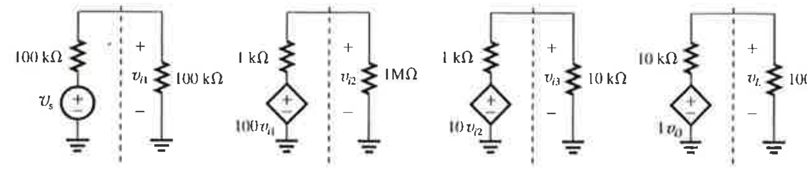
WEEK 1

ALSO - SOME EXTRA SOLUTIONS FOR REVIEW

This figure belongs to 1.47



1.45 continued here

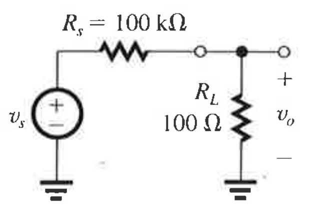
The signal loses about 90% of its strength when connected to the amplifier input (because $R_i = R_s/10$). Also, the output signal of the amplifier loses approximately 90% of its strength when the load is connected (because $R_L = R_o/10$). Not a good design! Nevertheless, if the source were connected directly to the load,

$$\frac{v_O}{v_S} = \frac{R_L}{R_L + R_S}$$

$$= \frac{100\ \Omega}{100\ \Omega + 100\ \text{k}\Omega}$$

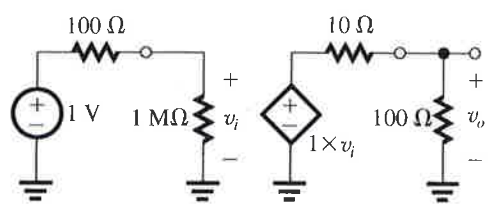
$\simeq 0.001$ V/V

$R_S = 100\ \text{k}\Omega$



which is clearly a much worse situation. Indeed inserting the amplifier increases the gain by a factor 8.3/0.001 = 8300.

1.46



$$v_O = 1\ \text{V} \times \frac{1\ \text{M}\Omega}{1\ M\Omega + 100\ \text{k}\Omega} \times 1 \times \frac{100\ \Omega}{100\ \Omega + 10\ \Omega}$$

$$= \frac{1}{1.1} \times \frac{100}{110} = 0.83\ \text{V}$$

$$\text{Voltage gain} = \frac{v_O}{v_S} = 0.83\ \text{V/V or } -1.6\ \text{dB}$$

Current gain =

$$\frac{v_O / 100\ \Omega}{v_S / 1.1\ \text{M}\Omega} = 0.83 \times 1.1 \times 10^4$$

= 9091 A/A or 79.2 dB

This figure belongs to 1.48a

$$\text{Power gain} = \frac{v_O^2 / 100\ \Omega}{v_S^2 / 1.1\ \text{M}\Omega} = 7578\ W/W$$

or 10 log 7578 = 38.8 dB

(This takes into acct. the power dissipated in the internal resistance of the source.)

1.47 In example 1.3 when the first and the second stages are interchanged, the circuit looks like the figure above

$$\frac{v_{i1}}{v_S} = \frac{100\ \text{k}\Omega}{100\ \text{k}\Omega + 100\ \text{k}\Omega} = 0.5\ \text{V/V}$$

$$A_{v1} = \frac{v_{i2}}{v_{i1}} = 100 \times \frac{1\ \text{M}\Omega}{1\ \text{M}\Omega + 1\ \text{k}\Omega}$$

= 99.9 V/V

$$A_{v2} = \frac{v_{i3}}{v_{i2}} = 10 \times \frac{10\ \text{k}\Omega}{10\ \text{k}\Omega + 1\ \text{k}\Omega}$$

= 9.09 V/V

$$A_{v3} = \frac{v_L}{v_{i3}} = 1 \times \frac{100\ \Omega}{100\ \Omega + 10\ \Omega} = 0.909\ \text{V/V}$$

$$\text{Total gain} = A_v = \frac{v_L}{v_{i1}} = A_{v1} \times A_{v2} \times A_{v3}$$

= 99.9 × 9.09 × 0.909 = 825.5 V/V

The voltage gain from source to load is

$$\frac{v_L}{v_S} = \frac{v_L}{v_{i1}} \times \frac{v_{i1}}{v_S} = A_v \cdot \frac{v_{i1}}{v_S}$$

= 825.5 × 0.5

= 412.7 V/V

The overall voltage has reduced appreciably. It is due to the reason because the input impedance of the first stage, R_{in}, is comparable to the source resistance R_S. In example 1.3 the input impedance of the first stage is much larger than the source resistance

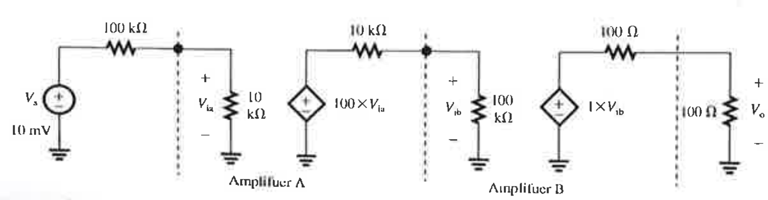
1.48 a. Case S-A-B-L

$$\frac{V_O}{V_S} = \frac{V_O}{V_{ib}} \times \frac{V_{ib}}{V_{ia}} \times \frac{V_{ia}}{V_S} =$$

