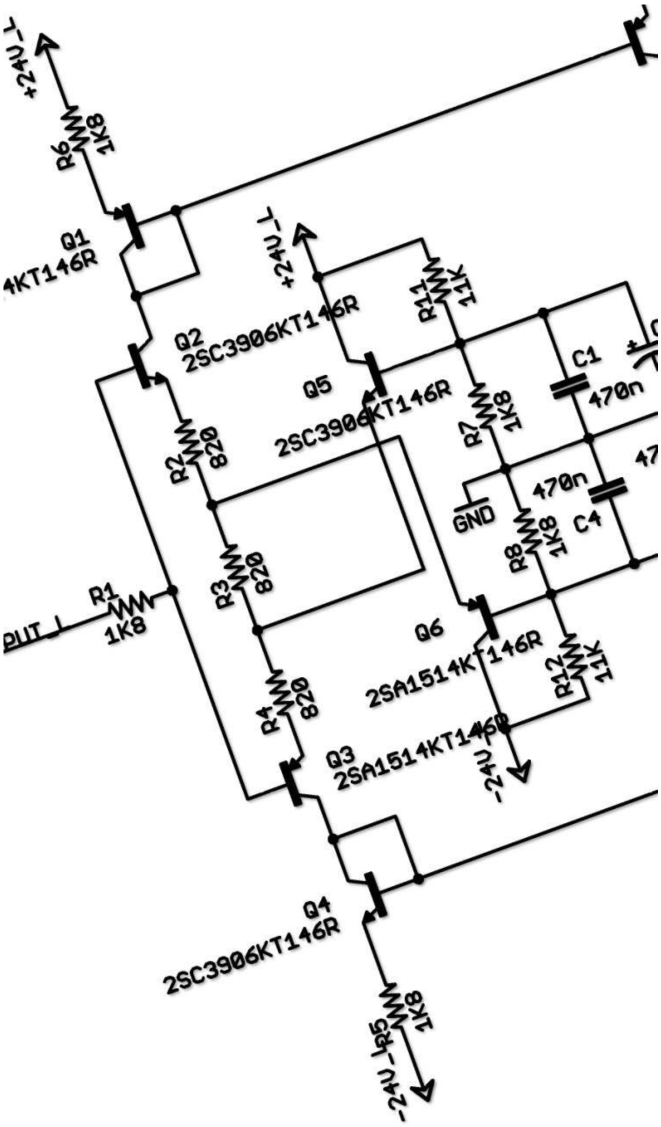
MONASH University
Engineering

ECE2131

Electrical Circuits

Laboratory Notes



2022 Edition

Name:	Student ID:	Email:

Electrical and Computer Systems Engineering, Monash University

2022

6 Frequency Response of 1st and 2nd Order Circuits

6.1 Learning Objectives and Introduction

The sinusoidal steady-state response of both first and second order series circuits as a function of frequency will be investigated in this experiment. Making use of what you learned in previous experiments, the relationship between the transient response and the frequency response of these circuits is to be practically examined.

This laboratory is divided into two parts, Part A and Part B. Part A deals with first-order linear circuits, mainly the RC case, and Part B with a second-order series RLC circuit. Sinusoidal voltages will be used to excite the circuits. This will allow the amplitude and phase of the output voltage in relation to the input voltage to be both predicted and measured.

By the end of this lab you should:

- Relate complex impedances to a frequency-domain representation (AC analysis) of circuits
- Measure the frequency response of a circuit with a network analyser
- Understand how to relate the frequency response to the effect on periodic signals (voltage waveforms …) coming into a circuit

6.2 Reference Equations

Additional equations are available in the lab addendum notes on Moodle, and in the lectures notes, but some key results are summarised below:

First order transfer function magnitude and phase components are given by:

$$\left|\underset{\sim}{A}_V\left(j\omega\right)\right| = \frac{1}{\sqrt{1+\left(\omega RC\right)^2}} \qquad \arg\left(\underset{\sim}{A}_V\left(j\omega\right)\right) = -\tan^{-1}\left(\omega RC\right)$$

Break frequency magnitude and phase (cf RC time constant):

$$\underset{\sim}{A}_V\left(j\omega_b\right) = \frac{1}{1+j\omega_b RC} = \frac{1}{1+j1} \rightarrow \left|\underset{\sim}{A}_V\left(j\omega_b\right)\right| = \frac{1}{\sqrt{2}} \approx 0.7071$$

$$\omega_b = \frac{1}{RC} = \frac{1}{\tau} \qquad \arg\left(\underset{\sim}{A}_V\left(j\omega_b\right)\right) = -\tan^{-1}\left(1\right) = \frac{-\pi}{4} \text{ radians, or } -45^\circ$$

6.3 Equipment and Components

- Breadboard
- 100 nF (0.1 μF) capacitor
- 100 mH inductor
- 820Ω and 1.6 kΩ resistors
- Potentiometer

6.4 EXPERIMENTAL WORK

6.4.1 Setting up for network analyser experiments

6.4.2 Network analyzers

Basically, network analyzers are tools that you can use to measure the AC magnitude and phase response of a circuit. They give you magnitude and phase plots.

