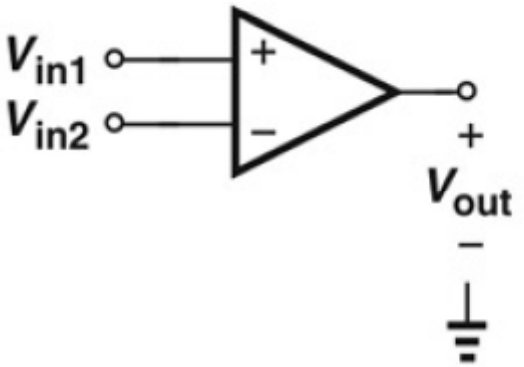
Lect. 4: Ideal Operational Amplifiers (Razavi 8.1-8.3)

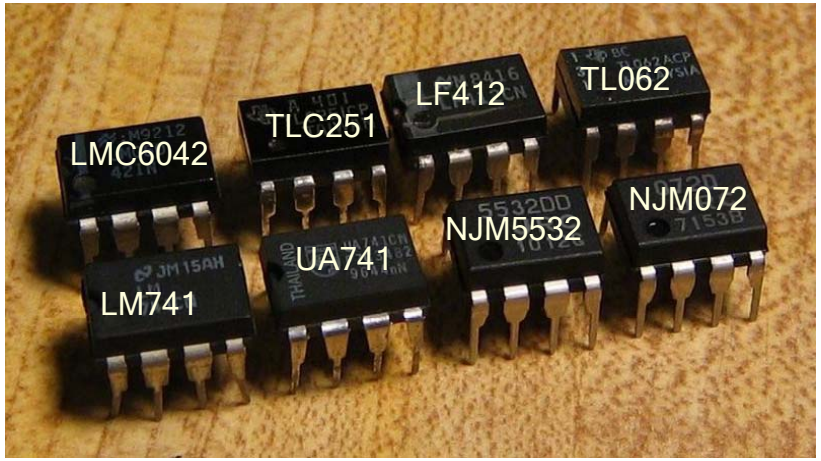


Operational amplifier (Op Amp)

- One of the most widely used electronic circuit

- Characteristics

$V_{out} = A_v(V_{in1} - V_{in2})$ with very large A_v

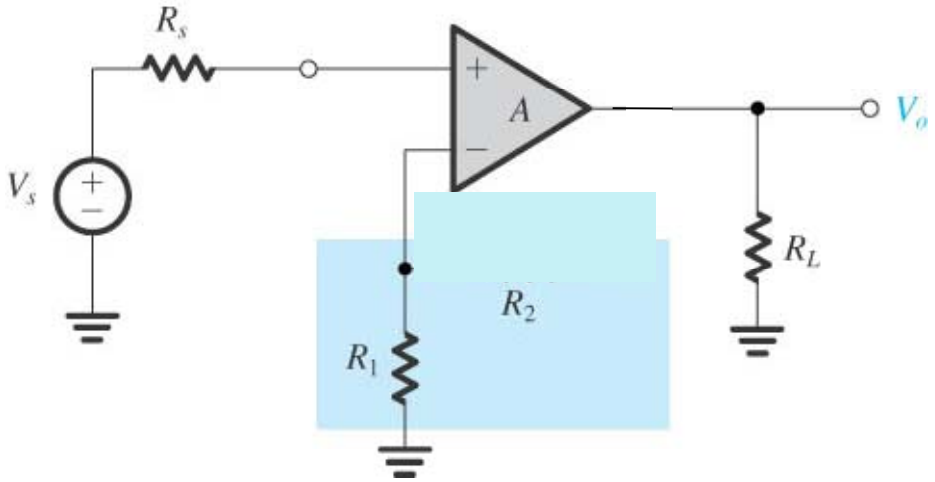


Input resistance R_{in1} and R_{in2} very large

➔Assumed infinite

➔ No currents into +,- input

Lect. 4: Ideal Operational Amplifiers



$V_o = A_v(V_s - 0)$

With feedback

$$V_o = A_v\left(V_s - V_o \cdot \frac{R_1}{R_1 + R_2}\right)$$

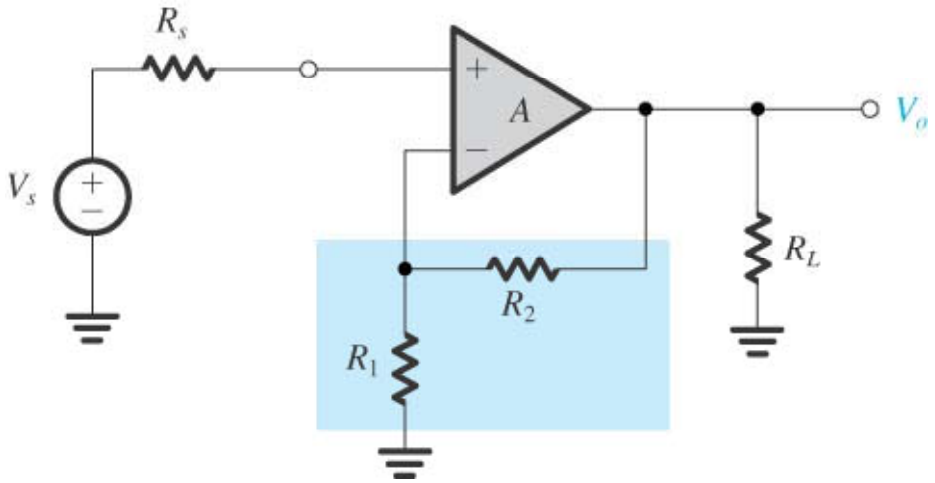
$$V_o\left(1 + \frac{A_v R_1}{R_1 + R_2}\right) = A_v V_s$$

