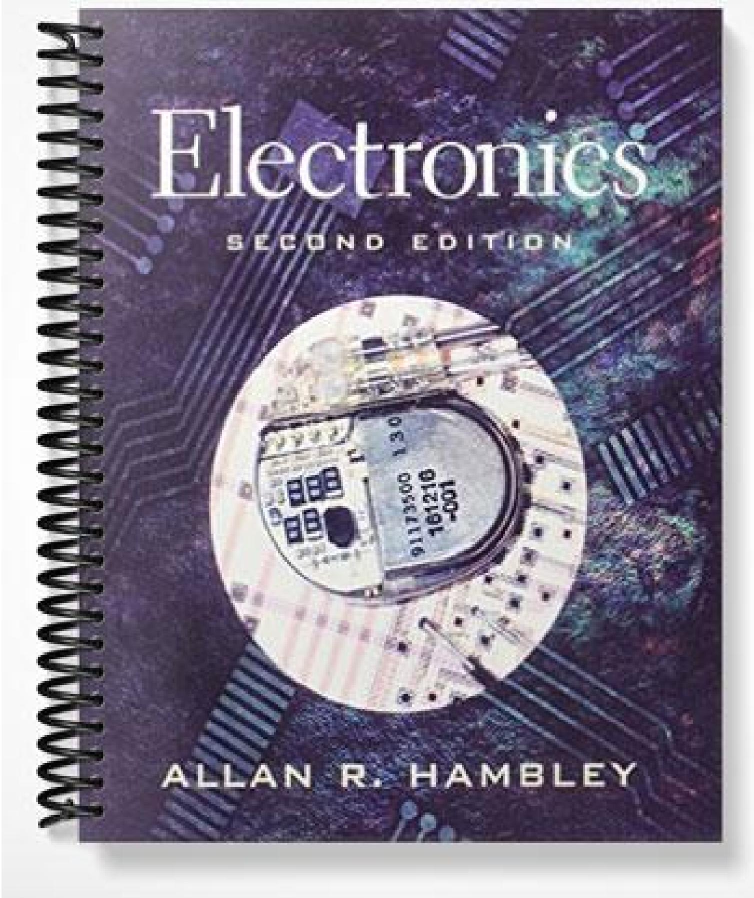
SOLUTIONS MANUAL



Solutions Manual Errata for
Electronics, 2nd ed. by Allan R. Hambley

Problem 1.17

In line two, change 3.135 W to 3.125 W.

Problem 1.29

In line one, inside the first integral, delete the exponent 2 on i_1.

In line four, change $\frac{20/\sqrt{2}}{8}$ to $\frac{\left(20/\sqrt{2}\right)^2}{8}$.

In line five, change I_{iavg} to I_{1avg}.

Problem 1.49

Toward the end of the solution, change "when R_s changes from 1 MΩ to 10 kΩ" to "when R_L changes from 1 MΩ to 10 kΩ".

Problem 1.50

Change "when R_s changes from 0 to 100 Ω" to "when R_L changes from 0 to 100 Ω".

Problem 1.62

In line two of Part (b), change $\frac{1}{2}(G_{m1} + G_{m2})R_L$ to $(G_{m1} - G_{m2})R_L$. Make the same change in line two of Part (c).

Problem 2.12

In Part (d), change $\frac{1}{j\omega(99C)}$ to $\frac{1}{j\omega(101C)}$.

In the last paragraph, change 99-pF to 101-pF.

Problem 2.14

After the figure, change $v_o = 8v_{in}$ to $v_o = -8v_{in}$ and change the gain from 8 to –8.

Problem 2.16

At the end of the solution, after "For $A_{OL} = 10^5$", change $A_v = -9.998$ to $A_v = -9.9989$ and change $-R_2/R_1 = 10$ to $-R_2/R_1 = -10$.

Problem 2.33

The problem statement should have specified W_{space} = 10 μm instead of 5 μm.

Problem 2.38

In the figure, change the upper 10-kΩ resistor (connecting the inverting input to the output of the first op amp) to 15 kΩ.

Problem 2.43

In Part (b), Equation (4), change R_1 to R_2. In Part (c), in the first equation after the figure, change v_i to $-v_i$.

Problem 2.53

In the first line, change f_{0CL} to f_{BCL}.

Problem 2.73

Before the figure, add the sentence: "The PSpice simulation is stored in the file named P2_73."

Problem 2.75

Delete the sentence stating that the plot of $v_o(t)$ is on the next page.

Problem 3.10

In line three (an equation), change i_D/R to v_D/R.

Problem 3.53

In the sentence beginning with "The dynamic resistance", change nV_T/I_{CQ} to nV_T/I_{DQ}.

Problem 3.56

In Part (a), change nV_T/I_{CQ} to nV_T/I_{DQ}.

Problem 3.57

The solution uses r_d for the diode resistance rather than r_z as specified in the problem statement.

Problem 3.58

In Part (c), line two (an equation), change the minus sign inside the parentheses to a plus sign.

Problem 3.70

In line one, change "electon" to "atom".

Problem 3.90

In Part (c), line one, change the denominator of the fraction in parentheses from I_R to $-I_R$.

Problem 3.92

At the end of the solution, add: "Larger capacitance produces less output voltage ripple and higher peak diode current".

Problem 4.10

In line five of the solution (an equation), change "10 – 0.6585" to "0.6585 – 10".

Problem 4.25

In the equation for I_S (line seven of the solution), each of the two denominators should end with) – 1 instead of – 1).

Problem 4.34

In the line for part (d) with $\beta = 100$, we should have $I = 9.53$ mA (instead of 10 mA) and $V = 9.53$ V (rather than 10 V).

Problem 4.45

Change $A_{VO} = -\beta R_L/r_\pi$ to $A_{VO} = -\beta R_C/r_\pi$.

Problem 4.50

At the end of step one, add: "Set all other independent signal sources to zero."

Problem 4.54

Next to the figure, change V_{EQ} to V_{BEQ} .

Problem 4.60

In the first line after the figure, second equation, change I_{BEQ} to I_{BQ}.

Problem 4.65

In the first line after the figure, insert an equals sign after I_B.

Problem 5.3

Calculation of the drain currents was omitted. The drain currents are:

(a) $i_D = K(v_{GS} - V_{to})^2 = (W/L)(KP/2)(v_{GS} - V_{to})^2 = 2.25$ mA

(b) $i_D = K[2(v_{GS} - V_{to})v_{DS} - (v_{DS})^2]$

$= (W/L)(KP/2)[2(v_{GS} - V_{to})v_{DS} - (v_{DS})^2]$

$= 2$ mA

(c) $i_D = 0$

Problem 5.7

In the last sentence, change $K = 25$ to $K = 25\ \mu A/V^2$.

