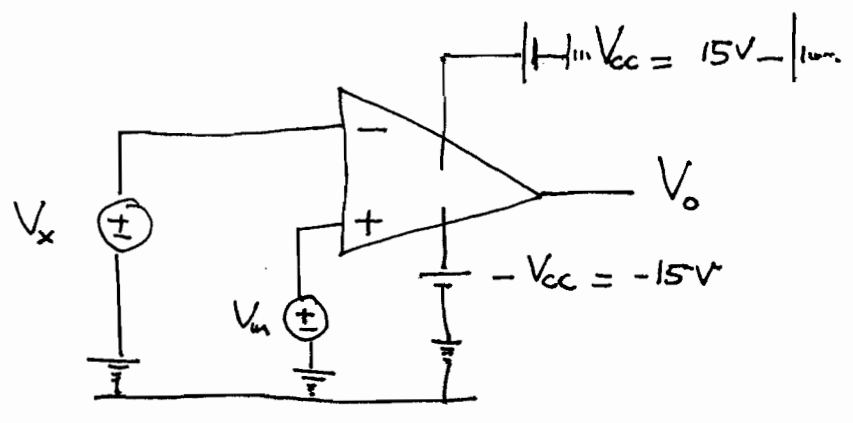


Operational Amplifier (Review)

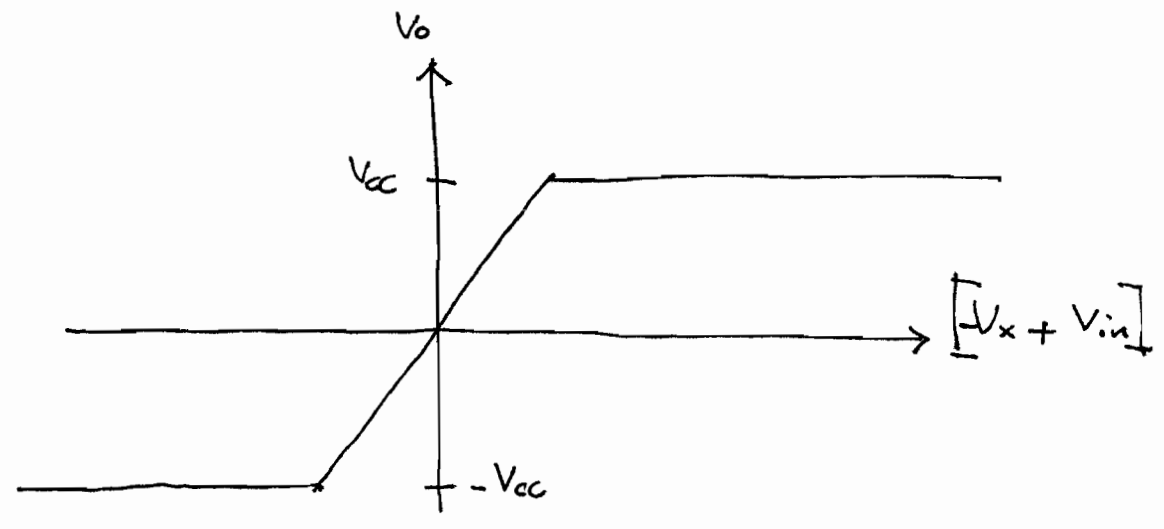
Open Loop Mode:



Two inputs (\$V_+\$ & \$V_-\$)
One output

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

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



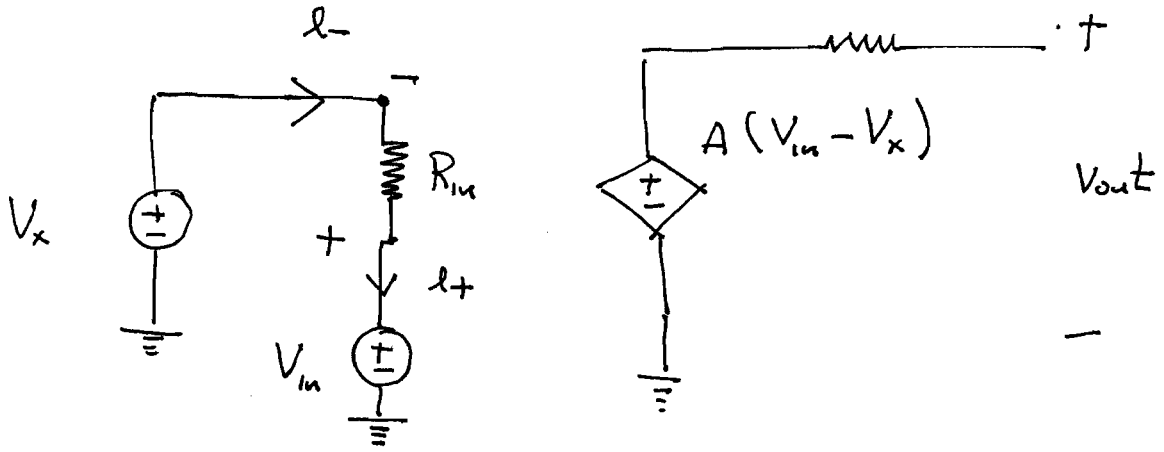
Linear Region $|V_x - V_{in}| < \frac{V_{cc}}{A}$

