rightarrow \boxed{\frac{E_o}{E_i} = \frac{(R/R_m)(R_m/R_i)}{1 + (R/R_m)(R_m/R_i)}}$$

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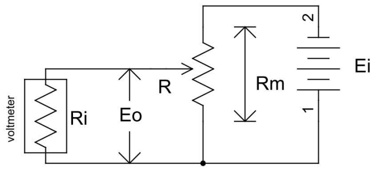
- Voltmeter impedance is very high & draws negligible current.
- Change in R is indicated by voltage change.
- Sensitivity, $S = \frac{dE_o}{dR} = \frac{E_i R_i}{(R+R_i)^2}$
- For maximum sensitivity, $\frac{dS}{dR_i} = 0 = \frac{E_i(R-R_i)}{(R+R_i)^3} :\Longrightarrow \boxed{R_i = R}$

$\leadsto$ *Homework: Example 4.1 (Holman)*

Voltage-divider Circuit



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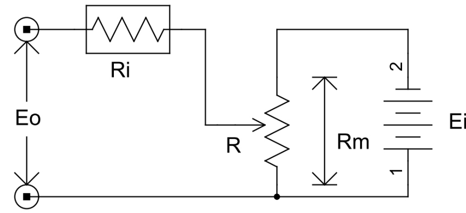
$$\text{Loading Error} = \frac{\left[\frac{E_o}{E_i}\right]_{true} - \left[\frac{E_o}{E_i}\right]_{ind}}{\left[\frac{E_o}{E_i}\right]_{true}}$$

- Source voltage E_i is impressed across the total transducer resistance R_m, while the variable contact is connected to a voltmeter with internal resistance R_i.
- For $R_i \gg R_m$: $\Longrightarrow \boxed{\left[\frac{E_o}{E_i}\right]_{true} = \frac{R}{R_m}}$
- For $R_i \not\gg R_m$: $\Longrightarrow \boxed{\left[\frac{E_o}{E_i}\right]_{ind} = \frac{R/R_m}{1+(R/R_m)(1-R/R_m)(R_m/R_i)}}$

$\rightsquigarrow$ *Homework: Example 4.2 (Holman)*

Voltage-balancing Potentiometer Circuit



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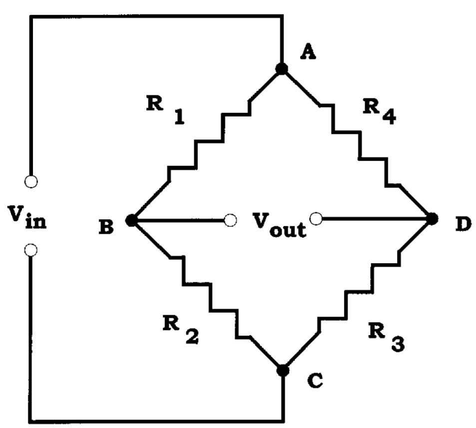
- Used for precise measurements of small electrical potentials by comparison, particularly those generated by thermocouples.
- A known portion of source voltage E_i is balanced against the unknown voltage E_o through the use of a variable resistor R_m.
- At balance point, current through the galvanometer is zero.

  $\Longrightarrow \boxed{\frac{E_o}{E_i} = \frac{R}{R_m}}$
- Galvanometer resistance R_i does not effect the reading.
- Source voltage E_i must be accurately known to determine E_o.

Wheatstone Bridge Circuit



$$V_B = V_{in}\frac{R_2}{R_1 + R_2}$$

$$V_D = V_{in}\frac{R_3}{R_3 + R_4}$$

$$V_{out} = V_B - V_D$$

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Null Method:

- $V_{out} = 0 \longmapsto i_g = 0 \Longrightarrow \frac{R_2}{R_1} = \frac{R_3}{R_4}$
- If the resistor R_2 varies with changes in the measured physical variable, one of the other arms of the bridge can be adjusted to null the circuit and determine the resistance. The balancing mechanism may be accomplished manually or automatically through a closed loop controller circuit. The values of the other resistors must be precisely known.

Deflection Method:

- Used for dynamic signals where time is insufficient for balancing.
- Galvanometer/detector deflection indicates the deviation at one of the arms (transducer arm) from some balanced condition.
- Bridge output may be measured by:
  1. Low-impedance device $\rightsquigarrow$ Current-sensitive circuit.
  2. High-impedance device $\rightsquigarrow$ Voltage-sensitive circuit.

WB Circuit: Deflection Method

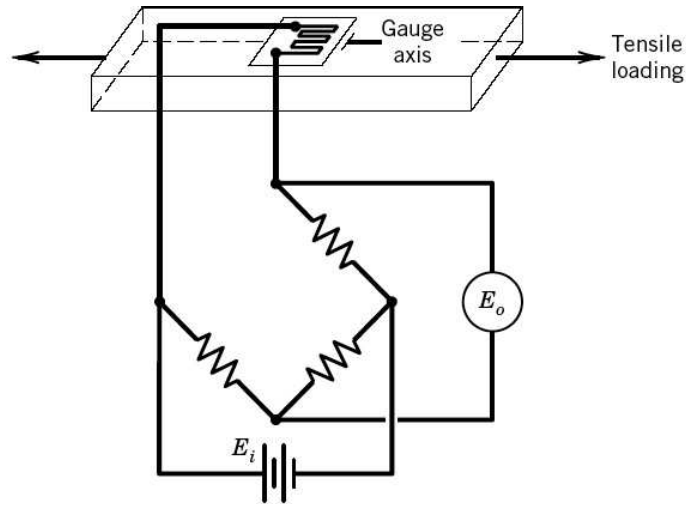
Voltage-sensitive Circuit: V_{out} is measured by high impedance device. At balanced condition, $V_{out} = 0$. If $R_2 \to R_2 + \Delta R_2$.
$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{R_2+\Delta R_2}{R_1+R_2+\Delta R_2} - \frac{R_3}{R_3+R_4} = \frac{\Delta R_2/R}{4+2(\Delta R_2/R)} \leftarrow R_1 = \cdots = R_4 = R$

Current-sensitive Circuit: i_g is measured by galvanometer with R_g.
$\Rightarrow i_g = \frac{V_{out}}{R_{TH} + R_g} = \frac{V_{out}}{C}(R_2R_4 - R_1R_3)$
$C = R_1R_2(R_3 + R_4) + R_3R_4(R_1 + R_2) + R_g(R_1 + R_2 + R_3 + R_4)$
At null position $\Longrightarrow R_2R_4 = R_1R_3 \ : \ i_g = 0$
If transducer resistance, $R_2 \to R_2 + \Delta R_2 \quad \Longrightarrow \quad i_g \to \Delta i_g$.
$\Longrightarrow \Delta i_g = \frac{V_{out}}{C}\left[(R_2 + \Delta R_2)R_4 - R_1R_3\right] = \frac{V_{out}}{C} R_4 \Delta R_2$

⇝ *Homework: Example 4.4, 10.6 & 10.7 (Holman)*

⇝ *Homework: Example 6.4 & 6.5 (Figliola)*

Strain Gauge using Wheatstone Bridge



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