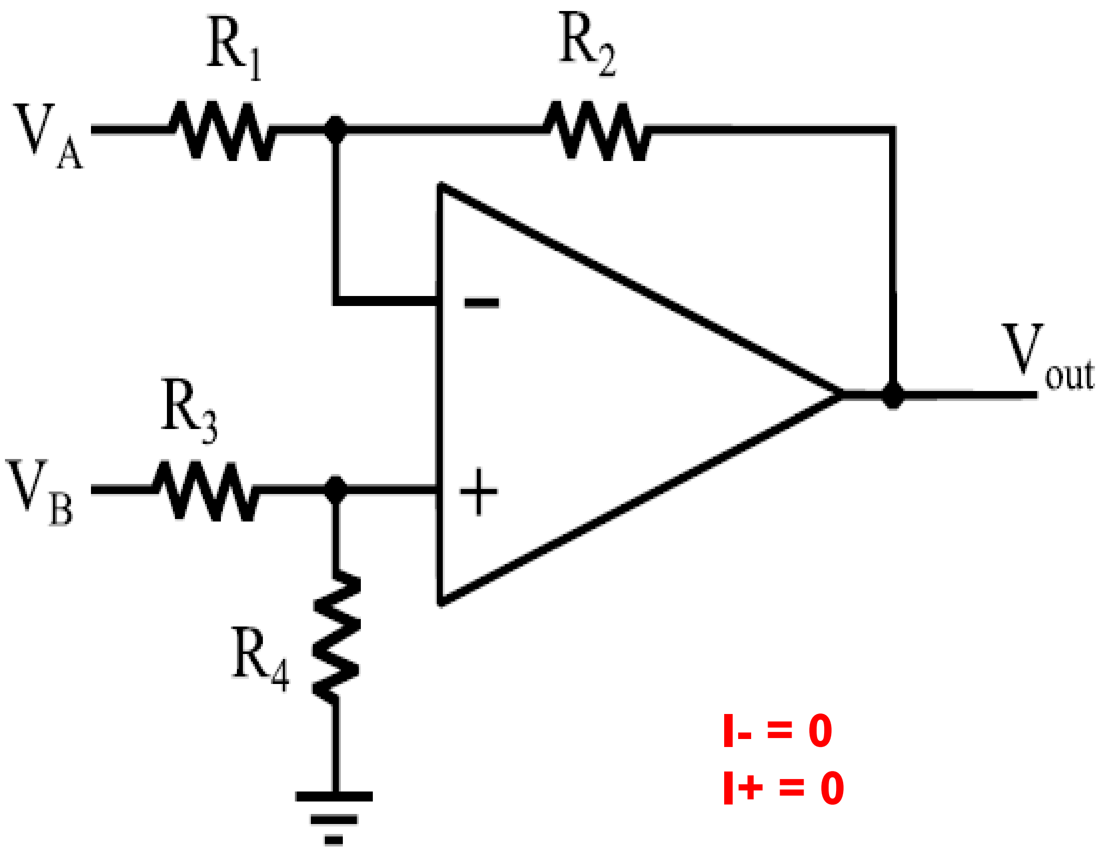
Electronic Circuits

Lecture 8.2: Operational Amplifiers (OPAMPs)

Difference Amplifier



I- = 0
I+ = 0

$$V_+ = V_B \frac{R_4}{R_3 + R_4}$$

$$V_- = V_{out} \frac{R_1}{R_1 + R_2} - V_A \frac{R_2}{R_1 + R_2}$$

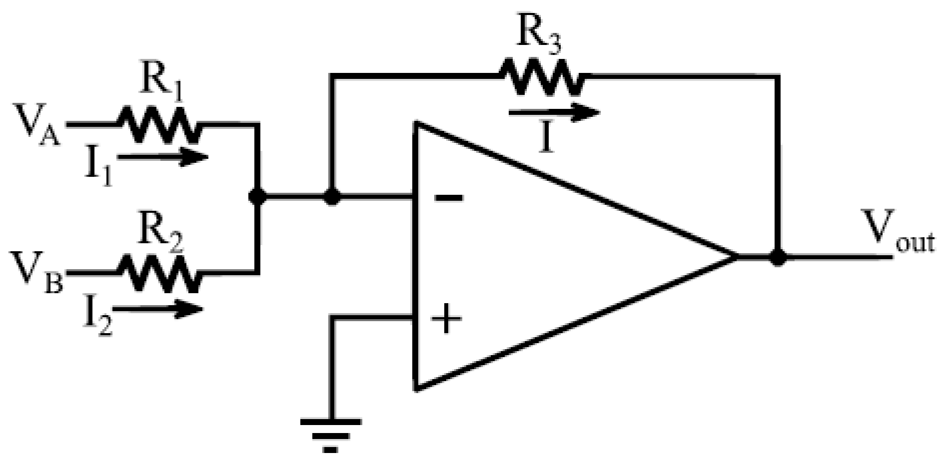
$$V_+ = V_-$$

$$V_{out} = \frac{R_1 + R_2}{R_1} \left(V_B \frac{R_4}{R_3 + R_4} - V_A \frac{R_2}{R_1 + R_2} \right)$$

