The Breadboard; DC Power Supply; Resistance of Meters; Node Voltages and Equivalent Resistance; Thévenin Equivalent Circuit

Objectives: To correctly operate the DC power supply; to observe the effects of the internal resistances of an ammeter and a voltmeter on circuits; to account for differences between nominal and actual resistor values; to experimentally verify node voltages, to replace a resistor combination with its equivalent; to replace a circuit with its Thévenin equivalent circuit.

The DC Power Supply

The DC power supply can operate in 6V, +20V, -20V, or 20/-20 V modes.

- Turn on the power switch on the front of the instrument.
- To select 6V output mode depress the 6V button.
- To select 20V output mode depress the 20V button.
- To select -20V output mode depress the -20V button.
- To select 20/-20 V output mode depress the +20V button and turn the Tracking ratio dial clockwise until it clicks.
- In all modes the desired output voltage is selected by turning the 6V or +/- 20V dial.
- When in 20/-20 mode, the displayed voltage is available at the 20V output terminal and its negative is available at the -20V output.
- In all modes connect the red wire to the corresponding output terminal and THE BLACK WIRE TO THE “COM” OUTPUT TERMINAL.
Voltage Source

- Select the 6V mode on the DC power supply, and set the voltage to 5V.
- Connect a red wire to the +6V output terminal and a black wire to the COM output terminal.
- Now connect a resistor of around 800 Ω to the output. How much current is DC power supply measuring?
  \[ I_{\text{measured}} = \underline{\phantom{00000}} \]

- According to Ohm’s Law, what current should flow?
  \[ I_{\text{theory, ideal meter}} = \underline{\phantom{00000}} \]

- Explain briefly where this error is coming from.

**Resistance of Meters**

We will start by determining how “ideal” are the laboratory voltmeters and ammeters. This in turn should give us some idea how much effect these instruments are likely to have on our experiments. We will measure the resistance \( R_V \) of voltmeter and the resistance \( R_A \) of ammeter.

Figures below represent schematics of real voltmeter and ammeter.
Two diagrams below show circuits you will use for the measurements in this part of the lab. Have in mind real voltmeter and ammeter characteristics shown above.

Assume: \( R_{Vg} = 0 \, \Omega \) (not shown)
Recommended: \( R_1 = 10 \, \text{M}\Omega \)

Assume: \( R_{Vg} = 0 \, \Omega \) (not shown)
Recommended: \( R_1 = 1 \, \Omega \)
Recommended: \( R_g = 1 \, \text{k}\Omega \)

6. a) Re-draw previous circuits using schematics of real voltmeter and ammeter (showing internal resistances of both meters)

b) Calculate the voltmeter resistance from your experimental measurements:

\[ R_V \text{ (measured)} = \]__________

c) Calculate the ammeter resistance from you experimental measurements:

\[ R_A \text{ (measured)} = \]__________
7. a) For the circuit shown below, calculate $I$ by applying Ohm’s Law using the nominal, not measured, resistor value.

![Circuit Diagram]

$I_{\text{theory}} = \underline{\quad \quad \quad \quad}$

b) Build this circuit and then measure the current by inserting an ammeter.

$I_{\text{measured}} = \underline{\quad \quad \quad \quad}$

c) What is the percentage error of measured value compared to the theoretical?

$\% \text{ Error} = \underline{\quad \quad \quad \quad}$

d) Let’s explore two possible reasons for any error. Using the digital multimeter, measure the actual value of the resistor.

$R_{\text{measured}} = \underline{\quad \quad \quad \quad}$

e) What is the percentage difference in the resistor value as compared to the desired 5.1 $\Omega$?

$\% \text{ Difference} = \underline{\quad \quad \quad \quad}$

f) Now consider the effect of the ammeter resistance on the measured current. Taking into account the ammeter resistance and using the true resistor value, calculate the current that should flow.

$I_{\text{revised}} = \underline{\quad \quad \quad \quad}$

g) What is the percentage error in $I_{\text{measured}}$ as compared to $I_{\text{revised}}$?

