Lab# 6 RLC transient Circuits

Leonardo Fusser (1946995)

Objectives:
- Measure an RLC transient circuit resonance and ringing frequency
- Measure an RLC transient circuit overshoot
- Measure an RLC transient circuit Damping factor

Material: Mindi simulator

To hand in to Team Assignment

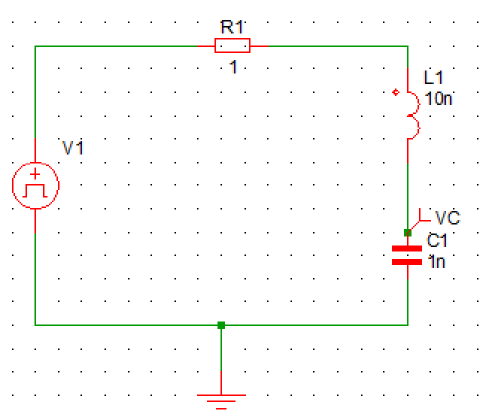
1- This document with the answers and measures. Copy-paste screenshots when required.
2- You provide comments to all screenshots
3- Upload the wxsch project file for all parts

Lab work

When a pulse generator or a DC source with a switch is connected to an RLC circuit the transient response at the output might oscillate and ring depending on the resistor value.

Under damping:

Wire the following circuit with a 1 Ohm resistor R1:



Set the simulator analysis to:
- ◦ Transient
- ◦ Stop time to 150nS

Set V1 waveform generator to:
- ◦ Frequency: 100kHz
- ◦ Pulse: 10V
- ◦ Wave Shape: square
- ◦

Measure the characteristics of the waveform V_C across the capacitor:

	Resonant frequency f_r (Hz)	Damping factor ζ	Does it overshoot? (Yes / No)
Theoretical	$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10nH * 1nF}} = 50.326MHz$	$\zeta = \frac{R}{2}\sqrt{\frac{C}{L}} = \frac{1\Omega}{2}\sqrt{\frac{1nF}{10nF}} = 0.15$	See Fig.1 Yes
Measured	$f_r = \frac{1}{t_1 - t_0} = \frac{1}{37.71nS - 16nS} = 46.061MHz$	Compare Fig.1 with your waveform $\zeta = 0.1$	Compare Fig.1 with your waveform Yes

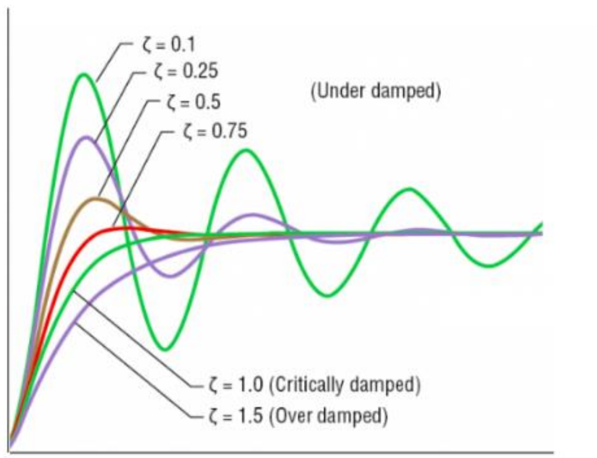


Fig 1 Resonant circuit transient response

Over damping:

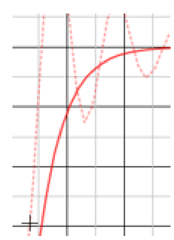
The circuit's resistor increases the decay of these oscillations, which is also known as damping. The circuit's resistor also reduces the peak resonant frequency also known as overshoot.

Increase R1 to 10 Ohms.

