Chapter 1

1.1 From Eq. (1.1)

$$V_{LSB} = \frac{V_{FS}}{2^n} = \frac{3.5}{2^8} = 136.7\ mV$$

1.2 From Eq. (1.1)

$$V_{LSB} = \frac{V_{FS}}{2^n} = \frac{5}{2^{16}} = 76\ mV$$

1.3 From Eq. (1.1)

$$V_{LSB} = \frac{V_{FS}}{2^n} = \frac{3.5}{2^{16}} = 53.4\ \mu V$$

1.4 From Eq. (1.2)

$$v_o = (1x2^{-1} + 0x2^{-2} + 1x2^{-3})\, x\, 5 = (0.5 + 0.125)\, x\, 5 = 0.625\, x\, 5\ V$$

$$v_o = 3.125 V$$

1.5 From Eq. (1.2)

$$v_o = (1\,x\,2^{-1} + 1\,x\,2^{-2} + 0\,x\,2^{-3} + 1\,x\,2^{-4})\, x\, 5V$$

$$v_o = (0.5 + 0.25 + 0.125)\, x\, 5V = 4.375\ V$$

1.6

$$v_{AB} = 6.5 + 5\,x10^{-3}\,\text{Sin}\,200\,\pi t$$

$$V_{DC} = 6.5\ V$$

$$I_{DC} = \frac{V_{DC}}{R_L} = \frac{6.5}{1K\Omega} = 6.5\ mA$$

$$v_{ab} = 5\,x10^{-3}\,\text{Sin}\,200\,\pi t\ V$$

$$i_a = \frac{v_{ab}}{R_L} = \frac{5\,x10^{-3}\,\text{Sin}\,200\,\pi t}{1K\Omega} = 5\,x10^{-3}\,\text{Sin}\,200\,\pi\, t\ mA$$

$$v_{AB} = 6.5 + 5\,x10^{-3}\,\text{Sin}\,200\,\pi\, t\ V$$

$$V_{ab} = \sqrt{6.5^2 + (\frac{5\,x10^{-3}}{\sqrt{2}})^2} \simeq 6.5\ V$$

$$I_a = \sqrt{6.5^2 + (\frac{5\,x10^{-3}}{\sqrt{2}})^2}\ mA \simeq 6.5\, mA$$

1.7 Given

$$v_{DC} = 7.5 + 10\,x10^{-3}\,\text{Sin}\,2000\,\pi\,t\;V$$

$$V_{DC} = 7.5\;V$$

$$I_{DC} = \frac{V_{DC}}{R_L} = \frac{7.5}{1\,K\Omega} = 7.5\,mA$$

$$v_{ab} = 10\,x10^{-3}\,\text{Sin}\,2000\,\pi\,t$$

$$i_a = \frac{10\,x10^{-3}\,\text{Sin}\,2000\,\pi\,t}{1K} = 10\,x10^{-3}\,\text{Sin}\,2000\,\pi\,t\;mA$$

$$V_{ab} = \sqrt{(7.5)^2 + (\frac{10\,x10^{-3}}{\sqrt{2}})^2} \simeq 7.5V$$

$$i_A = 7.5\,mA + 10\,x10^{-3}\,\text{Sin}\,2000\,\pi\,t\;mA$$

$$I_a = \sqrt{(7.5)^2 + (\frac{10\,x10^{-3}}{\sqrt{2}})^2}\;\;mA$$

$$I_a \simeq 7.5\;mA$$

1.8

$$v_s = 1.5 + 12\,x10^{-3}\,\text{Sin}\,\omega t\;V$$

$$v_o = 7.5 + 2.5\,\text{Sin}\,\omega t\;V$$

From Eq. (1.9)

$$A_V = \frac{7.5}{1.5} = 5$$

From Eq. (1.10)

$$A_v = \frac{2.5}{12\,x10^{-3}} = 208.3$$

1.9

$$v_s = 2.5 + 20\,x10^{-3}\,\text{Sin}\,\omega t$$

$$v_o = 7.5 + 4.5\,x10^{-3}\,\text{Sin}\,\omega t$$

From Eq. (1.9)

$$A_V = \frac{7.5}{2.5} = 3$$

From Eq. (1.10)

$$A_v = \frac{4.5}{20\,x10^{-3}} = 225$$

1.10

(a) From Eq. (1.12)

$$\text{Power gain}\;\;A_P = \frac{P_L}{P_i} = \frac{{v_o}^2 / R_L}{{v_s}^2 / R_i} = \frac{1 / 100\,K\Omega}{(40\,x10^{-3})^2 / 50\,K\Omega} = 312.5$$

(b) For $R_L = R_i = 50\,K\Omega$

$$A_P = \frac{P_L}{P_i} = \frac{v_o^{\ 2}}{v_s^{\ 2}} = \frac{1}{(40\,x10^{-3})^2} = 625$$

From Eq. (1.11)

$$A_I = \frac{i_o}{i_s} = \frac{v_o / R_L}{v_s / R_i} = \frac{1}{40\ mV} = 25$$

1.11

(a)

From Eq. (1.12)

$$A_P = \frac{v_o^{\ 2} / R_L}{v_s^{\ 2} / R_i} = \frac{1.2^2 / 147K\Omega}{(80\,x10^{-3})^2 / 100K\Omega} = 153$$

(b)

$$R_L = R_i = 100\,K\Omega$$

$$A_i = \frac{v_o / R_L}{v_s / R_i} = \frac{1.2}{80\,x10^{-3}} = 15$$

1.12

(a)

$$A_v = \frac{v_{o(peak)}}{v_{i(peak)}} = \frac{6.5}{50 \times 10^{-3}} = 1.30 \times 10^3 = 130 \text{ or } 42.28 \text{ dB}$$

$$i_o = \frac{v_o}{R_L} = \frac{6.5 \sin 1000\pi t}{5000} = 1.3 \sin(1000\pi t) \text{ mA}$$

$$A_i = \frac{i_{o(peak)}}{i_{L(peak)}} = \frac{1.3 \times 10^{-3}}{1 \times 10^{-6}} = 1300 \text{ or } 62.28 \text{ dB}$$

$$A_p = A_v \cdot A_i = 130 \times 1300 = 169 \times 10^3 \text{ or } 52.28 \text{ dB } (10 \log P_o/P_i)$$

$$R_i = \frac{v_{i(peak)}}{i_{i(peak)}} = \frac{50 \times 10^{-3}}{1 \times 10^{-6}} = 50 \text{ k}\Omega$$

(b)

$$P_{dc} = V_{CC} I_{CC} + V_{EE} I_{EE} = 15\,(15 + 15) \text{ mW} = 450 \text{ mW}$$

$$P_L = \frac{v_{o(peak)}}{\sqrt{2}} \cdot \frac{i_{o(peak)}}{\sqrt{2}} = \frac{6.5 \times 1.3 \times 10^{-3}}{2} = 4.225 \text{ mW}$$

$$P_i = \frac{v_{i(peak)}}{\sqrt{2}} \cdot \frac{i_{i(peak)}}{\sqrt{2}} = \frac{50 \times 10^{-3} \times 1 \times 10^{-6}}{2} = 25 \text{ nW}$$

$$\eta = \frac{P_L}{P_{dc} + P_i} = \frac{4.225 \times 10^{-3}}{450 \times 10^{-3} + 25 \times 10^{-9}} \simeq 0.938\%$$

(c) $A_v\, v_{i(max)} = V_{o(max)} = V_{CC}$

$$v_{i(max)} = \frac{15}{130} = 115.4 \text{ mV}$$

1.13

$$V_o = 5.3 \text{ V at } V_I = 21 \text{ mV}, \quad V_o = 5.8 \text{ V at } V_I = 27 \text{ mV}$$

$$\Delta V_o = 5.8 - 5.3 = 0.5 \text{ V}, \quad \Delta V_I = 27 - 21 = 6 \text{ mV}$$