Problems 5.23

The last line of part (a) should read: $V_{DSQ} = 20 - 2I_{DQ} = 12$ V.

Problem 5.25

Change the second equation from $R_S I_{DSQ} = 6$ V to $R_S I_{DQ} \cong 6$ V.

Problem 5.46

Change "greater than zero" to "greater than unity".

Problem 5.65

In the third-to-last sentence, change $K(v_{GS5} - V_{to})$ to $K(v_{GS5} - V_{to})^2$.

Problem 5.74

In the sentence after the opening equation, change "saturation" to "triode region". In part (c) before the table, insert "Using the value of *C* given in part (d) of the problem, we have:"

Problem 6.16

At the beginning of the solution, insert "The following solution is for an inverter operating at 400 MHz." At the end of the solution, add "For an inverter operating at 400 Hz, $P_{dynamic} = 3.6 \times 10^{-10}$ W."

Problem 6.23

In the third line, change "$I_{OL} = -1$ mA" to "$I_{OL} = 1$ mA".

Problems 6.24

In the first line, change "$P_{dynamic} = If$ " to "$P_{dynamic} = Kf$".

Problem 6.25

In the equation for Energy, change $(4^2 - 1^2)$ to $(5^2 - 0^2)$ and change 150 pJ to 250 pJ. In the equation for $P_{dynamic}$, change 150 to 250 and change 3.75 mW to 6.25 mW.

Problem 6.32

In the circuit diagram, the device should be an enhancement MOSFET rather than a depletion MOSFET.

Problem 6.36

Change the middle of the fourth line to read "$V_{IH} = 2.04$ V, $V_{IL} = 1.08$ V".

Problem 6.51

At the end of the first paragraph, just before the figure, insert the following: [Note: The solution assumes $(W/L)_p = 1$. On the other hand for $(W/L)_p = 2$, we would need $(W/L)_n = 16$.]

Problem 7.1

Delete the comma after the phrase "high precision".

Problem 7.11

In the first sentence, change "below" to "on the next page".

Problem 7.18

Toward the end of the main paragraph, in the equation for R_2, insert a left-hand parenthesis the before 26mV.

Problem 7.20

Actually the current decreases when β decreases. Thus, the percentage increase should be stated as -0.99%.

Problem 7.22

At the beginning of part (a), add the following: (Note: The problem should have asked for proof that I_O, rather than I_{C2}, is independent of V_{BE}.)

Problem 7.25

In the first line, change V_{CC} in the fraction numerator to 10.

Problem 7.28

In the first sentence after the diagram, change P7_27 to P7_28.

Problem 7.37

In the third line, change $(15 + V_{GS1} - V_{GS3})$ to $(15 - V_{GS1} - V_{GS3})$.

Problem 7.38

At the beginning of the solution, add the following: "The problem statement should refer to Figure P7.38, not P7.36."

Problems 7.60 and 7.61

In the next-to-last sentence of each solution, change A_{cm} to A_{vcm}.

Problem 7.65

In the first paragraph, change the value found for A_{v1} from 64.6 to 36.23. At the end of the solution, change the value found for the overall gain A_v from 20.4×10^3 to 11.5×10^3.

Problem 7.66

At the end of the solution, add the following sentence: "The *pnp* stage drops the dc level down so it comes out zero after the last (Q_6) stage."

Problem 7.67

Throughout the solution, change all occurrences of $2000\pi t$ to $200\pi t$.

Problem 7.71

After the diagram, add the following: (Note: For the transistors to operate in the active region, the emitters of the current sinks must be connected to $-V_{EE}$ rather than to ground.)

In the third line of the main paragaph, change "Q_3 is a simple mirror" to "Q_8 is a simple mirror".

Problem 7.74

In the the top line of page 327, change (10 μA)/β to (100 μA)/β.

Problem 7.75

At the very end, change the value found for A_1/A_2 from 0.953 to 0.926.

Problem 8.8

In part (a) of the solution, the components of the phase plot are incorrectly added. The correct phase plot should show a phase of +90° for low f , 0° for high f, and should decrease in a straight line between 3.18 MHz and 318 MHz.

Problem 8.14

In the first line of part (b), change "drain" to "source". Notice that the expression abbreviated as B simplifies to $C_{gs}(R_{sig} + R_L') + C_{gd}R_{sig}(g_m R_L' + 1)$, and the expression abbreviated as A simplifies to $C_{gs}C_{gd}R_{sig}R_L'$.

Problem 8.18

In part (e), change "$r_d = \infty$ (because $\lambda = 0$)" to "$r_d \cong 1/\lambda I_{DQ} = 40$ kΩ". Change the sentence about the break frequency to read simply: "The break frequency is 251 kHz."

Problem 8.24

Change the table to appear thus:

R_L	1 kΩ	10 kΩ
R_L'	995 Ω	9.52 kΩ
A_V	-4.99	-9.05
$R_{in,Miller}$	33.4 kΩ	19.9 kΩ
R_x	25.0 kΩ	16.6 kΩ

Problem 8.25

Change the second line after the first figure to read:

$R_{in} = R_i || R_{in,Miller} \cong 0.1\ \Omega$.

Problem 8.30

Change "Equations 8.41 and 8.42" to "Equations 8.42 and 8.43".

Problem 8.33

In the second line change "Problem 8.33" to "Problem 8.32". In the equation for i_C, change 50sin(2000πt) to 500sin(2000πt). Change the value found for $I_{C,rms}$ to 354 μA.

Problem 8.36

Note that in the equation for h_{oe}, the current term $\frac{1}{r_\pi + r_\mu}$ is small, and has been ignored.

Problem 8.40

In the first line of part (a), in the equation for I_{BQ}, change "100" to "(1mA)/100".

Problem 8.42

In the table, change the units of the right-column value of R_E from mΩ to MΩ.

Problem 8.43

In the middle of part (a), "Solving Equation (2) for v_o" should read "Solving Equation (2) for v_π". In part (b), R_{EF} should be R_{E1}.

Problem 8.56

In the second circuit diagram, change $R'_{sig} = R_{sig}||R_D$ to $R'_{sig} = R_{sig}||R_G$.

Problem 8.66

The derivation of C_1 should read as follows:

Thus, the input resistance of the amplifier is

$R_{in} = R_B||[r_{\pi 1} + (\beta + 1)(R_{E1}||R_{E2}||r_{e2})] = 1046\ \Omega$

The resistance in series with C_1 is $R_{in} + R_s = 1096\ \Omega$.

$C_1 = 1/(2\pi f_1 1096) = 1/(2\pi 10 \times 1096) = 14.5\ \mu F$

Also, in the equation for C_2, change "$1/(2\pi f_2 1168)$" to "$1/(2\pi f_2 1020)$".

