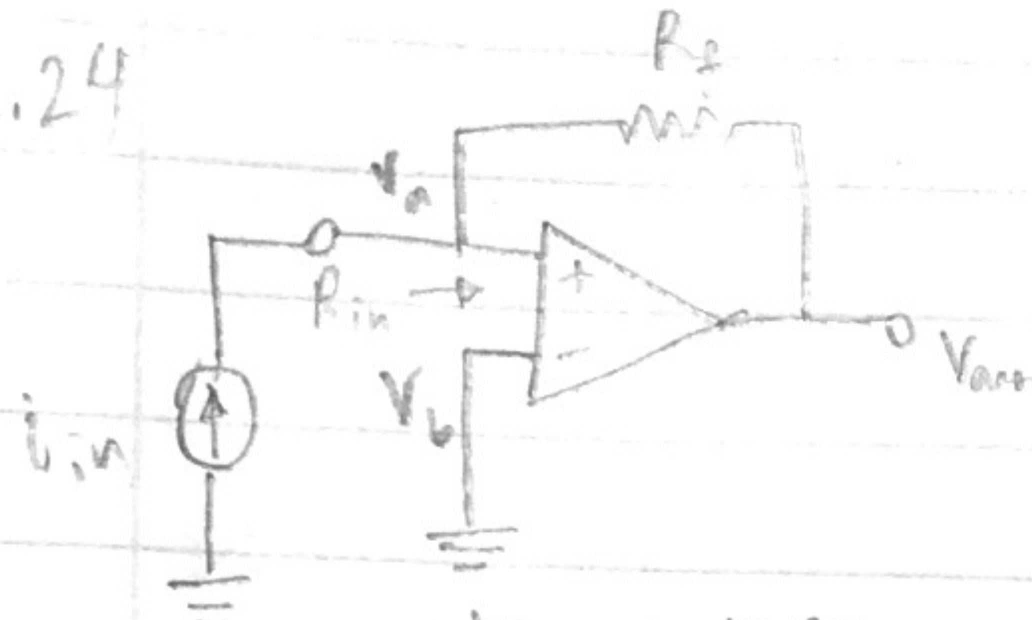
2.24



$R_{in} = \frac{V_{in}}{i_{in}}$, $V_{in} = V_a - V_b$

$R_{in} = \frac{V_a - V_b}{i_{in}}$

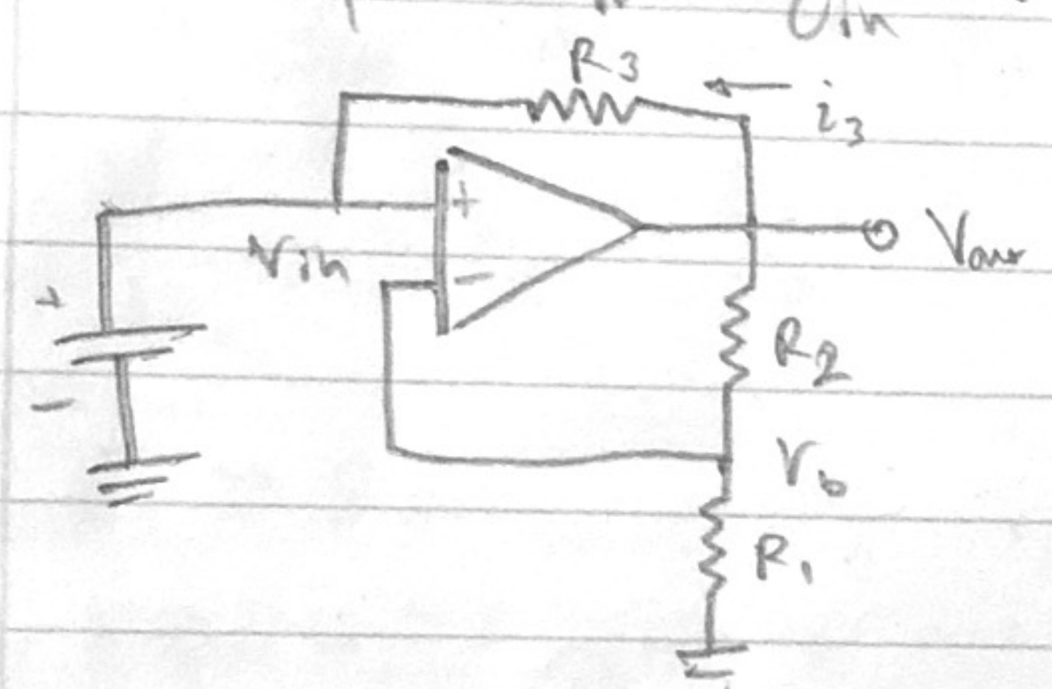
V_{out} : KCL at non inverting input

$i_{in} = \frac{V_a - V_{out}}{R_F}$, $V_a = V_b = 0$

$i_{in} = \frac{0 - V_{out}}{R_F} \Longrightarrow V_{out} = -i_{in} \cdot R_F$

flow path for i_{in} is $V_{out} \to R_F \to V_a \to$ gnd ~~opposite~~