(a) $$A_v = \frac{\Delta V_o}{\Delta V_I} = \frac{0.5}{6 \times 10^{-3}} = 83.3 \text{ or } 38.4 \text{ dB}$$

(b) $$A_{dc} = \frac{V_o}{V_I} = \frac{5.5}{24 \times 10^{-3}} = 229 \text{ or } 47.2 \text{ dB}$$

(c) $$\frac{V_o - V_{(min)}}{A_v} \le V_F - 24 \text{ mV} \le \frac{V_{o(max)} - V_o}{A_v}$$

$$\frac{-5.5 + 2}{83.3} \le V_I - 24 \text{ mV} \le \frac{11 - 5.5}{83.3}$$

$$-42 \text{ mV} \le V_I - 24 \text{ mV} \le 66 \text{ mV}$$

$$-18 \text{ mV} \le V_I \le 90 \text{ mV}$$

1.14

(a) $$i_o = \frac{v_o}{R_L} = \frac{2\text{ V}}{10 \text{ k}\Omega} = 0.2 \text{ mA}$$

$$i_i = \frac{v_i}{R_i} = \frac{1 \text{ mV}}{100 \text{ k}\Omega} = 10 \text{ nA}$$

$$A_i = \frac{i_o}{i_i} = \frac{0.2 \times 10^{-3}}{10 \times 10^{-9}} = 2 \times 10^4 \text{ or } 86 \text{ dB}$$

$$A_v = \frac{v_o}{v_i} = \frac{2}{1 \times 10^{-3}} = 2 \times 10^3$$

$$A_p = A_v A_i = 2 \times 10^3 \times 2 \times 10^4 = 4 \times 10^7 \text{ or } 152 \text{ dB}$$

(b) $$v_i = i_i R_i = 1 \times 10^{-3} \times 100 = 10^{-1} \text{ V}$$

$$v_o = i_o R_L = 100 \times 10^{-3} \times 10^3 = 100 \text{ V}$$

$$A_v = \frac{v_o}{v_i} = \frac{100}{0.1} = 1000 \text{ or } 60 \text{ dB}$$

$$A_i = \frac{i_o}{i_i} = \frac{100 \times 10^{-3}}{10^{-3}} = 100 \text{ or } 40 \text{ dB}$$

$$A_p = A_v A_i = 1000 \times 100 = 10^5 \text{ or } 50 \text{ dB}$$

1.15

(a) From Eq. (1.23)

$$A_v = \frac{A_{vo}}{(1 + R_s/R_i)(1 + R_o/R_L)}$$

$$= \frac{150}{(1 + 200/1800)(1 + 50/4700)} = 133.6$$

From Eq. (1.24)

$$A_i = \frac{A_{vo} R_i}{R_L + R_o} = \frac{150 \times 1800}{4700 + 50} = 56.84$$

From Eq. (1.25)

$$A_p = A_v A_i = 133.6 \times 56.84 = 7593.82$$

(b) Problem 1.15 Amplifier

```
VS     1  0   AC   100MV
RS     1  2   200
RI     2  0   1.8K
E1     3  0   2  0   150
R0     3  4   50
RL     4  0   4.7K
. TF   V(4)   VS
. End
```

1.16

For maximum power transfer

$$R_o = R_L = 50\ \Omega$$

$$P_L = v_o i_o$$

$$= (A_v v_i)(A_i i_i)$$

$$= \frac{A_{vo} \cdot v_i}{(1 + R_S/R_i)(1 + R_o/R_L)} \cdot \frac{A_{vo} R_i}{R_L + R_o} i_i$$

$$= \frac{A_{vo}^2 R_i R_L v_i}{(R_i + R_s)(R_L + R_o)} \cdot \frac{A_{vo} \cdot v_i}{(R_L + R_o)}$$

$$= \frac{A_{vo}^2 R_i R_L}{(R_L + R_o)^2 (R_i + R_s)} \cdot v_i^2$$

$$= \frac{A_{vo}^2 R_i R_L}{(R_L + R_o)^2 (R_i + R_s)} \cdot \frac{R_i^2 v_s^2}{(R_i + R_o)^2}$$

$$= \frac{A_{vo}^2 R_L R_i^3 v_S^2}{(R_L + R_o)^2 (R_i + R_s)^3}$$

$$\therefore \quad P_{L(max)} = \frac{150^2 \times 50 \times 1800^3 (100 \times 10^{-3})^2}{100^2 (1800 + 200)^3}$$

$$= 820 \text{ mW}$$

1.17

$$\frac{\Delta v_o}{v_o} = \frac{R_o}{R_L + R_o}$$

$$\frac{\Delta v_o}{v_o} = 0.15 = \frac{R_o}{1.5\text{ k} + R_o}$$

$$R_o = \frac{1.5 \times 10^3 \times 0.15}{0.85} = 264.7\ \Omega$$

1.18

(a) $$v_o = A_{vo}\, v_i \frac{R_L}{R_L + R_o} = A_{vo} \frac{R_L}{R_L + R_o} \cdot \frac{R_i \cdot V_s}{R_i + R_s}$$

$$= \frac{200 \times 22 \times 10^5 \times 50 \times 10^{-3}}{(22 + 20)\,(10^5 + 1500)} = 5.16\text{ V}$$

(b) From Problem 1.16

$$P_L = \frac{A_{vo}^2 \quad R_L\ R_i^3\ V_s^2}{(R_L + R_o)^2\ (R_i + R_S)^3}$$

$$= \frac{200^2 \times 22 \times 10^{15} \times (50 \times 10^{-3})^2}{(22 + 20)^2 \cdot (10^5 + 1500)^3}$$

$$= 1.19\text{ W}$$

(c) $A_v = \dfrac{v_o}{v_s} = \dfrac{5.16}{50 \times 10^{-3}} = 103.2$

(d) $A_i = \dfrac{i_o}{i_s}$, $\quad i_o = \dfrac{5.16}{22 + 20} = 122.86\text{ mA}$

$$i_s = \frac{v_s}{R_s + R_i} = \frac{50 \times 10^{-3}}{1500 + 10^5} = 4.93 \times 10^{-7}\text{ A}$$

$$A_i = \frac{122.86 \times 10^{-3}}{4.93 \times 10^{-7}} = 249 \times 10^3$$

(e) $A_p = A_v\, A_i \;= 103.2 \times 249 \times 10^3$
$\qquad = 25.7 \times 10^6$

1.19

$$i_s \le 1\ \mu\text{A} = \frac{v_s}{R_s + R_i} = \frac{10 \times 10^{-3}}{2.5\text{k} + R_i}$$

$R_i \geq 7500\ \Omega$

From Eq. (1.27)

$$\frac{\Delta v_o}{v_o} = \frac{R_o}{R_L + R_o}, \quad R_L \text{ ranging from 2 k}\Omega \text{ to 10 k}\Omega$$

