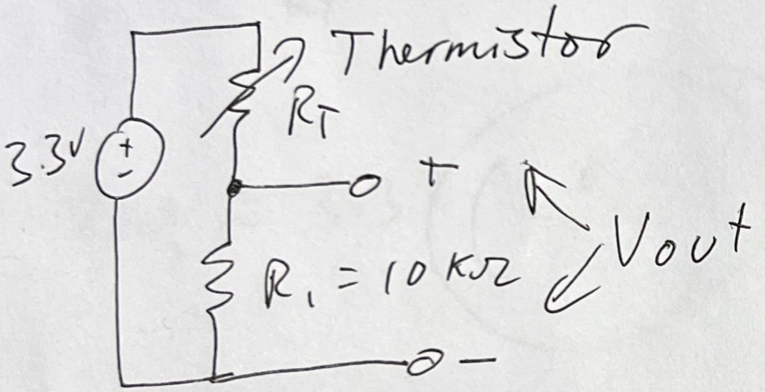
Temperature controlled R

$$R = R_0 e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

$$R(T_0) = R_0 e^{\beta\left(\frac{1}{T_0} - \frac{1}{T_0}\right)} = R_0 \cancel{e^{\beta \cdot 0}}^{\,1} = R_0$$



$$\cancel{V_{out}(R_T)}^{\,0} = 3.3 - V_{R_1} - V_{R_T}$$

$\cancel{I_{R_T}}$

$$V_{R_1} = IR_1 \,;\; V_{R_T} = IR_T$$

$$I = \frac{3.3}{R_1 + R_T}$$

$$\cancel{V_{out}(R_T)}^{\,0} = 3.3 - \frac{3.3\,R_1}{R_1+R_T} - \frac{3.3\,R_T}{R_1+R_T}$$

$$= 3.3\left(1 - \overbrace{\cancel{\frac{R_1}{R_1+R_T}}}^{V_{out}} - \frac{R_T}{R_1+R_T}\right)$$

$$= 3.3\,(1 - (R$$

$$V_{out} = 3.3\left(1 - \frac{R_T}{R_1+R_T}\right) = 3.3\left(\frac{R_1 + \cancel{R_T - R_T}}{R_1+R_T}\right)$$

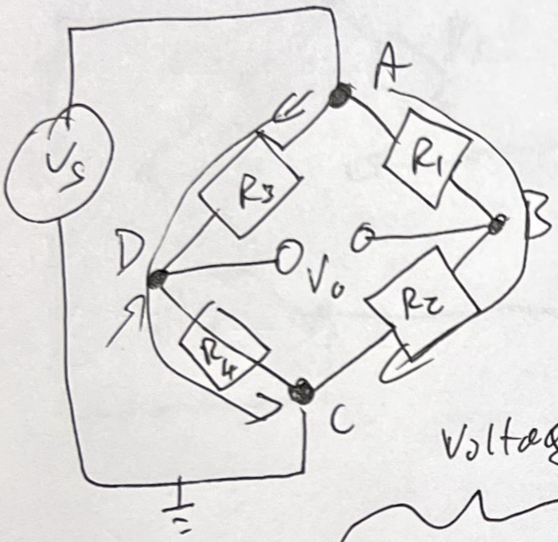
$$V_{out} = 3.3 \left(\frac{R_1}{R_1 + R_T} \right)$$

