EE 521: Instrumentation and Measurements

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Bridge Circuits

Used for a variety of applications including measuring change in resistance, change in inductance, change in capacitance, etc.

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Basic measuring methods

- bridge balance method, and
- imbalance output method.

Constant-Voltage Resistance Bridge

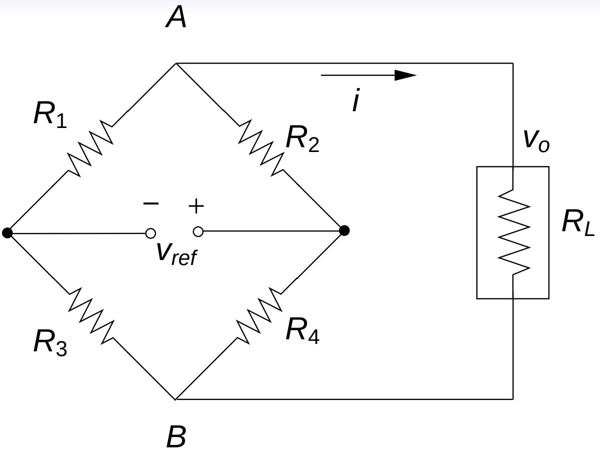

Figure: Wheatstone bridge (constant voltage resistance bridge)

$$\begin{aligned} v_o &= v_A - v_B \\ &= \frac{R_1 v_{ref}}{R_1 + R_2} - \frac{R_3 v_{ref}}{R_3 + R_4} \\ &= \frac{R_1 R_4 - R_2 R_3}{(R_1 + R_2)(R_3 + R_4)} v_{ref} \end{aligned} \tag{1}$$

For balanced bridge

$$
\begin{aligned}
v_o &= v_A - v_B \\
&= \frac{R_1 v_{ref}}{R_1 + R_2} - \frac{R_3 v_{ref}}{R_3 + R_4} \\
&= \frac{R_1 R_4 - R_2 R_3}{(R_1 + R_2)(R_3 + R_4)} v_{ref} = 0
\end{aligned}
\tag{2}
$$

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$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \tag{3}$$

Measuring change in voltage

Assuming $R_1 = R_2 = R_3 = R_4 = R$, then if there is a slight change in the resistance of $R_1 = R + \delta R$,

$$\delta v_o = \frac{R(R + \delta R) - R^2}{(2R + \delta R)(2R)} v_{ref} \quad (4)$$

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non-linear

$$\frac{\delta v_o}{v_{ref}} = \frac{\delta R / R}{4 + 2\delta R / R} \qquad (5)$$

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$$\frac{\delta v_o}{v_{ref}} = \frac{\delta R/R}{4 + 2\delta R/R} \tag{5}$$

linearized assuming $\delta R/R$ is small

$$\frac{\delta v_o}{v_{ref}} = \frac{\delta R}{4R} \tag{6}$$

Linearization Error

$$N_P = \left(1 - \frac{linearized}{actual}\right) \times 100 \qquad (7)$$

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for Wheatstone bridge

$$N_P = \frac{1}{2}\frac{\delta R}{R} \times 100 \quad (8)$$

Constant-Current Resistance Bridge

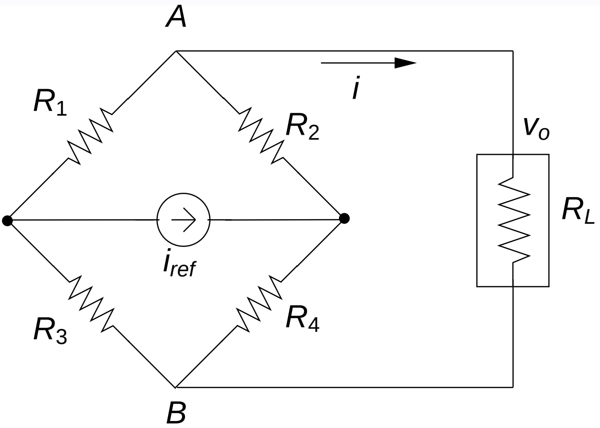

Figure: Constant-current resistance bridge

$$i_{ref} = \frac{v_{ref}}{R_1 + R_2} + \frac{v_{ref}}{R_3 + R_4} \tag{9}$$

therefore,

$$v_{ref} = \frac{(R_1 + R_2)(R_3 + R_4)}{R_1 + R_2 + R_3 + R_4} \tag{10}$$

and

$$v_o = \frac{R_1 R_4 - R_2 R_3}{R_1 + R_2 + R_3 + R_4} i_{ref} \tag{11}$$

For balanced bridge

Assuming $R_1 = R_2 = R_3 = R_4 = R$, then if there is a slight change in the resistance of $R_1 = R + \delta R$,

