1. Ohm's law relates V, I, and R for a resistor. For each of the situations following, find the missing item:

   (a) (2½ points) $R = 1\,\text{k}\Omega, V = 5\,\text{V}$

   Solution: $I = \frac{V}{R} = \frac{5V}{1k} = 5mA$

   (b) (2½ points) $V = 5\,\text{V}, I = 1\,\text{mA}$

   Solution: $I = \frac{V}{I} = \frac{5V}{1mA} = 5k$

   (c) (2½ points) $R = 10\,\text{k}\Omega, I = 0.1\,\text{mA}$

   Solution: $V = IR = 10k * 0.1mA$=1V

   (d) (2½ points) $R = 100\,\Omega, V = 1\,\text{V}$

   Solution: $I = V/R = 10mA$

2. FIG 1 (a) shows a two-resistor voltage divider. Its function is to generate a voltage V_o (smaller than the power-supply voltage V_{DD}) at its output node X. The circuit looking back at node X is equivalent to that shown in FIG 1 (b). Observe that this is the Thevenin equivalent of the voltage-divider circuit.

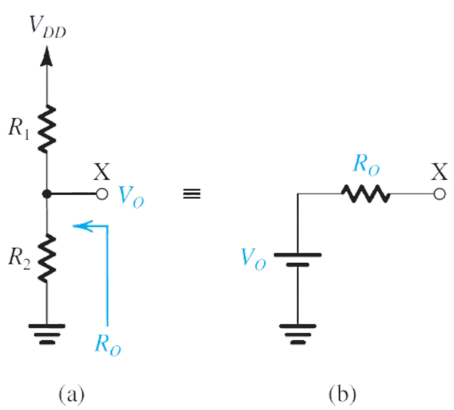


FIGURE 1. Two-resistor voltage divider.

   (a) (5 points) Find expressions for V_o for $V_{DD} = 5V, R_1 = R_2 = 1k$

Solution: $V_o = V_{DD}\frac{R_2}{R_1+R_2} = \frac{5V \cdot 1k}{2k} = 2.5V$
According to the Thevenin equivalent principal, R_o is found by shorting V_{DD} into the node X.

(b) (5 points) Find expressions for Ro for $V_{DD} = 5V, R_1 = R_2 = 1k$

Solution: $R_o = R_1||R_2 = \frac{R_1 \cdot R_2}{R_1+R2} = 500\Omega$

3. (20 points) An amplifier has the following RMS[1] characteristics: $v_I = 100mv, i_I = 100\mu A, v_o = 10V, R_L = 100\Omega$. Find its the voltage, current, and power gains (A_v ,A_i , and A_p, respectively) both as ratios and in dB

Solution: $A_v = \frac{v_o}{v_I} = \frac{10V}{100mV} = 100V/V = 20log_{10}100 = 40dB$
$A_i = \frac{i_o}{i_I} = \frac{v_o/R_L}{i_I} = \frac{10V/100\Omega}{100\mu A = 1000A/A = 20log_{10}10000 = 60dB}$
$A_p = \frac{v_o \cdot i_o}{v_I \cdot i_I} = 100 \cdot 10000 = 10^5 W/W = 50dB$

4. Suppose you are part of team that needs to design a voltage amplifier which will be driven from a signal source v_s with an amplitude of $v_s = 5mV$ peak amplitude and a source resistance of $R_s = 10k\Omega$. Assuming that the amplifer must supply a peak output of $v_o = 2V$ across a $R_L = 1k\Omega$ load $\cdots$

(a) (5 points) What is the required voltage gain from the source to the load?

Solution: The voltage gain is

$$A_v = \frac{v_o}{v_s} = \frac{2V}{0.005V} = 400^V/_V \tag{1}$$

(b) (5 points) If the peak current available from the source is $0.1\mu A$, what is the smallest input resistance allowed?

Solution: The smallest input resistor R_i that is allowed is given

$$0.1\,\mu\text{A} = \frac{5mV}{R_s + R_i} \Leftrightarrow R_s + R_i = 50\,\text{k}\Omega \Rightarrow R_i = 40\,\text{k}\Omega \tag{2}$$

[1] Remember the root-mean-square (RMS) value of a voltage V_a is equal to$V_{RMS} = \frac{V_a}{\sqrt{2}}$

(c) (5 points) For the design with the value of R_i obtained in question (b) above, find the overall current gain and power gain.

