SP.764, Practical Electronics
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Lecture 6: Op Amps

Topics:

1) Op Amps as Amplifiers
   - Example
   - "Golden Rules" of their Use
   - Analyze example
   - More Examples
2) Op Amp as a Comparator

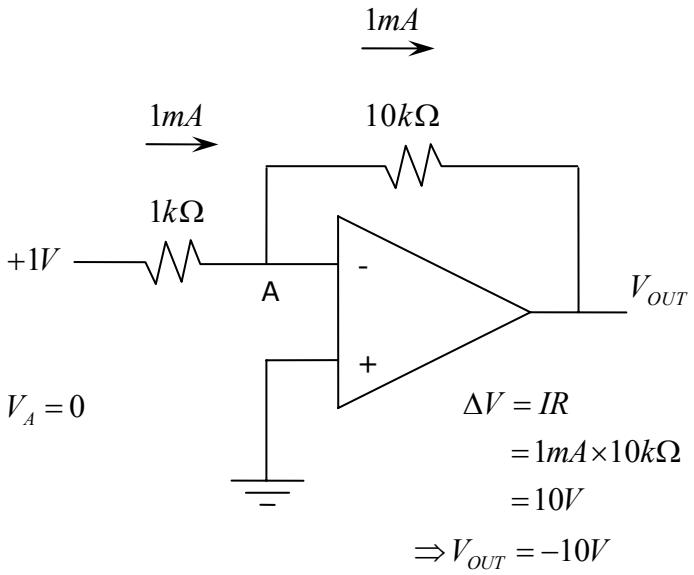
Op Amps:

- Op amps are semiconductor devices.
- Op amps are mostly optimized to have high-speed or low-noise features.
- Even though they are remarkably sophisticated circuits, they are really easy to work with.
- If you connect the power supply incorrectly, the op amp might blow up.

Comparator:

- Remarkably useful: Feed two voltages, and comparator compares them.
- The comparator is heart of digital electronics because of its ability to decide whether a voltage is higher or lower than a threshold value.

Question 1: What is the output going to be?



Question 2: If instead of 1V, the input is half a volt.

- You would get half the output.

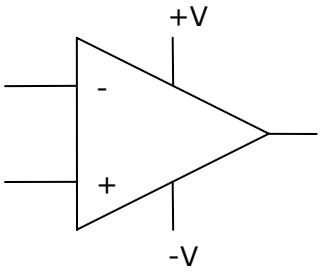
Question 3: What about double?

- Tricky! The op amp saturates at -15V, so output cannot go beyond -15V.

Op amps are usually run off bipolar supplies (+/-15V).

Op Amps:

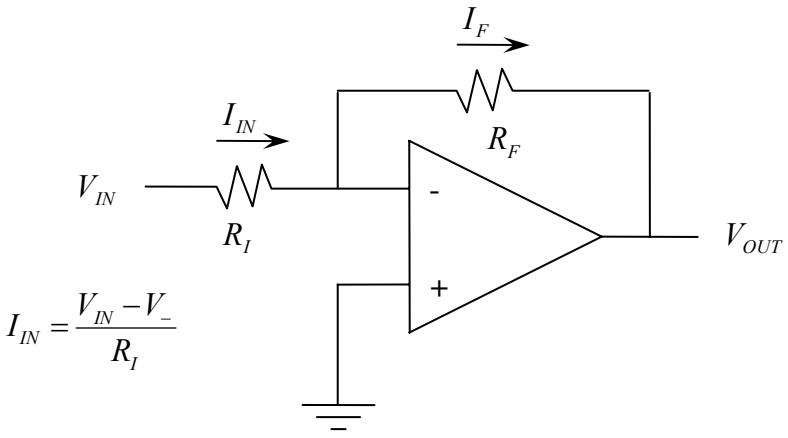
- 2 Inputs: (V_+, V_-)
  - Non-inverting Input
  - Inverting Input
- 1 Output: $(-V < V_{OUT} < +V)$
- 2 Voltage Supplies: $(+V, -V)$



Golden Rules:

1) The Op-Amp Inputs draw no current.
2) With Negative Feedback, the inputs are at the same voltage (i.e., V+=V-)

Now, one can generalize the first circuit:



Golden Rule #2 tells us

$$V_- = 0$$

$$\Rightarrow I_{IN} = \frac{V_{IN}}{R_I}$$

Golden Rule #1 requires

$$I_F = I_{IN}$$

$$\Rightarrow (\underbrace{V_-}_{\mathbf{0}} - V_{OUT}) = I_F R_F$$

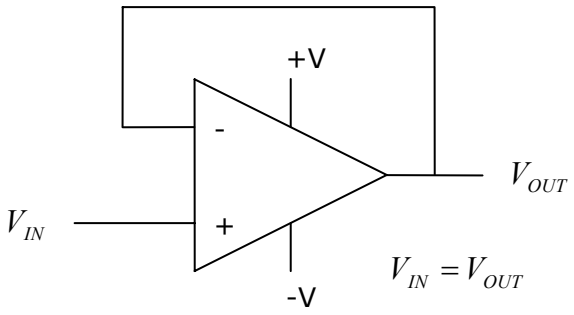
$$\Rightarrow -V_{OUT} = \frac{V_{IN}}{R_I} R_F$$

