AERO | ASTRO

16.682 - Prototyping Avionics
Spring 2006

LECTURE 4

February 21, 2006

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS
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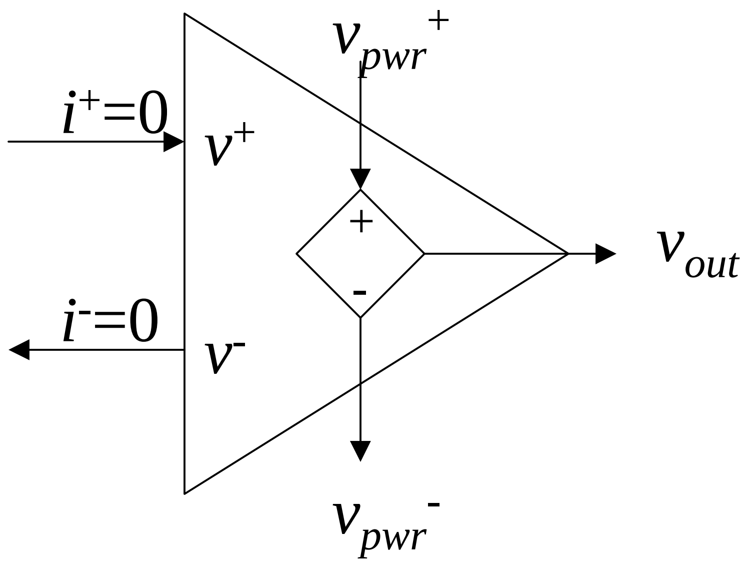
Outline

- **Amplifiers**
  - **Ideal vs. Real**
  - **Basic linear uses**
    - **Voltage follower (current source)**
    - **Voltage amplifier**
    - **Voltage invert & subtract**
  - **Positive feedback**
  - **Active filters**

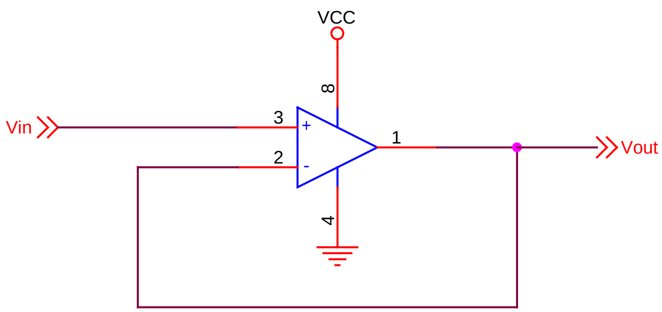
Operational Amplifiers

- **Assume ideal during development:**
  - ***$v^+ = v^-$***
  - ***$i^+ = 0$, $i^- = 0$***
  - **Saturation at input power voltage only**
  - **Linear**
- **Keep in mind for implementation:**
  - **Maximum amplification (e.g., 100, 1000, normally max < 10^6)**
  - **Saturation**
    - **Op-Amps require external +/- supplies!**
  - **Non-linear region**
    - **Frequency region**