Solution:

- For R_i =40 kΩ and 0.1 µA peak current, the overall current gain is

$$\frac{{}^{v_o}/_{R_L}}{i_i} = \frac{\frac{2V}{1\,\mathrm{k\Omega}}}{0.1\,\mu\mathrm{A}} = 2 \times 10^4 \, {}^{A}/_{A} \tag{3}$$

- If we take into consideration the power dissipated into the internal resistor of the source, the overall power gain is given

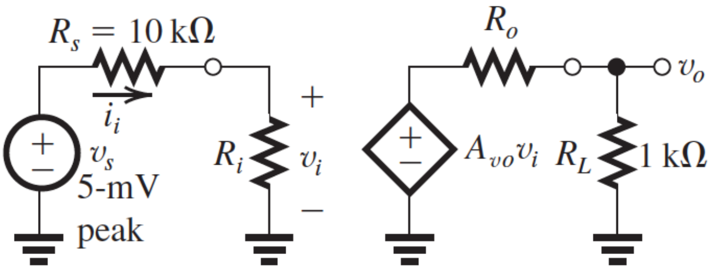
$$\frac{P_o(rms)}{P_i(rms)} = \frac{v^2_{o(rms)}/R_L}{v_{s(rms)} \times i_{i(rms)}} \tag{4}$$

The above equation reduces to (in RMS values):

$$\frac{\left(\frac{2}{\sqrt{2}}\right)^2/1000}{\frac{5\times10^{-3}}{\sqrt{2}} \times \frac{0.1\times10^{-6}}{\sqrt{2}}} = 8 \times 10^6 W/W \tag{5}$$

(d) (5 points) If the amplifier power supply limits the peak value of the output open-circuit voltage to 3 V, what is the largest output resistance allowed?

Solution: The circuit can be modeled as follows:



If the amplifier power supply limits the peak value of the output open-circuit voltage to 3 V, then largest value of the output resistor R_o is given by

$$R_o = 3V \times \frac{R_L}{R_L + R_o} = 2 \tag{6}$$

Thus, the maximum output resistor allowed is given by

$$R_o = \frac{1}{2} R_L = 500\,\Omega \tag{7}$$

5. A spectrum analyzer is used to measure a square a square-wave signal. The spectrum analyzer is a frequency-selective voltmeter and show its spectrum to contain adjacent components (spectrallines) at 98 kHz and 126 kHz of amplitudes 63 mV and49 mV, respectively.

   (a) (5 points) For this signal, what would direct measurement of the fundamental show its frequency and amplitude to be?

   (b) (5 points) What is the RMS value of the fundamental?

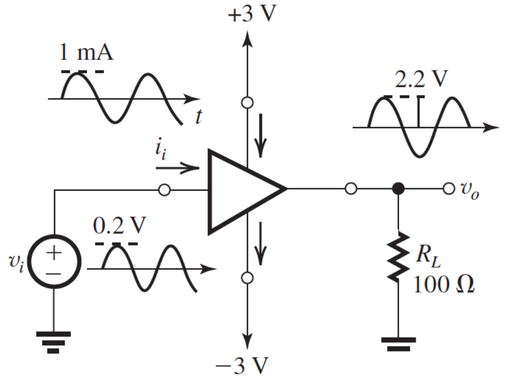
   (c) (5 points) What are the peak-to-peak amplitude and period of the originating square wave?

Solution: Please skip this question. It was not covered in our lectures

6. An amplifier operating from $\pm 3V$ supplies provides a $2.2V$ peak sine wave across a $100\,\Omega$ load when provided with a 0.2 V peak input from which 1.0mA peak is drawn. The average current in each supply is measured to be 20 mA.

   (a) (5 points) Find the voltage gain of the amplifier

Solution:
The amplifier can be modeled as follows



The voltage gain, vo/vi is given by

$$\frac{V_o}{V_i} = \frac{2.2}{0.2} = 11V/V = 20.8dB \tag{8}$$

   (b) (5 points) Find the current gain of the amplifier

Solution: The current gain

$$\frac{I_o}{I_i} = \frac{2.2/0.1}{1} = 22A/A = 26.8dB \tag{9}$$

(c) (5 points) Find the power gain of the amplifier and express it in decibels

Solution:

$$\frac{V_o I_o/2}{V_i I_i/2} = 11 \times 22 = 242W/W = 23.8dB \tag{10}$$

(d) (10 points) Find the supply power, amplifier dissipation, and amplifier efficiency.

Solution: The supply power is

$$\frac{V_o^2}{2R_L \times \frac{1}{\eta}} = \frac{2.2^2}{2 \times 0.1 \times 0.1} = 242mW \tag{11}$$