$$\therefore \frac{Vo}{V_s} = \frac{A_v}{1 + \frac{A_v R_1}{R_1 + R_2}} \sim \frac{R_1 + R_2}{R_1}$$

No dependence on A_v, R_L

(Closed-loop gain)

Lect. 4: Ideal Operational Amplifiers



$$\frac{V_o}{V_s} = \frac{R_1 + R_2}{R_1}$$

The same result can be obtained by assuming $V^+ = V^-$ (Virtual Short)

$$V_s = V_o \frac{R_1}{R_1 + R_2}$$

$$\therefore \frac{V_o}{V_s} = \frac{R_1 + R_2}{R_1}$$

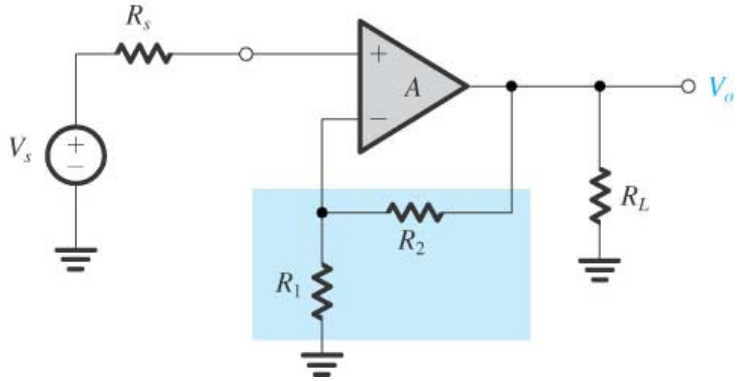
➔ Feedback tries to maintain $V^+ = V^-$

Use virtual short condition for Op-Amp analysis!

➔ Ideal Op-Amp analysis

Lect. 4: Ideal Operational Amplifiers

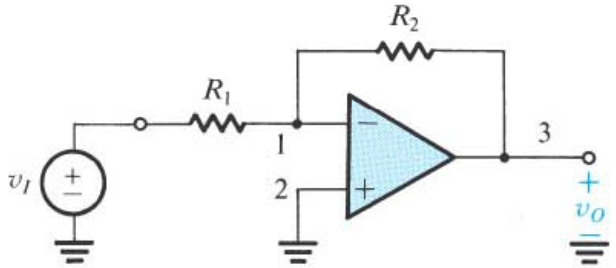
What good is it?



$$\frac{V_o}{V_s} = \frac{R_1 + R_2}{R_1}$$ Voltage amplifier

- Same gain regardless of R_L
- Gain is stable and
  can be easily changed

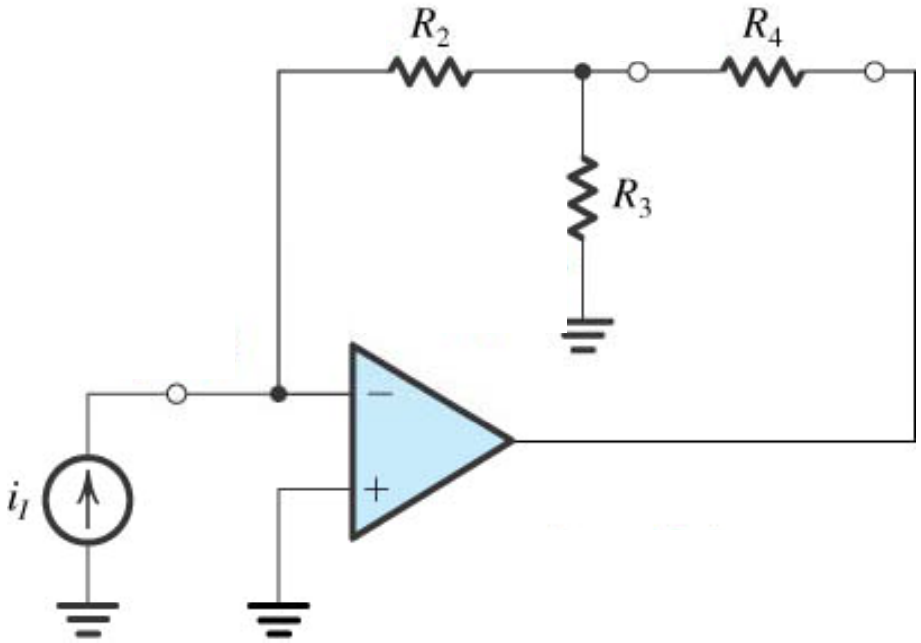
Voltage amplifier with negative gain?



