Lecture 5B

Admin:

1. Mid-Semester Survey
2. Midterm Redo

Agenda:

→ Op Amp Circuit Analysis

→ Inverting and Non-Inverting Amplifiers

→ Circuit Design (Intro)

Review

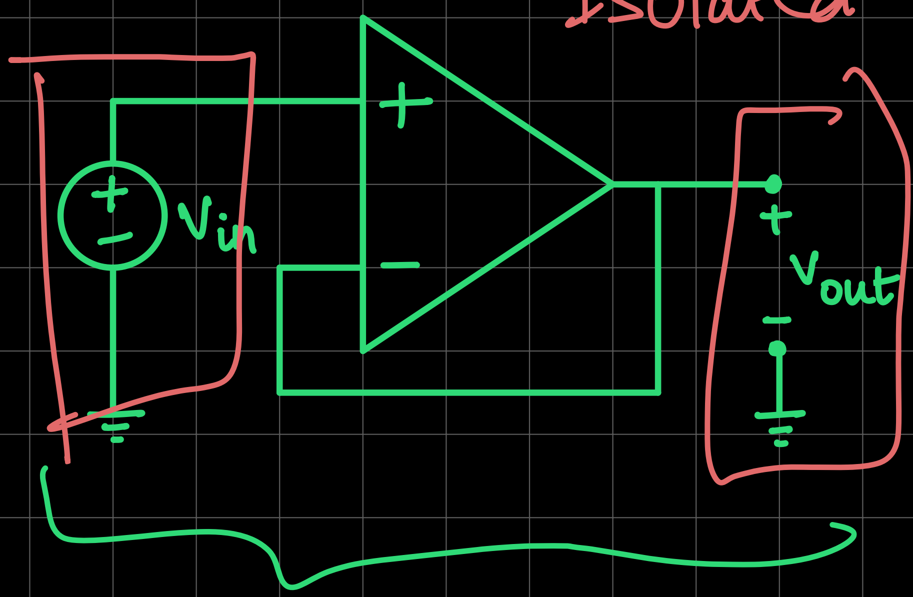
Golden Rules –

1. No input current: $I_+ = I_- = 0$
2. In NFB, $u^+ = u^-$

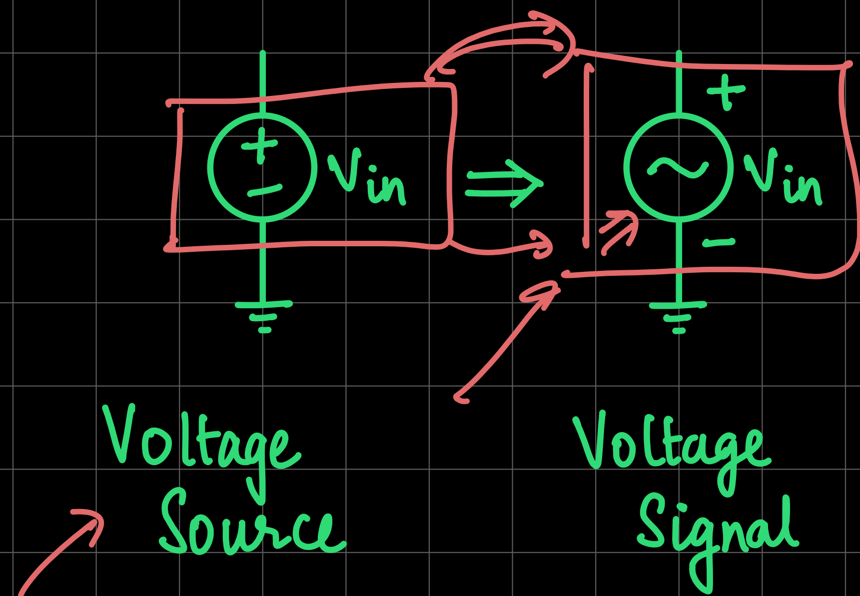
} → Ideal Op-Amps ($A \to \infty$)