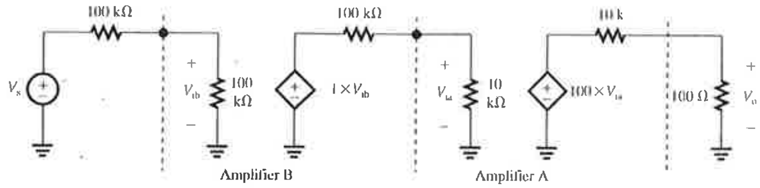
$$\left(1 \times \frac{100}{100 + 100}\right) \times \left(100 \times \frac{100}{100 + 10}\right) \times \left(\frac{10}{100 + 10}\right)$$

$$\frac{V_O}{V_S} = 4.13\ \text{V/V and gain in dB } 20 \log 4.1 =$$

12.32 dB (See figure below)



This figure belong to 1.48b



b. Case S-B-A-L

$$\frac{V_O}{V_S} = \frac{V_O}{V_{ia}} \cdot \frac{V_{ia}}{V_{ib}} \cdot \frac{V_{ib}}{V_S}$$

$$= \left(100 \times \frac{100}{100 + 10\text{ K}}\right) \times \left(1 \times \frac{10\text{ K}}{10\text{ K} + 100}\right) \times$$

$$\left(\frac{100\text{ K}}{100\text{ K} + 100}\right)$$

$\frac{V_O}{V_S} = 0.49\ V/S$ and gain in dB is $20 \log 0.49 =$ -6.19 dB case a is preferred as it provides higher voltage gain.

1.49

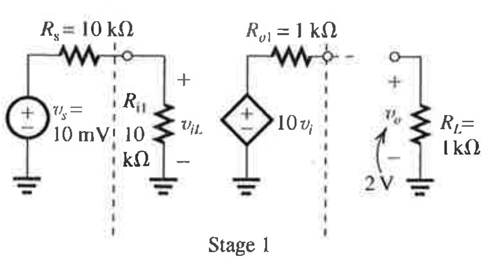
Required overall voltage gain = 2 V/10 mV = 200 V/V. Each stage is capable of providing a *maximum* voltage gain of 10 (the open-circuit gain value). For n stages in cascade the maximum (unattainable) voltage gain in 10^n. We thus see that we need at least 3 stages. For 3 stages, the overall voltage gain obtained is

$$\frac{v_O}{v_S} = \frac{10}{10 + 10} \times 10 \times \frac{10}{1 + 10} \times 10 \times \frac{10}{1 + 10}$$

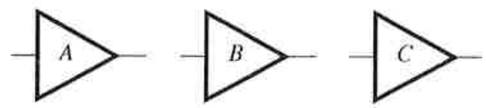
$$\times 10 \times \frac{1}{1 + 1}$$

= 206.6 V/V

Thus, three stages suffice and provide a gain slightly larger than required. The output voltage actually obtained is 10 mV × 206.6 = 2.07 V.



1.50 Deliver 0.5W to a 100Ω load
Source is 30mV RMS with 0.5MΩ source resistance. Choose from 3 amplifiers types



A	B	C
R_i= 1MΩ	R_i= 10kΩ	R_i= 10kΩ
A_v= 10 v/v	A_v= 100 v/v	A_v= 1 v/v
R_o= 10kΩ	R_o= 1kΩ	R_o= 20Ω

Choose order to eliminate loading on input and output
A - 1st-to minimize loading on 0.5 MΩ source
B - 2nd-to boost gain
C - 3rd - to minimize loading at 100Ω output.
(See figure below)

$$\frac{v_O}{v_S} = \frac{2\ V}{30mV} = 235.7 < \left(\frac{1\mu}{0.5\mu + 1\mu}\right)(10)$$

$$\left(\frac{10}{10 + 10}\right)(100)\left(\frac{10}{10 + 1}\right)(1)\left(\frac{100}{20 + 100}\right)$$

235.7 < 253.6

$$v_O = (253.6)(30\text{mV}) = 7.61\text{ v RMS}$$

$$P = \frac{v_O^2}{R_L} = \frac{(7.61)^2}{100} = 0.58\text{ W}$$

1.51 (a) Required voltage gain $= \frac{v_O}{v_S}$

$$= \frac{3\text{ V}}{0.01\text{ V}} = 300\text{ V/V}$$

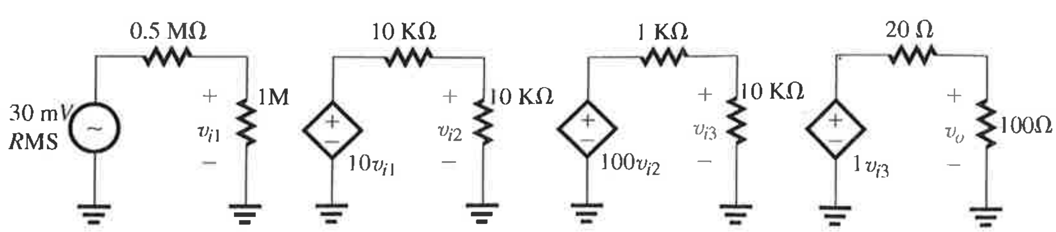
(b) The smallest R_i allowed is obtained from

$$0.1\ \mu A = \frac{10\text{ mV}}{R_S + R_i} \Rightarrow R_S + R_i = 100\text{ k}\Omega$$

