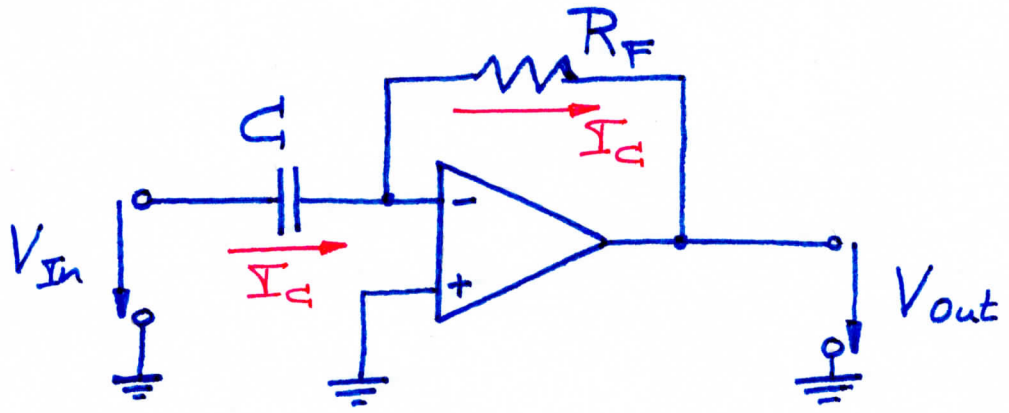
Op amp as differentiator



We can write:

$$V_{In} = V_C \qquad \text{(KVL)}$$

Recall: $Q = CV \Rightarrow \dot{Q} = C\dot{V}$, where $\dot{Q} = I_C$

$$\Rightarrow I_C = C\dot{V}_C = C\dot{V}_{In}$$

Furthermore:

$$V_{out} = -I_C R_F \qquad \text{(KVL)}$$

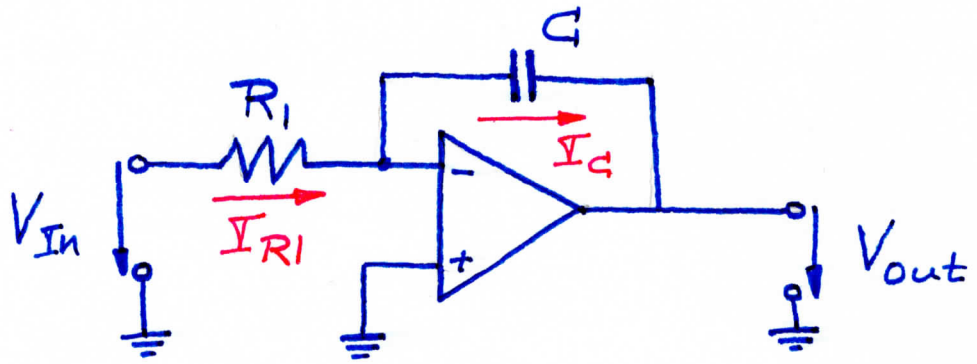
$$= -C\dot{V}_{In} R_F$$

$$\Rightarrow \boxed{V_{out} = -R_F C \dot{V}_{In}}$$

$\Rightarrow$ V_{out} is temporal derivative of V_{In}

$\Rightarrow$ Op amp works as mathematical differentiator

Op amp as integrator



We can write:

$$I_C = I_{R1} \qquad I_{R1} = \frac{V_{In}}{R_1} \quad (\text{Ohm})$$

Recall: $Q = CV \Rightarrow \dot{Q} = C\dot{V} \Rightarrow \dot{V} = \frac{I_C}{C}$

($\dot{Q} = I_C$)

$$\Rightarrow V = V_C = \int_t \frac{1}{C} I_C \, dt$$

Furthermore:

$$V_{out} = -V_C = -\frac{1}{C}\int I_C \, dt \quad (V_{out} = -V_C \text{ by KVL})$$

$$= -\frac{1}{C}\int \frac{V_{In}}{R_1} dt = -\frac{1}{R_1 C}\int_0^t V_{In} \, dt$$

$$\Rightarrow \boxed{V_{out} = -\frac{1}{R_1 C}\int_0^t V_{In} \, dt}$$

$\Rightarrow V_{out}$ is temporal integral of V_{In}

$\Rightarrow$ Op amp works as mathematical integrator