Electronics
Operational Amplifier Basics

Terry Sturtevant

Wilfrid Laurier University

October 4, 2016

Ideal Operational Amplifiers

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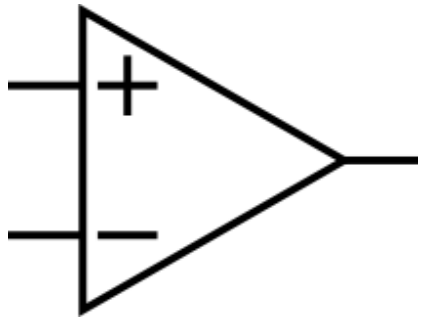
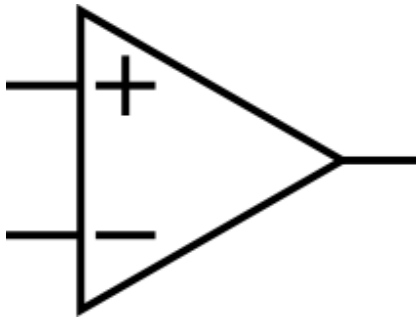


Ideal Operational Amplifiers

inverting
input



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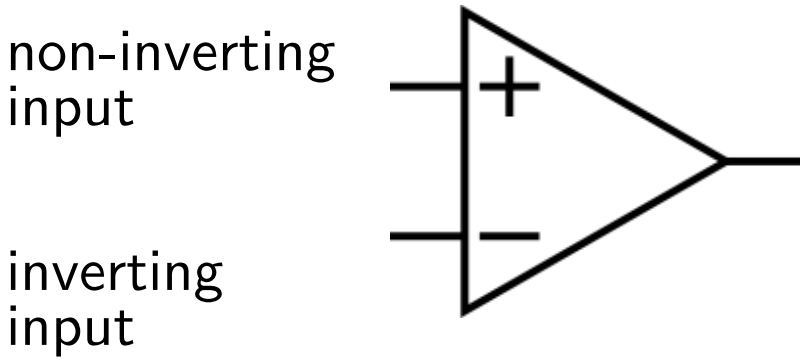

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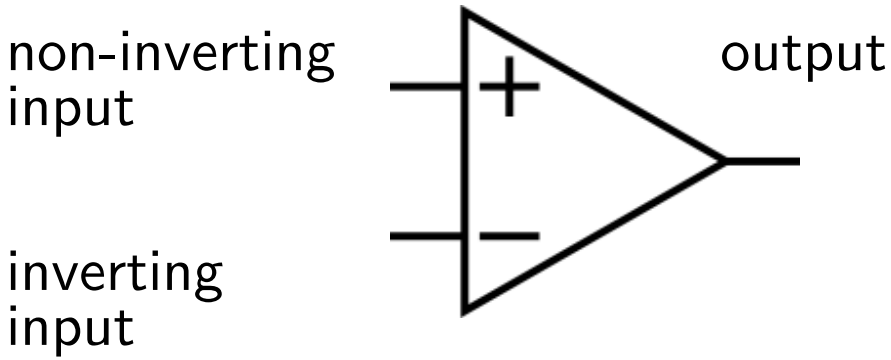

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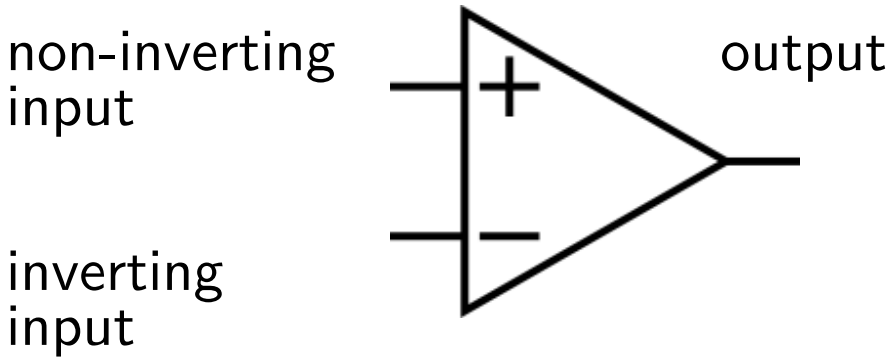

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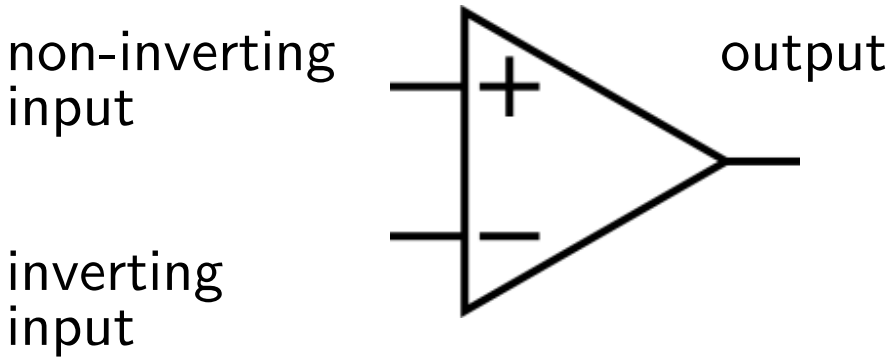

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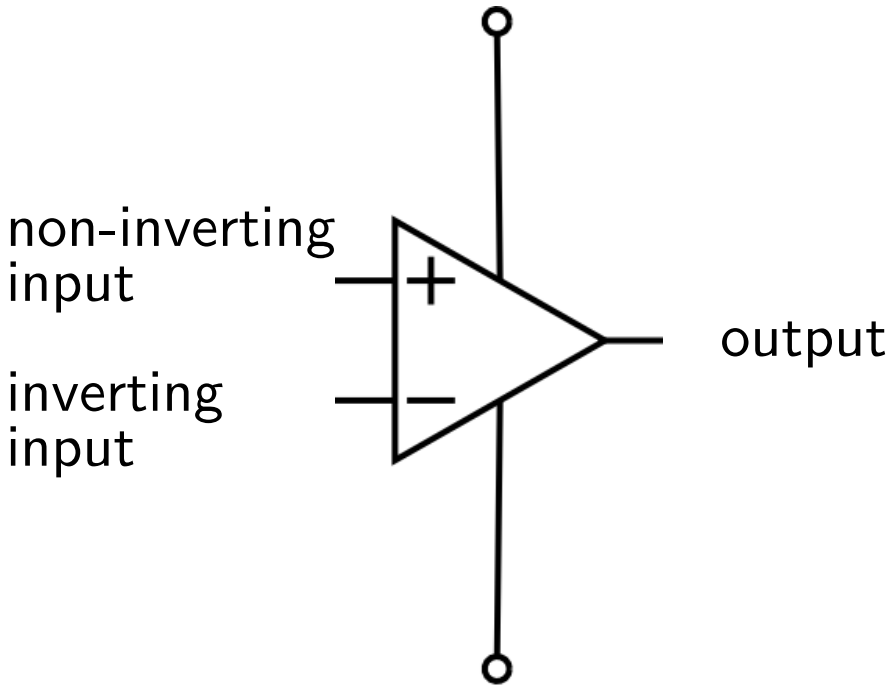
Active device; requires power to work, even though power connections often not shown