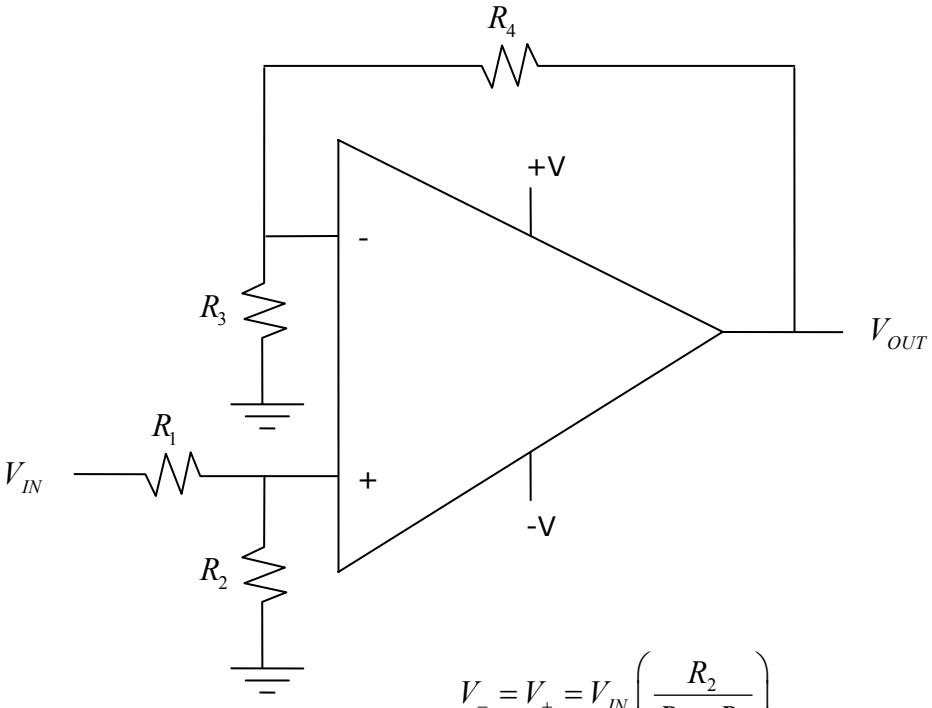
$$\Rightarrow V_{OUT} = -\left(\frac{R_F}{R_I}\right) V_{IN}$$

"Negative Feedback" means there is a current path from V_{OUT} to the "-" input.

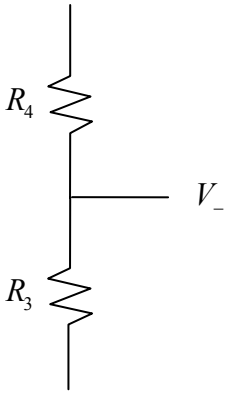
<u>More examples</u>: $V_{OUT} = f(V_{IN})$

Unity Gain Buffer





$$V_- = V_+ = V_{IN}\left(\frac{R_2}{R_1 + R_2}\right)$$



$$\frac{V_{OUT} - V_-}{R_4} = \frac{V_-}{R_3}$$

$$\frac{R_3}{R_4}V_{OUT} = V_-\left(1 + \frac{R_3}{R_4}\right)$$

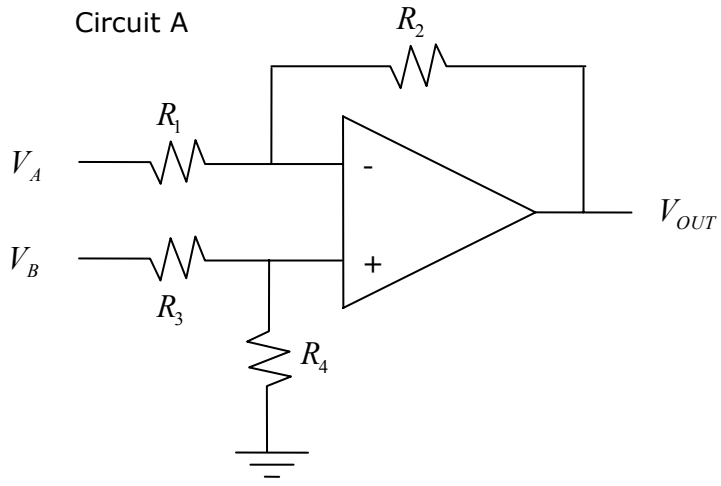
$$\frac{R_3}{R_4}V_{OUT} = V_{IN}\left(\frac{R_2}{R_1 + R_2}\right)\left(\frac{R_4 + R_3}{R_4}\right)$$

$$V_{OUT} = \frac{R_2}{R_3}\left(\frac{R_3 + R_4}{R_1 + R_2}\right)V_{IN}$$

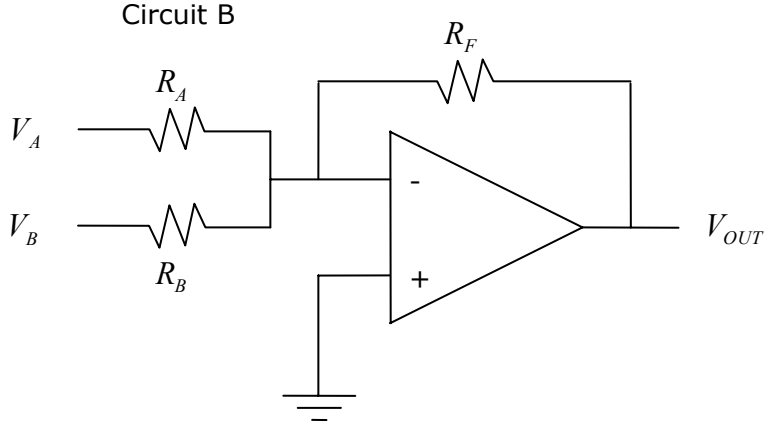
Assignment:

- Work out the following circuits before next Lab.
- For the following circuits, $V_{OUT} = f\left(V_A, V_B\right)$
- Find V_{OUT}.

Circuit A



Circuit B



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