Buffer

Isolated



$V_{in} = V_{out}$



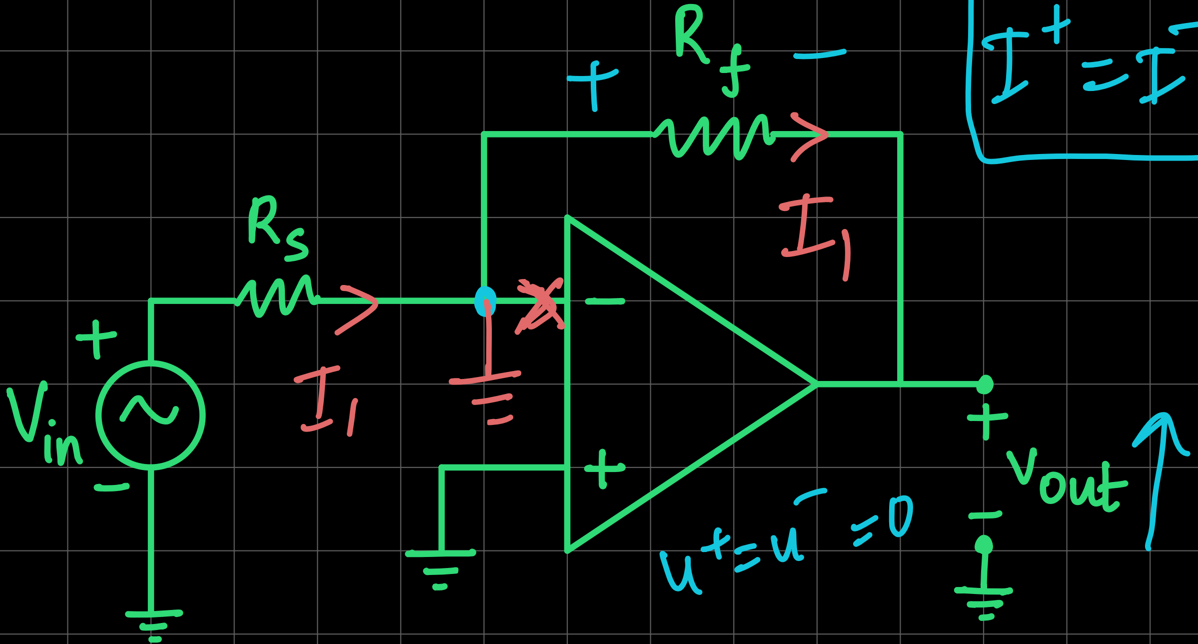
Voltage Source

Voltage Signal

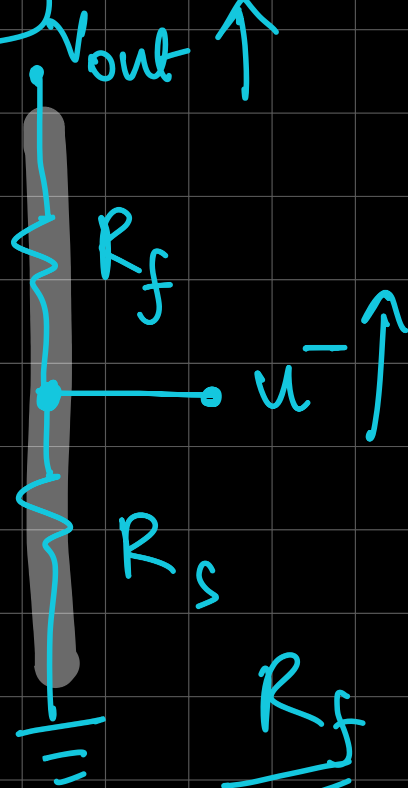
Inverting Amplifier

V_{out} ?

