Lecture24:
Operational amplifier (3)

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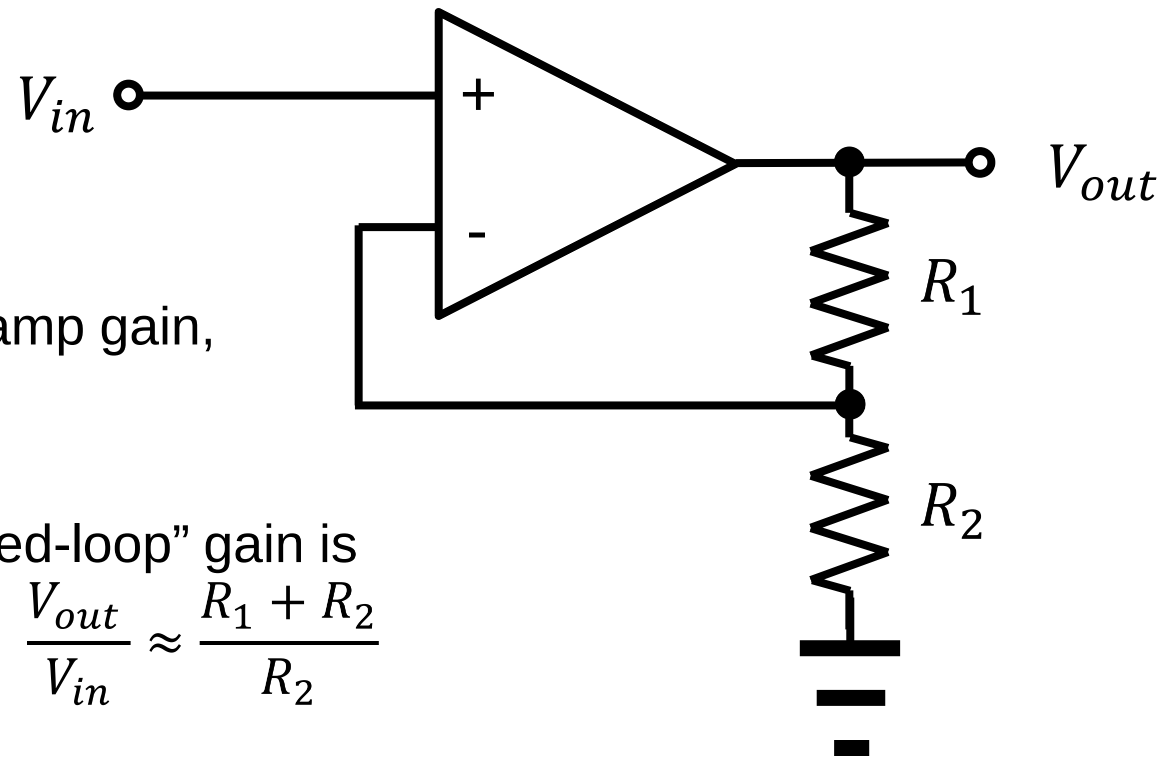
Noninverting amplifier (1)

- Calculate the gain.
  - The input resistance of the op amp is large.