Showing power connections



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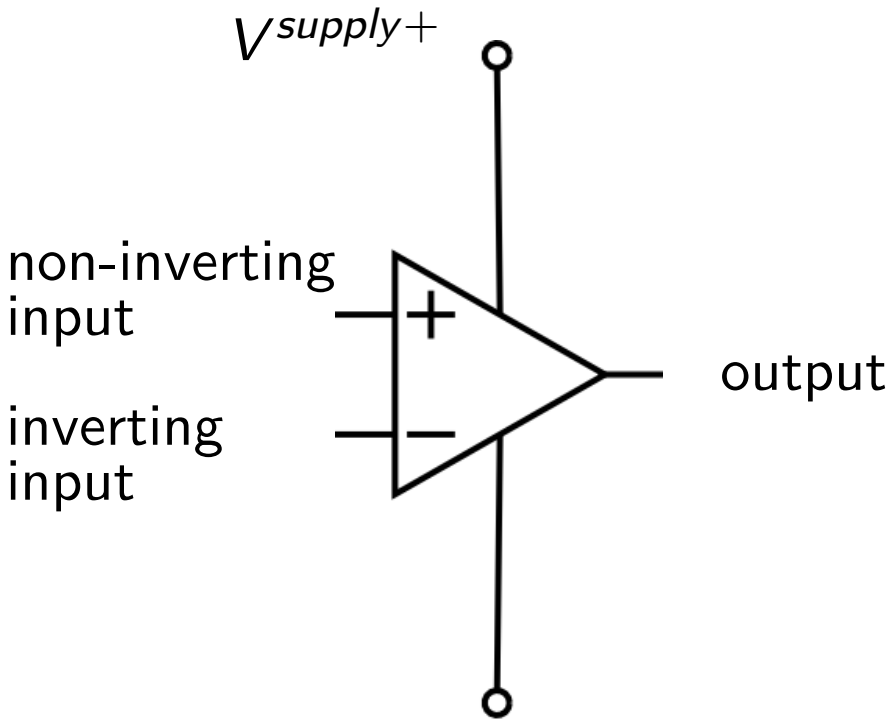

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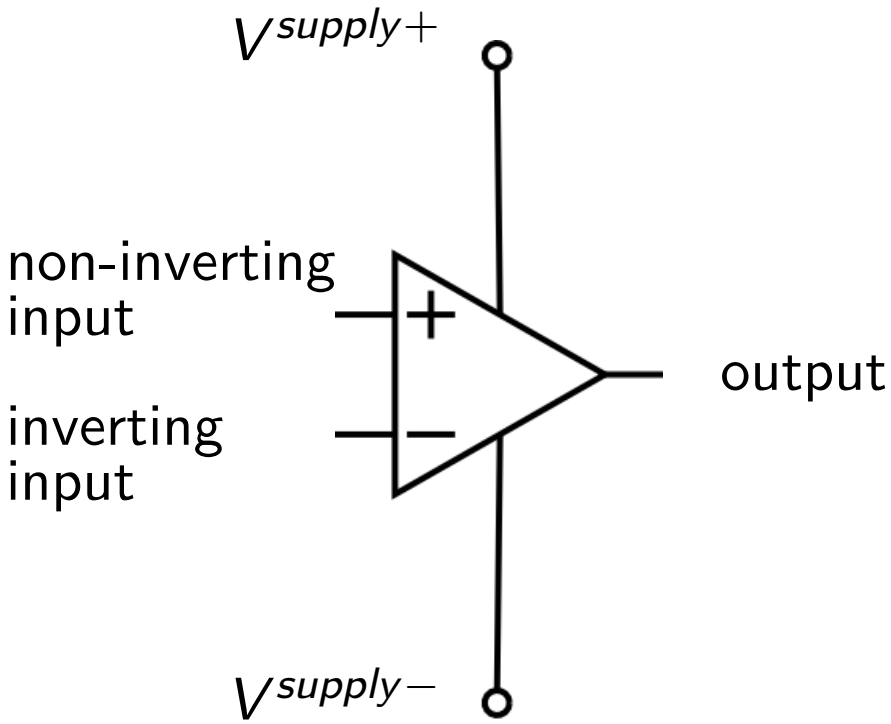

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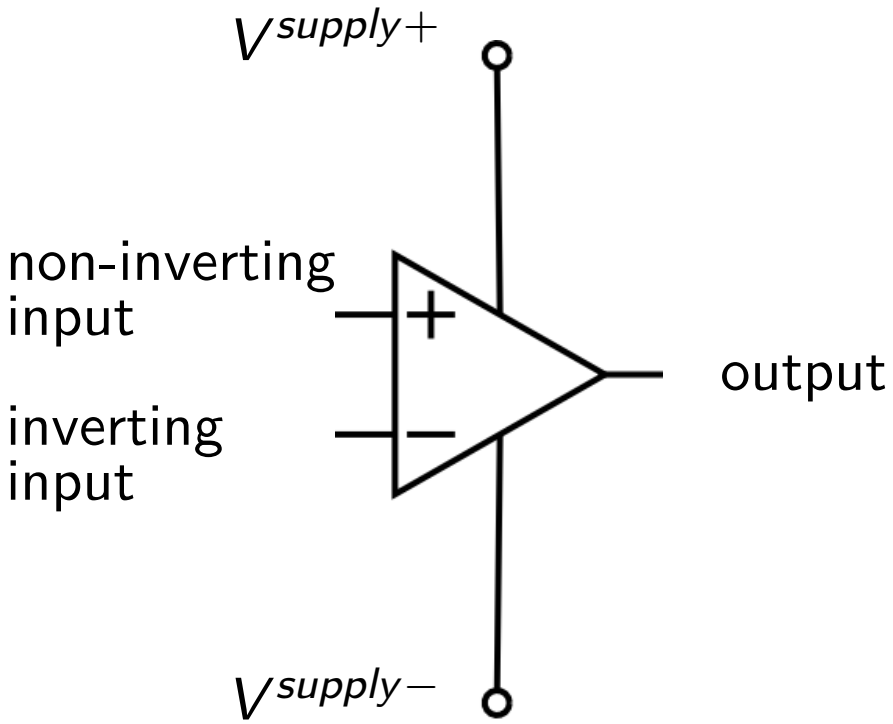

Supplies are usually not shown, but must be used.