① Check −ve feedback



$$I^+ = I^- = 0$$



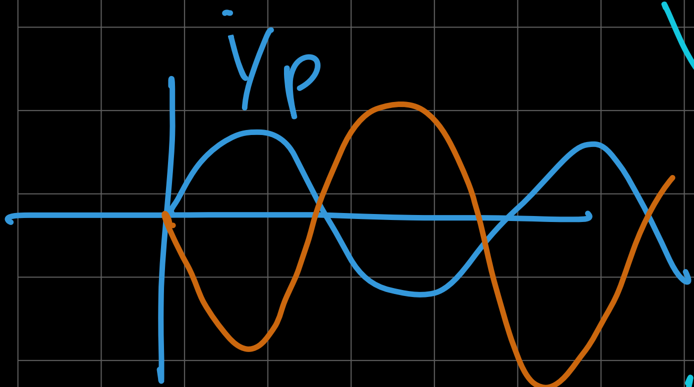
$$o/p \rightarrow A(u^+ - u^-)$$

$$R_f .$$

$$u^+ = u^- = 0$$

$$I_1 = \frac{V_{in} - 0}{R_s}$$

$$V_{R_f} = 0 - V_{out}$$
$$= I_1 R_f$$



$V_{R_f} = 0 - V_{out}$

$= I_1 R_f$

$I_1 = \frac{V_{in}}{R_s}$

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

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

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

$-\frac{R_f}{R_s}$

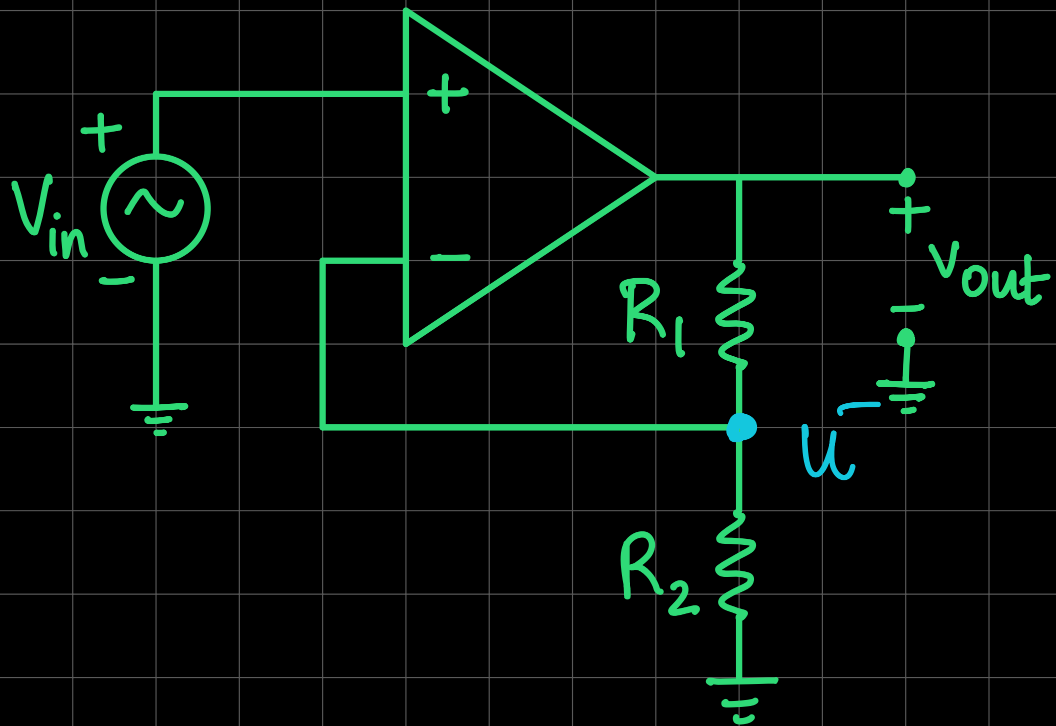
Check NFB.

(1) zero out all independent sources

(2) $V_{out} \uparrow$

$\downarrow$ o/p $A(u^+ - u^-)$

Non-Inverting Amplifier



$V_{out} \uparrow$

$u^- \uparrow$

O/P $A(u^+ - u^-) \downarrow$

NFB ✓

V_{out}?

$u^+ = u^- = V_{in}$ $\left(1 + \frac{R_1}{R_2}\right)$

$$u^- = \frac{R_2}{R_1 + R_2} V_{out} = V_{in}$$

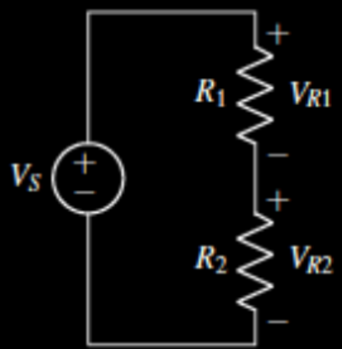
$$V_{out} = \frac{R_1 + R_2}{R_2} V_{in} = \left(1 + \frac{R_1}{R_2}\right) V_{in}$$

$$V_{out} = 10 V_{in}$$

$$\frac{R_1}{R_2} = 9$$

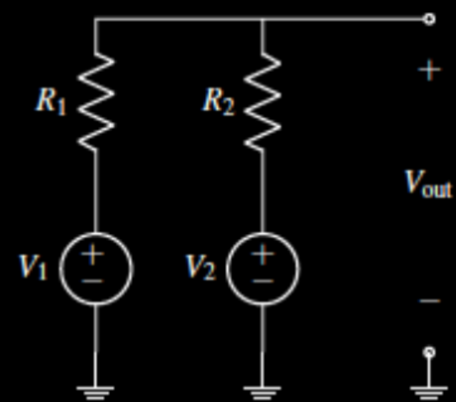
OP-AMP CHEAT SHEET

Voltage Divider



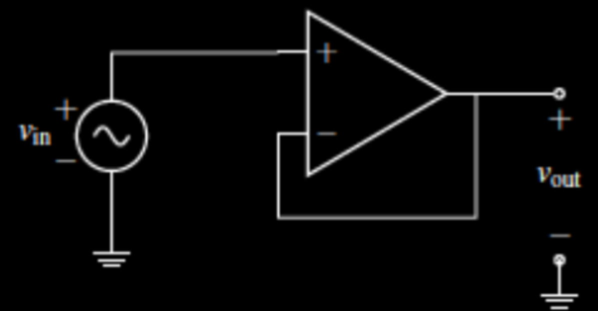
$$V_{R2} = V_S\left(\frac{R_2}{R_1+R_2}\right)$$

