CENG4480
Lecture 02 Review

Bei Yu

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byu@cse.cuhk.edu.hk

香港中文大學
The Chinese University of Hong Kong

Voltage gain A

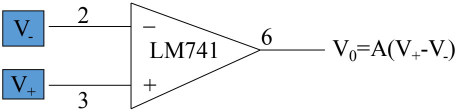
$$A = \frac{V_{out}}{V_{in}}$$

- Usually voltage gain may be either very large or very small
- Invonvenient to express as a simple ratio
- Therefore, **decibel** (dB):

Voltage gain in **dB**

$$A = 20 \cdot \log_{10} \frac{V_{out}}{V_{in}}$$

R_{in} & R_{out}



- R_{in}: input impedance (High)
- R_{out}: output impedance (Low)

Ideal Op-Amp Rules

Rule 1

No current flows in or out of the inputs

Rule 2

The Op-Amp tries to keep the inputs the same voltage

* only for negtive feedback op-amp

Ideal Op-Amp v.s. Real Op-Amp

Open-Loop Gain A

Ideal: Infinite, thus $V^+ = V^-$
Real: Typical range (20,000, 200,000), thus $V_{out} = A(V^+ - V^-)$

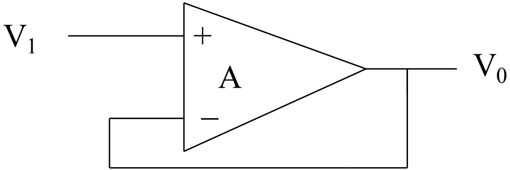
Input Impedance

Ideal: Infinite. Since $Z_{in} = \frac{V_{in}}{I_{in}}$, zero input current
Real: No such rule.

Bandwidth

Ideal: Infinite Bandwidth
Real: Gain-Bandwidth product (GB).

Voltage follower

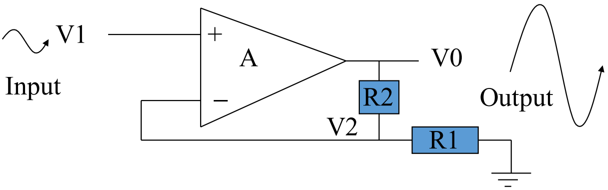


- Unit voltage gain
- Output $V_0 = V_1$
- high current gain, high input impedance

In real op-amp

$$V_0 = A(V_1 - V_0) \Rightarrow V_0 = \frac{V_1 A}{1 + A} \approx V_1$$

Non-inverting Amplifier



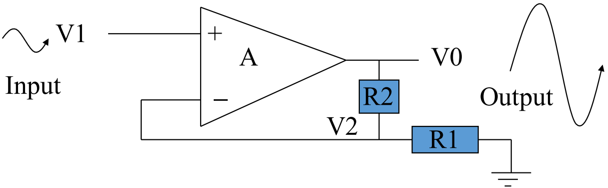
- R_{in}: High input impedance

In real op-amp

$$V_0 = A(V_1 - V_0) \text{ and } \frac{V_2}{V_0} = \frac{R_1}{R_1 + R_2}$$

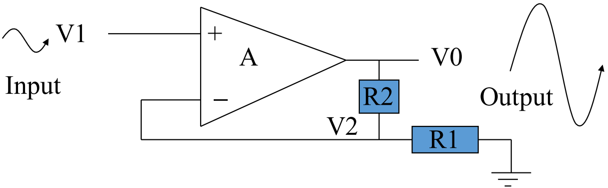
$$\Rightarrow \frac{V_0}{V_1} = \frac{R_1 + R_2}{R_1 + (R_1 + R_2)/A} \approx \frac{R_1 + R_2}{R_1}$$

Question: Non-inverting Amplifier Gain



Calculate $\frac{V_0}{V_1} =$

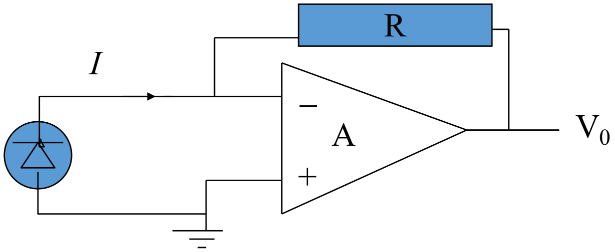
Question: Non-inverting Amplifier Gain



Calculate $\frac{V_0}{V_1} =$

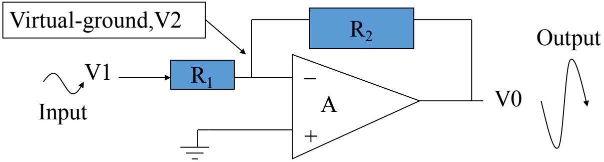
$$1 + \frac{R_2}{R_1}$$

Current to Voltage Converter



$$V_0 = I \cdot R$$

Inverting Amplifier

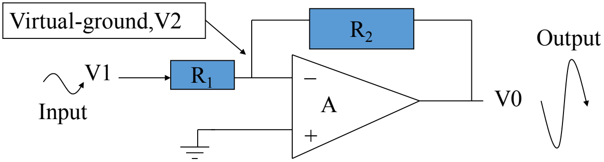


In real op-amp

$$V_0 = A(0 - V_2) \text{ and } \frac{V_0 - V_1}{R_1 + R_2} = \frac{V_2 - V_1}{R_1}$$

