203-NYB-05
Electricity and Magnetism
Professor: Ernest Dubeau

AC Circuits: Lab 1

By:

Philipe Goulet

November 5, 2018

Departement of Physics
Champlain Regional College
Lennoxville, Quebec, Canada

Prelab

1.1 An Oscilloscope is connected across a power source and the screen displays the image seen in figure.

a) What is the peak voltage of the signal (include the uncertainty)?

$$(20.0 \pm 0.5)\text{V} \tag{1.1}$$

b) What is the period of the signal (include the ucnertainty)?

$$(0.100 \pm 0.005)\text{s} \tag{1.2}$$

c) What is the frequency of the power source (include the uncertainty)?

$$\begin{aligned} f &= \frac{1}{T} \\ &= \frac{1}{(0.100 \pm 0.005)\text{s}} \\ &= (10.0 \pm 0.5)\text{Hz} \end{aligned} \tag{1.3}$$

d) If a DMM were to be connected across the same power source, what reading would you expect (Include the uncertainty)?

$$\begin{aligned} \Delta\text{V}_{rms} &= \frac{\Delta\text{V}_{\text{max}}}{\sqrt{2}} \\ &= \frac{(20.0 \pm 0.5)\text{V}}{\sqrt{2}} \\ &= (14.1 \pm 0.7)\text{V} \end{aligned} \tag{1.4}$$

e) Write the sinusoidal function that represents the signal given off by the power source (do not include the uncertainty)?

$$\begin{aligned}\sin(\omega t+\phi) &= \sin(2\pi f * t+\phi)\\ &= \sin(2\pi 10 * +0)\\ &= \sin(20\pi t)\end{aligned} \tag{1.5}$$

f) This power source is now connected to a single resistor with resistance $R = (100 \pm 2)\Omega$.What is the value of $I_{\max}$ (include uncertainties)?

$$\begin{aligned}\Delta \mathrm{V}_{\max} &= I_{\max} R\\ I_{\max} &= \frac{\Delta \mathrm{V}_{\max}}{R}\\ I_{\max} &= \frac{(20.0 \pm 0.5)\mathrm{V}}{(100 \pm 2)\Omega}\\ I_{\max} &= (200 \pm 9)\mathrm{mA}\end{aligned} \tag{1.6}$$

g) How much current passes through this resistor at $t = 0.0050\mathrm{s}$ (no uncertainties)

$$\begin{aligned}I(t) &= \frac{\Delta \mathrm{V}(t)}{R}\\ I(0.050) &= \frac{\Delta \mathrm{V}(0.050)}{R}\\ &= \frac{0\mathrm{V}}{100\Omega}\\ &= 0\end{aligned} \tag{1.7}$$

h) How much power (on average) is delivered to this resistor (include uncertainties)?

$$\begin{aligned}P_{rms} &= \Delta \mathrm{V}_{rms} I_{rms}\\ &= \frac{\Delta \mathrm{V}_{\max}}{\sqrt{2}}\frac{I_{\max}}{\sqrt{2}}\\ &= \frac{(20.0 \pm 0.5)\mathrm{V}}{\sqrt{2}}\frac{(200 \pm 9)\mathrm{mA}}{\sqrt{2}}\\ &= (3.17 \pm 0.38)\mathrm{W}\end{aligned} \tag{1.8}$$

i) How much current passes through this resistor at $t = 0.025\text{s}$ (no uncertainties)

$$\begin{aligned} I(t) &= \frac{\Delta \mathrm{V}(t)}{R} \\ I(0.025) &= \frac{\Delta \mathrm{V}(0.025)}{R} \\ &= \frac{20\mathrm{V}}{100\Omega} \\ &= 0.2\mathrm{A} \end{aligned} \tag{1.9}$$

j) How much current passes through this resistor at $t = 0.10\text{s}$ (no uncertainties)

$$\begin{aligned} I(t) &= \frac{\Delta \mathrm{V}(t)}{R} \\ I(0.10) &= \frac{\Delta \mathrm{V}(0.10)}{R} \\ &= \frac{0\mathrm{V}}{100\Omega} \\ &= 0 \end{aligned} \tag{1.10}$$

Aims

This lab was conceived to explore the basic concepts of AC circuits and observe and measure the properties of different components (such as resistors, capacitors and inductors) when exposed to alternating currents of various frequencies.

