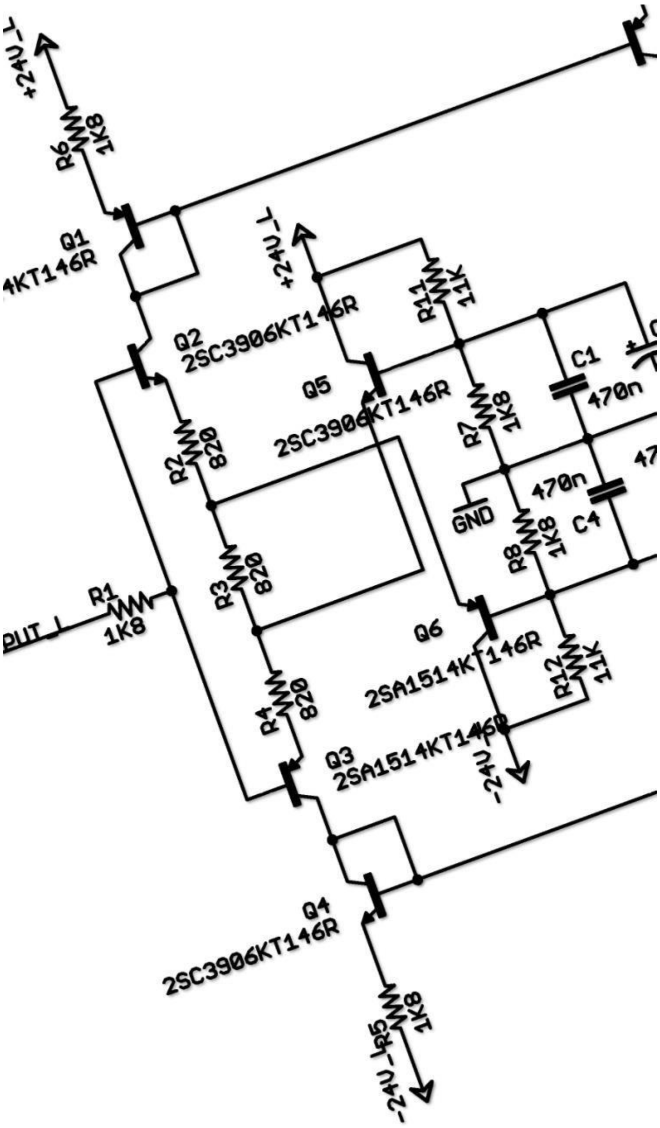
MONASH University
Engineering

ECE2131

Electrical Circuits

Laboratory Notes



2022 Edition

Name:	Student ID:	Email:

Electrical and Computer Systems Engineering, Monash University

2022

3 Transient Responses of Second Order Circuits

3.1 LEARNING OBJECTIVES AND INTRODUCTION

Following the practical experience with first order RC and RL circuits obtained in Laboratory 2, this experiment is intended to provide further practical experience of and familiarity with the step- responses of simple series circuits which contain two energy-storage elements, along with other associated lumped elements. The circuits will be driven by a square wave voltage source so that they can be mathematically described by second-order differential equation with a zero or a constant forcingfunction. The detailed mathematical analysis of such circuit has been discussed in lectures. You may need to consult the lecture notes to complete the Preliminary Work and experiment tasks in this laboratory session.

By the end of this lab you should:

- Understand how voltage and current behave in second order circuits
- Understand that electrical components have some parasitic features that cause them to be imperfect
- Characterise how an RLC circuit oscillates

3.2 EQUIPMENT AND COMPONENTS

Provided for this laboratory are a square wave generator, DSO, and:

- breadboard
- 100nF capacitor
- 100 mH inductor
- potentiometer (variable resistor)

In LTSpice, resistances in wires and internal resistances in inductors and capacitors are by default 0Ω. However, we already know that in real physical circuits, these resistances are not 0Ω. Therefore, to recreate non-zero internal resistances in wires, inductors and/or capacitors in LTSpice simulations, we need to manually set these values in LTSpice.

For this experiment, we will only set residual resistances in inductors. However, remember that residual resistances in inductors are not identical values. Inductors from the same batch manufactured can have varying amounts of residual resistances. Therefore, we should also mimic this situation as much as possible in LTSpice. Although you and your friend can have the inductors of the same inductance values, its residual resistance values would most likely be different.

To create residual resistances in LTSpice, perform the following steps:

[Compulsory for online students]

Right-click the inductor component in LTSpice.

