Note: This is a preliminary draft, and may be revised on Wednesday.

Read the EE 242 manual version of Experiment 6 for background for these instructions. Also read Alexander and Sadiku Sections 14.5-6 for reference. In this project the oscilloscope will be used to measure the magnitude and phase function of a parallel circuit with the resistance as a parameter by measuring the phasor of the output voltage with respect to a fixed input sinusoidal current. Then the step response of the circuit for one value of resistance will be measured. The project is in four parts. The first part performs a PSpice analysis using the nominal values for R, C, and L to predict the frequency response and the step response. In the second part, measurements are taken for the frequency response. In the third part, measurements are taken for the step response. Then, measurements will be made with the LC meter to get a more accurate estimate for the L and C values, and the DMM to measure the resistance value. These measurements will be used in the fourth part to get a enhanced PSpice simulation for the responses, which will be compared with the measurements.

1. Perform a PSpice simulation for the frequency response, magnitude and phase response, of the circuit in figure 1. Display in one PROBE window the magnitude and phase of V1 for frequencies between 500 and 1500 Hz for R = 100, 330, 500 ohms and an open circuit. Perform another PSpice simulation for the step response for the circuit in figure 2. Obtain printouts for each of the PROBE displays; be sure to annotate them appropriately.

2. Set up the circuit in figure 1, and obtain measurements for the output phasor V1 with respect to the input current using V2, which is to be held constant at 0.5 V (this is equivalent to driving the circuit with a 2.5 mA current source). Take measurements for frequencies between 600 and 1400 Hz with R = 100, 330, 500 ohms and an open circuit. You are encouraged to use the quick measurement soft keys to make these measurements as efficiently as possible. Present the data in a table for future reference. Plot the responses on the PROBE printout, using frequency values that will yield a smooth response curve for the magnitude and phase plots. Estimate the values for the resonant frequency and the bandwidth, and compare with the calculated values.

3. Set up the circuit in figure 2, and obtain measurements for the input and output voltage for one period of the square wave input function. Use the oscilloscope display (you may wish to obtain a hardcopy) to estimate the values for \( \omega_0 \) and compare to the calculated values.

4. Use the LC meter and the DMM to measure the components to get a more accurate model for the circuit and use this model in a revised PSpice simulation of the two circuits. Compare the results with the measured values for each.

\[
V_{\text{out}} = 0.5 \sin 2\pi ft \quad V
\]

\[
V_{\text{in}} : 10 \text{ Vpp}, 5 \text{ Vdc}, 50 \text{ Hz squarewave}
\]

**Note:** \( V_{\text{in}} \) has output resistance of 50 \( \Omega \), i.e., total resistance is 330 \( \Omega \).
Find the transfer function $H(s) = \frac{V_o(s)}{V_i(s)}$.

Then, the frequency function $H(j\omega) = \frac{H(s)}{j\omega}$.

$$H(s) = \frac{\frac{1}{s} V_o + \frac{1}{sL} V_o + \frac{1}{sC} V_o}{\frac{1}{s} V_i + \frac{1}{sC} + \frac{1}{sL}} = \frac{\frac{1}{sC}}{s^2 \frac{1}{C} s + \frac{1}{sC}} = \frac{\frac{1}{sC}}{s^2 + \frac{1}{sC}}$$

$$H(j\omega) = \frac{\frac{1}{(\omega C)^2} + \frac{1}{sC} \omega + \frac{1}{sC}}{\frac{1}{(\omega C)^2} + \frac{1}{sC} (\frac{1}{C} - \omega^2)} = \frac{\frac{1}{(\omega C)^2} + \frac{1}{sC} \omega + \frac{1}{sC}}{\frac{1}{(\omega C)^2} + \frac{1}{sC} (\frac{1}{C} - \omega^2)}$$

Find the step response for the circuit given:

$$V_i = V_{pa} \frac{\frac{1}{sC} \frac{1}{s} + \frac{1}{sL}}{\frac{1}{s} + \frac{1}{sC} + \frac{1}{sL}} = V_{pa} \frac{\frac{1}{sC} \frac{1}{s} + \frac{1}{sL}}{\frac{1}{s} + \frac{1}{sC} + \frac{1}{sL}} = V_{pa} \frac{\frac{1}{sC} \frac{1}{s} + \frac{1}{sL}}{\frac{1}{s} + \frac{1}{sC} + \frac{1}{sL}}$$

$$\frac{d^2 V_i}{dt^2} + \frac{1}{C} \frac{dV_i}{dt} + \frac{1}{L} V_i = \frac{1}{RC} \frac{dV_m}{dt}$$

$V_{i,m}(t) = \frac{V_m(t)}{t}$, $t > 0$, $V_i(0) = 0$ and $\frac{dV_m}{dt} = \frac{V_m}{t}$.