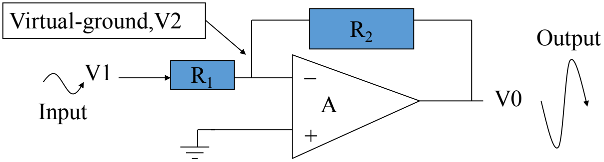
$$\Rightarrow \frac{V_0}{V_1} = \frac{R_2}{R_1} \cdot \frac{R_1 A}{R_1 A + R_1 + R_2} \approx -\frac{R_2}{R_1}$$

Inverting Amplifier



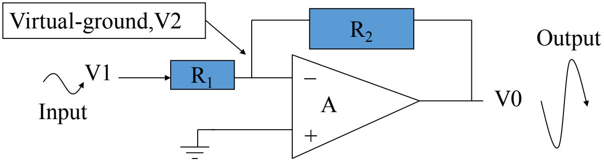
- $R_{in} = R_1$
- Gain $(G) =$

Inverting Amplifier



- $R_{in} = R_1$
- Gain $(G) = -\frac{R_2}{R_1}$

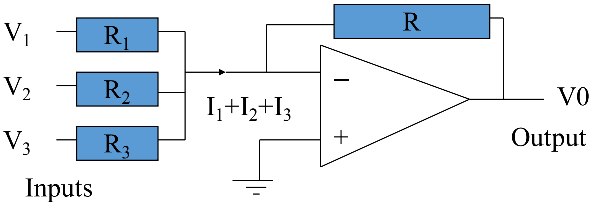
Inverting Amplifier



- $R_{in} = R_1$
- Gain $(G) = -\frac{R_2}{R_1}$

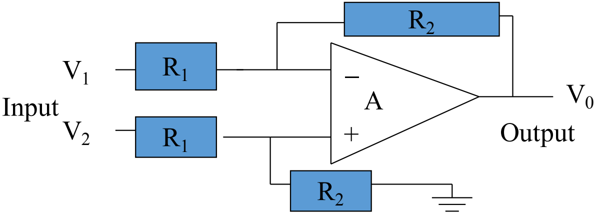
Question: How to increase input impedance?

Summing Amplifier



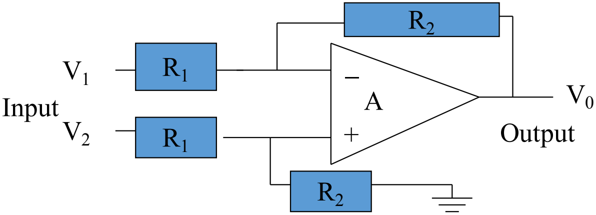
$$V_0 = -R \cdot \{\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\}$$

Differential Amplifier



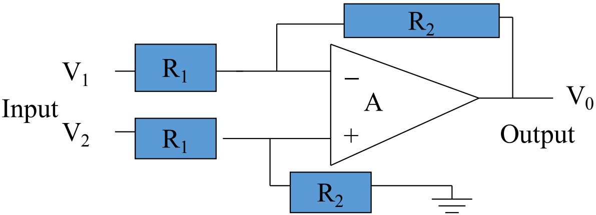
- Calculate the difference between V_1 and V_2
- Can control gain

Question: Differential Amplifier Gain



Calculate $V_0 =$

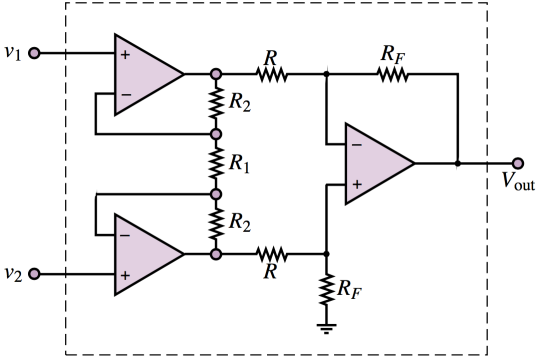
Question: Differential Amplifier Gain



Calculate $V_0 =$

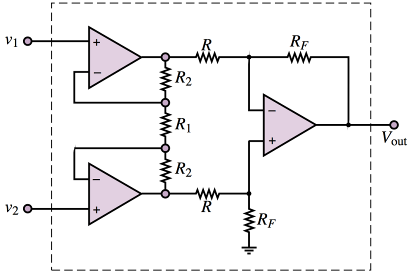
$$\frac{R_2}{R_1} \cdot (V_2 - V_1)$$

Instrumental Amplifier



- To make a better DC amplifier from op-amps
- combine 2 noninverting amplifier & 1 differential amplifier

Instrumental Amplifier (cont.)



- For each non-inverting amplifier: $A = 1 + \frac{2R_2}{R_1}$
- Connecting to differential amplifier:

$$
\begin{aligned}
V_{out} &= \frac{R_F}{R}(A_{v1} - A_{v2}) \\
&= \frac{R_F}{R}(1 + \frac{2R_2}{R_1})(v_1 - v_2)
\end{aligned}
$$