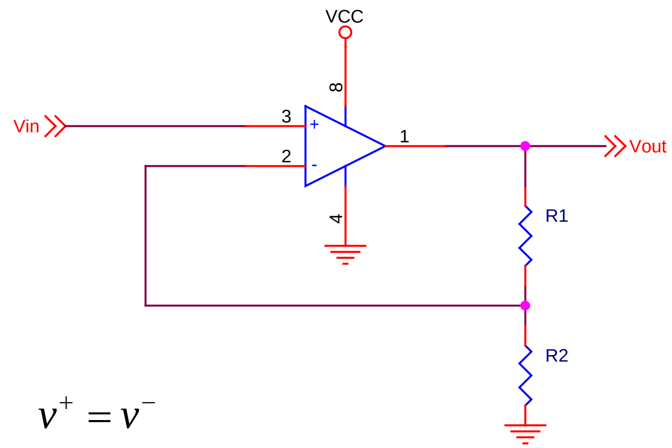
OpAmp Examples

- **Buffer/follower**



$$v^+ = v^-$$
$$v^+ = V_{in}$$
$$v^- = V_{out}$$
$$V_{out} = V_{in}$$

- **Amplifier**



$$v^+ = v^-$$
$$v^+ = V_{in}$$
$$i^- = 0 \rightarrow i_R = \frac{V_{out}}{R_1 + R_2}$$
$$v^- = R_2 \frac{V_{out}}{R_1 + R_2} = v^+ = V_{in}$$
$$V_{out} = V_{in} \frac{R_1 + R_2}{R_2}$$

OpAmp Examples

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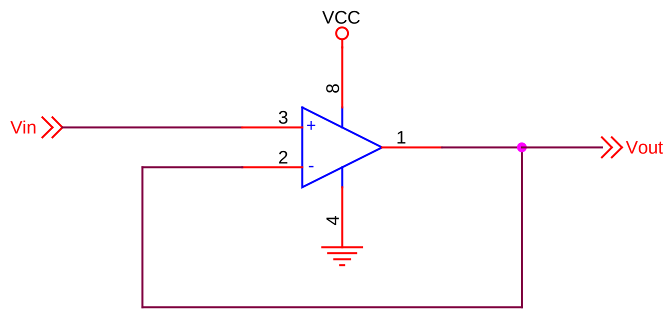

$$v^+ = v^-$$

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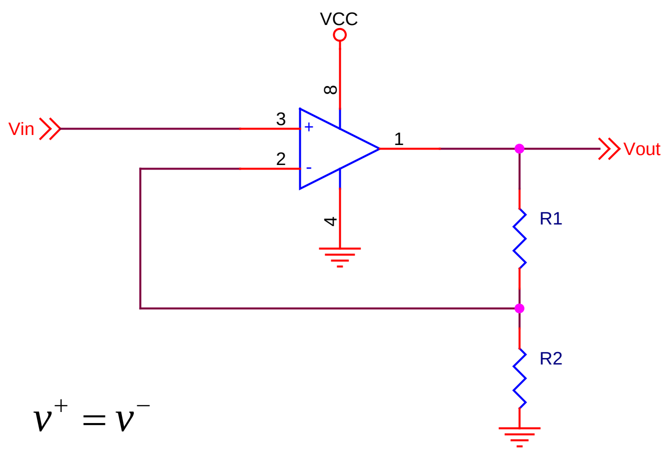
- **Amplifier**



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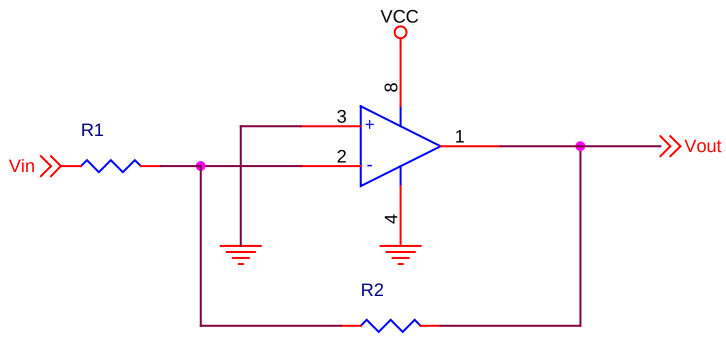
OpAmp Examples

