Chapter 4 Lab Writeup

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Overview

The purpose of this lab is to determine which components are within the Mystery Boxes.The first box examined contained one component while the second contained two components in series.

Process

To determine the content of the boxes, we connected a 1k resistor in series to the boxes, applied a DC voltage to the box and resistor, and measured the result. We noted the voltage response across the resistor and across the box. As expected, the sum of these two voltages was equal to the voltage applied. We then divided the voltage drop across the resistor by the known value of the resistor to determine current. All components are in series, and thus the current through the resistor is equal to the current through the box. Impedence of the box can then be determined by dividing voltage drop across the box by the current of the circuit. We then applied an AC current at five different frequencies and determined the phase difference of the resultant voltage drop vs the original applied voltage. We varied the frequency to produce an approximately $\angle 45°$ difference.

Results

Here are the numerical results we found for each respective box.

Box: Mercedes Benz

We began by testing the resistor for accuracy using the multimeter and found it to be 979Ω. We also tested the box alone for resisitivity and found a very small value, suggesting an inductor. We connected a $5V$ DC power supply to the resistor and box in series, and set the multimeter to voltage mode. We found a $4.8V$ drop across the resistor and a $115mV$ drop across the box. Next, we connected a $5V$ AC source at $1KHz$ cooresponding to a source sinusoid of

$5\cos(2000\pi t)$. The time delay between the source voltage and voltage measured across the box was found to be $190\mu s$.The phase shift is then given by: $\angle = 360°(1000Hz)(190\mu) = 68.4°$.

Next we found the voltage across the resistor by subtracting voltage drop across the box from the source voltage: $5\angle 0° - 0.28\angle 68.4° = 4.90\angle - 3.04°$ By dividing this result by the measured resistor value of 979Ω we yield a series current of $0.005\angle - 3.04° A$. Overall impedance can now be found by dividing voltage drop across the box by the current through the series components: $Zb = -0.28\angle 68.4°/0.005\angle{-3.04°} = 55.90\angle 71.44°$. Since we're looking for the non-real component of impedence corresponding to what we believe to be an inductor, we take $55.90\sin 71.44° = 52.99 = wl$ dividing by 2000π yields $l = 8.4mH$. We estimated that this was probably a 10mH inductor which was confirmed by the TA.

Figure 1: Measurements for Mercedes Benz

Frequency DC	Period μs	Voltage mV	Phase Angle degree
103Hz	500	324	18.54
400Hz	320	156	46.08
495Hz	300	172	53.46
1kHz	190	280	68.4
1.4kHz	140	408	70.56
2kHz	104	576	74.88

Box: Tenacious D

We used a very similar approach for the second box as we did the first box. We began by measuring the resistance of the box which was found to be around 800Ω which allowed us to determine that there was a resistor in series with an inductor inside the box. We knew it must be an inductor since a capacitor would have given a much larger value of resistence.

Connceting the 5V DC power supply to the box and 1k resistor in series gave a value of 1.77V across the box. A 5V AC source at 1KHz was applied to the circuit. The phase angle was found by measuring the time delay between the source and the voltage across the box and taking $\angle = 360°(1000Hz)(88\mu) = 31.68°$.

Voltage across the resistor: $5\angle 0° - 2.3\angle 31.68° = 3.27\angle - 21.65°$. Current across resistor by taking V/R: $0.0027\angle 0° A$. Impedence of the circuit by voltage drop across box divided by the current through the series components: $Zb =$

$-2.3\angle 31.68^\circ / 0.0027\angle 0^\circ = 851.85\angle 31.68^\circ$. Solve for inductance as the imaginary component of the impedence: $851.85 \sin 31.68^\circ = 447.37 = wl$ dividing by 2000π yields $l = 71mH$. Solve for resistence by just getting the real component of the impedence: $851.85 \cos 31.68^\circ = 724\Omega$ The inductor has a value of $71mH$ and the resistor a value of 724Ω.

Figure 2: Measurements for Tenacious D

Frequency DC	Period μs	Voltage V	Phase Angle degree
250Hz	160	1.96	14.4
500Hz	130	1.8	23.4
1kHz	88	2.3	31.86
2kHz	42	3.76	30.24
10kHz	4	V	14.4

Conclusion

In conclusion we were able to determine what components were inside each box with a great deal of accuracy given the tolerances of the components were not ideal. By using few tools such as an oscilloscope, a multimeter, and a function generator we were able to determine a successful method for determining the value of a component of unknown type and value as well as an unknown component in series with a resistor.

Study Questions

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1. Measure the resistance of the unknown element to determine if the element is a resistor or a capacitor.
2. Find a resistor of a known value and of a somewhat significant value
3. Place the known resistor in series with the unknown element
4. Using the oscilloscope, compare sinusoid from voltage source to voltage measured across the box to find the time delay. The phase angle of the voltage across the box can be determined by $\angle = (360)(freqinHz)(\Delta t)$. Note the peak voltage across the box.
5. Find the current through the resistor by dividing the voltage across the resistor (with appropriate phase angle) by the known resistor value. The components are in series so we now know the current through the box.

6. Find total impedance of the box by dividing the voltage across the box by the current through the circuit.

7. Multiply the magnitude of impedance by the sine of the angle of impedance to find reactance. Divide by the frequency of the voltage source to find the value of your component.

3) Comparisons based on frequency lead us to a couple conclusions. The first and most obvious conclusion we can note is that it is not simply a resistor inside either box, as response varies dependant on frequency. When observed at extremely high or low frequencies, we can distinguish between capacitors and inductors; at high frequencies, a capacitor looks like a short and an inductor acts as an open, while at low frequencies this is reversed. In this lab, we were encouraged to operate within a median frequency range, as the distortion expereienced between real and simulated data increases as you extend to extreme high or low frequency. A simulation might still return a valid piece of data at 100,000 Hz but real observed data is likely to be heavily flawed.