Characterize the new waveform V_C by filling up the following measure table:

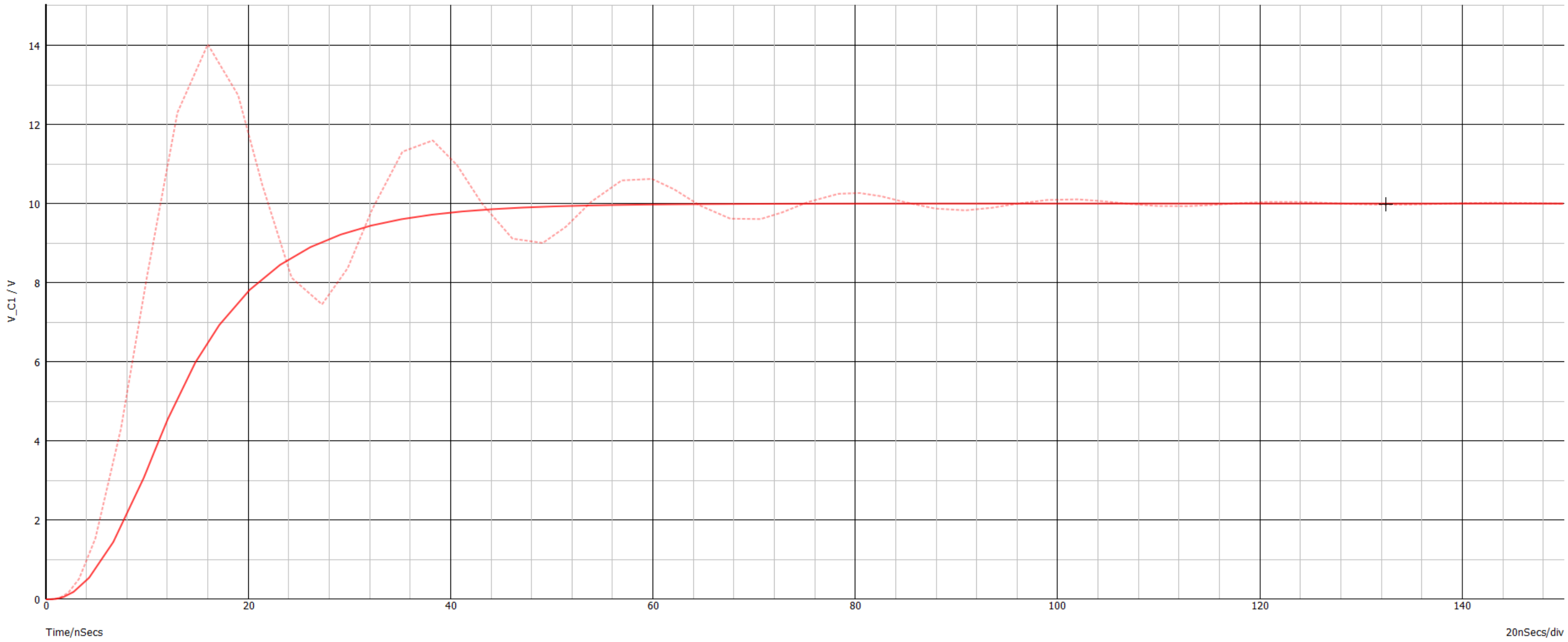
	Resonant frequency f_r (Hz)	Damping factor ζ	Does it overshoot? (Yes / No)
Theoretical	N/A (non-periodical waveform)	$\zeta = \frac{R}{2}\sqrt{\frac{C}{L}} = \frac{10\Omega}{2}\sqrt{\frac{1nF}{10nF}} = 1.58$	See Fig.1 No
Measured	N/A (non-periodical waveform)	Compare Fig.1 with your waveform $\zeta = 1.5$	Compare Fig.1 with your waveform No

Take a screenshot of the voltage. For easy comparison, the screenshot must contain **both waveforms** – 1 Ohm and 10 Ohm - on the same curve.



The axis ranges must be as follows: from 0V to 15V

(See next page for screenshot)



Screenshot for under damping and over damping RLC circuit. Solid red line is when R = 10Ω (over damping) and the dotted red line is when R = 1Ω (under damping) An explanation can be found in the first question below under "After lab questions".

Oscillating circuit - no damping:

Reducing the circuit's resistor to near zero, results in an undamped oscillation having constant amplitude oscillation.