For $\frac{\Delta v_o}{v_o} \leq 0.5\%$

$$\frac{5}{1000} = \frac{R_o}{R_L + R_o}, \; R_o \leq 10\ \Omega$$

$$A_v = \frac{5\text{ V}}{10\text{ mV}} = 500 \text{ or } 53.98\text{ dB}$$

From Eq. (1.23)

$$500 = \frac{A_{vo}}{(1 + R_s/R_i)(1 + R_o/R_L)} = \frac{A_{vo}}{(1 + 2.5\text{ k}/7.5\text{ k})(1 + 10/2000)}$$

$$\therefore \quad A_{vo} = 669.8$$

1.20

From Eq. (1.23)

$$A_v = \frac{A_{vo}}{(1 + R_s/R_i)(1 + R_o/R_L)}$$

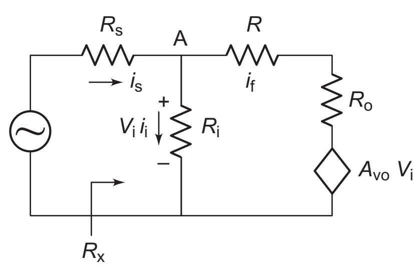
Variation in A_v will be contributed by A_{vo}, R_S, and R_L. Assume equal contribution by each. Hence the value of R_o that will keep the variation in gain within 0.5% for variation in R_L from 5 kΩ to 20 kΩ can be found from

$$\frac{5\text{k}}{5\text{k} + R_o} = \frac{20\text{k}}{20\text{k} + R_o} \times 0.995$$

$$R_o = \frac{20\text{k}\,(1 - 0.995)}{4 \times 0.995 - 1} \geq 33.5\ \Omega$$

1.21

(a) By Kirchoff's current law at node A



$$i_s = i_i + i_f = \frac{v_i}{R_i} + \frac{v_i - A_{vo}\,v_i}{R + R_o}$$

$$= v_i\left[\frac{1}{R_i} + \frac{1 - A_{vo}}{R + R_o}\right]$$

$$R_x = \frac{v_i}{i_s} = \frac{1}{1/R_i + (1 - A_{vo})/(R + R_o)}$$

(b) For $R_i = 50$ k, $R_o = 75\ \Omega$, $A_{vo} = 2$, $R = 10$ k

$$R_x = \frac{1}{1/50\text{ k} + (1-2)/(10\text{ k} + 75)}$$

$$= -12.62\text{ k}\Omega$$

$$i_s = \frac{V_s}{R_s + R_x} = \frac{20\text{ mV}}{1.5\text{ k}\Omega - 12.62\text{ k}\Omega} = -1.8\ \mu\text{A}$$

(c) For $i_s = 2.5\ \mu$A, $R_s + R_x = \dfrac{v_s}{i_s}$

$$= \frac{20\text{ mV}}{-2.5\ \mu\text{A}} = -8\text{ k}\Omega$$

$$\therefore \quad R_x = -8\text{ k} - 1.5\text{ k} = -9.5\text{ k}\Omega$$

1.22

$$A_{is} = 200,\ R_i = 150\ \Omega,\ \ R_o = 2.5\text{ k}\Omega$$

$$R_L = 100\ \Omega,\ i_s = 4\text{ mA},\ R_s = 47\text{ k}\Omega$$

(a) From Eq. (1.30)

$$A_i = \frac{A_{is}}{(1 + R_i/R_s)(1 + R_L/R_o)} = \frac{200}{(1+150/47\text{ k})(1+100/2500)}$$

$$= 191.7$$

$$A_v = A_i \frac{R_L}{R_s} = 191.7 \times \frac{100}{47\text{k}} = 0.4078$$

$$A_p = A_v A_i = 191.7 \times 0.407 = 78.17$$

(b) Problem 1.22a Amplifier

```
VS      1  0     AC  1MV
RS      1  2    47K
RI      3  0    150
F1      0  4     VX  200
VX      2  3     0V
VY      4  5     DC   0V
R0      4  0   2.5K
RL      4  0    100
. TF    V(s)     VS
. END
```

Problem 1.22b Amplifier

```
IS     0  1    AC  1MA
RS     1  0    47K
RI     2  0    150
F1     0  3    VX  200
VX     1  2    DC   0V
VY     3  5    DC   0V
R0     3  0   2.5K
RL     5  0    100
. TF   I(VY)   IS
. END
```

1.23

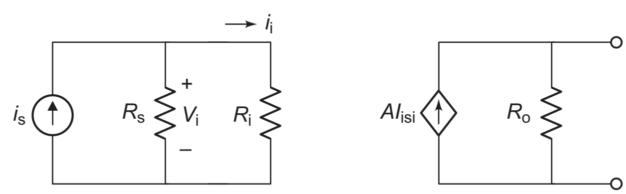
From Eqs. (1.28) and (1.29)

$$i_o = \frac{A_{is}\, R_o}{R_o + R_L} \cdot \frac{R_s}{R_s + R_i} \cdot i_s$$

$$= \frac{10 \times 22 \times 10^3}{22 \times 10^3 + 150} \times \frac{100 \times 10^3}{10^5 + 50} \times 50 \times 10^{-3}$$

$$= 4.96 \text{ A}$$

1.24



(a) Output resistance $= \dfrac{\text{open-circuit voltage}}{\text{short-circuit current}}$

$$= \frac{12}{100 \times 10^{-3}} = 120\ \Omega$$

$$A_{is}\, i_i = \text{short circuit current} = 100 \times 10^{-3} \text{ A}$$

$$i_i = i_s \frac{R_s}{R_i + R_s} = \frac{5 \times 10^{-6} \times 100 \text{ k}}{50 + 100 \text{ k}} \simeq 5 \times 10^{-6} \text{ A}$$

$$A_{is} = \frac{100 \times 10^{-3}}{5 \times 10^{-6}} = 20 \times 10^3$$

$$A_v = \frac{v_o}{v_s} = A_{is}\, i_L \frac{R_o}{R_o + R_L} \cdot \frac{R_L}{i_s R_s}$$

$$= 100 \times 10^{-3} \times \frac{120}{120 + 2700} \times \square \frac{2700}{5 \times 10^{-6} \times 10^{5}}$$

$$= 22.98$$

(b) $$A_i = \frac{20 \times 10^3}{(1 + 50/100\text{ k})(1 + 2.7\text{ k}/120)} = 850.6$$

(c) $A_p = A_v A_i = 22.98 \times 850.6$

$= 19{,}547$

1.25

Following Example 1.4 we have

$$0.99 \frac{R_o}{R_o + 20} = \frac{R_o}{R_o + 500}$$

$$R_o (1 - 0.99) = 500 \times 0.99 - 20$$

$$R_o = 47.5\text{ k}\Omega$$

For R_i

$$0.99 \times \frac{100\text{ k}}{100\text{ k} \times R_i} = \frac{10\text{ k}}{10\text{ k} + R_i}$$

$$R_i = 111.23\ \Omega$$

$$A_{is} = \frac{20 \times 10^{-3}}{100 \times 10^{-6}} = 200\text{ A/A}$$

1.26

Assume A_i varies equally due to contribution from A_{is} R_s, and R_o.

$$\frac{R_o}{R_o + R_L} = 0.995, \quad \frac{R_o}{R_o + 100} = 0.995$$

$$R_o = \frac{100 \times 0.995}{1 - 0.995} \geq 19.9\text{ k}\Omega$$

Similarly

$$\frac{R_s}{R_s + R_i} = 0.995, \quad \frac{100\text{ k}}{100\text{ k} + R_i} = 0.995$$

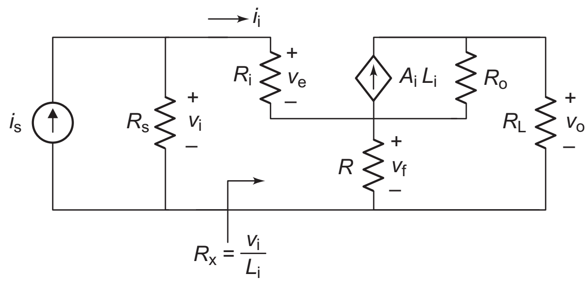
$$R_i \leq 503\ \Omega$$

$$A_i = \frac{A_{is}}{(1 + R_i/R_s)(R_L/R_o)}$$

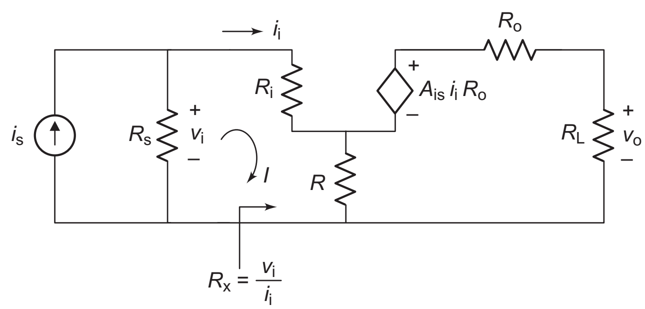
$$50 = \frac{A_{is}}{(1 + 503/100\text{ k})(1 + 100/19.9\text{ k})} \simeq A_{is}$$

