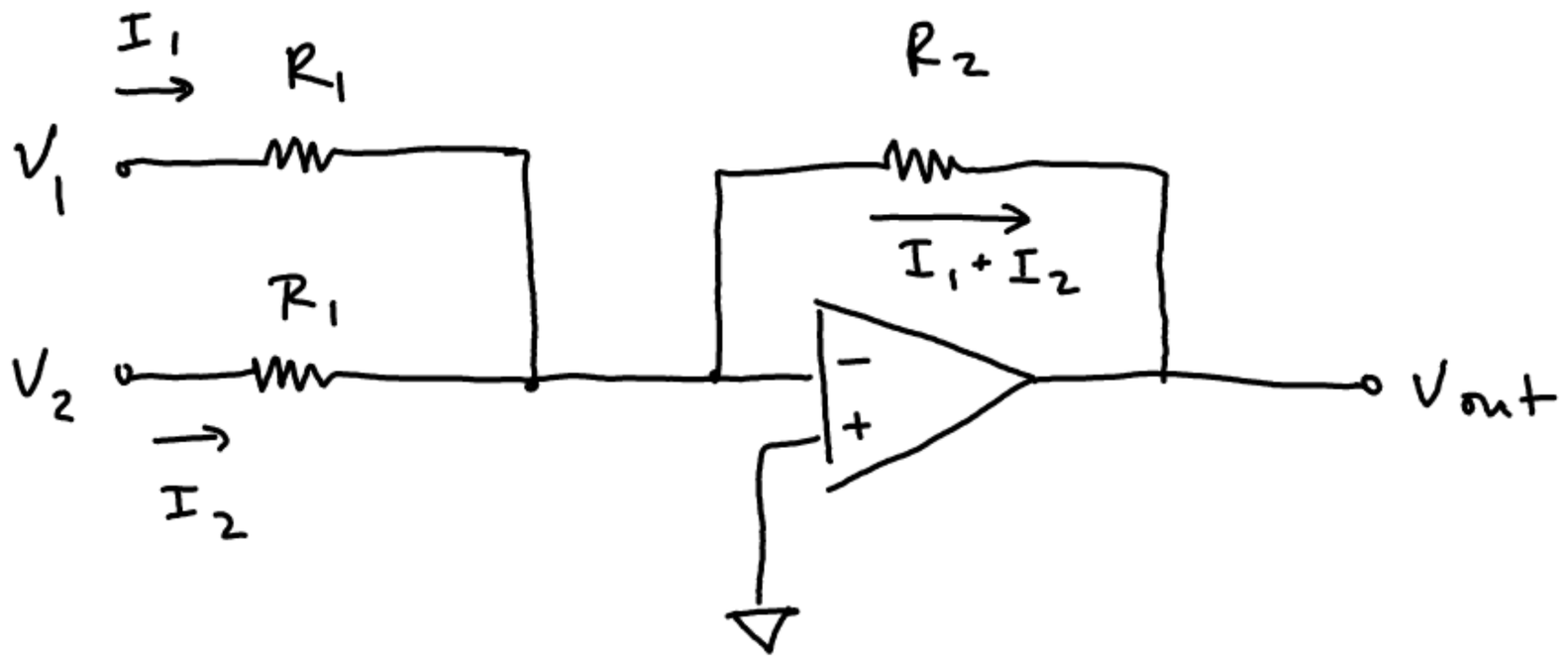
Summing Circuits



What is V_{out} in terms of V_1, V_2 ?

