

# Electronics

## Operational Amplifier Basics

Terry Sturtevant

Wilfrid Laurier University

October 4, 2016

Ideal Operational Amplifiers

Analyzing Op Amp Circuits

Common Operational Amplifier Circuits

Op amp circuit input resistance

Basic Schematic Symbol

Showing power connections

Operational amplifier supply voltage rules

Equivalent circuit

Negative feedback

# Ideal Operational Amplifiers

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## Basic Schematic Symbol

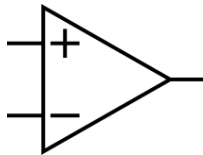
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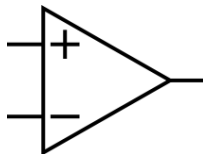
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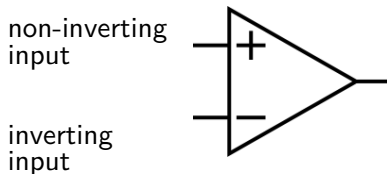


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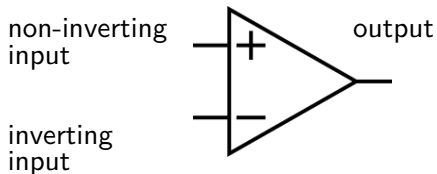
inverting  
input



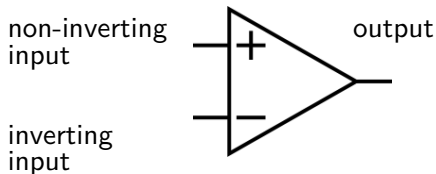
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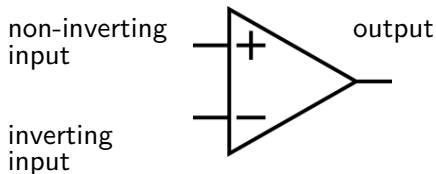


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Output is proportional to the *difference* between the non-inverting and inverting inputs

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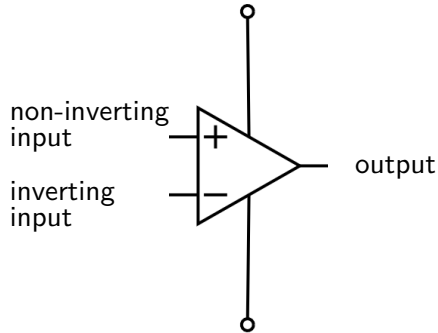


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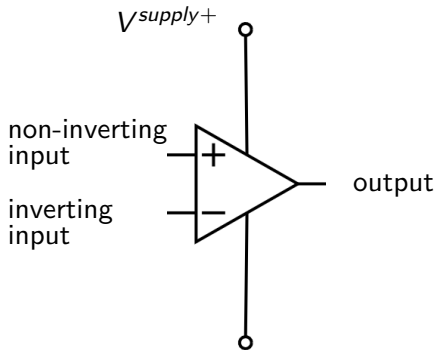
Active device; requires power to work, even though power connections often not shown



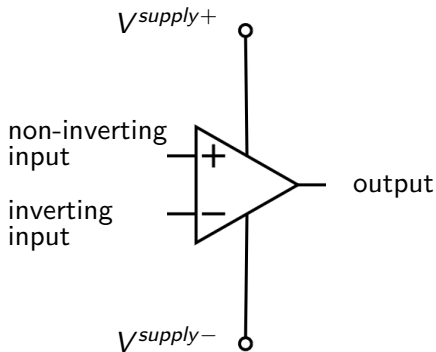
## Showing power connections



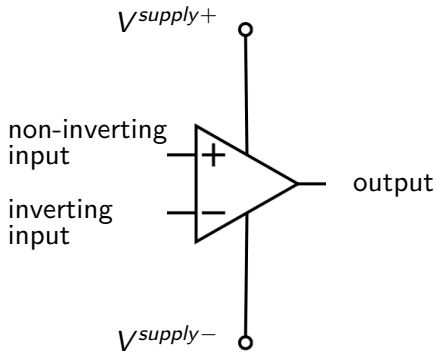
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Supplies are usually not shown, but must be used.

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# 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*.

