Recap: Op-amp golden rules

- Golden Rule #1: the inputs draw no current
  Because $Z_{in} = \infty$
- Golden Rule #2: $V_+ = V_-$
  Because $A = \infty$
  This requires negative feedback

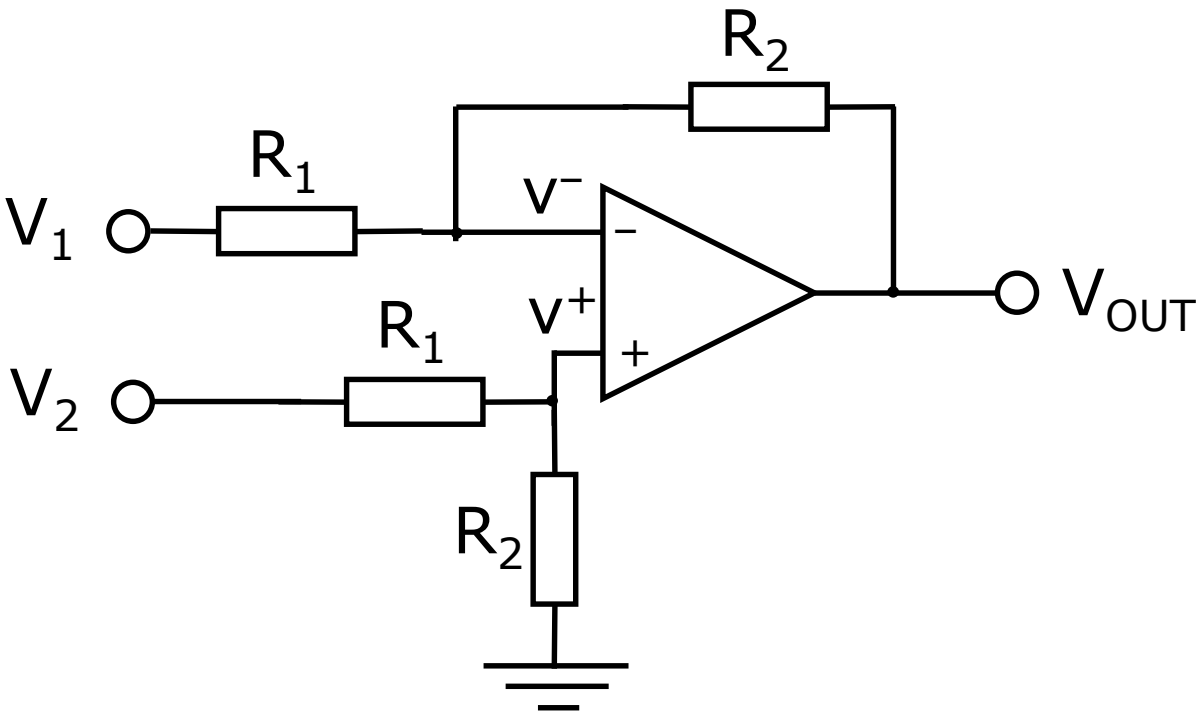
Applying these means you can analyse a circuit containing an op-amp without knowing anything about the details of the op-amp

