Ex: 2.4

The gain and input resistance of the inverting amplifier circuit shown in Figure 2.5 are $-\frac{R_2}{R_1}$ and R_1 respectively. Therefore, we have:

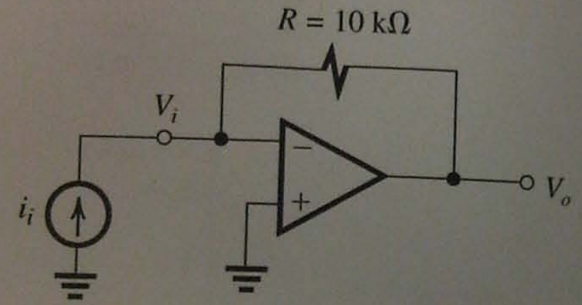
$R_1 = 100\ \text{k}\Omega$ and

$$-\frac{R_2}{R_1} = -10 \Rightarrow R_2 = 10\ R_1$$

Thus:

$$R_2 = 10 \times 100\ \text{k}\Omega = 1\ \text{M}\Omega$$

Ex: 2.5



From Table 1.1 we have:

$$R_m = \left.\frac{V_O}{i_i}\right|_{i_o = 0}$$, i.e., output is open circuit

The negative input terminal of the op amp, i.e., V_i is a virtual ground, thus $V_i = 0$

$$V_O = V_i - Ri_i = 0 - Ri_i = -Ri_i$$

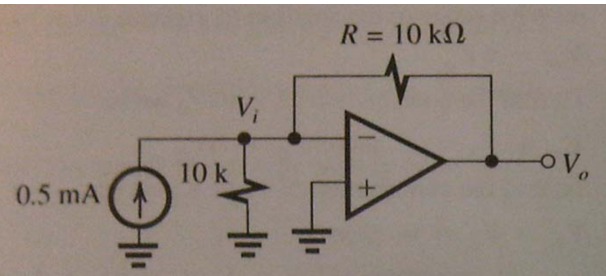
$$R_m = \left.\frac{V_O}{i_i}\right|_{i_o = 0} = -\frac{Ri_i}{i_i} = -R \Rightarrow R_m = -R$$

$$= -10\ \text{k}\Omega$$

$R_i = \frac{V_i}{V_i}$ and V_i is a virtual ground ($V_i = 0$),

thus $R_i = \frac{0}{i_i} = 0 \Rightarrow R_i = 0\ \Omega$

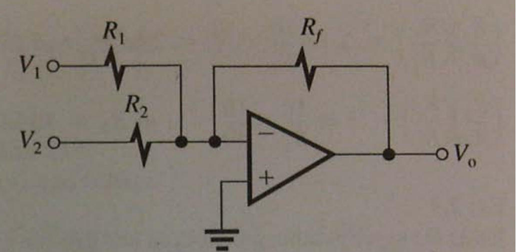
Since we are assuming that the op amp in this transresistance amplifier is ideal, the op amp has zero output resistance and therefore the output resistance of this transresistance amplifier is also zero. That is $R_O = 0\ \Omega$.



Connecting the signal source shown in Figure E2.5 to the input of this amplifier we have: V_i is a virtual ground that is $V_i = 0$, thus the current flowing through the 10 kΩ resistor connected between V_i and ground is zero. Therefore

$$V_O = V_i - R \times 0.5 \text{ mA} = 0 - 10 \text{ K} \times 0.5 \text{ mA}$$
$$= -5 \text{ V}$$

Ex: 2.7



For the circuit shown above we have:

$$V_O = \left(\frac{R_F}{R_1} V_1 + \frac{R_F}{R_2} V_2\right)$$

Since it is required that $V_O = -(V_1 + 5V_2)$.

We want to have:

$$\frac{R_F}{R_1} = 1 \text{ and } \frac{R_F}{R_2} = 5$$

It is also desired that for a maximum output voltage of 10 V the current in the feedback resistor does not exceed 1 mA.