2.26



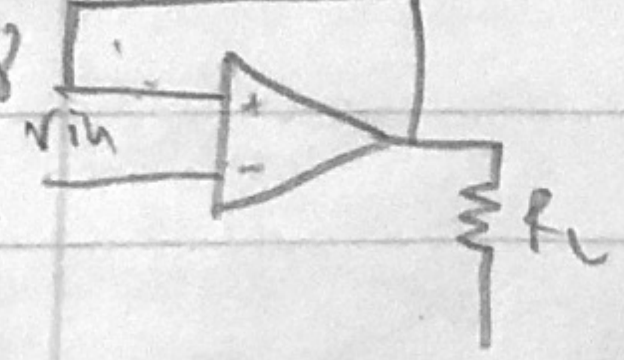
$V_{R_2} = V_{out} \cdot \frac{R_2}{R_1 + R_2} = V_b$

$\left.\begin{array}{l} V_a = V_{in} \\ V_b = V_{out}\left(\frac{R_2}{R_1+R_2}\right) \end{array}\right\} V_a = V_b = V_{in} = V_{out}\left(\frac{R_2}{R_1+R_2}\right)$

$i_3 = \frac{V_{out} - V_a}{R_3} = \frac{V_{out} - V_{out}\left(\frac{R_2}{R_1+R_2}\right)}{R_3} = \frac{V_{out}}{R_3}\left(\frac{R_1}{R_1+R_2}\right)$

