Lab 3: AC Circuits

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February 2, 2017

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Introduction

The purpose of this lab was to investigate the workings of AC circuits. In particular, the transient state behavior of RC and RL series circuits will be examined, as well as the behavior of a resonant RLC circuit. To gain a model for the circuits’ activities, the voltage drops across both the inductor and the capacitor in their transient periods were taken. Linear regression was done on the data acquired to investigate the circuits’ behaviors more deeply. Resonant frequency in an RLC circuit was also examined. The frequency was measured using two different methods: one using a function generator, and one using a BODE analyzer.

Analysis

Figure 1: Linearized RC Capacitor Voltage in Transient State Plot.

The linearized graph relates the relationship amongst the RC time constant, the voltage across the capacitor, and the transient time. The functional form is linear and the equation is: The slope in the function is equal to the expression 1/RC, which when inverted has a magnitude around 0.0095. This magnitude is the magnitude of the time constant of the RC circuit.

|  |  |  |
| --- | --- | --- |
|  | *Coefficients* | *Standard Error* |
| Intercept | 2.910412632 | 0.040490229 |
| X Variable 1 | -104.9240593 | 1.003513077 |

Table 1: Linear Regression data for Figure 1.

The values measured have noticeably low standard errors, which points to the high accuracy and precision of the experiment.

The theoretical value of the time constant was computed to be 0.01. This was calculated by multiplying the magnitude of the 10k Ohm resistor with the magnitude of the 1 microfarad capacitor. Compared to the experimental value of 0.0095, the values are extremely close to each other with an error of around 5%. This error is reasonable as the gap between them can be attributed to the systematic errors present in the experiment like the state of the devices used and human error in the handling of the components.

Figure 2: Graph of voltage drop across inductor as a function of time in the transient region. The folding time is taken to be 0.00076 s. This value was finding the time when the voltage across the inductor becomes equal to the voltage across the battery divided by e. The mean time constant was calculated to be 0.000867 s. The functional form of the equation is an exponential and then tapers off at a specific voltage value. This is to be expected as the voltage across the inductor is expected to converge completely after 10 time constants have passed.

The experimental value of the time constant was taken by getting the difference between the time when voltage was first non-zero and the time when voltage across the inductor was equal to the voltage at the battery divided by e. This was done for higher powers of e as well, now with the coefficient of e being a divisor of the difference between the times.

The theoretical value of the time constant was computed using the relation L/R, with a 50 Ohm resistor from the function generator connected in series to the RL circuit. A 100 mH inductor and a 1000 Ohm resistor was used to yield a value of 0.000095 s for the time constant. This value is very close to the experimentally determined value, with the experimentally determined value differing by 8.7% to the theoretical value. Possible errors in the experiment could be due to the internal resistance present in the inductor, which could have corrupted the results. The calculation of the experimental time constant was also fairly arbitrary, as more and more multiples of the folding time could have been incorporated into the mean time constant and the values will vary from the theoretical time constant.

Figure 3: Output Voltage Gain vs. Frequency of an RLC resonant circuit.

The graph relates the output voltage gain with the input frequency. It appears that the rate of the change of the voltage gain is very high up until the resonant frequency is reached, and then the graph levels off exponentially. This is to be expected as the resonant frequency should theoretically give out the highest voltage gain, and then levels off with higher frequencies.

Using data taken from the BODE analyzer, the resonant frequency was found to be 502.77 Hz. With the oscilloscope, the measured frequency was found to be 514 Hz. When these two frequencies are compared to the theoretical frequency of 503.29 Hz, the degree of error present in the oscilloscope frequency was higher compared to the BODE analyzer one. The errors are 0.18% for the BODE analyzer and 2.13% for the oscilloscope. Looking at the data, it seems to be that the resonant frequency measured by the BODE analyzer is more accurate in comparison to the resonant frequency measured by the oscilloscope. The higher error for the oscilloscope is expected, as there are more systematic errors present. The tuning of the frequency knob in the oscilloscope to find the resonant frequency is one of the these.

The Q factor was calculated by dividing the resonant frequency by the square root of 2, and the value was then matched to the voltage gains in the graph and their corresponding frequencies. The frequencies measured by eyeballing the graph were 159 Hz and 1858 Hz. The resonant frequency was then divided by the difference between these two frequencies. A Q factor of 0.2957 was acquired using this method.