Lab 1

Verification of Kirchhoff’s Voltage and Current Laws for Series and Parallel AC circuits

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EEL3112C: Circuits 2

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**Objectives:**

The goal of this experiment was to verify both of Kirchhoff’s Circuit Laws - Kirchhoff’s Voltage Law (KVL) and Kirchhoff’s Current Law (KCL) - for circuits with alternating current (AC). In a series AC circuit, KVL and the voltage divider rule can be used to obtain the equivalent impedance of multiple components in series. Meanwhile, KCL and the current divider rule are utilized to derive the equivalent impedance for any number of components in parallel with each other. These rules can be used on circuits with various combinations of resistors, inductors, and capacitors.

**Equipment:**

* Voltmeter x3 (Oscilloscope)
* Ammeter x3 (Oscilloscope)
* Impedance Meter x1
* Resistor x5 (Intended Values Below)
  + (Shunt)
* Inductor x2 (Intended Values Below)
* Capacitor x2 (Intended Values Below)
* AC Voltage Source x1 (Function Generator)

**Theory Development:**

Part 1:

According to KVL, given that the current is the same throughout a loop, the total voltage of a series circuit can be expressed as the sum of the individual voltage across each component. Applying Ohm’s Law to this, the equivalent impedance over the voltage source is the sum of the impedances of every component in the circuit. Taking into consideration that a component in this case may include a resistor and an imaginary-impedance-inducing element (inductor or capacitor), with 2 components, the current may be calculated as . Knowing that and , the voltage division-relationship can be determined without knowing the current flowing through via and .

Part 2:

In a parallel circuit, where once more, each component can be a resistor and another impeding element, the voltage across each component is equal to the voltage over the source terminal. Applying KCL at the top node when there’s a current source states that the source current is equivalent to the sum of the current through each branch of the circuit. Likewise, it is also the same as the voltage over the source multiplied by the sum of every component’s admittance, which is the inverse of its impedance. With 2 components, after utilizing the property of impedance and admittance being the reciprocal of each other several times, the equivalent impedance of a parallel circuit is found to be . As , the current in each branch may be calculated via and .

**Methods/Procedures:**

Part 1:

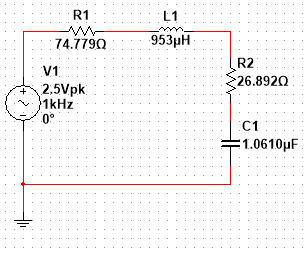
To obtain the voltage over each pair of components, the circuit was constructed according to the Part 1 circuit diagram. The impedance meter was then used to obtain the actual equivalent impedance of the circuit with the voltage source disconnected. Afterwards, the function generator was connected to the circuit to provide the desired voltage signal of 2.5 V pk at 1 kHz frequency. The voltage drops were then measured by grounding the ground clamp of the oscilloscope to the common ground and then placing the measuring probe on each end of each component pair (resistor 1 + inductor and resistor 2 + capacitor). Subtracting the post-cluster and pre-cluster voltages yielded the drop across the component pairs. The current was then derived by simply dividing the source voltage by the circuit’s equivalent impedance.

Part 2:

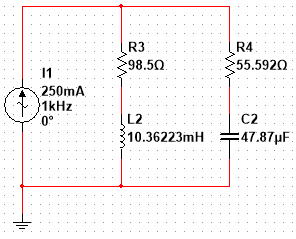
The second circuit was constructed based on the Part 2 circuit diagram in preparation for measuring the current through each branch of the circuit. However, it was constructed in a manner so that a voltage source could be utilized in place of the nonexistent current source. Once again, the impedance meter was utilized for recording the equivalent impedance of this circuit without a source connected. This time, however, prior to each measurement, a 1 ohm shunt resistor was connected to the end of the branch that was being measured. This was used to directly correlate the voltage over itself with the current associated in the current divider circuit without the need to multiply or divide anything. It was obtained by connecting the ground to the side of the shunt closer to the other branch component and placing the probe on the opposite side. This was then repeated with the shunt moved to the other branch for the second voltage-current correlation measurement. The voltage drops were recorded in the same manner as Part 1 without the shunt resistor.

**Circuit Diagrams:**

Part 1:



Part 2:



**Results (Theoretical and Experimental):**

Part 1:

Values Used:

* + Is a 3rd parallel line in the circuit.

| Theoretical | | | |
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| Experimental (Multisim) | | | | |
| --- | --- | --- | --- | --- |
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| Experimental (Hardware) | | | | |
| --- | --- | --- | --- | --- |
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Part 2:

Values Used:

* + Internal resistance of the inductor does not affect theoretical values.

| Theoretical | | | |
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| Experimental (Multisim) | | | | |
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| Experimental (Hardware) | | | |
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**Results Analysis and Discussion:**

Significant error has caused the results to vary between the theoretical, simulated, and actual versions of the two circuits. For example, in the voltage divider circuit, although the voltage drop values were consistent between the theoretical and simulated circuits, was almost 3 times smaller than expected in the physical circuit whereas was slightly higher. Similarly, the current through each branch of the physical current divider circuit was between about 2 and 4 times as large as they were supposed to be according to the calculated and simulated current dividers. Meanwhile, the equivalent impedances of both circuits vary greatly between all 3 variants of each circuit. Lastly, the sums of the votlage drops in the simulated and physical voltage divider are greater than the source voltage, and the same can be said regarding the currents of the current divider branches and the source.

One of the most probable causes of these errors is the internal resistances of the inductors. While an ideal inductor should have no internal resistance, the 10 mH inductor provided nearly 27 additional ohms of non-complex resistance to the current divider. The 1 mH inductor also likely introduced additional resistance to the voltage divider. Inductors are known for having real resistance, considering that the wire inside is coiled, increasing its distance greatly when compared to a straight wire the same length of the inductor. Alternative error sources may include internal resistance of the breadboard and the wires surrounding the components as well as using a shunt resistor to convert the current source to a voltage source for the physical circuit.

**Conclusion:**

Kirchoff’s Voltage and Current Laws are the basis for the voltage divider and current divider rules respectively. By using these four rules, it is possible to find the voltage over and current through voltage and current dividing components of an AC circuit in a similar manner to a DC one. However, additional factors, such as the internal resistance of inductors, may greatly impact how much voltage and current is present over and through each component, as demonstrated by this experiment.

References:

<https://learnabout-electronics.org/ac_theory/reactance61.php#:~:text=Resistance%20in%20Inductors&text=The%20voltage%20across%20the%20internal,to%20shift%20towards%200%C2%B0>.