Power in AC Circuits

Resistors and Power
In previous labs we have verified the equations for finding the equivalent resistance for resistors and capacitors in series and parallel.

\[
R_{eq} = R_1 + R_2 + R_3 \quad (1)
\]

In a series combination, the current is the same in each resistor and the voltages across each resistor \(( V_1 = I R_1, \text{ etc})\) are different.

\[
\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad (2)
\]

In a parallel combination, the voltage across each resistor is the same but the currents through each resistor \(( I_1 = V / R_1 )\) are different.

The power in a component of an electric component is given by \(P = I V\). If the component obeys Ohms law, then we can have

\[
P = I V = I^2 R = \frac{V^2}{R} \quad (3)
\]

In a circuit there must be a device such as a power supply to provide the power and devices such as resistors to dissipate the power.

AC Circuits

Fig. 1. Voltage vs. time for an ac voltage.

The voltage produced by an alternating current (ac) generator is sinusoidal and can be represented by the function

\[
V = V_0 \sin 2\pi f t \quad (4)
\]

The voltage oscillates between \(+ V_0\) and \(- V_0\). \(V_0\) is the amplitude or peak voltage. In this lab you will use an oscilloscope and it is easier to measure the distance between \(+ V_0\) and \(- V_0\). This is called the peak to peak voltage \(V_{pp}\). Note that

\[
V_{pp} = 2V_0 \quad (5)
\]
Another way of expressing the magnitude of ac voltage is to calculate $V_{rms} -$ the square of the average voltage squared over one cycle. It can be shown that 

$$V_{rms} = 0.707 V_0$$  \hspace{1cm} (6)

and the average power is

$$\bar{P} = \frac{1}{2} \frac{V_0^2}{R}$$  \hspace{1cm} (7)

One advantage of the $rms$ voltage and $rms$ current is that they can be substituted directly in the DC formulas for average power:

$$\bar{P} = I_{rms} V_{rms} = I_{rms}^2 \frac{V_{rms}^2}{R}$$  \hspace{1cm} (8)

**Procedure**

1. **AC Voltage and Power**

   1. Measure the accurate resistance of a nominal resistor $R_1 = 1.0 \, \text{k}\Omega$ and make sure you use that value in your calculations. Set up the circuit shown in Fig. 2 using that resistor.

   ![Figure 2. Circuit for Part 1.](image)

   2. Set the Wavetek Signal Generator to a sine wave with amplitude of about $10 \, V_{pp}$, frequency of about 60Hz, and DC offset to zero. (The on-off switch for the generator is on the back.) The digital display of the Wavetek Signal Generator shows these quantities one at a time and you can switch between them by pressing Display Select button. The Amplitude knob will allow you to control the peak-to-peak voltage, the DC offset knob will allow you to control the DC offset. To set the frequency to 60 Hz, press the Frequency Range button for 200 Hz, and then adjust it with the Frequency knob.

   3. Open the Data Studio and 'Create Experiment'. In the 'Experiment Setup' from the list of sensors select the 'Voltage Sensor' icon and connect it to the analog channel “A” and “B” on the picture of the 'Interface
Box’. Open the 'Scope' display for channel “A” first, and then drag the icon of 'Voltage Channel “B”' to the same scope display, so the signals from both can be viewed on the same window for Part 2. Press “Start”. Your instructor will tell you how to adjust the controls for a stable picture. In ac circuits, the black connector is ground and the red has the oscillating voltage.

4. Measure $V_{pp}$ using the scope. From the measured peak-to-peak voltages, calculate the equivalent $rms$ voltages using Eqns. 5 and 6.

5. Use the multimeter to measure the $V_{rms}$ across $R_1$. Compare with the value resulting from step 4.

6. Calculate the power of each resistor and the power supply using the scope measurements and Eqns. 5 and 7. Also calculate the power using the multimeter measurements and calculate the % difference between the two.

7. Calculate the theoretical power in the resistor using the Eqn. 7 and the three versions of Eqn. 8. Discuss any differences.

2. AC Circuits

1. Set up the circuit shown in Fig. 3 with nominal resistors: $R_1 = 1.0$ kΩ and $R_2 = 2.2$ kΩ.

2. Use the same Data Studio and signal generator settings as Part 1. Make sure you have the channel B working correctly.

4. Measure $V_{pp}$ and make a table similar to Table 1. From the measured peak-to-peak voltages, calculate the equivalent $rms$ voltages using Eqns. 5 and 6.

5. Use the multimeter to measure the $V_{rms}$ for each resistor and the power supply.

6. Calculate the power dissipated in each resistor and the power supply using the scope measurements and Eqns. 5 and 7. Also calculate the power using the multimeter measurements and calculate the % difference between the two.

7. Calculate the theoretical power in each resistor using the $rms$ voltage output of the power supply and the measured resistance of each resistor. Then calculate the % difference between these theoretical power values and the experimental power values calculated from the $V_{rms}$ values measured by the multimeter.

<table>
<thead>
<tr>
<th>i</th>
<th>$R_i$ (ohms)</th>
<th>$V_{pp}$ (V) scope</th>
<th>$V_{rms}$ (V) scope</th>
<th>$V_{rms}$ (V) meter</th>
<th>P (W) scope</th>
<th>P (W) Meter</th>
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Table 1
Figure 3. Circuit for Part 2. The Channel B wires will be moved to measure the voltage across each resistor.