1) $s^2 + \frac{1}{C} s + \frac{1}{L} = 0$ \implies $s_1 = -\frac{1}{2} \left( 1 \pm \sqrt{1 - \frac{1}{2} \frac{1}{L}} \right) \implies -2 \frac{1}{2} \frac{1}{L}$

$V_i = k e^{s_1 t} + k' e^{s_2 t}$ for $(\frac{1}{2C})^2 < \frac{1}{L}$.

2) $V_i(0) = 0$.

3) $V_i(t) = k e^{s_1 t} + k' e^{s_2 t}$ and $V_i(0) = 0 \implies k = -k' \implies k = \frac{1}{b}$.

With $k = a + b$.

4) $V_i = (a+b)e^{s_1 t} - (a-b)e^{s_2 t} = (a+b)(e^{s_1 t} - e^{s_2 t}) = J b e^{-at} (e^{-jwt} - e^{jwt})$.

$V_i(t) = J b e^{-at} (2 \sin wt t)$.

5) $\frac{dV}{dt} = 2 \pi b a e^{-at} \sin wt - 2 \pi b e^{-at} \cos wt$.

$\Rightarrow \frac{dV}{dt} = \frac{V_m}{RC} = 0 - 2 \pi b a \Rightarrow a = -\frac{V_m}{2 \pi RC}$.

$V_i(t) = \frac{V_m}{RC} \sqrt{\frac{1}{C} - \omega^2} e^{-at} \sin wt$, $t > 0$ with $a = \frac{1}{2C}$.

$\omega t = \sqrt{\frac{1}{C} - \omega^2}$.
think of $e^{jwt} \rightarrow e^{st}$  
where $s = j\omega$

low-pass circuit example

$$V_0(s) = \frac{V_s(s) R_0}{\frac{1}{C} + \frac{R_0 + R_s}{R_0 L C} s + \frac{R_0 + R_s}{R_0 L C}} = \frac{\frac{V_s(s)}{s^2 + \frac{1}{RC} + \frac{1}{LC} s + \frac{\omega_0}{s^2 + \frac{1}{RC} + \frac{1}{LC} s}}}{\frac{V_s(s)}{s^2 + \frac{1}{RC} + \frac{1}{LC} s + \frac{\omega_0}{s^2 + \frac{1}{RC} + \frac{1}{LC} s}}}
$$

characteristic equation (poles of $H(s)$)

$$\Rightarrow \frac{d^2 V_0(t)}{dt^2} + \left(\frac{1}{R_0 C} + \frac{1}{L C}\right) \frac{dV_0(t)}{dt} + \frac{R_0 + R_s}{R_0 L C} V_0(t) = \frac{1}{R_0 C} V_s(t)
$$

band pass circuit example

$$Z_{eq}(s) = \frac{1}{sL + \frac{1}{RC} + \frac{1}{R_0}} = \frac{sL R_0 L}{s^2 L R_0 L + sL + R_0}
$$

$$V_0(s) = \frac{V_s(s) s L R_0 L}{s^2 L R_0 L + sL + R_0} = \frac{V_s(s) s L R_0 L}{s^2 L R_0 L + sL + R_0} = \frac{V_s(s) s L R_0 L}{s^2 L R_0 L + sL + R_0}$$

$$\Rightarrow \frac{d^2 V_0(t)}{dt^2} + \left(\frac{R_0 + R_s}{R_0 R_0 L C}\right) \frac{dV_0(t)}{dt} + \frac{1}{R_0 C} V_0(t) = \frac{1}{R_0 C} \frac{dV_s(t)}{dt}
$$

Note: The above process can be mathematically justified by the Laplace transform.