NETWORK MEASUREMENTS

1. EXPERIMENT AIMS

- To determine experimentally the Thévenin and Norton equivalent circuit of a “Black Box” network consisting of resistive elements and a voltage source.
- To determine the value of the load resistance connected across the two terminals of the “Black Box” such that maximum power is transferred from the network to the load.
- To make measurements upon circuits to determine certain network parameters.

2. LEARNING OBJECTIVES

- To understand the behaviour of given circuits and explain their outputs.
- To understand the Thévenin and Norton principles, the principle of maximum power transfer and their implications for practical systems.

3. EQUIPMENT

- Signal Generator
- Oscilloscope
- DC Power Supply
- Multimeter
- Locktronics Experiment Board
- Thevenin Circuits for Network Theorems ‘Black Box’
- 10kΩ Variable Resistor
- 1kΩ, 5kΩ, 10kΩ Resistors
- 0.01μF Capacitor

4. PREPARATION

Before coming to the laboratory you should:

- Read and understand the experiment. You may need to revise some of your lecture material or do some extra reading to make sure you understand the experiment. You may be quizzed on your knowledge.
- Begin the write-up in your laboratory book. You should prepare the title, date, experiment-number, aims, apparatus and any special notes on method.

5.1 THÉVENIN AND NORTON EQUIVALENT CIRCUITS

5.1.1 THEORY

A valuable method of representing active networks by simpler equivalent circuits is described in the statement of **Thévenin’s Theorem**:

“Any linear resistive two terminal circuit is equivalent to an ideal voltage source V_{th} in series with a resistance R_{th}, where V_{th} is open-circuit voltage at the two terminals and R_{th} is the ratio of open-circuit voltage to the short-circuit current (I_{sc}) at the terminals".

An alternative proposition to Thévenin is described by the following statement, called **Norton's Theorem**:

"Any linear resistive two terminal circuit is equivalent to a parallel combination of an ideal current source I_n and a resistance R_n, where I_n is the short-circuit current at the terminals and R_n is the ratio of the open-circuit voltage to the short-circuit current".

These theorems are both shown in Figure 1.

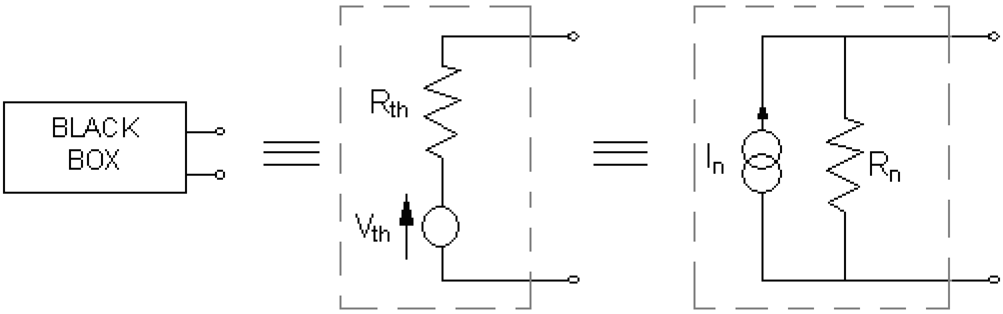


Figure 1. Thévenin and Norton circuit theorem representations

Hence,

$$R_{th} = \frac{V_{th}}{I_{sc}} = \frac{V_{th}}{I_n} = R_n$$
$$V_{th} = R_{th} \cdot I_{sc} = R_n \cdot I_n \qquad (1)$$

5.1.2 PROCEDURE

Without looking at the reverse of the Thevenin circuit, construct the circuit shown in Figure 2. Use a 15 V_{DC} supply to excite the circuit. What would you consider to be a "Black Box"?

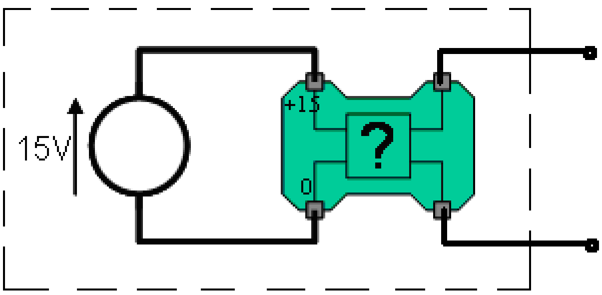
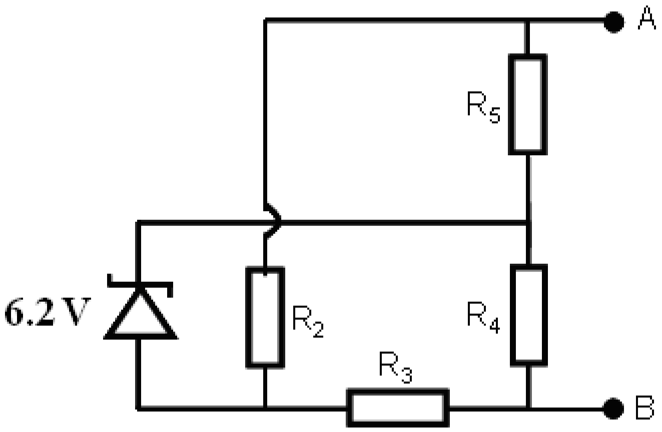


Figure 2. "Black box" circuit

The parameter V_{th} is determined by measuring the open circuit voltage at the two "output" terminals of the "Black Box" circuit, whilst R_{th} can be determined by measuring the short circuit current.

Do measurements for the values of 12 V_{DC} and 18 V_{DC} of the excitation voltages.

Turn over the Thevenin circuit component and draw a schematic diagram representation.



R_2 = Ω

R_3 = 2700 Ω

R_4 = Ω

R_5 = 3300 Ω

Figure 3. "Black box" circuit schematics

Is Figure 3 similar to what you have drawn? If not, briefly explain why not. Do you recognise all components in the circuit? Identify the values for components R_2 and R_4 ? Can you calculate Thevenin voltage V_{th} and Thevenin resistance R_{th} of this circuit?

Provide a Quick Summary of your findings.

5.2 MAXIMUM POWER TRANSFER

5.2.1 THEORY

Before doing this experiment think on what do you expect the Maximum Power Transfer would be for the Black Box.

5.2.2 PROCEDURE

Connect a 10KΩ variable resistor across the output of the "Black Box" and measure the current through and the voltage across the resistor. Vary the resistance and record the current and voltage as a function of the resistance. A graduated scale on the variable resistor can be used to approximate the value of the resistance only. Use your current and voltage measurements to plot a Figure of power dissipated in the real resistance versus real resistance.

From the plotted Figure determine the value of resistance that provides for maximum power transfer. What is the maximum power that is transferred?

Provide a Quick Summary of your findings.

5.3 CIRCUIT TIME CONSTANT

5.3.1 THEORY

Relatively simple circuits containing R and C or L elements (as shown in Figure 4) can be represented by one value only the Time Constant. The time constant of a circuit is often given the symbol τ and has the units of seconds. For an RC circuit, as in Figure 4:

$$\tau = RC \qquad (seconds) \qquad (2)$$

The voltage across the capacitor (V_C) in such RC circuit, when a positive input step of V volts is applied is given in Figure 5. The current in the circuit is also shown, which has a maximum value as predicted by Ohms Law (viz. V / R).