$I_1 = V_1 / R_1$

$I_2 = V_2 / R_1$

$V_+ = V_- = 0 \rightarrow -V_{out} = (I_1 + I_2) R_2$

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

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

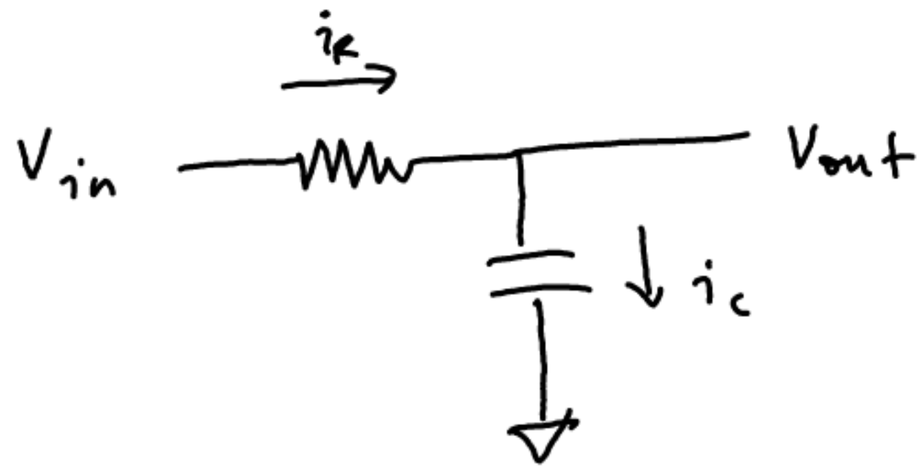
↑ inverting amp

↑ sums the two inputs

To get weighted sum, use different resistors.

Integrator

Previous integrator:



AKA low-pass filter

$$i_c = \frac{dQ_c}{dt} = C\frac{dV_c}{dt} = C\frac{dV_{out}}{dt}$$

$$V_{out} = \frac{1}{C}\int_0^t i_c\, dt$$

$$i_c = i_R = \Delta V_R / R$$

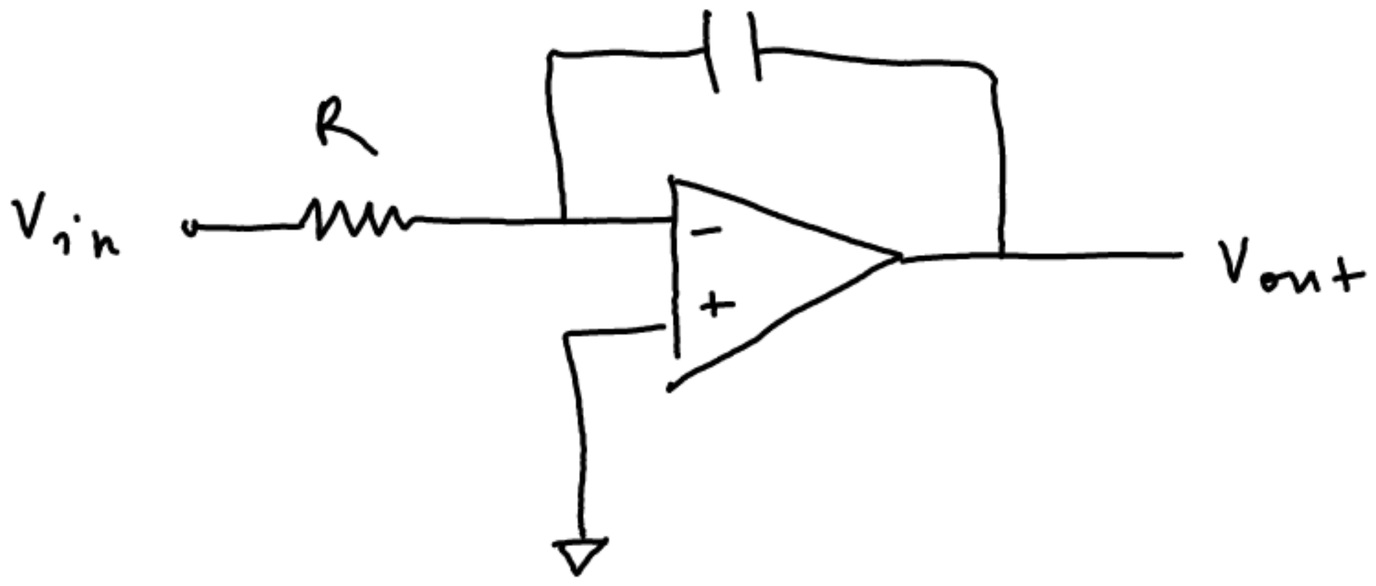
$$\Delta V_R = V_{in} - V_{out}$$

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

a good integrator IF $V_{out} << V_{in}$

Passive circuit requires $V_{out} << V_{in}$

Not always useful. Op-amp will take care of this.



