EXPERIMENT 3
EQUIVALENT SOURCES

I) Pre-lab Assignment

Read the following paragraphs about source resistance measurement.

Determining Output Resistance of a Source

Sources are most often modeled by their Thevenin equivalent network comprising a voltage source connected through a source resistance, $R_s$. Knowledge of the value of $R_s$ enables the prediction of the effect of various loads to be connected to the source. Several methods are available to measure $R_s$ in a working network, and five of them will be detailed.

1) **Ohmmeter measurement**

   In this method, all independent sources in the network are deactivated and an ohmmeter is connected across the output terminals to measure $R_s$. This method is often not practical such as when the source contains nonlinear devices with different characteristics between their on and off states.

2) **Voltage-probe method**

   This method is another implementation of the previous one. All independent sources inside the network are shut off and a voltage source, $V_p$, (often 1 V) is applied across the output terminals with the facility to measure the current, $I_p$, flowing into the output terminals of the network-under-test. The output source resistance can now be computed as $R_s = \frac{V_p}{I_p}$. This method has the same limitations as the ohmmeter measurement technique.

Unlike the first two, the last three methods enable the source to remain active during the measurement of $R_s$.

3) **Load extremes method**

   In this method the source network-under-test remains active while its load is changed between two states. First, the load is removed and the corresponding open-circuit voltage, $V_{oc}$, is measured. Next, the output terminals are shorted with an ammeter, and the short-circuit current, $I_{sc}$, is measured. The measured output resistance is
computed as $R_s = \frac{V_{oc}}{I_{sc}}$. Many sources cannot safely drive a short circuit, nor have vastly different output characteristics under such a high-current load. Hence, the load-extremes method cannot be applied in these cases.

4) **Matched load method**

In this method, the open-circuit voltage of the source is measured. Next, a variable load resistor is connected across the output and adjusted until the load voltage drops to exactly one-half $V_{oc}$. At this point, $R_s$ can be stated as equal to the load resistance setting, $R_L$.

5) **Generalized voltage drop method**

In some cases the source will not operate properly when the output voltage is loaded down as far as $V_{oc}/2$. In a more general test, the variable load resistor is adjusted for a load voltage $V_L < V_{oc}$. A voltage reduction factor, $\beta$, is computed as $\beta = \frac{V_L}{V_{oc}}$ where $0 < \beta < 1$. The measured equivalent source resistance can now be calculated from $R_s = \frac{1-\beta}{\beta} R_L$. For example, when the source is loaded to an output voltage of 75% below $V_{oc}$, then $R_s = \frac{R_L}{3}$.

II) **Laboratory experiments**

(a) **Source Characterization**

1) Obtain a resistor network box from the instructor.
2) Connect a 10-V source to the input terminals of the box.

3) Measure the open-circuit voltage ($V_{oc}$) and the short circuit current ($I_{sc}$) at the output of the box. Compute $R_s = V_{oc}/I_{sc}$.
4) Disconnect the voltage source and place a short circuit across the input terminals 1–4.
5) Use a multimeter to measure the resistance across output terminals 2–3 ($R_s$).
6) To show that the voltage probe method is equivalent, connect a 1-V source in series with an ammeter to the output terminals while leaving the input shorted. Measure the current $I_p$ flowing into the output. Compute $R_s$ as $1/I_p$.

7) In practice, there are often times that the engineer does not have the option of turning off the source when measuring its source resistance. In this case, one method of determining $R_s$ is to connect a load resistor to the source and adjust it until $V_L$ is $\frac{1}{2}V_{oc}$. Connect the 10-V source to the input terminals and the Decade Resistance box at your station to the output terminals. Then, vary the resistance to set $V_L = \frac{1}{2}V_{oc}$. Record the value on the Decade Resistance box as $R_L = R_s$.

8) Sometimes the source cannot be loaded down to half $V_{oc}$. As another method of measurement, adjust the Decade Resistance box so that $V_L = 0.8 V_{oc}$. Compute $R_s$ using the formula from method 5 above.

b) Maximum Power Transfer

1) Compute $R_s$ as the mean value of the five $R_s$ measurements made above and use the result to calculate the various load resistances in step 3 below.

2) Connect the 10-V source to terminals 1–4 and connect in series with an ammeter a Decade Resistance box to terminals 2–3 as the load resistor.

3) Set the decade resistance box in turn to each of the following values: $0.05R_s$, $0.1R_s$, $0.2R_s$, $0.5R_s$, $R_s$, $2R_s$, $5R_s$, $10R_s$, and $20R_s$. At each load resistance value, measure the load voltage, the load current and compute the power dissipated in the load. (Use the Hewlett-Packard multimeter to measure the current and the Fluke multimeter to simultaneously measure the voltage).

III) Lab Report

The lab report should be in standard format and include the following specific items:

1) Purpose
2) Model numbers of all test equipment used and the number of the resistor network box
3) Block diagrams of the test setups used
4) Test Procedure
5) Schematic drawings, with parameters given, of both Thevenin and Norton equivalent circuits for the resistor network box when connected to 10 V.
6) Comparison of the results of all five methods of determining $R_s$. Compute the mean value of measurements. Compute the deviation in % of each $R_s$ measurement from the measurement made with the multimeter in step 5) of the lab procedure.
7) Table of power measurements versus load resistor value from part b). Compare the maximum power in the table with the value of available power $P_{AV}$ computed from the parameters of the Thevenin model recorded in item (5) of this report.
8) Conclusions