$$\frac{\delta v_o}{R i_{ref}} = \frac{\delta R / R}{4 + \delta R / R} \tag{12}$$

For balanced bridge

Assuming $R_1 = R_2 = R_3 = R_4 = R$, then if there is a slight change in the resistance of $R_1 = R + \delta R$,

$$\frac{\delta v_o}{R i_{ref}} = \frac{\delta R/R}{4 + \delta R/R} \tag{12}$$

linearized assuming $\delta R/R$ is small

$$\frac{\delta v_o}{R i_{ref}} = \frac{\delta R}{4R} \tag{13}$$

Linearization Error

for constant current bridge

$$N_P = \frac{1}{4}\frac{\delta R}{R} \times 100 \tag{14}$$

Hardware Linearized Bridge

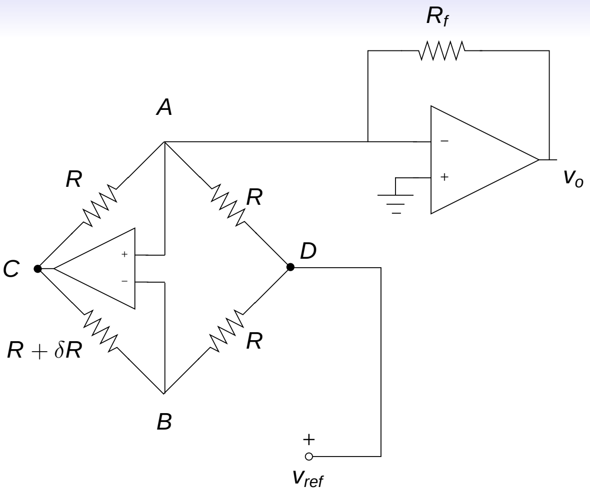

Figure: Linearized bridge

Writing the current summation at nodes A and B, respectively,

$$\frac{v}{R} + \frac{v_{ref}}{R} + \frac{v_o}{R_f} = 0 \tag{15}$$

$$\frac{v_{ref}}{R} + \frac{v}{R + \delta R} = 0 \tag{16}$$

then,

$$\frac{\delta v_o}{v_{ref}} = \frac{R_f \delta R}{R^2} \tag{17}$$

Half Bridge

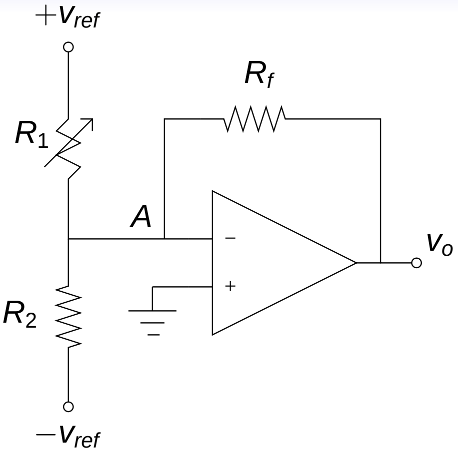

Figure: Half bridge

$$v_o = R_f \left(\frac{1}{R_2} - \frac{1}{R_1} \right) \tag{18}$$

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Assuming $R_1 = R_2 = R$, then if there is a slight change in the resistance of $R_1 = R + \delta R$,

non-linear equation

$$\frac{\delta v_o}{v_{ref}} = \frac{R_f}{R} \frac{\delta R/R}{1 + \delta R/R} \tag{19}$$

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$$\frac{\delta v_o}{v_{ref}} = \frac{R_f}{R} \frac{\delta R / R}{1 + \delta R / R} \tag{19}$$

Linearization error

$$N_P = \frac{\delta R}{R} \times 100 \tag{20}$$