

## **Chapter 4**

# **Mystery Box Challenge**

### 4.1 Pre-Lab

The answers to the following questions are due at the beginning of the lab. If they are not done at the beginning of the lab, no points will be awarded.

1. Using the data sheets provided on the lab webpage, find the typical value for DC resistance or equivalent series resistance of the following components; Inductor, Ceramic Capacitor, and Electrolytic Capacitor. (Note: you probably won't be able to find a value for one or two of these. Why?)
2. List the impedance equations for an inductor and a capacitor. What is the simplified equation for a capacitor and an inductor in series? In parallel? Do these equations include the DC resistance or equivalent series resistance?

### 4.2 Section Overview

In this lab the electrical contents of several mystery boxes will be found. The possible components inside the mystery box could include a resistor, a capacitor, an inductor or a combination of these elements in series or parallel. First a simple mystery box (one reactive component) will be researched. Then one additional mystery box (a resistor in series with a reactive component) will be explored. Finally an LTSpice simulation will be created to validate the contents.

**IMPORTANT:** *The boxes need to be handled with care and if taken home or tampered with, it will result in immediate failure of lab 4.*

### 4.3 Mystery Box 1

#### 4.3.1 Overview

There is one reactive component in mystery box 1. The boxes are labeled and it is important to record which box you are using. The value you find for the component must be within 20% of the actual value. The strategies in the following section will aid you with this level of accuracy. **Make sure your mystery box is labeled with a car manufacturer.**

#### 4.3.2 Strategies for Solving Mystery Box 1

1. When analyzing reactive components, it is important to look at the components using a variety of frequencies. This is important since it is difficult to tell the difference between a resistor and a capacitor at only a single frequency. To perform the analysis make sure measurements are taken at DC, and 5 AC frequencies. For one of the AC frequencies, try to make sure the phase shift is about 45 degrees. Then aim for two frequencies with a phase shift of less than 45 degrees, and two more with a phase shift greater than 45 degrees. For greatest accuracy, don't use a phase shift less than 10 degrees or greater than 80 degrees. These frequencies will most likely occur between 100Hz and 100kHz... but could be outside that range, depending on the box you selected and the external resistor used.
2. When performing some of the analysis steps, an external resistor may need to be used (hint hint...). To ensure as much accuracy as possible, measure the resistance exactly of the resistor rather than just assuming it is the value indicated on it. Be aware that the value of the resistor also should be 'with in range' of the black box component. Several different resistors may need to be used based on the frequency used for analysis. A good place to start is somewhere between 1k $\Omega$  and 10k $\Omega$  though once again, some values you end up using might be outside this range.

- Using a multimeter will measure DC characteristics while using the oscilloscope and function generator will allow for measuring the AC characteristics at different frequencies. Comparing the differences between the DC measurements and the AC measurements will help to identify impedances due to real components versus reactive components.

### 4.3.3 Procedure

- Using what you have learned in previous labs, identify the component inside the mystery box, draw the schematic of the component include its value. For each frequency record the appropriate information about the waveform
- Use LTSpice to draw the schematic for your test setup and simulate the results. Refer to lab 2 for help with simulation in LTSpice.
- Compare the results with what is observed in real life with the 5 different input frequencies between 100Hz and 100KHz used earlier.

## 4.4 Mystery Box 2

### 4.4.1 Overview

Mystery Box 2 contains 2 elements. Any of the elements listed above could be inside. The task is to find out what the elements are, their values and simulate the results. Another task is to create a plan of action to quickly determine the elements. The layout of mystery box 2 is in figure 4.1. Use the layout along with prior knowledge obtained throughout this lab to find out what the components are and their values. **Make sure your mystery box is labeled with a band or singer.**

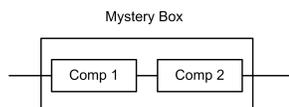


Figure 4.1: Mystery Box 2 Layout

### 4.4.2 Procedure Mystery Box 2

- Using the methods from mystery box 1, determine the contents of mystery box 2. The internal components will be in a series combination. This can help dramatically since it means that the impedance of the box must be something of the form shown in figure 4.2, from there it is a matter of figuring how much each resistance and/or reactance each element has. Once again, you will need a measurement at DC and 5 AC frequencies.

$$Z_T = Z_1 + Z_2$$

Figure 4.2: Series Impedance Equation

- Once the components inside the mystery box are identified, draw the schematic of how each component is connected to the terminals. Use LTSpice to draw the schematic of your test setup.
- Compare the the time domain waveforms of your LTSpice circuit with the oscilloscope waveforms showing the output of function generator and the center node of the test circuit. You only need to do this for one of the five frequencies that shows a "large" phase shift.

4. Compare the results with what is observed in real life with the 5 different input frequencies between 100Hz and 100Khz used earlier.

### 4.5 Study Questions

1. Be sure to turn in all schematics, calculations, and simulation results with your group's lab report.
2. Describe the 'best' systematic method to find out what the components are. (Why did you choose the methodology you did?)
3. For both boxes, comparisons with simulations were made at multiple frequencies. Why were all of these comparisons made? There will be slight variations between simulation and real measurements. Do these differences change depending on the frequency observed? If they do why? If they do not, why not?