Voltage Summer



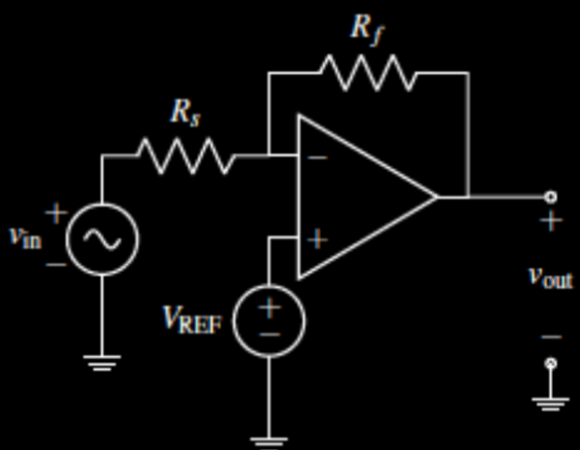
$$V_{out} = V_1\left(\frac{R_2}{R_1+R_2}\right) + V_2\left(\frac{R_1}{R_1+R_2}\right)$$

Unity Gain Buffer



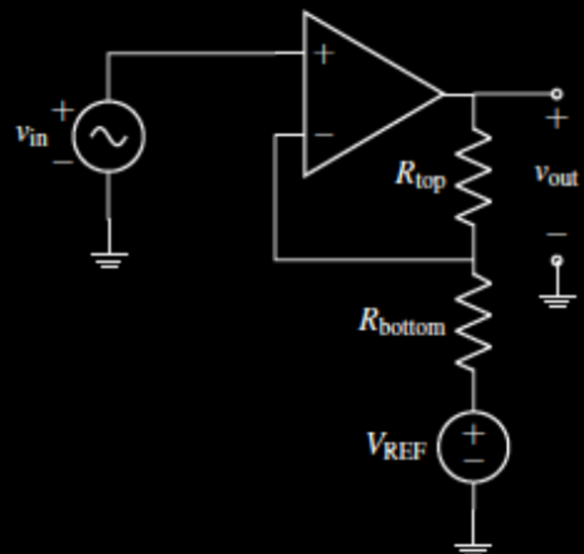
$$\frac{v_{out}}{v_{in}} = 1$$

Inverting Amplifier



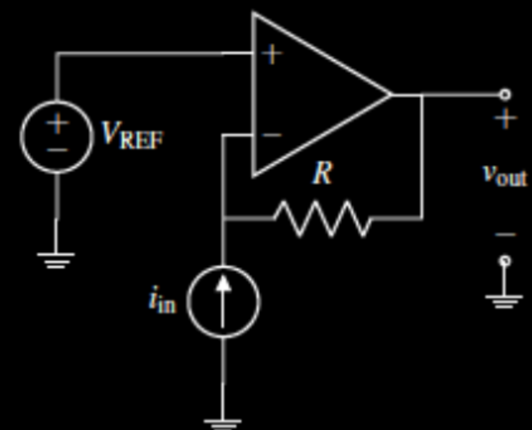
$$v_{out} = v_{in}\left(-\frac{R_f}{R_s}\right) + V_{REF}\left(\frac{R_f}{R_s}+1\right)$$

