University of Victoria

ELEC 250

Linear Circuits I

Lab 2 - Phasor Analysis

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1 Object

This lab will study the steady-state responses of an RC and RL circuit when exposed to a purely sinusoidal voltage source. The current response and the phase shift of current relative to voltage will be calculated and compared with measured values.

2 Results

An Agilent 33220A signal generator was used to create the sinusoidal voltage source used in this lab. A peak-to-peak voltage of 10.5V was used for both circuits. Different frequencies were used in each section and is discussed further in sections 2.1 and 2.2.

An Agilent DSOX-2012A oscilloscope was used to analyze the maximal current and phase shift.

2.1 RC Circuit

The circuit was connected as show in figure 1 using selectable capacitor and resistor boxes provided in the lab. A 5 nF capacitor was used in the circuit. A sinusoidal voltage source with a frequency 10 kHz was applied to the circuit.

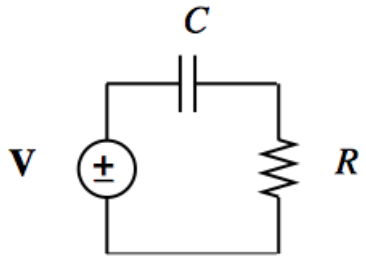

Figure 1: The RC circuit used in the lab

The expected phase shift, with current leading voltage, is given by equation (1), where $\omega = 2\pi f$. The expected maximum current is given by equation (2).

$$\tan\theta = \left(\frac{1}{\omega RC}\right) \tag{1}$$

$$I_{max}(t) = \frac{V_{max}(t)}{\sqrt{R^2 + (\frac{1}{C\omega})^2}} \tag{2}$$

The calculated and measured values of the current (I) and phase shift (θ) are summarized in table 1.

	Calculated		Measured	
R (kΩ)	I (mA)	θ (°)	I (mA)	θ (°)
1	3.15	72.56	3.10	70.89
5	1.77	32.48	1.76	31.12
10	1.00	17.67	0.98	14.89

Table 1: Calculated and measured values in the RC circuit

2.2 RL Circuit

The circuit was connected as shown in figure 2. The resistor box was reused and discrete inductors were obtained from the lab (see tables 2 and 3). The frequency of the voltage source was set to 500 kHz.

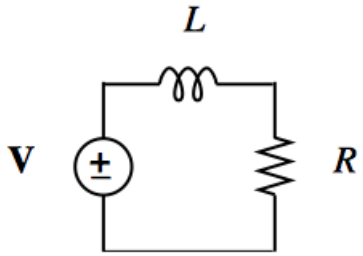

Figure 2: The RL circuit used in the lab

The expected phase shift of current with respect to voltage is given by equation (3). The negative sign indicates that voltage will lead current. The expected maximum current is given by equation (4).

$$\tan\theta = \left(\frac{-\omega L}{R}\right) \tag{3}$$

$$I_{max}(t) = \frac{V_{max}(t)}{\sqrt{R^2 + L^2\omega^2}} \tag{4}$$

Calculated values for each pairing of resistor and inductor is summarized in table 2. Measured results are presented in table 3.

	1μH		220μH		470μH		1000μH	
R (kΩ)	I (mA)	θ ($^\circ$)	I (mA)	θ ($^\circ$)	I (mA)	θ ($^\circ$)	I (mA)	θ ($^\circ$)
1	10.50	-0.18	8.64	-34.65	5.89	-55.89	3.18	-72.34
5	2.10	-0.04	2.08	-7.87	2.01	-16.45	1.78	-32.14
10	1.05	-0.02	1.05	-3.95	1.04	-8.40	1.00	-17.44

Table 2: Calculated values in the RL circuit

	1μH		220μH		470μH		1000μH	
R (kΩ)	I (mA)	θ ($^\circ$)	I (mA)	θ ($^\circ$)	I (mA)	θ ($^\circ$)	I (mA)	θ ($^\circ$)
1	3.00	-84	9.00	-36	6.00	-63	3.18	-82
5	2.46	-61	2.34	-9	2.58	-25	2.66	-58
10	2.01	-51	1.17	-5	1.41	-13	2.01	-42

Table 3: Measured values in the RL circuit

3 Discussion and Conclusion

The RC series circuit performed as expected. Minor discrepancies in phase shift and circuit current were observed which could be attributed to the use of non-ideal components that introduce a factor of uncertainty.