Operational amplifier supply voltage rules

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When an op amp hits one of the rails, its output can be called **saturated**, or we can say the op amp is *in saturation*.

*In a **dual supply** op amp, typically the positive and negative supplies are similar, such as* $\pm 12V$.

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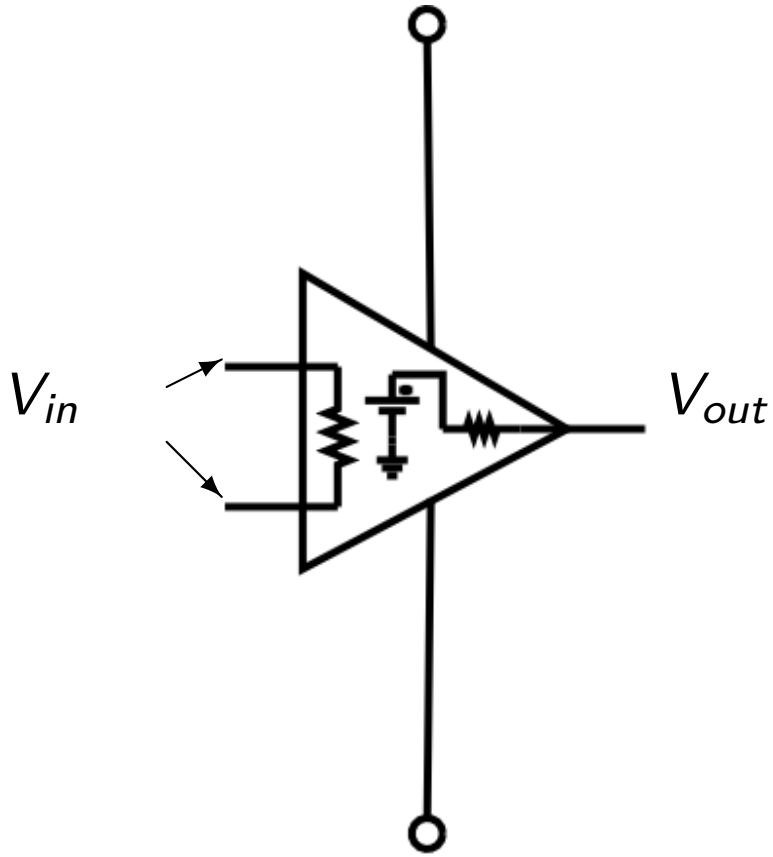
$\rightarrow$ *Single supply op amps* are an exception to the previous rule; you usually can usually get within a few millivolts of the *negative* supply.

Equivalent circuit

Equivalent circuit



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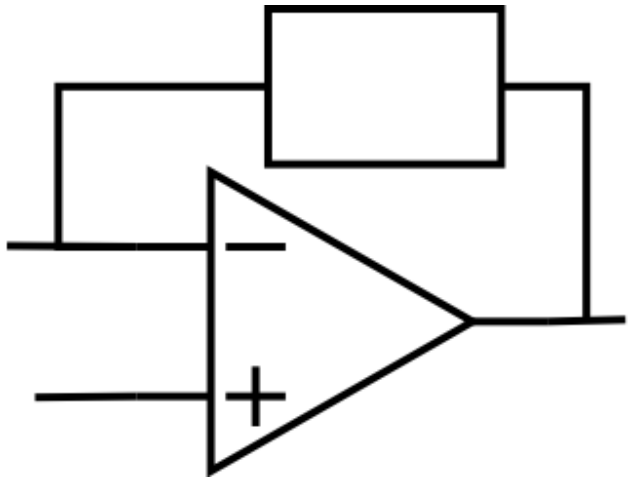
$V_{out} = A_v (V_+ - V_-)$

Negative feedback



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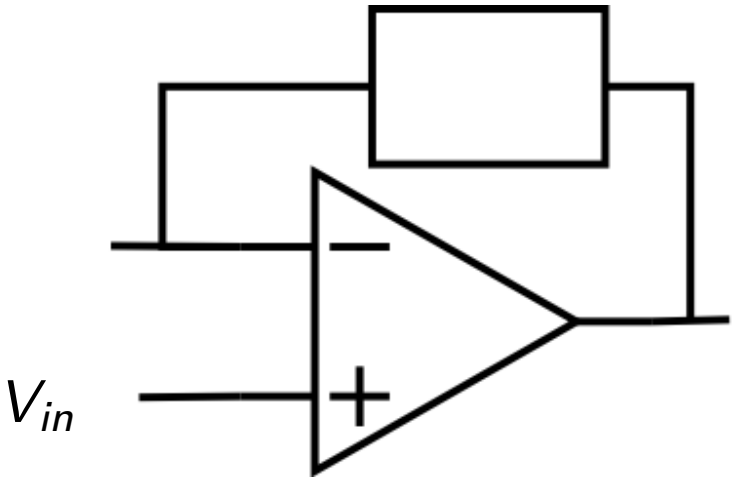

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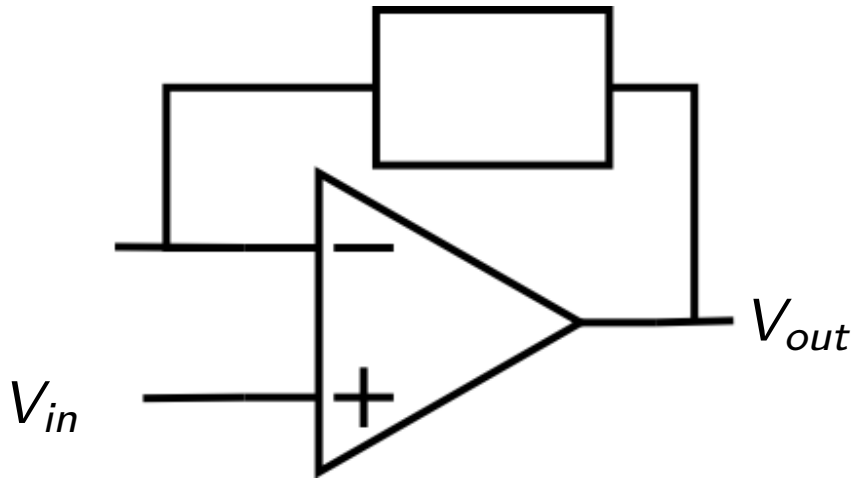

