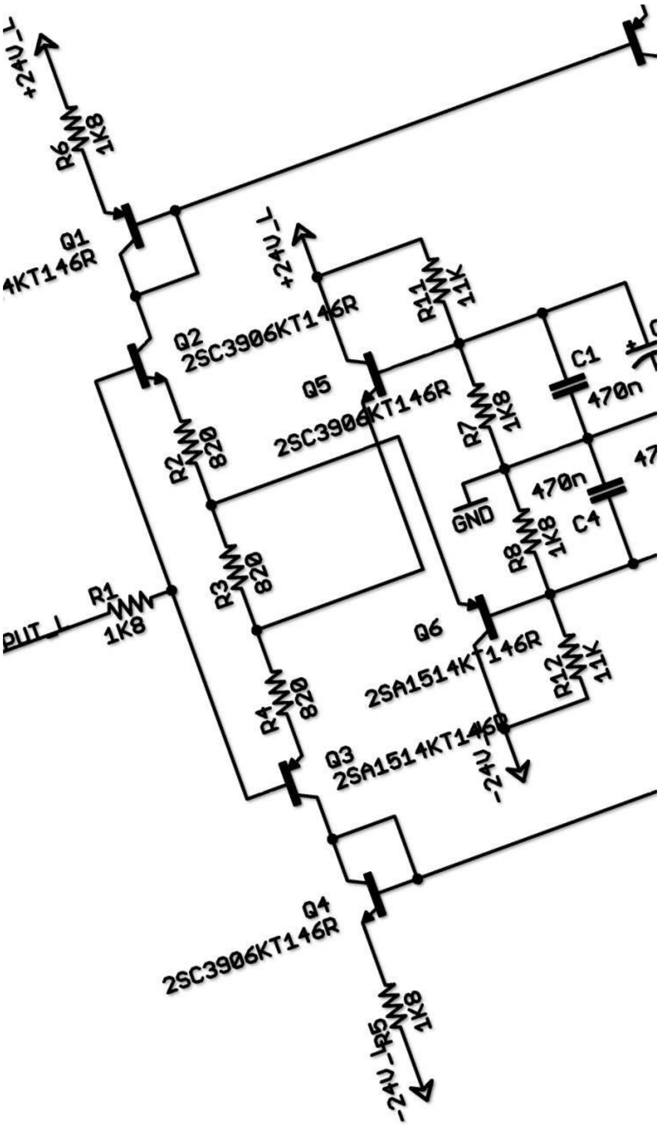
k MONASH University
Engineering

ECE2131

Electrical Circuits

Laboratory Notes



2022 Edition

Name:	Student ID:	Email:

Electrical and Computer Systems Engineering, Monash University

2022

5 Network Theorems

5.1 Learning Objectives and Introduction

This experiment provides experimental verification of Norton and Thévenin equivalent circuits. This also provides you with some understanding as to how to use an equivalent circuit, and why that might be preferable to fully understanding the internal layouts of complex circuits (e.g. signal generators, oscilloscopes, general test and measurement equipment, …).

By the end of this lab you should:

- Understand how equivalent circuits can be included in larger overall circuits
- Generate equivalent circuits for both circuit designs and test equipment attached to them
- Predict the effects of connecting test equipment to circuits by analysing their equivalent circuits

5.1.1 Thévenin's Theorem

This experiment is restricted to circuits and networks operating under sinusoidal steady-state conditions. Under these conditions, consider a linear network N (as shown in Figure S5.1) connected toan arbitrary (not necessarily linear) load between A and B. Further assume that the only interaction between N and the load is via the terminals A and B (this means for example there is no magnetic coupling between N and the load).

Thévenin's theorem then states that:

The terminal current and voltage will be unchanged if N is replaced by its Thévenin equivalent circuit, consisting of an impedance Z_{eq} (the equivalent impedance) in series with a voltage source V_{oc} (the opencircuit voltage).

In particular, the short-circuit current, I_{sc}, of the equivalent circuit and hence of N is given by V_{oc}/Z_{eq}. The equivalent circuit can be found experimentally or theoretically from any two of V_{oc}, Z_{eq} and I_{sc}. Four methods of varying practicality can be distinguished.