i_3 flows into the battery and not op-amp due to the high input resistance

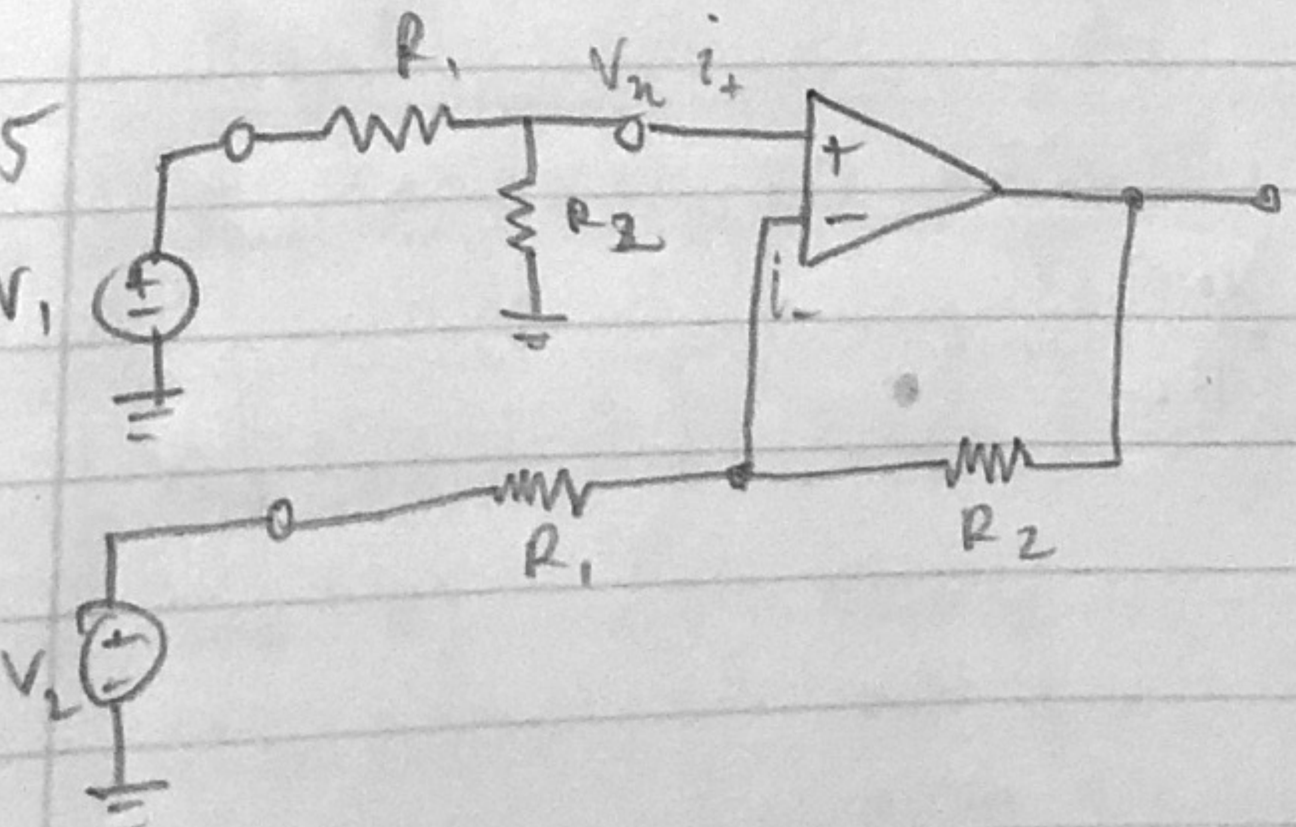
2.58



$V_0 = V_{in} = -2V$

$P = \frac{V_0^2}{R_L} = \frac{(-2)^2}{4.7K} = 0.85$ mW

2.65



$\frac{V_x - V_1}{R_1} + \frac{V_x}{R_2} = 0$

$V_x\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{V_1}{R_1}$

$V_x\left(\frac{R_1 + R_2}{R_2}\right) = \frac{V_1}{R_1}$

$V_x = \frac{V_1 R_2}{(R_1 + R_2)}$

ideal summing point $V_x = V_y$, KCL at V_y

$$\frac{V_y - V_1}{R_1} + \frac{V_y - V_{out}}{R_2} = 0$$

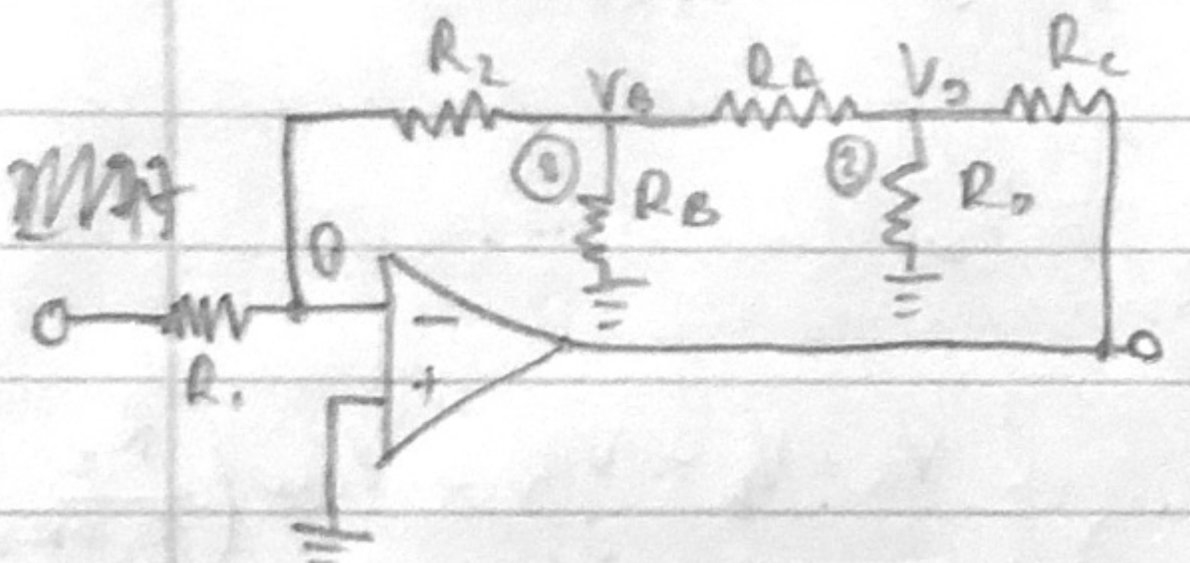
$$V_y\left(\frac{R_1+R_2}{R_1R_2}\right) = \frac{V_{out}}{R_2}$$

$$\frac{V_1 R_2}{R_1+R_2}\left(\frac{R_1+R_2}{R_2R_1}\right) = \frac{V_{out}}{R_2} + \frac{V_2}{R_1}$$

$$V_{out}\left(\frac{1}{R_2}\right) = (V_1 - V_2)\cdot\frac{1}{R_1}$$

$$V_{out} = \left(\frac{R_2}{R_1}\right)(V_1 - V_2) \quad \therefore \quad R_{eq} = \frac{R_2}{R_1}$$

2.04



$$\text{KCL at 1}: \frac{V_{in} - 0}{R_1} = \frac{0 - V_B}{R_2} \Rightarrow V_B = -\frac{R_2}{R_1}V_{in} \qquad — (1)$$