Aparatus

- Oscilloscope
- Stopwatch
- Pasco Digital Function Generator (ac source)
- Digital Multimeter (*BK* and *Brunelle*)

- Lamp
- A 1µF capacitor

AC circuit with a single resistor

4.1 Procedure

- Replicate the circuit shown in figure 11.
- Turn on both digital multimeters and set them to ac mode.
- Set the frequency of the AC source to 1000hz.
- Connect the lamp to the channel A of your oscilloscope using the coaxial cable. You should observe a sinusoidal pattern on the oscilloscope's screen.
- Adjust the amplitude of the AC source to have a $\Delta V_{\max}$ of 4.0V as measured on the oscilloscope. Use this value of $\Delta V_{\max}$ to calculate ΔV_{rms}. Include the uncertainties.
- Draw a sketch of the oscilloscope screen and make sure to include a scale (and units).
- Use the Brunelle DMM to measure the *rms* voltage across the resistor (a lamp) and use the BK digital multimeter to measure the *rms* current (note uncertainties in both cases).
- Compare the ΔV_{rms} measured with the digital multimeter to the ΔV_{rms} calculated previously to verify whether or not the digital multimeter actually measures the *rms* voltage. Make sure to account for uncertainties.
- Use the AC readings of both digital multimeters and Ohm's law in AC (see theory) to calculate the resistance of the lamp (include uncertainties). Use the measure values of ΔV and I_{rms} to determine the average power delivered to R (include uncertainties)
- Measure the period T of the signal on the oscilloscope's screen. Use this measured value to calculate the frequency and compare it to the frequency given by the AC power source. (include uncertainties).
- Change the frequency of the AC power source to 100 Hz.
- Adjust the time/div knob of the oscilloscope until you can cleary see the sinusoidal wave on the screen. Note down the new time scale used.

- Set the AC source to 10Hz and repeat the last step.
- Predict how many times the lamp would blink in 10 seconds if you set the frequency to 1Hz. Write down your prediction.
- Change the frequency of the AC source to 1Hz and verify your prediction.
- Turn off the AC source before performing the next step for safety.

4.2 Measurements

$$\Delta \mathrm{V}_{\max} = (4.0 \pm 0.2)\mathrm{V} \tag{4.1}$$
$$\Delta \mathrm{V}_{rms} = (2.79 \pm 0.06)\mathrm{V} \tag{4.2}$$
$$I_{rms} = (4.0 \pm 0.2)\mathrm{V} \tag{4.3}$$
$$T = (1.00 \pm 0.04)\mathrm{ms} \tag{4.4}$$

4.3 Calculations

$$\Delta \mathrm{V}_{rms} = \frac{\Delta \mathrm{V}_{\max}}{\sqrt{2}}$$
$$\Delta \mathrm{V}_{rms} = \frac{(4.0 \pm 0.2)\mathrm{V}}{\sqrt{2}}$$
$$\Delta \mathrm{V}_{rms} = (2.8 \pm 0.1)\mathrm{V} \tag{4.5}$$

$$P_{avg} = \Delta \mathrm{V}_{rms} I_{rms}$$
$$P_{avg} = (2.79 \pm 0.06)\mathrm{V} * (4.0 \pm 0.2)\mathrm{V}$$
$$P_{avg} = (0.285 \pm 0.012)\mathrm{W} \tag{4.6}$$

$$F = \frac{1}{T}$$
$$F = \frac{1}{(0.0010 \pm 0.0004)\mathrm{s}}$$
$$F = (1000 \pm 40)\mathrm{Hz} \tag{4.7}$$

4.4 Discussion

The voltage$_{rms}$ measured at (4.2) agrees with the calculated value at (4.5)
The frequency calculated at (4.7) agrees with the given value of 1000 Hz
When the frequency was set to 100Hz, a time scale of 2ms/div was needed for proper observation

When the frequency was set to 10Hz, a time scale of 20ms/div was needed for proper observation. The sine wave shown on the oscilloscope also started flashing
Since this is an ac circuit, the lamp should flash twice per period. Thus, by setting the frequency to 1 Hz should make the lamp light up 20 times over 10 seconds. This was confirmed when tested, and the lamp does flash twice per period because there are two voltage peaks during one period.

AC circuit with an inductor

5.1 Procedure

- Replace the lamp by a 10mH inductor.
- Set the frequnecy of the AC source to 1800 Hz
- Adjust the horizontal scale of the oscilloscope to see the sinusoidal pattern on the screen.
- Measure the value of ΔV_{Lrms} and I_{Lrms}. Use these values to calculate X_L (include uncertainties and units on X_L).
- Use the calculated value of X_L to caluclate L with its uncertainties.
- Verify that the calculated value of L is in agreement with the nominal value of (10 ± 1)mH
- Now set frequency of the AC source to 1600 Hz. Observe how the reading of both digital multimeters change. Interpret the variatiation
- Turn off the AC source before performing the next step for safety.