Problem 9.7

In part (a) of the solution, the final equation should read

$$A_f = \frac{X_o}{X_s} = \frac{A_1 A_{2f}}{1 + \beta_2 A_1 A_{2f}} = \frac{A_1 A_2}{1 + \beta_1 A_2 + \beta_2 A_1 A_2}$$

Also, in line four of part (b) change A_2 to A_3 and change "a a gain" to "a gain".

Problem 9.10

Change > to >>.

Problem 9.14

Part (a) uses $|V_{BE}| = 0.7$ V in saturation, not 0.6 V as specified in the problem.

Problem 9.35

In the first line, delete the second occurrence of i_i.

Problem 9.44

In the last line, change "parallel" to "voltage".

Problem 9.45

The last sentence, should read: "Since we want $A\beta$ to be very large in magnitude, we choose small resistances for a current feedback network."

Problem 9.47

At the very end of the solution, change the units of the value found for R_{of} from Ω to kΩ.

Problem 9.49

The problem should have called for $R_{mf} = -5000\ \Omega$. In the solution, change the units of the value found for R_{if} from MΩ to Ω.

Problem 9.51

In the third line of part (a), delete the second occurrence of v_i.

Problem 9.52

In part (a) change the equation that begins line four to

$$v_o / i_i = -A_v R_i \times \frac{R_L}{R_o + R_L} = -417 \text{ M}\Omega$$

In the last line of part (a), add a negative sign in front of the value found for β. In the fourth line of part (b), change $\beta = 1/R_f$ to $\beta = -1/R_f$.

Problem 9.53

In the third line of part (a), add a negative sign in front of $A_{vo}R_i$. At the end of part (a), change the value found for β to -2.16×10^{-5}. In part (b), in the first line after the diagram, add a negative sign after the = and before the fraction.

Problem 9.59

In part (d), change both instances of "1000*t*" to "100*t*".

Problem 9.64

In the last line, change 3500 Hz to 350 Hz.

Problem 9.66

In the next-to-last line, change "imaginary" to "complex".

Problem 9.72

In the next-to-last line, change 180° to –180°.

Problem 9.86

In part (c), the last two sentences should read: "Finally setting $A\beta = 1$ yields $A = -29$ and $\omega = \sqrt{6}/(RC)$. Thus an inverting amplifier is needed."

In part (d), change the sign on the last term from – to + in the denominator of the second equation.

Problem 10.11

Delete the closing parenthesis after 0.0025 in the middle of the first equation. Change the value found for θ_{JA} to 150 °C/W.

Problem 10.23

The trigonometric identity should read $2\sin^2(x) = 1 - \cos(2x)$. In the integral equation that follows, change $10\sin(4000\pi t)$ to $10\cos(4000\pi t)$.

Problem 10.27

In the fifth line, change the integrand to $[1 - \cos(2\omega t)]$.

Problem 10.35

In part (a), change $(V_{CC}/\sqrt{2})R_L$ to $(V_{CC}/\sqrt{2})^2/R_L$.

Problem 10.37

In part (d), the final equation should read

$$P_{Q1max} = (V_{CC}/2) \times V_{CC}/(2R_L) = V_{CC}^2/(4R_L) = 7.03\ \text{W}.$$

Problem 10.45

In Equation 10.49 in the text, $\frac{R_2}{R_1 + R_2}$ should be replaced by $\frac{R_1 + R_2}{R_2}$.

Problem 10.50

In the second line of the solution, change "op amp" to "transistor".

Problem 10.63

In the second line, change "on the next page" to "below".

Problem 11.16

In the equation for C, insert a closing square bracket after the L.

Problem 11.21

In the third line of the solution, change $\omega_R = 3\omega_0$ to $f_R = 3f_0$.

Problem 11.37

In the first line after the last set of diagrams, change $Q_2^2 = R_L / R_s$ to $Q_2 = \sqrt{R_L / R_s}$.

Also note that in the first diagram of the solution, R_S represents the internal source resistance, while in the rest of the solution, R_S represents the series equivalent of R_L.

Problem 11.38

Note that R_s represents the series equivalent of R_L. In the second line, note that Q_C = 10 and change the value found for R_S to 5 Ω. In the third line, change 4.47 to 3.16, change 1423.5 to 1006.6, and change 409.77 to 465.2. Then the simulation results closely match predictions.

Problem 11.39

Note that R_s represents the series equivalent of R_L. In the second line, change the value found for R_s to 50 mΩ. (Note that Q_C = 100.)

Problem 11.45

In part (c), change 256.51 pF to 316.43 pF and change 20.21 nF to 1269 pF.

Problem 11.50

Note that in the solution r_d has been taken to be very large.

Problem 11.54

At the end of the solution sentence, change the period to a comma and add "or approximately 20 MHz. The third overtone frequency is about 30 MHz."

Problem 11.57

Note that "antiresonant frequency" means the same thing as "parallel-resonant frequency."

Problem 12.11

Note that in the solution, "node 2" refers to the noninverting input.

Problem 12.12

After the first paragraph, change $v_O = V_B + 4.7$ to $v_O = V_B - 4.7$. After the second paragraph, change $v_O = V_B - 4.7$ to $v_O = V_B + 4.7$ and change $v_{in} > V_B$ to $v_{in} < V_B$. In the plot at the end of the solution, change –1.3 on the *y*-axis to –1.7.

Problem 12.17

Note that in the problem statement, the v_2 referenced in the ninth line should be v_1 .

Problem 12.40

At the end of the solution, change $i_O R/2$ to $-i_O R/2$ and change 9.96 V to –9.96 V.

Chapter 1

Exercise 1.1

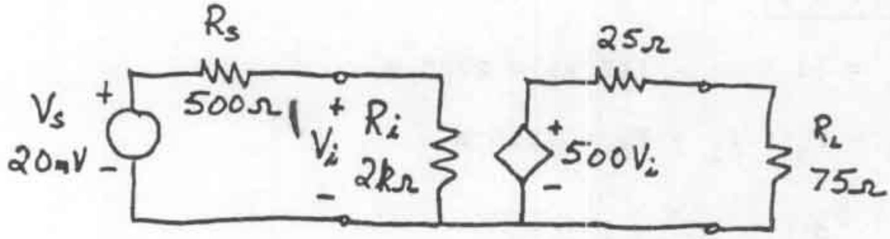
(a) For a noninverting amplifier $A_v = +50$ and we have:

$$v_o(t) = A_v v_i(t) = 50 \times 0.1\sin(2000\pi t) = 5\sin(2000\pi t)$$

(b) For an inverting amplifier $A_v = -50$ and we have:

$$v_o(t) = A_v v_i(t) = -50 \times 0.1\sin(2000\pi t) = -5\sin(2000\pi t)$$

Exercise 1.2



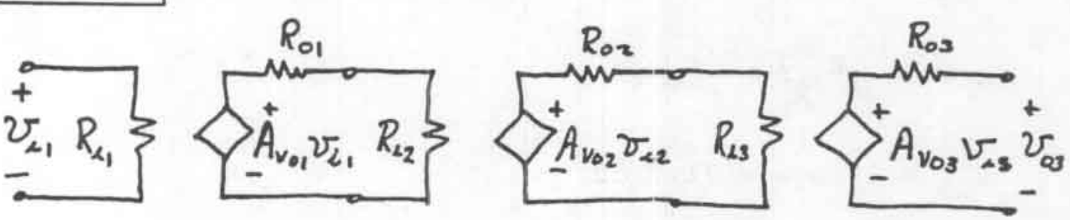
$$A_{vs} = \frac{R_i}{R_s + R_i} \times A_{vo} \times \frac{R_L}{R_L + R_o} = 300 \qquad A_i = A_v \frac{R_i}{R_L} = 10^4$$

$$A_v = \frac{V_o}{V_i} = A_{vo} \times \frac{R_L}{R_L + R_o} = 375 \qquad G = A_v A_i = 3.75 \times 10^6$$

Exercise 1.3

For maximum power transfer to the load, we must have $R_L = R_o = 25\ \Omega$. Then as in Exercise 1.2 we find $A_v = 250$, $A_i = 2 \times 10^4$, and $G = 5 \times 10^6$.

Exercise 1.4



$$A_{vo} = A_{vo1} \frac{R_{i2}}{R_{o1} + R_{i2}} A_{vo2} \frac{R_{i3}}{R_{o2} + R_{i3}} A_{vo3} = 5357$$

$R_i = R_{i1} = 1000\ \Omega$ $\qquad$ $R_o = R_{o3} = 300\ \Omega$

Exercise 1.5

$$A_{vo} = A_{vo3} \frac{R_{i2}}{R_{o3} + R_{i2}} A_{vo2} \frac{R_{i1}}{R_{o2} + R_{i1}} A_{vo1} = 4348$$

$R_i = R_{i3} = 3000\ \Omega$

$R_o = R_{o1} = 100\ \Omega$

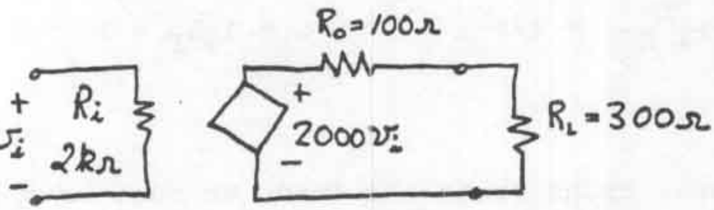
Exercise 1.6

$$P_s = (1.5\ \text{A}) \times (15\ \text{V}) = 22.5\ \text{W}$$

$$P_d = P_s + P_i - P_o = 20.5\ \text{W}$$

$$\eta = \frac{P_o}{P_s} \times 100\% = 11.1\%$$

Exercise 1.7



$$A_v = v_o/v_i = 2000 \frac{R_L}{R_L + R_s} = 1500$$

$$A_{vdB} = 20\log|A_v| = 63.5\ \text{dB}$$

$$G = (A_v)^2 \frac{R_i}{R_L} = 1.5 \times 10^7$$

$$G_{dB} = 10\log G = 71.8\ \text{dB}$$

Exercise 1.8

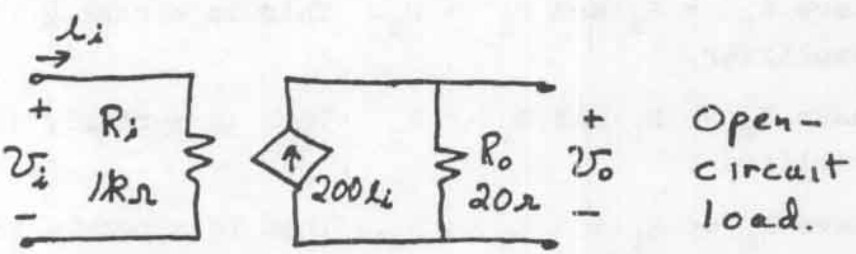
$$P_{dBW} = 10\log\left(\frac{P}{1\ \text{W}}\right) = 10\log\left(\frac{5\times10^{-3}}{1}\right) = -23.0\ \text{dBW}$$

$$P_{dBm} = 10\log\left(\frac{P}{1\ \text{mW}}\right) = 10\log\left(\frac{5\times10^{-3}}{10^{-3}}\right) = 10\log(5) = 6.99\ \text{dBm}$$

Exercise 1.9

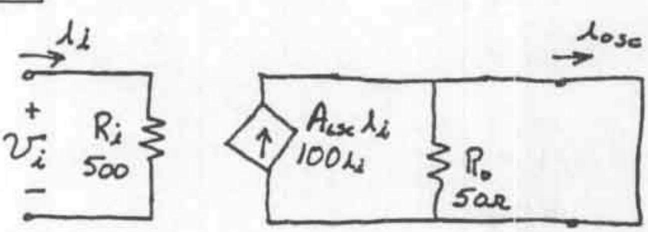
$$20\log\left(\frac{V_x}{1\ \text{V}}\right) = 23 \quad \Rightarrow \quad V_x = 10^{23/20} = 14.13\ \text{V}$$

Exercise 1.10



$$A_{vo} = \frac{v_o}{v_i} = \frac{200 i_i R_o}{i_i R_i} = 4 \qquad R_i = 1000\ \Omega \qquad R_o = 20\ \Omega$$

Exercise 1.11

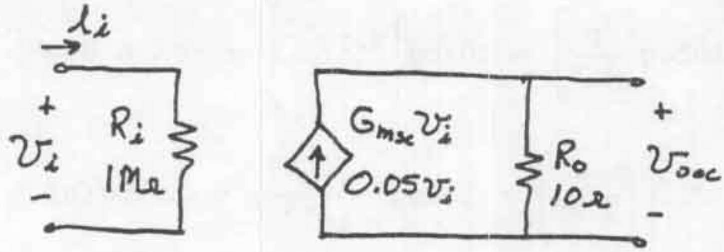


$$G_{msc} = \frac{i_{osc}}{v_i} = \frac{100 i_i}{500 i_i} = 0.2\ \text{S}$$

$R_i = 500\ \Omega$

$R_o = 50\ \Omega$

Exercise 1.12



$$R_{moc} = \frac{v_{ooc}}{i_i} = \frac{G_{msc}v_iR_o}{v_i/R_i} = G_{msc}R_oR_i = 500\ \text{k}\Omega$$

Exercise 1.13

(a) We have $R_s << R_i$ and $R_L >> R_o$. This is a nearly ideal voltage amplifier.

