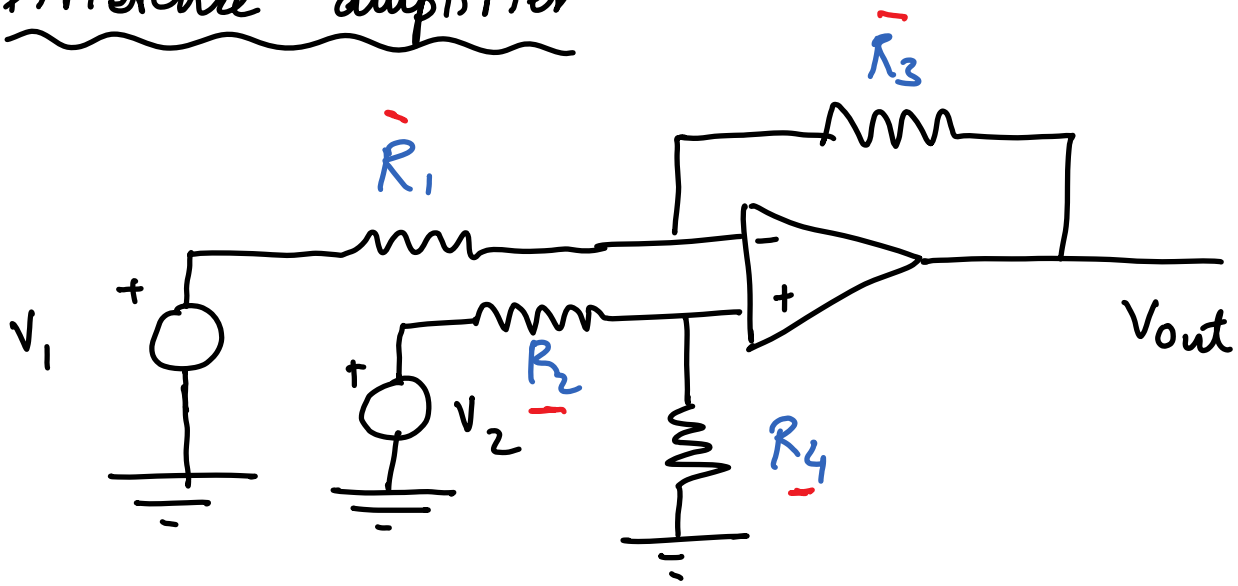
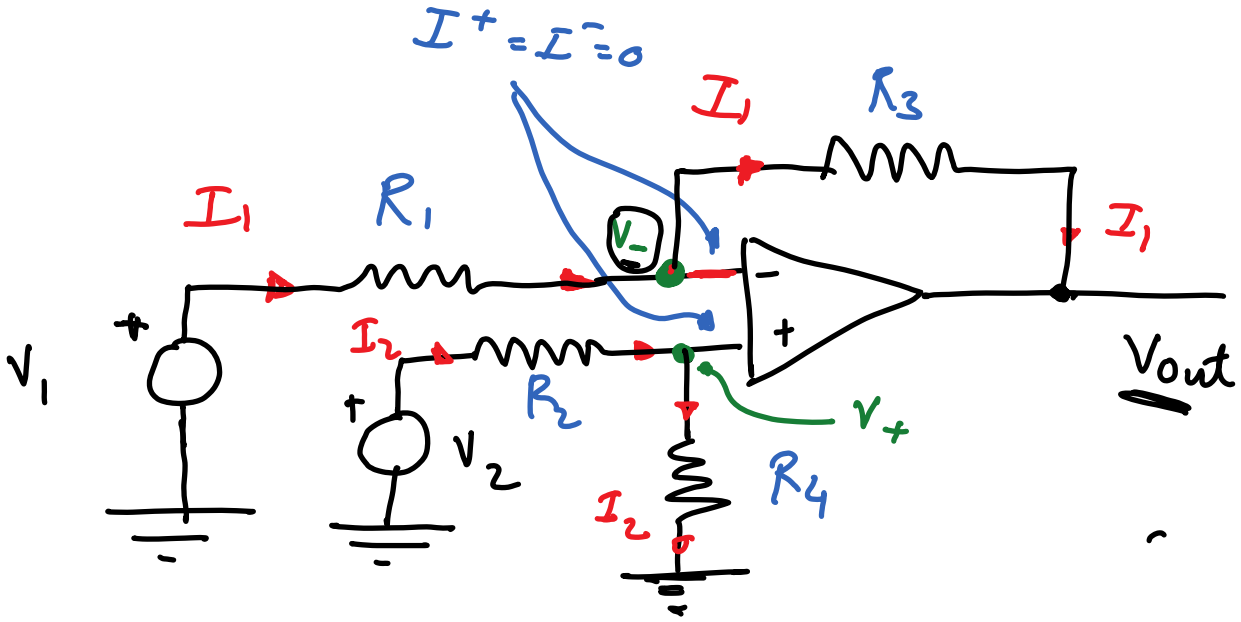
Difference amplifier