For the special case where $R_1 = R_3$ and $R_2 = R_4$,

$$V_{out} = \frac{R_2}{R_1} (V_B - V_A)$$

Summing Amplifier



$$I = I_1 + I_2 = \frac{V_A}{R_1} + \frac{V_B}{R_2}$$

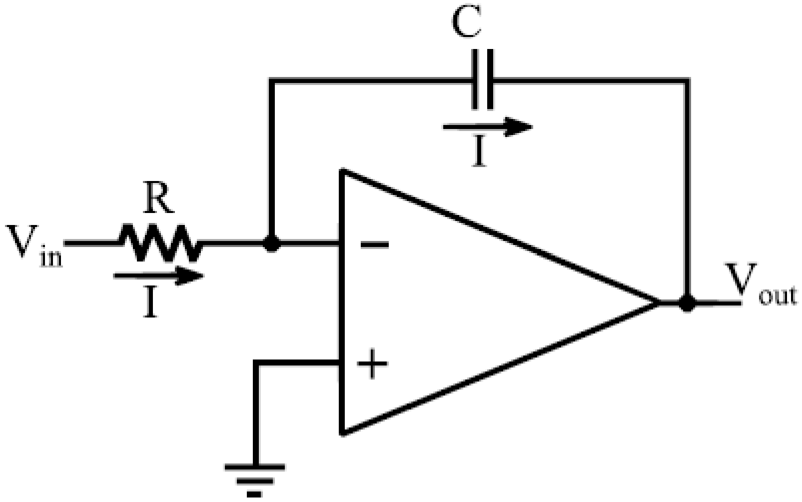
$$V_{out} = -R_3\left(\frac{V_A}{R_1} + \frac{V_B}{R_2}\right)$$

For the special case where $R_1 = R_2$,

$$V_{out} = -\frac{R_3}{R_1}(V_A + V_B)$$

I- = 0
I+ = 0

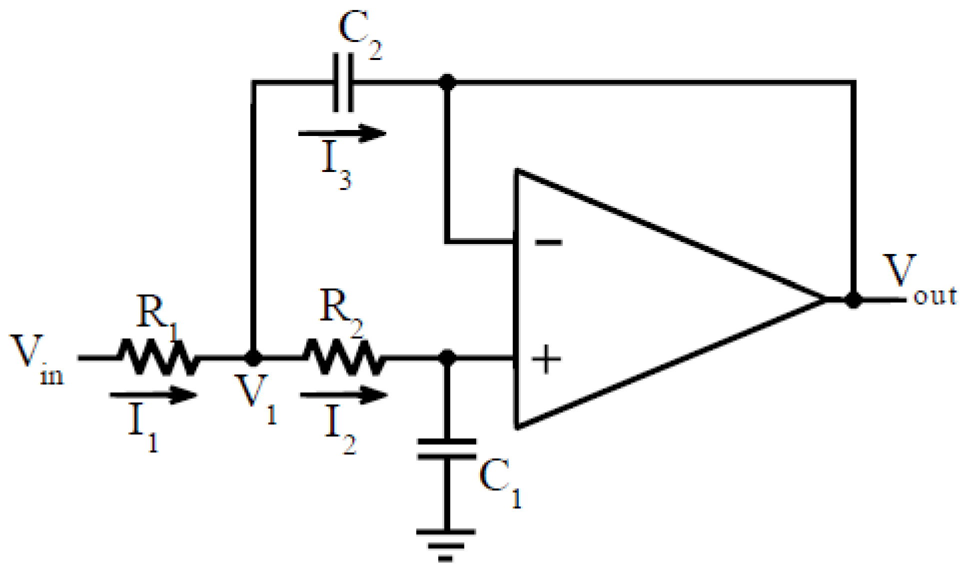
Integrator



$$V_c(t) = V_{out} = -V_c(0) - \frac{1}{RC}\int_0^t V_{in}(t)dt$$

I- = 0
I+ = 0

Low-Pass Filter



$$V_{out} = V_- = V_+$$

$$V_+ = V_1 \frac{1/i\omega C_1}{R_2 + 1/i\omega C_1} = \frac{V_1}{1 + i\omega R_2 C_1} = V_{out}$$