Non-inverting Amplifier



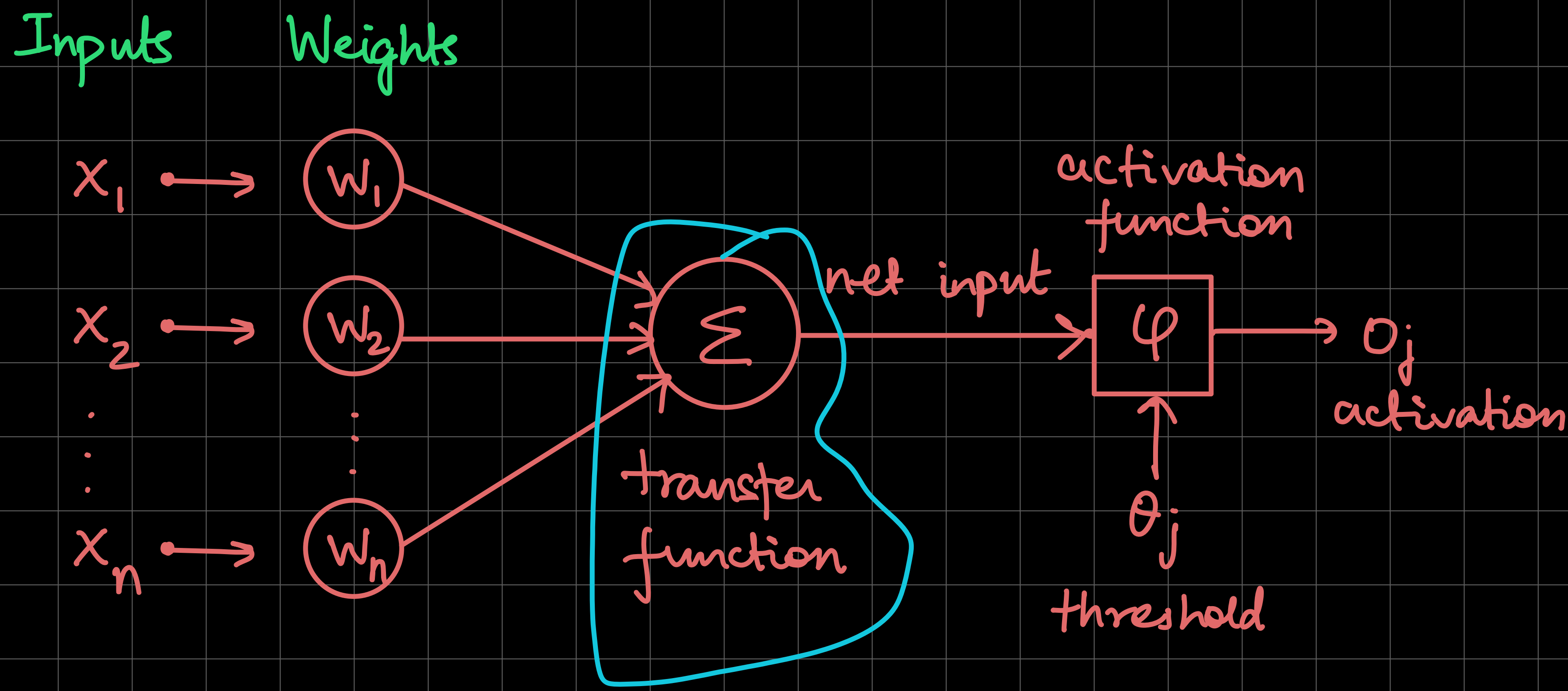
$$v_{out} = v_{in}\left(1+\frac{R_{top}}{R_{bottom}}\right) - V_{REF}\left(\frac{R_{top}}{R_{bottom}}\right)$$