Today

More examples

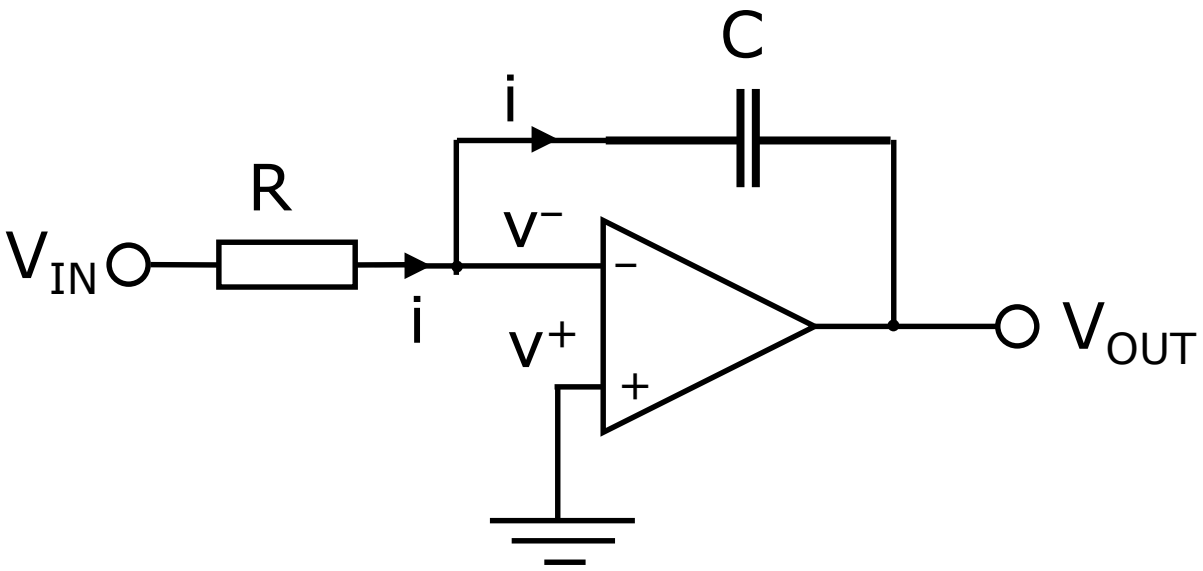
- Difference amplifier
- Integrator
- Differentiator
- AC analysis
- Using saturation

Difference amplifier



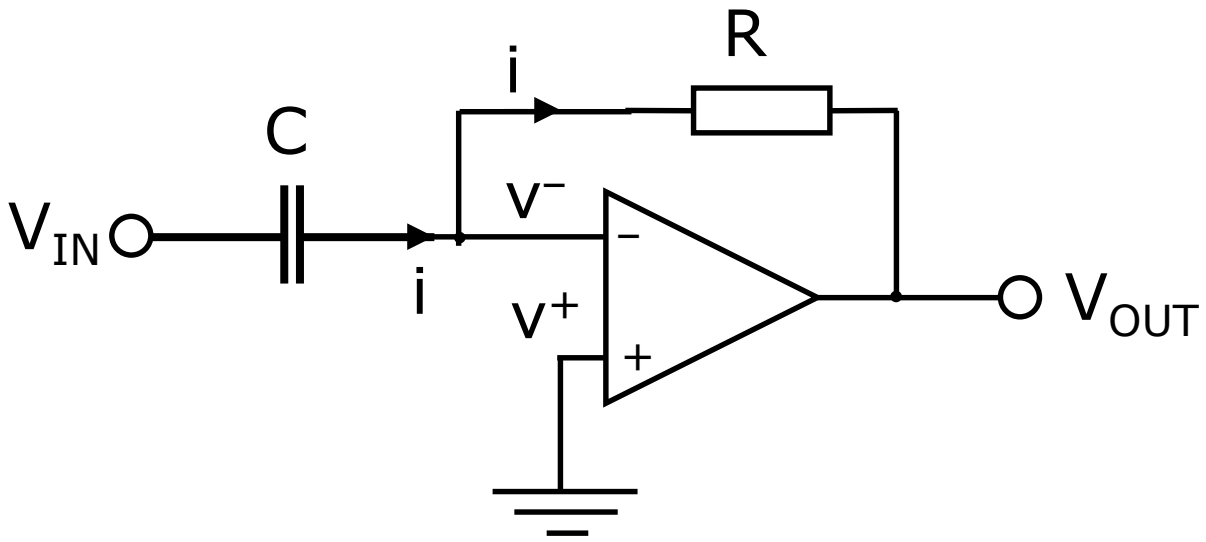
$$V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$$