Enter the series resistance (SR) value using the formula below:

SR = 2.5 + (0.##)x1.5

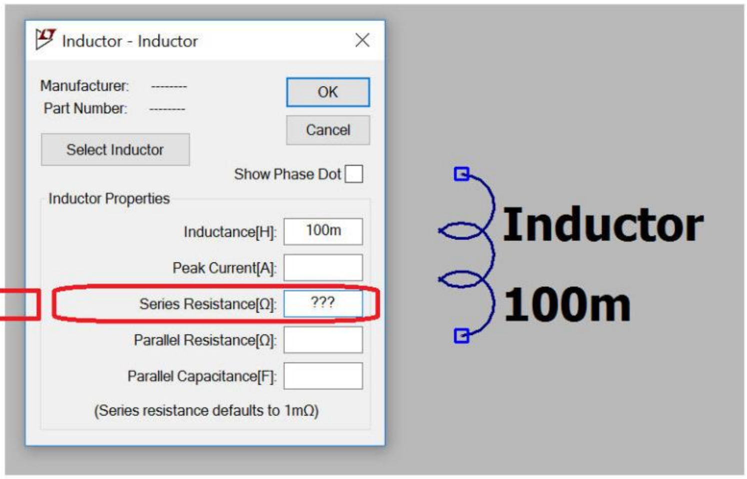
is the last two digits of your Monash student ID.

For example, if your ID is 12345678, then ## would be 78

The SR that you MUST use for the entirety of your Lab 3 circuits and report is:

SR = 2.5 + (0.78)x1.5 = 3.67Ω

Show this value in your report, preferably using screenshot.



After setting this residual resistance, you will continue to do your LTSpice simulations as per the instructions in next sections of this lab manual. Throughout this lab manual, all inductors must used this series resistance value. **Screenshot this and put it in your lab report, anywhere that does not block the other contents of the lab manual, or as appendix.**

When asked about residual resistances in the inductor, you "cannot" know its exact value, similar to how we don't know the exact residual resistances in a physical capacitor or inductor that we use the laboratory. However, it is still possible to estimate the resistance using equations and/or formulas from your lecture notes.

3.3 EXPERIMENTAL WORK

3.3.1 SERIES RLC CIRCUIT

In the series RLC circuit under study, the "common" terminal of the square wave generator and the "common" terminal of the DSO should be connected together. It should also be constructed in such a way that the voltage waveform across the element to be observed has a "common" terminal connected to the "common" of the whole circuit.

3.3.1.1 MEASUREMENT OF ω_0 AND ω_d

As investigated in the preliminary quiz, α and ω_d, the two important parameters of the zero-input response, are the same for both the circuit current and the capacitor voltage. In fact they are also the same for the inductor voltage! Thus, they can be measured from observation of either the circuit current or the capacitor voltage. However, it is more convenient to measure the capacitor voltage ratherthan the current, since this is possible even when the variable resistor is set to zero. Are there any complications associated with observing the inductor voltage directly? Describe below:

☐ CHECKPOINT: Get a demonstrator to check your answers, and initial here

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Connect the RLC circuit so that the capacitor voltage can be displayed directly on the DSO (i.e. one of the terminals of the capacitor must be connected to the "common" terminal). Note that ω_0 is the limiting value of ω_d when $\zeta=0$, corresponding to R=0. As the total circuit resistance cannot practically be made equal to zero, one can only get an approximate value for ω_0 by reducing R to a minimum. Describe what factors determine the total resistance of the RLC circuit (the **whole** circuit)?

☐ CHECKPOINT: Get a demonstrator to check your answers, and initial here

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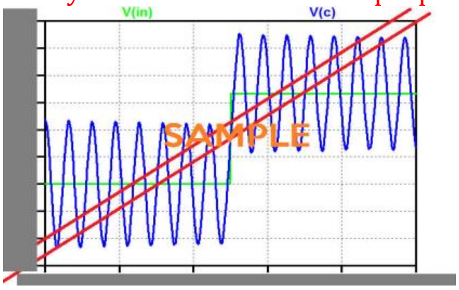
Set the variable resistance to zero (or short circuit) and display the capacitor voltage on the DSO. Measure the frequency of oscillation f_0 by measuring the time for a suitable number of complete oscillations. If you have trouble, try using a smaller square wave of input.

This is an example of what you should obtain. Delete this image from your lab report and replace it with your own results. Inclue proper labels, axis, etc. Include also any other calculations necessary.



☐ CHECKPOINT: Get a demonstrator to check your answers, and initial here

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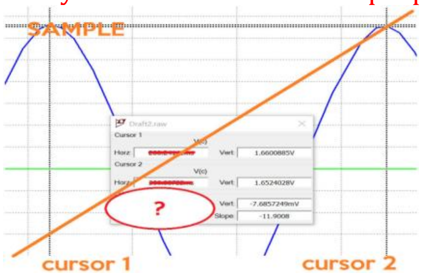
Determine the frequency ω_d from your measurement and compare it with the theoretically predicted ω_0 and comment on the discrepancy (remember these are ω, not f). You should measure at the frequency at the zero crossings (or using the frequency measurement function of the DSO)

This is an example of what you should obtain. Delete this image from your lab report and replace it with your own results. Inclue proper labels, axis, etc. Include also any other calculations necessary.