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

$R_{in} = \infty$

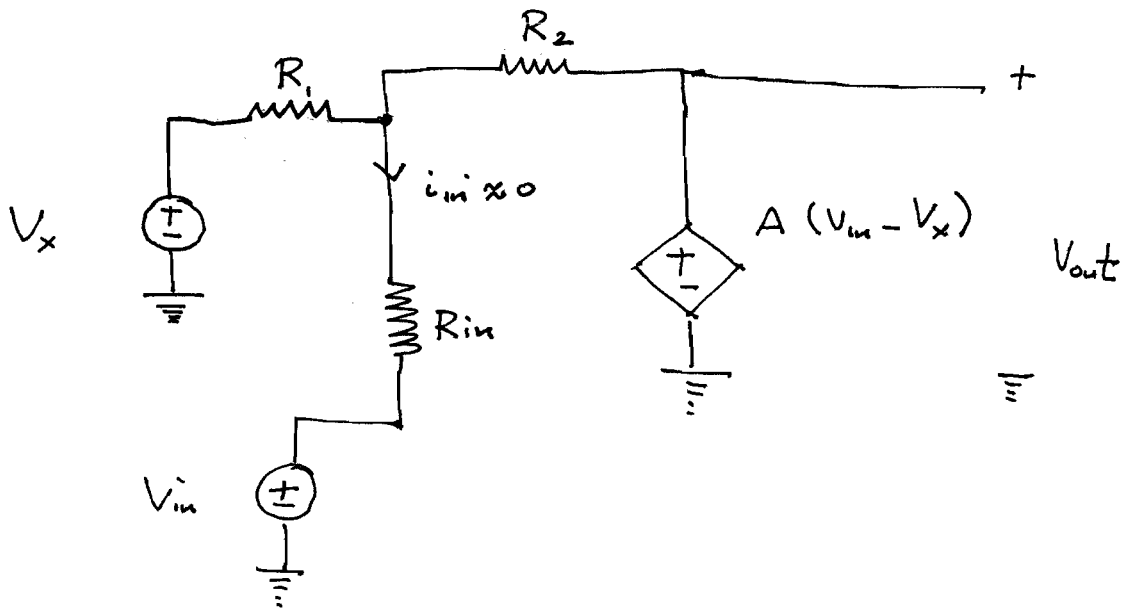
$R_{out} = 0$

Controlled Voltage Source Model



If $i_+ = i_- = 0$
 $R_{in} = \infty$

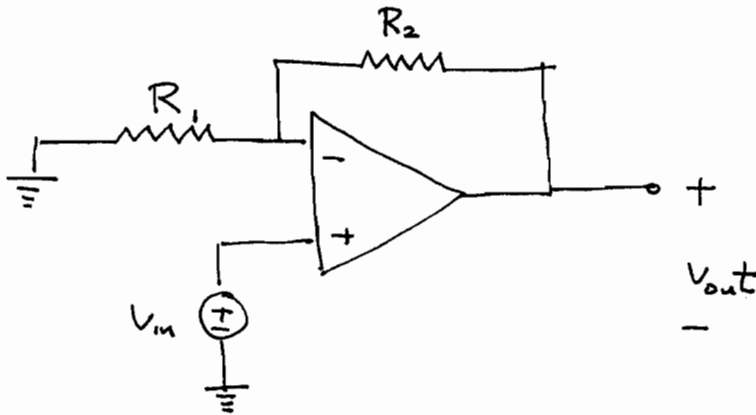
Closed Loop Mode



19-782 500 SHEETS, FILLER 5 SQUARE
 19-783 100 SHEETS, FILLER 5 SQUARE
 42-382 100 SHEETS, VE-EAS 5 SQUARE
 42-383 200 SHEETS, VE-EAS 5 SQUARE
 42-384 100 SHEETS, VE-EAS 5 SQUARE
 42-385 200 SHEETS, VE-EAS 5 SQUARE
 42-386 100 RECYCLED WHITE 5 SQUARE
 42-387 200 RECYCLED WHITE 5 SQUARE
 Made in U.S.A.