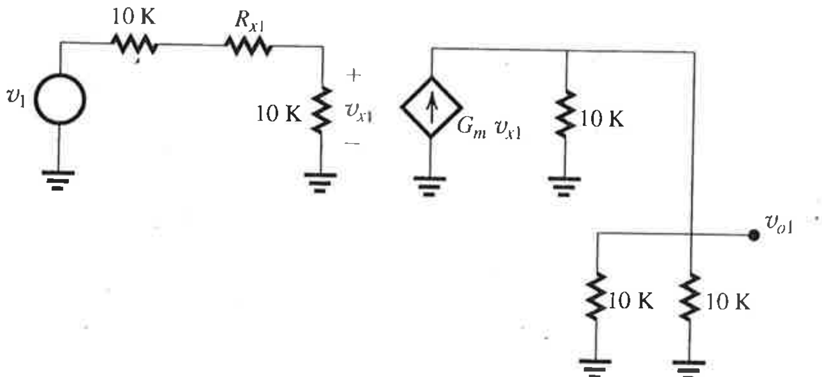
Thus $R_i = 90$ kΩ.
For $R_i = 90$ kΩ, $i_i = 0.1$ μA peak, and

Overall current gain $= \frac{v_O / R_L}{i_i}$

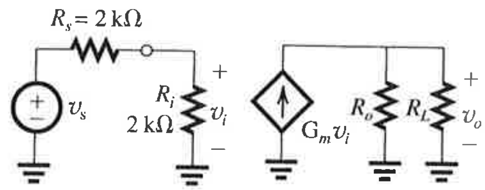
This figure belongs to 1.50



This figure belongs to 1.55b



1.54



$G_m = 40$ mA/V
$R_o = 20\ \text{k}\Omega$
$R_L = 1\ \text{k}\Omega$

$$v_i = v_S \frac{R_i}{R_S + R_i}$$

$$= v_S \frac{2}{2+2} = \frac{v_S}{2}$$

$$v_O = G_m v_i (R_L \parallel R_O)$$

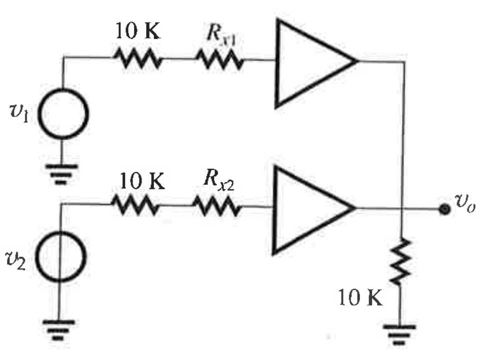
$$= 40 \frac{20 \times 1}{20 + 1} v_i$$

$$= 40 \frac{20}{21} \frac{v_S}{2}$$

Overall voltage gain $\equiv \dfrac{v_O}{v_S} = 19.05$ V / V

1.55 Need $V_0 = 10v_1 + 20v_2$

R_{X1} and R_{xe} are used to get the appropriate gains on v_1 and v_2



Use superposition (See figure above)

$$v_{o1} = G_m v_{x1}\left(\frac{10\ \text{K}}{5\ \text{K} + 10\ \text{K}}\right)(5\ \text{K})$$

$$= \underbrace{G_M\left(\frac{10\ \text{K}}{5\ \text{K} + 10\ \text{K}}\right)}\ (5\text{K})\left(V_1\left(\frac{10\ \text{K}}{10\ \text{K} + 10\ \text{K} + R_{x1}}\right)\right)$$

$$v = i \times R$$

$$\frac{v_{o1}}{v_1} = 10 = \left(\frac{20\ \text{mA}}{\text{V}}\right)\left(\frac{10\ \text{K}}{15\ \text{K}}\right)5\ \text{K}\left(\frac{10\ \text{K}}{20\ \text{K} + R_{x1}}\right)$$

$$0.15 = \frac{10\ \text{K}}{20\ \text{K} + R_{x1}}$$

$$\therefore R_{x1} = 46.67\ \text{k}\Omega$$

Use same procedure for v_2 but you will find 1 stage is not enough again, thus: (See figure below)