Op-amp Integrator

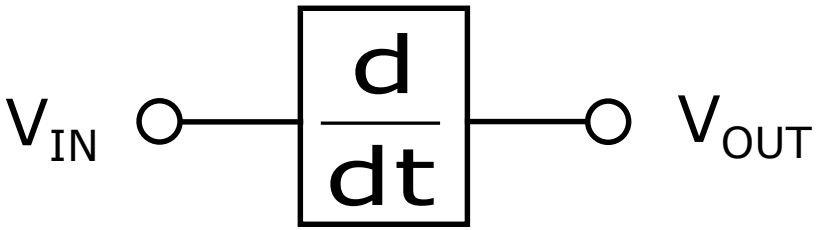


$$V_{out} = -\frac{1}{RC}\int_0^t V_{in}\,dt$$

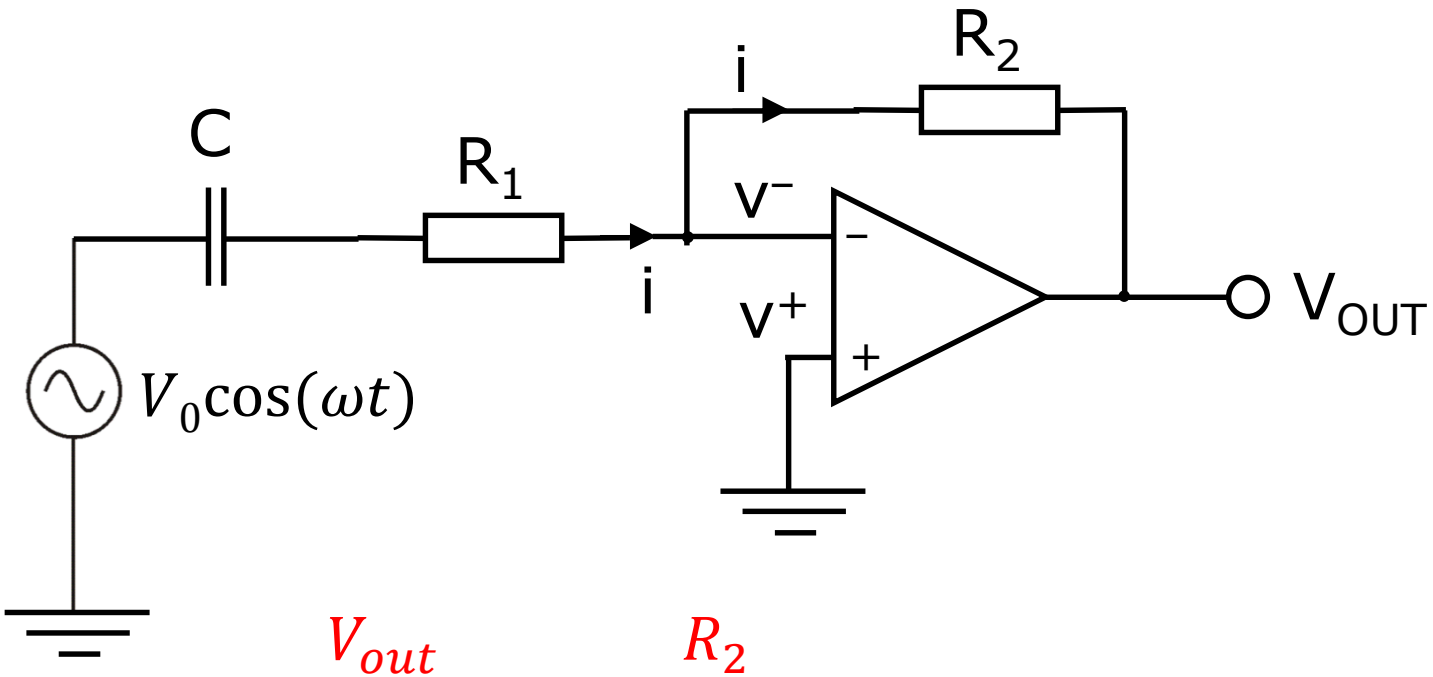
Op-amp Differentiator



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



Complex analysis



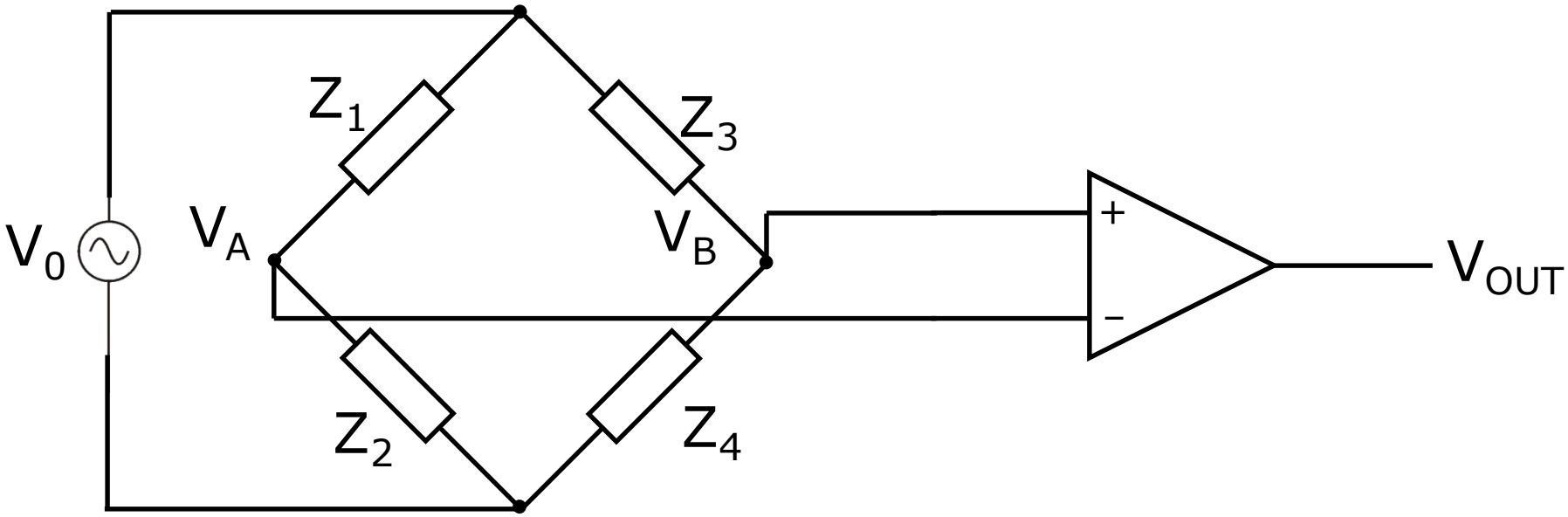
$$\frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1 + \frac{1}{i\,\omega C}}$$

$$\omega \to 0 \quad \left|\frac{V_{out}}{V_{in}}\right| \to 0$$

High pass filter

$$\omega \to \infty \quad \left|\frac{V_{out}}{V_{in}}\right| \to \frac{R_2}{R_1}$$

