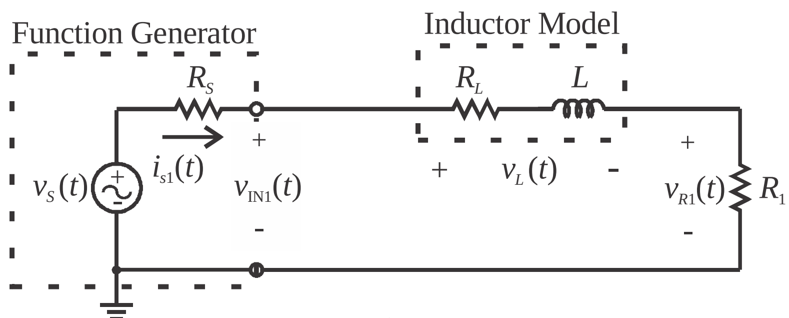
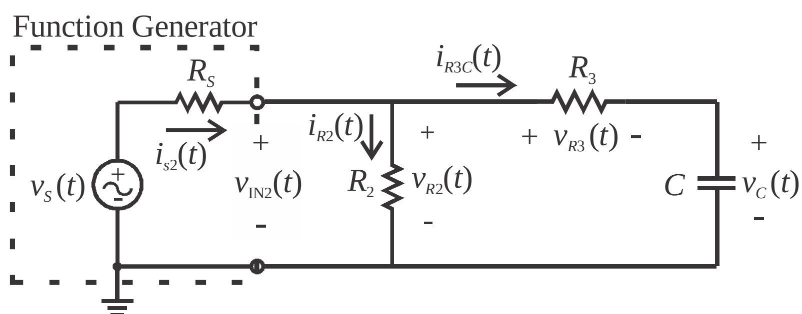
EE 220/220L Circuits I (Fall 2019)
Laboratory Project 13 AC Sinusoidal Circuits



a) *RL* circuit



b) *RC* circuit

Figure 1 AC sinusoidal steady-state circuits for laboratory

<u>Preliminary</u>

In this laboratory, you will investigate sinusoidal steady-state circuits and the use of impedances and phasors. The function generator is modeled as an ideal voltage source $v_s(t) = 3.9\cos(\omega t)$ V, operating at **1.667 kHz**, in series with a source resistance $R_S = 50\,\Omega$. For the *RL* circuit, model the inductor as an ideal $L = 85$ mH inductor in series with a resistance $R_L = 130\,\Omega$ (wire resistance and ferrite core losses) and resistor $R_1 = 680\,\Omega$. For the *RC* circuit, resistor $R_2 = 680\,\Omega$ in parallel with the series combination of resistor $R_3 = 150\,\Omega$ and capacitor $C = 0.47\,\mu$F will be used.

1) Draw the **phasor** equivalent circuits for the *RL* and *RC* circuits shown in Figure 1.
2) For each circuit, calculate the equivalent impedance (rectangular format) seen by the ideal voltage source and all labeled **phasor** currents and voltages (polar format w/ $\angle$ in degrees). Show that KVL holds true for *RL* circuit. Then, show that KCL (top center node) holds true for *RC* circuit.
3) For each circuit, sketch a single **<u>labeled</u>** phasor diagram (i.e., polar format/vectors on complex plane) showing **all** the phasor currents and voltages. Put a table next to each diagram summarizing the values of all the phasor quantities.
4) Next, for each circuit, draw another **<u>labeled</u>** phasor diagram with all of the phasors rotated **equally** about the origin so that the vector representing $\overline{V}_{\mathrm{INx}}$ is aligned with the positive real axis (i.e., at zero degrees). [Why? We will use v_{INx}(t) as our <u>reference</u> voltage when taking measurements with the oscilloscope.] Put a table next to each diagram summarizing the values of all the rotated phasor quantities.
5) Have the lab instructor/TA check and sign your preliminary before you do the experiment.

Experiment

1) With the function generator connected **directly** to oscilloscope, set up the voltage source $v_s(t)$. Adjust oscilloscope so horizontal scale is a large as possible while showing ~2 periods of $v_s(t)$. Set vertical scale to 1 V/div. Measure & record magnitude, frequency, and period of $v_s(t)$. Display maximum, minimum, & RMS of $v_s(t)$, save bitmap, print, and put in logbook. Use multimeter to measure RMS source voltage $V_{S,\mathrm{RMS}}$. Based on the magnitude, what RMS value is expected?

2) Set up *RL* circuit shown in Figure 1a. Use multimeter to measure resistor R_1, RMS current $I_{s1,\mathrm{RMS}}$, and RMS voltages $V_{\mathrm{IN1,RMS}}$, $V_{L,\mathrm{RMS}}$ & $V_{R1,\mathrm{RMS}}$. Using oscilloscope, display $v_{\mathrm{IN1}}(t)$ (ch. 1), $v_{R2}(t)$ (ch. 2), and $v_L(t)$ (use MATH menu: ch. 1 - ch. 2). Save bitmap of display, print, label traces, and put in logbook. Assuming $v_{\mathrm{IN1}}(t)$ (reference signal) has a phase angle 0º, take measurements necessary to determine all the phasor currents and voltages (need magnitude & phase, see tips).