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

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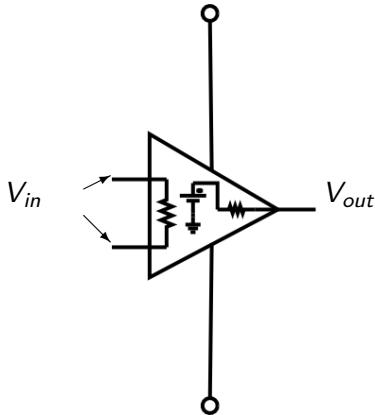
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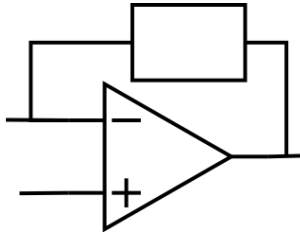
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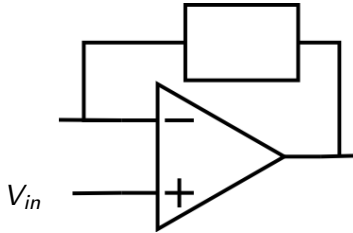
$$V_{out} = A_v (V_+ - V_-)$$



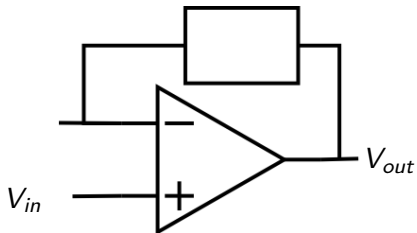
## Negative feedback



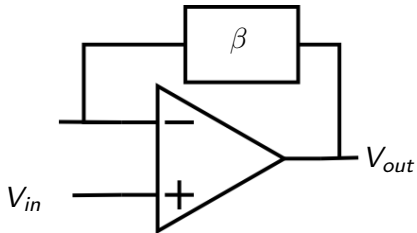
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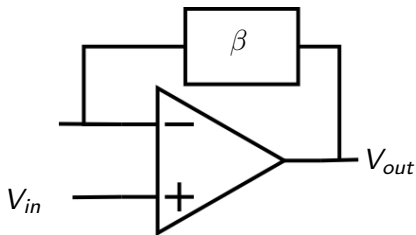
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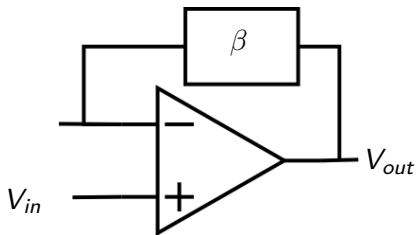


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→ They usually use *negative feedback*.

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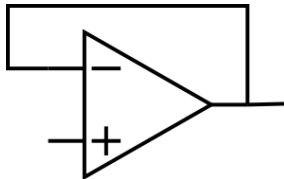
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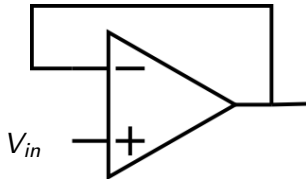
Instead of thinking of the device as an amplifier, you can think the purpose of the device is to keep the inputs equal

## Buffer (or voltage follower)

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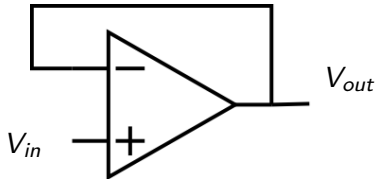


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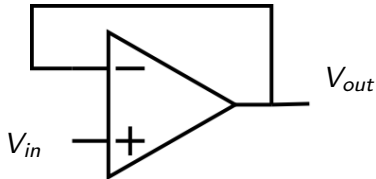




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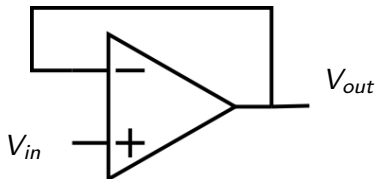


## Buffer (or voltage follower)



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

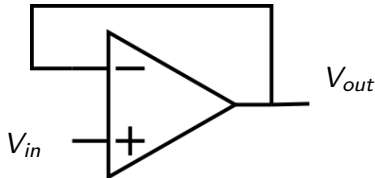
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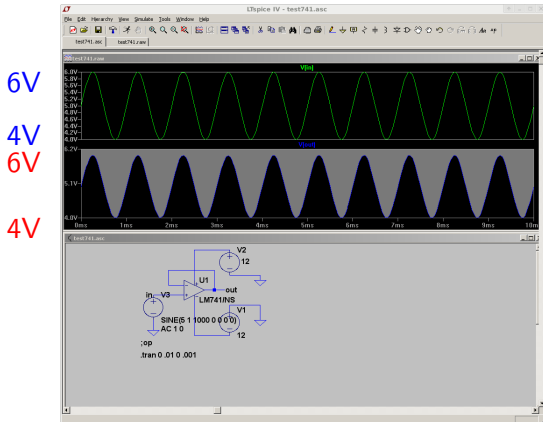
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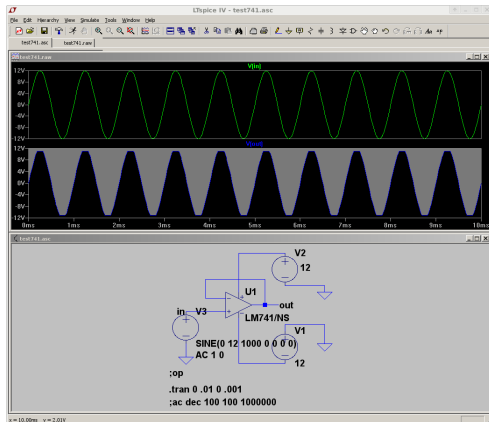
$$V_- \approx V_+ \text{ (virtual equality)}$$

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



Here's a simulation.