$$V_1 = V_{out}(1 + i\omega R_2 C_1)$$

$$V_1 - V_{out} = i\omega R_2 C_1 V_{out}$$

Using KCL and Ohm's law,

$$I_1 = I_2 + I_3$$

$$I_2 = \frac{V_1 - V_+}{R_2} = \frac{V_1 - V_{out}}{R_2} = i\omega C_1 V_{out}$$

$$I_3 = \frac{V_1 - V_{out}}{1/i\omega C_2} = \frac{i\omega R_2 C_1 V_{out}}{1/i\omega C_2} = -\omega^2 R_2 C_1 C_2 V_{out}$$

and so

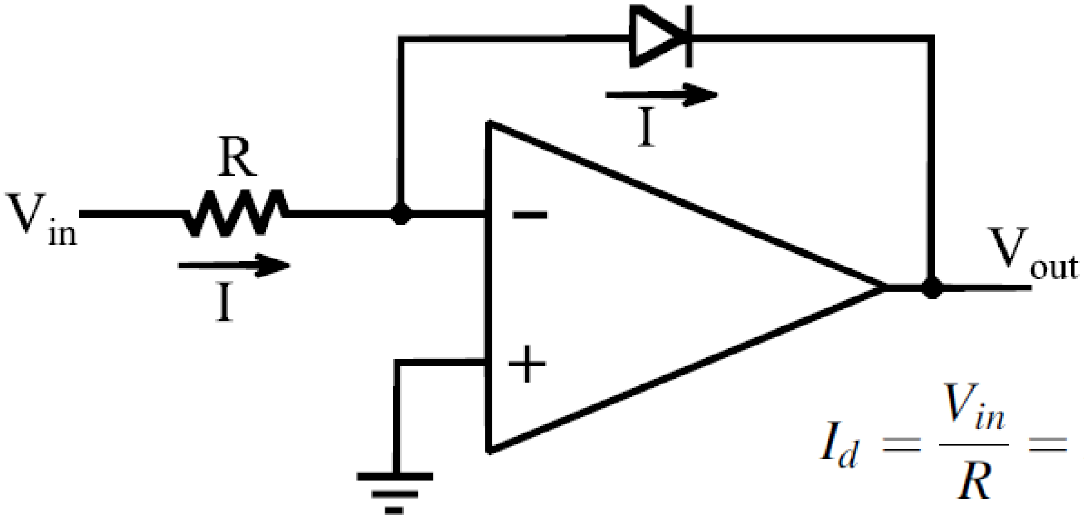
$$V_{in} = I_1 R_1 + V_1 = (I_2 + I_3)R_1 + V_{out}(1 + i\omega R_2 C_1)$$

$$= V_{out}\left(1 + i\omega(R_1 + R_2)C_1 - \omega^2 R_1 R_2 C_1 C_2\right)$$

Then

$$V_{out} = V_{in} \frac{1}{1 - \omega^2 R_1 R_2 C_1 C_2 + i\omega C_1 (R_1 + R_2)}$$

Logaritmic Amplifier

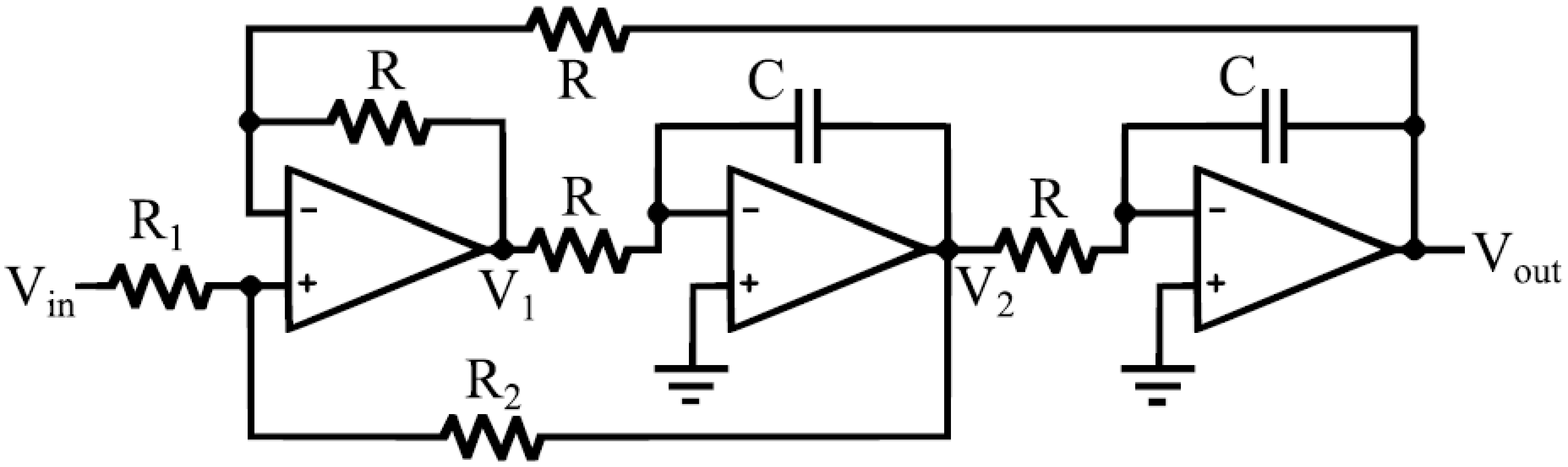


$$I_d = \frac{V_{in}}{R} = I_0\left(\exp\left(-\frac{V_{out}}{\eta V_T}\right) - 1\right)$$