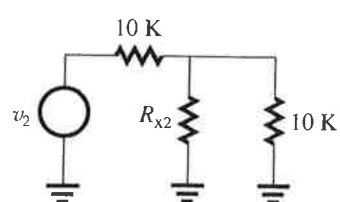
$$\frac{v_{o2}}{v_2} = 20 = \left(\frac{20\ \text{mA}}{\text{V}}\right)\left(\frac{10\ \text{K}}{5\text{K} + 10\text{K}}\right)(5\ \text{K})\left(\frac{20\ \text{mA}}{\text{V}}\right)$$

$$\left(\frac{10\ \text{K}}{10\ \text{K} + 10\ \text{K}}\right)(10\ \text{K})\left(\frac{10\ \text{K}}{10\ \text{K} + 10\ \text{K} + R_{x2}}\right)$$

$$20 = 6.67 \times 10^3\left(\frac{10\ \text{K}}{20\ \text{K} + R_{x2}}\right)$$

$\therefore R_{x2} = 3.3\text{M}\Omega$ series

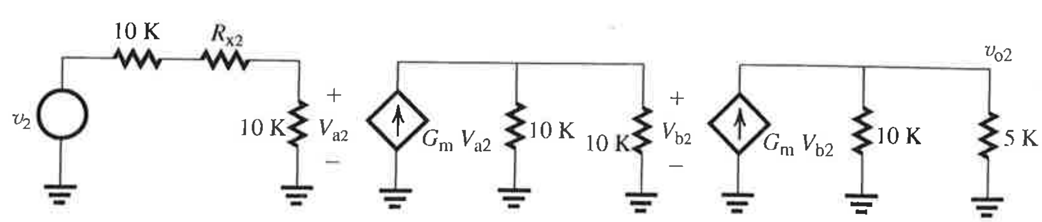
or can use of v_2



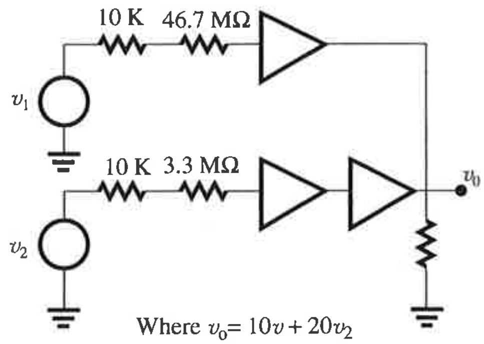
then

$R_{x2} = 30\ \Omega$

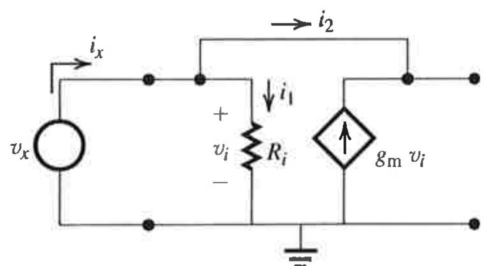
This figure belongs to 1.55c



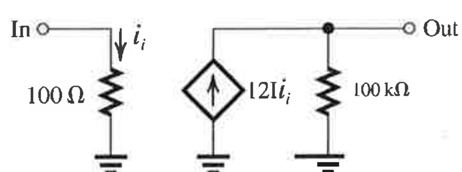
Finally,



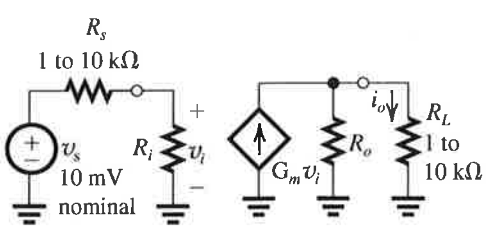
1.56



$$\left.\begin{aligned} i_x &= i_1 + i_2 \\ i_1 &= v_i / R_i \\ i_a &= g_m + v_i \\ v_i &= V_x \end{aligned}\right\} \quad \begin{aligned} i_x &= v_x / R_i + g_m v_x \\ i_x &= v_x + \left(\frac{1}{R_i} + g_m\right) \\ \frac{v_x}{i_x} &= \frac{1}{1/R_i + g_m} \\ &= \frac{R_x}{1 + g_m R_i} = R_{in} \end{aligned}$$



1.57 Transconductance amplifier.



For R_s varying in the range 1 to 10 kΩ, and Δi_o limited to 10% we have to select R_i sufficiently large;

$R_i \geq 10 R_{smax}$

$R_i = 100$ kΩ

For R_L varying in the range 1 to 10 kΩ, the change in i_o can be kept to 10% if R_o is selected sufficiently large;

$R_O \geq R_{Lmax}$

Thus $R_O = 100$ kΩ

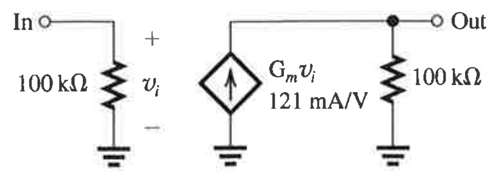
For $v_S = 10$ mV,

$$i_{o\,min} = 10^{-2} \frac{R_i}{R_i + R_{smax}} G_m \frac{R_O}{R_O + R_{Lmax}}$$

$$10^{-3} = 10^{-2} \frac{100}{100 + 10} G_m \frac{100}{100 + 10}$$

$$G_m = 1.21 \times 10^{-1} \text{ A/V}$$

$$= 121 \text{ mA/V}$$



1.58 Transresistance amplifier

To limit Δv_o to 10% corresponding to R_s varying in the range 1 to 10 kΩ, we select R_i sufficiently low;