(b) We have $R_s >> R_i$ and $R_L << R_o$. This is a nearly ideal current amplifier.

(c) We have $R_s << R_i$ and $R_L << R_o$. This is a nearly ideal transconductance amplifier.

(d) We have $R_s >> R_i$ and $R_L >> R_o$. This is a nearly ideal transresistance amplifier.

(e) We have $R_s = R_i$ and $R_L << R_o$. This is not close to any ideal amplifier.

Exercise 1.14

$A_{cm} = v_{ocm}/v_{icm} = 0.1/1 = 0.1$

$A_{cmdB} = 20\log|A_{cm}| = -20$ dB

$$CMRR_{dB} = 20\log\frac{|A_d|}{|A_{cm}|} = 20\log\frac{50 \times 10^3}{0.1} = 114\ \text{dB}$$

Exercise 1.15

(a) $v_{id} = v_{i1} - v_{i2} = 1\text{ V}$

$v_{icm} = \frac{1}{2}(v_{i1} + v_{i2}) = 0\text{ V}$

$$v_o = A_1 v_{i1} - A_2 v_{i2} = \frac{A_1 + A_2}{2}$$

$$A_d = v_o/v_{id} = \frac{A_1/2 + A_2/2}{1} = \frac{1}{2}(A_1 + A_2)$$

(b) $v_{id} = v_{i1} - v_{i2} = 0\text{ V}$

$v_{icm} = \frac{1}{2}(v_{i1} + v_{i2}) = 1\text{ V}$

$v_o = A_1 v_{i1} - A_2 v_{i2} = A_1 - A_2$

$A_{cm} = v_o/v_{icm} = A_1 - A_2$

(c)

$$\text{CMRR} = 20\log\frac{|A_d|}{|A_{cm}|} = 20\log\left|\frac{A_1 + A_2}{2(A_1 - A_2)}\right| = 20\log\left|\frac{201}{2(100-101)}\right| = 40\text{ dB}$$

Problem 1.1

Some examples of electronic systems are electronic brakes, printers, cash registers, microwave ovens, CD players, airport landing systems, electronic door locks, and so forth.

Problem 1.2

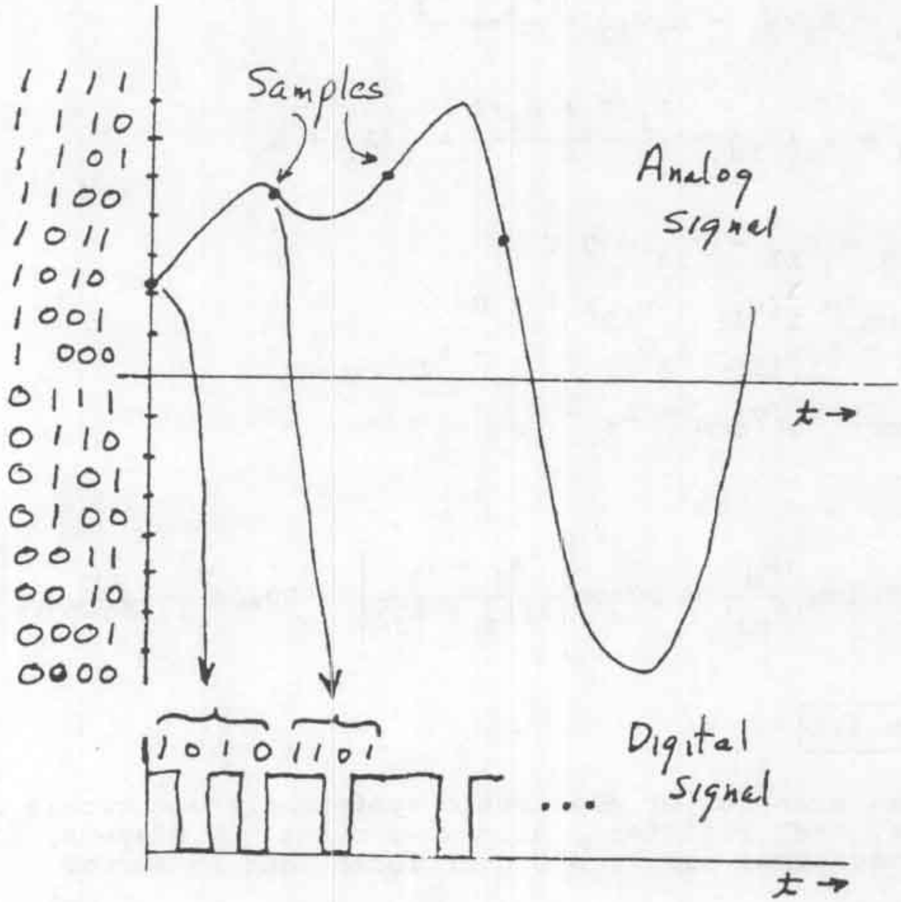
Electronic system blocks include amplifiers, filters, signal sources, wave-shaping circuits, digital logic functions, digital memories, power supplies, and converters.

Problem 1.3

Some electronic systems process information in electronic form and some power (hopefully as little as possible) is consumed. In power electronics, the power delivered to a load is the main concern.

Problem 1.4

Conversion of analog signals to digital form is a two-step process. First, the signal is sampled at periodic points in time. Second, each sample is approximately represented by a codeword.



Problem 1.5

Provided that it is not too large in amplitude, noise can be completely removed from a digital signal. Noise tends to accumulate in analog signals. Digital circuits tend to be easier than analog circuits to implement with integrated techniques. Thus extremely complex digital systems are feasible while equally complex analog systems are not. Digital systems are more adaptable than analog systems to a variety of uses.

Problem 1.6

Number of bits per second = $16 \times 44.1 \times 10^3$ = 705.6 kbit/s (for monaural) (1.411 Mbits/s are used for stereo.)