Transresistance Amplifier



$$v_{out} = i_{in}(-R) + V_{REF}$$

Artificial Neuron

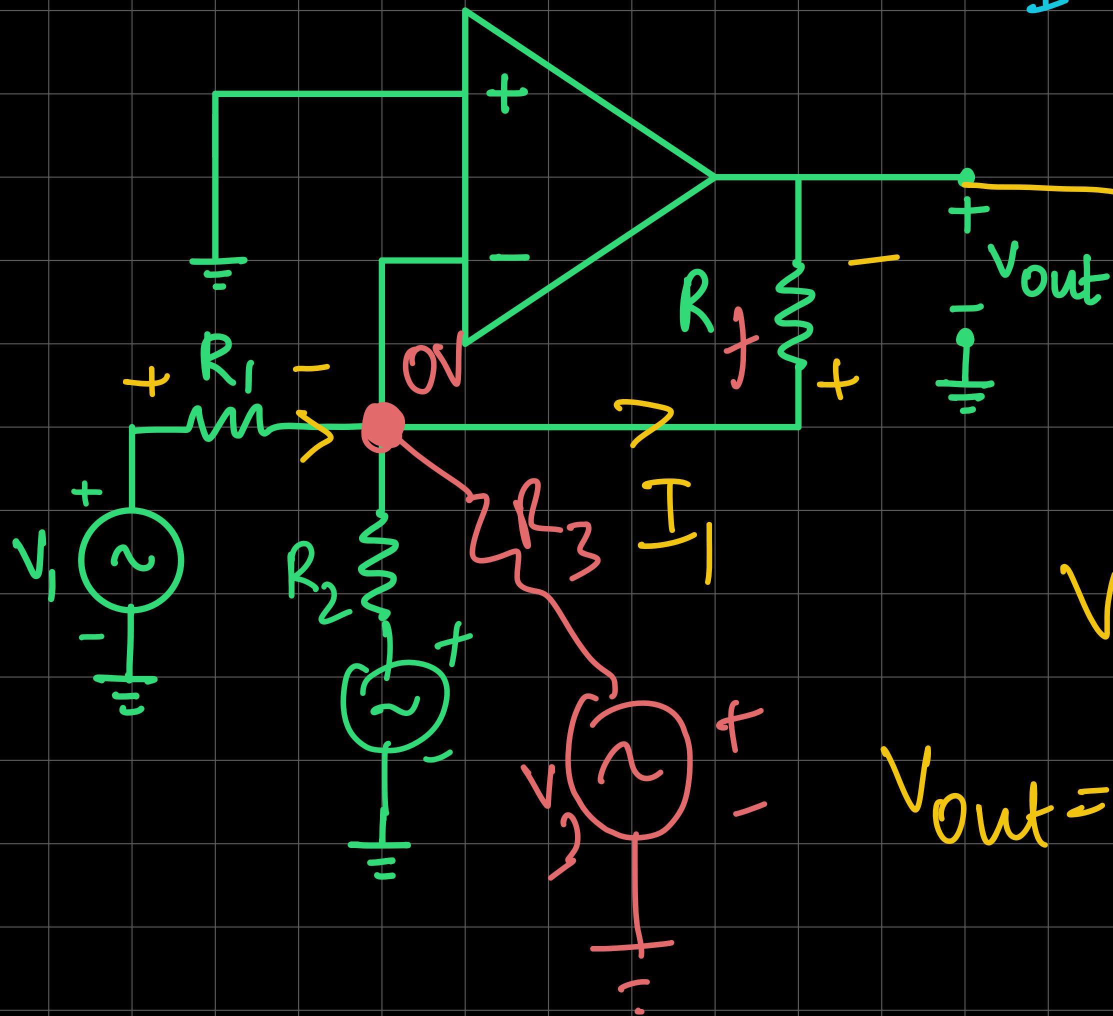


Output ⇒ $x_1 w_1 + x_2 w_2 + \cdots x_n w_n$

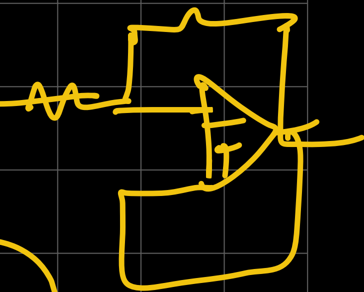
$\geq 0 \quad \geq 0 \quad \geq 0$

Artificial Neuron