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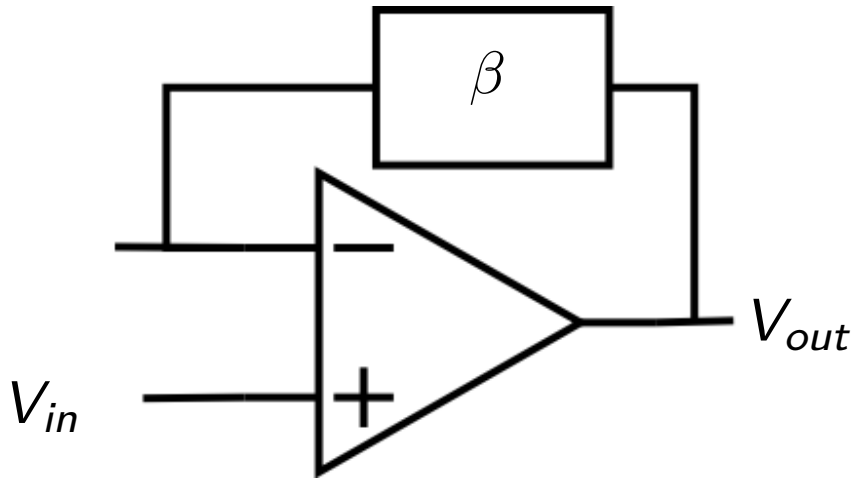

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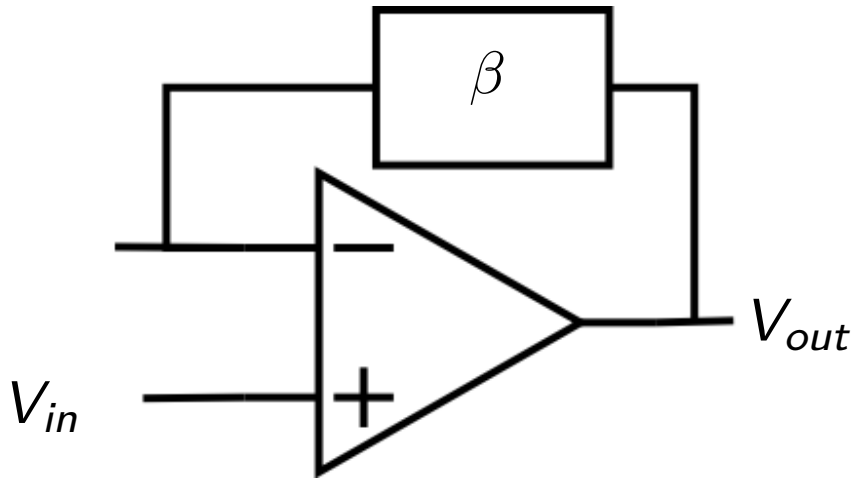

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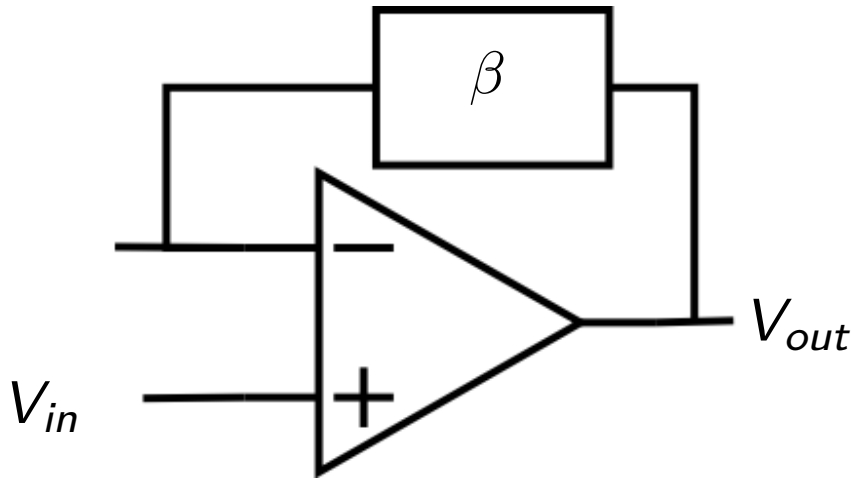

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$R_{in} \approx R_{in}(1 + \beta A)$

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$gain = \frac{1}{\beta}$; i.e. **the output depends only on the feedback, not on the op amp characteristics**

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Instead of thinking of the device as an amplifier, you can think the purpose of the device is to keep the inputs equal

Buffer (or voltage follower)

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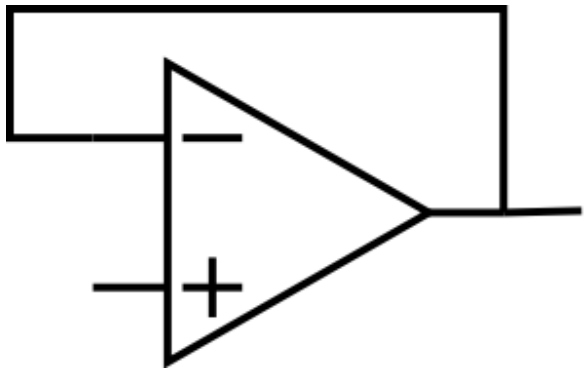

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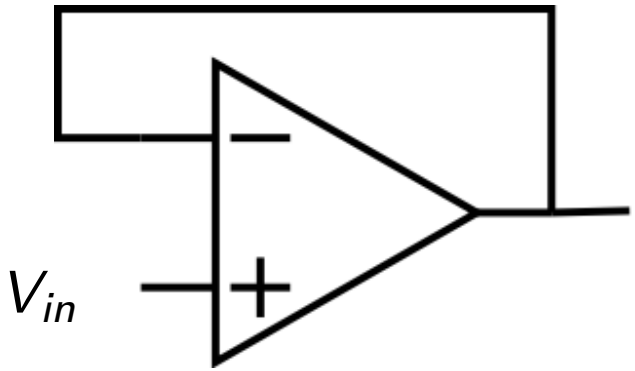

