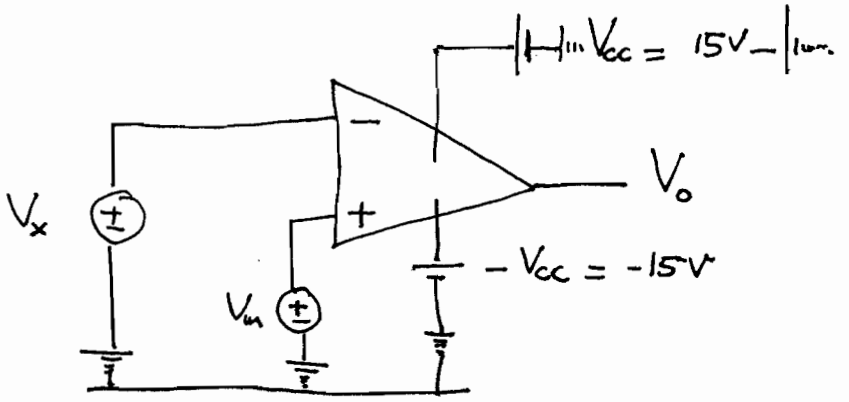
ECE-314, Fall 2008

Operational Amplifier (Review)

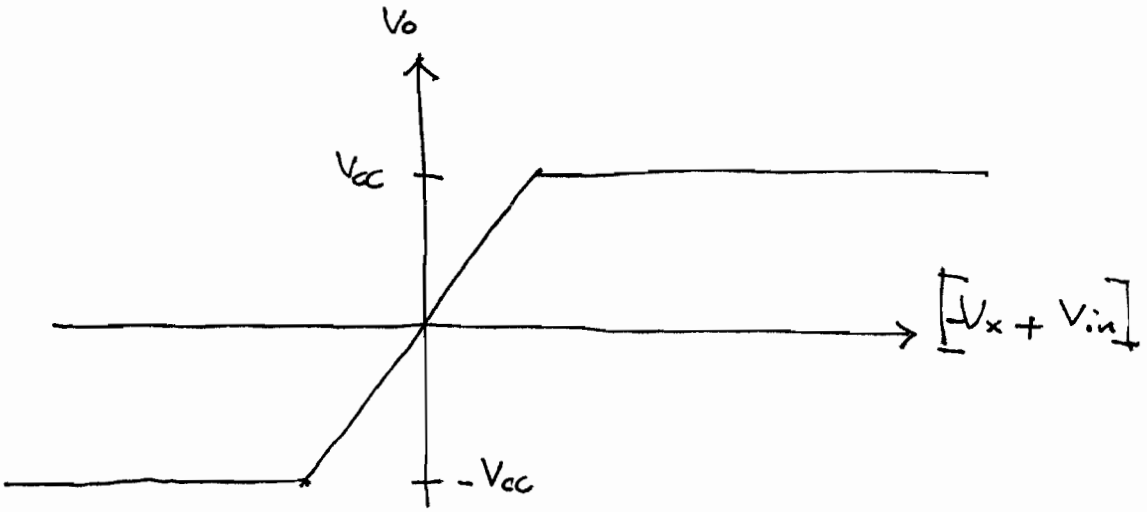
Open Loop Mode:



Two inputs (V_+ & V_-)
One output

$$V_o = (V_{in} - V_x) A$$

A is open loop gain & very large $\approx 10^6$



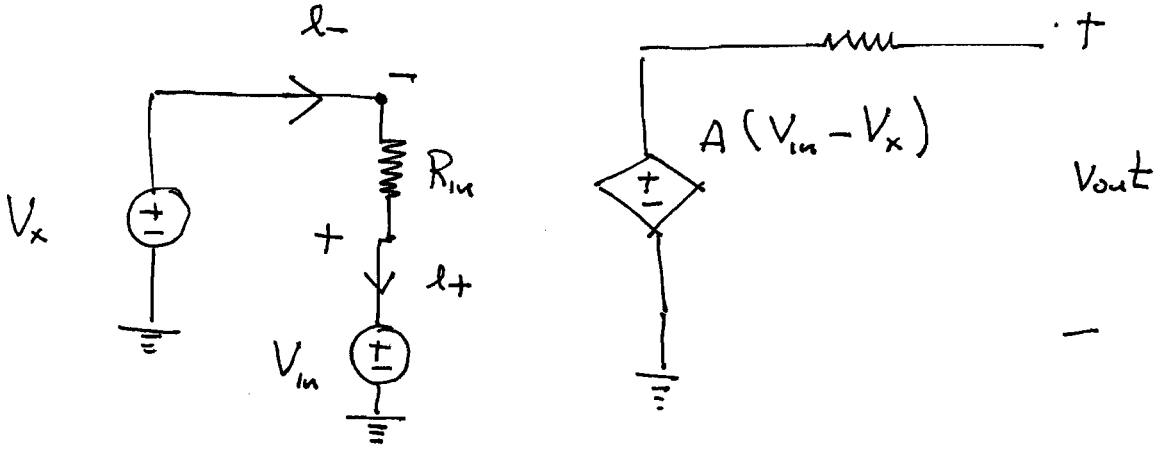
Linear Region $\quad |V_x - V_{in}| < \frac{V_{cc}}{A}$