Essentially, a swept frequency is input to a circuit, and the output is measured. Timing (i.e. phase) is either done internally, or (in the case of this lab) with an external reference measurement. So, instead of having to analyse a series of measurements of sinusoids, you are able to measure amplitude and phase over thousands of points in matter of seconds.

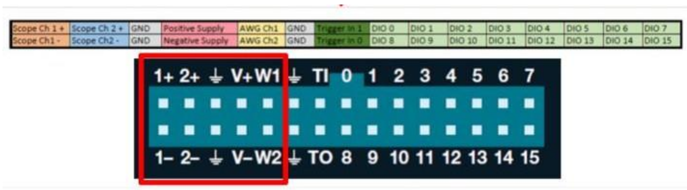
What this builds for you is a frequency-domain transfer function for the circuit, which you can then use to understand the circuit's AC behaviour.

6.4.3 Connect ADALM2000 boards, open Scopy and set-up experiment

a) Connect the ADALM USB board to lab computer & Connect the 2x5 pin connector to the left-most pins on the ADALM2000 module

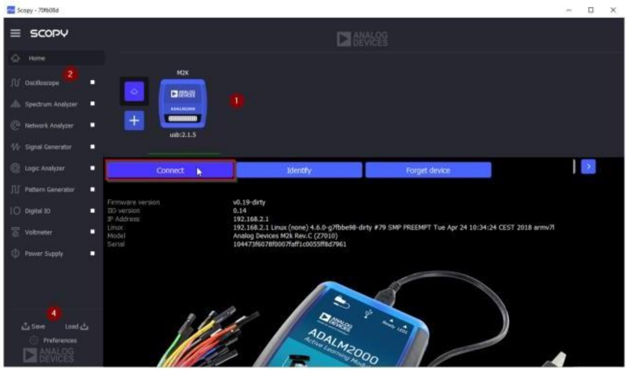
Connect micro-USB

Connect to PC



We only need these 10 pins for our labs

b) Open Scopy, click on device in Home screen and click connect.