Number of amplitude zones = 2^{16} = 65,536

$$\Delta = \frac{5 - (-5)}{65536} = 152.6\ \mu V$$

Problem 1.7

Minimum sampling rate = $2f_H$ = 200 sample/s

$N = \dfrac{10\ \text{mV}}{0.01\ \text{mV}} = 1000$ which requires k = 10 at least (2^{10} = 1024)

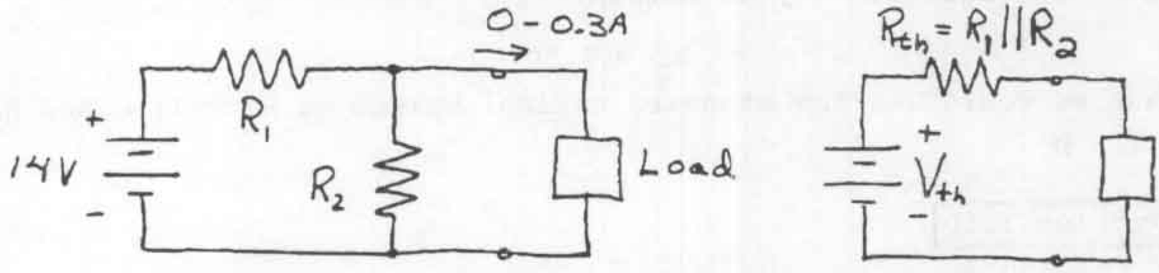
Number of bits per second = 200×10 = 2 kbit/s

Problem 1.8

See Figure 1.6 in the book.

Problem 1.9

Because we are limited to resistors, the only option is a resistive voltage divider as shown below.



We denote the nominal values of the resistors as R_1 and R_2. The highest load voltage (at most 6 V) occurs when $I_L = 0$, when the resistor in parallel with the load has its highest value (which is $1.05R_2$), and when the resistor in series with the source has its lowest value (which is $0.95R_1$). To achieve the desired no-load voltage we need

$$14 \frac{1.05R_2}{0.95R_1 + 1.05R_2} = 6$$

Solving for R_2, we have

$$R_2 = 0.6786 R_1 \qquad (1)$$

The smallest load voltage (at least 4 V) occurs with I_L = 0.3 and resistance values of $0.95R_2$ and $1.05R_1$. For these values, the Thévenin voltage is

$$V_{th} = 14 \frac{0.95 R_2}{1.05R_1 + 0.95R_2}$$

and the load voltage is

$$V_L = 4 = V_{th} - R_{th}I_L$$

$$4 = 14 \frac{0.95 R_2}{1.05R_1 + 0.95R_2} - 0.3 \frac{0.95(1.05) R_1R_2}{1.05R_1 + 0.95R_2} \qquad (2)$$

Using Equation (1) to substitute for R_2 in Equation (2) and solving we obtain:

$$R_1 = 11.06 \ \Omega$$

Then from Equation (1) we obtain:

$$R_2 = 7.507 \ \Omega$$

Thus we could use the standard nominal values of $R_1 = 11 \ \Omega$ and $R_2 = 7.5 \ \Omega$.

Problem 1.10

System engineers design the block diagrams of systems including specifications for each block. Circuit designers design the circuits for each block. Process engineers design the fabrication processes. Semiconductor physicists research fundamental processes used in electronic devices.

Problem 1.11

The components of integrated circuits and their interconnections are manufactured concurrently on a semiconductor wafer by a sequence of photolithographic processing steps. The components of a discrete circuit are manufactured separately and then interconnected, usually on a circuit board. Often overall cost can be reduced by integrating the system onto as few chips as possible because chip cost is nearly independent of complexity (within certain bounds).

Problem 1.12

The area consumed by each transistor is $(10\ \mu m) \times (10\ \mu m) = 10^{-10}\ m^2$. The chip area is $(2\ cm) \times (2\ cm) = 4 \times 10^{-4}\ m^2$. Thus the number of transistors that can be placed on the chip is

$$(4 \times 10^{-4})/(10^{-10}) = 4 \times 10^{6} \text{ transistors/chip}$$

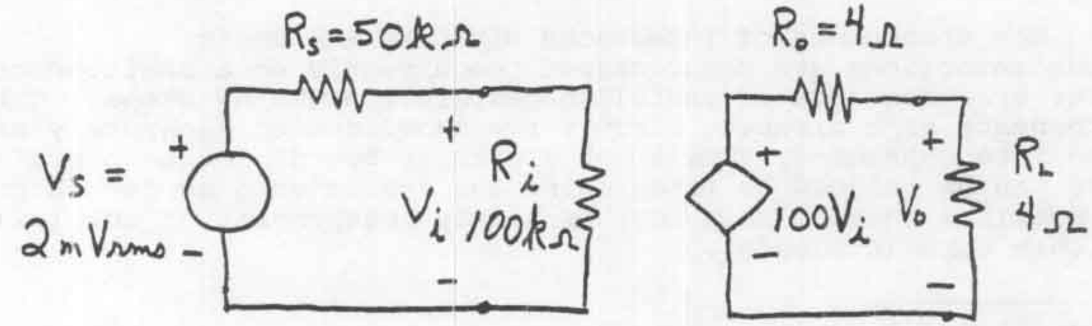
Problem 1.13

Gain is a negative number for an inverting amplifier, and the output signal is an inverted version of the input signal. Gain is a positive number for a noninverting amplifier, and the output signal has the same polarity as the input signal at each instant of time.

Problem 1.14

"Loading effects" refer to the fact that the input voltage of an amplifier is less than the internal source voltage because of the voltage drop across the internal source impedance. Also the amplifier output voltage is less than the open-circuit voltage gain times the input voltage because of the voltage drop across the output impedance of the amplifier.

Problem 1.15



$$A_v = \frac{V_o}{V_i} = A_{vo} \frac{R_L}{R_L + R_o} = 50$$

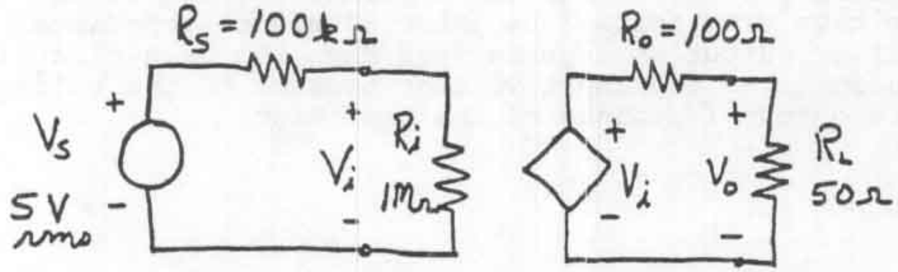
$$A_{vs} = \frac{V_o}{V_s} = A_{vo} \frac{R_L}{R_L + R_o} \frac{R_i}{R_i + R_s} = 33.3$$

$$A_i = A_v \frac{R_i}{R_L} = 1.25 \times 10^6$$

$$G = A_v A_i = 6.25 \times 10^7$$

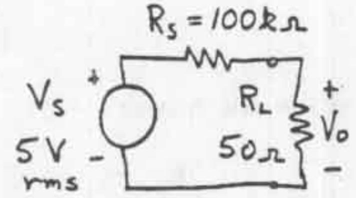
Problem 1.16

Using the unity-gain amplifier we have:



$$V_o = V_s \frac{R_i}{R_i + R_s} \frac{R_L}{R_L + R_o} = 1.52 \text{ V rms} \quad \text{and} \quad P_o = V_o^2/R_L = 45.9 \text{ mW}$$

With the source connected directly to the load, we have:



$$V_o = V_s \frac{R_L}{R_L + R_s} = 2.5 \text{ mV rms}$$

$$P_o = V_o^2/R_L = 125 \text{ nW}$$

Thus the output power is much larger if the unity-gain amplifier is used.