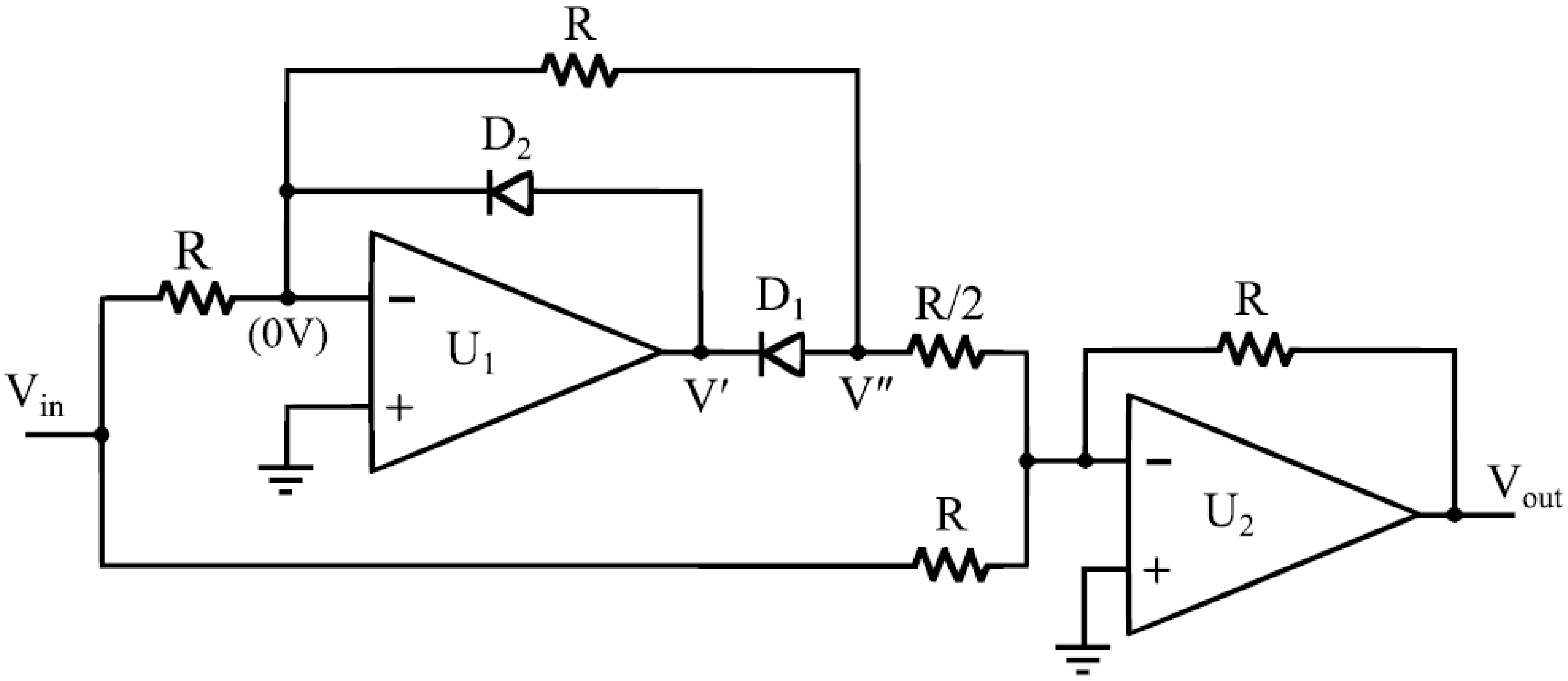
$$\log(V_{in}) = \log(RI_0 \exp(-V_{out}/\eta V_T)) = -V_{out}/\eta V_T + \log(RI_0)$$

$$V_{out} = -\eta V_T \log(V_{in}/RI_0).$$

Left To Students (1)



Left To Students (2)



Left To Students (3)

- Design High-Pass Filter using Low-Pass Filter Design Example.
- Design Band-Pass Filter using Low- and High-Pass Filter Examples.
- Design a Derivator using Integrator Design Example.

Thanks for listening ☺

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