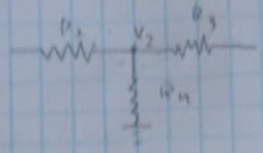
7.1)



$V_+ = V_- = 0$

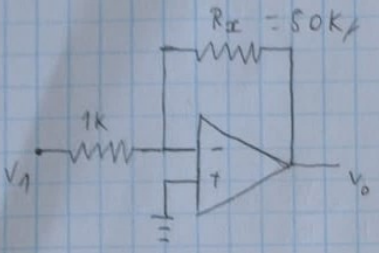
$$\begin{cases} \frac{V_- - V_1}{R_1} + \frac{V_- - V_2}{R_2} = 0 \\ \frac{V_2 - V_-}{R_2} + \frac{V_2 - V_0}{R_3} + \frac{V_2}{R_4} = 0 \end{cases} \Leftrightarrow \begin{cases} -\frac{V_1}{R_1} = \frac{V_2}{R_2} \\ \frac{V_2}{R_2} + \frac{V_2}{R_3} + \frac{V_2}{R_4} = \frac{V_0}{R_3} \end{cases} \Leftrightarrow \begin{cases} - \\ V_2 \left(= \frac{V_0}{R_3\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)}\right. \end{cases}$$

$$V_1 = -\frac{R_1}{R_2} V_2 \rightarrow V_1 = -\frac{R_1}{R_2} \cdot \frac{V_0}{R_3\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)} \Leftrightarrow \frac{V_0}{V_1} = -\frac{R_2 R_3\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)}{R_1}$$

7.2)

$\frac{V_0}{V_1} = -50$

$R_i = 1K$

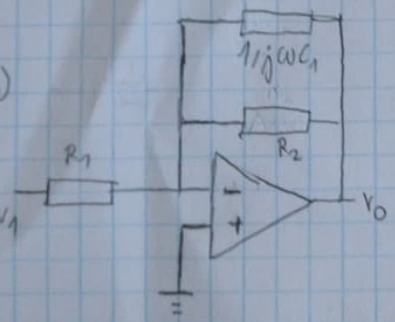


$V_+ = V_- = 0$

$$\frac{V_- - V_1}{1K} + \frac{V_- - V_0}{R_x} = 0 \Leftrightarrow -\frac{R_x}{1K} = \frac{V_0}{V_1} \Leftrightarrow -\frac{R_x}{1K} = -50 \Leftrightarrow$$

$R_x = 50K\Omega$

7.3) a)



$V_- = V_+ = V_0$

$$\frac{V_- - V_1}{R_1} + \frac{V_- - V_0}{Z_+} = 0 \Leftrightarrow -\frac{V_1}{R_1} Z_+ = V_0 \Leftrightarrow$$

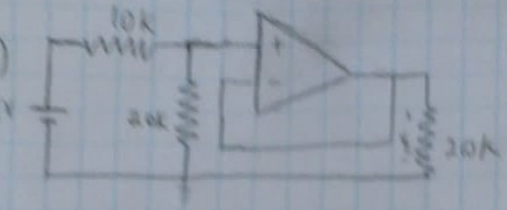
$$\Leftrightarrow \frac{V_0}{V_1} = -\frac{Z_+}{R_1} = -\frac{R_2}{R_1(j\omega C_1 R_2 + 1)} //$$

$$Z_+ = \frac{1}{j\omega C_1} // R_2 = \left(j\omega C_1 + \frac{1}{R_2}\right)^{-1} = \frac{R_2}{j\omega C_1 R_2 + 1}$$

Com R_2 tem um ganho limitado a $-\frac{R_2}{R_1}$

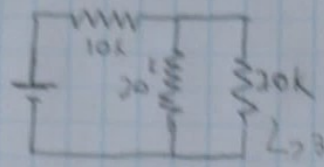
i) Sem R_2 $\quad -\frac{V_1}{R_1} = j\omega C_1 V_0 \Leftrightarrow \frac{V_0}{V_1} = -\frac{1}{j\omega C_1 R_1}$

7.4)



$V_+ = V_- = V_0 = V_2$

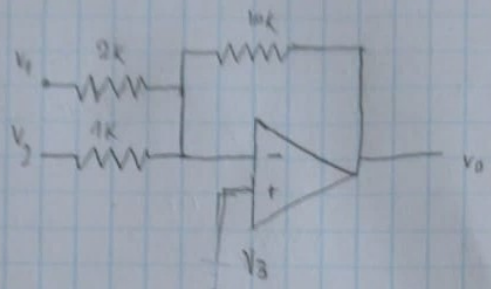
$\frac{V_2 - 6}{10} + \frac{V_+}{20} \Leftrightarrow V_+ = 4V = V_2$



7.6) $V_3 = 1V$

a) $V_3 = 0$

$V_1 = V_1(\omega_0 t)$



V_2: $V_+ = V_- = 0$

$\frac{V_- - V_2}{1K} + \frac{V_- - V_0}{10K} = 0 \Leftrightarrow -\frac{1}{1K} - \frac{V_0}{10K} = 0 \Leftrightarrow V_0 = -\frac{1}{1K} \cdot 10K \Leftrightarrow V_0 = -10V$

V_1: $\frac{V_- - V_1(t)}{2K} + \frac{V_- - V_0}{10K} = 0 \Leftrightarrow -\frac{V_1(t)}{2K} = \frac{V_0}{10K} \Leftrightarrow V_0 = -5V_1(t)$

$V_0 = -10 - 5V_1(t)$

$V_{1m} = 1.2 \quad (-16V = V_0)$

b) $V_3 = V_+ = V_-$

$\frac{V_1 - V_-}{2K} + \frac{V_2 - V_-}{1K} + \frac{V_0 - V_-}{10K} = 0 \Leftrightarrow -\frac{V_3}{2K} + \frac{V_3}{1K} + \frac{V_0}{10K} - \frac{V_3}{10K} = 0 \Leftrightarrow V_0 = 16V_3$

$$V_0(t) = \begin{cases} -16V & ; V_3(t) \leq -1V \\ 16V_3(t) & ; -1V \leq V_3(t) \leq 1V \\ 16V & ; 1V \leq V_3(t) \end{cases}$$