The RL series circuit performed nearly as expected for the $220\mu H$ with the $470\mu H$ and $1mH$ varying slightly. The discrepancies between measured and calculated values could be attributed to: *(a)heat:* results in added resistance produced by the components, and *(b)use of non-ideal components:* each circuit component adds a degree of uncertainty.

The $1\mu H$ inductor circuit, whether combined with the $1k\Omega$, $5k\Omega$, or the $10k\Omega$ resistors, provided results that appeared nearest to the values expected of a $1mH$. This part of the experiment was performed with two different inductors that yielded similar results. Possible justification for these discrepancies include: *(a)faulty components:* in this case, both $1\mu H$ inductors must be faulty, or *(b)mislabeled inductors:* the difference between the symbol for mH and μH may be difficult to differentiate when handwritten on heat shrink.

Capacitors are more predictable than inductors when connected to a circuit. This could be due to a by-product of heat produced within an inductor, or the improved accuracy of mass-producing capacitors versus inductors.

4 LaTeX Tips

Check the source file for additional information in the comments.

4.1 Symbols

Most math symbols and all equations are bounded by $ delimiters. `$ A=\pi r^{2} $` produces $A = \pi r^2$. To find the appropriate symbol you will have to use a LaTeX IDE with a built in symbol editor or use another program to produce the code and copy-and-paste it into your document.

4.2 Figures

```
\begin{figure}[h]
\centering
\includegraphics[width=0.75\textwidth]{Uvic_logo}
\caption{A logo used by the University of Victoria}
\label{fig:uvic_logo}
\end{figure}
```

Figure 3: A logo used by the University of Victoria

A good tutorial for the use of figures can be found at: `http://en.wikibooks.org/wiki/LaTeX/Floats,_Figures_and_Captions`

4.3 Tables

```
\begin{table}[h]
\centering
\begin{tabular}{llr}
\hline
\multicolumn{2}{c}{Item} \\
\cline{1-2}
Animal    & Description  & Price (\$) \\
\hline
Gnat & per gram & 13.65      \\
        & each        & 0.01       \\
Gnu & stuffed      & 92.50      \\
Emu & stuffed & 33.33      \\
Armadillo & frozen & 8.99       \\
\hline
\end{tabular}
\caption{Exotic meat prices}
\label{table:meats}
\end{table}
```

Item		
Animal	Description	Price ($)
Gnat	per gram	13.65
	each	0.01
Gnu	stuffed	92.50
Emu	stuffed	33.33
Armadillo	frozen	8.99

Table 4: Exotic meat prices

Apparently tables are more readable if the vertical rulings are omitted. I'm inclined to agree.
A good tutorial for the use of tables can be found at: `http://en.wikibooks.org/wiki/LaTeX/Tables`

4.4 Labels and References

LaTeX's dynamic referencing system gives it an advantage over other multi-user document tools. References point to assigned labels rather than a pre-defined numbering. Changing the order and number of references will leave the citations untouched if label referencing is used.

The `\label{}` tag should be attached to all sections, figures and tables. To reference these elements, use the `\ref{}` command. To reference the table in Section 4.3, you would write `Table \ref{table:meats}` which will appear as Table 4.

A consistent naming schema will make collaboration easier. Labels should be implemented with the corresponding prefix:

Sections	`{sec:}`
Figures	`{fig:}`
Tables	`{table:}`

You may encounter a situation where a citation or page number appears as `??`. This often occurs when major changes have occured to the reference or page order. The LaTeX compiler requires two executions of the typesetting function to correctly address the references: one to build the .aux file and another to read from it. The compiler is often nice enouch to pass a warning when the .aux file has undergone significant changes to its references and prompts you do another typesetting.

4.5 Resources

- Video playlist from McMaster that covers the installation and use of LaTeX. Uses TeXShop for examples. Covers document setup, tables, figures, bibliographies and some other stuff I haven't watched yet.