Therefore

$$\frac{10\text{ V}}{R_f} \leq 1 \text{ mA} \Rightarrow R_f \geq \frac{10\text{ V}}{1\text{ mA}} \Rightarrow R_f \geq 10 \text{ k}\Omega$$

Let us choose R_f to be 10 kΩ, then

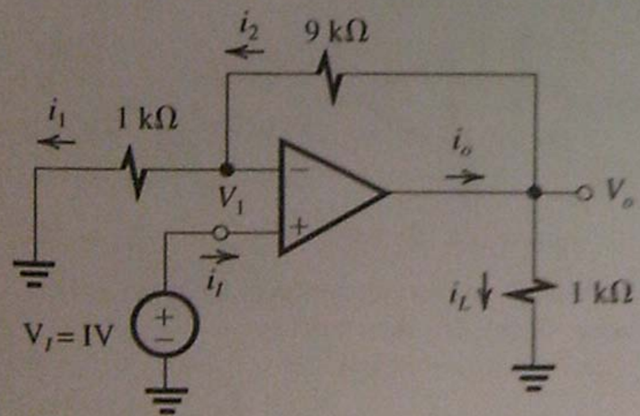
$$R_1 = R_f = 10 \text{ k}\Omega \text{ and } R_2 = \frac{R_f}{5} = 2 \text{ k}\Omega$$

Ex: 2.13

$i_I = 0\text{A},\ V_1 = V_I = 1\text{ V},$

$$i_1 = \frac{V_1}{1\text{ k}\Omega} = \frac{1\text{ V}}{1\text{ k}\Omega} = 1\text{ mA}$$

$i_2 = i_1 = 1\text{ mA},$



$$V_O = V_1 + i_2 \times 9\text{ k}\Omega = 1 + 1 \times 9 = 10\text{ V}$$

$$i_L = \frac{V_O}{1\text{ k}\Omega} = \frac{10\text{ V}}{1\text{ k}\Omega} = 10\text{ mA},$$

$$i_O = i_L + i_2 = 11\text{ mA}$$

$$\frac{V_O}{V_I} = \frac{10\text{ V}}{1\text{ V}} = 10\frac{\text{V}}{\text{V}} \text{ or } 20\text{ dB}$$

$$\frac{i_L}{i_I} = \frac{10\text{ mA}}{0} = \infty$$

$$\frac{P_L}{P_I} = \frac{V_O \times i_L}{V_I \times I_I} = \frac{10 \times 10}{1 \times 10} = \infty$$

Ex: 2.26

From equation (2.28) we have:

$$w_t = A_O w_b \Rightarrow f_t = A_O f_b \Rightarrow f_b = \frac{f_t}{A_O}, \text{ and}$$

we know

$20 \log A_O = 106$ and $f_t = 3$ MHz, therefore $f_b \simeq 15$ Hz

By definition the open-loop gain (in dB) at f_b is:

$A_O(\text{in dB}) - 3 = 106 - 3 = 103$ dB

To find the open-loop gain at frequency f we can use equation (2.31) (especially when $f >> f_b$ which is the case in this exercise) and write:

Open-loop gain at $f \simeq 20 \log\left(\frac{f_t}{f}\right)$

Therefore:

Open-loop gain at 300 Hz =

$$20 \log \frac{3 \text{ MHz}}{300} = 80 \text{ dB}$$

Open-loop gain at 3 kHz =

$$20 \log \frac{3 \text{ MHz}}{3 \text{ kHz}} = 60 \text{ dB}$$

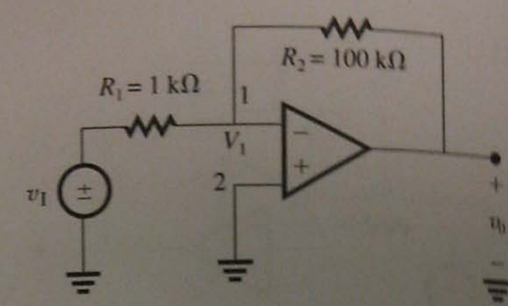
Open-loop gain at 12 kHz =

$$20 \log \frac{3 \text{ MHz}}{12 \text{ kHz}} = 48 \text{ dB}$$

Open-loop gain at 60 kHz =

$$20 \log \frac{3 \text{ MHz}}{60 \text{ kHz}} = 34 \text{ dB}$$

2.20



a. $\frac{v_o}{v_I} = -\frac{R_2}{R_1} = -100$ V / V

Since $R_{in} = 1$ kΩ $= R_1$

$\therefore R_2 = R_1 \times 100 = 100$ kΩ

b. Op. Amp has open loop gain of 2000 V/V

$v_I = -\frac{v_o}{A}$ where $A = 2000$ Given

Apply KCL at note V_1

$$\frac{v_I - v_1}{R_1} = \frac{v_1 - v_0}{R_2}$$

Then substitute $v_1 = -\frac{v_o}{A}$ and solve for $\frac{v_o}{v_I}$

$$\frac{v_o}{v_I} = \frac{-\frac{R_2}{R_1}}{1 + \left(1 + \frac{R_2}{R_1}\right) \cdot \frac{1}{A}}$$

$$= \frac{-100/1}{1 + \left(1 + \frac{100}{1}\right) \times \frac{1}{2000}} = -66.4 \text{ V / V}$$

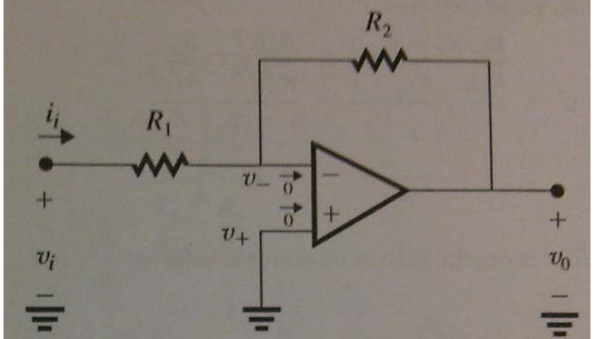
c. Let $R_1' = R_x \| R_1$ where $R_1 = 1$ kΩ

Need $\frac{v_o}{v_I} = -100$ V/V

Again apply KCL at node V_1, and R_1 is replaced by R_1'

$$\frac{v_I - v_1}{R_1'} = \frac{v_1 - v_o}{R_2}$$

2.23



$v_o = -A v_- = v_- - i_i R_2$

$i_i R_2 = v_- (1 + A)$

$$v_- = \frac{i_i R_2}{1 + A}$$

Again $v_i = i_i R_1 + v_-$

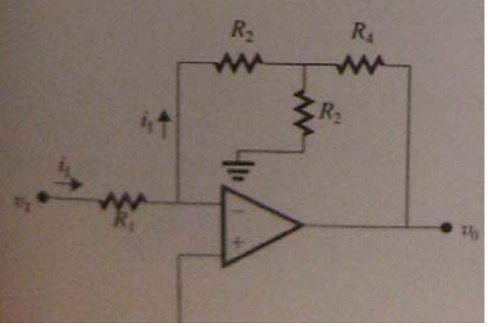
$$= i_i R_1 + i_i \frac{R_2}{1 + A}$$

So $R_{in} = \dfrac{v_i}{i_i} = R_1 + \dfrac{R_2}{A + 1}$

2.30

$i_I = \dfrac{v_I}{R_1}$, $v_x = -i_I R_2 = -\dfrac{v_I}{R_1} R_2$

So $\dfrac{v_x}{v_I} = -\dfrac{R_2}{R_1}$ or $\dfrac{v_I}{v_x} = -\dfrac{R_1}{R_2}$



