EGR 261
Signals and Systems
File: N261PS1A

Due date: ________________
(See Due Dates Table)

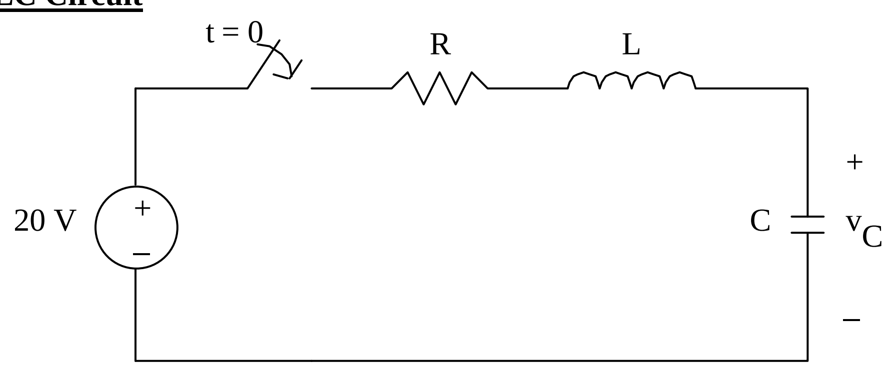
PSPICE Assignment #1:
Transient Responses of Second-Order Circuits

General Information:
It is required that you use Orcad Capture version 9.0 or later for this assignment.

Reference: (also see the instructor's web page)
Schematic Capture Using Cadence PSPICE by Herniter.
Handout: ***Sample PSPICE Report***
Example: ***Transient Analysis of a Second-Order Underdamped Circuit*** (File: Second.opj)
Example: ***Parametric and Transient Analysis of a Second-Order Circuit***
(File: Parametric & Transient - Second Order.opj)

Assignment:
1. **Problem 13.9 (in Electric Circuits, 8th Edition, by Nilsson)**
   - A) Analyze the circuit by hand to find $v_o(t)$. Note that this was a homework problem.
   - B) Use Excel, MatLab, or MathCAD to graph $v_o(t)$. Let t vary from 0 to 5Tau for the dominant root.
   - C) Find the maximum value (or minimum if negative) of $v_o(t)$ by hand (i.e., solve d $v_o(t)$/dt to find t_{max} and then find $v_{max} = v(t_{max})$.
   - D) Analyze the t > 0 circuit using PSPICE. Use the initial conditions that were found by hand for the inductor and capacitor. If you put a switch in the circuit, change the transition time property on the switch (TTRAN) from 1us to 1 ps or else it will affect your values. Display the changed property next to the switch. Perform a transient analysis. Use a final time of 5Tau for the dominant root. Graph $v_o(t)$ versus t. Use a cursor to find the maximum value of $v_o(t)$ and have PSPICE mark the point (label the value).
   - E) Compare the graphs from parts B and D. Compare the maximum values from parts C and D.

2. **Series RLC Circuit**



Circuit 1

First, some background information is presented on pages 2 and 3. The assigned steps for this series RLC circuit are shown on page 4.

<u>Background information for the Series RLC Circuit</u>:

The series RLC circuit shown in Circuit 1 can be easily analyzed using Laplace transforms to show that:

$$V_C(s) = \frac{\frac{20}{LC}}{s\left(s^2 + \frac{R}{L}s + \frac{1}{LC}\right)} \qquad \text{(Equation 1)}$$

The quadratic factor in the denominator will result in either an overdamped, underdamped, or critically damped response, depending on the values of R, L, and C. The roots of the quadratic factor are $s_1, s_2 = \dfrac{\frac{-R}{L} \pm \sqrt{\left(\frac{R}{L}\right)^2 - \frac{4}{L \cdot C}}}{2}$

so critical damping occurs for $\left(\dfrac{R}{L}\right)^2 = \dfrac{4}{L \cdot C}$ or $R = 2 \cdot \sqrt{\dfrac{L}{C}}$

Values of R, therefore, can be chosen to make the series RLC circuit produce overdamped, underdamped, or critically damped responses. As an example, we might calculate R as follows:

Case 1) $R = 2 \cdot \sqrt{\dfrac{L}{C}}$ (for a critically damped response)

Case 2) $R = 6 \cdot \sqrt{\dfrac{L}{C}}$ (for an overdamped response)

Case 3) $R = 0.5 \cdot \sqrt{\dfrac{L}{C}}$ (for a slightly underdamped response)

Case 4) $R = 0.04 \cdot \sqrt{\dfrac{L}{C}}$ (for a very underdamped response)

<u>Calculating the final time to be used in a transient analysis</u>:

<u>Critically damped response</u>:

For a critically damped response, the roots of the quadratic are

$$s_1 = s_2 = s = \frac{-R}{2L}$$

and in general the form of the response is

$v(t) = (At + B)e^{st}$

and if the circuit decays within 5(Tau) then 5(Tau) = -5/s = final time for transient analysis

<u>Overdamped response</u>:

For an overdamped response, the roots of the quadratic are

$$s_1, s_2 = \frac{\frac{-R}{L} \pm \sqrt{\left(\frac{R}{L}\right)^2 - \frac{4}{L \cdot C}}}{2}$$

and in general the form of the response is

$$v(t) \;=\; A_1 e^{s_1 t} \;+\; A_2 e^{s_s t}$$

where the smaller (absolute value) of s_1 and s_2 is the “dominant root” (the term that decays more slowly) and if the circuit decays within 5(Tau) then

5(Tau) = $-5/s_{dominant}$ = final time for transient analysis

<u>Underdamped response</u>:

For an underdamped response, the roots of the quadratic are

$$s_1 \;,\; s_2 = \alpha \;\pm\; j\beta$$

and in general the form of the response is

$$v(t) \;=\; e^{\alpha t}(A_1 \cos(\beta t) \;+\; A_2 \sin(\beta t))$$

where the $e^{\alpha t}$ term controls the length of the response

and if the circuit decays within 5(Tau) then

5(Tau) = $-5/\alpha$ = final time for transient analysis

(continued)

<u>Assignment using the Series RLC Circuit</u>:
Now that we have studied the background information, here are the assigned steps for problem 2.

Use the following component values in Circuit 1:

L = 1mH
C = 30 + (last 4 digits of EmplID)^2 in pF
For example: if last 4 digits = 1254 then
C = 30 + (1254)^2 = 1572546 pF = 1.57 μF
(C may be rounded to 3 significant digits)

A) Derive Equation 1. Calculate resistor values using the 4 equations for R provided above in order to produce critically damped, overdamped, slightly underdamped, and very underdamped circuits. Calculate the values of s_1 and s_2 for each case.

B) Draw Circuit 1 in PSPICE using the resistor value calculated for the **critically damped** circuit. Label with schematic as being critically damped. Include text indicating the length of the transient response used and show how it was calculated. Set the initial condition for the capacitor and the inductor to 0 and display these properties. Graph the capacitor voltage within probe. Use two cursors to find and label the ***rise time*** for the capacitor voltage.

C) Repeat step 2B using the resistor value calculated for the **overdamped** circuit.

D) Repeat step 2B using the resistor value calculated for the **slightly underdamped** circuit. Also measure and label the ***% overshoot*** for this circuit.

E) Repeat step 2B using the resistor value calculated for the **very underdamped** circuit. Graph the capacitor voltage as with the previous circuits (you may need to adjust the amount of time used in the transient analysis). Include a second graph where the time scale is zoomed in to show only the first oscillation. Use cursors to find and label the rise time and the % overshoot.

F) In your conclusion compare the three rise times from steps 2B, 2C, 2D, and 2E in a table and discuss the results. Which type of response is fastest? What is the tradeoff to achieve a faster response?

G) Use a PARAMETRIC and TRANSIENT analysis together to generate a series of 4 curves ranging from your smallest R value to your largest R value in steps 2B through 2E above. Use the longest of the final transient times from the previous circuits. You may round off the R values to obtain nicer values if you wish. Plot the capacitor voltage and label the R values on next to each curve.