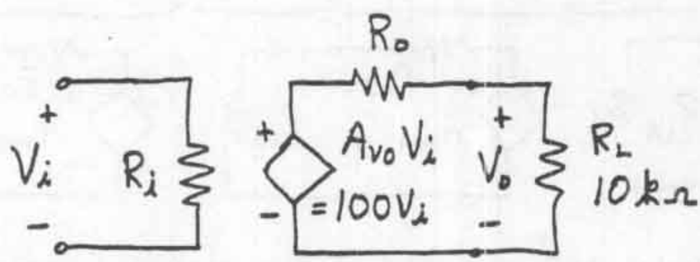
Problem 1.17

$$P_{in} = V_{in}^2/R_{in} = 0.333 \text{ pW}$$

$$P_o = V_o^2/R_L = 3.135 \text{ W}$$

$$G = P_o/P_{in} = 9.376 \times 10^{12}$$

Problem 1.18



$$A_v = 90 = A_{vo} \frac{R_L}{R_o + R_L} = 100 \frac{10^4}{R_o + 10^4}$$

Solving we find that $R_o = 1.11 \text{ k}\Omega$

Problem 1.19

With the switch open we have:

$$V_o = 50 \text{ mV} = V_s \frac{R_i}{R_i + 10^6} A_{vo} \frac{R_L}{R_L + R_o} \qquad (1)$$

With the switch closed we have:

$$V_o = 100 \text{ mV} = V_s A_{vo} \frac{R_L}{R_L + R_o} \qquad (2)$$

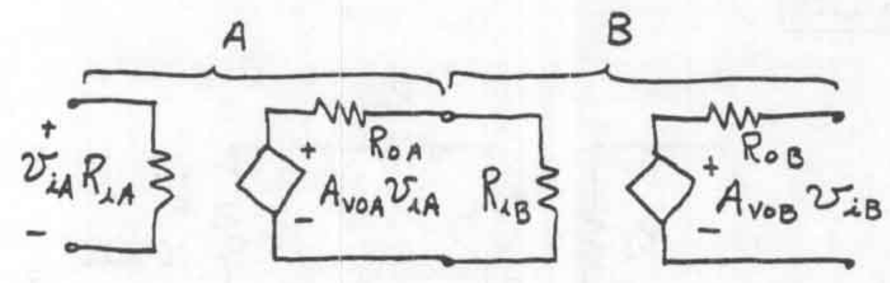
Dividing the respective sides of Equation (1) by those of Equation (2), we have:

$$\frac{50 \text{ mV}}{100 \text{ mV}} = \frac{R_i}{R_i + 10^6}$$

Solving we obtain $R_i = 1 \text{ M}\Omega$.

Problem 1.20

If we cascade two amplifiers A and B the equivalent circuit is:



The open-circuit voltage gain of the cascaded amplifier is:

$$A_{vo} = A_{voA}A_{voB} \frac{R_{iB}}{R_{oA} + R_{iB}}$$

Problem 1.21

See the figure shown in the solution for Problem 1.20. When the amplifiers are cascaded in the order A-B, we have:

$$R_i = R_{iA} = 3\ k\Omega$$

$$R_o = R_{oB} = 20\ \Omega$$

$$A_{vo} = A_{voA}A_{voB}\frac{R_{iB}}{R_{oA} + R_{iB}} = 4.998 \times 10^4$$

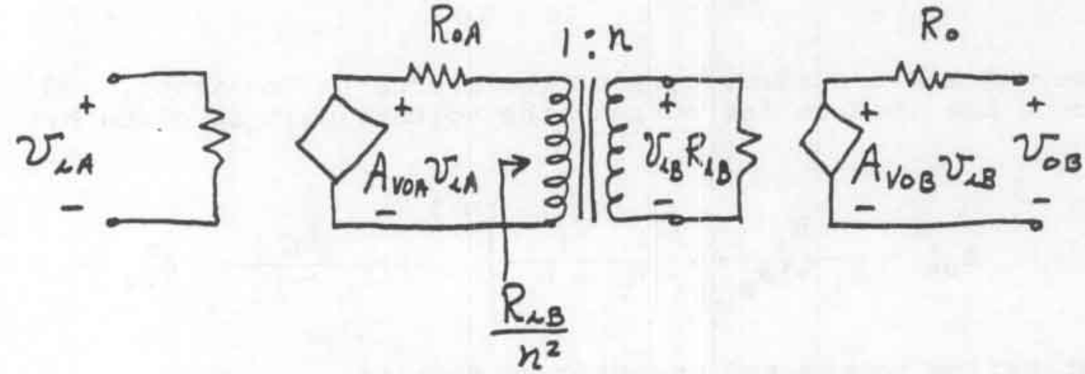
On the other hand for the B-A cascade we have:

$$R_i = R_{iB} = 1\ M\Omega$$

$$R_o = R_{oA} = 400\ \Omega$$

$$A_{vo} = A_{voA}A_{voB}\frac{R_{iA}}{R_{oB} + R_{iA}} = 4.967 \times 10^4$$

Problem 1.22



$$\left|A_{vo}\right| = \frac{v_{oB}}{v_{iA}} = \left|A_{voA}\right| \times \frac{R_{iB}/n^2}{R_{oA} + R_{iB}/n^2} \times n \times \left|A_{voB}\right|$$

$$\left|A_{vo}\right| = \left|A_{voA}\right| \times \left|A_{voB}\right| \times \frac{R_{iB}n}{n^2R_{oA} + R_{iB}}$$

$$\frac{d|A_{vo}|}{dn} = 0 = \left|A_{voA}\right| \times \left|A_{voB}\right| \times \frac{R_{iB}^2 - n^2 R_{oA} R_{iB}}{(n^2 R_{oA} + R_{iB})^2}$$

Solving for n we have:

$$n = \sqrt{\frac{R_{iB}}{R_{oA}}}$$

Problem 1.23

The internal source impedance is:

$$R_s = \frac{\text{open-circuit voltage}}{\text{short-circuit current}} = \frac{20 \times 10^{-3}}{10^{-6}} = 20\ \text{k}\Omega$$

