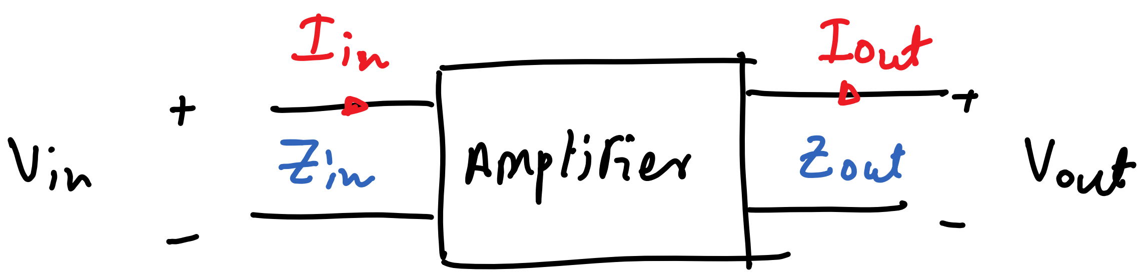
Amplifier

- used to amplify signals so that they can be measured.



$$\frac{V_{out}}{\Delta V_{in}} = A_V$$ (big)

$A_V \rightarrow$ voltage gain

A_V — linear (at all frequencies)

$$\frac{V_{in}}{I_{in}} = z_{in}$$ (Big)

I_{in} (small)

$$\frac{V_{out}}{z_{out}} = z_{out}$$ (small)

$\Downarrow$

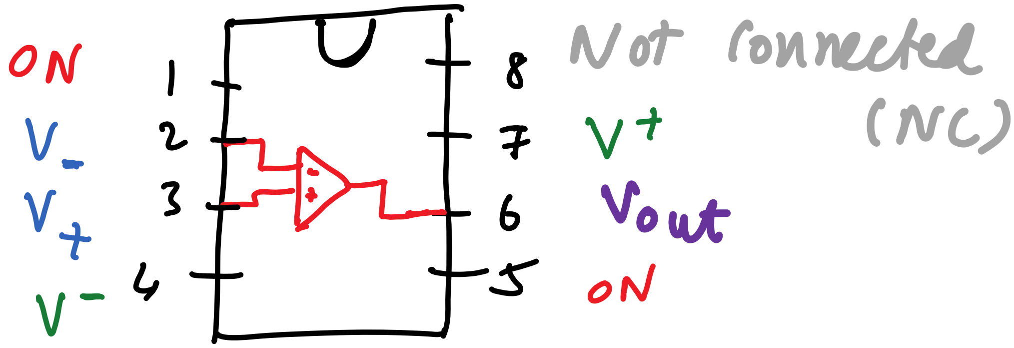
$V_{out} \approx$ small

does not affect the current in the load

Operational amplifier (Op-amp)

- integrated circuit (resistors, capacitors, BJTs ...)
- manufactured as a single chip of silicon
- building block
  - amplifier
  - integrators
  - summers
  - differentiator
  - comparator
  - Analog to Digital / Digital to Analog converters
  - sample & hold amplifiers (e.g. LCD display)