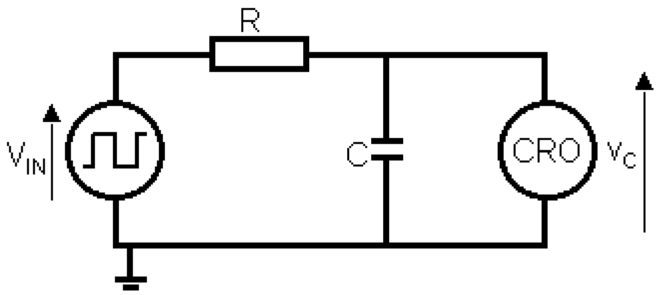


Figure 4. Typical RC circuit

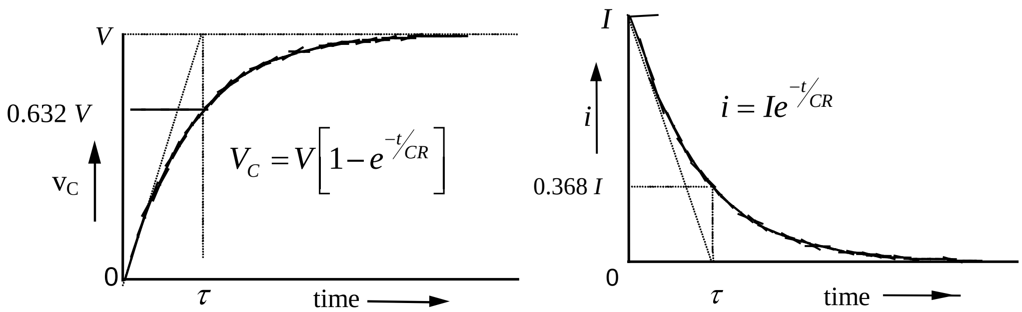


Figure 5. Typical RC circuit response for a step input excitation

5.3.2 PROCEDURE

Construct the circuit of Figure 4 with R = 10KΩ and C = 0.01μF. Set the signal generator to output a 1KHz, $1V_{PP}$ squarewave. Carefully draw the transient response across V_C for one cycle and identify the circuit time constant from your Figure. How this signal is related to a squarewave input V_{IN}?

Change R to 1KΩ and identify the circuit time constant for this case as well.

Finally, swap the positions of R = 10KΩ and C = 0.01μF in the circuit in Figure 4 and draw the waveform of the transient voltage, V_R, across the resistor.

Provide a Quick Summary of your findings.

6. DISCUSSION TO DO NOW AND FOR THE LONG REPORT

The following points should be discussed in groups and with the lecturer at the end of the lab after your experimental work is finished:

6.1 DISCUSSION OF SUBEXPERIMENT 1

Does varying the DC supply have an effect upon the measurements you make, and if not then why not? What component on the underside of the "Black Box" is different from the others? What is its function?

Derive the Thévenin equivalent (both V_{th} and R_{th}) for this circuit using Ohm's law and compare with your measured results (*you must do that for the Long Report*).

Sketch the characteristic of a component that is different from the others and identify its operating point upon its characteristic (*you must do that for the Long Report*).

6.2 DISCUSSION OF SUBEXPERIMENT 2

How do the value of resistance that provides for maximum power transfer and the maximum power that is transferred relate to your theoretical values? Comment upon any deviation.

Batteries can be modelled as a Thévenin or a Norton circuit. Given this, then what property of the battery limits the maximum power it can deliver into a load?

Derive mathematically the expression for maximum power transfer (*you must do that for the Long Report*).

6.3 DISCUSSION OF SUBEXPERIMENT 3

How do the predicted from theory and measured from Figures time constants for both compared? Does its value lie within your predicted error? How does the value of resistance influence time constants?

Explain the difference in the output signal compared with your input signal for RC and swapped CR circuits.

Why have you been asked to swap the circuit components (why not just measure the voltage across the resistor when the circuit was in its original configuration)? (*you must answer that for the Long Report*)

6.4 DISCUSSION FOR THE LONG REPORT

To the Discussion Section of the Long Report describe a typical application of each of the circuits you have investigated. For a Long Report always think what should be included into the theory section. Perhaps some derivations of formulas? Some theoretical Figures? Comparison of theoretical curves with the measured curves on the same Figure?