$\% \text{ Error} = \underline{\quad \quad \quad \quad}$
8. a) Build the following circuit using resistors from the bins, of the nominal values shown. Before building the circuit, carefully measure the values of the resistors and enter these measured values into the blanks above the nominal values in the circuit diagram.

Using measured resistor values, calculate all node voltages using formulas from the PreLab. Calculate value of current $I$. Show your work below:

b) Calculated circuit variables using measured resistor values:

$$V_B = \text{__________} \quad V_C = \text{__________} \quad I = \text{__________}$$
Now measure the actual node voltages and current $I$.

c) Measured circuit variables:

\[
V_B = \underline{\text{__________}} \quad V_C = \underline{\text{__________}} \quad I = \underline{\text{__________}}
\]

d) How well (in terms of percent error) do your measured node voltages and current agree with your predicted node voltages calculated in part 8.b?

\[
V_B \ % \ Error = \underline{\text{__________}} \\
V_C \ % \ Error = \underline{\text{__________}} \\
I \ % \ Error = \underline{\text{__________}}
\]

Now that you have characterized the original circuit, you will replace some of the resistors with their equivalent and see how much the remaining circuit changes.

e) Calculate the equivalent resistance of the resistor combination inside the dotted box using their measured values. Show your work here

\[
R_e = \underline{\text{__________}}
\]

f) Finally, replace the combination of resistors inside the dashed box with one resistor whose measured value is as close to $R_e$ as possible. Theoretically, nothing to the left of the dotted line should change. However, because of the possible inaccuracy of our replacement resistor, small changes are not uncommon. Re-measure all the node voltages that still exist in the circuit and the current $I$.

Measured circuit variables with $R_e$ connected:

\[
V_B' = \underline{\text{__________}} \quad V_C' = \underline{\text{__________}} \quad I' = \underline{\text{__________}}
\]

g) How well do these measured values agree (in terms of percent error) with the values of $V_B$, $V_C$ and $I$ predicted in part 8.b?

\[
V_B \ % \ Error = \underline{\text{__________}} \\
V_C \ % \ Error = \underline{\text{__________}} \\
I \ % \ Error = \underline{\text{__________}}
\]
**Thévenin Equivalent Circuit**

9. The resistors in the dashed box have been replaced by their equivalent $R_e$ and we will now focus on the elements that were formerly outside the box. Enter the measured values into the blanks in the circuit diagram:

![Circuit Diagram]

a) Using measured values, calculate the Thévenin equivalent circuit of everything to the left of $R_e$. Show your calculations here:

$$V_{Th} = \text{__________} \quad R_{Th} = \text{__________}$$

b) Now get $V_{Th}$ and $R_{th}$ experimentally by measuring the open circuit voltage and short circuit current:

$$V_{oc} = \text{__________} \quad I_{sc} = \text{__________}$$

c) Use measured values from previous part to calculate Thévenin voltage and Thévenin resistance of the circuit. Show calculations here:

$$V_{Th} = \text{__________} \quad R_{Th} = \text{__________}$$
Enter the Thévenin equivalent values into the circuit below. Get an actual resistor for $R_{Th}$ from the bins, measure its value, and enter that into the circuit also. Enter the measured value of the $R_e$ that you are using:

![Circuit Diagram]

At this stage, you have replaced all the resistors in the original dashed box with their equivalent $R_e$, and you have replaced all of the circuit components outside the original dashed box with their Thévenin equivalent circuit.

d) Measure the only two remaining circuit variables from the original circuit.

**Measured values:**

\[ V_{C}'' = \_\_\_\_\_\_ \quad I'' = \_\_\_\_\_\_ \]

e) How well do these values agree (in terms of percent error) with the calculated $V_C$ and $I$ using the measured values of resistors (part 8.b of this Lab)?

\[ V_C \ \% \ \text{Error} = \_\_\_\_\_\_ \]

\[ I \ \% \ \text{Error} = \_\_\_\_\_\_ \]

Upon completion of this lab, obtain your GTA’s signature on the front page.
POSTLAB ASSIGNMENT:

10. Use Cadence to simulate circuit from part 8 of this Lab and calculate $V_B$, $V_C$ and $I$ using:
   a) Nominal values
   b) Measured values

   Include a printout of your circuit that shows node currents and voltages.