Reduce the resistor to 0.1 Ohm

Set the simulator analysis to:

- Transient
- Stop time to 500nS

Measure the new damping factor of the waveform V_C

	Damping factor ζ
Theoretical	$\zeta = \frac{R}{2}\sqrt{\frac{C}{L}} = \frac{100m\Omega}{2}\sqrt{\frac{1nF}{10nF}} = 0.015$
Measured	Compare Fig.1 with your waveform $\zeta = < 0.1$

Does the circuit sustain an undamped oscillation or does the oscillation decay after some period of time? The circuit does not sustain an undamped oscillation (it is damped) and the oscillation decays after some period of time.

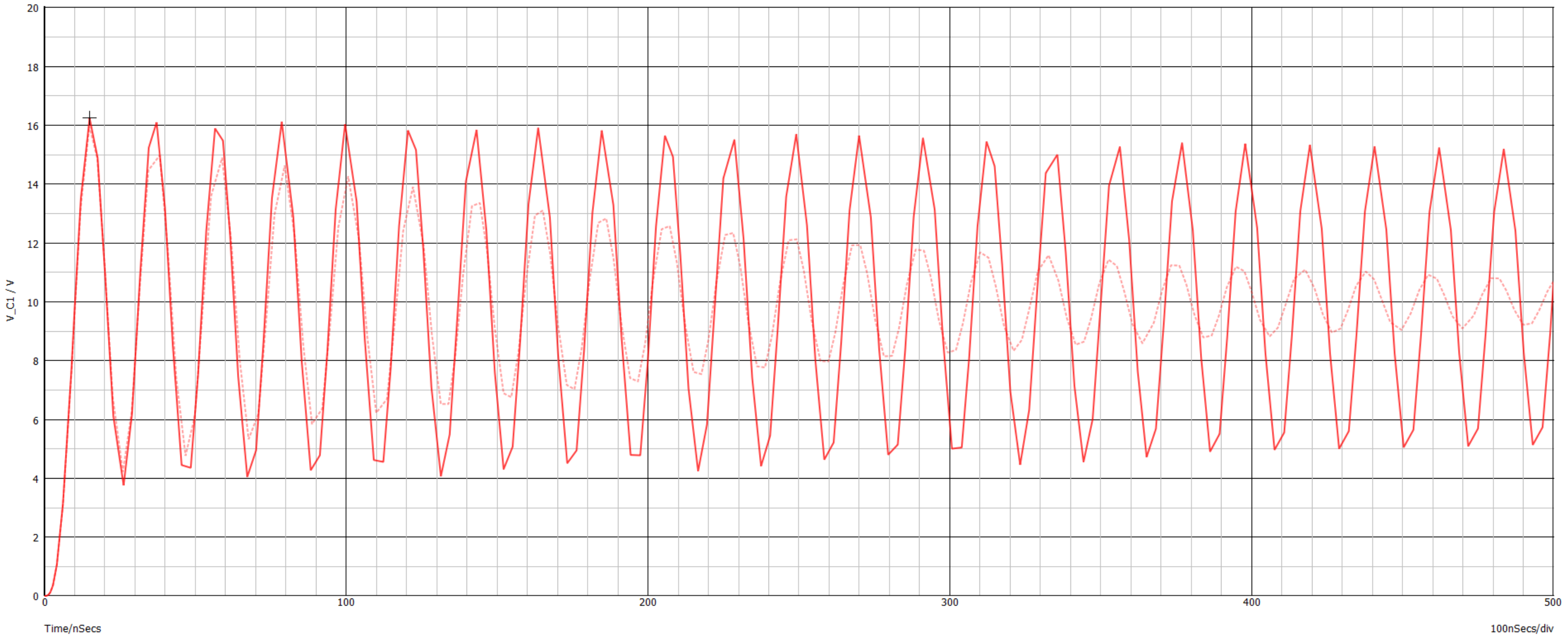
Now reduce R even more: R = 0.01 Ohm

Again, does the circuit sustain an undamped oscillation or does the oscillation decay after some period of time? The circuit does sustain an undamped oscillation and the amplitude of the oscillations does not decay after some period of time (constant throughout).

