2.21 closed-loop Gain $A_v = -\frac{R_2}{R_1}$, one $R = 10K\Omega$, the other $R \geq 10K\Omega$

(a) $A_v = -1V/V = -\frac{R_2}{R_1} \Rightarrow R_1 = R_2 = 10K\Omega$

(b) $A_v = -2V/V = -\frac{R_2}{R_1} \Rightarrow R_1 = 10K\Omega,\ R_2 = 20K\Omega$

(c) $A_v = -0.5V/V = -\frac{R_2}{R_1} \Rightarrow R_1 = 20K\Omega,\ R_2 = 10K\Omega$

(d) $A_v = -100V/V = -\frac{R_2}{R_1} \Rightarrow R_1 = 10K\Omega,\ R_2 = 1M\Omega$

2.32.

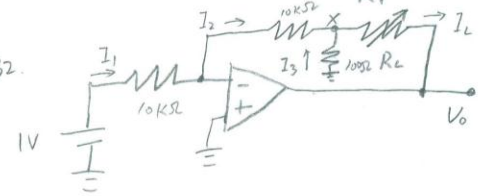


Fig1.

a. $I_1 = \frac{1V}{10K\Omega} = 0.1mA$

$I_2 = I_1 = 0.1mA$

$I_3 \times 100\Omega = I_2 \times 10K\Omega \Rightarrow I_3 = 10mA$

$-V_x = I_3 \times 100\Omega \Rightarrow V_x = -1V$

$I_L = I_2 + I_3 = 10.1mA$

b. $R_{L,max} = \frac{V_x - V_{o,min}}{I_L} = 1188\Omega$

c. $100\Omega \leq R_L \leq 1K\Omega$

$I_L = I_2 + I_3 = 10.1mA$, $V_x = -1V$

$V_o = V_x - R_L \cdot I_L$, linear relationship.

when $R_L = 100\Omega$, $V_o = -2.01V$ & when $R_L = 1K\Omega$, $V_o = -11.1V$

$\Rightarrow -11.1V \leq V_o \leq -2.01V$.

2.46. $v_i = v = v_o = R \cdot i \Rightarrow R = \frac{v}{i} = \frac{10V}{0.1mA} = 100K\Omega$

i only depends on v and R. The meter resistance does NOT effect it.

2.51.

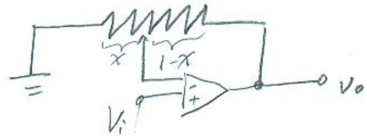


Fig 2 (a)

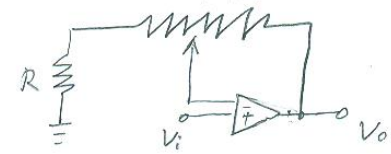


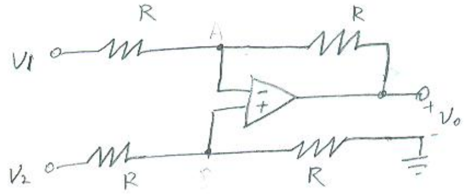
Fig 2 (b)

In Fig2(a), $\frac{V_o}{V_i} = 1 + \frac{1-x}{x} = \frac{1}{x}$, $0 \le x \le 1 \Rightarrow 1 \le \frac{V_o}{V_i} \le \infty$

In Fig2(b), we add a resister R, $\frac{V_o}{V_i} = 1 + \frac{(1-x) \times 10K\Omega}{x \times 10K\Omega + R}$

when $\frac{V_o}{V_i}\Big|_{max} = 11$ $x=0$. $\frac{V_o}{V_i} = 1 + \frac{10K\Omega}{R} \Rightarrow R = 1K\Omega$

2.62

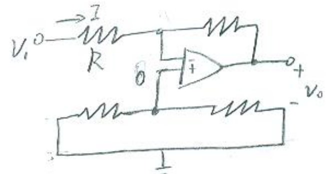


$V_+ = V_-$

$\Rightarrow V_1 + \frac{V_o - V_1}{2} = \frac{V_2}{2} \Rightarrow V_o = V_2 - V_1$

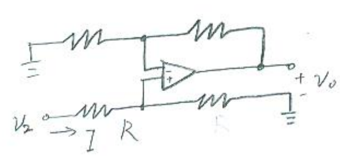
or $\frac{V_o}{V_2 - V_1} = \frac{R_2}{R_1} = \frac{R}{R} = 1 \Rightarrow V_o = V_2 - V_1$

V_1 alone,



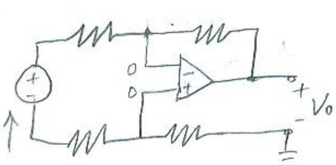
$R_i = \frac{V_1}{I} = R$

V_2 alone,



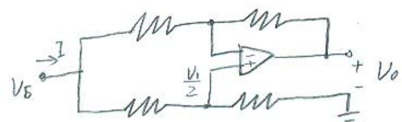
$R_i = \frac{V_2}{I} = 2R$

V_s between V_1 & V_2



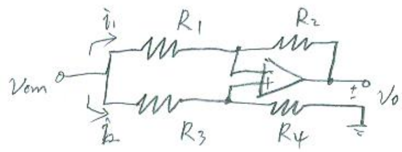
$R_i = \frac{V}{I} = 2R$

V_s connected to both V_1 and V_2



$R_i = \frac{V}{I} = R$

2.63



$$v_+ = v_- = v_{cm}\frac{R_4}{R_3+R_4}$$

$$i_2 = \frac{v_{cm}}{R_3+R_4}$$

$$i_1 = \frac{v_{cm}-v_-}{R_1} = \frac{v_{cm} - \frac{v_{cm}R_4}{R_3+R_4}}{R_1} = v_{cm}\left(\frac{1}{R_1} - \frac{R_4}{R_1(R_3+R_4)}\right)$$

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow \frac{R_4}{R_3+R_4} = \frac{R_2}{R_1+R_2} \Rightarrow i_1 = v_{cm}\left(\frac{1}{R_1} - \frac{R_2}{R_1(R_1+R_2)}\right)$$

$$= v_{cm}\cdot\frac{R_1+\cancel{R_2}-\cancel{R_2}}{R_1(R_1+R_2)} = \frac{v_{cm}}{R_1+R_2}$$

$$i = i_1 + i_2 = \frac{v_{cm}}{R_1+R_2} + \frac{v_{cm}}{R_3+R_4} = v_{cm}\left(\frac{1}{R_1+R_2} + \frac{1}{R_3+R_4}\right)$$

$$\Rightarrow \frac{1}{R} = \frac{1}{R_1+R_2} + \frac{1}{R_3+R_4} \quad \Rightarrow (R_1+R_2) \parallel (R_3+R_4)$$

2.73 (a) Gain $A_v = 1 + \frac{R_2}{R_1} = 101$

If the op amps saturate at $\pm 14V$. $-14V \le V_1 \le 14V \Rightarrow \frac{-14}{101} \le v_{icm} \le \frac{+14}{101}$

$\Rightarrow -0.14V \le v_{icm} \le 0.14V$

(b) In Fig 2.20b, v_- for A_1 and A_2 is the same, so no current flow through $2R_1$.

$\Rightarrow$ v_o for A_1 & A_2 is the same as v_{icm}

$-14V \le v_o \le 14V \Rightarrow -14V \le v_{icm} \le 14V$.

Compared with Fig 2.20a, the circuit in Fig 2.20b allow for bigger range of v_{icm}.

2.83 $R_{in} = R = 20k\Omega$, $\omega = 2\pi \times 10\,KHz$.

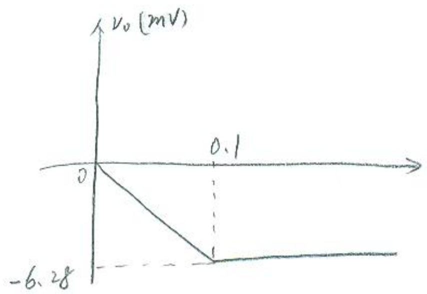
$$|T| = \frac{1}{\omega RC} = 1 \Rightarrow C = \frac{1}{2\pi \times 10\,KHz \times 20K} = 0.796\,nF$$

$$\frac{v_o}{v_i} = \frac{R_F/R}{1+sCR_F}$$, the finite DC gain is $\frac{-R_F}{R}$

$$40\,dB = 100\,V/V \Rightarrow -\frac{R_F}{R} = -100\,V/V \Rightarrow R_F = 100 \times 2K = 2\,M\Omega$$

The corner frequency is $\frac{1}{CR_F} = \frac{1}{0.796\,nF \times 2M\Omega} = 628\,Hz$

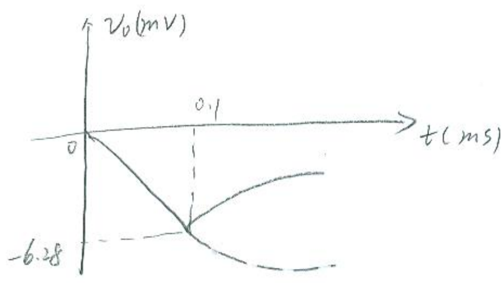
(a) Without R_F



$$v_o(t) = \frac{-1}{RC}\int_0^t 1\,dt = -62.8t \quad 0 \le t \le 0.1ms$$

$$v_o(0.1) = -6.28\,mV$$

(b) with R_F



$$v_o(t) = v_o(\infty)\,(1 - e^{-t/CR_F})$$

$$v_o(\infty) = -1 \times R_F = -\frac{1V}{20k} \times 2M = -100\,V.$$

$$v_o(t) = -100\,(1 - e^{-t/1.6})$$

2.88. $\frac{V_o}{V_i}(s) = -sRC = -s \times 0.01 \times 10^{-6} \times 10 \times 10^3 = 10^{-4}s$

$$\frac{V_o}{V_i}(j\omega) = -j\omega \times 10^{-4} \Rightarrow \left|\frac{V_o}{V_i}\right| = -\omega \times 10^{-4} = 10^4 rad/s \times 10^{-4} = 1$$

$\phi = 90°$ $\quad f = 1.59\,KHz$

For $10f_o$, $\left|\frac{V_o}{V_i}\right| = 10$, 10 V peak to peak

$$\Rightarrow v_o(t) = -5\sin(\omega t + \phi) = -5\sin(10^5 t + 90°)\ V$$