The desired voltage gain is required to be at least:

$$A_{vs} = \frac{V_o}{V_s} = \frac{10}{20 \times 10^{-3}} = 500$$

If we cascade n stages, connect the source to the input, and connect the load to the output, the voltage gain is given by:

$$A_{vs} = \frac{R_i}{R_i + R_s} \times \left(\frac{R_i}{R_i + R_o}\right)^{n-1} \times \frac{R_L}{R_L + R_o} \times A_{vo}^n$$

Substituting values and reducing we obtain:

$$A_{vs} = 0.02381 \times (0.9091)^{n-1} \times (10)^n$$

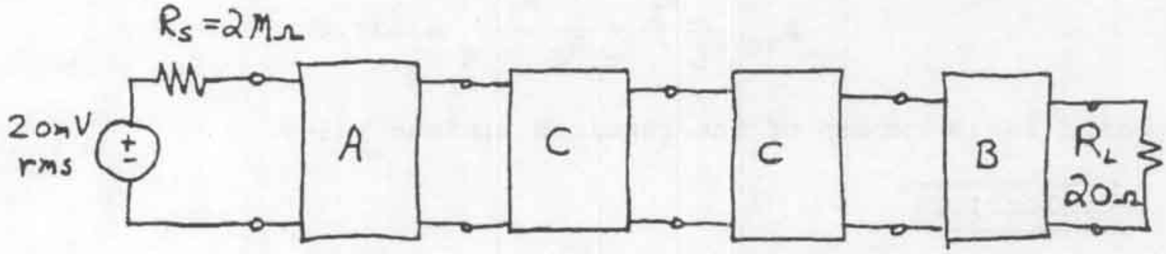
By trial and err we determine that we must have n = 5 to achieve A_{vs} in excess of 500.

Problem 1.24

To avoid excessive loading effects at the input, we should choose the first stage such that its input resistance is larger than the source resistance. Therefore we choose type A as the input stage. To avoid excessive loading effects at the output, we should choose the last stage such that its output impedance is much less than the load impedance. Therefore we choose type B as the output stage.

To achieve output power of 1 W we need $P_o = 1 = V_o^2/R_L$. Solving we determine that $V_o = 4.472$ V rms. Thus we require an overall gain of $A_{vs} = V_o/V_s = 4.472/(20 \times 10^{-3}) = 223.6$ as a minimum value.

To attain the required gain with the least number of stages we use intermediate stages of type C. Thus the amplifier diagram is:



The cascade has $R_i = 10$ MΩ, $R_o = 1$ Ω, and $A_{vo} = 376.9$. The resulting loaded gain is

$$A_{vo} \frac{R_L}{R_L + R_o} \frac{R_i}{R_i + R_s} = 299.1$$

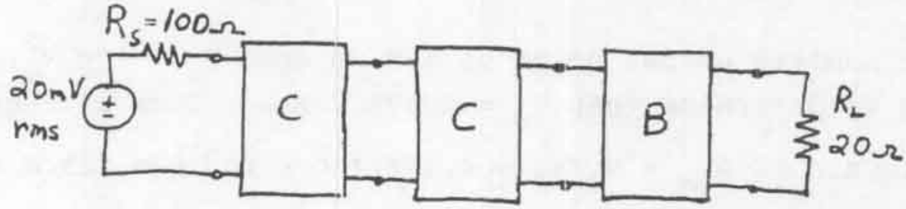
which is in excess of the required minimum value.

Problem 1.25

The source impedance is lower than the input impedances of any of the stage types. Therefore we choose type C as the input stage to achieve the highest gain. To avoid excessive loading effects at the output, we should choose the last stage such that its output impedance in much less than the load impedance. Therefore we choose type B as the output stage.

To achieve output power of 1 W we need $P_o = 1 = V_o^2/R_L$. Solving we determine that $V_o = 4.472$ V rms. Thus we require an overall gain of $A_{vs} = V_o/V_s = 4.472/(20 \times 10^{-3}) = 223.6$ as a minimum value.

To attain the required gain with the least number of stages we use intermediate stages of type C. Thus the amplifier diagram is:



The cascade has $R_i = 20\ k\Omega$, $R_o = 1\ \Omega$, and $A_{vo} = 452.2$. The resulting loaded gain is

$$A_{vo} \frac{R_L}{R_L + R_o} \frac{R_i}{R_i + R_s} = 428.6$$

which is in excess of the required minimum value.

Problem 1.26

The efficiency η of an amplifier is the output power divided by the supply power times 100%.

$$\eta = \frac{P_{out}}{P_{supply}} \times 100\%$$

Dissipated power is the power converted to heat.

Problem 1.27

$$P_{in} = V_{in}^2/R_{in} = (0.1)^2/10^5 = 0.1\ \mu W$$

$$P_{out} = V_o^2/R_L = (10)^2/8 = 12.5\ W$$

$$P_{supply} = V_{CC}I_{CC} = 15 \times 2 = 30\ W$$

$$P_{dissipated} = P_{supply} + P_{in} - P_o = 17.5\ W$$

$$\eta = \frac{P_{out}}{P_{supply}} \times 100\% = \frac{12.5}{30} \times 100\% = 41.67\%$$

Problem 1.28

Power is delivered to the amplifier by both of the 15-V sources. Part of this power is returned to the 5-V source. The net power supplied is

$$P_{supply} = 15 \times 1 + 15 \times 2 - 5 \times 1 = 40 \text{ W}$$

Problem 1.29

$$I_{1avg} = \frac{1}{T}\int_0^T i_1^2(t)\,dt = \frac{1}{0.01}\int_0^{0.005} 2.5\sin(200\pi t)\,dt =$$

$$\frac{250}{200\pi}\Big[-\cos(200\pi t)\Big]_0^{0.005} = \frac{500}{200\pi} = 0.7958 \text{ A}$$

Similarly $I_{2avg} = 0.7958$ A.

$$P_{out} = \frac{V_{o,rms}^2}{R_L} = \frac{20/\sqrt{2}}{8} = 25 \text{ W}$$

$$P_{supply} = (25 \text{ V}) \times I_{iavg} + (25 \text{ V}) \times I_{2avg} = 39.79 \text{ W}$$

$$\eta = \frac{P_{out}}{P_{supply}} \times 100\% = 62.83\%$$

Problem 1.30

$$G_{dB} = 10\log(G)$$

$$A_{vdB} = 20\log|A_v|$$

Problem 1.31

$$R_{in} = \frac{V_{in}}{I_{in}} = \frac{10 \text{ mV}}{1\ \mu\text{A}} = 10 \text{ k}\Omega$$

$$A_v = \frac{V_{out}}{V_{in}} = \frac{5 \text{ V}}{10 \text{ mV}} = 500 \qquad A_{vdB} = 20\log(A_v) = 53.98 \text{ dB}$$