$$V_{in2} = \frac{R_2}{R_1 + R_2} V_{out}$$



  - Due to the high op amp gain,

$$V_{in2} \approx V_{in}$$

  - Therefore, the "closed-loop" gain is

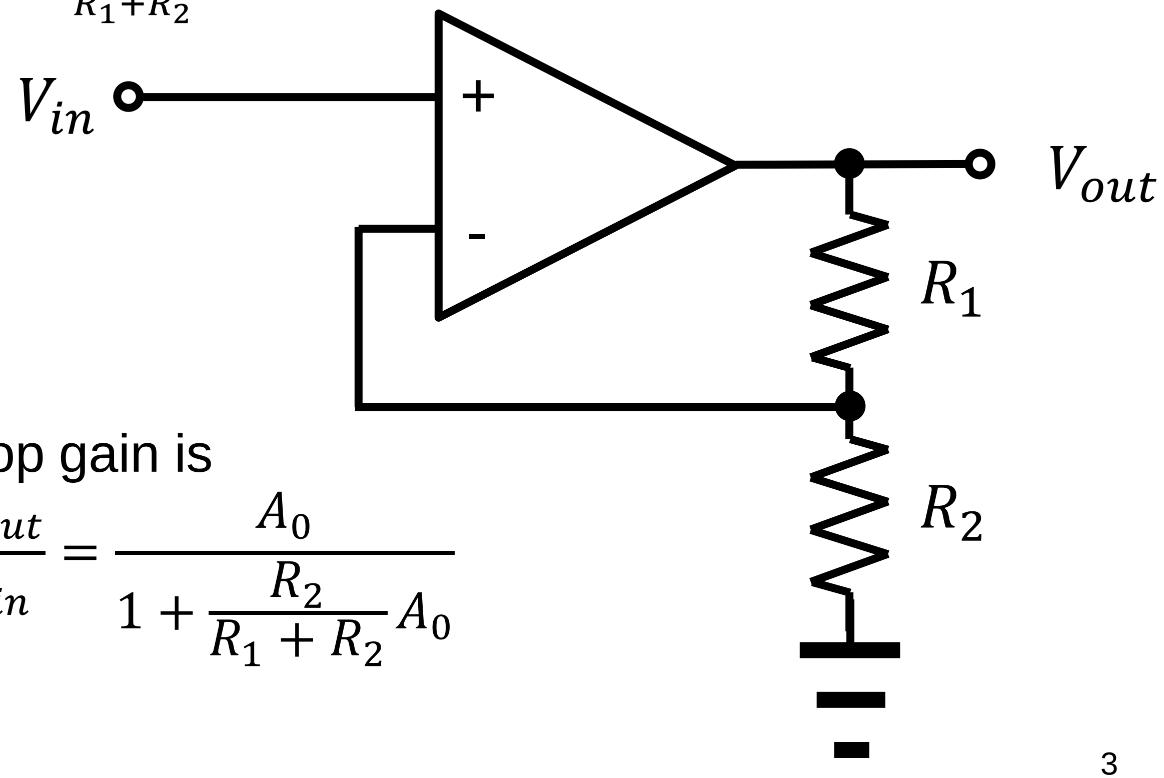
$$\frac{V_{out}}{V_{in}} \approx \frac{R_1 + R_2}{R_2}$$

Noninverting amplifier (2)

- Repeat it again with a finite A_0.
  - Now,

$$V_{out} = A_0(V_{in} - V_{in2})$$

  - Remember that $V_{in2} = \frac{R_2}{R_1+R_2}V_{out}$.



  - Then, the closed-loop gain is

$$\frac{V_{out}}{V_{in}} = \frac{A_0}{1 + \frac{R_2}{R_1 + R_2}A_0}$$

Example 8.3

- Let us assume that $A_0 = 1000$.

  (a)

  – When we have $\frac{R_1}{R_2} = 4$, we expect to have a closed-loop gain of 5. (For a case of an ideal op amp)

  – However, with a finite A_0, the gain becomes $\frac{1000}{201} \approx 4.9751$. About 0.5 % reduction. It is called a <u>gain error</u>.

  (b)

  – When we have $\frac{R_1}{R_2} = 49$, we expect to have a closed-loop gain of 50.

  – The gain becomes $\frac{1000}{21} \approx 47.619$. About 4.8 % reduction.

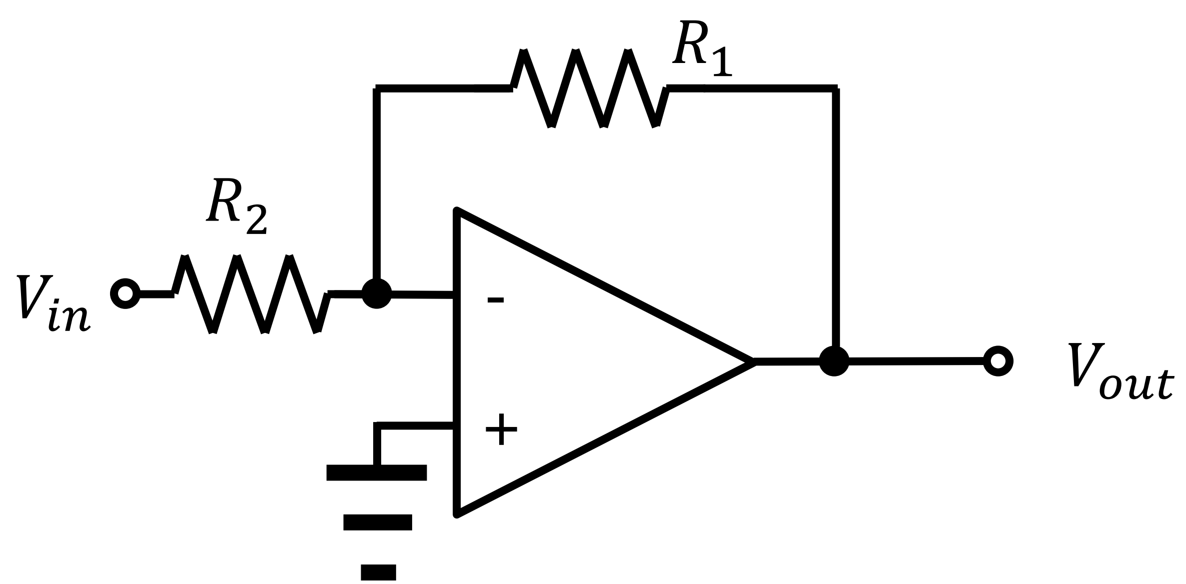
  – A higher closed-loop gain inevitably suffers from less accuracy.