$|V_x - V_{in}| <$ few microvolts

$R_{in} = \infty$

$R_{out} = 0$

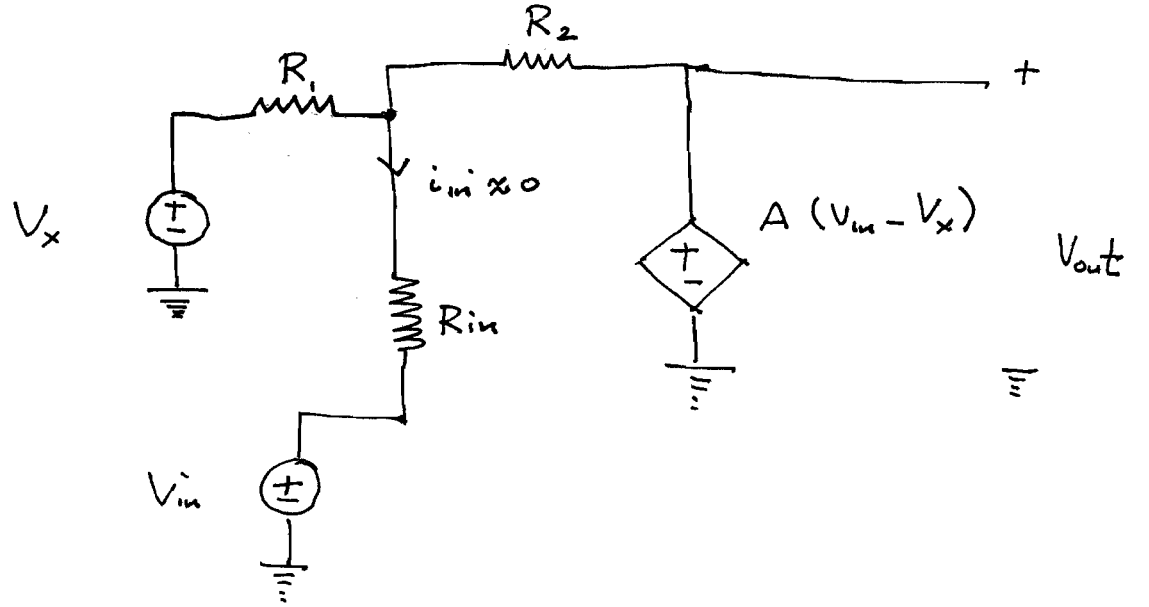
Controlled Voltage Source Model



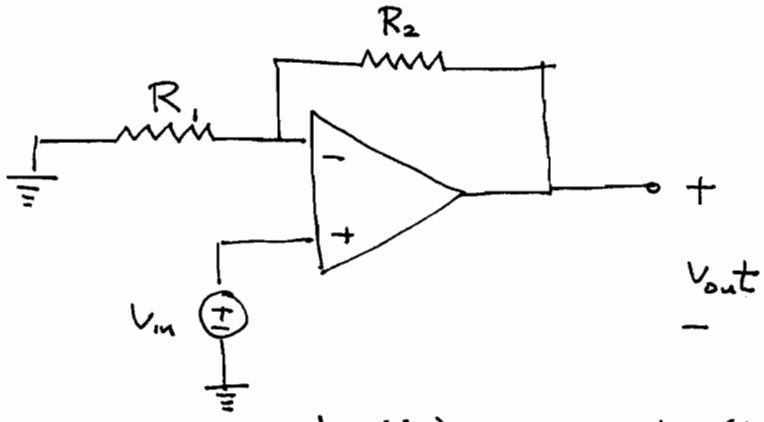
If $i_+ = i_- = 0$

$R_{in} = \infty$

Closed Loop Mode



Non-Inverting Amplifier

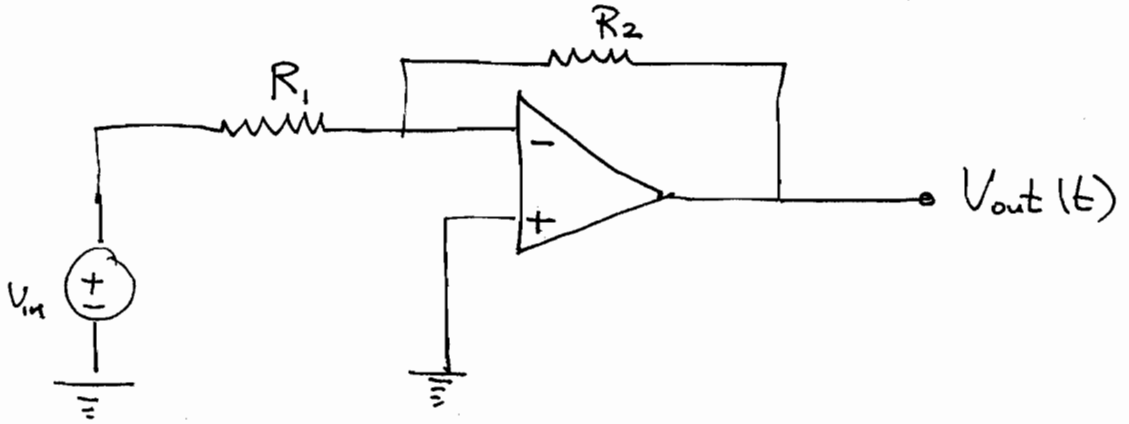


$$\frac{V_{out}(j\omega) - \cancel{V_-}^{V_{in}(j\omega)}}{R_2} + \frac{0 - \cancel{V_-}^{V_{in}(j\omega)}}{R_1} = 0$$

$$\frac{V_{out}(j\omega)}{R_2} = V_{in}(j\omega)\left[\frac{1}{R_2} + \frac{1}{R_1}\right]$$

$$\frac{V_{out}(j\omega)}{V_{in}(j\omega)} = \left(1 + \frac{R_2}{R_1}\right) = H(j\omega)$$

Inverting amplifier:

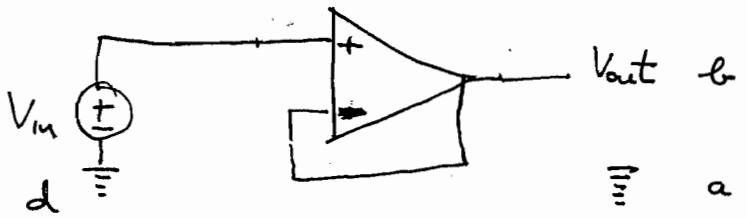


$$\frac{V_{out}(j\omega) - \cancel{V_-}^{0}}{R_2} + \frac{V_{in}(j\omega) - \cancel{V_-}^{0}}{R_1} = 0$$

$$\frac{V_{out}(j\omega)}{V_{in}(j\omega)} = -\frac{R_2}{R_1}$$

$$\Rightarrow \quad \frac{v_{out}(t)}{v_{in}(t)} = -\frac{R_2}{R_1}$$

Voltage Follower:



$$V_o = V_- = V_+ = V_{out}$$

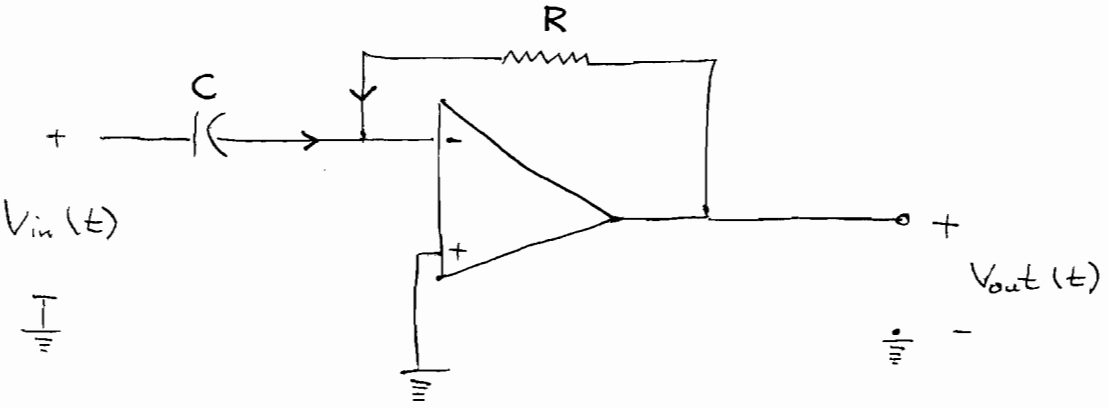
$$V_{out}(t) - V_{in}(t) = 0$$

$$\Rightarrow V_{out}(t) = V_{in}(t) \quad [\text{Unity gain}]$$

Used to provide buffering between circuits

Different from just connecting wires because $R_{in} = \infty$ & $R_{out} = 0$

Integrator or Differenciator:



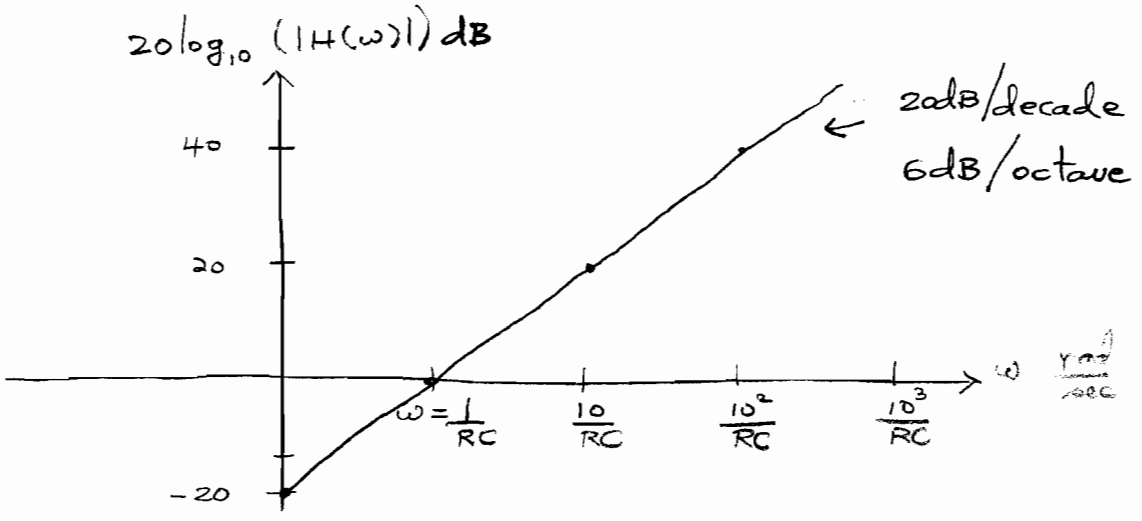
$$\frac{V_{out} - V_-}{R} + \frac{V_{in} - V_-}{\frac{1}{j\omega C}} = 0$$

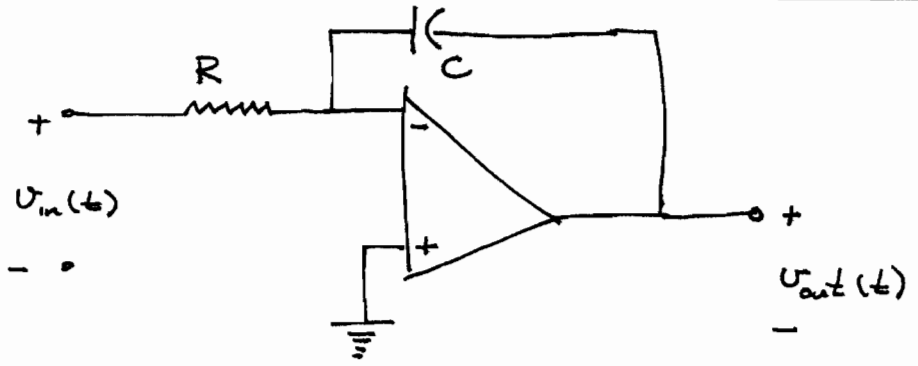
$$\frac{V_{out}(j\omega)}{R} + j\omega C\, V_{in}(j\omega) = 0$$

$$\frac{V_{out}(j\omega)}{V_{in}(j\omega)} = H(j\omega) = -j\omega RC$$

$$20\log_{10}\left(|H(j\omega)|\right) = 20\log_{10}(\omega RC)$$

$$= 20\log_{10}(\omega) + 20\log_{10}(a)$$





$$\frac{V_{out}(j\omega) - \cancel{V_-}^{\,0}}{\frac{1}{j\omega C}} + \frac{V_{in}(j\omega) - \cancel{V_-}^{\,0}}{R} = 0$$

$$j\omega C\, V_{out}(j\omega) = -\frac{V_{in}(j\omega)}{R}$$

$$H(j\omega) = \frac{V_{out}(j\omega)}{V_{in}(j\omega)} = -\frac{1}{j\omega RC}$$

$$20\log_{10}\left(|H(j\omega)|\right) = -20\log_{10}(\omega RC) \quad \text{dB}$$