$\therefore \quad A_{is} \simeq 50$

1.27



(a) R allows a voltage that is proportional to lead current i_o to be fed back to the input side. Converting current source to voltage source



Applying KVL to loop II

$$A_{is} R_o i_i = R_o i_o = R(i_i - i_o) + R_L i_o$$

$$= (R_o + R_L + R)\, i_o - R i_i$$

$$i_o = \frac{A_{is} R_o + R}{R_o + R_L + R}\, i_i \qquad (1)$$

Applying KVL to loop I

$$v_i = R_i i_i + R(i_i - i_o)$$

$$= (R_i + R)\, i_i - R i_o \qquad (2)$$

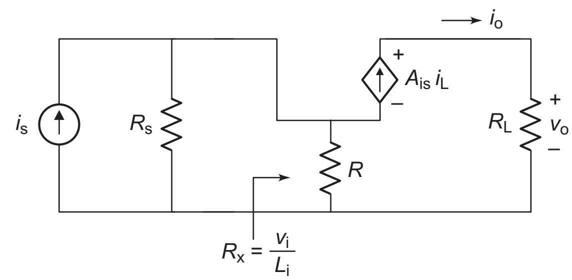
Substituting i_o from Eq. (1) into Eq. (2) and simplifying

$$v_i = (R_i + R)\, i_i - R \cdot \frac{A_{is} R_o + R}{R_o + R_L + R}\, i_i$$

$$\frac{v_i}{i_i} = R_i + R - R\, \frac{A_{is} R_o + R}{R_o + R_L + R}$$

$$R_x = \frac{v_i}{i_i} = R_i + \mathrm{R} - R\frac{\left(A_{is} + R/R_o\right)}{1 + (R_L + R)/R_o}$$

(b) Assume ideal current amplifier with $R_i = 0$ and $R_o = \infty$, we have the reduced figure as



$R_x = R - RA_{is} = R(1 - A_{is})$

For $A_{is} > 1$, R_x is negative, and if $A_{is} = 2$

$R_x = -R$

For $R_x = -10$ kΩ we need $R = 10$ kΩ.

Thus an ideal current amplifier with $A_{is} = 2$ and $R = 10$ kΩ will simulate a negative resistance.

1.28

(a) Using the result of Problem 1.27 for $A_{is} = 2$ and substituting R by impedances $Z(s)$

$$Z_x = \frac{V_i(s)}{I_i(s)} = -Z(s) = -\left[R + \frac{-R\left(R + 1/sC\right)}{-R + R + 1/sC}\right]$$

$$= -[R - sCR^2 - R] = sCR^2$$

$Z_x = sL_e$ where the effective inductance L_e is given by CR^2. Thus, the circuit simulates an inductance.

(b) To simulate $L_e = 10$ mH, let $C = 0.01$ μF,

$$10 \times 100^{-3} = 0.01 \times 10^{-6} \times R^2$$

$$R^2 = 10^6,\ R = 1\ \text{k}\Omega$$

(c) Problem 1.28 Inductance Simulation

```
IS    0    4    AC   1MA
V1    4    1    DC    0V
F1    1    0    V1    2
R1    1    2    1K
R2    2    3    1K
C1    3    0    0.01UF
V2    2    5    DC    0V
R3    5    0    1K
F2    5    0    V2    2
.AC LIN  10   1K   10K
.PRINT   AC   VM(1)VP(1)
.END
```

1.29

(a) $$v_o = -G_{m1}\, v_i(s) \cdot \frac{1}{sC}$$

$$i_i(s) = -G_{m2}\, v_o(s) = G_{m1}\, G_{m2}\, \frac{v_i(s)}{sC}$$

$$Z_i = \frac{v_i(s)}{i_i(s)} = \frac{SC}{G_{m1}G_{m2}}$$

$$Z_i(j\omega) = j\omega\, \frac{C}{G_{m1}G_{m2}}$$

(b) Problem 1.29 Amplifier

```
VS    1    0    AC    1V
RS    1    2    100
G1    0    2    3 0   3M
G2    3    0    2 0   3M
C1    3    0    0.1UF
R1    3    0    100M
. TRAN15US1.5 MS
. PROBE
. END
```

1.30

Assuming that the discharging time constant $\tau = CR_i$ is related to the input frequency by $\tau = 10/f$,

$$CR_i = \frac{10}{60 \times 10^3}$$

(a) Let $C = 0.1$ μF, then $R_i = \dfrac{10}{0.1 \times 10^{-6} \times 60 \times 10^3}$

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

(b) Variation in G_m, according to Eq. (1.36), will be contributed by G_{ms} and R_L. Assume equal contributions, $R_s = 0$. The gain parameter

$$G_{ms} = \frac{i_o}{v_s} = \frac{20 \text{ cm}}{170 \text{ V}} \times \frac{5 \text{ mA}}{1 \text{ cm}}$$

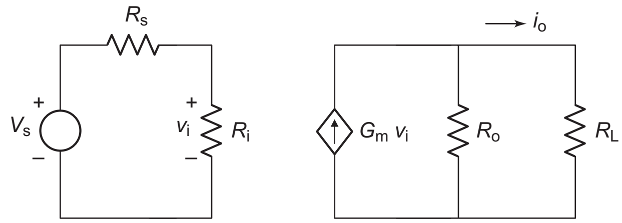
$$= 0.588 \text{ mA/V} \pm 1\%$$

The value of R_o that will keep gain variation within 1% for variation in R_L from 20 Ω to 500 Ω can be found from

$$0.99\, \frac{R_o}{R_o + 20} = \frac{R_o}{R_o + 500}$$

$$R_o \geq 47.5 \text{ k}\Omega$$

1.31



$$\frac{R_i}{R_i + R_s} \geq .99, \quad R_i\,(1 - 0.99) \geq 0.99\, R_s$$

For $R_s = 1$ kΩ,

$$R_i \geq \frac{0.99 \times 1\text{ k}}{0.01} = 99\text{ k}\Omega$$

Similarly

$$\frac{R_o}{R_o + R_L} \geq 0.99, \qquad R_o \geq \frac{0.99 \times 200}{0.01}$$

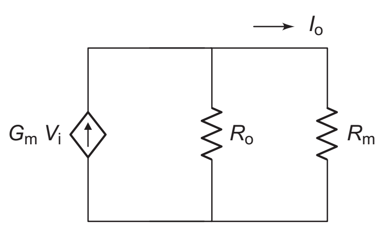
$$R_o \geq 19.8\text{ k}\Omega$$

1.32

For $R_m =$ 20 Ω to 100 Ω

$$\frac{0.99}{R_o + 20} = \frac{1}{R_o + 100}$$

$$R_o = 7.9\text{ k}\,\Omega$$



For R_s varying from 2 kΩ to 5 kΩ

$$\frac{0.99}{R_i + 2\text{k}} = \frac{1}{R_i + 5\text{k}}, \; R_i\,(1 - 0.99) = 5\text{ k} \times 0.99 - 2\text{ k}$$

$$R_i = 295\text{ k}\Omega$$

For $v_s = 10$ V, $I_o = 100$ mA

$$G_m = \frac{I_o}{v_s} = \frac{100\text{ mA}}{10\text{ V}} = 10\text{ mA/V}$$

Transconductance amplifier

1.33

Using Eq. (1.41)

$$Z_m = \frac{Z_{mo}}{(1 + R_o/R_L)(1 + R_i/R_s)} = \frac{0.5\text{ k}}{(1 + 4.7\text{ k}/4.7\text{k})(1 + 1.5\text{ k}/10\text{k})}$$

$$= 217.39\text{ V/A}$$

From Eq. (1.42)

$$A_v = \frac{Z_{mo}\ R_L}{(R_s + R_i)(R_L + R_o)} = \frac{0.5 \times 10^3 \times 4.7 \times 10^3}{(10 \times 10^3 + 1.5 \times 10^3)(4.7 \times 10^3 + 4.7 \times 10^3)}$$

$$= 21.739 \times 10^{-3}$$

$$i_i = \frac{R_s}{R_s + R_i} \cdot i_s = \frac{10^4 \times 50 \times 10^{-3}}{10^4 + 1.5 \times 10^3} = \frac{500}{11.5 \times 10^3}\text{ mA}$$

