## Lab 4: Mesh, Nodal, and Superposition Principle

# Objectives

# 1) Practice wiring several voltage sources on a breadboard using a multi-channel power supply.

# 2) Demonstrate the validity of mesh and nodal analysis, and the superposition principle with physical-build circuit measurements.

### Background

**Mesh analysis** determines all the mesh (or loop) currents of the circuit. **Nodal analysis** provides all the nodal voltages with respect to a ground reference node. The application of each analysis follows a sequence of calculation steps, each of which will result in a set of equations with unknown variables (mesh currents for the mesh analysis, and nodal voltages for the nodal analysis). It is then only a matter of solving these equations for the various variables to be determined.

**Superposition principle** offers a useful technique to solve for a circuit that has multiple independent sources. It allows one to break down such a circuit into several sub-circuits, each sub-circuit having a single independent power source, while the other independent sources are deactivated. The voltage or current at any location of the complete circuit is the sum of the sub-circuit’s voltages or currents at that location. A key point of the superposition analysis is how to deactivate an independent source. To deactivate a voltage source, remove the source from the circuit, and replace the resulting gap with a wire (i.e., short circuit). To deactivate a current source, remove the source from the circuit, and leave the gap as is (i.e., open circuit). In most cases, just switching off the power supply is not enough to deactivate it.

# Part 1: Mesh Analysis

Construct the following circuit (physical build). Note that you have two independent voltage sources, so you need to use two channels of your power supply. For each resistor, you need to use DMM to measure the actual resistance of each resistor. Also, measure the actual voltages of the two power supplies.

Diagram, schematic

Description automatically generated

Perform the mesh analysis with the following steps.

a. Use LTspice to determine the theoretical values of the two mesh (loop) currents, designated in the clockwise direction (which is the conventional mesh current direction). Make sure to indicate the currents’ values and directions (e.g., by using a hack DMM). Keep at least 3 significant digits. Include the LTspice .op simulation output screenshot in your lab report.

b. For your physical build circuit, turn on both channels of the power supply to energize the circuit. Measure the two mesh currents with DMM. Use a suitable DMM with a suitable current setting – the current value should have at least 3 significant figures. These mesh current values will be your measured result. Enter your measured result in the datasheet at the end of this lab instruction, and compare with the theoretical result.

c. We will use the same circuit build for the next parts of the lab, so don’t completely disassemble the circuit yet.

**Part 2: Nodal Analysis**

a. Use LTspice simulation to determine the theoretical values of all the nodal voltages of the circuit. There are four nodes, not counting the reference ground node. Keep at least 3 significant digits. Include the LTspice output screenshot in your lab report.

b. For the physical build, energize the circuit and measure all the nodal voltages using DMM. Enter your measured nodal voltage values in the datasheet at the end of this lab instruction, and compare with the theoretical values.

**Part 3: Superposition Principle**

1. LTspice simulation: using the same circuit as before, investigate all the four nodal voltages at nodes Va, Vb, Vc, and Vd in two steps.
2. In the first step, with only one independent source V1 acting while the other independent source V2 is deactivated, determine the partial nodal voltage of each of the four nodes. A tricky issue here is how to deactivate an independent source. What are the different methods to deactivate a voltage source and a current source? What is the theoretical basis of these deactivation methods? Screenshot the LTspice circuit and the output.
3. Repeat the previous step, but this time with V2 acting alone and V1 being deactivated.
4. Verify that for each of the four nodes, the sum of the two partial voltages is the same as the total nodal voltage (obtained previously in Part 2a) of that node.
5. Physical-build investigation: use measurement of the actual physical circuit to perform the same superposition analysis.
6. In the first step, with only one independent source V1 acting while the other independent source V2 is deactivated, use a DMM to measure the partial nodal voltage of each of the four nodes. How do you deactivate a power supply channel in a physical build situation? Just switching off the power supply channel is not enough to deactivate it. Why?
7. Repeat the previous step, but this time with V2 acting alone and V1 being deactivated.
8. Verify that for each of the four nodes, the sum of the two partial voltages is the same as the total nodal voltage (obtained previously in Part 2b) of that node. Compare the theoretical results and the measured results.

**Data tables**

Mesh analysis

|  |  |  |
| --- | --- | --- |
| Mesh current (clockwise) | Theoretical result (μA) | Measured result (μA) |
| Ia |  |  |
| Ib |  |  |

Nodal analysis

|  |  |  |
| --- | --- | --- |
| Nodal voltage | Theoretical result (V) | Measured result (V) |
| Va |  |  |
| Vb |  |  |
| Vc |  |  |
| Vd |  |  |

Superposition analysis

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Theoretical result (V) | | | Measured result (V) | | |
| Node | V1 alone | V2 alone | V1 & V2 | V1 alone | V2 alone | V1 and V2 |
| Va |  |  |  |  |  |  |
| Vb |  |  |  |  |  |  |
| Vc |  |  |  |  |  |  |
| Vd |  |  |  |  |  |  |
| Superposition principle verified? (Yes/No) | | | | |  | |

Also include:

Screenshots of LTspice circuits and output images – mesh analysis, nodal analysis, superposition.