Steady-State AC Behavior of Passive Circuit Elements

ECE 2100 Circuit Analysis Laboratory
updated 13 September 2018

Equipment and Supplies

<table>
<thead>
<tr>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>oscilloscope</td>
</tr>
<tr>
<td>function generator</td>
</tr>
<tr>
<td>resistors</td>
</tr>
<tr>
<td>10 Ω</td>
</tr>
<tr>
<td>500Ω (via variable resistor box)</td>
</tr>
<tr>
<td>39mH inductor (small black box with banana plugs)</td>
</tr>
<tr>
<td>0.026μF capacitor (via variable capacitor box)</td>
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Pre-Laboratory Assignment

1. Consider the circuit of Figure 1 with a 16 volt peak-to-peak 5000 Hz sinusoidal voltage source. Rcsr is a current sampling resistor and Rs is the internal resistance of the voltage source (a function generator). Resistor Rcsr will enable display of the current I through R1 using an oscilloscope (an instrument that can only measure voltage). Using phasor analysis, find the voltage \( V \) across R1 and \( I \) through R1 assuming that Rs and Rcsr are shorts.

   NOTE: The voltage source in Figure 1 is a cosine source created by shifting a sine wave by 90 degrees. This is not necessary since the sinusoidal steady state is not dependent on the circuit initial conditions, but is done to be consistent with our choice of cosines for phasor computations.

2. Simulate the circuit with the given values of Rs and Rcsr using a transient analysis. Set “Stop Time” to 3 ms, “Time To Start Saving Data” to 1 ms, and “Maximum Time Step” to 0.1us in your SPICE engine, plot \( V(t) \) for 2 ms by plotting \( V(2)-V(1) \) in SPICE. On the same plot, plot \( 1000\times(V(1)/10) \); that graph shows the current I through R1 in mA. Note that SPICE will show units of V instead of mA. Your plot should look like Figure 2. What is the phase relationship between the resistor voltage and current? Insure that your hand analysis and simulation results (for voltage amplitude, current amplitude, and phase angle between the voltage and current) closely agree (they will not match exactly – Why not?).
3. Replace $R_1$ with a 39 mH inductor and repeat pre-laboratory step 2.

4. Replace $R_1$ with a 0.026 uF capacitor and repeat pre-laboratory step 2.

5. Bring an electronic copy of your simulation files to lab.

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Figure 1. Circuit to Measure Steady-State Behavior of a Resistor

Figure 2. Steady State Voltage (smaller signal has units V) and Current (larger signal has units mA) for the Resistor of Figure 1.
Procedures

Part One

1. Build the circuit of Figure 1. Use the function generator as the voltage source. Since one lead of the oscilloscope is grounded, we cannot directly measure \( V(2) - V(1) \). Connect oscilloscope CH 1 to node 2 (with the ground of the oscilloscope lead connected to the ground of the function generator). We will consider \( V(2) \) to be the voltage across \( R_1 \); this is not correct, but we can get away with this here (see Analysis question 1). Connect oscilloscope CH 2 to measure \( V(1) \). Note that \( V(1) \) is directly proportional to the current through \( R_1 \). Setup the scope to display at least two complete cycles of the waveforms. Verify the frequency of the source. Find the phase angle between the resistor voltage and current. Compare these experimental results (voltage amplitude, current amplitude, and phase angle) with simulation (SPICE) and hand analysis results (use a table). Find experimental errors using the hand analysis results as the reference.

Part Two

2. Repeat laboratory procedure step 1 after replacing \( R_1 \) with a 39 mH inductor. Compute the actual inductor value using your measurements of circuit voltages and the source frequency. Update your hand analysis and simulation (SPICE) results with this measured value as needed.

Part Three

3. Repeat laboratory procedure step 1 after replacing \( R_1 \) with a 0.026 uF capacitor. Compute the actual capacitor value using your measurements of circuit voltages and the source frequency. Update your hand analysis and simulation (SPICE) results with this measured value as needed.

Analysis

1. Why can the voltage \( V(2) \) be considered as roughly the same as \( V(2) - V(1) \)?

2. Prepare phasor diagrams that show phasors \( V \) and \( I \) for laboratory procedures parts 1-3.

3. What is the primary source of the error between experimental and hand analysis results for this experiment?

Credits and Copyright

Adapted from material developed by current and former ECE faculty, including Professor Joseph Kelemen. Thanks to Sepehr Emamian for improvements to this lab.

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