From Eq. (1.39)

$$v_o = Z_{mo}\frac{i_i\ R_L}{R_L + R_0} = 0.5\text{ k} \times \frac{500}{11.5 \times 10^3} \times \frac{4.7 \times 10^3}{(4.7 \times 10^3 + 4.7 \times 10^3)}$$

$$= 10.87\text{ V}$$

$$i_o = \frac{10.87}{4.7 \times 10^3} = 2.31 \times 10^{-3}\text{ A}$$

$$A_i = \frac{i_o}{i_s} = \frac{2.3 \times 10^{-3}}{50 \times 10^{-3}} = 0.046$$

1.34

Since the output variation should be kept within ±2%, variation of effective transimpedance Z_m should be kept to ±2%. According to Eq. (1.41) the variation in Z_m will be contributed by Z_{mo} and R_o. Assume equal contribution to the variation.

Let $R_i = 10\ \Omega$. Then

$$Z_{mo} = \frac{10\text{ V}}{2\text{ cm}} \times \frac{20\text{ cm}}{100\text{ mA}} = 1000\text{ V/A} \pm 1\%$$

The value of R_o that will keep gain variations within 1% for variation of R_L from 2 kΩ to 10 kΩ is

$$\frac{0.99 \times 10\text{ k}}{10\text{ k} + R_o} = \frac{2\text{ k}}{2\text{ k} + R_o}$$

$$R_o \cong 25\ \Omega$$

Design specifications are $Z_{mo} = 1000$ V/A, $R_o \le 25\ \Omega$, and $R_i \le 10\ \Omega$.

1.35

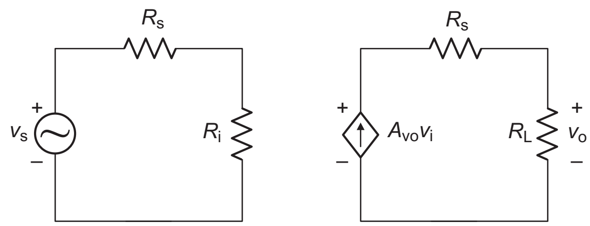
Let $R_i = 10\text{ k} << R_s$

$$i_i = \frac{R_s}{R_s + R_i} \cdot i_s = \frac{10^5 \times 0.5}{10^5 + 10^4} = 454.5\text{ mA}$$

$$\frac{R_s}{R_i + R_s} = 0.99, \quad R_i \times 0.99 + 0.99R_s = R_s$$

$$R_i = \frac{R_s\,(1-0.99)}{0.99} = \frac{100\text{ k}\times 0.01}{0.99}$$
$$= 101\text{ k}\Omega$$
$$\frac{R_m}{R_m + R_o} = 0.99, \quad R_o = \frac{R_m\,(1-0.99)}{0.99}$$
$$= \frac{20\text{ k}\times 0.01}{0.99} = 202$$
$$Z_{mo} = \frac{V_o}{i_i} = \frac{5}{454\cdot 5\times 10^{-3}} = 11\ \text{V/A} \pm\ 1\%$$

1.36



Voltage amplifier

For ideal voltage amplifier

$$R_o = 0 \text{ and } R_i = \infty$$
$$v_o = A_{vo}\, v_i \qquad (1)$$

For ideal current amplifier

$$R_o = \infty,\ R_i = 0$$
$$i_o = A_{is}\, i_s \qquad (2)$$
$$\therefore \quad v_o = A_{vo}\, v_i = i_o\, R_o = A_{is}\, i_s\, R_o = A_{is}\, i_i\, R_o$$

Using $v_i = i_i\, R_i$

$$A_{vo}\, i_i\, R_i = A_{is}\, i_i\, R_o$$
$$A_{vo} = A_{is}\,\frac{R_o}{R_i} \qquad (3)$$

For ideal transconductance amplifier

$$i_o = G_{ms}\, v_s \quad \text{for } R_o = \infty, \quad R_i = \infty$$
$$v_o = A_{vo}\, v_i = i_o\, R_o = G_{ms}\, v_i\, R_o$$
$$\therefore A_{vo} = G_{ms}\, R_o \qquad (4)$$

For ideal transimpedance amplifier

$$R_i = 0, \quad R_o = 0$$
$$v_o = Z_{mo}\, i_s = Z_{mo}\cdot i_i$$
$$v_o = A_{vo}\, v_i = Z_{mo}\,\frac{v_o}{R_i}$$
$$\therefore \quad A_{vo} = \frac{Z_{mo}}{R_i} \qquad (5)$$

Using $A_{vo} = A_{is}\,\dfrac{R_o}{R_i}$

$$A_{is} = A_{vo}\,\frac{R_i}{R_o} = 250 \times \frac{50\times10^3}{1\times10^3} = 12{,}500 \text{ A/A}$$

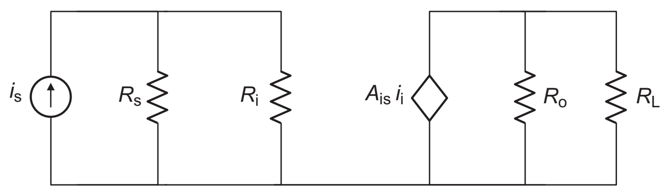
$$A_{vo} = G_{ms}\,R_o,\quad G_{ms} = \frac{A_{vo}}{R_o} = \frac{250}{1000}$$

$$= 0.25 \text{ A/V}$$

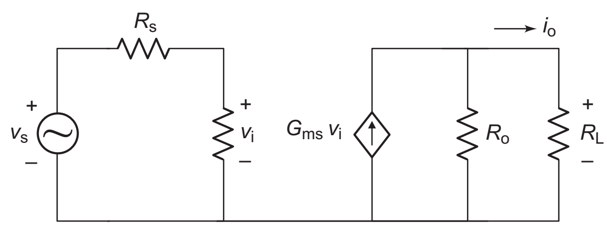
$$Z_{mo} = A_{vo}\cdot R_i = 250\times 50\times10^3$$

$$= 12.5 \text{ M}\Omega$$

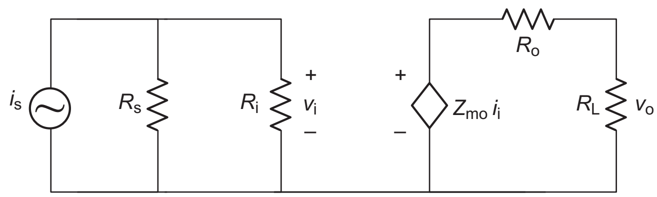
Equivalent amplifiers are:



Equivalent current amplifier

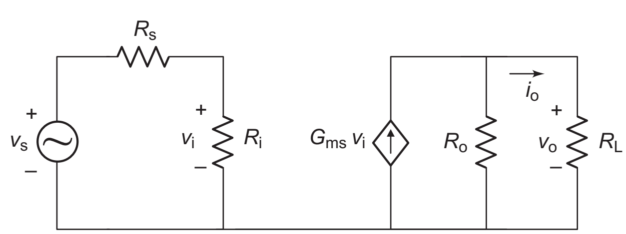


Equivalent transconductance amplifier



Equivalent transimpedance amplifier

1.37



Transconductance amplifier

$G_{ms} = 20$ mA/V

$$A_{vo} = G_{ms} R_o = 20 \times 10^{-3} \times 2 \times 10^3 = 40 \text{ V/V}$$

$$A_{vo} = A_{is} \frac{R_o}{R_i}$$

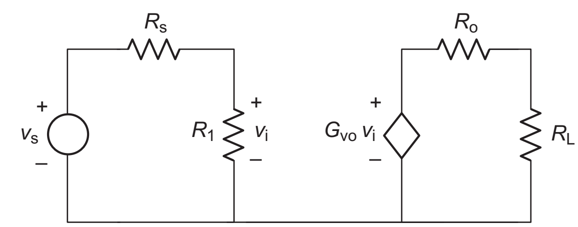
$$\text{or } A_{is} = A_{vo} \cdot \frac{R_i}{R_o} = \frac{40 \times 100 \times 10^3}{2 \times 10^3}$$

$$= 40 \times 50 = 2000 \text{ A/A}$$

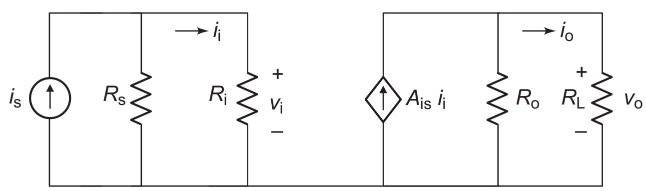
$$Z_{mo} = A_{vo} \cdot R_i = 40 \times 100 \times 10^3$$

$$= 4 \text{ M}\Omega$$

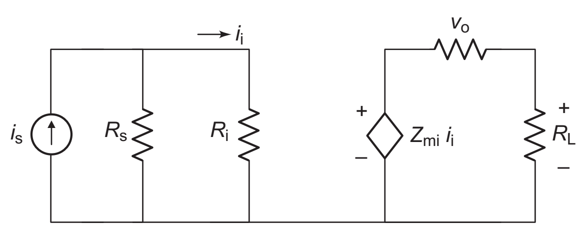
Equivalent circuits



Voltage amplifier



Current amplifier



Transimpedance amplifier

1.38

(a) From Eq. (1.21)

$$A_{v1} = A_{v2} = A_{vo} \frac{R_{i2}}{R_{i2} + R_{o1}} = \frac{50 \times 2.5 \times 10^3}{2.5 \times 10^3 + 100}$$

$$= 48$$

From Eq. (1.45), the overall open-circuit voltage gain

$$A_{vo} = \frac{V_o}{V_i} = A_{v1} \cdot A_{v2} \cdot A_{v3}$$

$$= 48 \times 48 \times 50 = 115{,}200 \quad \text{or} \quad 101.22 \text{ dB}$$

Total effective voltage gain using Eq. (1.23)

$$A_v = \frac{V_o}{V_s} = \frac{A_{vo} R_i R_L}{(R_i / R_s)(R_L / R_o)}$$

$$= \frac{115200 \times 2.5 \times 10^3 \times 2.5 \times 10^3}{(2.5 \times 10^3 + 200 \times 10^3)(2.5 \times 10^3 + 100)}$$

$$= 1367.5 \quad \text{or} \quad 62 \text{ dB}$$

Overall current gain

$$A_i = \frac{i_o}{i_i} = \frac{A_{vo} \cdot R_{i1}}{R_L + R_{o3}} = \frac{115200 \times 2500}{2500 + 100}$$

$$= 110{,}769 \text{ or } 100.9 \text{ dB}$$

$$A_p = \frac{P_L}{P_i} = A_v \cdot A_i = 1367.5 \times 110769$$

$$= 1.5 \times 10^8 \quad \text{or} \quad 81.7 \text{ dB}$$

(b) Problem 1.38 Cascaded Amplifier

```
VS     1  0   AC 100 MV
RS     1  2   200K
RI1    2  0   2.5K
E1     3  0   4    50
R01    3  4   100
RI2    4  0   2.5K
E2     5  0   40   50
R02    5  6   100
RI3    6  0   2.5K
E3     7  0   60   50
R03    7  8   100
RL     8  0   2.5K
. TF   V(8)   VS
. END
```

1.39

(a) Using Eq. (1.21), A_v of stage 1 and 2 is given by

$$A_{v1} = A_{v2} = \frac{A_{vo1}\, R_{i2}}{R_{i2} + R_{o1}} = \frac{80 \times 2500}{2500 + 100}$$

$$= 76.9$$

From Eq. (1.45), the overall open-circuit voltage gain

$$A_{vo} = A_{v1} \cdot A_{v2} \cdot A_{vo3} = 76.9^2 \times 80 = 473{,}088 \quad \text{or} \quad 113.5 \text{ dB}$$

From Eq. (1.23)

$$A_v = \frac{A_{vo} \cdot R_i\, R_L}{(R_i + R_s)(R_L + R_o)} = \frac{473{,}088 \times 2500 \times 1500}{(2500 + 200 \times 10^3)(1.5 \times 10^3 + 300)}$$

$$= 4867 \quad \text{or} \quad 73.7 \text{ dB}$$

$$A_i = \frac{A_{vo}\ R_{Li}}{R_L + R_{o3}} = \frac{473,088 \times 2500}{1.5 \times 10^3 + 300} = 657{,}066.7 \quad \text{or} \quad 116.6\text{ dB}$$

$$A_p = A_v A_i = 4867 \times 657{,}066.7 = 3.19 \times 10^9 \quad \text{or} \quad 95\text{ dB}$$

(b) Problem 1.39 Cascaded Amplifier

```
VS     1  0   AC100MV
RS     1  2   200K
RI1    2  0   2.5K
E1     3  0   2 0 80
R01    3  4   100
RI2    4  0   2.5K
E2     5  0   4 0 80
R02    5  6   100
RI3    6  0   2.5K
E3     7  0   6080
R03    7  8   300
RL     8  0   1.5K
. TF   V(8)   VS
. END
```

1.40

(a)

$$i_o = \frac{A_{is3}\ i_{i3}\ R_{o3}}{R_{o3} + R_L} = \frac{A_{is3}\ R_{o3}}{R_{o3} + R_L}\ \frac{A_{is2}\ i_{i2}\ R_{o2}}{R_{o2} + R_{i3}}$$

$$= \frac{A_{is3}\ A_{is2}\ R_{o3} R_{o2}}{(R_{o3} + R_L)(R_{o2} + R_{i3})} \cdot \frac{A_{is1} i_{i1} R_{o1}}{(R_{o1} + R_{i2})}$$

$$= \frac{A_{is3}\ A_{is2}\ A_{is1}\ R_{o3} R_{o2}\ R_{o1}}{(R_{o3} + R_L)(R_{o2} + R_{i3})(R_{o1} + R_{i2})} \cdot \frac{R_s\ i_i}{R_s + R_{i1}}$$

$$A_i = \frac{i_o}{L_s} = \frac{A_{is3}\ A_{is2}\ A_{is1}\ R_{o3} R_{o2}\ R_{o1}}{(R_{o3} + R_L)(R_{o2} + R_{i3})(R_{o1} + R_{i2})} \cdot \frac{R_s}{(R_s + R_{i1})}$$

$$= \frac{100^3 (4.7 \times 10^3)^3 \times 20 \times 10^3}{(4700 + 100)(4700 + 100)(4700 + 100)(20 \times 10^3 + 100)}$$

$$= 934{,}122 \quad \text{or} \quad 119.4\text{ dB}$$

$$A_v = \frac{V_o}{V_s} = \frac{i_o}{i_{i1}} \frac{R_i}{\cdot R_{i1}} \text{ on substitution for } A_v \text{ from above}$$

$$A_v = \frac{A_{is3}\ A_{is2}\ A_{is1}\ R_{o3}\ R_{o2}\ R_{o1}\ R_L}{(R_{o3} + R_L)(R_{o2} + R_{i3})(R_{o1} + R_{i2}) R_{i1}}$$

$$= \frac{10^6 \times 10^9 \times 4.7^3 \times 10^2}{48^3 \times 10^6 \times 10^2}$$

$$= 42{,}498.5 \quad \text{or} \quad 92.56\text{ dB}$$

$$A_P = A_v A_i = 42{,}498.5 \times 934{,}122 = 3.97 \times 1010 \text{ or } 105\text{ dB}$$