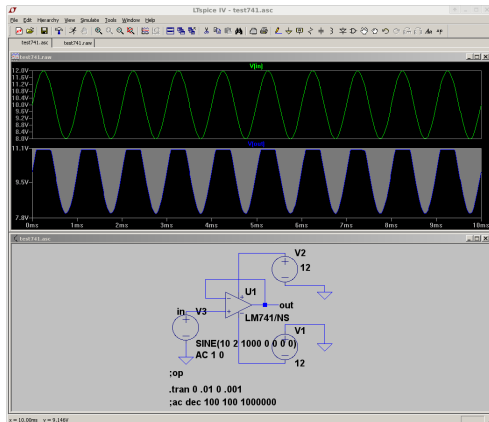
12V  
-12V  
12V  
-12V



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

12V

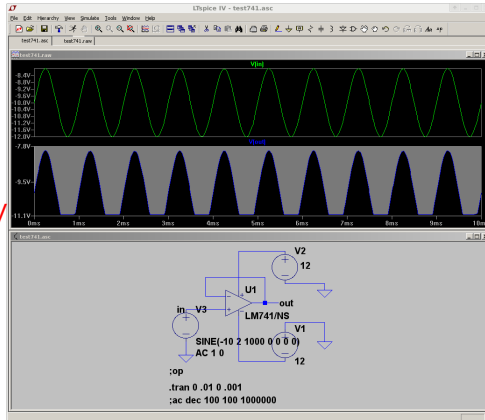
11.1V



This is a closer look at the positive rail.

-12V

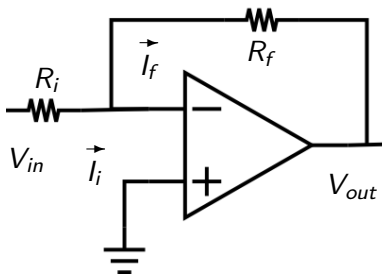
-11.1V



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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$$I_f = I_i \text{ (no current into inputs)}$$

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

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

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



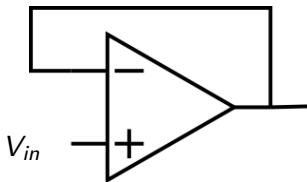
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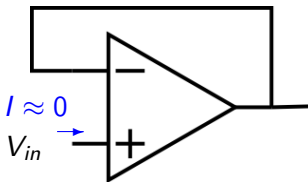
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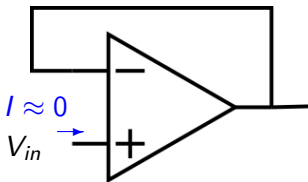
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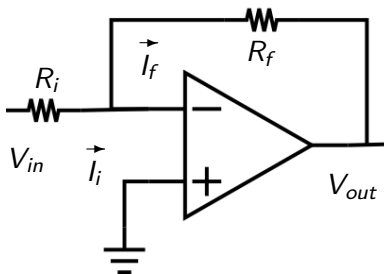
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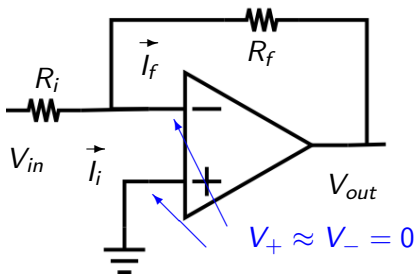
For the buffer circuit, since the signal goes directly into an op amp input, then the input resistance is very large.

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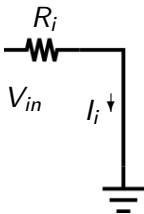


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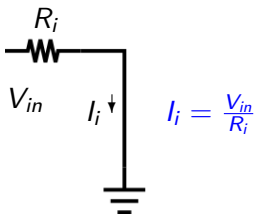


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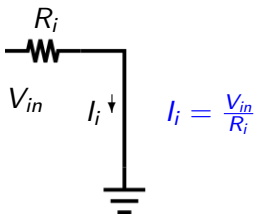
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The effective input resistance is  $R_i$  .