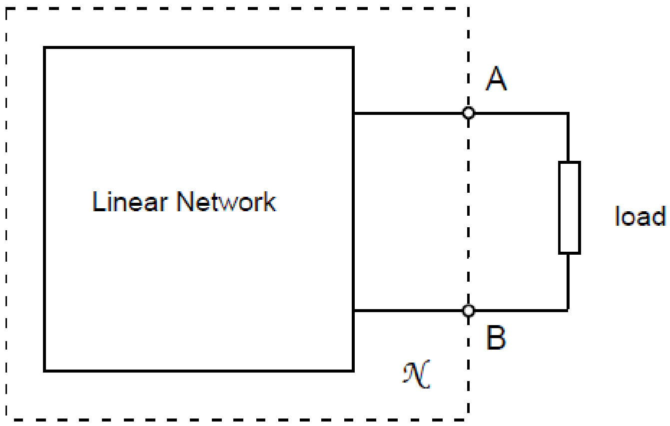


Figure S5.1 Network connected to a load

5.1.2 FINDING THE THÉVENIN'S EQUIVALENT CIRCUIT

Possible methods of measuring the equivalent circuit for network N:

1 Measurement of V_{oc} and output impedance with the sources turned to zero output.

This requires application of an externally applied voltage to measure Z_{eq}. Under laboratory condition, direct measurement of Z_{eq} is not practical because not all generators are capable of safely and linearly "sinking" current, and because turning a generator off may make its impedance totally undefined, due to the internal circuitry of the generator.

2 Measurement of open circuit voltage and short circuit current

This also needs to be applied with extreme care as a short circuit load may damage the equipment, or more likely cause it to reach some overload condition, in which case the network is no longer linear.

3 Apply two different loads to N and in each case measure the voltage across and the current flowing through the load.

If the loads are known impedances, it is sufficient to measure either the voltage or the current. The parameters can be found by solving the simultaneous equations that result.

4 <u>Half voltage method</u>

If Z_{eq} is known to be resistive, we can (a) measure the open circuit voltage and (b) connect a resistive load and reduce the load resistance until the voltage is half its open circuit value. That resistance is equal to Z_{eq} (to be proven in Question 1 of Preliminary Work).

5.1.3 NORTON'S THEOREM

Norton's theorem states that:

A linear network can be represented by a parallel combination of a current generator equal to I_{sc} and the Thévenin equivalent impedance Z_{eq}.

5.2 EQUIPMENT AND COMPONENTS

The components required for this laboratory are:

- Breadboard
- Resistors: 2x 100 Ω
- Capacitors: 2.2 μF
- 1k Ω potentiometer

5.3 EXPERIMENTAL WORK

To illustrate Thévenin's theorem, the circuit in Figure S5.2 is tested in this experiment.

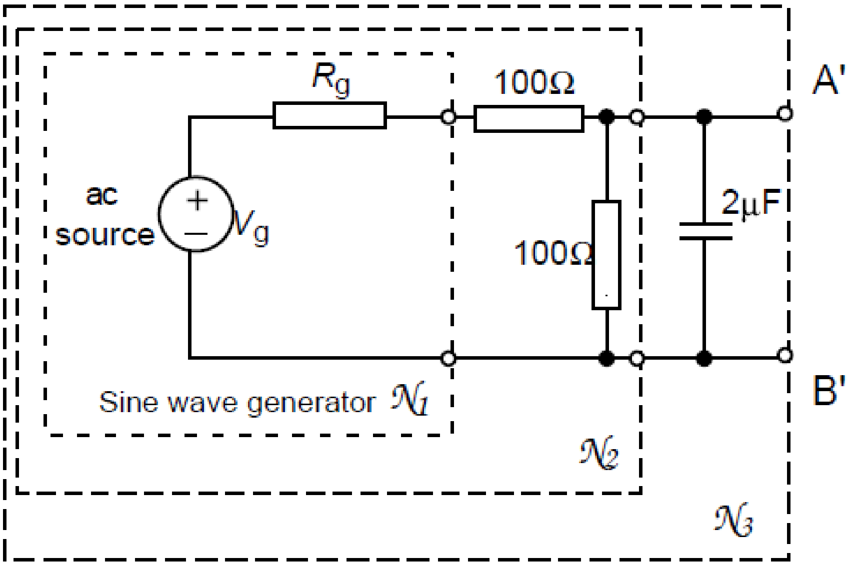


Figure S5.2 Networks under tests

Use the provided components to construct the networks, first N_1, and then N_2. You will first study N_1 and then in the later part of this laboratory you will add resistors to construct N_2, and calculate and measure the Thévenin equivalent of N_2. Finally, a capacitor will be added to construct N_3. The Norton equivalent of this circuit is also then considered.

5.3.1 EQUIVALENT CIRCUIT OF THE SINE WAVE GENERATOR (N_1)

Determine R_g. Set your signal generator to sine wave with an output voltage level of 5.0 V (pp) at an operating frequency of 1.0 kHz. R_g is the internal resistance of the source (signal generator). It is **NOT** a component to connect in your breadboard. In LTSpice, set the voltage series resistance (Rser) to 50Ω.

5.3.1.1 Use a potentiometer as load, and use voltage divider rule to determine R_g. This method is most accurate when the potentiometer is adjusted until the voltage is half of the input. What is the value of R_g?

5.3.1.2 What happens when you change between high Z and 50 Ohms (this only applies to the desktop oscilloscope equipment in the laboratory)? What happens to the value the signal generator displays?