$$\text{KCL at 2}: \frac{0 - V_B}{R_2} = \frac{V_B}{R_B} + \frac{V_B - V_D}{R_A} \qquad — (2)$$

$$\frac{V_D}{R_A} = V_B\left[\frac{1}{R_A} + \frac{1}{R_B} + \frac{1}{R_2}\right]$$

$$V_D = V_B \cdot \frac{R_A}{(R_A \| R_B \| R_2)}$$

$$\text{KCL at 3}: \frac{V_B - V_D}{R_A} = \frac{V_D}{R_D} + \frac{V_D - V_{out}}{R_C}$$

$$\frac{V_B}{R_A} = V_D\left(\frac{1}{R_A} + \frac{1}{R_C} + \frac{1}{R_D}\right) - \frac{V_{out}}{R_C}$$

$$\frac{V_D}{(R_A \| R_C \| R_D)} - \frac{V_B}{R_A} = \frac{V_{out}}{R_C}$$

① and ② : $\frac{V_B R_A}{(R_A \| R_B \| R_2)(R_A \| R_C \| R_D)} - \frac{V_B}{R_A} = \frac{V_{out}}{R_C}$

Assuming $R_2 \gg R_A \| R_B$; $R_A \gg R_C \| R_D$

$$\frac{V_B R_A}{R_2 \cdot R_A} - \frac{V_B}{R_A} = \frac{V_{out}}{R_C}$$

$$-\frac{R_2}{R_1} \cdot \frac{V_{in}}{R_2} + \frac{R_2 V_{in}}{R_1 R_A} = \frac{V_{out}}{R_C}$$

$$V_{in}\left(\frac{R_2}{R_A} - 1\right) = V_{out} \cdot \frac{R_1}{R_C}$$

$$\frac{V_{out}}{V_{in}} = \frac{R_C}{R_1} \cdot \left(\frac{R_2}{R_A} - 1\right)$$