LM 741



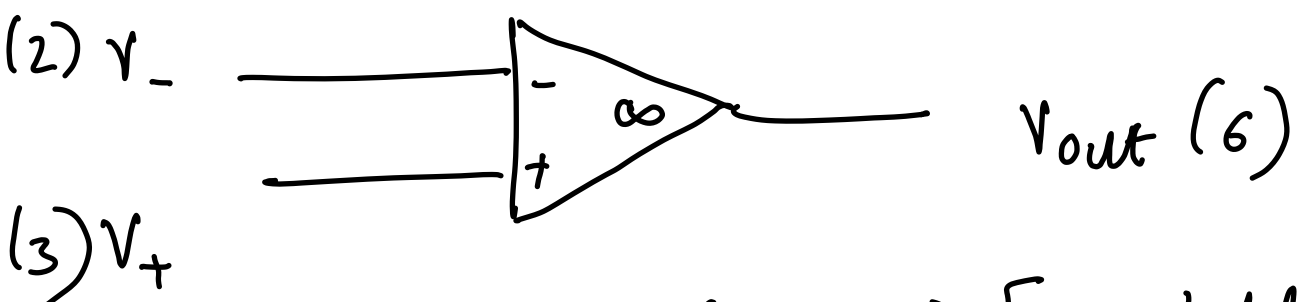
→ ON – Offset Null

→ V_-, V_+ – inputs

→ V^-, V^+ – supply voltages (external voltage)
+15 V, −15 V

→ V_{out} – output voltage

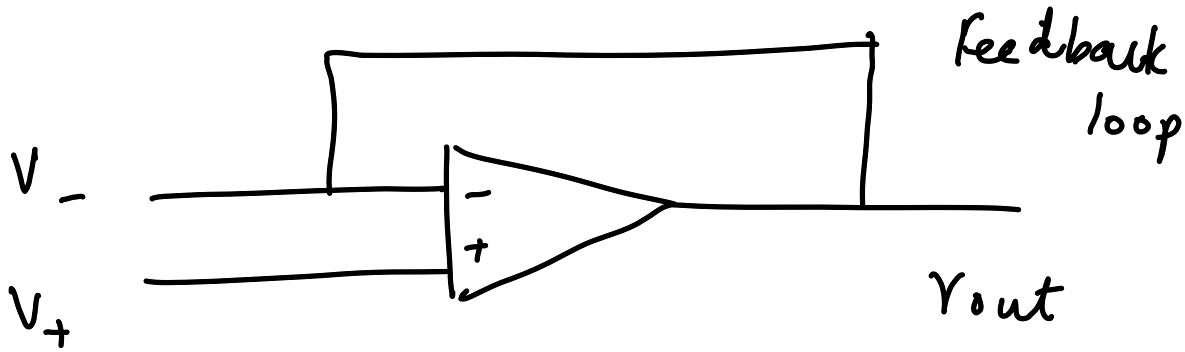
2, 3, 6 – circuit diagrams



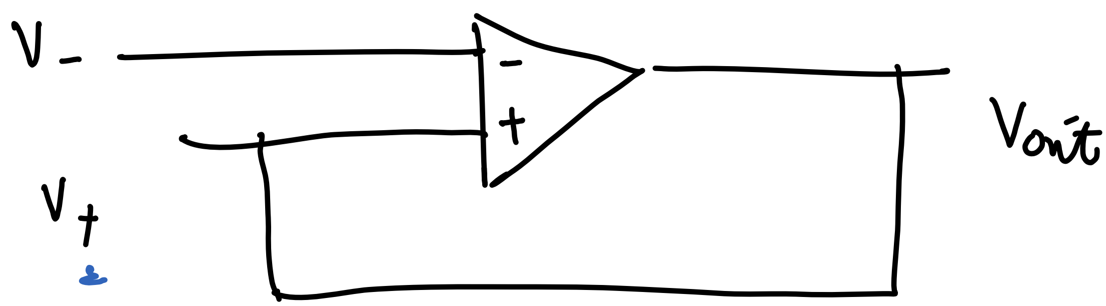
open-loop (op-amp) [unstable]

× used sometimes.

Negative feedback (Stable)

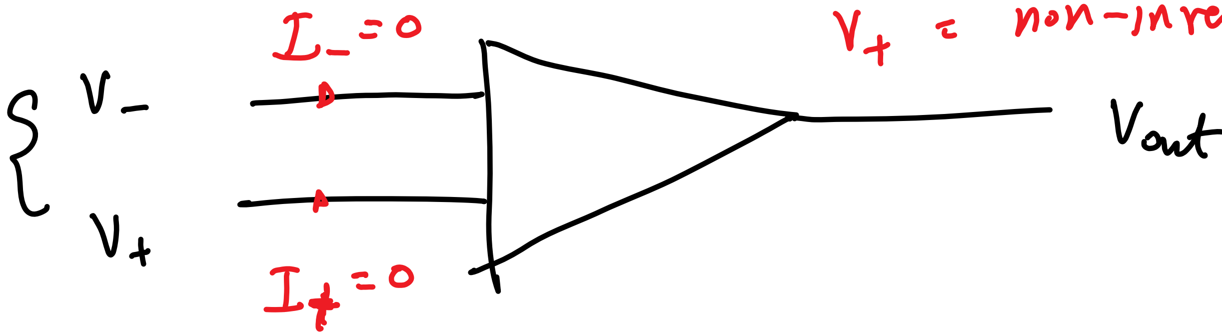


Positive feedback (Unstable)



Ideal op-amp model

V_- = inverting input
V_+ = non-inverting input



$$\boxed{\begin{array}{l} ① \quad I_- = 0 \quad \& \quad I_+ = 0 \\ ② \quad V_+ = V_- \end{array}}$$