5.1.1 Measurements

With F=1800Mhz

$$\Delta V_{Lrms} = (2.73 \pm 0.06)\mathrm{V} \tag{5.1}$$
$$I_{rms} = (23.8 \pm 0.8)\mathrm{mA} \tag{5.2}$$

With F=1600Mhz

$$\Delta V_{Lrms} = (2.73 \pm 0.06)\mathrm{V} \tag{5.3}$$
$$I_{rms} = (26.4 \pm 0.8)\mathrm{mA} \tag{5.4}$$

5.1.2 Calculations

$$\begin{aligned}
\Delta \mathrm{V}_{Lrms} &= X_L I_{rms} \\
X_L &= \frac{\Delta \mathrm{V}_{Lrms}}{I_{rms}} \\
X_L &= \frac{(2.73 \pm 0.06)\mathrm{V}}{(23.8 \pm 0.8)\mathrm{mA}} \\
X_L &= (11.47 \pm 0.29)\frac{\mathrm{V}}{\mathrm{A}} \qquad (5.5)
\end{aligned}$$

$$\begin{aligned}
X_L &= \omega L \\
L &= \frac{X_L}{\omega} \\
L &= \frac{(114.7 \pm 0.3)\frac{\mathrm{V}}{\mathrm{A}}}{2\pi 1800\mathrm{Hz}} \\
L &= (10.14 \pm 0.26)\mathrm{mH} \qquad (5.6)
\end{aligned}$$

5.1.3 Discussion

The value of L calulated at (5.6) agrees with the nomival value of 10mH ± 1mH When the frequency of the ac source was changed to 1600hz the $\Delta \mathrm{V}_{Lrms}$ did not change and the I_{rms} went down linearly.

AC Circuit with a capacitor

6.1 Procedure

- Replace the inductor by a 1.0µF capacitor and set the frequency of the AC source to 1000Hz
- Measure the $\Delta \mathrm{V}_{Crms}$ and I_{Crms} using both digital multimeters.
- Calculate X_C using these measurements (ignore uncertainties).
- Use the calculated X_C to determine C (ignore uncertainties).
- Calculate the percent error on C.
- Predit the value of I_{Crms} when the frequency of the power source is 600Hz

6.2 Measurements

$$\Delta \mathrm{V}_{Crms} = 2.76\mathrm{V} \tag{6.1}$$
$$I_{Crms} = 16.8\mathrm{mA} \tag{6.2}$$
$$I_{Crms(600hz)} = 10.1\mathrm{mA} \tag{6.3}$$

6.3 Calculations

$$\begin{aligned} \Delta \mathrm{V}_{Crms} &= X_L I_{Crms} \\ X_C &= \frac{\Delta \mathrm{V}_{Crms}}{I_{Crms}} \\ X_C &= \frac{2.76\mathrm{V}}{16.8\mathrm{mA}} \\ X_C &= 164.3\frac{\mathrm{V}}{\mathrm{A}} \end{aligned} \tag{6.4}$$

$$\begin{aligned} X_C &= \frac{1}{\omega C} \\ C &= \frac{1}{\omega X_C} \\ C &= \frac{1}{2\pi 1000\mathrm{Hz} * 164.3\frac{\mathrm{V}}{\mathrm{A}}} \\ C &= 0.9687\mathrm{\mu F} \end{aligned} \tag{6.5}$$

$$\begin{aligned} \%error &= 100 * (C_{cal} - 1.00\mathrm{\mu F})/1.00\mathrm{\mu F} \\ \%error &= 100 * (0.9687\mathrm{\mu F} - 1.00\mathrm{\mu F})/1.00\mathrm{\mu F} \\ \%error &= 3.13\% \end{aligned} \tag{6.6}$$

$$\begin{aligned} \Delta \mathrm{V}_{Crms} &= X_L I_{Crms} \\ I_{Crms} &= \frac{\Delta \mathrm{V}_{Crms}}{X_L} \\ I_{Crms} &= \frac{2.76\mathrm{V}}{\frac{1}{2\pi * 600\mathrm{Hz} * 1.00\mathrm{\mu F}}} \\ I_{Crms} &= 10.4\mathrm{mA} \end{aligned} \tag{6.7}$$

6.4 Discussion

I predicted that the current would go down to 10.4mA as calculated in(6.7). However, the measured I_{Crms} went down to 10.1mA. A logical explanation for this would be that I wrongly assumed the voltage would stay identical, but since I have control of the source, I dont believe that to be correct. A 3% difference could've been explained by uncertainties in both the calculation and the measurement.