Compute $V_{out} = f(V_1, V_2)$ and resistors R_1, R_2, R_3, R_4



$V_- = V_+$ (op-amp assumption)

$V_1 - V_- = I_1 R_1$

$V_- - V_{out} = I_1 R_3$

$V_2 - V_+ = I_2 R_2$

$V_+ - 0 = I_2 R_4$

Unknowns: (5)

$V_-, V_+, I_1, I_2, V_{out}$

Equations (5)

Solving for V_{out}

$$V_{out} = \frac{R_4}{R_3 + R_4}\left(1 + \frac{R_2}{R_1}\right) V_2 - \frac{R_2}{R_1} V_1 \quad \text{(I)}$$

$$V_2 - V_1 = V_d$$

$$V_2 + V_1 = 2V_{cm}$$

Solving for V_1, V_2

$$\Rightarrow V_1 = \frac{2V_{cm} - V_d}{2}$$

$$V_2 = \frac{2V_{cm} + V_d}{2}$$

} — (II)

Substitute (II) in (I)

$$V_{out} = \left(\frac{R_4}{R_3 + R_4}\right)\left(1 + \frac{R_2}{R_1}\right)\left(\frac{2V_{cm} + V_d}{2}\right) - \frac{R_2}{R_1}\left(\frac{2V_{cm} - V_d}{2}\right)$$

Simplifying, we get

$$V_{out} = 0.5\left[\frac{R_4}{(R_3+R_4)}\left(1+\frac{R_2}{R_1}\right)+\frac{R_2}{R_1}\right]\underbrace{V_d}_{V_2-V_1} + \underbrace{\quad}_{=0}$$

$$\Rightarrow \left(\left[\frac{R_4}{(R_3+R_4)}\left(1+\frac{R_2}{R_1}\right)-\frac{R_2}{R_1}\right]V_{cm}\right)_{=0}, \quad V_{cm} = \frac{V_1+V_2}{2}$$