(b) Problem 1.40 Cascaded Current Amplifier

```
IS     1  0   AC 100MA
RS     1  0   20K
V1     1  2   DC  0V
RI1    2  0   100
F1     0  3   V1 100
R01    3  0   4.7K
V2     3  4   DC  0V
RI2    4  0   100
R02    5  0   4.7K
V3     5  6   DC 0V
RI3    6  0   100
F3     7  0   V3 100
R03    7  0   4.7K
VX     7  8   DC  0V
RL     8  0   100
. TF I(VX)IS
. END
```

1.41

(a)

$$i_o = \frac{G_{ms}\ V_{i2}\ R_{o2}}{R_{o2} + R_L} = -\frac{G_{ms}\ R_{o2}}{R_{o2} + R_L} \cdot \frac{Z_{mo}\ \ i_i\ R_{i2}}{R_{o1} + R_{i2}}$$

$$A_i = \frac{i_o}{i_i} = \frac{-20 \times 10^{-3} \times 10^5}{10^5 + 10^3} \times \frac{10^4 + 10^6}{200 + 10^6} = -198$$

$$A_v = \frac{V_o}{V_i} = \frac{+i_o\ R_L}{i_i\ R_{i1}} = -\frac{198 \times 10^3}{50 \times 10^3} = -3.96$$

$$A_p = A_i\, A_v = -198 \times -3.96 = 784$$

(b) Problem 1.41 Transconductance Amplifier

```
VS     1  0   AC10MV
RS     1  2   5K
VX     2  3   DC  0V
RI1    3  0   50K
H1     4  0   VX 10K
R01    4  5   200
RI2    5  0   1MEG
G1     6  0   5   0    20M
R02    6  0   100K
RL     6  0   1K
. TF   V(6)  VS
. END
```

1.42

From Eq. (1.54d)

$$f_L = \frac{1}{2\pi R_1 C_1} = \frac{1}{2\pi\, x\, 147K\Omega\, x\, 0.1nF} = 10.8\,KHz$$

1.43

From Eq. (1.54d)

$$f_L = \frac{1}{2\pi R_1 C_1}$$

$$R_1 = \frac{1}{2\pi f_L C_1} = \frac{1}{2\pi\, x\, 4\, x\, 10^3\, x\, 0.01\, x\, 10^{-6}} = 3.979K\Omega$$

1.44

From Eq. (1.59d)

$$f_H = \frac{1}{2\pi\, x\, 147\, x\, 10^3\, x\, 0.1\, x\, 10^{-9}} = 10.8\,KHz$$

1.45

From Eq. (1.59d)

$$f_H = \frac{1}{2\pi R_2 C_2}$$

$$R_2 = \frac{1}{2\pi f_H C_2} = \frac{1}{2\pi\, x\, 25\, x\, 10^3\, x\; 0.01\, x\, 10^{-6}} = 636.6\,K\Omega$$

1.46

$$A_v(j\omega) = \frac{200}{1 + j\omega/100} = \frac{2\times 10^4}{100 + j\omega}$$

$$|A_v(j\omega)| = \frac{210^4}{\sqrt{\omega^2 + 10^4}}$$

(a) $$100 = \frac{2\times 10^4}{\sqrt{\omega_H^2 + 10^4}},\ \omega_H = \sqrt{3\times 10^4}$$

$$= 173.2 \text{ rad/s}$$

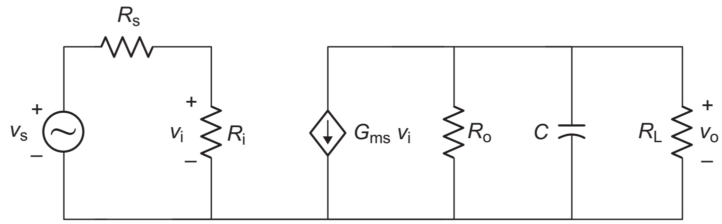
$$f_H = \frac{173.2}{2\pi} = 27.56 \text{ Hz} = \text{BW}$$

(b) $$50 = \frac{2\times 10^4}{\sqrt{\omega_H^2 + 10^4}},\ \omega^2_H \times 10^4 = 16\times 10^4$$

$$\omega_H = 387.29 \text{ rad/s}$$

$$f_H = \frac{387.29}{2\pi} = 61.64 \text{ Hz} = \text{BW}$$

1.47



(a)

$$v_o = -G_{ms}\, v_i \left(R_o \,\|\, \frac{1}{sC} \,\|\, R_L\right)$$

$$= -20 \times 10^{-3}\, v_i \left(980 \,\|\, \frac{1}{sC}\right) \qquad \text{(i)}$$

$$v_i = \frac{5 \times 10^5 v_s}{505 \times 10^3} = 0.99\, v_s \text{ then}$$

$$v_o = -20 \times 10^{-3} \times (0.99\, v_s) \times \left(980 \,\|\, \frac{1}{sC}\right)$$

$$A_v = \frac{-20 \times 10^3 \times 0.99 \times 980}{1 + 980\, j\omega C} = \frac{-19.404}{1 + j\omega 980 \times 0.1 \times 10^{-6}}$$

$$A_{v(mid)} = 19.404$$

$$\omega_H = \frac{10^6}{980 \times 0.1} = 10{,}204$$

$$f_H = \frac{10204}{2\pi} = 1624 \text{ Hz}$$

$$f_{bw} = A_{v(mid)} \times f_H = 19.404 \times 1624 = 31{,}512$$

(b)

$$R_L = 10\ \text{k}\Omega, \quad R_o \,\|\, R_L = 10\ \text{k} \,\|\, 50\ \text{k} = 8333\ \Omega$$

$$A_v = \frac{-20 \times 10^{-3} \times 0.99 \times 8333}{1 + j\omega\, 8333 \times 0.1 \times 10^{-6}} = -\frac{165}{1 + j\omega \times 833.3 \times 10^{-6}}$$

$$\omega_H = \frac{10^6}{833.3}, \quad f_H = 190 \text{ Hz}$$

$$f_{bw} = 165 \times 190 = 31{,}350$$

1.48

$$v_o = -g_m\, v_i \left(R_L \,\|\, \frac{1}{sC_L}\right) = \frac{-v_i g_m R_L}{1 + sR_L C_2}$$

$$= \frac{-v_i\, g_m}{C_2\,(s + 1/R_L C_2)} \qquad (1)$$

$$v_i = \frac{v_s R_i}{R_s + R_i + 1/sC_i} = \frac{v_s\, R_i s}{(R_s + R_i)[s + 1/C_i(R_s + R_i)]} \qquad (2)$$

From (1) and (2)

$$v_o = -\frac{v_s\, g_m\, R_i s}{C_2(R_s + R_i)(s + 1/R_L C_2)[s + 1/C_i(R_s + R_i)]}$$