$$v_x = v_o \frac{(R_2 \parallel R_3)}{(R_2 \parallel R_3) + R_4}$$

$$= v_o \frac{R_2 R_3}{R_2 R_3 + R_2 R_4 + R_3 R_4}$$

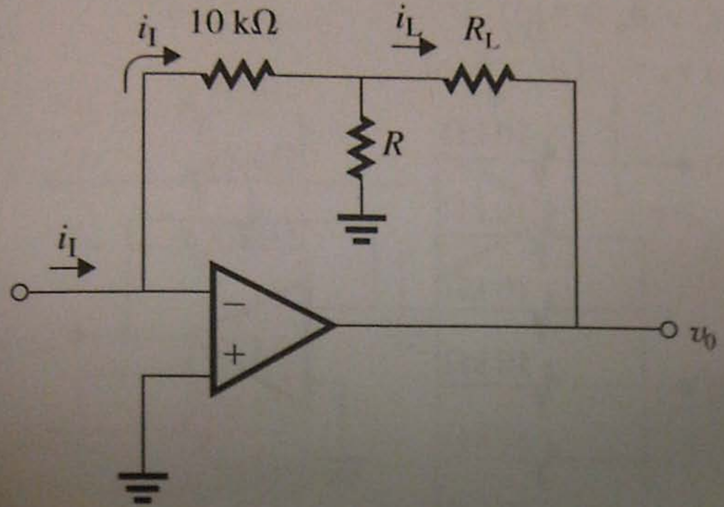
$$\frac{v_o}{v_x} = \frac{R_2 R_3 + R_2 R_4 + R_3 R_4}{R_2 R_3}$$

$$= 1 + \frac{R_4}{R_3} + \frac{R_4}{R_2}$$

$$\frac{v_o}{v_I} = \frac{v_o / v_x}{v_I / v_x} = \frac{1 + \frac{R_4}{R_3} + \frac{R_4}{R_2}}{-\frac{R_1}{R_2}}$$

$$= -\frac{R_2}{R_1}\left(1 + \frac{R_4}{R_3} + \frac{R_4}{R_2}\right)$$

2.34



a. $\frac{i_L}{i_I} = 10 \Rightarrow i_L = 10\, i_I$

$-10\text{ k}\Omega \times i_I = R\,(i_I - i_L)$

$$R = \frac{i_I \times 10\text{ k}\Omega}{i_L - i_I} = \frac{i_I \times 10\text{ k}\Omega}{10\, i_I - i_I} = 1.11\text{ k}\Omega$$

b. Input Resistance $R_i = \frac{v_I}{i_I} = \frac{0}{i_I} = 0\ \Omega$

Output Resistance $R_o = \frac{v_o}{i_o} = \frac{v_o}{0} = \infty$

c. $R_L = 1\text{ k}\Omega$ and v_o in the range of ± 10 V

$$V_o = R_L i_L + 10\text{ k}\Omega \times i_I = i_I\left(1\text{ k}\Omega\,\frac{i_L}{i_I} + 10\text{ k}\Omega\right)$$

$= i_I\,(1\text{ k}\Omega \times 10 + 10\text{ k}\Omega)$
$= 20\text{ K} \times i_I$

$\frac{v_o}{20} = i_I$ and $v_o = \pm 12$

$$\therefore -\frac{12}{20\text{ k}\Omega} \le i_I \le \frac{12}{20\text{ k}\Omega} \Rightarrow -0.6\text{ mA} \le i_I \le 0.6\text{ mA}$$

d. From part a
$i_L = 10\, i_I = 10 \times 0.2$ m
$= 2$ mA

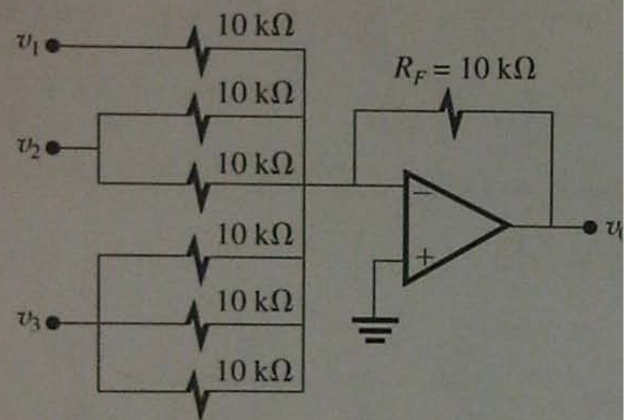
2.39

a) $v_o = -(v_1 + 2v_2 + 3v_3)$

$$\frac{R_F}{R_1} = 1 \Rightarrow R_1 = 10\ \text{k}\Omega,$$

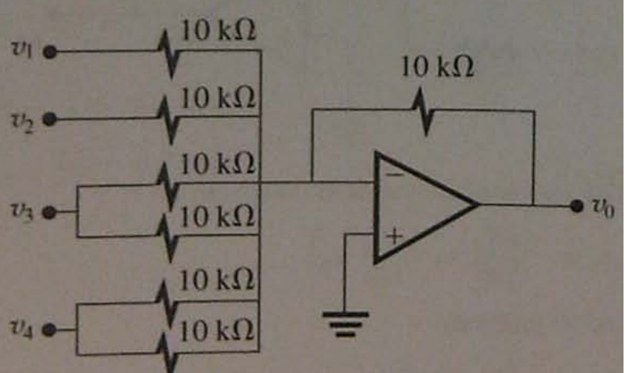
$$\frac{R_F}{R_2} = 2 \Rightarrow R_2 = 5\ \text{k}\Omega$$

