# LAB 4: Inductors and Time-Dependent Signals

# 

# 

# 

# PART 1: Time-Dependent Analysis of RL Circuits

# INTRODUCTION

Inductors are described as acting like capacitors--storing current in a magnetic field rather than charge in an electric field. In general, inductors resist change in current but, over time, will allow current to pass with very low impedance. Similar to RC circuits, resistor-inductor (RL) circuits can act as high- or low-pass filters for AC signals.

In part 1 of this lab, we sought to analyze the behavior of two configurations of a simple RL circuit with an AC input signal, and compare theoretical characterizations of the circuit to empirical characterizations. Our analysis of the filtering behavior of the circuits is mostly subjective, but the characteristic time of the circuit can be used to make some good connections to theory.

# EXPERIMENTAL

FIGURE: RL circuit

For an RL configuration, phasor analysis shows that for input frequencies much smaller than the characteristic frequency OMEGA\_C, the output voltage approaches zero. For frequencies much larger than OMEGA\_C, the output voltage approaches the input voltage.

EQUATION: Vout / Vin = ZL / ZL + ZR = iwL / iwL + R

EQUATION: Norm above

Where the characteristic frequency is given as OMEGA\_C = R / L

This suggests that the circuit will act as a high-pass filter, and will differentiate the input signal at sufficiently low frequencies.

The characteristic time of the circuit can be found using the CHI^2 optimization method, as in Lab 3, to fit a theoretical curve to a region of the output signal. For the RL configuration in particular, it’s most effective to choose an input frequency such that the “discharging” region of the output signal is long and easy to plot.

FIGURE: LR circuit

For the LR configuration, similar phasor analysis shows a case converse to the RL circuit--this circuit is expected to act as a low-pass filter, and differentiator at sufficiently high frequencies.

EQUATION: Phasor stuff

The output signal of the LR circuit is a little more forgiving in that you can choose charging or discharging regions to find the characteristic time, but in this case we chose to use a charging region.

The value for TAU found by using the CHI^2 method can be compared to a theoretical value, given as

EQUATION: TAU = L / R

# RESULTS

For the RL configuration, we chose to use a 10KOHM resistor and a 10 mHENRY inductor, with a square wave input of 2.00 V peak-to-peak at 100 Hz. The output signal was reliably similar to the signal in FIGURE: RL SIGNAL between 100 Hz and 10 kHz.

For a sine wave input of similar configuration, the output signal was a phase-shifted sine wave at frequencies greater than 1 KHZ. Below that frequency, the signal remained largely the same, but was attenuated as the input frequency approached zero. For a triangle wave, the output signal was unaffected above 50 KHZ, but somewhat resembled a square wave as it was attenuated approaching input frequency zero. Both of these output signals are what we would expect to see out of a differentiator--the resulting output signals approximate the rate of change of the input signal at sufficiently low frequencies.

It is noteworthy that the theoretical value for the characteristic frequency for this circuit is 100 KHZ, compared to all of the noted threshold frequencies above that are one to two orders of magnitude lower. Our suspicion is that this is largely a result of subjective observations--each of the noted “thresholds” was chosen based on our judgment of when the output signal looked significantly different from the input signal. Since the output signals were changing across orders of input frequency, one to two orders of magnitude is well within an expected margin of human error.

FIGURE: 1-RL output with theory curve

The theoretical and CHI^2 optimized curves, shown in FIGURE ABOVE, differ by a large margin. The theoretical value we calculated for the characteristic time TAU = L / R is 10^-6, compared to the experimental value 8.23\*10^-6, larger by a factor. The experimental value seems reasonable considering how well the curve it represents fits the data, and how far off our theory curve is from the data collected. It’s been suggested that there could be some stray capacitance or signal reflection in the circuit that could cause some error, but we also failed to record experimental values for the inductance and resistance of our circuit elements. It’s likely that the elements we used did not have exactly the properties they were labeled with.

# 

# CONCLUSION

# PART 2: Frequency Response of Both Configurations

# 

# INTRODUCTION

# EXPERIMENTAL

# RESULTS

# CONCLUSION