Inverting amplifier (1)

- The inverting input is called a "virtual ground."
  - Then, the output voltage is

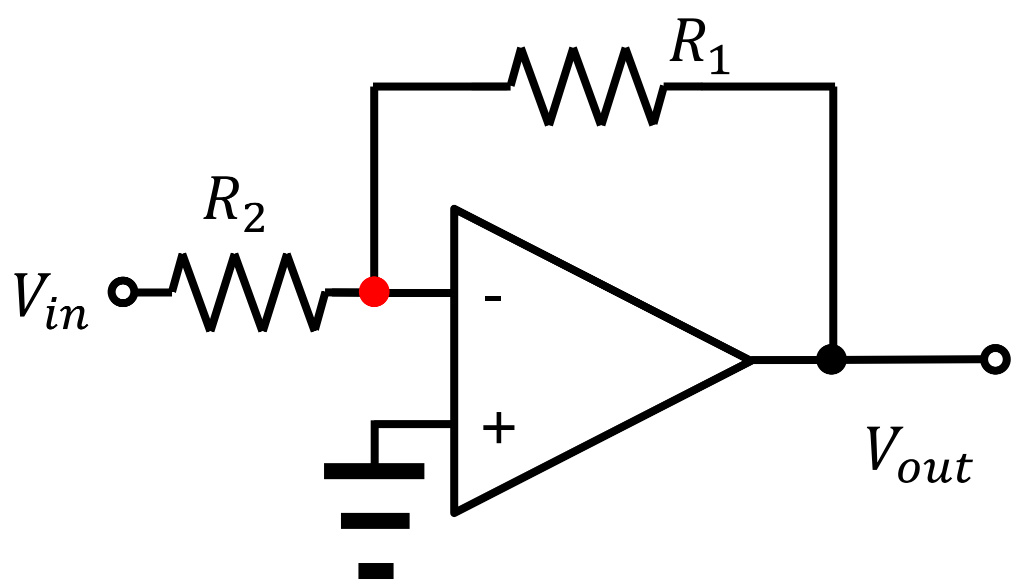
$$V_{out} = -R_1 \frac{V_{in}}{R_2}$$

  - Its input impedance is equal to R_2.



Inverting amplifier (2)

- Repeat it again with a finite A_0.
  - The op amp states that
$$V_{out} = A_0(-V_{in2})$$
  - The KCL at the inverting node yields
$$\frac{V_{in} - V_{in2}}{R_2} = \frac{V_{in2} - V_{out}}{R_1}$$
  - After manipulation,
$$\frac{V_{out}}{V_{in}} = -\frac{1}{\frac{R_2}{R_1} + \frac{1}{A_0}\left(1 + \frac{R_2}{R_1}\right)}$$



Example 8.4

- Let us assume that $A_0 = 5000$.
  - When we want to have a nominal gain of 4 (Actually -4), $\frac{R_1}{R_2} = 4$.
  - What is the gain error due to the finite A_0? It is about 0.1 %.

  - An input impedance of $10\ k\Omega$ is required.
  - Since the input inpedance is approximately R_2, we choose $R_2 = 10\ k\Omega$ and $R_1 = 40\ k\Omega$.

Integrator

- Instead of a resistor, a capacitor is introduced.
  - In the time domain,

$$\frac{V_1}{R_1} = -C_1 \frac{dV_{out}}{dt}$$