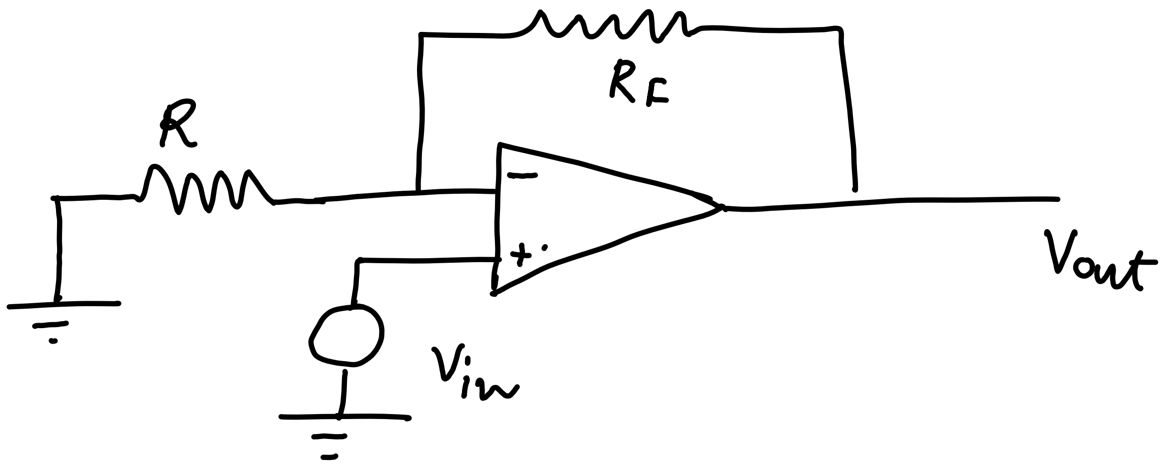
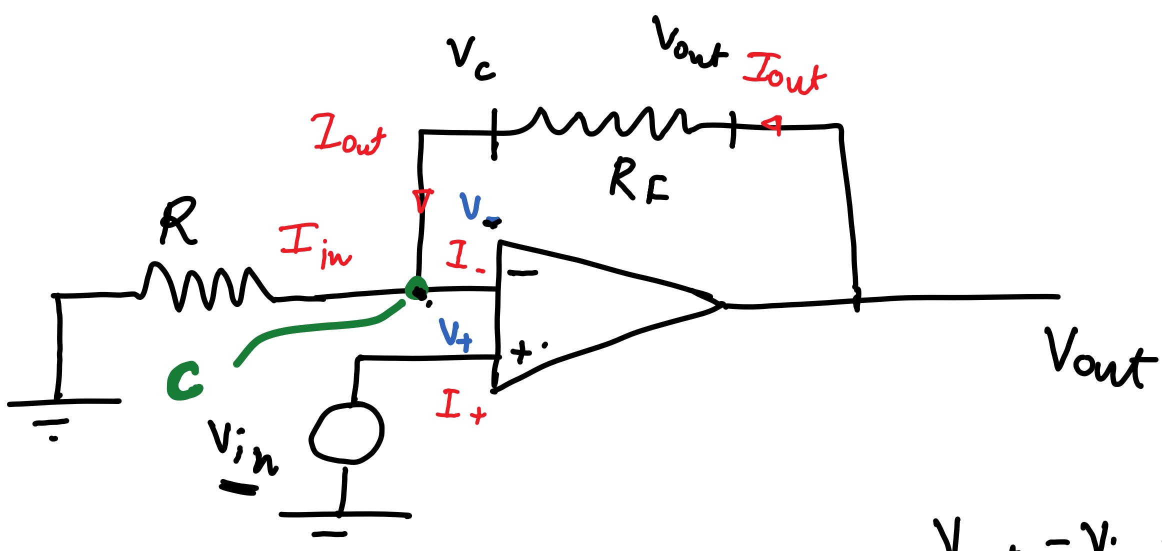
② Non-inverting amplifier

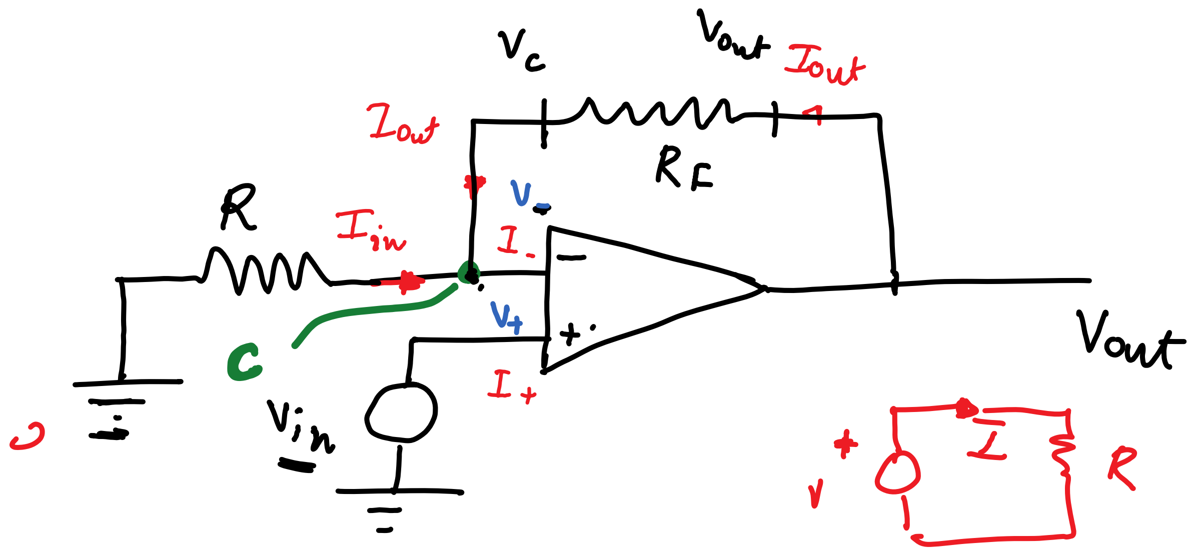


Compute $\dfrac{V_{out}}{V_{in}} = ?$



$$V_{out} - V_c = I_{out} R_F \longrightarrow V_{out} - V_{in} = I_{out} R_F$$

$$\left.\begin{cases} V_{in} = V_+ \\ V_+ = V_- \quad \text{(op-amp assumption)} \\ V_c = V_- \end{cases}\right\} \quad \underline{\underline{V_{in} = V_c}}$$



① — $V_{out} - V_{in} = I_{out} R_F$ (from previous page)

At C : $I_{out} + I_{in} = \underbrace{I_- = 0}_{\text{op-amp assumption}}$

② — $\underline{\underline{I_{out}}} = - \underline{\underline{I_{in}}}$

V_{in}
$\|$

③ — $V_c - 0 = -I_{in} R$

Because I_{in} is assumed to flow from 0 to C

from ① $\dfrac{V_{out} - V_{in}}{R_F} = I_{out}$ $\|$ $\dfrac{-V_{in}}{R} = I_{in}$ from ③

From ③ $\dfrac{V_{out} - V_{in}}{R_F} = \dfrac{V_{in}}{R}$

$$\frac{V_{out} - V_{in}}{R_f} = \frac{V_{in}}{R}$$

$$\frac{V_{out}}{R_f} = V_{in}\left[\frac{1}{R_f} + \frac{1}{R}\right]$$

$$\boxed{\frac{V_{out}}{V_{in}} = \left(1 + \frac{R_f}{R}\right)}$$

① $V_{out} \propto V_{in}$ (non-inverting)

② amplification $1 + \frac{R_f}{R}$

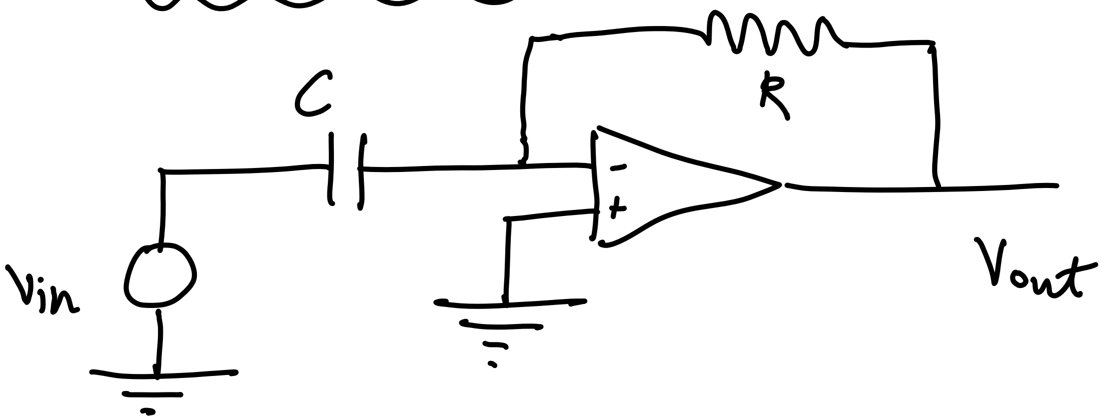
③ let $R >> R_f$

$$\frac{V_{out}}{V_{in}} \approx 1 \Rightarrow V_{out} \approx V_{in}$$

BUFFER or FOLLOWER

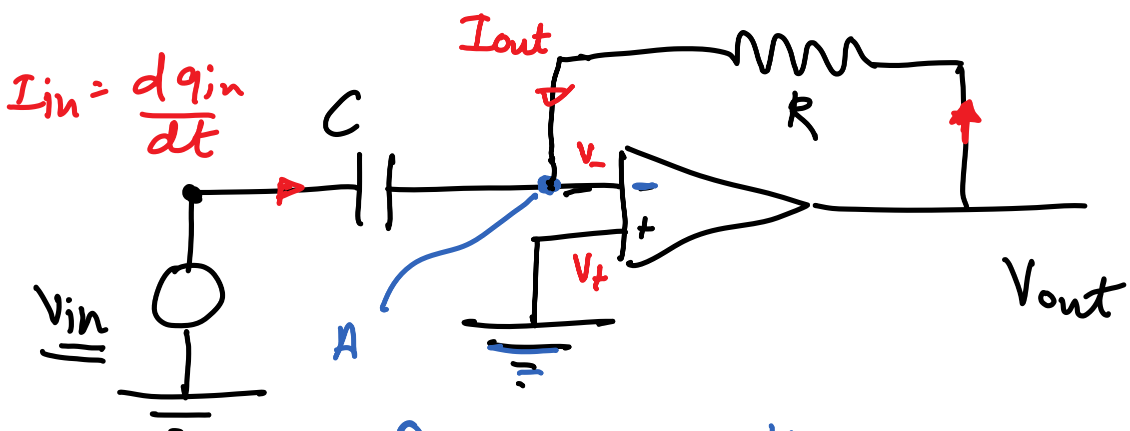
helps to isolate the voltage source (V_{in}) because of the high Resistance $R \to \infty$

③ Differentiator



$$V_{out} = f(V_{in})$$

↑ derivative



$$V_{out} - \overset{0}{V_A} = I_{out} R$$

$$V_{in} - \overset{0}{V_A} = \frac{q_{in}}{C}$$

At A:

$$I_{out} + I_{in} = I_- = 0$$

$$\left.\begin{aligned} V_- &= V_+ = 0 \\ V_A &= V_- \end{aligned}\right\} V_A = 0$$

$$① \quad V_{out} - \overset{0}{V_A} = I_{out} R$$

$$② \quad V_{in} - \overset{0}{V_A} = \frac{q_{in}}{C}$$

At A:

$$I_{out} + I_{in} = I_- = 0$$

$$I_{out} = -I_{in} = -\frac{dq_{in}}{dt}$$

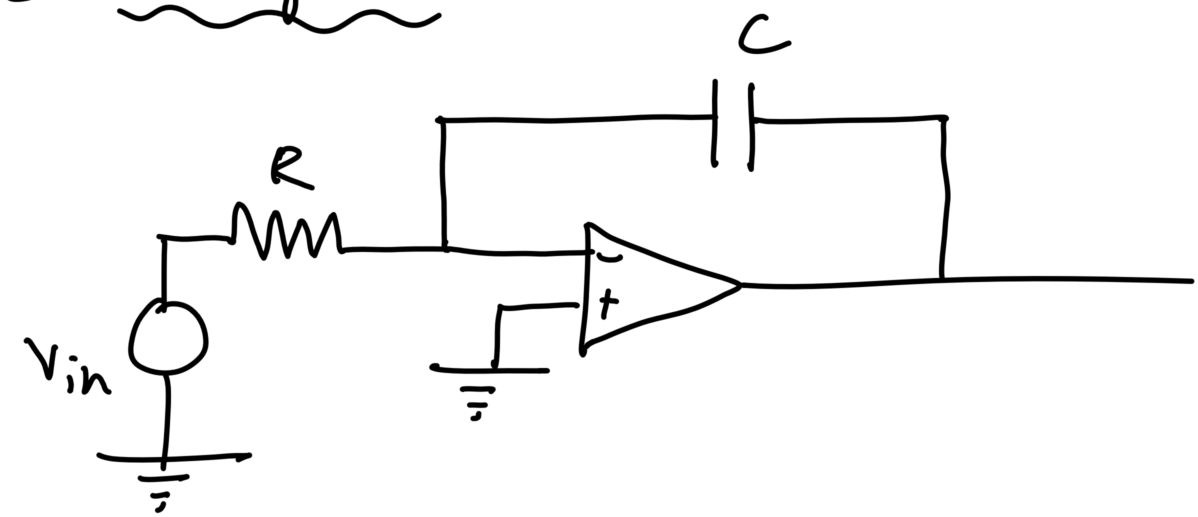
From ① & ②

$$\frac{V_{out}}{R} = -\frac{d}{dt}\left(C V_{in}\right)$$

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

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

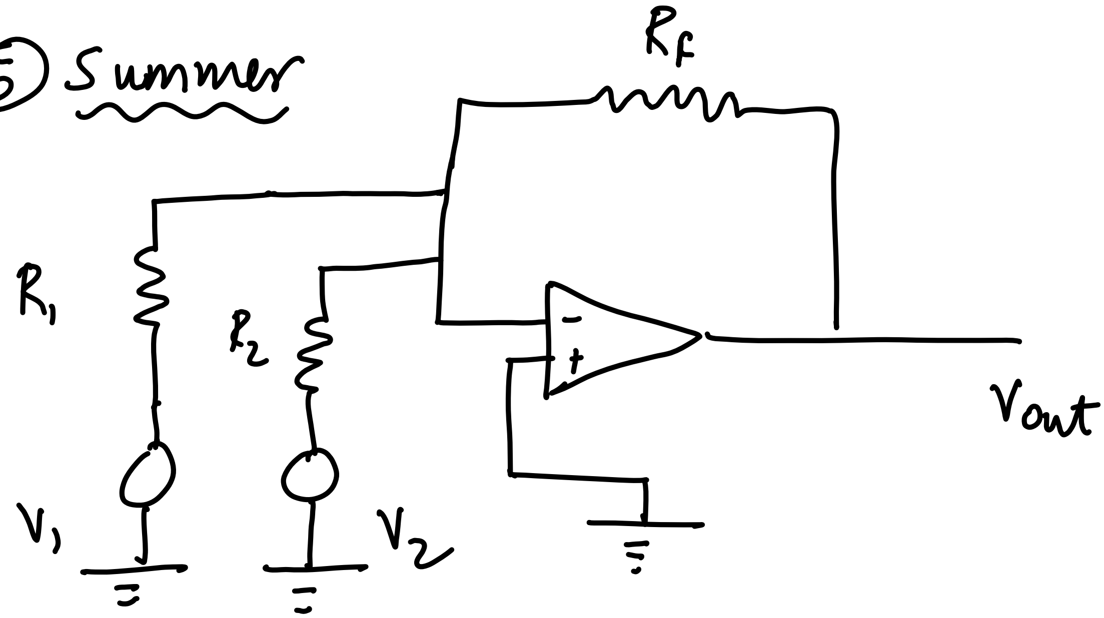
④ Integrator



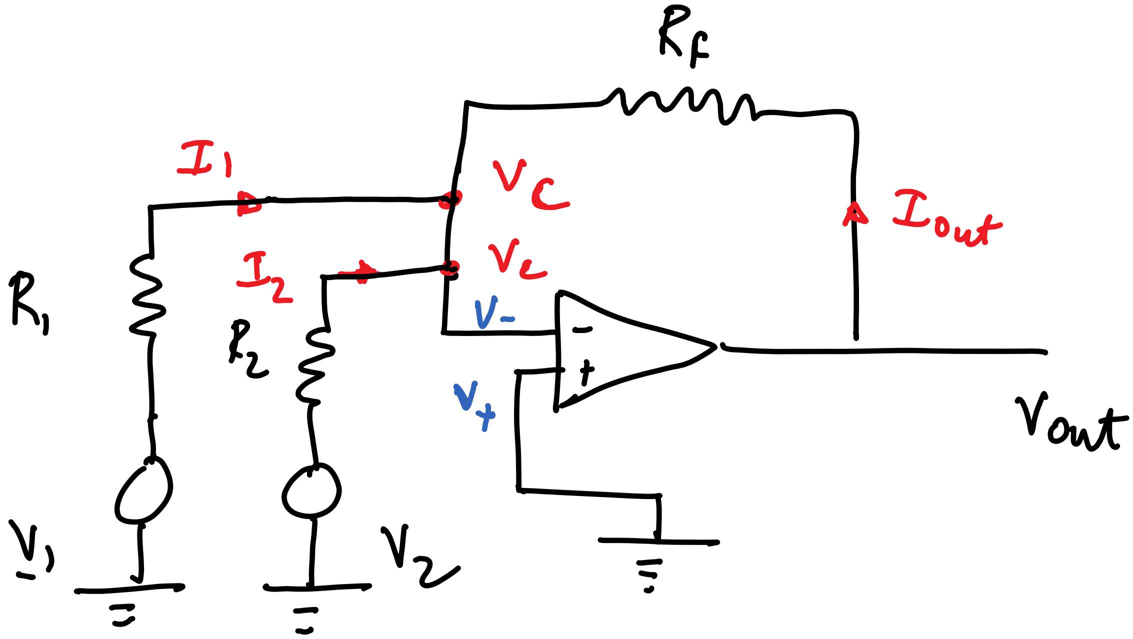
Show that

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

⑤ Summer



Compute V_{out} as a function of V_1, V_2



$$\left\{\begin{aligned} V_{out} - \cancel{V_c} &= \underline{I_{out}} R_f \\ V_1 - \cancel{V_c} &= I_1 R_1 \\ V_2 - \cancel{V_c} &= I_2 R_2 \end{aligned}\right\}$$

Unknowns I_{out}, I_1, I_2
V_c, V_{out}

$$\left.\begin{aligned} V_+ &= V_- \\ V_c &= V_- \\ V_+ &= 0 \end{aligned}\right\} \quad V_+ = V_- = V_c = 0$$

$$I_{out} + I_1 + I_2 = I_- = 0$$

$$\frac{V_{out}}{R_f} + \frac{V_1}{R_1} + \frac{V_2}{R_2} = 0$$

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

$R_1 = R_2 = R$ $\quad$ $V_{out} = -R_f$ ...

$R_1 = R_2 = R$

$$\boxed{V_{out} = -\frac{R_F}{R}\left(V_1 + V_2\right)}$$