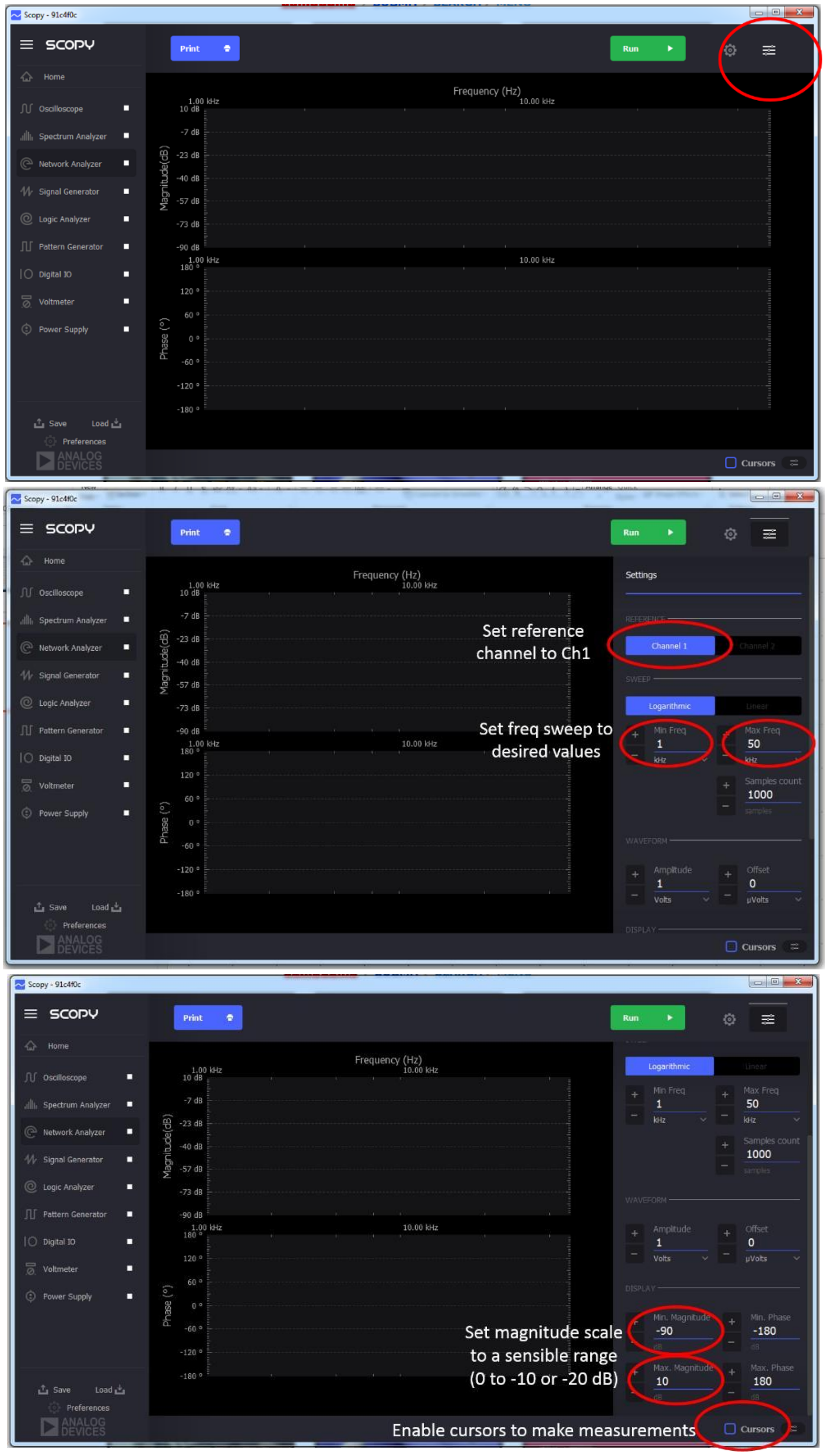


Wait a few seconds for it to connect and calibrate.

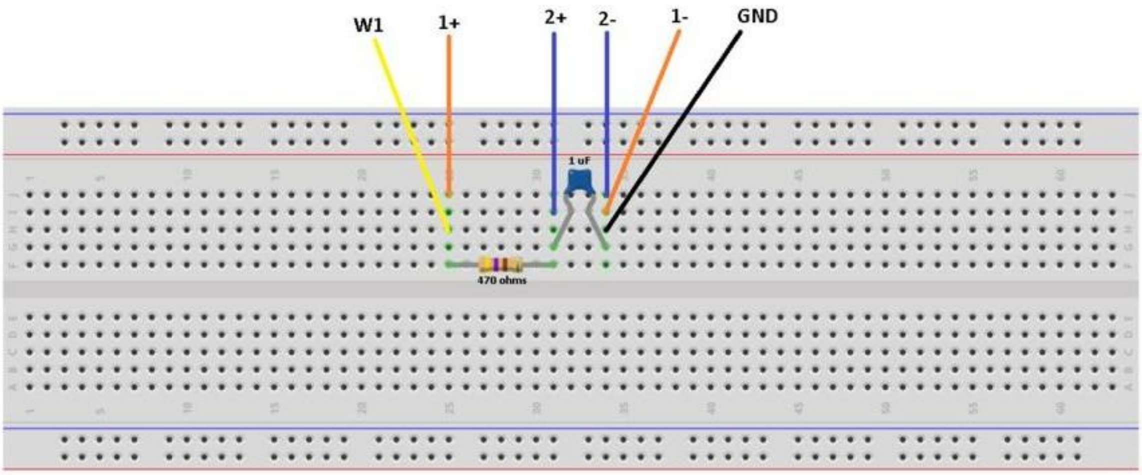
c) Open the Network Analyzer tab in Scopy set **Channel 1** to reference.

d) The ports from ADALM2000 that you will be using are as follows:

- W1 (yellow) as the signal generator, and use ground (black) as the negative terminal, **not W2**.
- Ports 1+ and 1- (orange wires) will be used as the reference probe (connected to the source) for this experiment. Connect 1- to ground.
- Ports 2+ and 2- (blue wires) of the oscilloscope will be the measurement probe (connected between the measurementnode and ground). Connect 2- to ground.



e) For the first circuit (RC first-order circuit), set out your circuit like so (**ignore values on the schematic image below**). Use the components as listed in section 6.3.



6.4.4 PART A: SERIES FIRST-ORDER CIRCUITS

Construct the circuit of Figure S5.2 with C = 0.1 μF 10% and R = 1,600 Ω.