- **Inverting Amplifier**

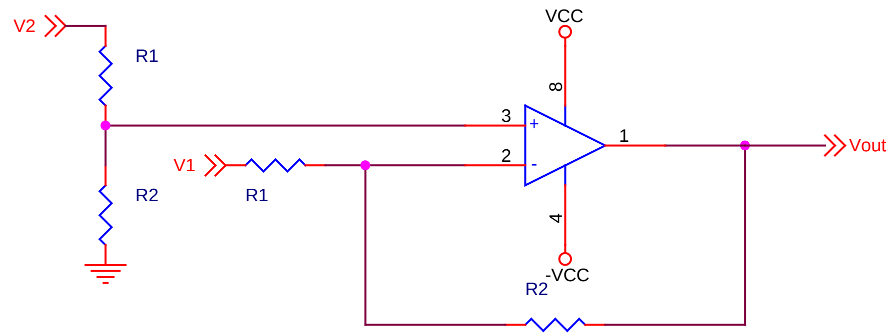


$$v^+ = v^- = 0$$

$$i^- = 0 \rightarrow i_R = \frac{V_{in}}{R_1}$$

$$V_{out} = -i_R \cdot R_2 = -V_{in} \frac{R_2}{R_1}$$

- **Amplifier/subtract**



$$v^+ = v^-$$

$$v^+ = V_2 \frac{R_2}{R_1 + R_2}$$

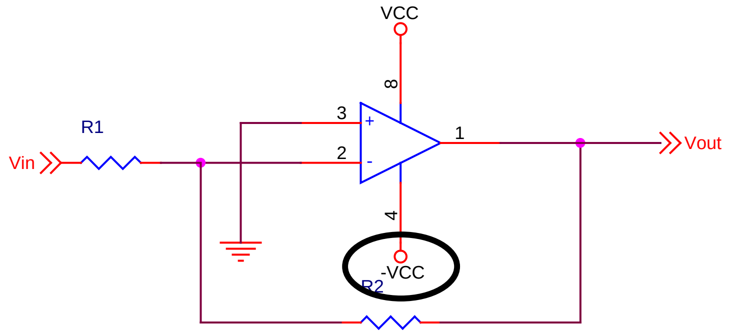
$$v^- = V_{out} + R_2 \frac{V_1 - V_{out}}{R_1 + R_2}$$

$$V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$$

But these do NOT work when Vin>0. Why? ...

OpAmp Examples

- **Inverting Amplifier**

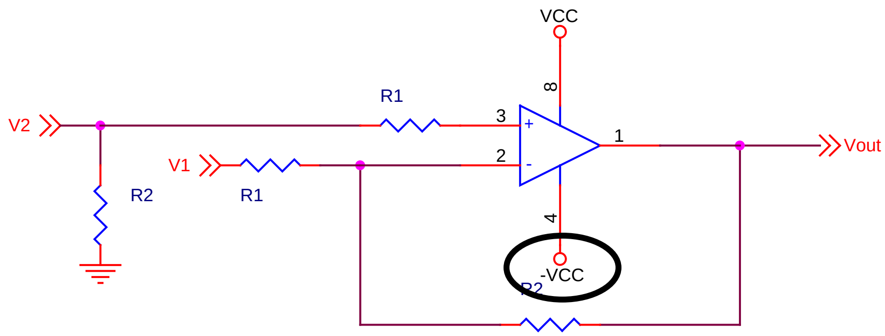


$$v^+ = v^- = 0$$

$$i^- = 0 \rightarrow i_R = \frac{V_{in}}{R_1}$$

$$V_{out} = -i_R \cdot R_2 = -V_{in}\frac{R_2}{R_1}$$

- **Amplifier/subtract**



$$v^+ = v^-$$

$$v^+ = V_2 \frac{R_2}{R_1 + R_2}$$

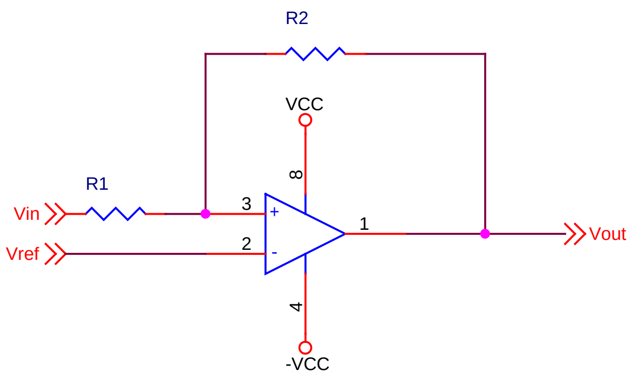
$$v^- = V_{out} + R_2 \frac{V_1 - V_{out}}{R_1 + R_2}$$

$$V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$$

Need a NEGATIVE power supply! (Since Vin is inverted.)