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

Choose $R_1 = R_3$ & $R_2 = R_4$

$$V_{out} = \frac{R_2}{R_1} V_d = \frac{R_2}{R_1}(V_2 - V_1)$$

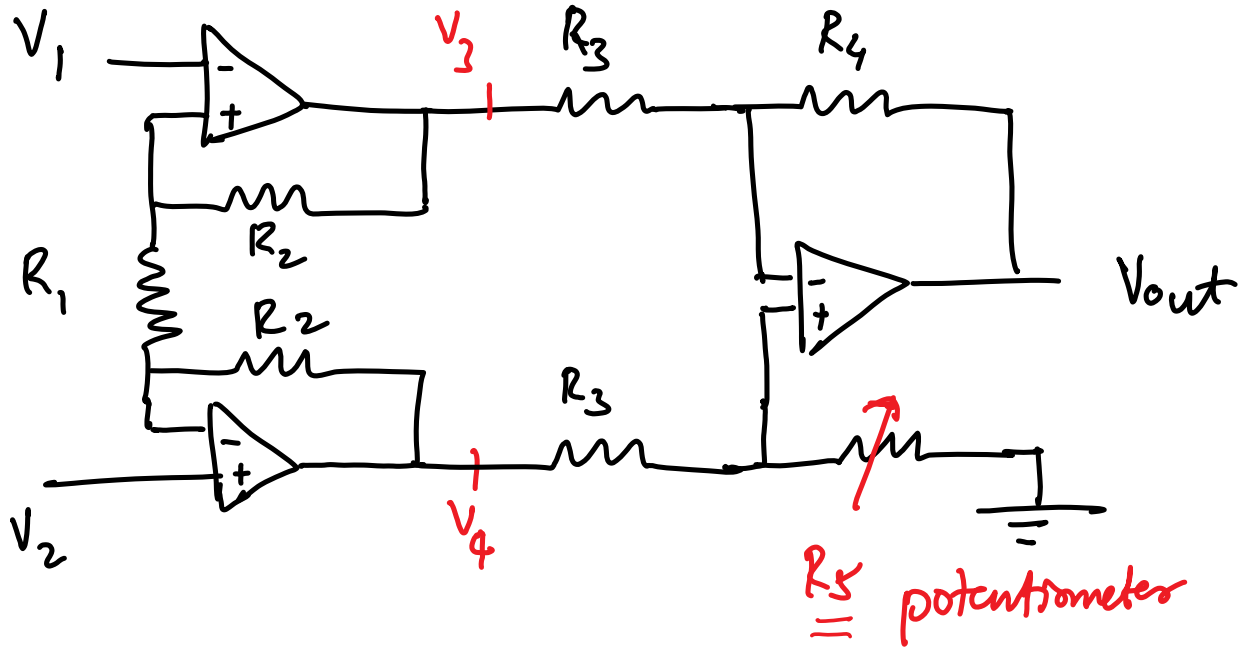
This is true when $R_1 = R_3$ & $R_2 = R_4$

Since this is based on perfect matching of resistors $R_1 = R_3$ & $R_2 = R_4$ this circuit is sensitive to this matching. If the resistance changes with time (e.g. resistance increases as the resistor is heated), this circuit will not be useful to compute the difference.

Hence, this is not used for computing the difference.

An instrumentation amplifier is used to compute the difference.

(7) Instrumentation amplifier



$$V_{out} = \frac{R_5}{R_1}\,\frac{(R_3+R_4)}{(R_3+R_5)}\,V_4 - \frac{R_4}{R_3}\,V_3$$