$$V_o = -\frac{R_2}{R_1} V_I$$

Lect. 4: Ideal Operational Amplifiers

Current amplifier



$$A_i = \frac{i_4}{i_i} = (1 + \frac{R_2}{R_3})$$

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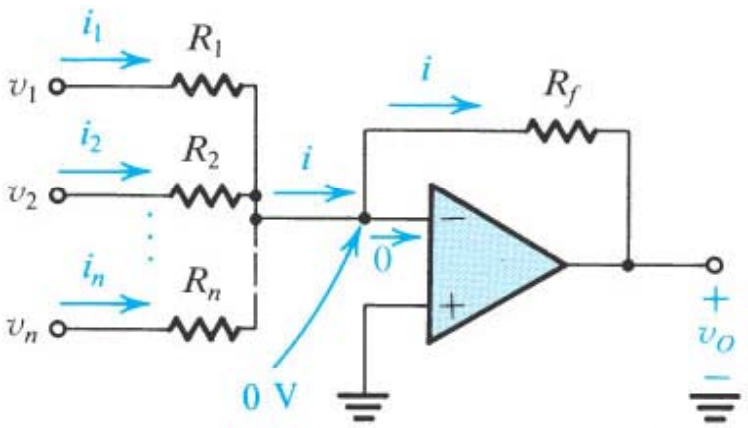
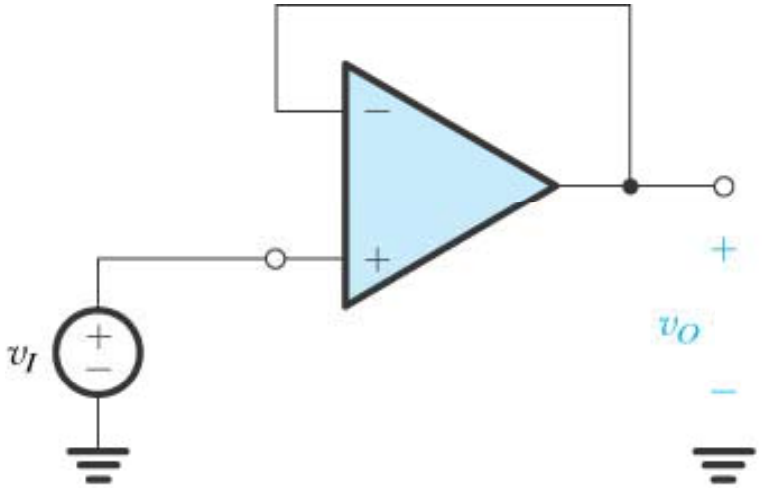


weighted summer (adder)



(a)

voltage buffer

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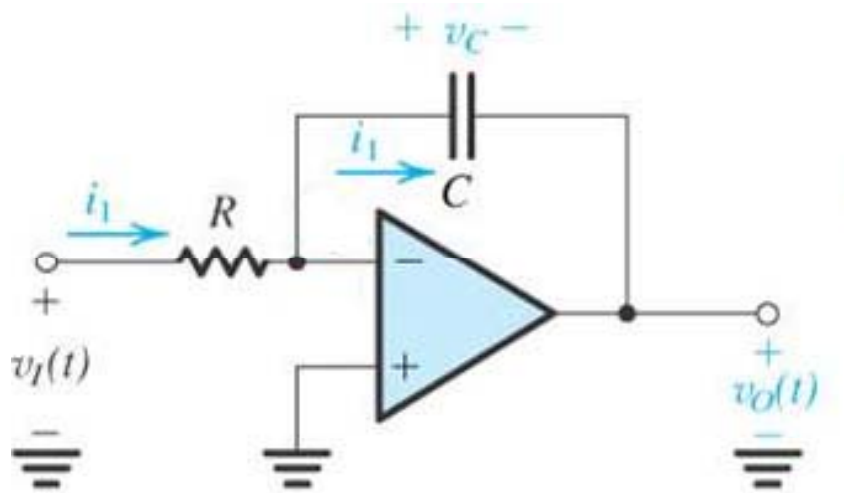

$$C\frac{d\upsilon_o(t)}{dt} = -\frac{v_i(t)}{R}$$

$$\upsilon_o(t) - \upsilon_o(t=0) = -\frac{1}{RC}\int_0^t v_i(t)\,dt$$

Integrator

Differentiator?

Op amps are used for many analog signal processing applications!

What is inside op amp? Transistor circuits!

What are transistors?

Lect. 4: Ideal Operational Amplifiers

Homework:

- Prob. 8.11 and 8.28 in Razavi

- Due on 9/14 Before Tutorial