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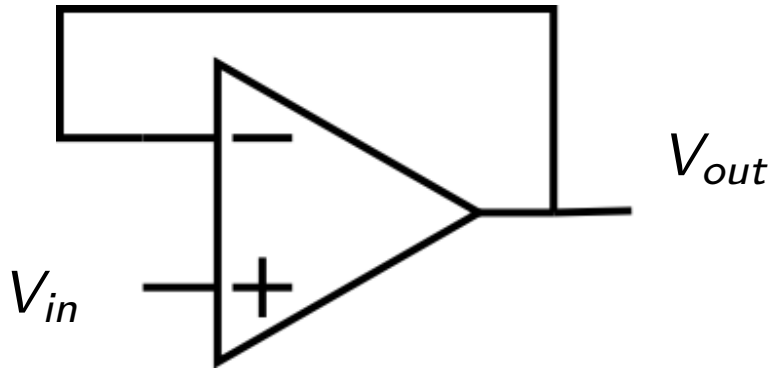

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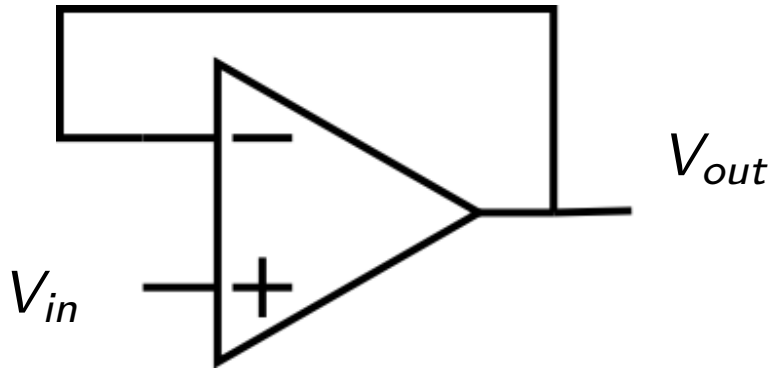

$$V_- = V_{out} \text{ and } V_+ = V_{in}$$

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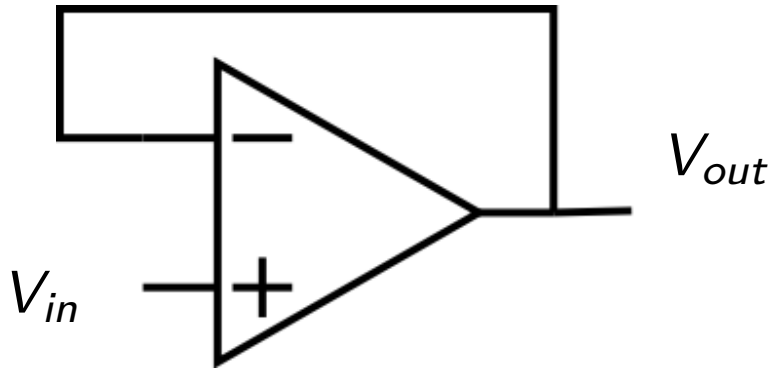

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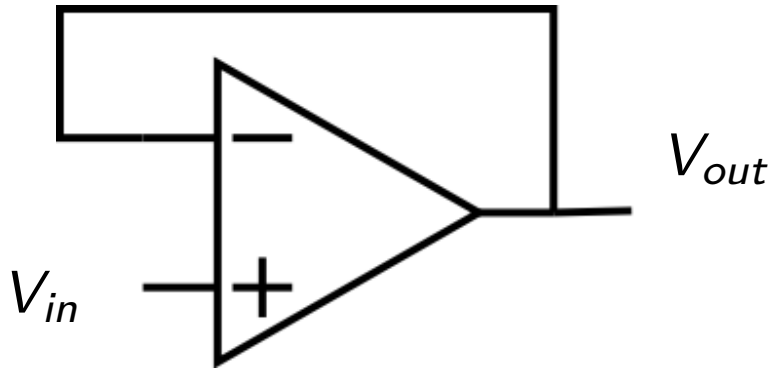


$V_- = V_{out}$ and $V_+ = V_{in}$

$V_- \approx V_+$ (virtual equality)

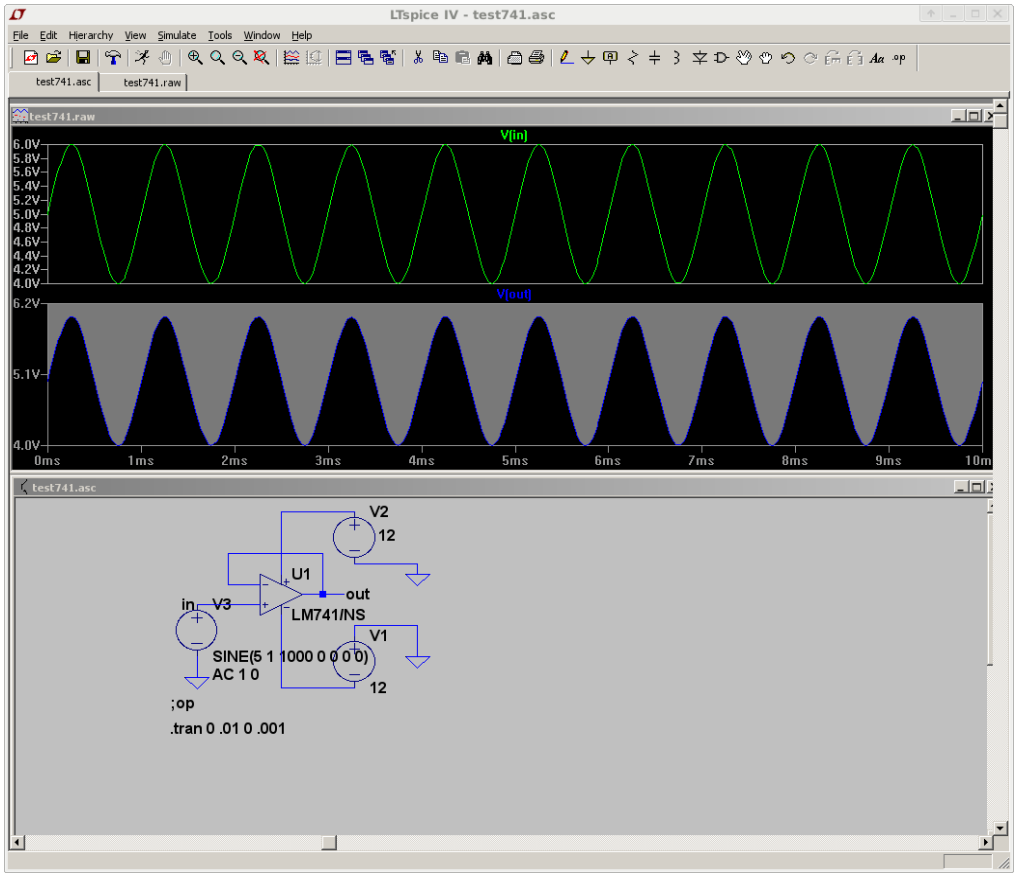
$\therefore V_{out} \approx V_{in}$

6V

4V

6V

4V



Here's a simulation.