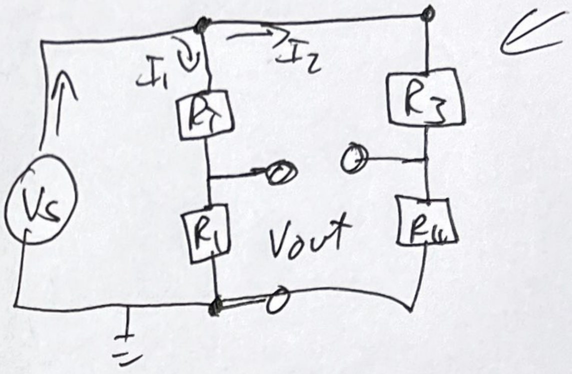
$$\Delta T \rightarrow \Delta V_{out}$$

$$R_1 >> R_T$$

$$R_1 << R_T$$

$$V_{out} \approx 3.3 \left(\frac{R_1}{R_T} \right)$$

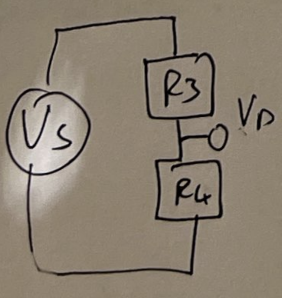


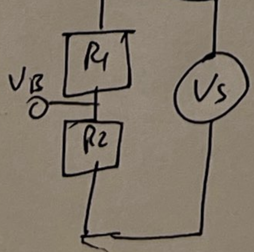


$$V_o = \overbrace{\left(V_s - V_{AD}\right)}^{\text{Voltage @ D: } V_D} - \overbrace{\left(V_s - V_{AB}\right)}^{V_B}$$

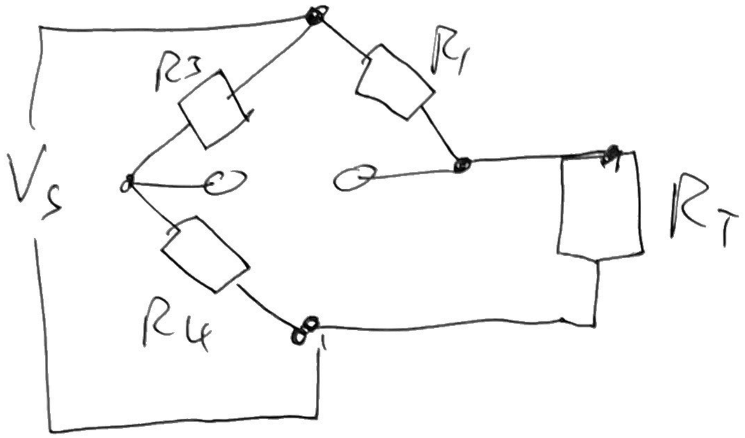
$$= V_s\left(\frac{R_1}{R_1+R_2} - \frac{R_3}{R_3+R_4}\right)$$

$$= V_s \frac{R_1 R_4 - R_2 R_3}{(R_1+R_2)(R_3+R_4)} = \frac{(R_1+\Delta R_1)R_2 - R_2 R_3}{(R_1+\Delta R_1+R_2)(R_3+R_4)}$$





$$= V_s \frac{\Delta R_1}{4R}$$

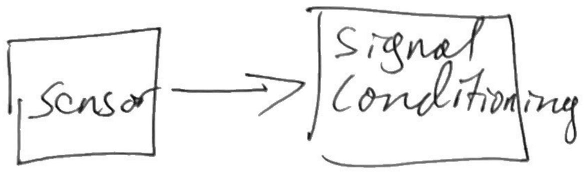


$$V_{out} \approx V_s \frac{\Delta R_T}{4R}$$

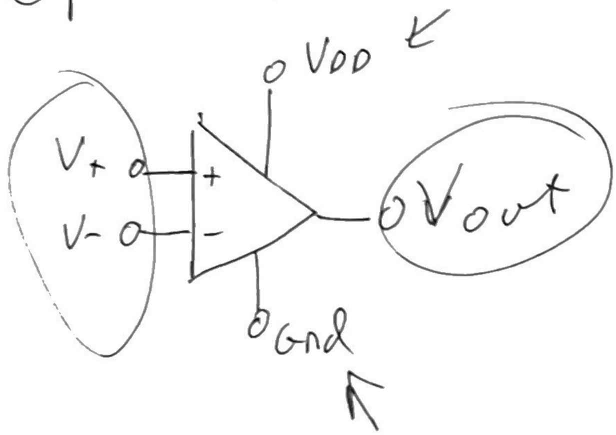
Sensitivity

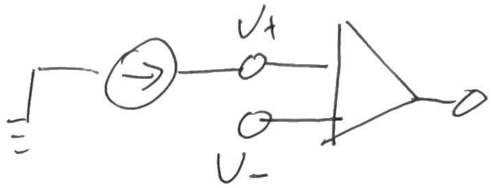
$$\frac{\Delta V_{out}}{\Delta T}$$ (Temperature sensor)

$$\frac{\Delta \text{ current}}{\Delta \text{ Optical Power}}$$ (Light)