   Hints: Remember current is directly proportional to the voltage across a resistor per Ohm's Law (no phase shift). Source voltage phasor will need to be found by KVL.

3) Set up *RC* circuit shown in Figure 1b. Use multimeter to measure resistors R_2 & R_3, RMS currents $I_{s2,\mathrm{RMS}}$, $I_{R2,\mathrm{RMS}}$ & $I_{R3C,\mathrm{RMS}}$, and RMS voltages $V_{\mathrm{IN2,RMS}}$, $V_{R3,\mathrm{RMS}}$, & $V_{C,\mathrm{RMS}}$. Using oscilloscope, display $v_{\mathrm{IN2}}(t)$ (ch. 1), $v_C(t)$ (ch. 2), and $v_{R3}(t)$ (use MATH menu: ch. 1 - ch. 2). Save bitmap of display, print, label traces, and put in logbook. Assuming $v_{\mathrm{IN2}}(t)$ (reference signal) has a phase angle 0º, take measurements necessary to determine all the phasor currents and voltages.

   Hint: Source current & voltage phasors will need to be found by KCL & KVL.

4) Have your experimental data signed-off before tearing down last circuit.

Analysis and Conclusions

- How does the measured RMS source voltage $V_{S,\mathrm{RMS}}$ compare to calculated analytic RMS source voltage $V_{S,\mathrm{calc,RMS}} = V_\mathrm{m}/\sqrt{2}$? What does this say about the multimeter?
- For each circuit, sketch a labeled phasor diagram showing all measured currents and voltages. Put a table next to each diagram summarizing all phasor quantities. Compare with those from step 4) of preliminary. Explain differences between measured and calculated phasors.
- Compare the measured phase of the current through to the phase of the voltages across the capacitor and inductor for the respective circuits. Are they ±90º out-of-phase?
- For the *RL* circuit, compute the measured inductor impedance $\bar{Z}_{L,\mathrm{meas}} = \dfrac{\bar{V}_{L,\mathrm{meas}}}{\bar{I}_{S1,\mathrm{meas}}} = R_{L,\mathrm{meas}} + jX_{L,\mathrm{meas}}$ and inductance $L_\mathrm{meas} = X_{L,\mathrm{meas}}/\omega$ using the experimentally determined phasor voltages & currents and frequency. How do these compare with the assumed values for R_L and L? Summarize & discuss results.
- For the *RC* circuit, compute the measured capacitor impedance $\bar{Z}_{C,\mathrm{meas}} = \dfrac{\bar{V}_{C,\mathrm{meas}}}{\bar{I}_{R3C,\mathrm{meas}}} = R_{C,\mathrm{meas}} - jX_{C,\mathrm{meas}}$ and capacitance $C_\mathrm{meas} = 1/(\omega X_{c,\mathrm{meas}})$ using the experimentally determined phasor voltages & currents and frequency. How does this compare with assumed value for C? Summarize & discuss results.

Measuring magnitude and relative phase angles of sinusoidal voltages

- Options to measure the **magnitude** of sinusoidal signals:
  a) On oscilloscope, use measurement menu to measure the peak-to-peak voltage V_{pp}. This works for channels 1 and 2 but NOT for Math. The voltage magnitude $V_m = V_{pp} /2$.
  b) Or, use the cursors (Type Y) menu to measure the peak-to-peak voltage V_{pp}. This works for channels 1, 2, and Math. The voltage magnitude $V_m = V_{pp} /2$.

- To determine the **phase angle** of signals relative to our reference signal $v_{\mathrm{IN}}(t)$:
  a) Use the cursors (Type X) and/or measurement menu to measure the period T of the sinusoidal signals. Remember that one period T is equivalent to 360° of phase.
  b) Use the cursors on the oscilloscopes to measure the *magnitude* of the time offset Δt_{off} (positive number) between the voltage on channel 2 and/or math "channel" with respect to $v_{\mathrm{INx}}(t)$ on channel 1. The *magnitude* of the offset angle is $\phi_{\mathrm{off}} = (\Delta t_{\mathrm{off}} / T) * 360°$.
  c) Comparing similar points on the voltage waveforms (e.g., zero crossings with positive slopes), if the sinusoidal voltage on channel 2 and/or math "channel" is shifted to the left of $v_{\mathrm{IN}}(t)$ on channel 1, ϕ_{off} is leading (**positive** angle). If the sinusoidal voltage on channel 2 and/or math "channel" is shifted to the right of $v_{\mathrm{IN}}(t)$, ϕ_{off} is lagging (**negative** angle).

- Details on measuring phasors are shown in example posted under Labs link on course web page: http://montoya.sdsmt.edu/ee220/handouts/AC_circuits_time_domain_measurements.pdf.