Series and Parallel Equivalent Circuits.

Lab Objectives

1. To predict the value of the components that make a series circuit equivalent to a parallel circuit at a given frequency
2. To compare the predicted circuit response to the simulated and measured responses.
3. To take data using the oscilloscope and analyze that data to demonstrate the equivalence of two circuits.
4. To evaluate how an R-C circuit's behavior changes as the frequency of the sinusoidal forcing function changes.
5. To understand how to choose a properly sized sample resistor to measure the current in a system without introducing a significant error.

Pre-Laboratory Preparation:

Prior to your scheduled laboratory meeting time the following items need to be completed. The prelab quiz will be based on this preparation. There are two lab notes near the end of this handout that will prove very helpful

1) Study the circuit shown in Figure 1. On green engineering or quadrille paper, calculate the total current $\mathbf{I_S}$ (magnitude and phase angle) drawn from the source (note the sample resistor shown, this will be used to measure $i_S(t)$ in lab). Calculate the total impedance $\mathbf{Z_T}$ for the circuit (magnitude and phase angle) excluding R_{SAMPLE}.
2) Use $\mathbf{Z_T}$ to predict the parallel R-C circuit that is equivalent to the original series circuit (you will use the same value sample resistor in the parallel circuit to measure the total current in lab). Sketch the series and parallel equivalent circuits on the same page as your prelab calculations, labeling the resulting voltages and currents in phasor form.
3) Create a Data Table in Excel, leaving space to log the calculated, simulated, and measured currents and impedances indicated, with their phase angles. Record your calculated values of $\mathbf{I_S}$ and $\mathbf{Z_T}$ for both the circuit in Fig 1 and for the equivalent parallel circuit you calculated in step 2.
4) Simulate the circuit of Figure 1. Show the applied voltage and the resulting current $i_S(t)$ (using the voltage across the sample resistor and an ohms law calculation, scaled by about 10x and not by simulating the current directly). Record the current $\mathbf{I_S}$ in your data table (in phasor form). Use $\mathbf{I_S}$ and $\mathbf{E_1}$ to calculate $\mathbf{Z_T}$ (don't forget to remove the value of Rsample). Record $\mathbf{Z_T}$ in your data table.
5) The prelab quiz may include the following topics:
   a) Understanding equivalent series and parallel R-C and R-L circuits.
   b) Measuring voltages and currents in the time domain using an oscilloscope.
   c) Using an oscilloscope and function generator.

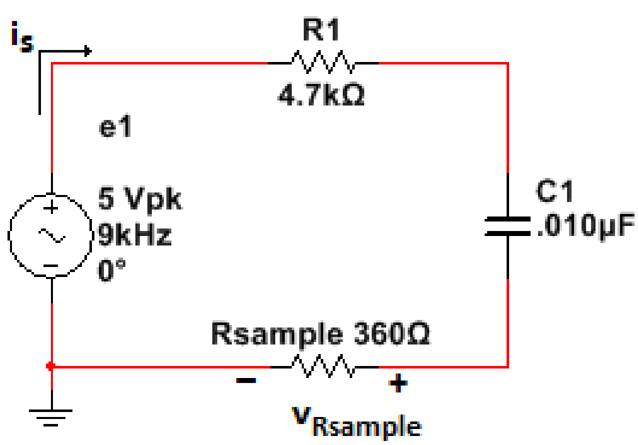

Figure 1 – Series RC Circuit with Rsample

Series and Parallel Equivalent Circuits.

AC Circuits Lab Procedure: Work with your lab partners and make sure you know your assigned roles

1) Build the series circuit shown in Figure 1 using the closest standard lab resistor for R_{SAMPLE}. Display $\mathbf{e_1}$ and $\mathbf{v_{Rsample}}$ for about 2 cycles on channels 1 and 2. Capture the image on the Oscilloscope, and embed it in a WORD Document titled **AC Circuits Lab 4 [your team name]**, label it properly. Calculate the source current $\mathbf{I}_S$ and the total impedance $\mathbf{Z_T}$ on the same sheet, showing your work. Include your schematic diagram. Record $\mathbf{I}_S$ and $\mathbf{Z_T}$ on your data table (and in Table 1 below) in the proper locations so that you can compare your predicted, simulated and measured values of $\mathbf{I}_S$ and $\mathbf{Z_T}$. <u>Record the MAGNITUDE and ANGLE for each parameter, use degrees and proper units.</u>
2) Build the parallel circuit equivalent that you predicted in prelab next to the series circuit on your breadboard and using the same $\mathbf{e_1}$ and $\mathbf{v_{Rsample}}$, repeat step 1.
3) You should now have calculated, simulated and measured values of $\mathbf{I}_S$ and $\mathbf{Z_T}$ for the circuit in Figure 1 as well as its equivalent parallel circuit. This will demonstrate that each series R-C circuit has an equivalent parallel circuit. <u>Have your instructor sign off after checking both pages of print outs from steps 1 and 2.</u>
4) **What happens if the frequency changes?** For the circuit of Figure 1 that is on your breadboard, change $\mathbf{e_1}$ to 5Vpk at <u>3kHz and</u> use the same sample resistor to determine the new value of $i_S(t)$. Repeat this process with the formerly equivalent circuit. Record your results from this step in the table below ($\mathbf{I_s}$ and $\mathbf{Z_T}$) and save your O'scope plots, using them to answer question 1. **(Note; this page becomes part of the post lab hand in, and is due at the <u>beginning</u> of next lab period.)** <u>Have your instructor sign off after checking your data table.</u>