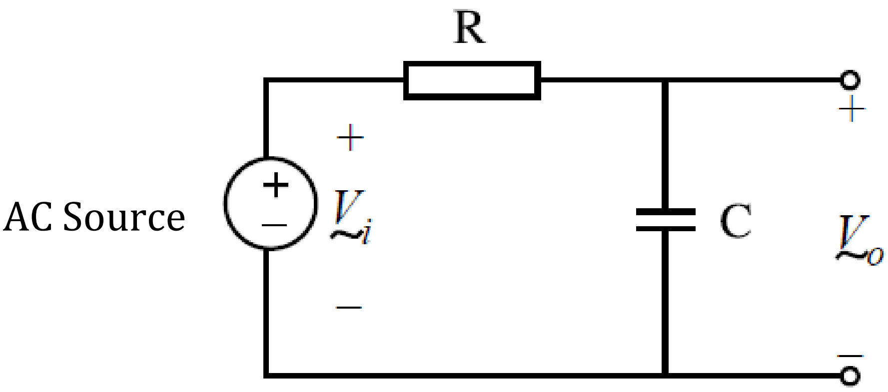
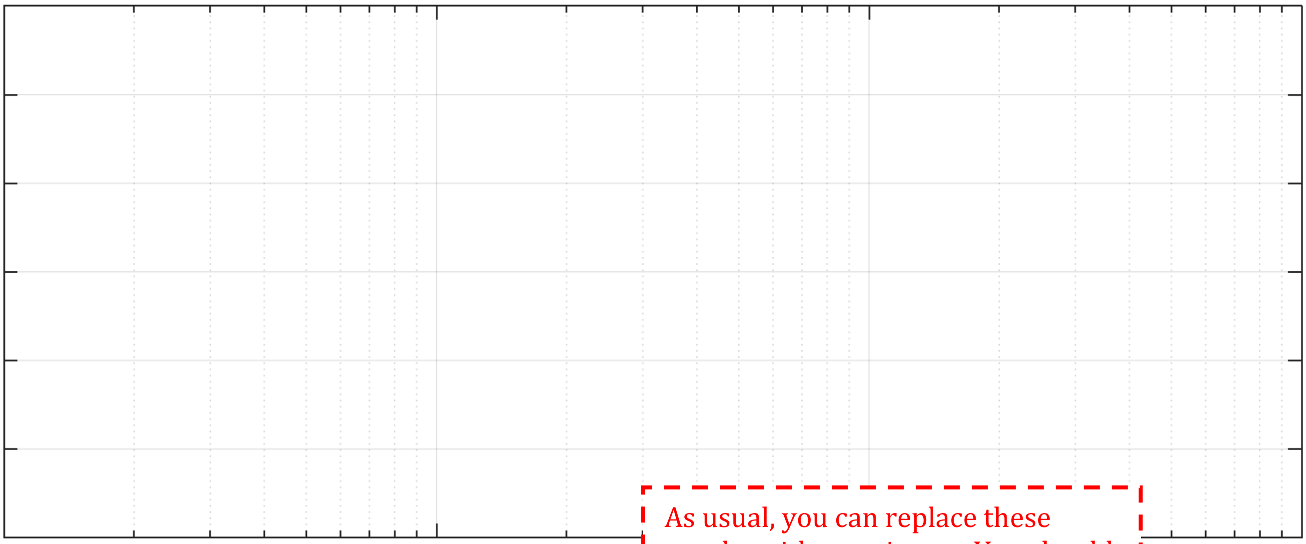