$I^+ = I^- = 0$ $\quad$ $u^+ = u^- = 0$



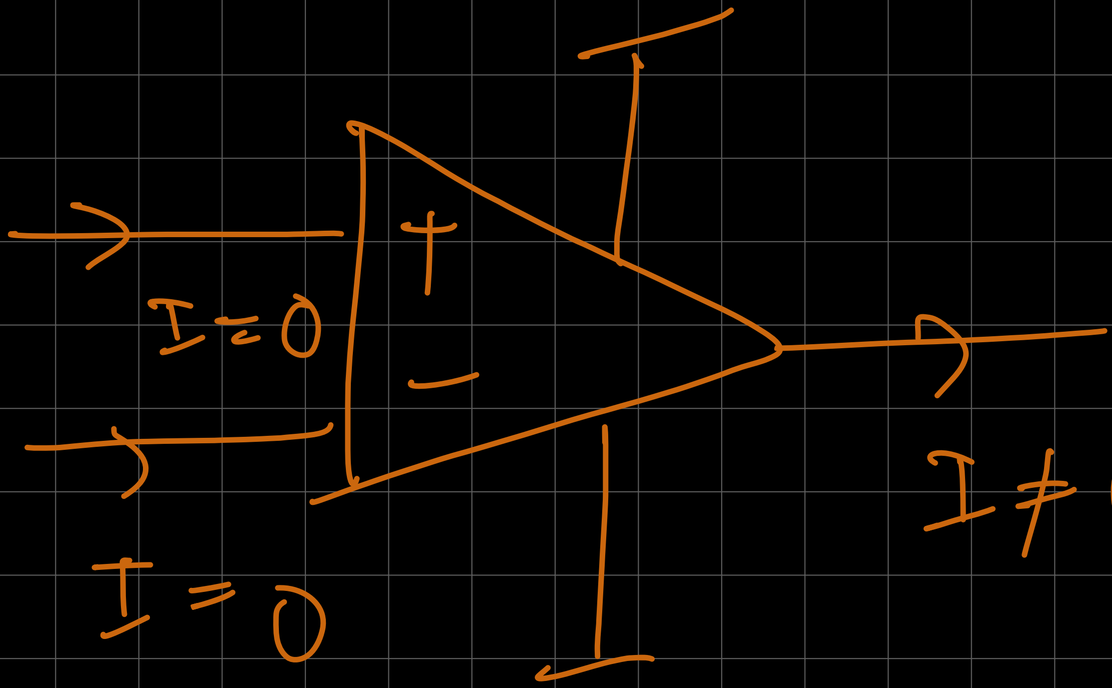
$V_{R_1} = V_1$



$I_1 = \frac{V_1}{R_1}$

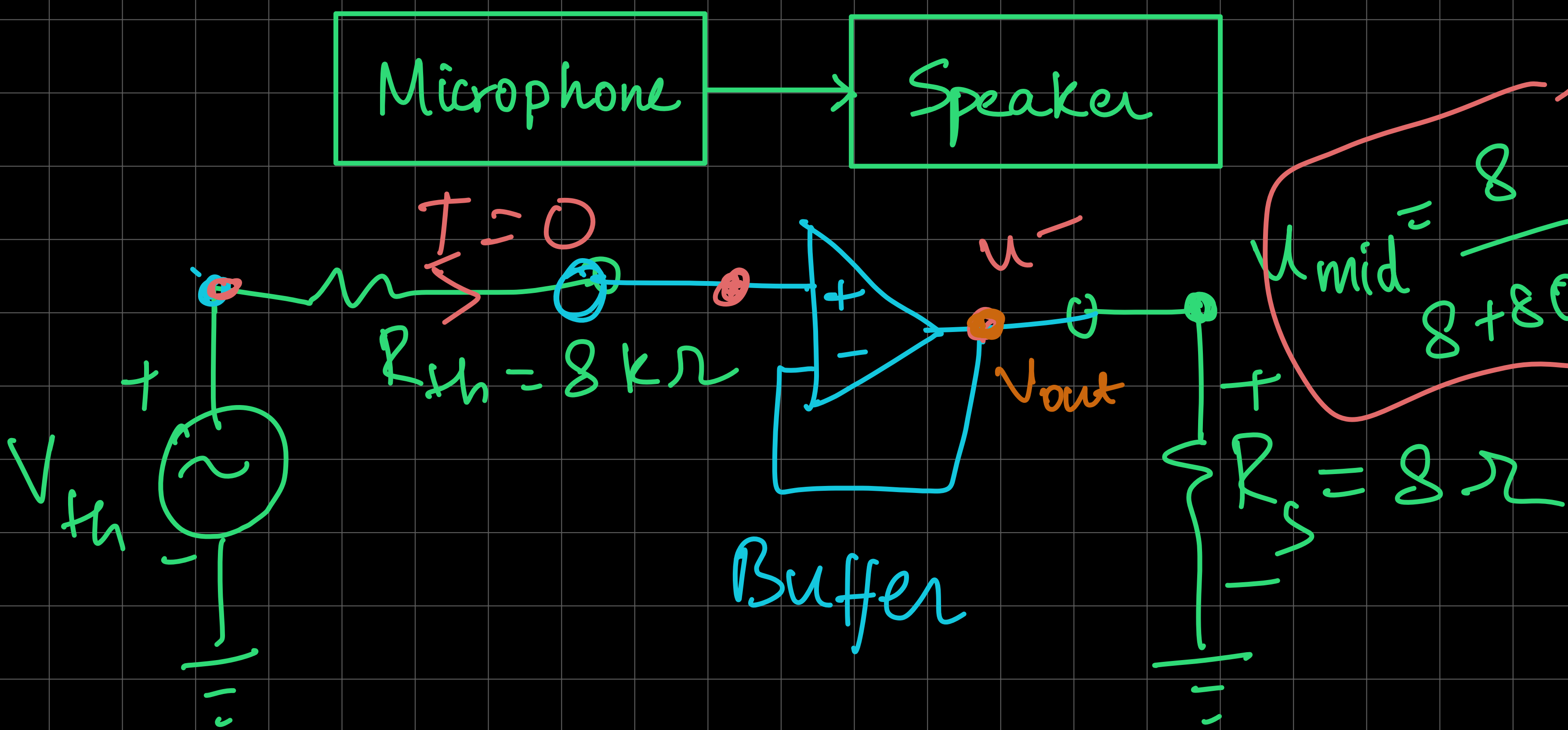
$V_{R_3} = 0 - V_{out} = I_1 R_3$

$$V_{out} = -\frac{R_f}{R_1} V_1 - \frac{R_f}{R_2} V_2 - \dots \frac{R_f}{R_n} V_n$$



