$$v_{oc} = v_s$$
$$i_{sc} = i_s$$
$$v_s = i_s R_s$$

Thus,

$$R_s = \frac{v_{oc}}{i_{sc}}$$

(a) $v_s = v_{oc} = 10$ V

$i_s = i_{sc} = 100\ \mu$A

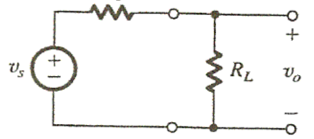
$$R_s = \frac{v_{oc}}{i_{sc}} = \frac{10\text{ V}}{100\ \mu\text{A}} = 0.1\text{ M}\Omega = 100\text{ k}\Omega$$

(b) $v_s = v_{oc} = 0.1$ V

$i_s = i_{sc} = 10\ \mu$A

$$R_s = \frac{v_{oc}}{i_{sc}} = \frac{0.1\text{V}}{10\ \mu\text{A}} = 0.01\text{ M}\Omega = 10\text{ k}\Omega$$

1.23



$$\frac{v_o}{v_s} = \frac{R_L}{R_L + R_s}$$

$$v_o = v_s \Big/ \left(1 + \frac{R_s}{R_L}\right)$$

Thus,

mV, kΩ
$$\frac{v_s}{1 + \frac{R_s}{100}} = 30 \quad (1)$$

and

mV, kΩ
$$\frac{v_s}{1 + \frac{R_s}{10}} = 10 \quad (2)$$

Dividing (1) by (2) gives

$$\frac{1 + (R_s/10)}{1 + (R_s/100)} = 3$$
$$\Rightarrow R_s = 28.6\text{ k}\Omega$$

Substituting in (2) gives

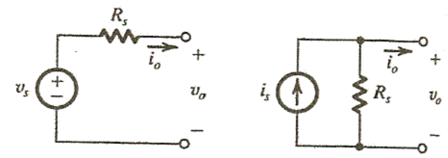
$$v_s = 38.6\text{ mV}$$

The Norton current i_s can be found as

$$i_s = \frac{v_s}{R_s} = \frac{38.6\text{ mV}}{28.6\text{ k}\Omega} = 1.35\ \mu\text{A}$$

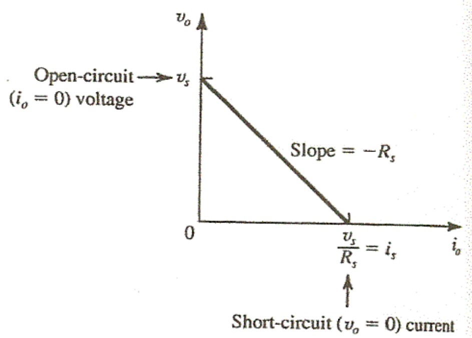
1.24 The observed output voltage is 1 mV/°C which is one half the voltage specified by the sensor, presumably under open-circuit conditions that is without a load connected. It follows that sensor internal resistance must be equal to R_L, i.e., 10 kΩ.

1.25

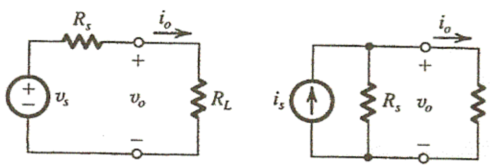


$$v_o = v_s - i_o R_s$$

$$v_o = (i_s - i_o)R_s$$
$$= i_s R_s - i_o R_s$$
$$v_o = v_s - i_o R_s$$



1.26



R_L represents the input resistance of the processor

For $v_o = 0.9\, v_s$,

$$0.9 = \frac{R_L}{R_L + R_s} \quad \Rightarrow \quad R_L = 9R_s$$

For $i_o = 0.9\, i_s$,

$$0.9 = \frac{R_s}{R_s + R_L} \quad \Rightarrow \quad R_L = R_s/9$$

1.27

Case	ω (rad/s)	f (Hz)	T (s)
a	6.28×10^9	1×10^9	1×10^{-9}
b	1×10^9	1.59×10^8	6.28×10^{-9}
c	6.28×10^{10}	1×10^{10}	1×10^{-10}
d	3.77×10^2	60	1.67×10^{-2}
e	6.28×10^3	1×10^3	1×10^{-3}
f	6.28×10^6	1×10^6	1×10^{-6}

1.28 (a) $V_{peak} = 117 \times \sqrt{2} = 165$ V

(b) $V_{rms} = 33.9/\sqrt{2} = 24$ V

(c) $V_{peak} = 220 \times \sqrt{2} = 311$ V

(d) $V_{peak} = 220 \times \sqrt{2} = 311$ kV

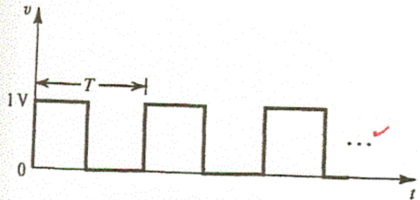
1.29 (a) $v = 10 \sin(2\pi \times 10^4 t)$, V

(b) $v = 120\sqrt{2} \sin(2\pi \times 60)$, V

(c) $v = 0.1 \sin(1000t)$, V

(d) $v = 0.1 \sin(2\pi \times 10^{+3} t)$, V

1.30 Comparing the given waveform to that described by Eq. 1.2 we observe that the given waveform has an amplitude of 0.5 V (1 V peak-to-peak) and its level is shifted up by 0.5 V (the first term in the equation). Thus the waveform look as follows



Average value = 0.5 V
Peak-to-peak value = 1 V
Lowest value = 0 V
Highest value = 1 V

$$\text{Period } T = \frac{1}{f_0} = \frac{2\pi}{\omega_0} = 10^{-3}\text{s}$$

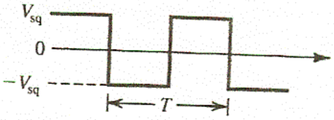
1.31 The two harmonics have the ratio $126/98 = 9/7$. Thus, these are the 7th and 9th harmonics. From Eq. 1.2 we note that the amplitudes of these two harmonics will have the ratio 7 to 9, which is confirmed by the measurement reported. Thus the fundamental will have a frequency of 98/7 or 14 kHz and peak amplitude of $63 \times 7 = 441$ mV. The rms value of the fundamental will be $441/\sqrt{2} = 312$ mV. To find the peak-to-peak amplitude of the square wave we note that $4V/\pi = 441$ mV. Thus,

$$\text{Peak-to-peak amplitude} = 2V = 441 \times \frac{\pi}{2} = 693 \text{ mV}$$

$$\text{Period } T = \frac{1}{f} = \frac{1}{14 \times 10^3} = 71.4\ \mu s$$

1.32 To be barely audible by a relatively young listener, the 5th harmonic must be limited to 20 kHz; thus the fundamental will be 4 kHz. At the low end, hearing extends down to about 20 Hz. For the fifth and higher to be audible the fifth must be no lower than 20 Hz. Correspondingly, the fundamental will be at 4 Hz.

1.33 If the amplitude of the square wave is V_{sq} then the power delivered by the square wave to a resistance R will be V_{sq}^2/R. If this power is to equal that delivered by a sine wave of peak amplitude $\hat{V}$ then



$$\frac{V_{sq}^2}{R} = \frac{(\hat{V}/\sqrt{2})^2}{R}$$

Thus, $V_{sq} = \hat{V}/\sqrt{2}$. This result is independent of frequency.