$$R_i \leq \frac{R_{smin}}{10}$$

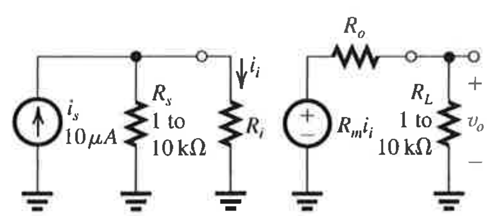
Thus, $R_i = 100\ \Omega$

To limit Δv_o to 10% while R_L varies over the range 1 to 10 kΩ, we select R_o sufficiently low;

$$R_O \leq \frac{R_{Lmin}}{10}$$

Thus, $R_O = 100\ \Omega$

Now, for $i_S = 10\ \mu A$,

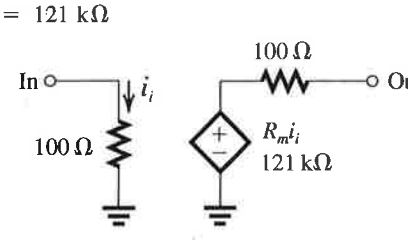


$$v_{Omin} = 10^{-5} \frac{R_{smin}}{R_{smin} + R_i} R_m \frac{R_{Lmin}}{R_{Lmin} + R_O}$$

$$1 = 10^{-5} \frac{1000}{1000 + 100} R_m \frac{1000}{1000 + 100}$$

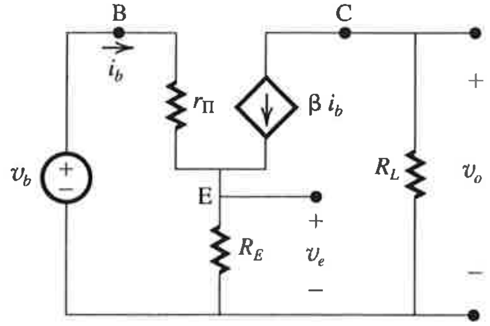
$$\Rightarrow R_m = 1.21 \times 10^5$$

$$= 121 \text{ k}\Omega$$



1.61

Apply kirchhoff's current law in the mesh on the left



$$-\bar{V}_b + r_\pi i_b + R_E(\beta i_b + i_b) = 0$$

$$v_b = i_b[r_\pi + (\beta + 1)R_E]$$

Now $v_c = -\beta \times i_b \times R_L$

$$\frac{v_c}{v_b} = -\frac{\beta R_L}{r_\pi + (\beta + 1)R_E}$$

$$v_e = (i_b + \beta i_b)R_E$$

$$= i_b(\beta + 1)R_E$$

$$\frac{v_e}{v_b} = \frac{(\beta + 1)R_E}{r_\pi + (\beta + 1)R_E}$$

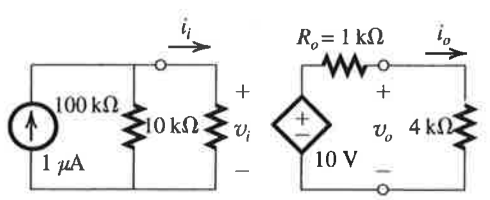
$$= \frac{R_E}{\frac{r_\pi}{\beta + 1} + R_E}$$

1.62

$$R_O = \frac{\text{Open-circuit output voltage}}{\text{Short-circuit output current}} = \frac{10\ \text{V}}{10\ \text{mA}}$$

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

$$v_O = 10 \times \frac{4}{1 + 4} = 8\ \text{V}$$



$$A_v = \frac{v_O}{v_i} = \frac{8}{1 \times 10^{-3} \times (100 \| 10) \times 10^3}$$

$$= 888\ \text{V/V or } 58.9\ \text{dB}$$

$$A_i = \frac{i_o}{i_i} = \frac{v_O / R_L}{10^{-3} \times \frac{100}{100 + 10}} = \frac{8/(4 \times 10^3)}{10^{-3} \times \frac{100}{110}}$$

$$= 2200\ \text{A/A or } 66.8\ \text{dB}$$

$$A_i = \frac{v_O^2 / R_L}{i_i^2 R_i} = \frac{8^2/(4 \times 10^3)}{\left(10^{-3} \times \frac{100}{100 + 10}\right)^2 10 \times 10^3}$$

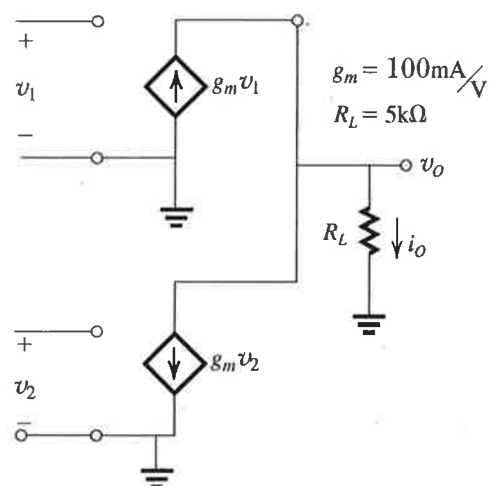
$$= 19.36 \times 10^5\ \text{W/W or } 62.9\ \text{dB}$$

$$\text{Overall current gain} = \frac{i_o}{1\ \mu A}$$

$$= \frac{v_O / R_L}{1\ \mu A} = \frac{8/(4 \times 10^3)}{10^{-3}}$$

$$= 2000\ \text{A/A or } 66\ \text{dB}$$

1.63 Using the voltage divider rule



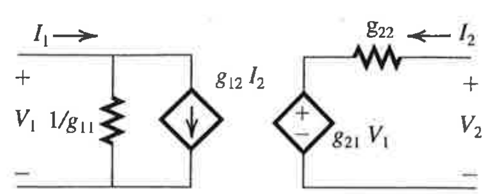
a. $i_o = g_m v_1 - g_m v_2$

$$v_O = i_o R_L = g_m R_L (v_1 - v_2) = v_0$$

b. $v_1 = v_2 \therefore v_0 = 0V$

$$\left.\begin{array}{l} v_1 = 1.01 \\ v_2 = 0.99 \end{array}\right\} \therefore v_0 = 10V$$

1.64



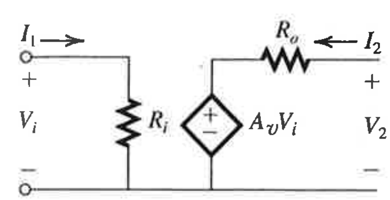


Figure 1.16a

$I_1 = g_{11}V_1 + g_{12}I_a$

$V_2 = g_{21}V_1 + g_{22}I_a$

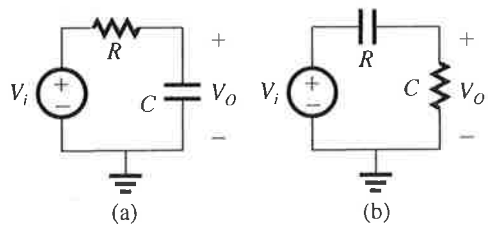
thus

$$\left.\frac{V_2}{I_2}\right|_{v_1=0} = g_{22} = R_0 \quad \left.\frac{I_1}{V_1}\right|_{I_2=0} = g_{11} = \frac{1}{R_i}$$

$$\left.\frac{V_2}{I_2}\right|_{I_a=0} = g_{21} = A\upsilon \quad \left.\frac{I_2}{I_1}\right|_{v_1=0} = g_{12} = \infty$$

due to unilateral nature of Figure 1.16a

1.65



$$\text{for (a) } V_0 = V_i\left(\frac{1/SC}{1/SC + R}\right)$$

$$\frac{V_0}{V_I} = \frac{1}{1 + SCR}$$

where k = 1

$$\omega_0 = \frac{1}{RC} \text{ from table 1.2 it is low pass.}$$

$$\text{for (b) } V_0 = V_I\left(\frac{R}{R + \frac{1}{SC}}\right)$$

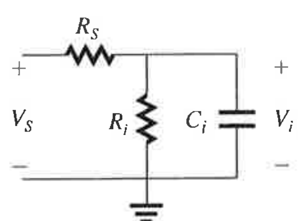
$$\frac{V_0}{V_I} = \frac{SRC}{1 + SCR}$$

$$\frac{V_0}{V_I} = \frac{S}{S + \frac{1}{RC}}$$

where k = 1

$$\omega_0 = \frac{1}{RC} \text{from table 1.2 it is high pass.}$$

1.66



$$\frac{V_i}{V_S} = \frac{\dfrac{R_i\frac{1}{sC_i}}{R_i + \frac{1}{sC_i}}}{R_S + \left(\dfrac{R_i\frac{1}{sC_i}}{R_i + \frac{1}{sC_i}}\right)} = \frac{\dfrac{R_i}{1 + sC_iR_i}}{R_S + \left(\dfrac{R_i}{1 + sC_iR_i}\right)}$$

$$= \frac{R_i}{R_S + sC_iR_iR_s + R_i}$$

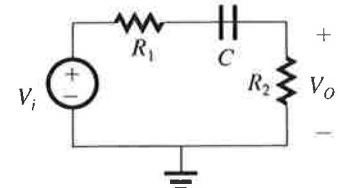
$$\frac{V_i}{V_S} = \frac{R_i}{(R_S + R_i) + sC_iR_iR_S} = \frac{\dfrac{R_i}{(R_S + R_i)}}{1 + S\left(\dfrac{C_iR_iR_S}{R_S + R_i}\right)}$$

$$\text{Where K} = \frac{R_i}{(R_S + R_i)}$$

$$\omega = \frac{R_S + R_i}{C_iR_iR_S} \text{ from table 1.2 low pass for given}$$

values $\omega_0 = 12.5$ MHz

1.67 Using the voltage-divider rule.



$$T(s) = \frac{V_O}{V_i} = \frac{R_2}{R_2 + R_1 + \frac{1}{sC}}$$

$$T(s) = \left(\frac{R_2}{R_1 + R_2}\right)\left(\frac{s}{s + \frac{1}{C(R_1 + R_2)}}\right)$$

which is from Table 1.2 is of the high-pass type with

$$K = \frac{R_2}{R_1 + R_2} \quad \omega_0 = \frac{1}{C(R_1 + R_2)}$$

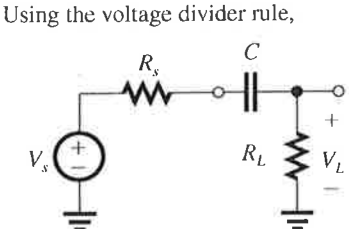
As a further verification that this is a high-pass network and $T(s)$ is a high-pass transfer function, we assume as $s \Rightarrow 0$, $T(s) \Rightarrow 0$; and as $s \to \infty$, $T(s) = R_2/(R_1 + R_2)$. Also, from the circuit observe as $s \to \infty$, $(1/sC) \to 0$ and $V_O/V_i = R_2/(R_1 + R_2)$. Now, for $R_1 = 10\text{ k}\Omega, R_2 = 40\text{ k}\Omega$, and $C = 0.1\ \mu F$.