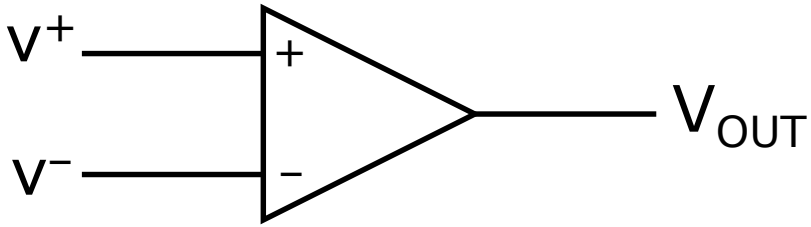
Bridge circuits



Bridge balanced when $V_A - V_B = 0$

$$Z_2 Z_3 = Z_4 Z_1$$

Exploiting op-amp saturation



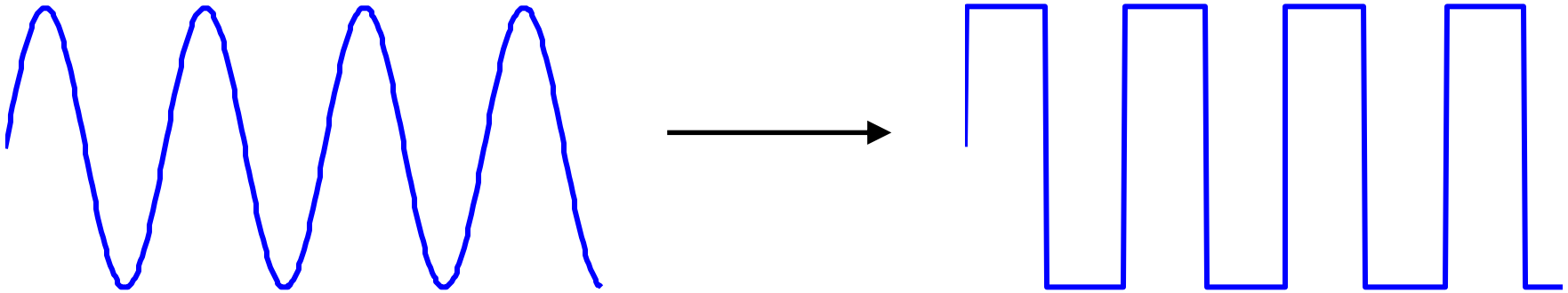
$V_{OUT} = A(v^+ - v^-)$

Saturation voltage

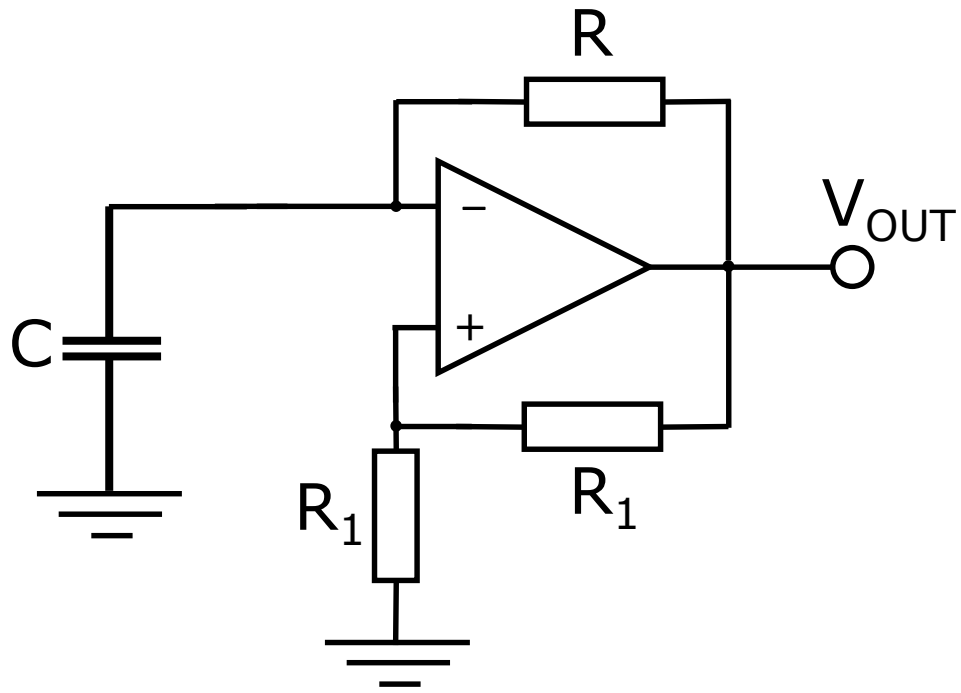
$A \rightarrow \infty$

$V_{OUT} = +V_{Sat}$ $\quad v^+ > v^-$

$V_{OUT} = -V_{Sat}$ $\quad v^+ < v^-$



Oscillator (non ideal)



What does this circuit do?

Op-amp applications

Building block of analogue electronics

- Signal amplifiers
- Audio amplifiers
- Integrators / differentiators
- Voltage / current sources
- Active filters
- Oscillators
- Digital-analogue and analogue-digital convertors