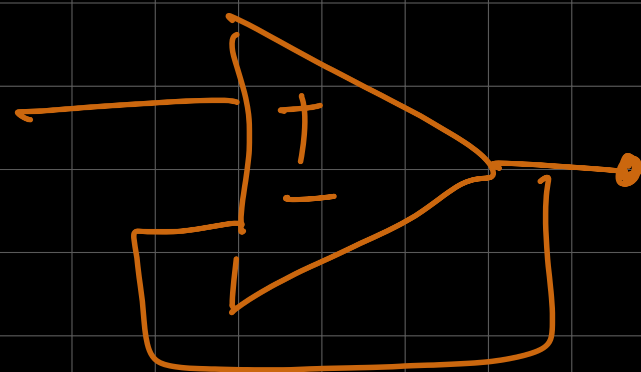
+
−
I = 0
I = 0
I ≠ 0

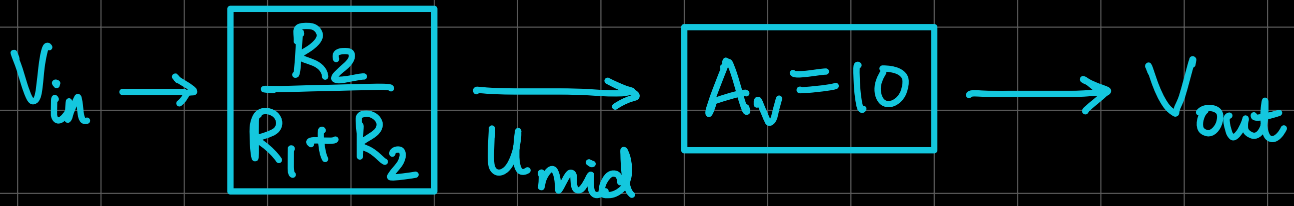
Loading and Cascading

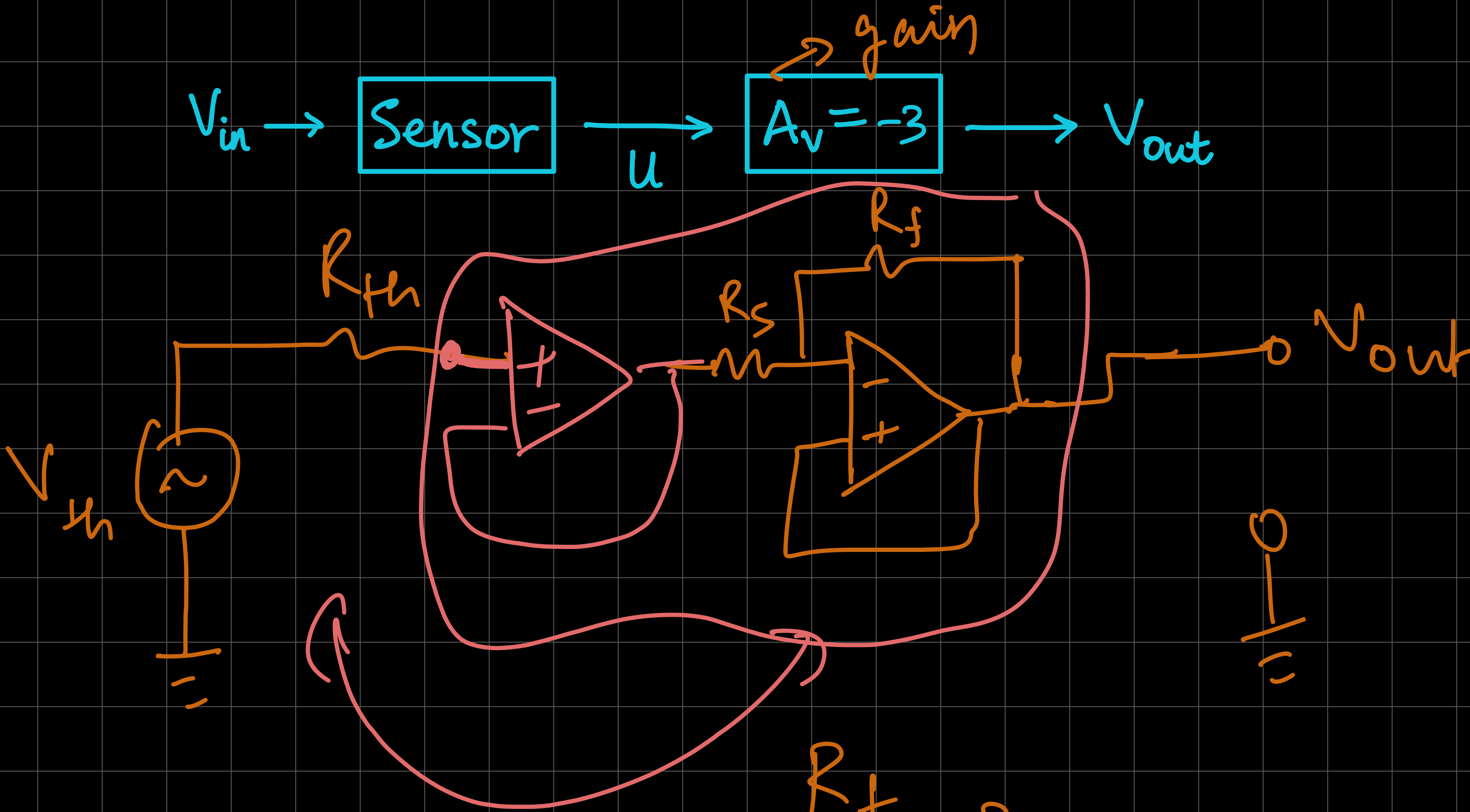


$$v_{mid} = \frac{8}{8+8000} V_{th}$$

$$v^+ = V_{th} = v^-$$




V_{in}
$\frac{R_2}{R_1+R_2}$
U_{mid}
$A_v = 10$
V_{out}



$$\frac{R_f}{R_s} = 3$$

Loading and Cascading

Before Connecting $V_{out} = 2V$
After Connecting $V_{out} = 2V$