$$f_o = \frac{\omega_0}{2\pi} = \frac{1}{2\pi \times 0.1 \times 10^{-6}(10 + 40) \times 10^3}$$

$$= 31.8 \text{ Hz}$$

$$|T(j\omega_0)| = \frac{\text{K}}{\sqrt{2}} = \frac{40}{10 + 40}\frac{1}{\sqrt{2}} = 0.57 \text{ V/V}$$

1.68 Using the voltage divider rule,



$$\text{CMRR} = 20\log\left|\frac{A_d}{A_{CM}}\right| = 20\log\frac{G_m}{\Delta G_m}$$

$$20\log_{10} A_d = 80\text{ dB} \Rightarrow A_d = 10^4$$

$$\frac{A_{CM}}{A_d} = \frac{\Delta G_m}{G_m} \Rightarrow A_{cm} = 10^4 \times \frac{0.1}{100} = 10$$

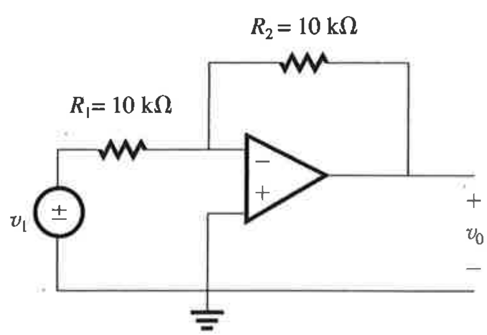
$$\text{CMRR} = 20\log\frac{G_m}{\Delta G_m} = 20\log\frac{1}{0.1/100} = 60$$

2.8

Circuit	v_o/v_i(V/V)	R_{in} (kΩ)
a	$\frac{-100}{10} = -10$	10
b	−10	10
c	−10	10
d	−10	10

virtual ground no current in 10 kΩ

2.9



Closed loop gain is $\frac{v_o}{v_I} = \text{A}$

$$\text{A} = \frac{v_o}{v_I} = -\frac{R_2}{R_1} = -\frac{10\text{ k}\Omega}{10\text{ k}\Omega}$$

$= -1$ V/V

For $v_I = +1.000$ V

$v_o = \text{A}v_I = +1 \times 1.000$

$= -1.000$ V

The two resistors are 1% resistors

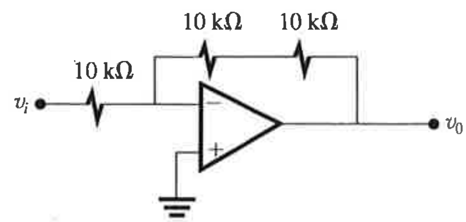
$$\left(\frac{v_o}{v_I}\right)_{\min} = -\frac{10(1-0.01)}{10(1+0.01)} = -0.98\text{ V/V}$$

$$\left(\frac{v_o}{v_I}\right)_{\max} = -\frac{10(1+0.01)}{10(1-0.01)} = -1.02\text{ V/V}$$

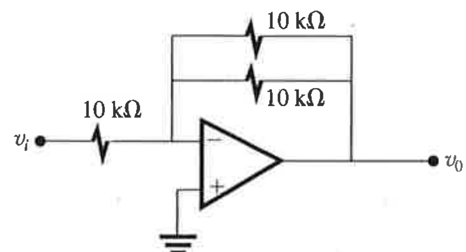
Range is −0.98 to −1.02 V/V

2.10

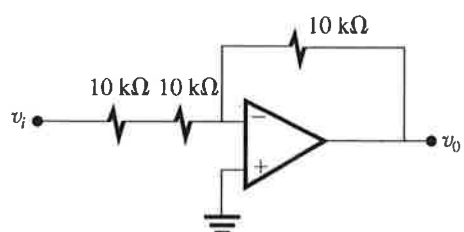
There are four possibilities:



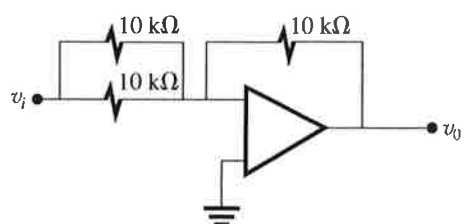
$\frac{v_o}{v_i} = -2$ V/V $R_{in} = 10$ kΩ