12V

-12V

12V

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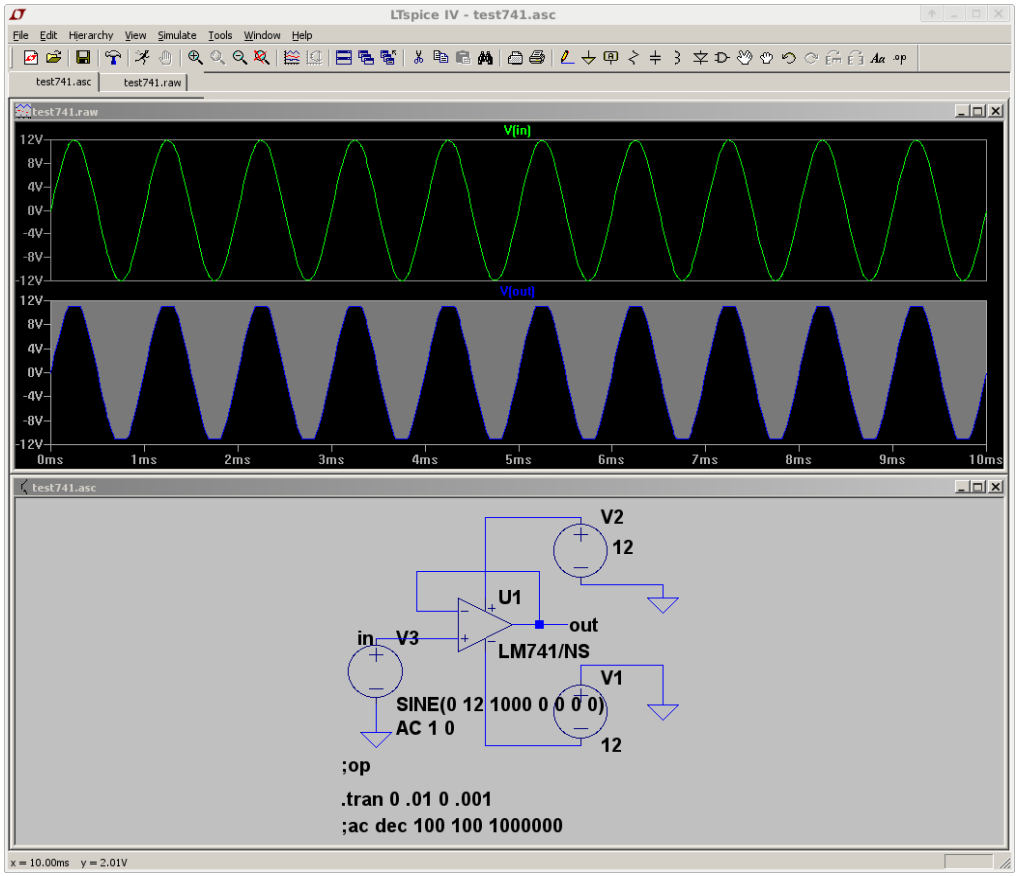
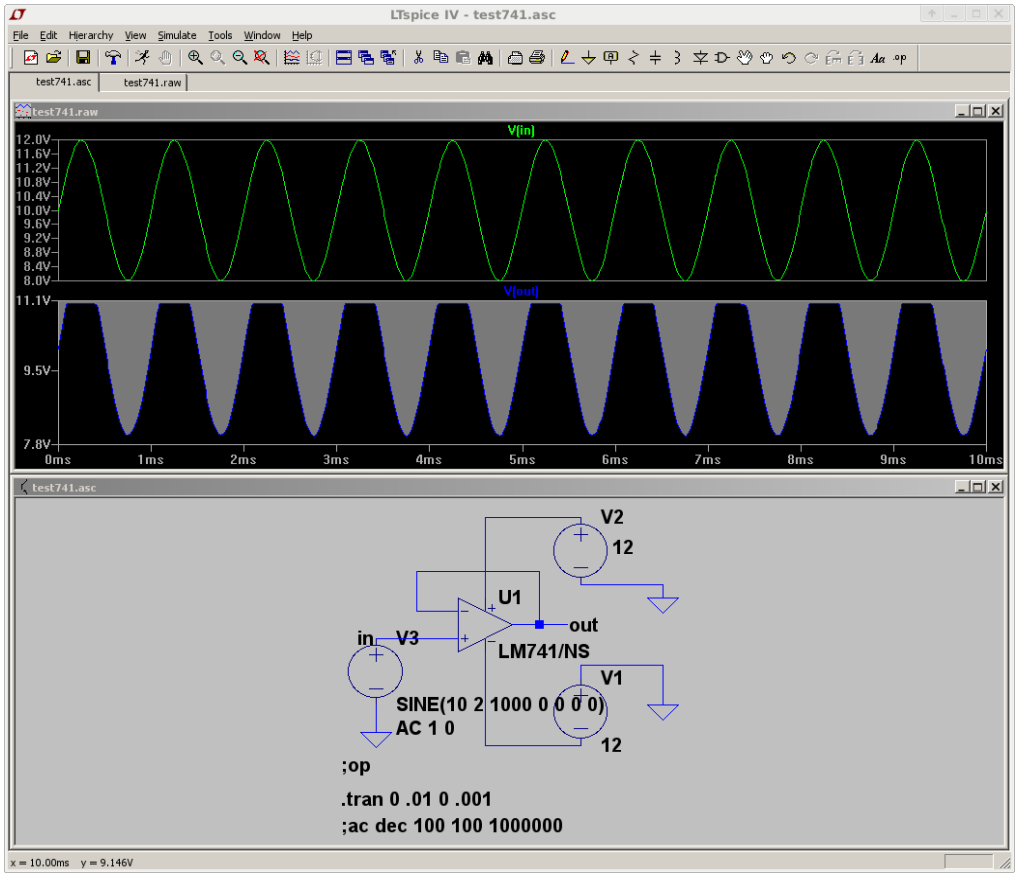


With a large amplitude signal, you can see the rails.

12V

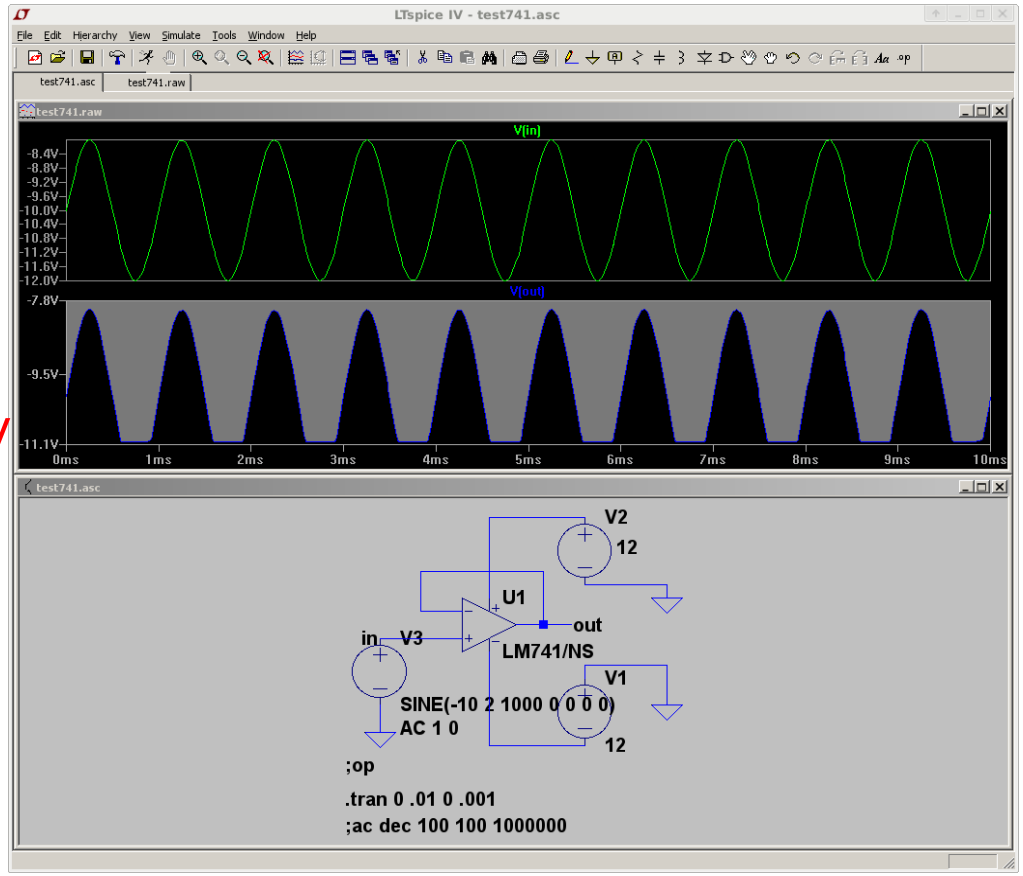
11.1V



This is a closer look at the positive rail.

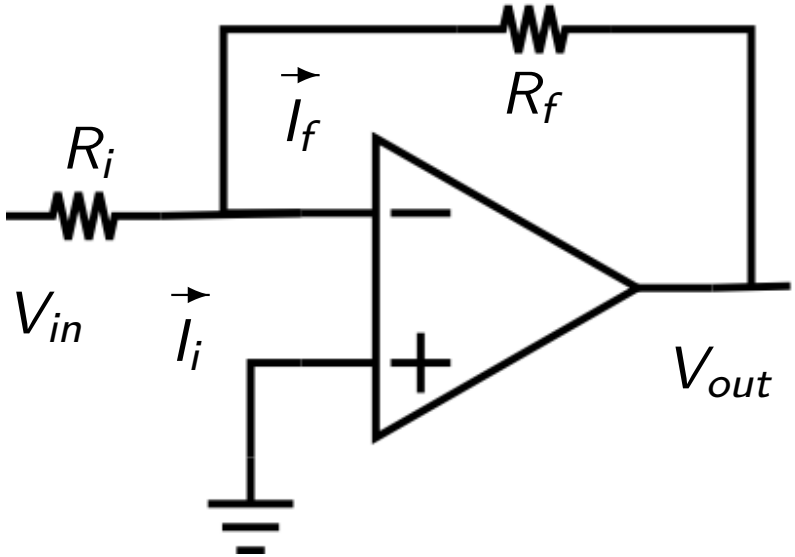
-12V

-11.1V



This is a closer look at the negative rail.

Inverting amplifier



Many op amp circuits are based on this.

$$V_+ = 0 \text{ (ground)}$$

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$$I_f R_f = V_{out} - V_-$$

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$$I_f R_f = V_{out} - V_-$$
$$I_i R_i = V_- - V_{in}$$

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$I_f = I_i$ (no current into inputs)

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$\therefore \frac{V_{out}-0}{R_f} = \frac{0-V_{in}}{R_i}$

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$I_i R_i = V_- - V_{in}$

$V_- \approx V_+$ (virtual equality)

$I_f = I_i$ (no current into inputs)

$\therefore \frac{V_{out}-0}{R_f} = \frac{0-V_{in}}{R_i}$

$\therefore V_{out} = -\frac{R_f}{R_i} V_{in}$

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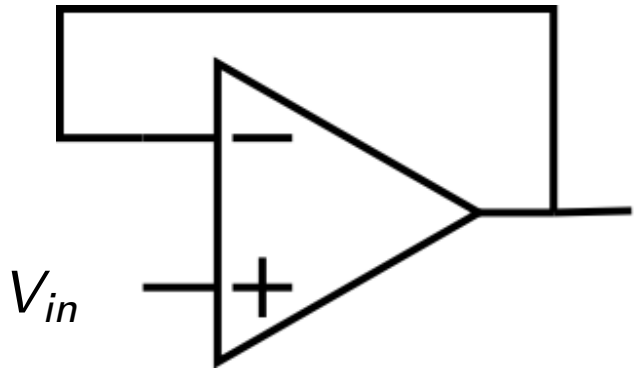

