LAB 3 Oral Presentation Contents

Introduction

Each student must make one oral presentation in lab during the semester. Contents for oral presentations are listed below for Lab 3. Talks start the second week of Lab 3.

Presentations will last **five minutes** and will be given at the beginning of the lab session. The presentations will typically describe work performed the previous or current week in lab by way of review. Practice your talk and be succinct. Stick to the five-minute time frame.

Presentation 3.1: Sinusoids and Kirchhoff's Laws

a) Explain that your presentation will discuss how Kirchhoff's laws apply to circuits with sinusoidal signals (like the circuit in Lab 3 that has an oscillator in it).

b) Draw a circuit consisting of four elements in parallel: a current source, an *L*, an *R*, and a *C*. Label the current source with an up arrow and a value of $i_g(t) = 3\cos(\omega t + 45^\circ)$ A. Label the L with a current of $i_L(t) = 2\cos(\omega t - 45^\circ)$ A in the downward direction. Label the R with a current of $i_R(t) = 3\cos(\omega t + 45^\circ)$ A in the downward direction. And label the C with a current of $i_C(t) = 2\cos(\omega t + 135^\circ)$ A in the downward direction.

c) Note that Kirchhoff's Law's apply to a current summation at the top node of the parallel circuit. Write the current summation equation $-i_g(t) + i_L(t) + i_R(t) + i_C(t) = 0A$, and note that it holds at *all times*. So the sinusoids cancel each other out all the time.

d) Sketch four superimposed sinusoids meant to represent the four currents in the circuit, and note that it is rather surprising that we can sum sinusoids to get a value that is zero all the time.

e) Point out that we can see why the sinusoids cancel out in our simple example: $i_g(t)$ and $i_R(t)$ are the same and cancel out in the equation (because we have $-i_g(t)+i_R(t)$), and $i_L(t)$ and $i_C(t)$ cancel out because they are 180° out of phase.

f) Conclude your presentation by commenting that Kirchhoff's law for summing voltage drops around loops also holds for sinusoidal signals, and that sinusoids can sum to zero for much more complicated cases than just having signals that are opposites of each other. Leave the students with the observation that *any* sum of two sinusoids of the same frequency is a sinusoid of that same frequency, (*not* a signal with, say, twice the frequency). Note that this is a powerful statement. It would not hold for other waveforms such as square waves. Sinusoids are somewhat unique in this regard.

Presentation 3.2: Sinusoids and complex numbers

a) Explain that your presentation will discuss how we use complex numbers to find sums of sinusoidal signals, (instead of using laborious trigonometric identities).

b) Draw the circuit from presentation 3.1 on the board again, including current values.

c) Comment that every signal is a sinusoid of the same frequency, so we can keep track of signals by merely writing down their magnitude and phase. Observe that we use complex numbers to do this because they consist of two values. Note that the polar form of a complex number is written in terms of magnitude and phase that correspond exactly to the magnitude and phase of a sinusoid.

d) Explain that we may think of complex numbers as vectors expressed in polar coordinates, (i.e., again, magnitude and phase). Draw the complex plane (real and imaginary axes) and plot the complex number vectors, (i.e., phasors), for each of the currents in the circuit: $P[i_g(t)] = 3$ angle 45° where P[ ] is the phasor transform, (plot this as a vector of length 3 at an angle of 45° to the real axis), $P[i_R(t)] = -3$ angle 45°, (plot this as a vector of length 3 at an angle of -135° to the real axis and note that a minus sign is equivalent to a 180° phase shift for sinusoids), $P[i_L(t)] = 3$ angle -45°, (plot this as a vector of length 3 at an angle of -45° to the real axis), and $P[i_C(t)] = 3$ angle 135°, (plot this as a vector of length 3 at an angle of 135° to the real axis).

e) Show that the sum of the four vectors is zero by plotting them end-to-end with the tip of that last one lying at the origin.

f) Conclude your presentation by noting that the (vector) sum of the complex numbers gives us a vector (in the general case) that tells us the magnitude and phase of the sinusoid that is the sum of the sinusoids represented by the complex numbers. In other words, using the complex numbers is equivalent to adding up sinusoids via trigonometric identities, and it's much easier!