$\frac{v_o}{v_i} = -0.5$ V/V $R_{in} = 10$ kΩ



$\frac{v_o}{v_i} = -0.5$ V/V $R_{in} = 20$ kΩ



$\frac{v_o}{v_i} = -2$ V/V $R_{in} = 5$ kΩ

2.11

a. G = −1 V/V
b. G = −10 V/V
c. G = −0.1 V/V
d. G = −100 V/V
e. G = −10 V/V

2.12

a. $G = -1\text{ V/V} = \frac{-R_2}{R_1} \Rightarrow R_1 = R_2 = 10\text{ k}\Omega$

b. $G = -2\text{ V/V}$

$= \frac{-R_2}{R_1} \Rightarrow R_1 = 10\text{ k}\Omega,\ R_2 = 20\text{ k}\Omega$

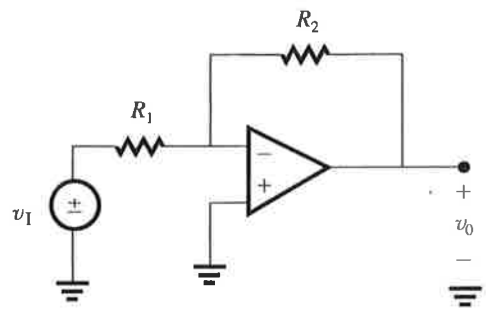
c. $G = -0.5\text{ V/V}$

$= \frac{-R_2}{R_1} \Rightarrow R_1 = 20\text{ k}\Omega,\ R_2 = 10\text{ k}\Omega$

d. $G = -100\text{ V/V}$

$= \frac{-R_2}{R_1} \Rightarrow R_1 = 10\text{ k}\Omega,\ R_2 = 1\text{ M}\Omega$

2.13



$\frac{v_o}{v_I} = -4\text{ V/V} = -\frac{R_2}{R_1}$

$\Rightarrow R_2 = 4\,R_1$

Total resistance used is 100 kΩ

$\therefore R_1 + R_2 = 100\text{ k}\Omega$

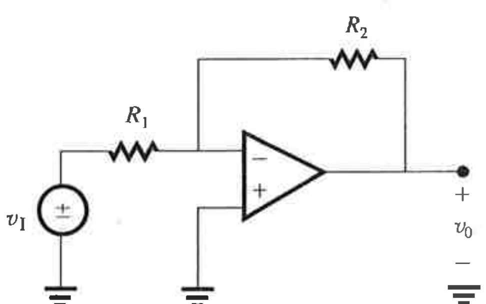
$R_1 + 4R_1 = 100\text{ k}\Omega$

$R_1 = 20\text{ k}\Omega$

and $R_2 = 4R_1 = 80\text{ k}\Omega$

2.14

Gain is 26 dB



$26\text{ dB} = 20\log|G|$

$G = 10^{26/20} = 19.95$

$\therefore \frac{v_o}{v_I} = -19.95\text{ V/V} = -\frac{R_2}{R_1}$

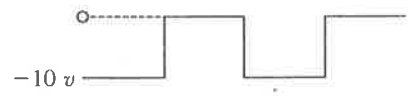
$\Rightarrow R_2 = 19.95\,R_1 \le 1\text{ M}\Omega$

For largest possible input resistance choose $R_2 = 1\text{ M}\Omega$

$R_1 = \frac{1\text{ M}\Omega}{19.95} \simeq 50.1\text{ k}\Omega$

$R_{in} = R_1 = 50.1\text{ k}\Omega$

2.15



$G = \frac{v_o}{v_i} = \frac{-R_2}{R_1} = \frac{-100}{10} = -10$

$v_{low} = 10\text{ V},\ v_{high} = 0,\ v_{avg} = -5\text{ V}$

2.16

$\frac{v_o}{v_I} = \frac{10\text{ k}}{1\text{ k}} = -10\text{ V/V}$

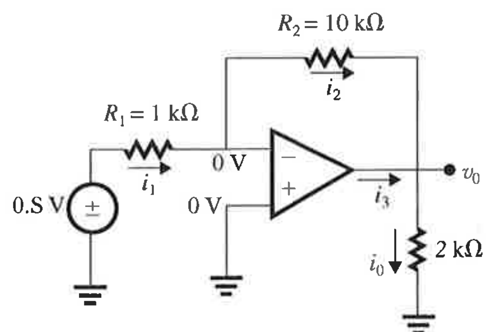
$v_o = -10\,v_I$

$= -10 \times (0.5)$

$= -5\text{ V/V}$

In the figure

$i_o = \frac{v_o}{2\text{ k}\Omega} = \frac{-5}{2\text{ k}\Omega} = -2.5\text{ mA}$



$i_1 = i_2 = \frac{0 - (v_o)}{10\text{ k}\Omega} = \frac{0 - (-5)}{10\text{ k}\Omega}$

$= +0.5\text{ mA}$

$i_3 = i_o - i_2 = -2.5 - 0.5$

$= -3\text{ mA}$

This additional current is supplied by the op amp.

2.17

$|\text{Gain}| = \frac{R_2}{R_1} = \frac{R_2\left(1 + \frac{X}{100}\right)}{R_1\left(1 + \frac{X}{100}\right)} \simeq \frac{R_2}{R_1}\left(1 \pm \frac{2X}{100}\right)$

So 2X is the tolerance on the closed loop gain G

$G = -100\ \frac{\text{V}}{\text{V}}$ and X = 1

Gain variation $-102 < G < -98$