Saturation

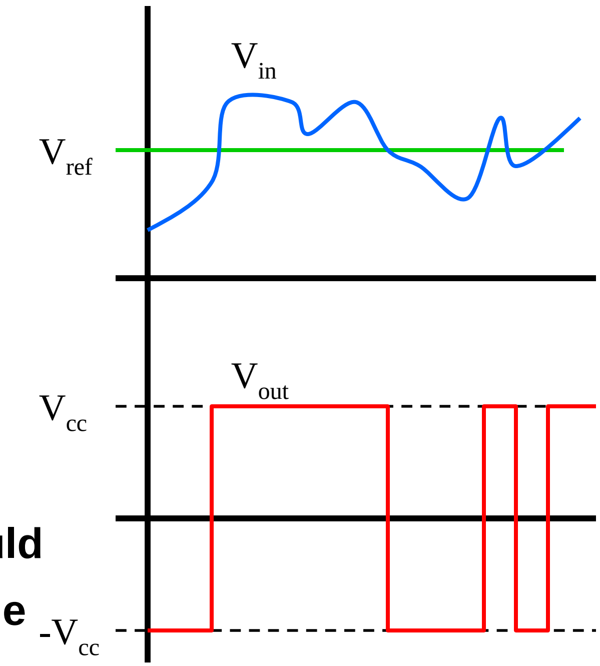
- **Positive feedback is unstable and usually leads to saturation of the output voltage**
  - **Positive Feedback is not very useful for linear tasks, but it can be useful for other jobs...**
  - **Create “digital” signals from analog sources**



$$v^+ = v^- = V_{ref}$$

$$i^+ = 0 \rightarrow v^+ = V_{out} + R_2 \frac{V_{in} - V_{out}}{R_1 + R_2}$$

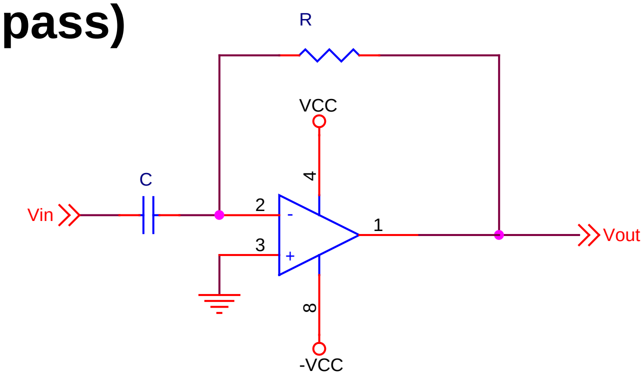
$$V_{out} = \frac{R_1 + R_2}{R_1} V_{ref} - \frac{R_2}{R_1} V_{in}$$



- **While the “ideal” math says that the system should be linear, in reality positive feedback saturates the output to the input voltages (+/- Vcc)**
  - **Can use $R_2 = \infty$ (open, no feedback)**

