Lab 9 – Notes

Fall 2023

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General Notes

- Lab 9 is an extra credit lab that you can do if you would like to get a bump to your grade.
- You can do the prelab 9 or/and the report 9.
- The submissions on gradescope are open till the end of the semester.

Prelab

Task 9.4.1: Prelab Questions

1. *Calculate* the step response $v_C(t)$ for $t > 0$ for the circuit in figure 9.10.

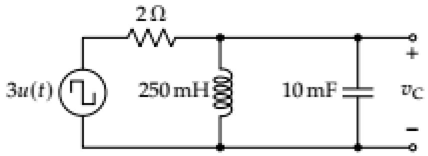


Figure 9.10: Parallel RLC Circuit

2. *Calculate* the Thévenin equivalent resistance shown in figure 9.11 by solving for the ratio v_{test}/i_{test}.

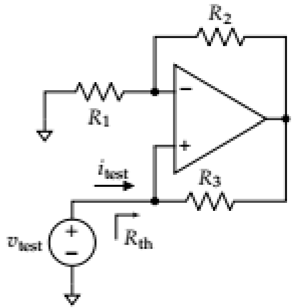


Figure 9.11: A negative impedance converter circuit

3. *Plot* the first 200 µs of $v_C(t)$ in figure 9.12 if $v_C(0) = 1\,\text{mV}$ and $i_L(0) = 0$ using Python's NumPy, MATLAB®, or a similar plotting tool.

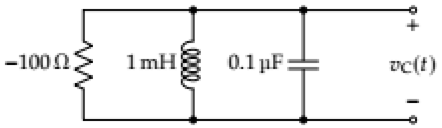


Figure 9.12: A parallel RLC circuit

1. You can solve either using Laplace or using the procedure in the solved examples, you don't need to start from the differential equations, just use the summary of relations (section 9.3.1).

2. This introduces the concept of negative resistance which you will be using in task 3.

3. Solve by the same way as problem 1 to get Vc(t). Make sure to use -100 Ω (negative value). Plot Vc(t) on Matlab for example for t:0-200us.

Task 1

Task 9.5.1: Series RLC response measurements

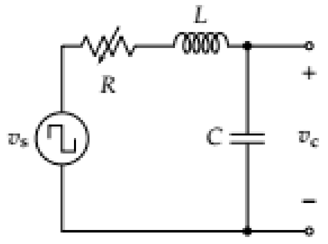


Figure 9.13: A series RLC circuit.

For this task, use $L = 1\,\text{mH}$ and $C = 0.001\,\mu\text{F}$. Assume zero initial conditions. Even though the input square wave *is* a time varying signal, if the period is much longer than the response, then it is effectively constant. One half of the square wave sets the initial conditions, and the other half provides a constant input.

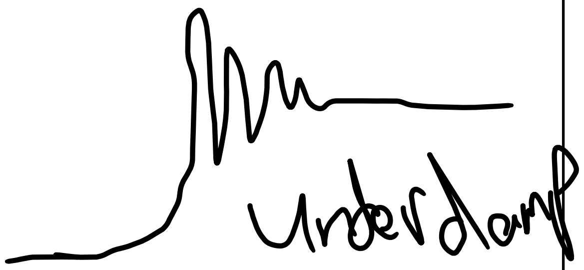
1. Let v_s be a square wave that varies between 0 V and 3 V at 1 kHz. *Adjust* the potentiometer R to obtain and *capture* an underdamped and overdamped v_c response.
2. *Calculate* the peak to peak value of v_s and a resistance value[a] to obtain the response

$$v_C(t) = 3.5e^{-1.558\times10^{6}t} - 8.5e^{-642\times10^{3}t} + 4$$

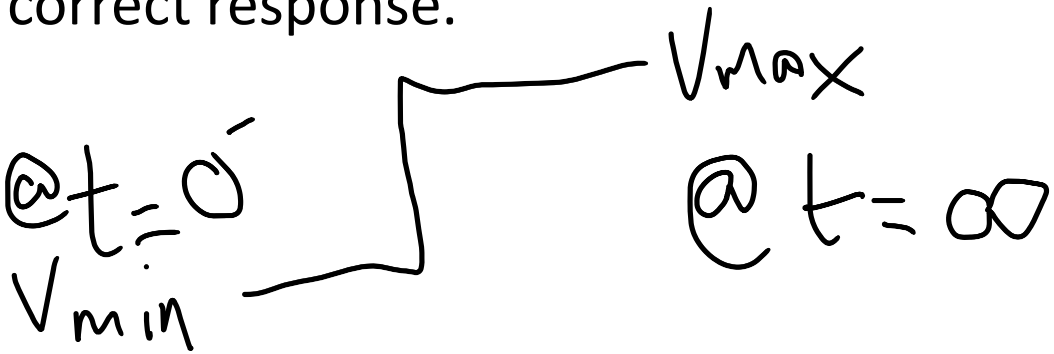
3. *Replace* the potentiometer with the fixed resistor computed in the last step. *Capture* the waveform v_c by *applying* the correct input and *downloading* the data from the oscilloscope.
4. *Use* Python's NumPy or MATLAB®, to *plot* and *compare* data collected from the oscilloscope with the expected response.