If $\frac{R_2}{R_A} \gg 1 \Rightarrow R_2 \gg R_A$

$\to \frac{V_{out}}{V_{in}} = \frac{R_C \cdot R_2}{R_A \cdot R_1} = 10^4$

Let $\frac{R_C}{R_A} = 100$, $\frac{R_2}{R_1} = 100$

Let $R_1 = 10K = R_A$, $R_C = R_2 = 1000K$

$R_2 \gg R_A$

1000K >> 10K → True

$R_2 \gg (R_A \| R_B)$

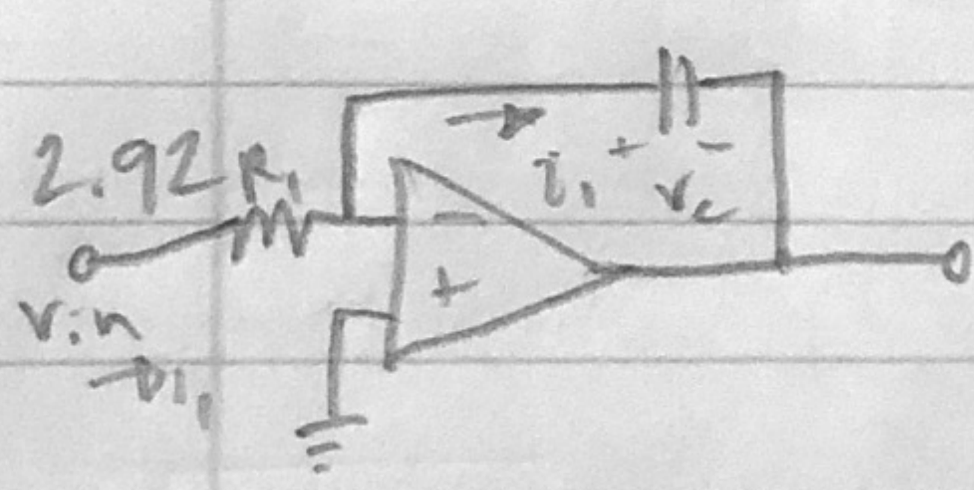
1000K >> 10K ∥ 10K

1000k >> 5k ⇒ True $\underline{R_B = 10k}$

$R_A \gg R_C \| R_D$

10K >> (1000K ∥ 1K)

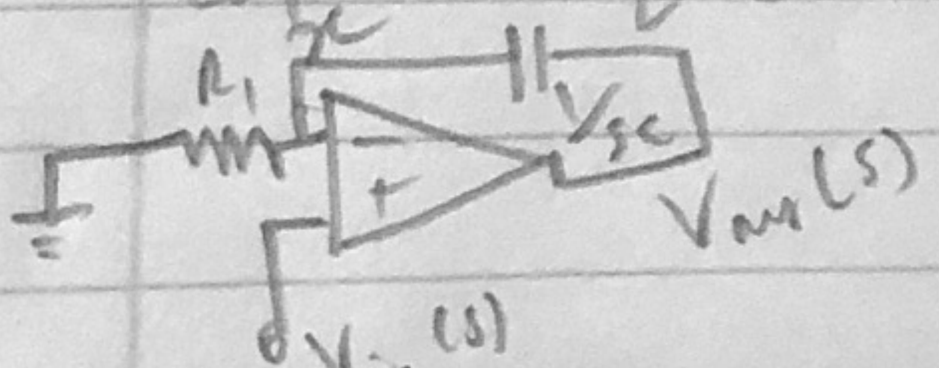
10K >> 1K → True $\underline{R_D = 1K}$



Vin step turns on at $t = 0$

$V_{in}(s) = \frac{5}{s}$

Laplace eq circuit



voltage at x is $V_{in}(s)$, KCL at x

$$\frac{V_{in}(s)}{R_1} + \frac{V_{in}(s) - V_{out}(s)}{1/sC} = 0$$

$$V_{out}(s) = V_{in}(s) + \frac{V_{in}(s)}{sCR_1} \Rightarrow V_{out}(s) = \frac{1}{s}\left[1 + \frac{1}{sCR_1}\right]$$