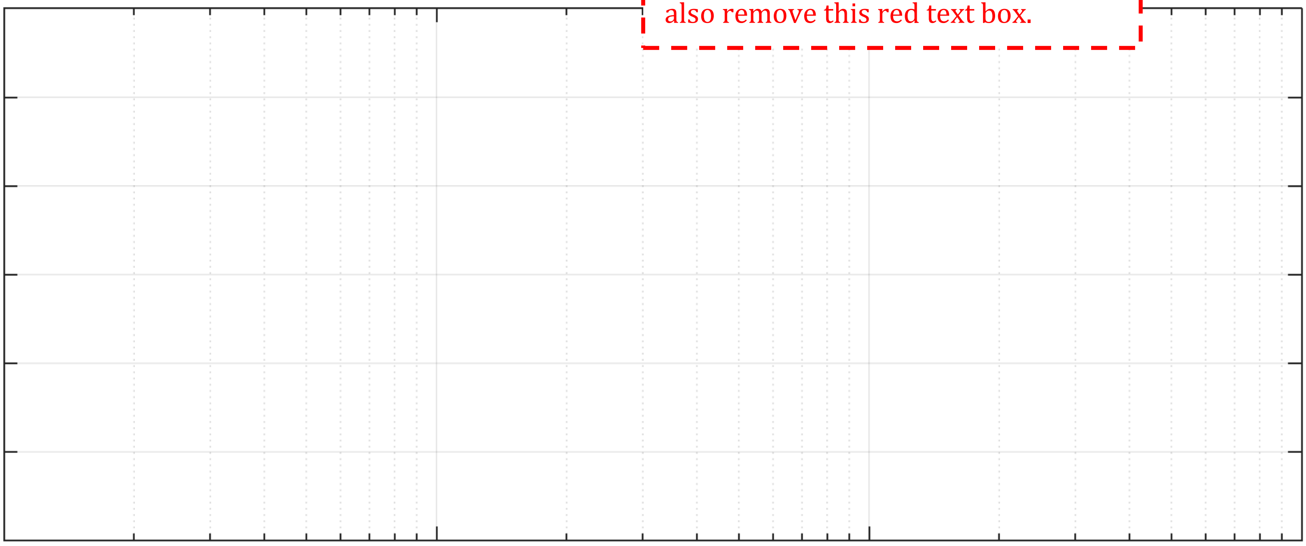
Figure S5.2 A series RC circuit

6.4.4.1 Measure the magnitude and phase of the voltage "gain" transfer function in the frequency range from 20 Hz to 20 kHz.

6.4.4.2 Plot both the amplitude- and phase- frequency responses using a **logarithmic scale for frequency**. It is recommended that a linear scale is used for amplitude and phase, and the units in dB, as per Scopy. **Remember to label your axes, as well as mark any measurement points in your graphs.**



As usual, you can replace these graphs with your image. You should also remove this red text box.



6.4.4.3 From the plots above, <u>determine</u> the break or corner frequency. <u>Compare</u> the angular corner frequency, $\omega_B = 2\pi f_B$ against the reciprocal of the time constant RC, $1/\tau$. <u>Compare</u> your plots with those of Figure S6.4 from the lab addendum notes available on Moodle.

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

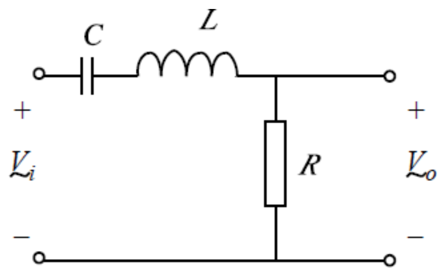
6.4.4.4 Now change the load resistance to 800Ω. Sweep the frequency of the source to find the new break point frequency. Compare your experimental value against theoretical values.

You're not provided with an 800Ω resistor, because it's not a common/typical component that we can easily obtain… however, you have been provided with multiple 1600Ω resistors :)

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

6.4.5 PART B: SERIES RLC CIRCUIT

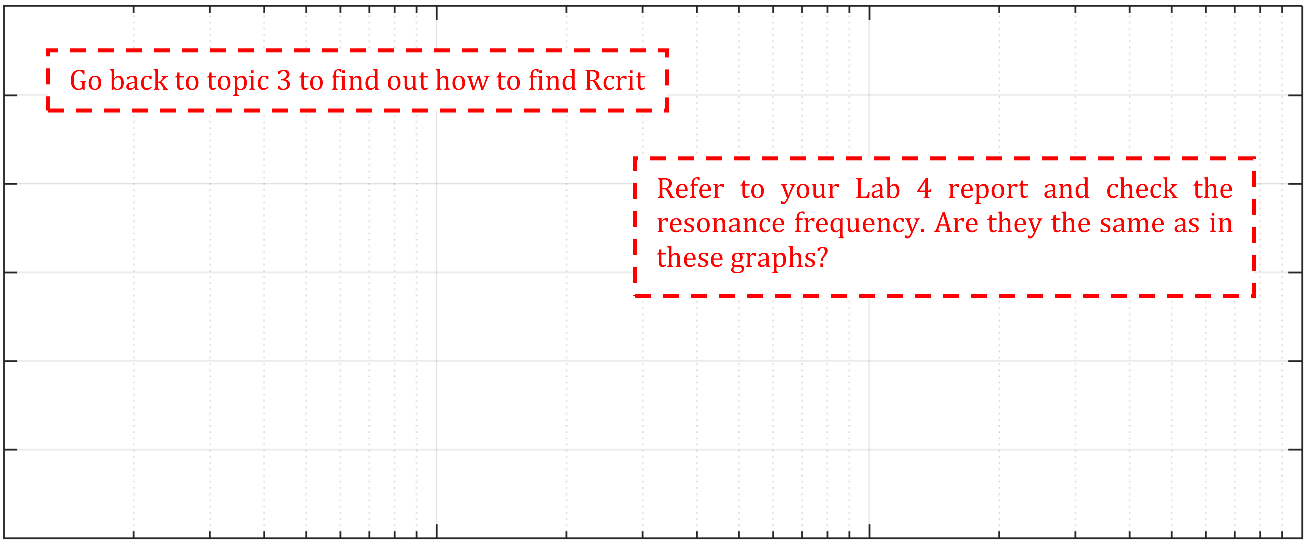
Construct the circuit of figure S6.6 using L = 100 mH, C = 0.1 μF, and a potentiometer for R.