[a] Hint: compute $s_1 + s_2$ using equation (9.10).

1. Tune the potentiometer and take screenshots for underdamped and overdamped responses.



2/3. You will need to compute Vmin and Vmax of the required square wave & the value of R first. Then you need to put input square wave from the wavegen with those values and place that R to get the correct response.



4. Extract the measured data and plot it over the relation of Vc(t) given is step 2, they should be very close to each other.

Task 2

Task 9.5.2: Parallel RLC response measurements

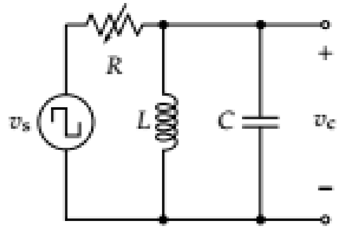


Figure 9.14: A parallel RLC circuit.

For this task, use $L = 1\,\text{mH}$ and $C = 2\,\text{nF}$. Assume zero initial conditions. Even though the input square wave *is* a time varying signal, if the period is much longer than the response, then it is approximately constant. One half of the square wave sets the initial conditions and the other half provides a constant input.

1. Let v_s be a square wave that varies between 0 V and 3 V at 1 kHz. *Adjust* the potentiometer R to obtain and *capture* an underdamped and overdamped v_c response.
2. *Determine* the peak value of v_s and *compute* a resistance value to obtain the response

$$v_C(t) = 1.3e^{-9.2\times1\times10^4 t}(\sin 7\times 1\times 10^5 t)$$

3. *Replace* the potentiometer with the fixed resistor computed in the last step. *Capture* the waveform v_c by applying the correct input and *downloading* the data from the scope.
4. *Use* Python's NumPy or MATLAB® to *plot* and *compare* data collected from the oscilloscope with the expected response.

1. Tune the potentiometer and take screenshots for underdamped and overdamped responses.

2/3. You will need to compute Vmax of the required square wave & the value of R first. Then you need to put input square wave from the wavegen with those values and place that R to get the correct response.

$V_c(0) = \frac{V_{max}}{2}$

4. Extract the measured data and plot it over the relation of Vc(t) given is step 2, they should be very close to each other.

Task 3

Task 9.5.3: Oscillator

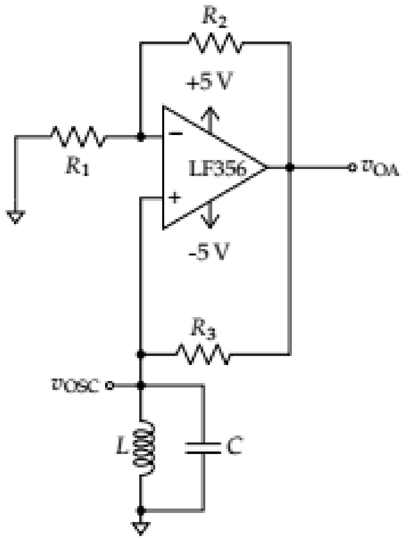


Figure 9.15: An oscillator circuit.

For this task, use $R_1 = R_2 = 1\,\mathrm{k\Omega}$, $R_3 = 100\,\Omega$, $L = 1\,\mathrm{mH}$, and $C = 0.1\,\mu\mathrm{F}$.

1. *Measure* the ESR of the inductor.
2. *Simulate* the circuit in figure 9.15. Use the measured ESR values for the inductor. *Obtain* plots of v_{OA} and v_{OSC}.
3. *Construct* the oscillator circuit.
4. *Capture* an oscilloscope screenshot showing v_{OUT} and v_{OSC} with frequency and peak to peak measurements.
5. *Calculate* the error between the simulated frequency and measured frequency. How do these relate to ω_d for the circuit?

1. You can measure the ESR (equivalent series resistance) by the AD2 using the Impedance Analyzer tool and use a series resistance of 100 Ω. Of course, you can use the ohmmeter or the DMM if you have.

2. Simulate the whole circuit on LT spice (check the guide on Brightspace). Please use the following link to download the opamp model: https://www.ti.com/lit/zip/snom255

3/4. Build the circuit and measure it. Note that the circuit is an oscillator which oscillates on its own (i.e. just needs the +/- 5v supplies).

5. Compute the oscillation frequency from the relation below, and compute it from the measurements and simulations. Compare the 3 values.

$$\omega_d = \sqrt{\frac{1}{LC} - \left(\frac{1}{2RC}\right)^2} \qquad \text{(Parallel)}$$

Note that $f_d = \frac{\omega_d}{2\pi}$, and R is value of the negative resistance (use the relation that you have derived in the perlab problem 2).