Non - Inverting Amplifier

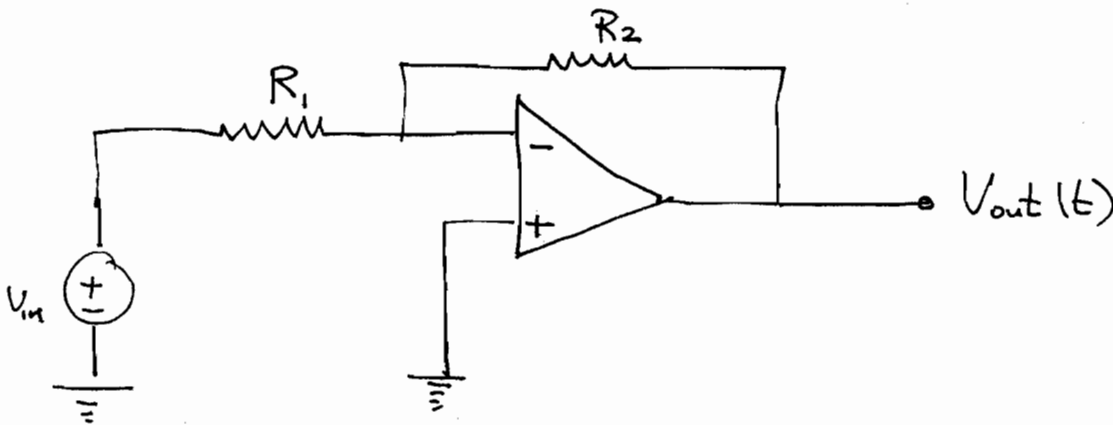


$$\frac{V_{out}(j\omega) - V_-}{R_2} + \frac{0 - V_-}{R_1} = 0$$

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

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

Inverting amplifier:



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

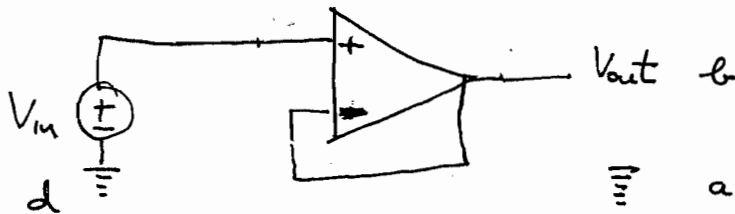
13-782 500 SHEETS FULLER 5 SQUARE
 42-382 500 SHEETS FULLER 8 SQUARE
 42-382 100 SHEETS EYE-EASE 5 SQUARE
 42-388 200 SHEETS EYE-EASE 5 SQUARE
 42-389 100 SHEETS EYE-EASE 8 SQUARE
 42-390 200 SHEETS EYE-EASE 8 SQUARE
 42-391 200 RECYCLED WHITE 5 SQUARE
 42-392 200 RECYCLED WHITE 8 SQUARE
 Made in U.S.A.



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

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

Voltage Follower:



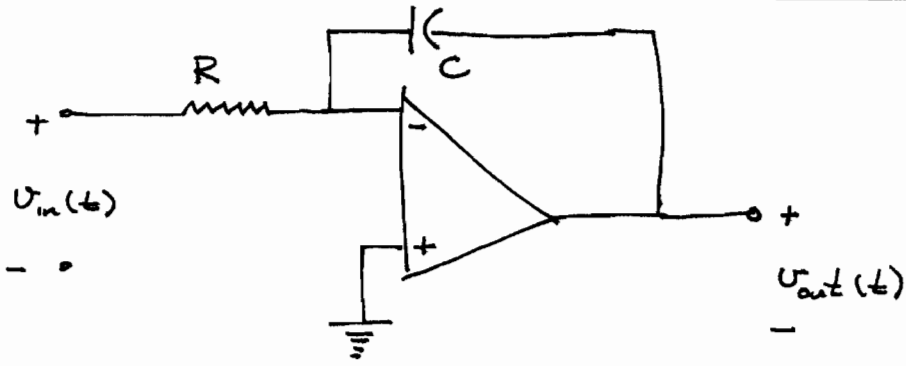
$$V_o = V_- = V_+ = V_{out}$$

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

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

Used to provide buffering between circuits

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



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

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

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

