Lab 5: AC Network Theorems

A. Objectives

- To investigate and verify Thevenin's Theorem and Superposition for AC circuits.

B. Background

Thevenin's theorem states that any two-terminal linear ac network can be replaced with an equivalent circuit consisting of a voltage source and an impedance in series.
Since the reactance of a circuit is frequency dependent, the Thévenin's circuit found for a particular network is applicable only at one frequency. If the Input signals frequency is changed while keeping the same amplitude, the E_{th} (Thevenin equivalent voltage) and Z_{th} (Thevenin equivalent impedance) of the Thévenin equivalent circuit will change.

Process of finding the Thevenin's equivalent circuits for an independent source:

1. Remove that portion of the network across which the Thévenin equivalent circuit is to be found.
2. Calculate Z_{Th} by first setting all voltage and current sources to zero (short circuit and open circuit, respectively) and then finding the resulting impedance between the two marked terminals.
3. Calculate E_{Th} by first replacing the voltage and current sources and then finding the open-circuit voltage between the marked terminals.

C. Apparatus

Components	Instruments
• Resistors: 1×1kΩ, 1×1.2kΩ, 1×2.2kΩ • Capacitors: 1×0.1µF • Variable Resistor: 1	• 1× Bread Board • 1× Function Generator • 1× Digital Multimeter • 1× Digital Storage Oscilloscope

D. Procedure

1. Measure the practical values of the resistors (R_1, R_2 and R_L) using the DMM and note down the values in Table 1.1. Use the measured values in all your calculations.
2. Measure the practical value of the capacitor (C) using an LCR meter and note down the value in Table 1.1.
3. Construct the circuit shown in Fig.B.1 on the bread board. Connect Channel 1 of the oscilloscope across the source VS (positive red port to node 'a' and negative black port to node '0' i.e. ground). Connect the channel 2 at node 'c' (positive red port to node 'b' and negative black port to node 0 i.e. ground).
4. To set 3V peak (6V peak to peak) and 1 KHz in the function generator, observe the generated signal on the oscilloscope screen (channel 1) and fine tune the amplitude & frequency of the input signal generated from the function generator to match the nominal values. Always set the amplitude after setting the frequency because changing the frequency of a non-ideal source might alter the amplitude.

5. Channel 2 of the Oscilloscope will show you the voltage drop across **RL**. From measurement, find out the peak voltage drop across **RL** ($V_{LOAD\ (ORIGINAL)}$) and record it in table 1.2.

6. Remove the load resistor (RL) from the circuit while keeping channel 2 of the oscilloscope connected (positive red port to node 'c' and negative black port to node '0' i.e. ground) to the circuit as shown in Fig. B.3.
7. From measurement (Vmax of CH-2), find out the peak value of the Thevenin's equivalent voltage ($E_{Thevenin}$) and note it down in the 'Measured' column of Table 1.3.

8. Now, construct the circuit shown in Fig.B.4. Here, Rs represents the internal impedance of the original source and R3 is a sense resistor. Use the Function Generator as VS2.
9. Use the oscilloscope to measure the magnitude and phase of V_{R3}. You can do this by connecting channel 2 at node 'c' and channel 1 at node 's'. The peak voltage in channel 2 is the magnitude of V_{R3} and the delay between the wave shapes in channel 1 and channel 2 can be used to calculate the phase. Calculate I_{R3}.

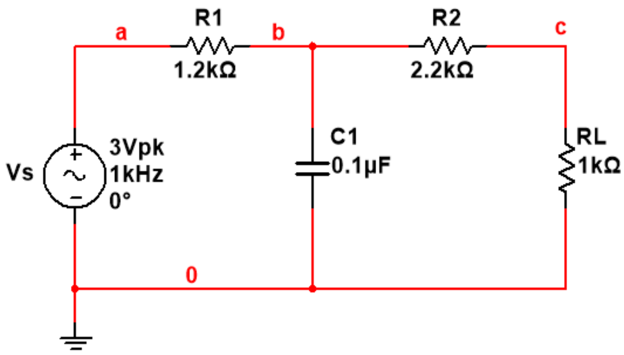

Fig.B.1: Original circuit

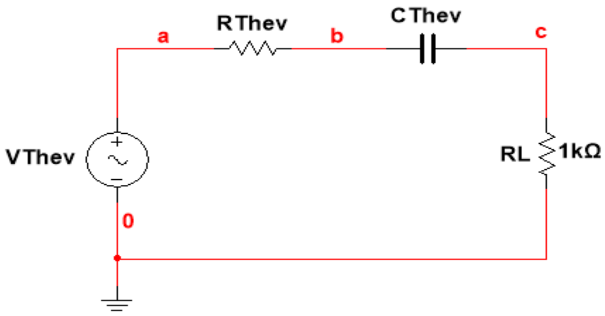

Fig.B.2: Thevenin's Equivalent circuit

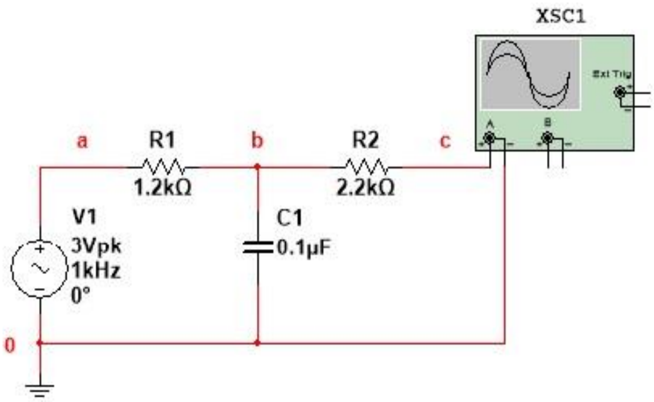

Fig.B.3: Measuring V_{Thev}

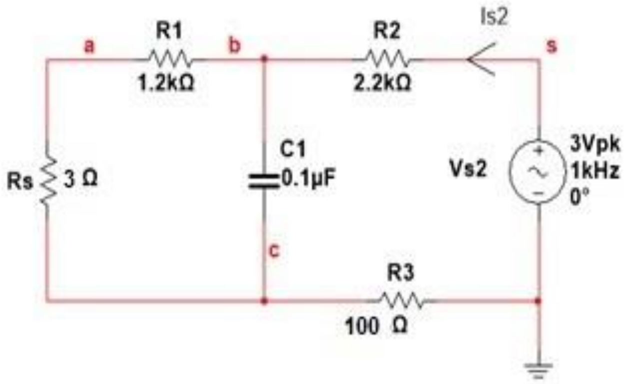

Fig.B.4: Measuring Z_{Thev}

10. Since I_{S2} and I_{R3} are equal, V_{S2} and I_{R3} can be used to calculate the total impedance on the circuit. This is the practical value of the Thevenin's equivalent impedance ($Z_{Thevenin}$). Note it down in the 'Measured' column of **Table 1.3**.

11. Construct the Thevenin's equivalent circuit in **Fig.B.2** using the $E_{Thevenin}$ and $Z_{Thevenin}$ values that you obtained in the previous steps.
12. Now, measure the load voltage from the Thevenin's equivalent circuit and note it down in **Table 1.2**.

F.2 Simulation

1. Construct the original circuit in Fig.B.1 in Multisim and use a DMM to show the RMS value of V_L.
2. Now, construct the Thevenin's equivalent circuit using the E_{Thev} and Z_{Thev} values you obtained from your experiment and again use a DMM to show the RMS value of V_L.
3. Attach the screen-shots of the circuit and DMM readings with your report.

G.2 Questions

1. What extra components did you need to construct the Thevenin's equivalent circuit? Did you face any difficulty constructing the circuit in the lab? If so, how were those issues resolved?
2. Why was an oscilloscope used to measure the values required to calculate $Z_{Thevenin}$ instead of a DMM?
3. Would the procedure used to determine the Thevenin's equivalent circuit change if the capacitor in the original circuit was replaced with an inductor?
4. Do the practical readings you obtained confirm the theoretical values? If any of the percentage differences are above 10%, suggest 3 possible reasons for the discrepancy.
5. Can a Norton's equivalent circuit be derived from the Thevenin's equivalent circuit? If so, convert the Thevenin's equivalent circuit of this experiment into a Norton's equivalent circuit. Finally, justify your answer.

E.1 Data Sheet: Lab 5, Experiment 1

Date:	Points:
Remarks:	

Signature of the Instructor

Student Information

Section:	Group:	Status:

E.1.1 Table 1.1: Component Values

R_1 (measured)(Ω)	**R_2 (measured)**(Ω)	**R_L (measured)**(Ω)	**C_1 (measured)**(F)	**X_C (Theory)** [$\frac{1}{2\pi f C}$] (Ω)

E.1.2 Table 1.2: Load Voltage comparison

(a) V_{Load} Theory (V)	(b) V_{Load} (measured) Original (V)	(c) V_{Load} (measured) Thevenin (V)	**% Deviation (Theory - Original)** [$\frac{a-b}{a} \times 100$]	**% Deviation (Original – Thevenin)** [$\frac{b-c}{b} \times 100$]

E.1.4 Table 1.3: Thevenin Voltage and Impedance Comparision

	(a) Theoretical	**(b) Measured**	**% Deviation** [$\frac{a-b}{a} \times 100$]
$Z_{Thevenin}$ (Ω)			
$E_{Thevenin}$ (V)			

E.1.3 Box 2.1: $E_{Thevenin}$ and $Z_{Thevenin}$ calculations