Presentation 3.3: Impedance

a) Explain that your presentation will discuss the concept of impedance for circuits with sinusoidal signals.

b) Draw an L and C on the board, and write the equations that describe them in the time domain:

$$v_L(t) = L\frac{di_L(t)}{dt} \qquad\qquad i_C(t) = C\frac{dv_C(t)}{dt}$$

c) Comment that we want to consider what happens if we have sinusoidal signals:

$$i_L(t) = A\cos(\omega t + \phi) \qquad\qquad v_C(t) = A\cos(\omega t + \phi)$$

d) Using these signals, take derivatives to calculate $v_L(t)$ and $i_C(t)$:

$$v_L(t) = -A\sin(\omega t + \phi)\omega L = A\cos(\omega t + \phi + 90^\circ)\omega L$$

$$i_C(t) = -A\sin(\omega t + \phi)\omega C = A\cos(\omega t + \phi + 90^\circ)\omega C$$

e) Observe that, if we use complex numbers (also called phasors) to capture the magnitude and phase of the sinusoids, we have the following equations (where multiplying by j is equivalent to a 90 degree phase shift):

$$V_L = I_L \cdot j\omega L \qquad\qquad I_C = V_C \cdot j\omega C$$

f) Finish your talk by noting that these equations are just like Ohm's law. The only twist is that we now use complex numbers to represent voltage and current, as well as the impedances, $z_L \equiv \frac{V_L}{I_L} = j\omega L$ and $z_C \equiv \frac{V_C}{I_C} = \frac{1}{j\omega C}$.

Presentation 3.4: Bridge circuit tutorial

a) Explain that your presentation will discuss the basic concept behind the bridge oscillator circuit of Lab 3: if the op-amp drives a balanced bridge, it cannot counteract an imbalance across the bridge—and its output gets very large.

b) Draw the circuit for the oscillator in Lab 3 on the board and note that the design of the oscillator causes the left side of the bridge (consisting of R_1, C_1, R_2, and C_2) to form a voltage divider and the right side of the bridge (consisting of R_3 and R_4) to form a voltage divider. The two voltage dividers are equivalent at one frequency—the frequency of oscillation.

c) Explain that, if the voltage dividers are the same, the voltages at the + and – inputs of the op-amp will track each other exactly as v_o changes. In other words, changing v_o does not change the voltage drop across the op-amp inputs.

d) Add a noise voltage-source called v_n and a resistance called R_n across the middle of the bridge circuit, from v_+ to v_-, and point out that we may use superposition to argue that the noise source creates a voltage drop across the + and - inputs of the op-amp. This in turn causes the op-amp to try to cancel this imbalance in the op-amp inputs by increasing v_o. By superposition again, however, this cannot alter the voltage drop across the + and – inputs of the op-amp. Thus the op-amp outputs an ever-increasing v_o at precisely the frequency for which the bridge is balanced—and the circuit oscillates.

e) Conclude your presentation by noting that the basic concept behind the bridge oscillator circuit is that we can defeat the feedback at one particular frequency, thanks to the bridge.

Presentation 3.5: Bridge circuit mysteries

a) Explain that your presentation will discuss details that arise in a detailed analysis of the bridge oscillator circuit of Lab 3 that are *not* covered in our linear analysis.
b) Draw the circuit for the oscillator in Lab 3 on the board.
c) Explain that the theory says v_o increases to infinity, whereas the actual v_o stops when it reaches the rail voltage. This is a nonlinear effect. Our analysis fails to account for it.
d) Explain that when v_o reaches the rail voltage, the oscillator waveform has a flattened top instead of being a pure sinusoid. This is a nonlinear effect. Our analysis fails to account for it.
e) Explain that for frequencies very close to the oscillation frequency, v_o should still be large because the bridge is almost balanced. Thus v_o is not really just one frequency. It is really a superposition of frequencies very close together. Our analysis fails to account for this.
f) Conclude your presentation by noting that despite all of the above issues, the design procedure that assumes linearity still works well enough. Also, a complete analysis requires a simulation. Analyzing nonlinear systems is difficult.

Presentation 3.6: Impedances and voltage dividers

a) Explain that your presentation will discuss measurement of an impedance using only voltages from a voltage divider.
b) Draw a circuit consisting of a resistor and inductor in series driven by a voltage source, v_s, on the board. Label the voltage between the resistor and inductor as v_1.
c) Draw the frequency-domain equivalent circuit for the circuit, with the source labeled as $\mathbf{V}_s = V_o\angle 0°$, the voltage between the R and L labeled as $\mathbf{V}_1$, and the L labeled with impedance $j\omega L$. (The R is labeled R, as in the time domain.)
d) Write down the voltage divider equation for $\mathbf{V}_1$:

$$\mathbf{V}_1 = \mathbf{V}_o \frac{j\omega L}{R + j\omega L}$$

e) Comment that we can determine the phasor for $\mathbf{V}_1$ from an oscilloscope measurement of the magnitude of the sinusoid at v_1 and the shift of the peak voltage of v_1 relative to the peak voltage of v_s. Note that we can then use $\mathbf{V}_1$ to solve our voltage divider equation for L:

$$L = \frac{\mathbf{V}_1 R}{j\omega(\mathbf{V}_o - \mathbf{V}_1)}$$

f) Conclude your presentation by commenting that a similar approach works for a resistor and capacitor in parallel as in Lab 3.