Is the oscillation underdamped? Why do you say this?

☐ CHECKPOINT: Get a demonstrator to check your answers, and initial here

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3.3.1.2 A MORE PRECISE DETERMINATION OF THE OSCILLATION FREQUENCY

The envelope of the peaks of the waveform $v_{Cp}(t)$ (the capacitor voltage) decays according to the equation $v_{cp} = v_c(0)e^{-\alpha t}$ as shown in Figure S2.1

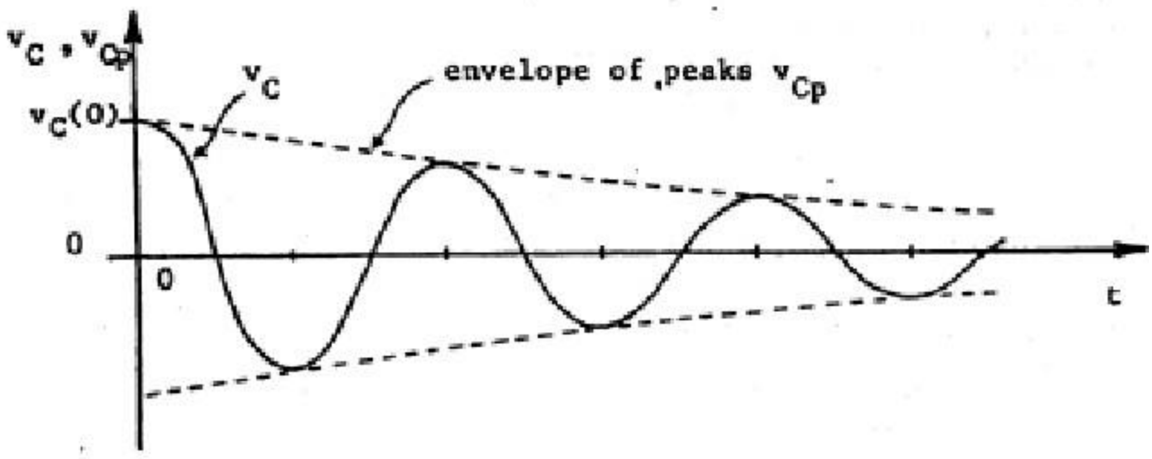

Figure S2.1 Capacitor voltage waveform when ζ << 1.

From this relation, determine α by <u>measuring</u> the peaks of V_{Cp} at two different times separated by a few cycles (don't select subsequent peaks). Then use these measurements and the equation above to find the value of α. Then use this measured value of α and the measured value of ω_d from the previous section to obtain an estimate of the natural frequency, ω_0. Compare the two values of ω_0 from this section and from section 3.3.1.1. What can you observe?

☐ CHECKPOINT: Get a demonstrator to check your answers, and initial here

Make use of the value of α and the nominal L to estimate the 'residual' resistance remaining in the LC circuit. Describe where this resistance comes from?

☐ CHECKPOINT: Get a demonstrator to check your answers, and initial here

3.3.2 VARIATION OF ω_d WITH R

Adjust the resistance R of the series RLC circuit until oscillations in the capacitor voltage just vanish. Measure this value of R_C, which should be close to the critical resistance R_{crit} (see lecture notes). Compare R_C with the theoretically predicted value of R_{crit}. Sketch the graph of the capacitor voltage for a few interesting values of R: (i) R_C (ii) $2R_C$ (iii) $0.5R_C$ (iv) $0.25R_C$. Explain the differences that you observe from the graphs.

Do not perform calculations to get R_C

Adjust your R, and repeat until the oscillations just vanish, NOT completely vanish... The experimental R_{crit} in this case is called R_C.

You should draw all four capacitor voltage graphs on the same axis. This helps to observe differences.

Do you think your experimental R_{crit} should exactly be the same as your theoretical R_{crit}?

Delete this text box from your lab report, and use this space for your calcultions, comparisons, and explanations.

☐ CHECKPOINT: Get a demonstrator to check your answers, and initial here

ASSESSMENT

Student Statement:

I have read the university's statement on cheating and plagiarism, as described in the *Student Resource Guide*. This work is original and has not previously been submitted as part of another unit/subject/course. I have taken proper care safeguarding this work and made all reasonable effort to make sure it could not be copied. I understand the consequences for engaging in plagiarism as described in *Statue 4.1 Part III – Academic Misconduct*. **I certify that I have not plagiarized the work of others or engaged in collusion when preparing this submission.**

Student signature:________________________________Date:____/____/____

TOTAL: ________(/7)

ASSESSOR: ________