0. Laboratory preparation

Please prepare for this lab assignment by a careful reading of Chapter 4 of the text and a review of your lecture notes on superposition, Thevenin’s theorem, and maximum power transfer.

In this lab, you will investigate the most basic and important principles of linear system analysis, starting with superposition. Superposition governs all linear systems and enables the application of extremely powerful tools in signal analysis. In ECE, you will steadily encounter new ways to appreciate the importance of this vital principle. The assignment also directs attention to the maximum power transfer theorem and the important concept of Thevenin equivalents.

I. Superposition

In this first exercise you are to employ the two separately controllable, independent DC voltage sources in the voltage supplies found at your bench. The idea is to test the basic notion of superposition, namely that the net response of a linear system to multiple inputs always can be expressed as a simple sum of the outputs due to each voltage and current source with all other sources turned off. (NB: When a voltage source is “turned off,” the branch defining it must be shorted. In contrast, a current source is turned off by open circuiting the branch.)

Build the circuit shown in Fig. 1 and use the multimeter to measure the current \( I \) as defined in the diagram. Connect the meter exactly as indicated, being careful to establish one (and only one) circuit ground. Next, take all current data needed to fill in the table found on the next page for each of the five (5) non-trivial conditions specified. Note that, to achieve a true open-circuit condition,
you must physically **disconnect** the voltage source from the circuit. Do not rely on the meters on the DC supply to measure $V_1$ and $V_2$, as they are not very accurate; instead, use your dual trace scope to measure them. Make a copy of the table in your notebook and fill it in with your current data. Then, while still in the lab, check to see if the superposition principle has been upheld by comparing the appropriate sum to the current value measured when both sources are turned on.

<table>
<thead>
<tr>
<th>$V_2$</th>
<th>$V_1 = 10\text{ Volts DC}$</th>
<th>$V_1 = 0\text{ Volts (short)}$</th>
<th>Open-circuited</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_2 = 5\text{ Volts DC}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_2 = 0\text{ Volts (short)}$</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Open-circuited</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Be sure to estimate and record all measurement uncertainties associated with your scope and multimeter readings. Then, when you do the lab report, use this information as you compare the calculated and measured values. Do not use either too many or too few places of accuracy in quantitative answers.

II. **Maximum power transfer**

When noise is present in an electronic device or a communications channel (and there ALWAYS is noise!), it is signal power rather than either voltage or current
magnitude that really limits the performance. Thus, engineers usually design receivers to detect the maximum power available. In this section of the lab, you will investigate the effect of receiver resistance on detected power.

The simple circuit of Fig. 2 consists of two resistors, $R_s$ and $R_l$, and a DC source. Build this circuit with $R_s = 1\, \text{k}\Omega$, and then measure the voltage across the load resistor $V_l$ for a set of values of $R_l$ approximately as follows: 200 $\Omega$, 400 $\Omega$, 600 $\Omega$, 800 $\Omega$, 1 k$\Omega$, 1.2 k$\Omega$, 1.5 k$\Omega$, 2 k$\Omega$, 5 k$\Omega$.

Use these measured voltage values to compute the power dissipated in $R_l$ using the formula: $p = V_l^2 / R_l$. Record these calculations and then, using the graph paper provided by your lab TA, immediately plot the calculated power $p$ versus $R_l$. The plot should reveal a maximum value. What is the value of $R_l$ at which this power is maximized?

III. Thevenin equivalent for a voltage supply

All realizable DC voltage sources have series resistance. This resistance $R_s$ in effect defines the limits of the unit as a constant voltage source. If the load resistor $R_l$ decreases to a value close to $R_s$, the available voltage starts to drop dramatically. We can use this phenomenon plus the voltage divider relation to obtain an estimate for the value of $R_s$.

Use the approach outlined above to measure the internal series resistance of the DC power supply at your bench by connecting different load resistor values until the voltage $V_l$ drops by a factor of two. *Warning: for this exercise do not operate the supply at more than ~2 Volts.* If you go higher, blow a fuse or overheat and blow the resistors (and maybe burn your fingers in the process). To increase the wattage of resistive loads and thus reduce the chances of overheating, you can connect two or more resistors in parallel.

Repeat this procedure to obtain an estimate for the effective series resistance $R_s$ of a 9 V battery. A problem here is that you have to measure voltages quickly before the battery starts to deteriorate due the inherent limits on the

![Figure 2. DC circuit for investigation of the max. power transfer condition.](image-url)
rate at which the electrochemical reaction can occur. If you accidentally draw down the open-circuit voltage of your battery $V_{oc}$, let it rest and recover for a few minutes before continuing.