(As $Z_{in} \to \infty$)

(As $A_V \to \infty$)

$$\frac{V_{out}}{\Delta V_{in}} = A_V$$

③ $Z_{out} = 0$

Vout does not depend on Iout

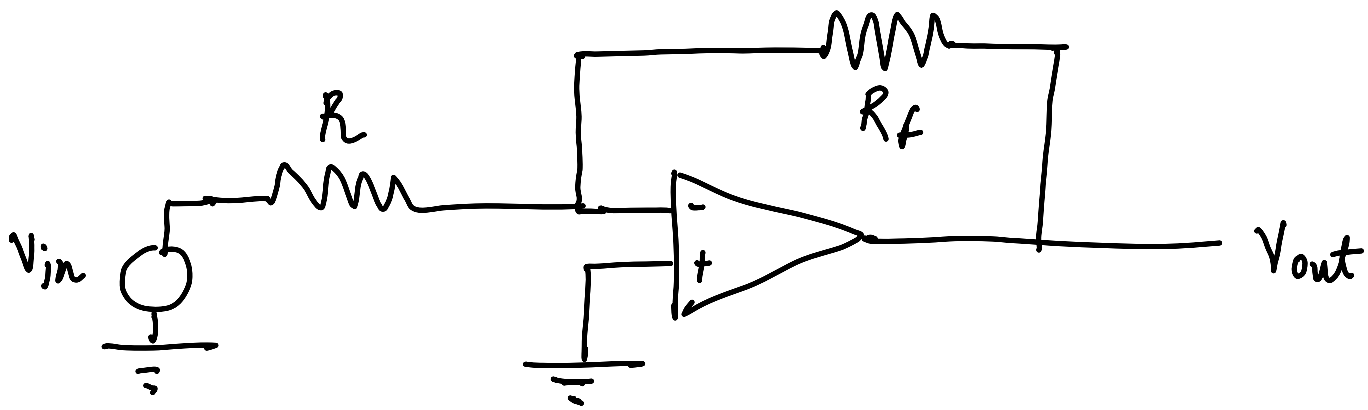
$$\frac{V_{out}}{V_+ - V_-} = A_V \to \infty$$

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

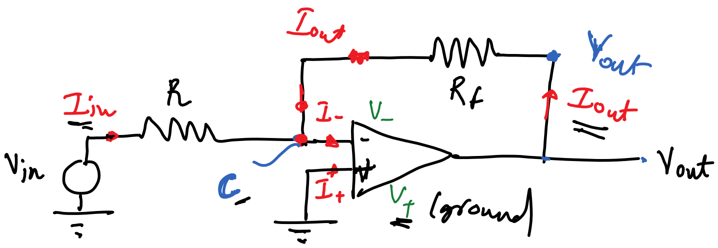
$\underset{\text{finite}}{\parallel} \qquad \underset{\infty}{\downarrow} \qquad \underset{0}{\downarrow}$

① Inverting amplifier

(-ive) (increase amplitude)



$$\frac{V_{out}}{V_{in}} = ?$$



$$\boxed{V_{out} / V_{in} = ?}$$

Assumptions for op-amp: $V_+ = V_-$

$\Rightarrow \boxed{I_- = I_+ = 0}$

$$\left.\begin{array}{l} V_{out} - V_c = I_{out} R_f \\ V_{in} - V_c = I_{in} R \end{array}\right\} \quad \frac{V_{out}}{V_{in}} = \frac{I_{out}}{I_{in}} \frac{R_f}{R}$$

$V_+ = 0 \Rightarrow V_- = V_+ \quad \Rightarrow V_- = 0$

$V_c = V_- \quad \Rightarrow \underline{\underline{V_c = 0}}$

At C: $I_{in} + I_{out} = I_- = 0$

KCL

$I_{out} = - I_{in} \Rightarrow \dfrac{I_{out}}{I_{in}} = -1$

$$\frac{I_{out}}{I_{in}} = 1 \quad \Bigg\| \quad \frac{V_{out}}{V_{in}} = \frac{I_{out}}{I_{in}} \frac{R_f}{R}$$

$$\boxed{\frac{V_{out}}{V_{in}} = -\frac{R_f}{R}}$$

(1) $V_{out} = - \frac{R_f}{R} V_{in}$

inverting

(2) $R_f = 10^3 R$

$\frac{V_{out}}{V_{in}} = -10^3$ (amplification)