$$\frac{R_F}{R_1} = 1 \Rightarrow R_1 = \frac{10}{3}\ \text{k}\Omega$$



$R_{f1} = 10\ \text{k}\Omega$
$R_{f2} = 5\ \text{k}\Omega$
$R_{f3} = 3.3\ \text{K}$

b) $v_o = -(v_1 + v_2 + 2v_3 + 2v_4)$



$$\frac{R_F}{R_1} = 1 \Rightarrow R_1 = 10\ \text{k}\Omega$$

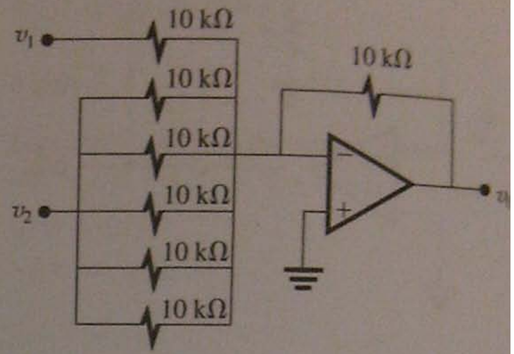
$$\frac{R_F}{R_2} = 1 \Rightarrow R_2 = 10\ \text{k}\Omega$$

$$\frac{R_F}{R_3} = 2 \Rightarrow R_3 = \frac{10}{2}\ \text{k}\Omega$$

$$\frac{R_F}{R_4} = 2 \Rightarrow R_4 = \frac{10}{2}\ \text{k}\Omega$$

$R_{f1} = R_{f2} = 10\ \text{k}\Omega$
$R_{f3} = R_{f4} = 5\ \text{k}\Omega$

c) $v_o = -(v_1 + 5v_2)$



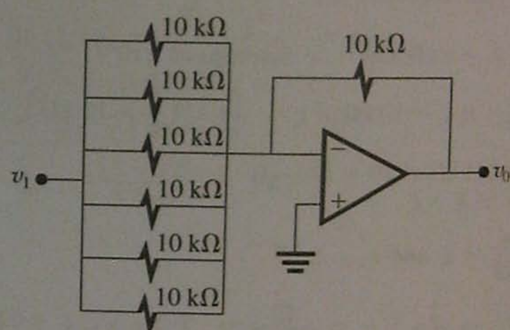
$R_1 = 10\ \text{k}\Omega$

$R_2 = \dfrac{10\ \text{k}\Omega}{5}$

$R_{f1} = 10\ \text{k}\Omega$
$R_{f2} = 2\ \text{k}\Omega$

d) $v_o = -6v_1$

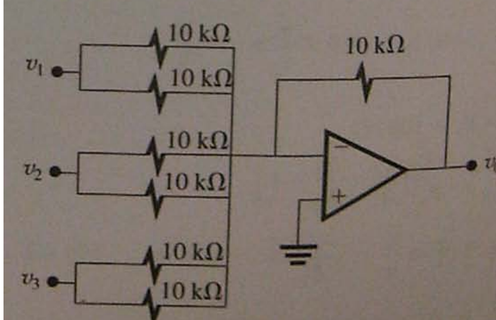
$R_1 = \dfrac{10\ \text{K}}{6}$



$R_f = 1.67\ \text{k}\Omega$

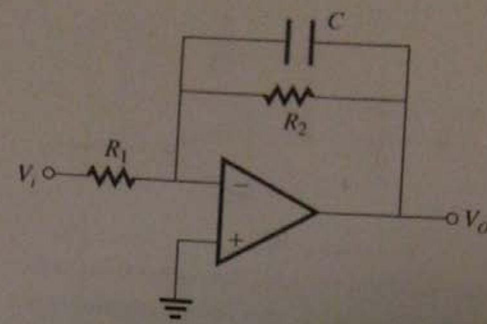
Suggested configurations:

$v_o = -(2v_1 + 2v_2 + 2v_3)$



$v_o = -(3v_1 + 3v_2)$

2.86



Let $Z_2 = R_2 \parallel \dfrac{1}{SC}$ and $Z_1 = R_1$

$$\frac{v_o}{v_i} = -\frac{Z_2}{Z_1} = -\frac{Y_1}{Y_2} = -\frac{1/R_1}{\dfrac{1}{R_2} + SC}$$

$$= -\frac{(R_2/R_1)}{1 + sCR_2}$$

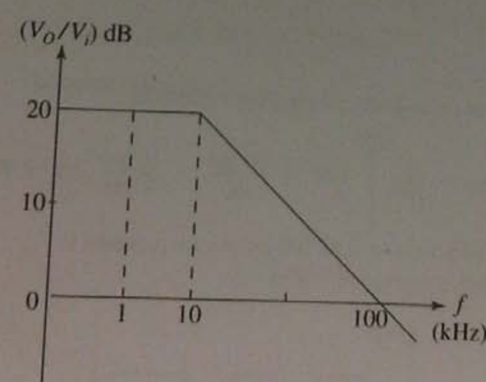
This function is of a STC, low pass circuit having a dc gain of $-\dfrac{R_2}{R_1}$ and 3-dB frequency

$$\omega_o = \frac{1}{CR_2}$$

$R_{in} = R_1 = 10\ \text{k}\Omega$

dc gain $= 20\ \text{dB} = 10$

$\therefore 10 = \dfrac{R_2}{R_1} \Rightarrow R_2 = 10\,R_1 = 100\ \text{k}\Omega$



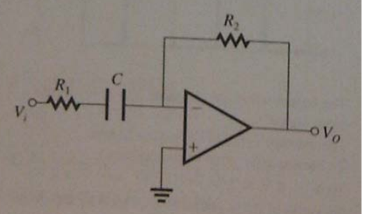
3dB frequency at 10 kHz

$\therefore \omega_o = 2\pi \times 10 \times 10^3 = \dfrac{1}{CR_2}$

$C = \dfrac{1}{2\pi \times 10 \times 10^3 \times 100\ \text{K}} = 0.5\ \text{nF}$

Unity gain frequency at 100 kHz

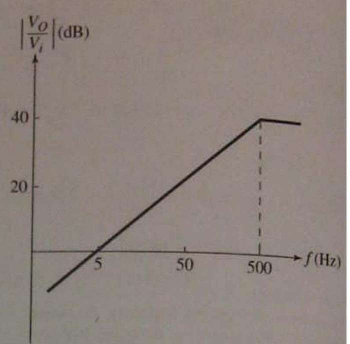
2.92



Let $Z_1 = R_1 + \frac{1}{sC}$, $Z_2 = R_2$

$$\text{Gain} = \frac{v_O}{v_i} = -\frac{Z_2}{Z_1} = -\frac{R_2}{R_1 + \frac{1}{}}$$

$$= \frac{-(R_2/R_1)s}{s + \frac{1}{R_1 C}}$$



This is the transfer function of a single time constant high pass filter having High frequency gain $= (R_2/R_1)$ and 3dB frequency at $w_O = \frac{1}{R_1 C}$.

At high frequency the input impedance abbroaches R_1 as 20 $\frac{1}{jwC}$ becomes very small

Select $R_1 = 10\ \text{k}\Omega$

Gain = 40 dB = 100 V/V

For a gain of 100, $\frac{R_2}{R_1} = 100$

and $R_1 = 10\ \text{k}\Omega$

$\therefore R_2 = 10\ \text{k}\Omega \times 100$

$= 1\ \text{M}\Omega$

For a 3dB frequency of 500 Hz

$$\frac{1}{R_1 C} = 2\pi \times 500$$

$$C = \frac{1}{2\pi \times 500 \times R_1} = 32\ \text{nF}$$

From the Bode-plot the gain $\frac{v_O}{v_i}$ reduces to unity at 5 Hz