

NORTHWESTERN UNIVERSITY
Department of Electrical and Computer Engineering
ECE-221 Fundamentals of Circuits

Lab 2: Thévenin's / Norton's Theorem and Kirchhoff's Laws

1: Theory

The purpose of this experiment is to investigate several fundamental principles in circuit theory. Thévenin's theorem tells us that for any linear network containing resistors, dependent and independent sources, there is an equivalent network, which is the series combination of an independent voltage source and a resistor. Norton's theorem defines another equivalent circuit, which is the parallel combination of an independent current source and a resistor. Kirchhoff's Laws tell us that the sum of all voltages around a loop and the sum of all currents flowing into or out of a node must be zero. If any of these concepts are not clear to you, consult your textbook for more information.

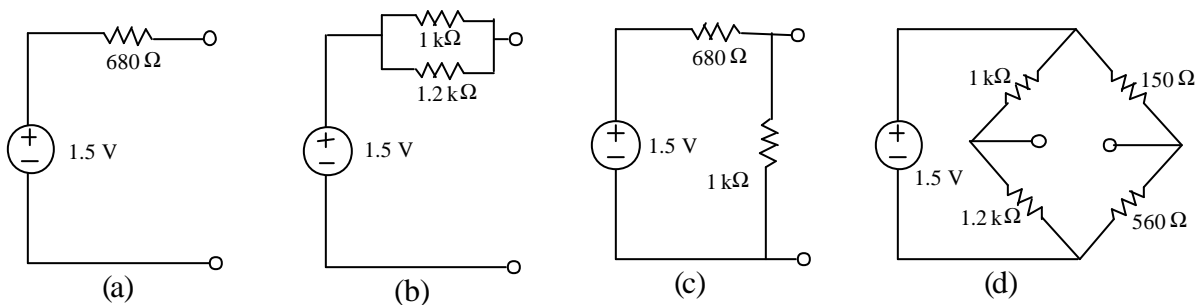


Figure 1

Report 1.1 Determine the Thévenin's and Norton equivalents of each of the circuits in Fig. 1.

2: Procedure

Thévenin's and Norton's Theorem

Now we are ready to experimentally determine the Thévenin and Norton equivalents of each of the circuits in Fig. 1. Although we would like to make these measurements using an ideal voltmeter and an ideal ammeter, since such things do not exist in real life, we will have to settle for the HP Data Acquisition Unit (DAU) which you have familiarized yourselves in the first lab.

Report 2.1: What is an ideal voltmeter? What is an ideal ammeter?

Report 2.2: To find the internal resistance of the DAU when measuring currents, first set the DAU to measure current. Build the circuit in Fig. 2, and then use the oscilloscope to measure the voltage across the DAU connections. Finally divide this voltage by the measured current. Record this value. Do you think this resistance will cause a significant error for our experiment?

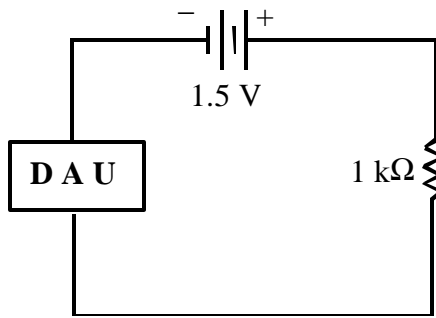


Figure 2

$I =$

$V =$

$R = V/I =$

Procedure: Now, construct each of the circuits in Fig. 1. Use the +6-volt output of the power supply, fixed resistors, and the breadboard provided. Review Lab 1 for operation procedures of the DAU unit, the oscilloscope, and the power supply. Measure V_{oc} by connecting the DAU probes across the indicated terminals, and then measure I_{sc} by connecting the DAU probes between those terminals. Record the measured values for all 4 circuits.

Report 2.3 Make a table comparing the theoretical and measured values of V_{oc} and I_{sc} for each of the circuits in Fig. 1, as well as the resulting percent error. List everything you can think of that might be a source of error in your measurements.