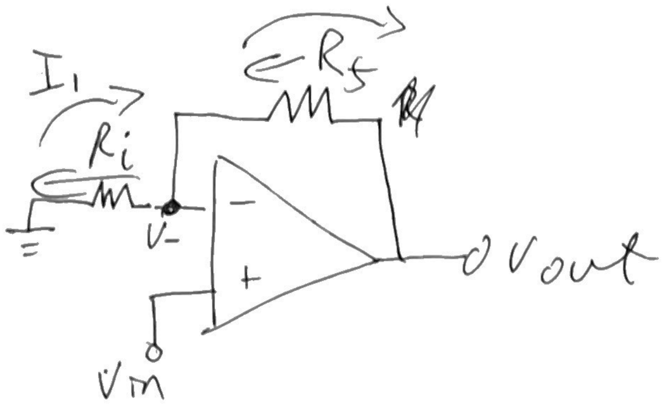


Op Amp





1. There is NO current that flows into the inputs V^+, V^-
2. The voltage of the two inputs is always the same
3. The output can support whatever current is needed



R_i = R input

R_f = R feed back

$$V_{out} = ? = V_{in} + V_{R_f}$$

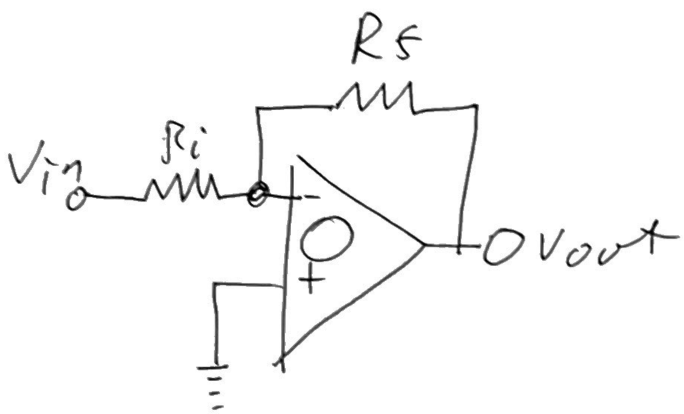
$$I_1 = \frac{V_-}{R_i} = \frac{V_{in}}{R_i}$$

$$V_{R_f} = I_1 R_f$$

$$V_{out} = V_{in} - I_1 R_f = V_{in} + \left(\frac{V_{in}}{R_i}\right) R_f = V_{in}\left(1 + \frac{R_f}{R_i}\right)$$

$$= V_{in}\left(\frac{R_i + R_f}{R_i}\right)$$

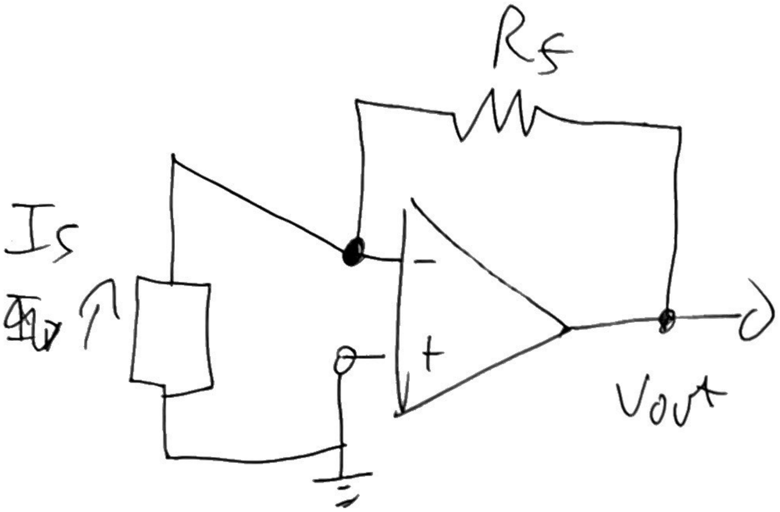
Inverting Op Amp



$$\frac{V_{in} - 0}{R_i} = \frac{0 - V_{out}}{R_f}$$

$$\frac{V_{in}}{R_i} = \frac{-V_{out}}{R_f}$$

$$V_{out} = -V_{in}\frac{R_f}{R_i}$$



$$\frac{0 - V_{out}}{R_f} = I_s$$

$$\frac{-V_{out}}{R_f} = I_s$$

$$V_{out} = -I_s R_f$$