& some other equations

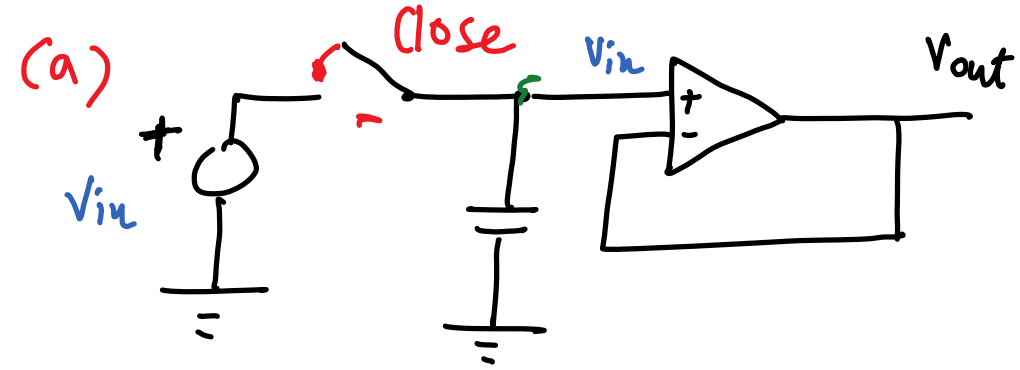
$\Rightarrow R_5 = R_4$

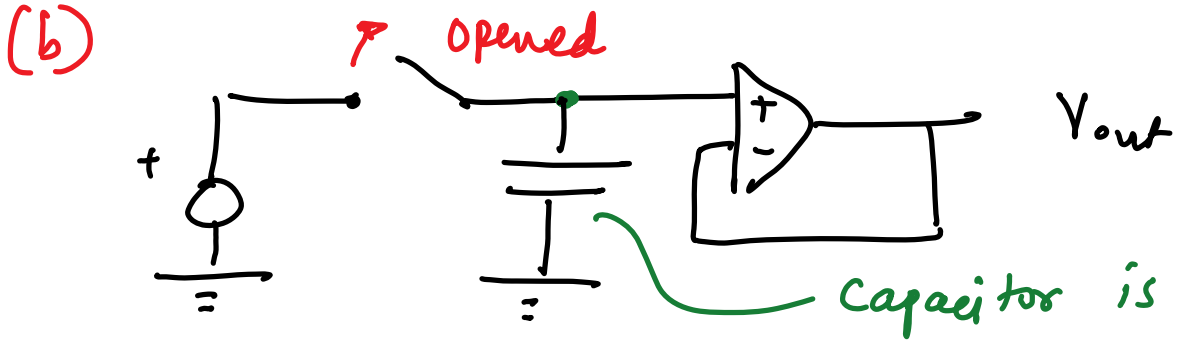
$$V_{out} = \left[\frac{R_4}{R_3}\left(1+\frac{2R_2}{R_1}\right)\right](V_2 - V_1)$$

Advantages over difference amp:

① Only 1 resistor to be matched ② R_5 uses a potentiometer.

⑧ Sample & hold





(a) Switch closed

$V_+ = V_{in}$

$V_- = V_+$

$V_- = V_{out}$

$\Rightarrow V_{in} = V_{out}$ follower

(b) Switch is opened

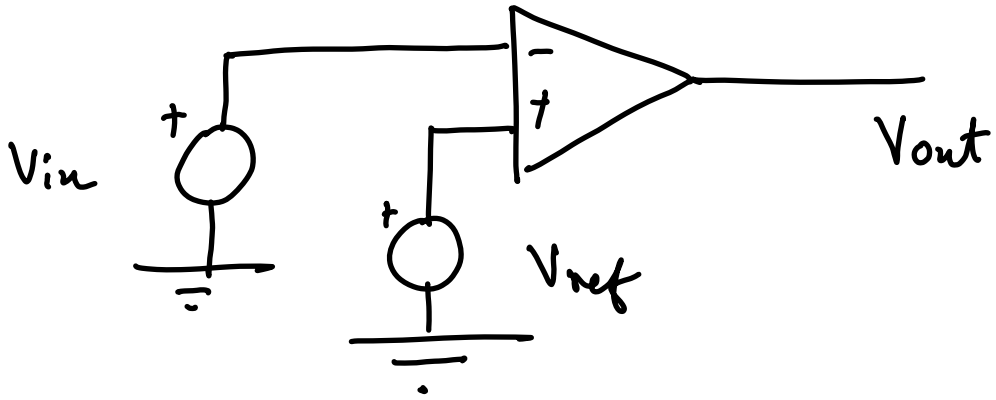
$$V_{out}(t) = V_{in}(t_{closed}) \quad t \geq t_{closed}$$

holds the voltage

Use

n polystrene or polypropene capacitors as they leak very little charge.

⑨ Comparator



- V_{out} saturates

$$- \quad V_{out} = \begin{cases} V_{sat} & V_{in} > V_{ref} \\ -V_{sat} & V_{in} < V_{ref} \end{cases}$$

$$V_{out} = A_V (V_+ - V_-)$$

$A_V \to \infty$

$V_{out} \to \infty$ for small diff in V_+ & V_-

$$V_{out} \begin{cases} = 15 - 1.4 = 13.6\ V & V_{in} > V_{ref} \\ = -15 + 1.4 = -13.6\ V & V_{in} < V_{ref} \end{cases}$$