Circuits
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Operational Amplifier

Spring 2022

Operational Amplifier

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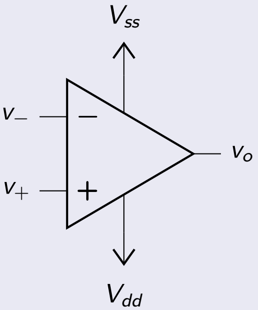

- Often called **op amps**
- Needs upper and lower power supplies (often called **rails**):
  - Upper power supply V_{ss} (or V_{cc})
  - Lower power supply V_{dd} (or V_{ee})
- Proper use: $V_{ss} > V_{dd}$
- 2 inputs:
  - Inverting input v_-
  - Non-inverting input v_+
- 1 output v_o

Purpose

As its name suggests, an operational amplifier **amplifies voltage**.

It amplifies the **difference of voltages on the input terminals** $v_+ - v_-$
The gain is usually huge (typically in the order of 10^5)

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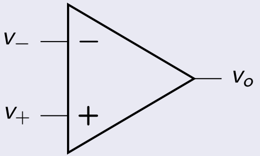
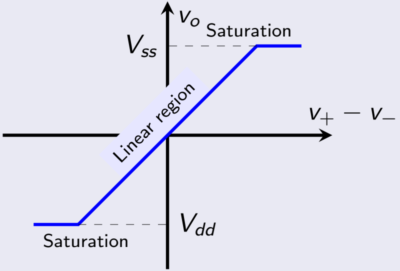
Rails are often omitted in circuit diagrams





Supply rails

- Very often, we'll set $V_{dd} = -V_{ss}$
- Even if they are not drawn on circuit diagram, they are always present
- They produce the power for amplification

Operational Amplifier

Open-loop gain vs closed-loop gain

The open-loop gain is usually huge, which means that the output voltage easily reaches saturation.

A way to *break* the gain is to create a **closed-loop circuit** by bringing back the output to one of the inputs (usually the inverting input).

Negative feedback

Negative feedback means that the **output terminal is connected to the inverting input** (with a short circuit or through a resistor, or another type of element).

If for some reasons the output tries to increase, then the voltage difference $v_+ - v_-$ will decrease, then forcing the output to also decrease. Negative feedback usually decreases the amplification but it **provides stability**.

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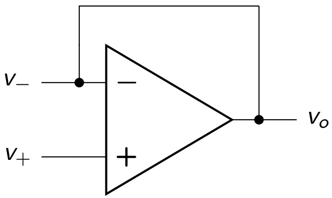
Positive feedback

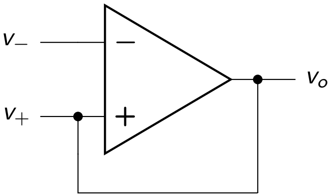
Positive feedback means that the **output terminal is connected to the non-inverting input** (with a short circuit or through a resistor, or another type of element).

If for some reasons the output tries to increase, then the voltage difference $v_+ - v_-$ will increase, then forcing the output to also increase. Positive feedback usually leads to **instable circuits**.



Negative feedback

Positive feedback



Ideal Op Amp

Ideal Op Amp

Rules for an ideal op amp:

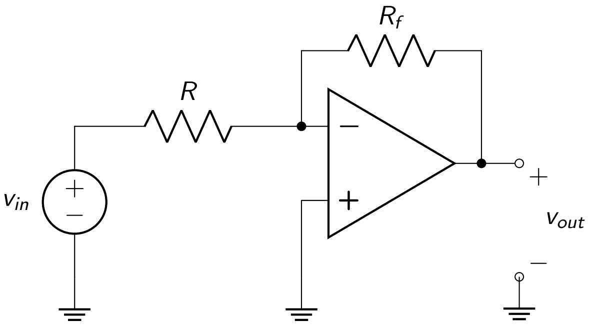
- No current flows into input terminals
- No voltage difference between input terminals (infinite gain)

Realistic model?

On a real op amp, very tiny leakage currents flow into input terminals. Compared to the other currents flowing in our circuits, we can fairly consider these currents to be zero in order to **simplify our analysis**.

Similarly, a small voltage difference exists between input terminals, but we can also neglect it for the same reasons.

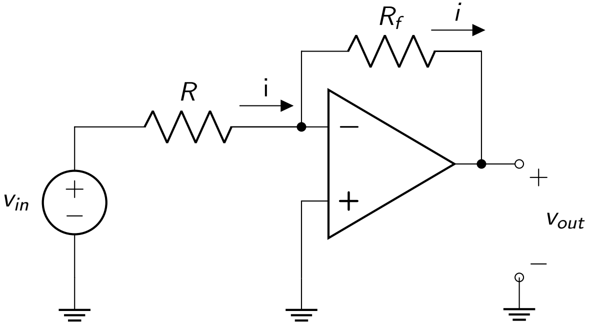
Ideal Op Amp



Ideal op amp

- Same current flowing in R and R_f (no current in inverting input)
- The voltage of inverting input is 0 (no voltage difference)

Ideal Op Amp



Current

- On R_1: $i = \frac{v_{in}}{R}$
- On R_f: $i = -\frac{v_{out}}{R_f}$

$$\Longrightarrow v_{out} = -\frac{R_f}{R} v_{in}$$