1.34

Decimal	Binary
0	0
5	101
8	1000
25	11001
57	111001

1.35

b_3 b_2 b_1 b_0	Value Represented
0 0 0 0	+0
0 0 0 1	+1
0 0 1 0	+2
0 0 1 1	+3
0 1 0 0	+4
0 1 0 1	+5
0 1 1 0	+6
0 1 1 1	+7
1 0 0 0	−0
1 0 0 1	−1
1 0 1 0	−2
1 0 1 1	−3
1 1 0 0	−4
1 1 0 1	−5
1 1 1 0	−6
1 1 1 1	−7

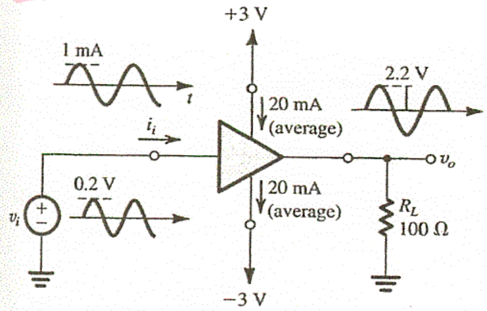
or, 20 log 1000 = 60 dB

$$A_p = \frac{v_o i_o}{v_i i_i} = \frac{v_o}{v_i} \times \frac{i_o}{i_i}$$

$$= 10 \times 1000 = 10^4 \text{ W/W}$$

or 10 $\log_{10} A_p = 40$ dB

1.40



$$A_v = \frac{v_o}{v_i} = \frac{2.2}{0.2}$$

$$= 11 \text{ V/V}$$

or 20 log 11 = 20.8 dB

$$A_i = \frac{i_o}{i_i} = \frac{2.2 \text{ V}/100\ \Omega}{1 \text{ mA}}$$

$$= \frac{22 \text{ mA}}{1 \text{ mA}} = 22 \text{ A/A}$$

or, 20 log A_i = 26.8 dB

$$A_p = \frac{p_o}{p_i} = \frac{(2.2/\sqrt{2})^2/100}{\frac{0.2}{\sqrt{2}} \times \frac{10^{-3}}{\sqrt{2}}}$$

$$= 242 \text{ W/W}$$

or, 10 log A_p = 23.8 dB

Supply power = 2 × 3 V × 20 mA = 120 mW

$$\text{Output power} = \frac{v_{orms}^2}{R_L} = \frac{(2.2/\sqrt{2})^2}{100\ \Omega} = 24.2 \text{ mW}$$

$$\text{Input power} = \frac{24.2}{242} = 0.1 \text{ mW} \quad \text{(negligible)}$$

Amplifier dissipation ≃ Supply power − Output power

$$= 120 - 24.2 = 95.8 \text{ mW}$$

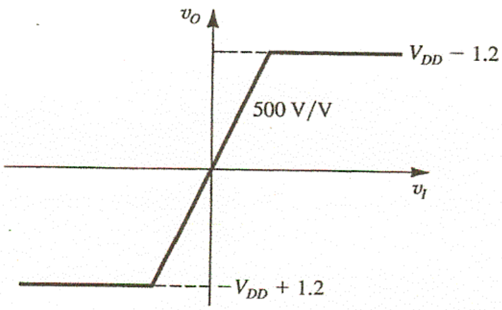
$$\text{Amplifier efficiency} = \frac{\text{Output power}}{\text{Supply power}} \times 100$$

$$= \frac{24.2}{120} \times 100 = 20.2\%$$

1.41 For $V_{DD} = 5$ V:

The largest undistorted sine-wave output is of 3.8-V peak amplitude or $3.8/\sqrt{2} = 2.7\,V_{rms}$. Input needed is 5.4 mV_{rms}.

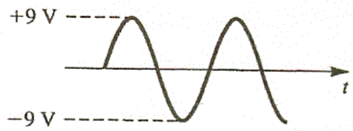
Supplies are V_{DD} and $-V_{DD}$



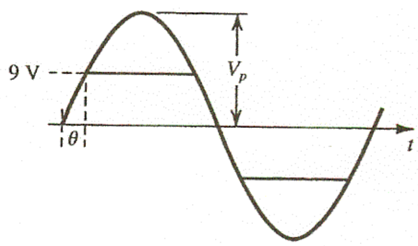
For $V_{DD} = 10$ V, the largest undistorted sine-wave output is of 8.8-V peak amplitude or 6.2 V_{rms}. Input needed is 12.4 mV_{rms}.