You are allowed to ignore this question. If you are interested, we can do this in the laboratory during your lab assessment.

To understand more about the high-Z and 50 Ohms settings in an oscilloscope, you should watch: https://www.youtube.com/watch?v=fOJ1aExSkhw

*Don't forget to delete all red text boxes like this from your lab report.

5.3.1.3 How would you prove that the internal impedance of the generator is a linear and constant resistance? Is the internal impedance of the generator linear and constant?

Explain your method, and do it with your circuit.
Hints: it's mostly about changing the input settings, as well as changing the output load. But what settings?

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

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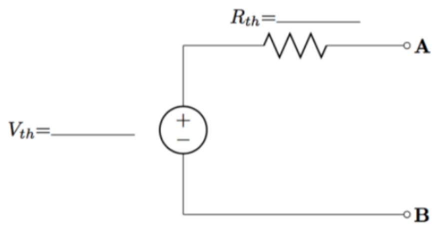
5.3.2 THÉVENIN'S EQUIVALENT NETWORK OF N_2

Construct the network N_2 two 100Ω resistors and a signal generator as shown in Figure S4.2. Write the theoretical values in the diagram on the left in the box below and use the space to write your workings. Measure the Thévenin open-circuit voltage of N_2 at the open terminals (the resistors are part of the Thevenin circuit, do not remove them). Write your measurements in the space on the right in the box below. Compare your experimental measurements with the theoretical values. Comment on any discrepancies/similarities.

Theoretical values in the circuit diagram. Show working below.

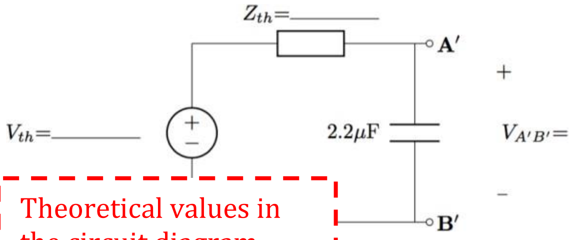


Write your measurements here, as well as explain your comparison and write comments here.

5.3.3 APPLICATION OF THÉVENIN'S THEOREM

Connect a 2.2 µF capacitor as the load for the N_2 Thevenin circuit. Measure $V_{A'B'}$.

<u>Write</u> the values of the Thévenin equivalent circuit of N_3 into the diagram below. <u>Compare</u> the theoretical Thevenin open-circuit voltage of N_3 in the diagram below, against the measured $V_{A'B'}$ from the previous question. <u>Explain</u> any discrepancies/similarities.



Theoretical values in the circuit diagram. Show working as well.

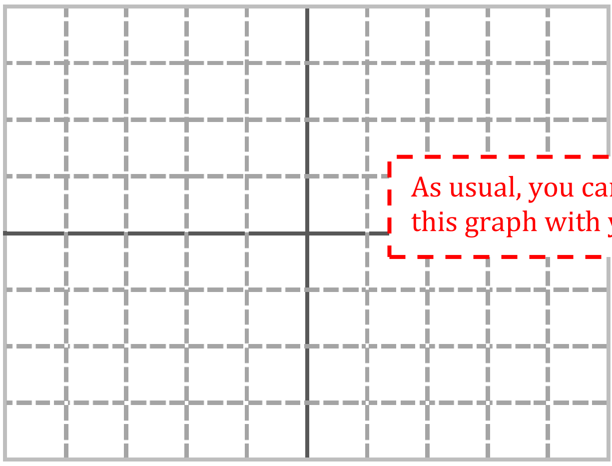
Write your measurements here, as well as explain your comparison and write comments here.

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

5.3.4 NON-SINUSOIDAL SOURCE

Suppose that the signal generator (source of the circuit) is non-sinusoidal, for example a square wave. What do you <u>expect</u> the output to look like?

Test your conclusion experimentally by switching the output of the generator to a square wave anduse an oscilloscope to examine the voltage waveform across $V_{A'B'}$. <u>Sketch</u> the output waveform below.



As usual, you can replace this graph with your image.

Comment and explain on your observation. Are you able to obtain this using AC analysis? Why/ why not?

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

5.3.5 NORTON'S THEOREM

Calculate the theoretical Norton equivalent of N_2 starting from the Thévenin equivalent circuit you found in 5.3.2.

Now calculate the Norton equivalent circuit of the network N_3.

Consider connecting a new load to N_3. Find the load impedance required to produce the maximum output power (remember that you can look up appropriate formula from lectures or the internet if required). What values of resistance and capacitance/inductance would need to construct this load?

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

For your lab assessment, you will be given a random load to connect to a Thevenin circuit. Use this space below to draw the circuit and write the theoretical values. You should also show your working to obtain these theoretical values. Use the space below also to write all measured experimental values. Comment on any discrepancies/similarities between theoretical and experimental values.

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: ________