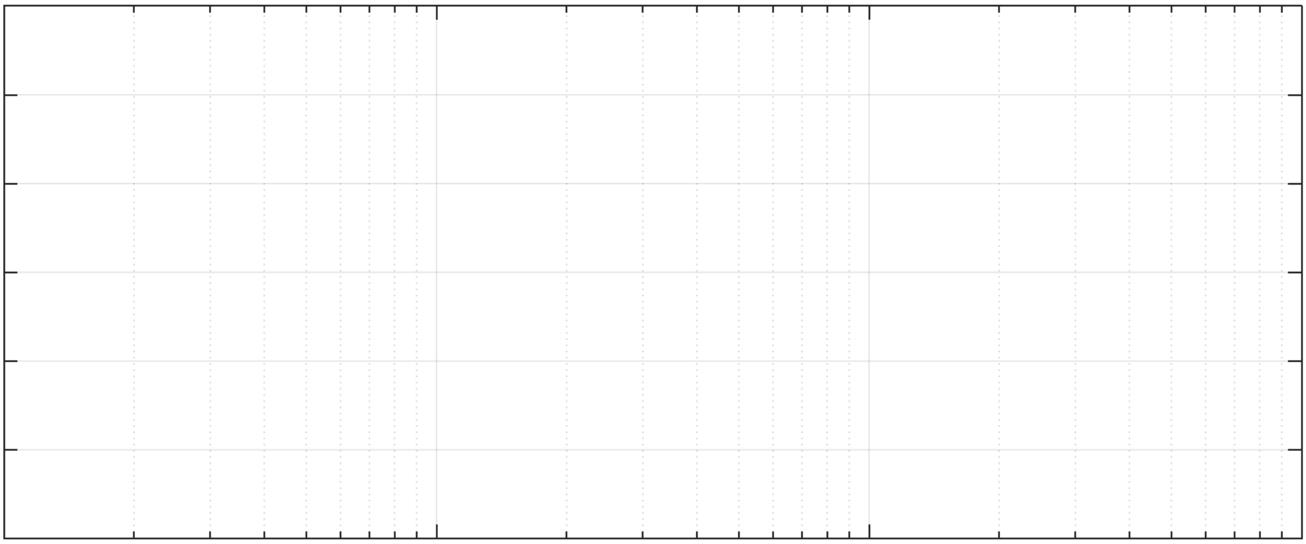


S6.6 - Series RLC circuit.

Copy the un-damped natural frequency ω_0 and R_{crit}, the critical circuit resistance from the prelim quiz. Show your working on how you obtained this value.

6.4.5.1 <u>Set</u> R to R_{crit} (to do this, you may either: adjust your potentiometer, or replace your potentiometer with one/some fixed-value resistors). <u>Examine</u> your calculated amplitude of V_o. <u>Test</u> your circuit and <u>check</u> that the circuit response changes significantly around the natural frequency ω_0. This is important, so that the rest of your analysis in this lab makes sense. <u>Plot</u> both the amplitude- and phase- frequency responses of this new circuit.