For $V_{DD} = 15$ V, the largest undistorted sine-wave output is of 13.8-V peak amplitude or 9.8 V_{rms}. The input needed is 9.8 V/500 = 19.6 mV_{rms}.

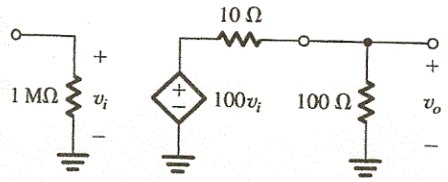
1.42 (a) For an output whose extremes are just at the edge of clipping, i.e., an output of 9-V_{peak}, the input must have 9 V/1000 = 9 mV_{peak}.



(b) For an output that is clipping 90% of the time, $\theta = 0.1 \times 90° = 9°$ and $V_p \sin 9° = 9 \text{ V} \Rightarrow V_p = 57.5$ V which of course does not occur as the output saturates at ±9 V. To produce this result, the input peak must be 57.5/1000 = 57.5 mV.



1.46 $20 \log A_{v_o} = 40 \text{ dB} \Rightarrow A_{v_o} = 100 \text{ V/V}$



$$A_v = \frac{v_o}{v_i}$$

$$= 100 \times \frac{100}{100 + 10}$$

$$= 90.9 \text{ V/V}$$

or, $20 \log 90.9 = 39.1$ dB

$$A_p = \frac{v_o^2/100\ \Omega}{v_i^2/1\ \text{M}\Omega} = A_v^2 \times 10^4 = 8.3 \times 10^7 \text{ W/W}$$

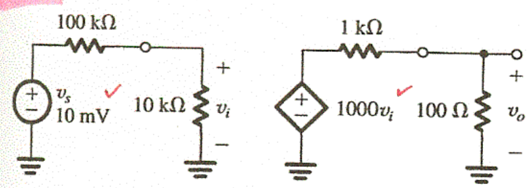
or $10 \log (8.3 \times 10^7) = 79.1$ dB.

For a peak output sine-wave current of 100 Ω, the peak output voltage will be 100 mA × 100 Ω = 10 V. Correspondingly v_i will be a sine wave with a peak value of 10 V/A_v = 10/90.9 or an rms value of $10/(90.9 \times \sqrt{2}) = 0.08$ V.

Corresponding output power $= (10/\sqrt{2})^2/100\ \Omega$

$= 0.5$ W

1.47



$$\frac{v_o}{v_s} = \frac{10\ \text{k}\Omega}{10\ \text{k}\Omega + 100\ \text{k}\Omega} \times 1000 \times \frac{100\ \Omega}{100\ \Omega + 1\ \text{k}\Omega}$$

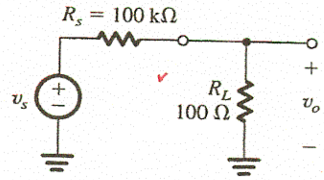
$$= \frac{10}{110} \times 1000 \times \frac{100}{1100} = 8.26 \text{ V/V}$$

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,

$$\frac{v_o}{v_s} = \frac{R_L}{R_L + R_s}$$

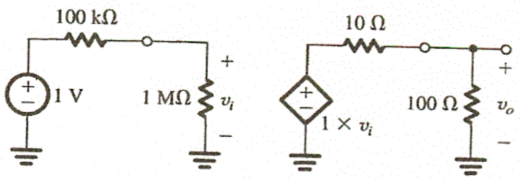
$$= \frac{100\ \Omega}{100\ \Omega + 100\ \text{k}\Omega}$$

$$\simeq 0.001 \text{ V/V}$$



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

1.48



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

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

Voltage gain $= \frac{v_o}{v_s} = 0.83$ V/V or -1.6 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

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.)