Active Filters

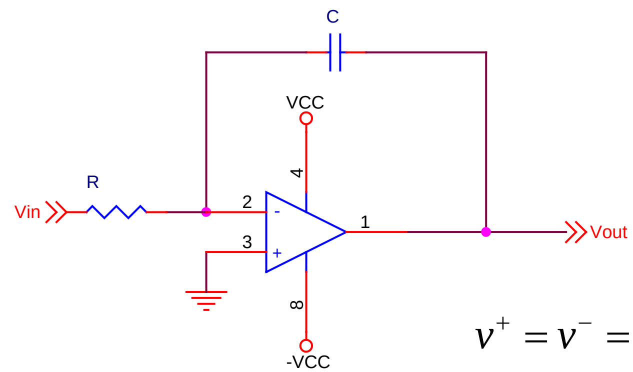
- **OpAmps allow active filtering of signals**
  - **The OpAmp provides power to follow the signals better**
  - **Feedback increases the performance of the filters**
  - **Enables to create both differentiators (high pass) and integrators (low pass)**



$$v^+ = v^- = 0$$

$$i^- = 0 \rightarrow i_R = C\frac{dV_{in}}{dt}$$

$$V_{out} = -RC\frac{dV_{in}}{dt}$$



$$v^+ = v^- = 0$$

$$i^- = 0 \rightarrow i_R = \frac{V_{in}}{R}$$

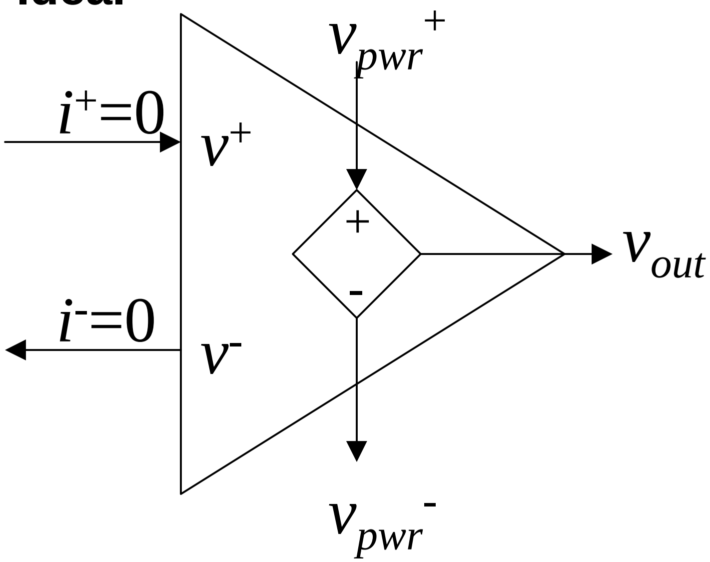
$$V_C = \int \frac{V_{in}}{RC} dt$$

$$V_{out} = -\frac{1}{RC}\int V_{in} dt$$

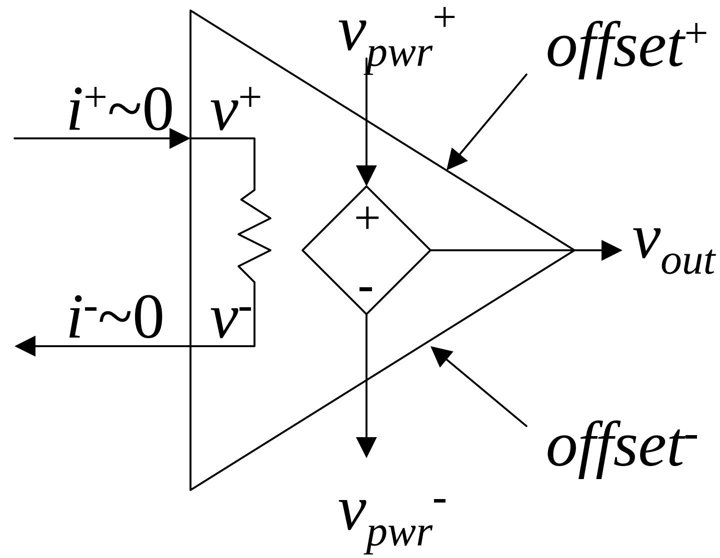
Real Operational Amplifiers

- **Remember the non-ideal conditions**

- **Ideal**



- **Real**



  - **Non-linear**
  - **Frequency dependent**
  - **Offsets**
  - **Saturation**
  - **Hysteresis**
  - **Temperature dependant**