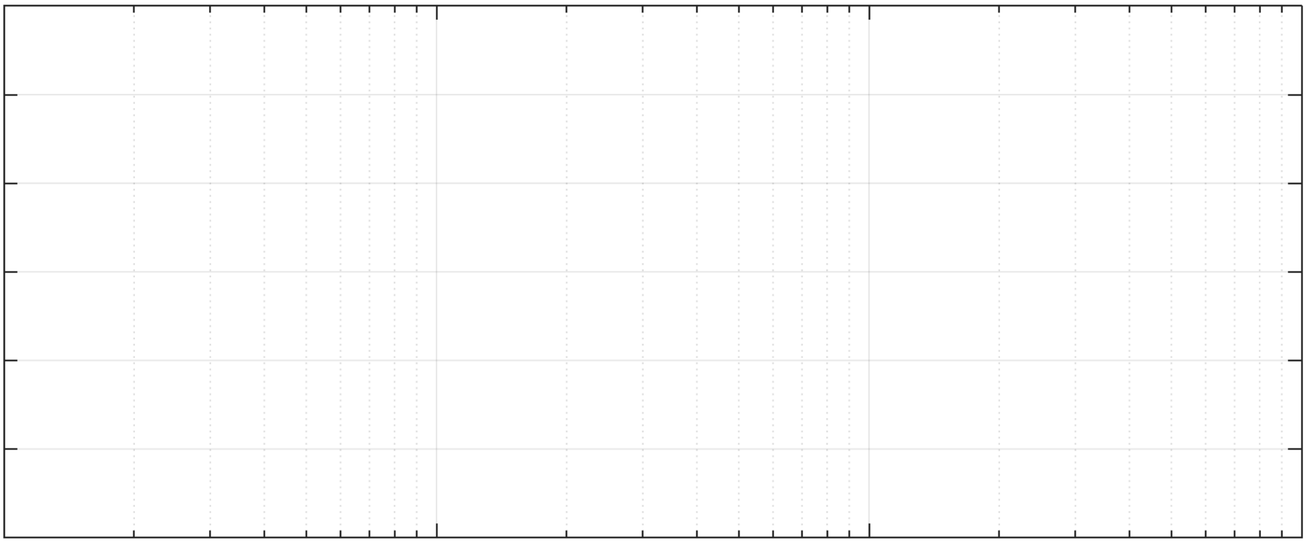


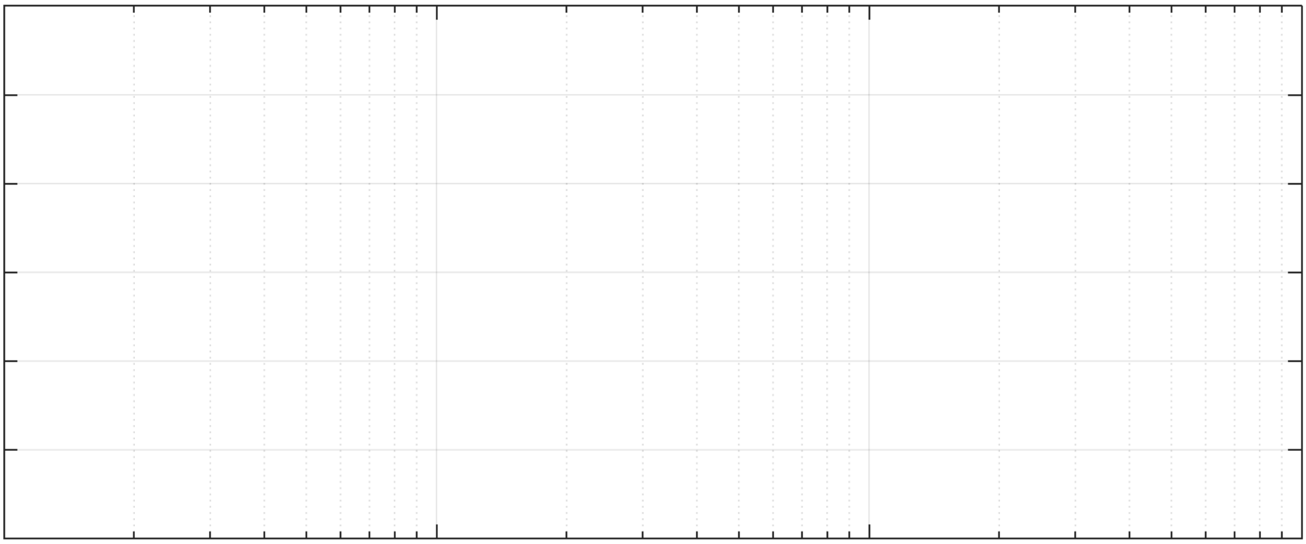
Are these responses as expected? What features from the graphs indicate this to you?

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

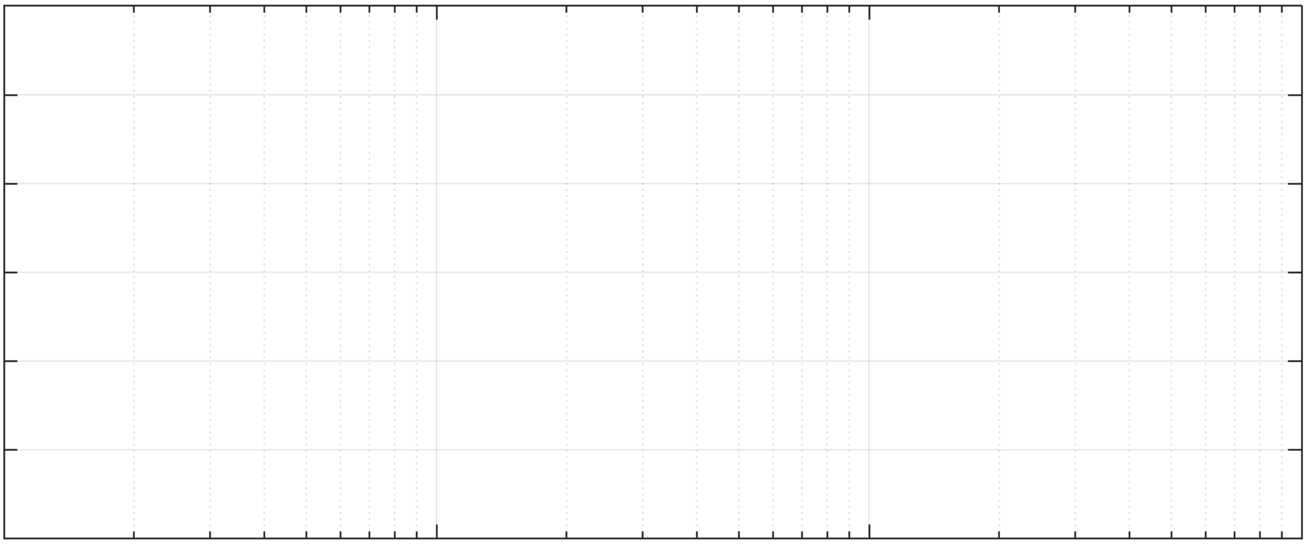
6.4.5.2 Measure the magnitude and phase responses of the voltage “gain” transfer function over a range of frequencies from 20Hz to 20 kHz. The gain is V_o/V_i. Perform this with two different resistance values: (a) $2R_{crit}$ and (b) $0.5R_{crit}$.

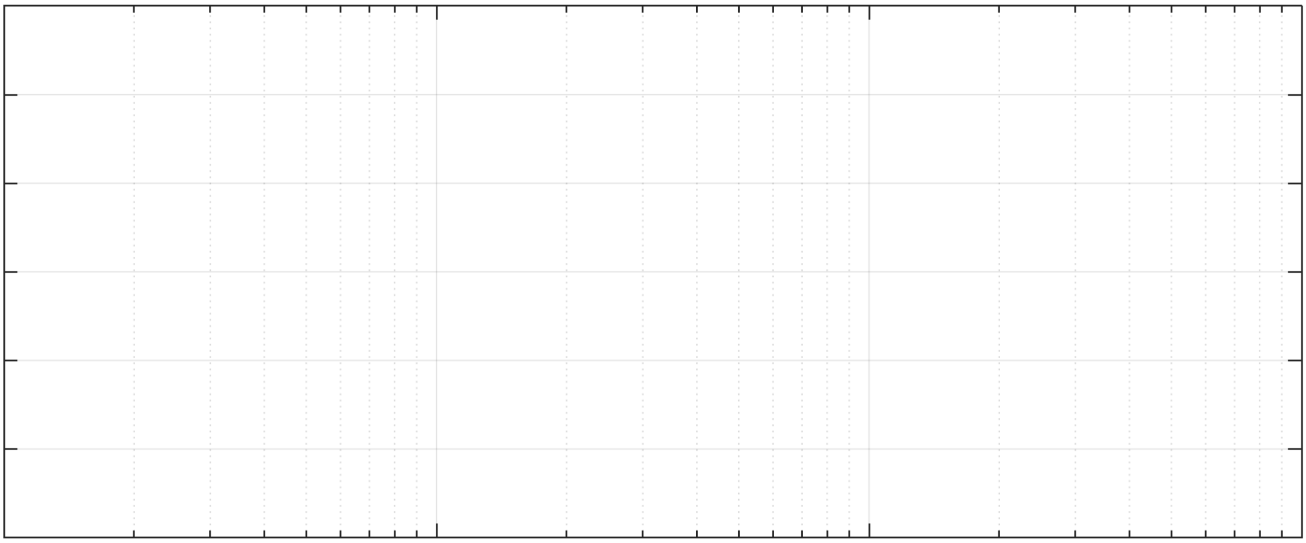
2 Rcrit





0.5 Rcrit





Show your working and the values of the damping ratio ζ and the quality factor Q for each of the two resistance cases measured in 6.4.5.2

Go back to topic 3 to find out these equations!

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

6.4.5.3 FILTERING PROPERTIES OF SERIES RLC CIRCUITS

Do trend of the graphs plotted in 6.4.5.2 reflect the values for the damping ratio ζ and the quality factor Q that you calculated? How does the width of the observed features of the amplitude frequency response relate to these values?

☐ 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: ________