Take a screenshot of the oscillation. The axis ranges must be as follows: from 0V to 20V

(See next page for screenshot)

To approve



Screenshot for oscillating (no damping) RLC circuit above. <u>Solid red line</u> is when R = 10mΩ (undamped) and the <u>dotted red line</u> is when R = 100mΩ (damped). An explanation can be found in the first question below under "After lab questions".

After lab questions:

Q1- Explain and compare the results of the experiment. Compare and explain the results for the four different resistors.

As mentioned above, when a pulse generator or a DC source with a switch is connected to an RLC circuit, the transient response at the output might oscillate and ring depending on the resistor value. Looking at the results seen in the lab, when the value of the circuit's resistor increases, there will be an increase of the decay of the number of oscillations that will occur (also known as damping). It will also reduce the peak resonant frequency (also known as overshoot). When the value of the resistor is reduced (to near zero), the outcome results in an undamped oscillation where the amplitude throughout the oscillations remains constant. As shown above, when the resistor was 1Ω, the resulting signal was damped and the amplitude of the oscillations decayed after some time. When the resistor was 10Ω, the resulting signal was also damped but there were virtually no oscillations visible along with no overshooting. When the resistor was 100mΩ, the resulting signal was again a damped signal but this time with results similar to when the resistor was 1Ω. Finally, when the resistor was 10mΩ, the resulting signal was undamped and the amplitude of the oscillations remained the same throughout.

Q2- Give an everyday example of damped/undamped oscillation.

An example of a damped oscillation system that can be found in real life is with a car's suspension system. The car's suspension system uses a damping technique to make the ride less bumpy and in turn, reduces the vibrations of the car when it's on the road. An example of an undamped oscillation system that can be found in real life would be a clock's pendulum. The clock's pendulum uses an undamped technique which swings back and fourth continuously forever without having any resistance to stop the movement of it.

Q3- For the following simple circuit connected on a breadboard, identify all possible parasitic LC components.

Hint:
Any copper material separated by an insulator like plastic has a small parasitic capacitance.
Any wire has a small parasitic inductance that increases with its length.

The two wires that are connected to the red and blue columns of the breadboard act like a capacitor (since they are relatively close together) and the individual red and blue wires that are connected to the BJT transistor and LED act like a RL circuit.

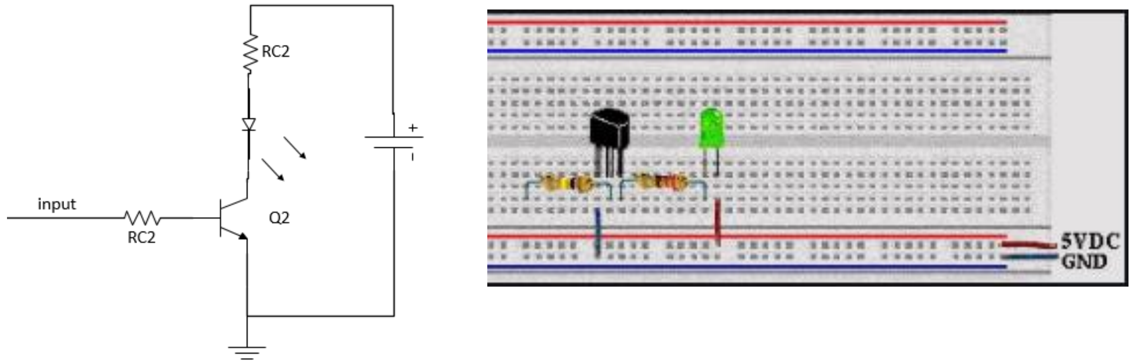


Fig 2 transistor-controlled LED circuit (left) and its prototyped circuit (right)

Q4- For the previous question's transistor-controlled LED circuit, explain how can the parasitic components be minimalized?

For the red and blue wires connected to the red and blue columns on the breadboard, a way to reduce the unwanted capacitor effect is by directly attaching those leads to the components on the breadboard, thereby separating the two wires far enough to not create the unwanted capacitor effect. They should also be not very long in length as it will avoid the problem with creating an unwanted RL circuit effect. With the modifications mentioned before, there will be no need for the other wires that are connected to the BJT transistor and LED, thus the unwanted RL circuit effect created by those two wires is no longer present.