$\Delta V_R = -V_{in}$ since $V_- = 0$

$\Delta V_C = V_{out}$ since $V_- = 0$

$$I = C \frac{dV_{out}}{dt}$$

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

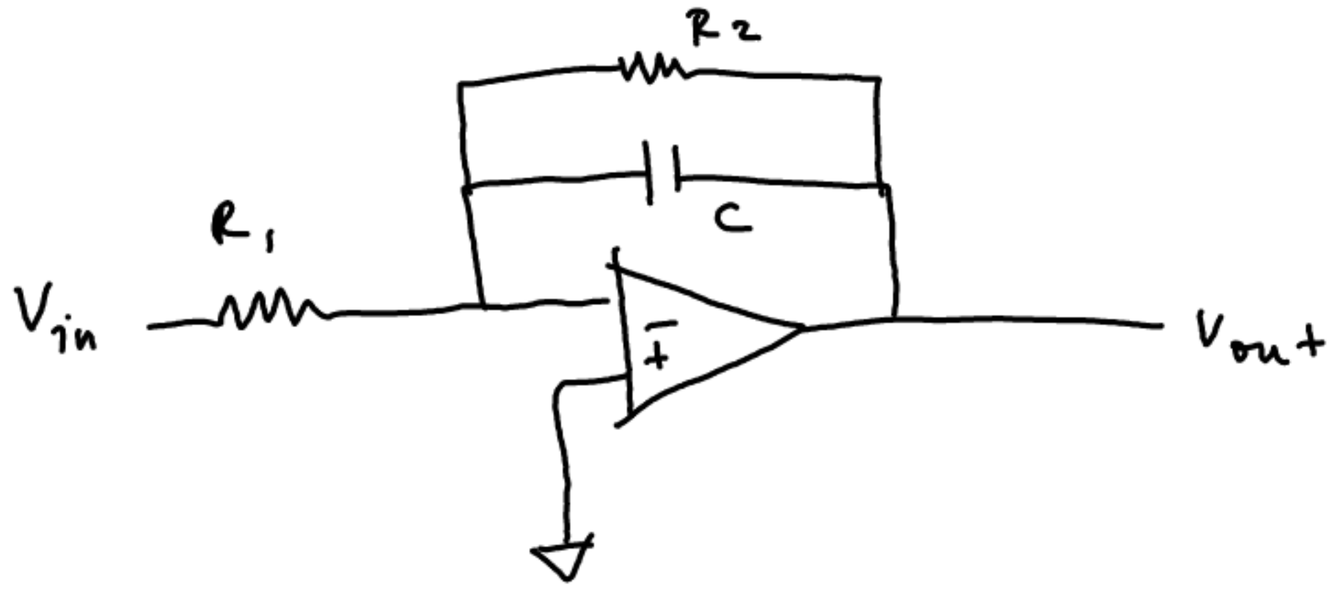
$$V_{out} = \frac{-1}{RC} \int_0^t V_{in}\, dt$$

Works until V_{out} saturates.

Since $G = -\frac{R_2}{R_1} = -\frac{1/jwC}{R} = \begin{cases} \infty & w = 0 \\ 0 & w = \infty \end{cases}$

we saturate fast.

Add another resistor for reasonable gain



$$G = -\frac{R_2 \| C}{R_1} = \begin{cases} -R_2/R_1 & w = 0 \\ 0 & w = \infty \end{cases}$$

Don't forget: this is also a filter!

$$G = -\frac{\left(\frac{1}{R_2} + iwC\right)^{-1}}{R_1} = -\frac{R_2}{R_1}\,\frac{1}{1 + iwR_2C}$$

$$f_c = \frac{1}{2\pi R_2 C}$$

can amplify

not just filter

$(|G| > 1)$

