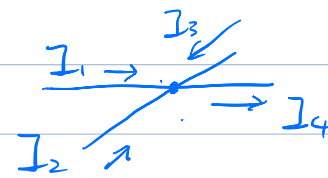
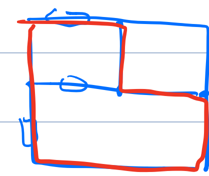
EECS 16B DIS 1 Gaoyue



Review

- KCL: the sum of all currents entering a node must equal 0
- KVL: the sum of all voltages in a circuit loop must equal 0



- Op-amp (operational amplifier)

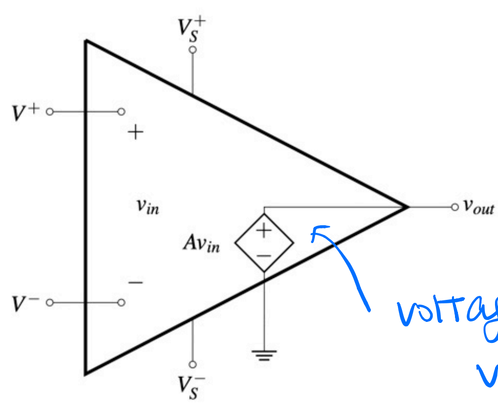
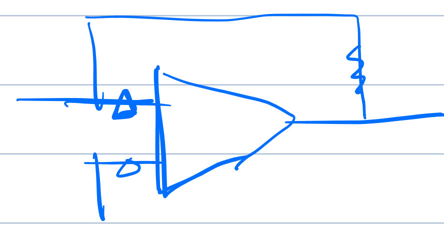


Figure 3: General Op-Amp Model

voltage-controlled voltage source



ideal op-amp:

a) $R_{in} \to \infty$

b) $R_{out} \to 0$

c) $A \to \infty$

gain

$$V_{out} = \overset{\infty}{A}(V_+ - V_-)$$

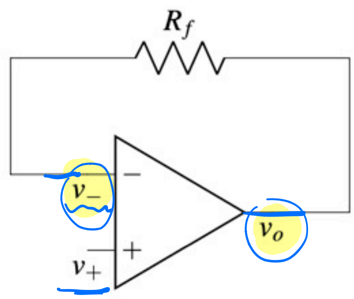


Figure 4: Ideal Op-Amp in Negative Feedback

Golden Rules of ideal op-amps in negative feedback:

regardless of negative feedback ✓

(a) No current can flow into the input terminals ($I_- = 0$ and $I_+ = 0$).

(b) The $(+)$ and $(-)$ terminals are at the same voltage ($V_+ = V_-$).

1. KVL/KCL Review

Use Kirchhoff's Laws on the circuit below to find V_x in terms of V_{in}, R_1, R_2, R_3.

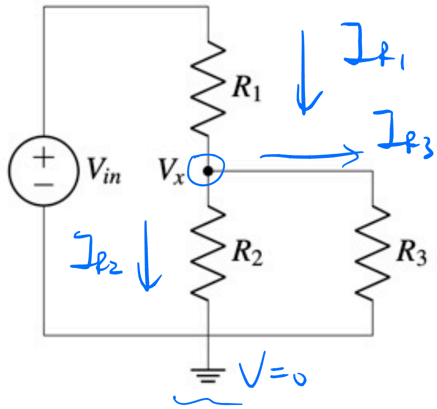


Figure 5: Example Circuit

(a) What is V_x?

(b) As $R_3 \to \infty$, what is V_x? What is the name we used for this type of circuit?

a) approach: use KCL at node V_x

$$I_{R_1} - I_{R_2} - I_{R_3} = 0$$

$$\frac{V_{in} - V_x}{R_1} - \frac{V_x - 0}{R_2} - \frac{V_x - 0}{R_3} = 0$$

$$\Rightarrow \quad V_x = V_{in} \frac{R_2 R_3}{R_1 R_2 + R_1 R_3 + R_2 R_3}$$

b) $R_3 \longrightarrow \infty$

may ignore

$$\Rightarrow V_x = V_{in} \frac{R_2}{R_1 + R_2}$$

voltage divider

2. Op-Amp Summer

Consider the following circuit (assume the op-amp is ideal):

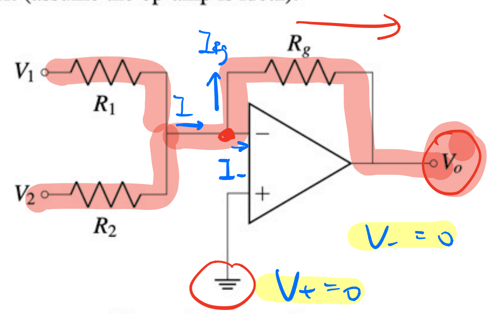


Figure 6: Op-amp Summer

What is the output V_o in terms of V_1 and V_2? You may assume that R_1, R_2, and R_g are known.

approach: KCL at V_-

$$I - I_{Rg} - \cancel{I_-}^{\,0} = 0$$

$$I = I_{Rg}$$

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} = I_{Rg}$$

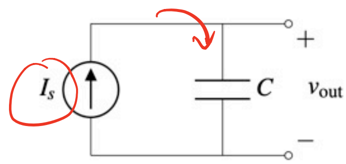
$$I_{Rg} = -\frac{V_o}{R_g}$$

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

3. Current Sources And Capacitors (The following problem has been adapted from EECS16A Fall 20 Disc 9A.)

Recall charge has units of Coulombs (C), and capacitance is measured in Farads (F) $= \frac{\text{Coulomb}}{\text{Volt}}$.
It may also help to note metric prefix examples: $3\,\mu F = 3 \times 10^{-6}$F.

Given the circuit below, find an expression for $v_{out}(t)$ in terms of I_s, C, V_0, and t, where V_0 is the initial voltage across the capacitor at $t = 0$.



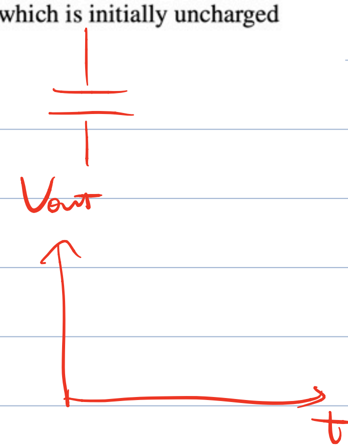
Then plot the function $v_{out}(t)$ over time on the graph below for the following conditions detailed below. Use the values $I_s = 1$mA and $C = 2\,\mu$F.

(a) Capacitor is initially uncharged $V_0 = 0$ at $t = 0$.

(b) Capacitor has been charged with $V_0 = +1.5$V at $t = 0$.

(c) **Practice:** Swap this capacitor for one with half the capacitance $C = 1\,\mu$F, which is initially uncharged $V_0 = 0$ at $t = 0$.

HINT: Recall the calculus identity $\int_a^b f'(x)dx = f(b) - f(a)$, where $f'(x) = \frac{df}{dx}$.



Capacitor: $Q = CV$

$$I = \frac{dQ}{dt} = C\frac{dv}{dt}$$

this problem →

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

$$V_{out}(t) = V_0 + \left(\frac{I_s}{C}\right)t$$