Table 1 - Figure 1 Circuit Equivalence Test (measurement based) with e_1 = 5Vpk

	Figure 1 - Series RC		Equivalent Parallel RC	
Parameter	**f = 9kHz**	**f = 3kHz**	**f = 9kHz**	**f = 3kHz**
$\mathbf{I_S}$ (A)				
$\mathbf{Z_T}$ (Ohms)				

Question:

1. If the series circuit in figure 1 is equivalent to the parallel circuit calculated at f=9kHz, explain why it isn't equivalent at 3kHz? Describe your reasoning in terms of $\mathbf{X_c}$ and $\mathbf{Z_T}$.

Series and Parallel Equivalent Circuits.

Post Lab Requirements:

1. After lab, **during a time specified by your instructor**, take the Post Lab Quiz on myCourses. You may use your prelab work, lab data and answers to the lab question as reference material.
2. Turn in your completed documentation at the beginning of next week's lab before you take that week's prelab quiz. Your submission package will be graded and returned with comments. Submit only the following 4 pages (in order) at the start of lab NEXT week:
   a. The following cover page (completely filled in by all of your team members) with sign-offs, one per team.
   b. Your two O'scope plots and associated calculations for lab procedure steps 1 and 2. Each plot on one page, properly titled and annotated with measurements shown, your calculations for **Is** and **Z_T** below each, complete and labeled with units and in polar form, and schematics, one per team.
   c. Table 1 and question 1 restated from page 2 on one page, in WORD format (not hand written) completed with units and a thoughtful discussion, one per team.

Lab Note 1: Engineering a Sample Resistor

A sample resistor is used when it is impossible or inconvenient to measure current directly. In the case of an oscilloscope, it's impossible without the use of special probes. A sample resistor must have 2 things going for it. First, it has to have **ALL** the current you're trying to measure pass through it, and second, it has to have a value small enough in comparison to the total circuit or branch impedance that its effect on the circuit (or branch) can be neglected.
If we address the second requirement, you have to define how much error can be neglected. If we define that to mean less than 5% error, then the sample resistor should be less than 5% of the magnitude of **Z_T**. Keep it simple, and use standard values. An example: If the total impedance of a circuit has a magnitude of 10kΩ, then a good sample resistor should have a magnitude of about 500Ω or less. You can use 470Ω or 560Ω for your sample resistor. (5% is pretty tight, so even though 560Ω is greater than 5% it still remains small compared to 10kΩ, and may give you a little better chance to read the voltage across it.).
What about where to place it? Note that in figure 1a and 1b, the sample resistor is placed between the circuit and the ground. All of the circuit current must pass through the sample resistor, so the voltage across it divided by its value (measure R_{SAMPLE} before using it since it has a tolerance too) is the current through it, and therefore is the value of the current through the entire circuit. This is particularly handy when measuring the total current through a parallel circuit branch.

Lab Note 2: Remember Ohm's Law? Use it to show equivalence.

Ohm's law is very useful, especially in the case of AC circuits, when you want to demonstrate equivalence. R-L and R-C circuits will have a total impedance **Z_T** that has a **magnitude** and a **phase angle**. If 2 circuits are equivalent, they will necessarily have the same impedance between their terminals. That means that for any given applied voltage, (**e_1**) the same resulting current (**i_S**) will flow. Regardless of the circuit configuration between the two terminals, if the impedance is the same, the 2 circuits must be equivalent.

Series and Parallel Equivalent Circuits.

Team Name and Lab Section:..

Team Members Present (printed)

First Name, Last Name	**Role This Lab**	**RIT Program**

TEAM LABORATORY RESULTS GRADE

(all work done neatly, legible and properly organized, all signoffs in place, oscilloscope plots and annotations included, Table 1 and Question 1 completed, no missing or extraneous information)

Instructor signature, O'Scope prints (step 3) ________	/15
Oscilloscope plots, annotations and calculations	/10

Instructor signature, freq. change data (step 4) _______	/15
Table 1 (data, accuracy, units, proper format)	/10
Question 1 (restated, detailed answer, accurate, well thought out and articulated, WORD format)	/10

Final Team Grade	**/60**

Instructor comments: