# Lab 2- Thévenin and Norton Equivalent Circuits

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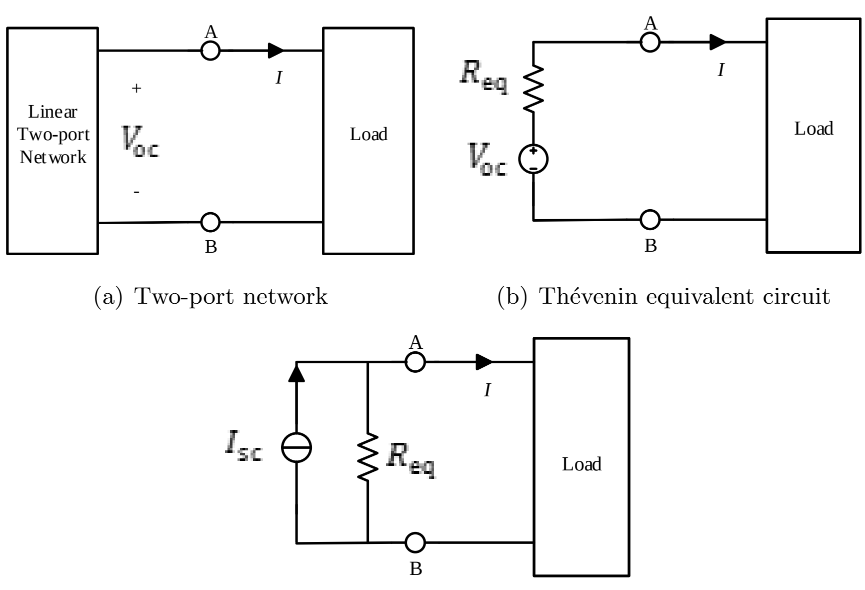
## 1 Goals

- Verifying Thévenin and Norton equivalent circuits
- Verifying the maximum power transfer principle.
- Implementing the circuits in an experimental setting, taking measurements, and comparing with theoretical results.

## 2 Review of Theory

1. Thévenin equivalent circuit: A powered linear two-port network can be equivalently modeled as a serial connection of a voltage source $V_{oc}$ and a resistor $R_{eq}$.




(a) Two-port network (b) Thévenin equivalent circuit

(c) Norton equivalent circuit

Figure 1

The equivalence is in the sense that, given any load connected to the two-port network, the voltage across and the current flowing through the load are unchanged when the two-port network is replaced by the equivalent circuit.

The voltage $V_{oc}$ can be obtained by measuring the open circuit voltage across the two output ports. The value of $R_{eq}$ can be obtained by first measuring the short-circuit current at the output ports followed by dividing $V_{oc}$ by the measured short-circuit current value.

2. Norton equivalent circuit: A linear two-port network with energy source can be equivalently modeled as a parallel connection of a current source $I_{sc}$ and the resistor $R_{eq}$.

   The current $I_{sc}$ can be obtained by measuring the short-circuit current at the output ports or simply obtained by $V_{oc}/R_{eq}$ from the Thévenin equivalent circuit.

3. Maximum power transfer principle: For a powered linear two-port network, the load connected to the output ports receives power. When the load resistance is equal to the equivalent resistance $R_{eq}$, the load receives the maximum power that the two-port network can provide.

# 3 Apparatus

1. DC power supply
2. Multimeter
3. Resistors (300Ω× 2, 1kΩ, 200Ω, 510Ω)
4. Resistor box × 2
5. Breadboard
6. Wires

# 4 Tips

- Always turn the power supply off whenever you change the circuit diagram or when you use multimeter to measure line currents.
- Note that the power supply works as a voltage source when the connected load has a resistance value larger than the critical impedance of the power supply (which is the ratio of the voltage value ('CV') and the current value ('CC') set in the power supply), otherwise the power supply works as a current source.

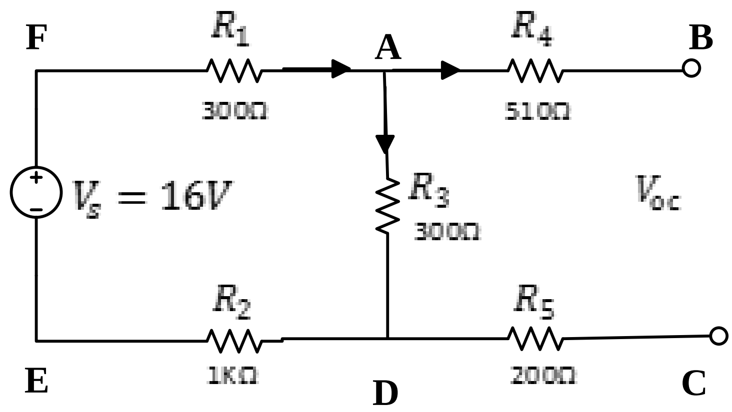



Figure 2: Original circuit setup.

# 5 Experiment 1: Thévenin equivalent circuit

S1. Build the circuit in Figure 2 on the breadboard. Set the voltage value of $S_1$ to 16V.