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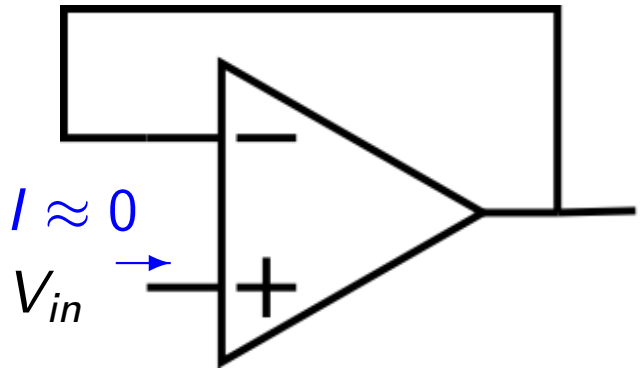

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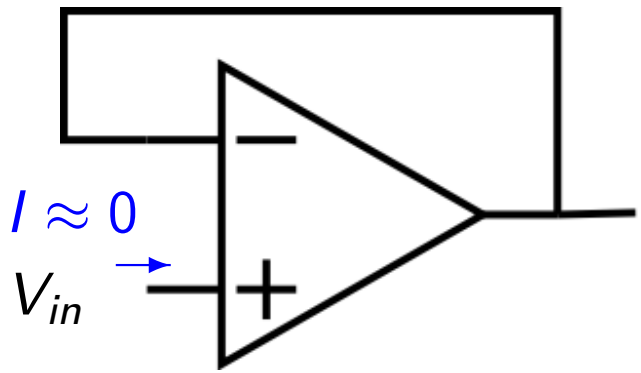

For the buffer circuit, since the signal goes directly into an op amp input, then the input resistance is very large.

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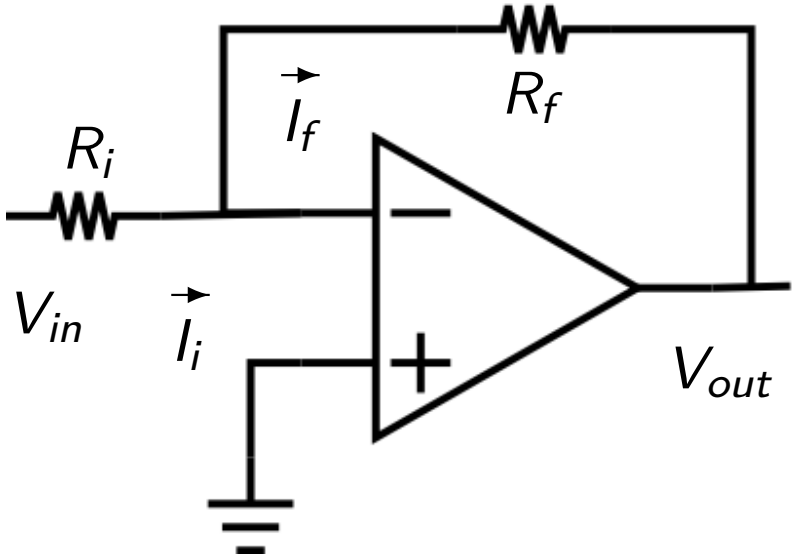

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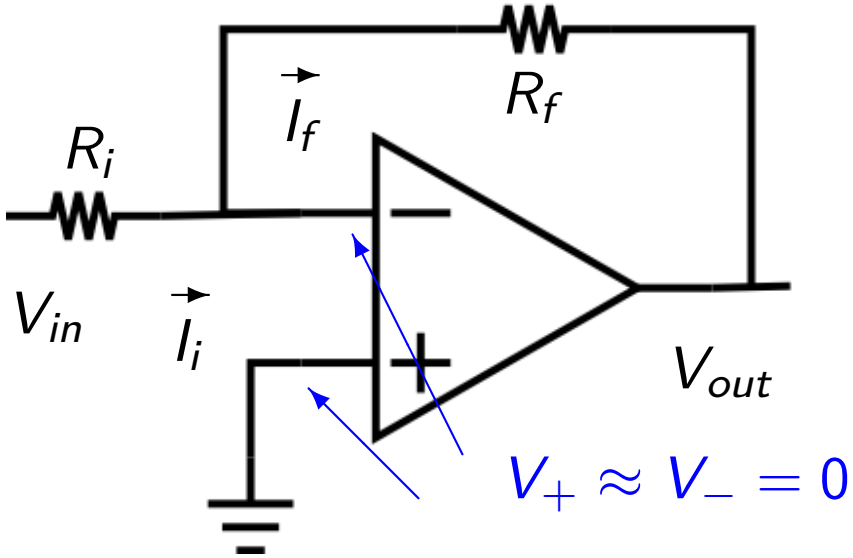

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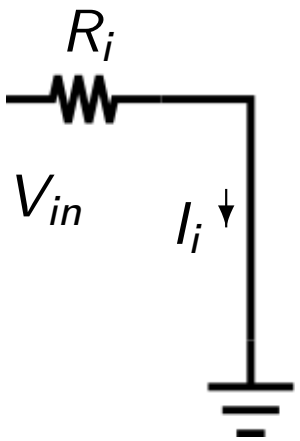

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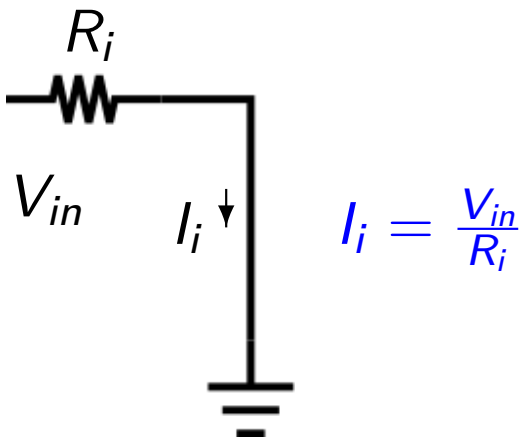
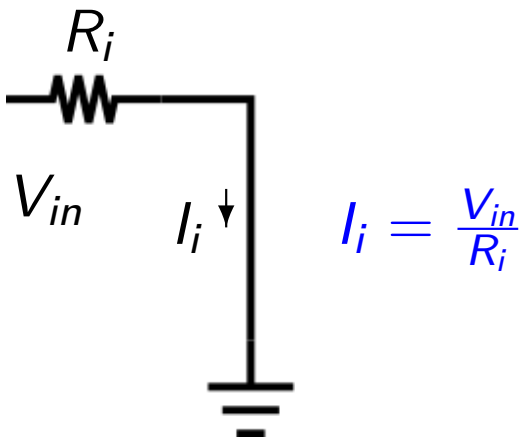


It looks more like this.

For a circuit like the inverting amplifier, the input signal *doesn't* go directly into the op amp input.



It looks more like this.

The effective input resistance is R_i .