The power supply is not an ideal voltage source; therefore we wish to experimentally determine Thévenin and Norton equivalents of this source. However, if we simply attach the DAU across its terminals, enough current will be generated to damage both the power supply and the DAU. Therefore, we will make use of a circuit whose voltage-current relationship is linear to determine I_{sc} as follows:

Procedure: Make the +6-volt output terminal of the power supply to output +1.5 volts. Now connect a decade resistor across the terminals of the power supply. Use the oscilloscope to measure the voltage drop across the resistor, and compute the current flowing through it. Set the decade box to each of the values given in the worksheet table 2.5, measure the voltage across it, and compute the resulting current.

Report 2.4: What is an ideal voltage source?

Report 2.5: Make a table of measured voltages, resistances used, and computed currents. Plot (by hand) this set of data on a graph with voltage on the vertical axis and currents on the horizontal. Connect the points with a straight line that also intersects both axes. If the points do not lie exactly on a straight line, make the best visual fit of the data that you can. Note that on this graph, V_{oc} represents that voltage when there is

no current flowing in the circuit (i.e., open circuit) or the V-axis intercept. Similarly, I_{sc} is represented by the I-axis intercept. Use Ohm's Law to compute R_{eq} from the measured value of V_{oc} and the value of I_{sc} obtained from your graph. Finally, indicate these values on the circuit diagram of the Thévenin and Norton equivalent of the power supply.

Kirchhoff's Law

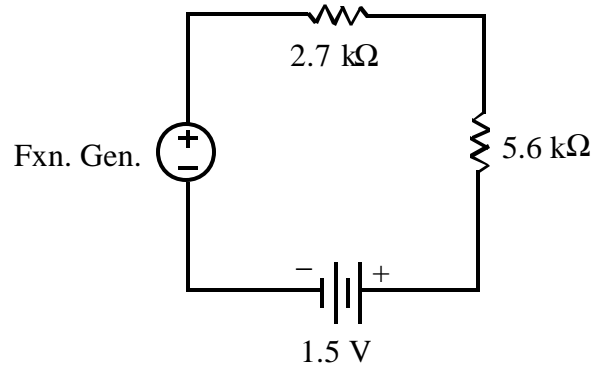


Figure 3

Procedure: Set the function generator to output an 8 V peak-to-peak (4 V amplitude) sine wave of 100 Hz. Use the scope to determine the maximum DC offset; record this value. Connect this source to the circuit of Fig. 3. Use the power supply, fixed resistors, and the breadboard. Use the scope to measure the voltage across each component in the circuit, recording separately the DC component and the peak-to-peak magnitude of the AC component, if any.

Report 3.1: Compute separate sums for the measured DC and AC components. Do they add to zero, as predicted by KVL? Compute the theoretical values and then the percent error for each of these voltages you measured. Is the error significantly larger in any of the four components than in the others? State the possible sources of errors.

Report 3.2: Was the voltage across the power supply after connecting it to the circuit different from that which you set it initially? Can you explain the differences?

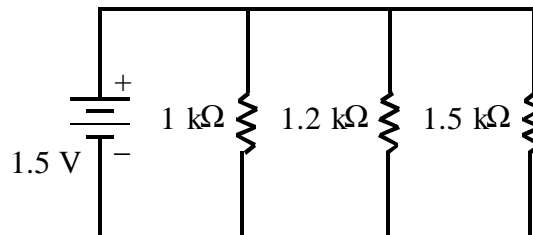


Figure 4

Procedure: Connect the circuit of Fig. 4, but leave the loop open for the moment by not connecting the negative terminal of the power supply. Set the DAU to measure current, and insert the probes of the DAU in series with the 1 kΩ resistor, connect the battery, and record the

current. Repeat this procedure with each of the other two resistors. Finally, connect the probes in series with the power supply and measure the current supplied to all three resistors.

Report 3.3: Compute the sum of the measured currents at the top node of the circuit. Do they add to zero as predicted by KCL? What are the possible sources of error associated with these measurements?