S2. Analyze the theoretical values of $V_{oc}$, $I_{sc}$ (the short-circuit current between points B and C) and $R_{eq}$. Put the results in Table 1.

**Table 1**

| Theoretical $V_{oc}$ | Theoretical $I_{sc}$ | Theoretical $R_{eq}$ |
|---|---|---|
| | | |

S3. Use the multimeter to measure $V_{oc}$ and $I_{sc}$, and then compute $R_{eq}$. (Note: To measure $I_{sc}$, first turn off $S_1$, short circuit the output port, and then turn on $S_1$ to 16V.) Put the results in Table 2.

**Table 2**

| Experimental $V_{oc}$ | Experimental $I_{sc}$ | Experimental $R_{eq}$ |
|---|---|---|
| | | |

S4. Connect the resistor box (with resistance $R_L$) to the output port, and measure the voltage across and current flowing through the resistor box when $R_L$ are respectively set to the values in Table 3. Write the measured results in Table 3.

**Table 3**

| $R_L$ $(\Omega)$ | 0 | 400 | 800 | 1200 | 1600 | 2000 | 2400 | 2800 | $\infty$ |
|---|---|---|---|---|---|---|---|---|---|
| $V_L$ | | | | | | | | | |
| $I_L$ | | | | | | | | | |

S5. Use the voltage source and resistor box to build the Thévenin equivalent circuit in Figure 3. Set the values of $V_{oc}$ and $R_{eq}$ according to Table 2.

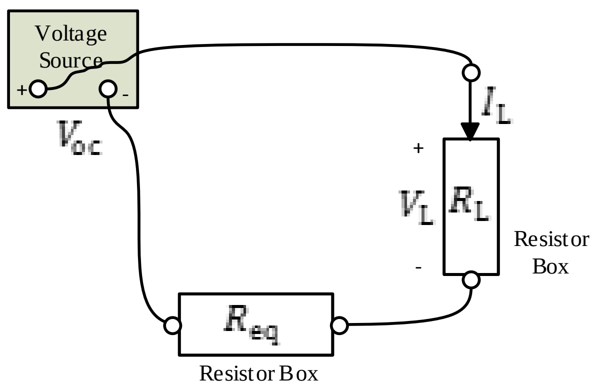



Figure 3: Equivalent circuit setup.

Repeat S4 and put the results in Table 4.

**Table 4**

| $R_L$ $(\Omega)$ | 0 | 400 | 800 | 1200 | 1600 | 2000 | 2400 | 2800 | $\infty$ |
|---|---|---|---|---|---|---|---|---|---|
| $V_L$ | | | | | | | | | |
| $I_L$ | | | | | | | | | |

S6. Discussion

## 6 Experiment 2: Norton equivalent circuit

S1. Based on Table 2, calculate the values of $I_{sc}$ of the Norton equivalent circuit of Figure 2. Use the current source and resistor box to build the Norton equivalent circuit in Figure 4, and set $I_{sc}$ and $R_{eq}$ in accordance with Table 2.

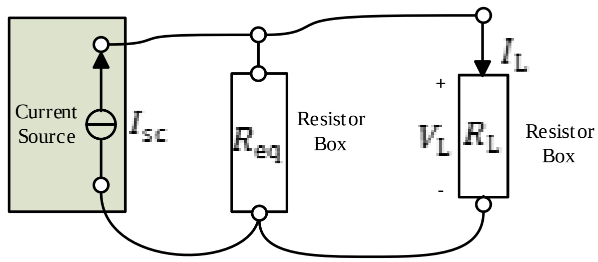



Figure 4: Equivalent circuit setup.

Repeat S4 in Experiment 1 and put the results in Table 5.

**Table 5**

| $R_L$ ($\Omega$) | 0 | 400 | 800 | 1200 | 1600 | 2000 | 2400 | 2800 | $\infty$ |
|---|---|---|---|---|---|---|---|---|---|
| $V_L$ | | | | | | | | | |
| $I_L$ | | | | | | | | | |

S2. Discussion

# 7 Experiment 3: Maximum power transfer principle

S1. Use the voltage source and resistor box to build the Thévenin equivalent circuit in Figure 3, and set $V_{oc}$ and $R_{eq}$ according to Table 2 (i.e., S5 in Experiment 1).

S2. Connect the resistor box (with resistance $R_L$) to the output port. Let $R_L = R_{eq} + \triangle R$. Following the values of $\triangle R$ in Table 6, measure the voltage across and current flowing through the resistor box. Calculate the corresponding power values. Summarize the results in Table 6.

**Table 6**

| $\triangle R$ ($\Omega$) | $-R_{eq}$ | -350 | -150 | -50 | 0 | 50 | 150 | 350 | $\infty$ |
|---|---|---|---|---|---|---|---|---|---|
| $V_L$ | | | | | | | | | |
| $I_L$ | | | | | | | | | |
| $P_L$ | | | | | | | | | |

S3. Discussion