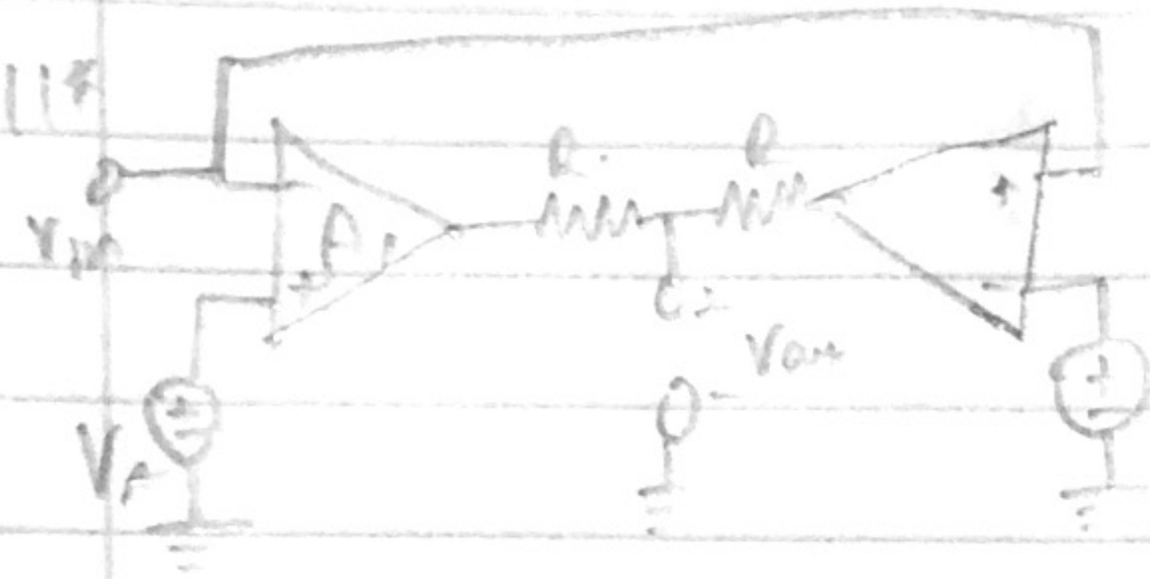
$$V_{out}(s) = \frac{1}{s}\left[1 + \frac{1}{sCR_1}\right] = \frac{1}{s} + \frac{1}{s^2 R_1 C} = \frac{1}{s} + \frac{2000}{s^2 R_1 C}$$

$$V_{out}(t) = [1 + 2000t]$$

$15 = 2000t + 1 \Rightarrow t = 7ms$

$$V_{out}(t) = \begin{cases} 1 + 2000t & 0 < t < 7ms \\ 15 & t > 7 \end{cases}$$

2.111*



for $V_{in} > V_A$ $V_{out} = -V_e$; supply $= -15v$

for $V_{in} < V_A$ $V_{out} = V_e$, supply $= +15v$

for $V_{in} < V_B$ $V_{out} = V_e$, supply $= -15v$

for $V_{in} > V_B$ $V_{out} = V_e$, supply $= 15v$

$$V_{out} = \begin{cases} -15v & \text{for } V_A < V_{in} < V_B \\ +15v & \text{for } V_B < V_{in} < V_A \end{cases}$$

Given $V_A = 8v$ and $V_B = -4v$

$V_{out} = 15v$ for $-4v < V_{in} < 8v$

$= -15v$ for $-15v < V_{in} < -4$ and $8 < V_{in} < 15$

2.141 $f_M = \dfrac{SR}{2\pi V_{os}}$

$$f_M = \frac{10^{-6}}{2\pi\,(10 \times 10^{-5})} = 15.9\,MHz$$