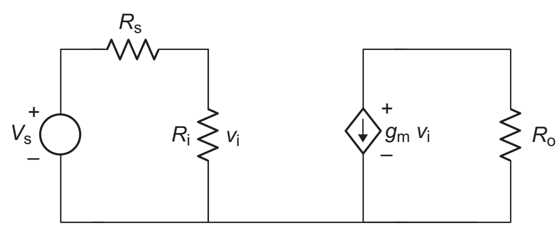
$$\omega_H = \frac{1}{R_L C_2} = \frac{1}{10 \times 10^3 \times 10 \times 10^{-12}} = 10^7 \text{ rad/s}$$

$$\text{or } f_H = \frac{10^7}{2\pi} = 1.59 \text{ MHz}$$

$$\omega_L = \frac{1}{C_1(R_s + R_i)} = \frac{1}{20 \times 10^{-6} \times 1500} = \frac{100}{3} \text{ rad/s}$$

$$f_L = \frac{100}{3 \times 2\pi} = 5.3 \text{ Hz}$$

For $A_{v(mid)}$



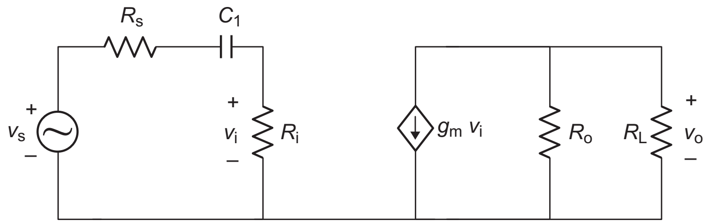
$$v_o = -g_m\, v_i\, R_o = -\frac{g_m R_i \cdot R_o}{R_s + R_i} v_s$$

$$= \frac{-15 \times 10^{-3} \times 10^4 \times 10^3}{1500} = -100$$

Problem 1.48

```
VS    1    0    AC    10MV
RS    1    2    500
C1    2    3    20UF
RI    3    0    1K
G1    4    0    3     0     15M
RL    4    0    10K
C2    4    0    10PF
.AC   DEC  100  1     10 MEG
.PRINT     AC   VM(4)
.PROBE
.END
```

1.49



Low-frequency equivalent circuit

$$v_o = -g_m v_i (R_o \| R_L) \quad = -15 \times 10^{-3} \times 5 \times 10^3 \, v_i$$

$$= -7.5 \, v_i \qquad \text{(i)}$$

$$v_i = \frac{R_i \, v_s}{R_s + R_i + 1/sC_1} = \frac{R_i \, sC_1 \, v_s}{1 + (R_s + R_1)sC_1}$$

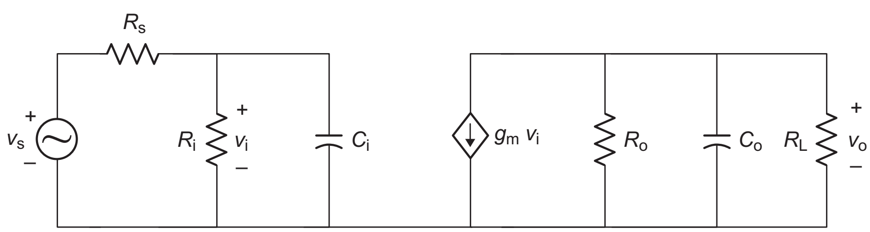
$$= \frac{v_s \, s \, 25 \times 10^3 \times 10 \times 10^{-6}}{1 + s(25 \times 10^3 + 1 \times 10^3) \, 10 \times 10^{-6}} = \frac{v_s \, s \, 0.25}{1 + 26 \times 10^{-2} s} \qquad \text{(ii)}$$

From (i) and (ii)

$$v_o = \frac{75 \times 0.255}{1 + 26 \times 10^{-2} s} \qquad \text{(iii)}$$

$$f_L = \frac{1}{26 \times 10^{-2} \times 2\pi} = 0.612 \text{ Hz}$$

For high-frequency equivalent circuit



$$v_o = -g_m v_i \left(R_o \, \| \, R_L \, \| \, \frac{1}{sC_o} \right)$$

$$= -15 \times 10^3 \, \frac{5 \times 10^3 v_i}{1 + 5 \times 10^3 \times 10 \times 10^{-12} s}$$

$$= \frac{-75 \, v_i}{1 + 5 \times 10^{-8} s}$$

$$v_i = \frac{(R_1 \, \| \, 1/sC_i) \, v_s}{R_s + R_i \, \| \, 1/sC_i}$$

$$= \frac{R_i \, v_s}{R_i + R_s + sR_i R_s C_i}$$

$$= \frac{25 \times 10^3 v_s}{25 \times 10^3 + 10^3 + s \times 25 \times 10^3 \times 10^3 \times 20 \times 10^{-12}}$$

$$= \frac{25\,v_s}{26 + s\,500 \times 10^{-9}} = \frac{25\,v_s}{26 + s \times 5 \times 10^{-7}}$$

$$A_{v(s)} = \frac{v_o}{v_s} = \frac{-75}{(1 + 5 \times 10^{-8} s)} \times \frac{25}{26 + 5 \times 10^{-7} s}$$

$$= \frac{-75 \times 25}{26\,(1 + 5 \times 10^{-8} s)\left(1 + 5 \times 10^{-7} s/26\right)}$$

$$f_H = \frac{1}{2\pi \times 5 \times 10^{-8}} = 3.18 \text{ MHz}$$

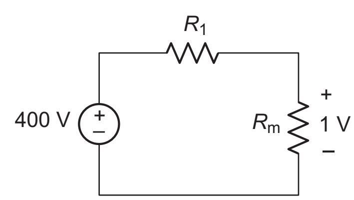
$$A_{v(mid)} = \frac{-75 \times 25}{26} = -72.1$$

Problem 1.49

```
VS     1   0   AC     10MV
RS     1   2   1K
C1     2   3   10UF
RI     3   0   25K
G1     4   0   3   0  15M
RL     4   0   10K
R0     4   0   10K
C0     4   0   10PF
. AC   DEC 100   1      10MEG
. PRINT AC VM(4)
. PROBE
. END
```

1.50

$$R_m = \frac{1\text{ V}}{I_m} = \frac{1\text{ V}}{100\ \mu\text{A}} = 10\text{ k}\Omega$$

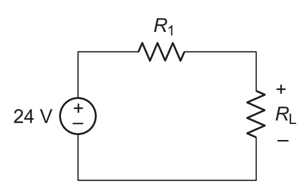


$$\frac{10\text{ k} \times 400}{R_1 + 10\text{ k}} = 1\text{ V},\ R_1 = 10\text{ k}\,(400 - 1) = 3990\text{ k}\Omega$$

Take $R_1 \simeq 4\text{ M}\Omega \pm 1\%$.

1.51

$$R_L = \frac{6\text{ V}}{5\text{A}} = 1.2\ \Omega$$

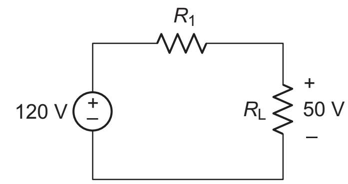


$$\frac{1.2 \times 24}{R_1 + 1.2} = 6\text{ V},\quad R_1 = \frac{1.2 \times 24}{6} - 1.2 = 3.6\ \Omega$$

Take $R_1 = 3.6\ \Omega \pm 5\%$.

1.52

$$\frac{V^2}{R_L} = \frac{50^2}{R_L} = 60\text{ W}$$



$$R_L = \frac{50^2}{60} = 41.667\ \Omega$$

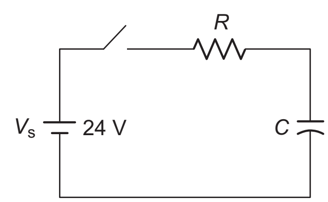
$$\frac{R_L \times 120}{R_1 + R_L} = 50\text{ V}$$

$$\frac{41.667 \times 120}{50} = R_1 + 41.667, \quad R_1 = 58.334\ \Omega$$

Take $R \simeq 62\ \Omega \pm 5\%$.

1.53

$$I_o = 1\text{ mA}$$



$$i(t) = \frac{V_s}{R}\ e^{-t/\tau}$$

$$\frac{V_s}{R} = \frac{24}{R} = 1\text{ mA}, \ R = 24\text{ k}\Omega \pm 5\%$$

1.54

$$|A_v| = \frac{V_O}{V_I} = \frac{400}{5} = 80, \quad Q = 60°$$