# Lab #2

#### Equipment/Supply Basics, VDR, CDR

# OBJECTIVES

1. Become familiar with a breadboard, the lab power supply, and review the measurement of voltage, current, and resistance using a Digital Multimeter (DMM).
2. Build and explore Voltage Division Rule – VDR.
3. Build and explore Current Division Rule – CDR.

# EQUIPMENT

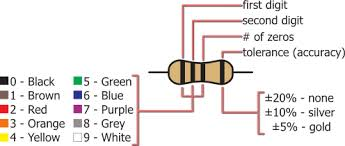
Circuit toolbox (containing a breadboard, DMM probes, wires), power supply, DMM, and extra 200mA fuses (if needed).

##### Part 1: Read resistor color code, and explore the connection pattern of a breadboard

1. Resistors are color-coded. Each color corresponds to a number:

|  |  |
| --- | --- |
| Black | = 0 |
| Brown | = 1 |
| Red | = 2 |
| Orange | = 3 |
| Yellow | = 4 |
| Green | = 5 |
| Blue | = 6 |
| Violet | = 7 |
| Grey | = 8 |
| White | = 9 |

Each resistor typically has four colored bands. The first two bands represent the **mantissa**/coefficient of a number, the third band is the **exponent** (power of 10). The last band is either gold or silver, and represents the **tolerance**. Gold band is +/- 5% and Silver band is +/- 10%.



Part 1 – answer the following questions

|  |  |
| --- | --- |
| Resistor color band | Resistor value (Ohm or kOhm) |
| What is red, red, red? |  |
| What is Brown, Black, orange? |  |
| What is Orange, green, black? |  |

It is helpful to use a mnemonic device to remember the color codes:

“Beetle Bailey Ran Over Your General Before Very Good Witnesses”

You now know how to determine the printed nominal value of a resistor. However, a nominal value is only an approximate value, and the resistors are only expected to have the printed value within the tolerance range. Values will vary by +/- 5% if the tolerance is Gold. To get an actual value you will have to measure the resistor with a DMM.

1. Set the DMM setting to Ohm. Attach mini-grabber probes to the DMM, with one probe in common hole and the other probe in the Ohm hole. Now take two resistors (nominal value = 1k and 5k) and measure their actual values using the DMM. How far off is the measured value compared to the printed nominal value?

Part 1 – measuring resistance

|  |  |
| --- | --- |
| Nominal value (Ohm) | Measured value (Ohm) |
| 1k |  |
| 5k |  |

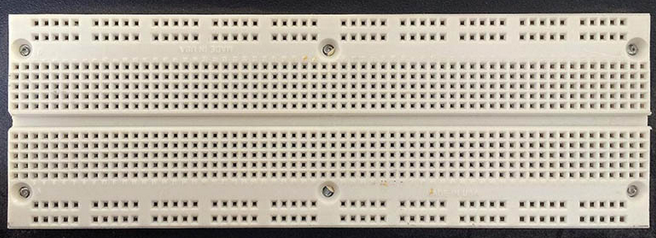
1. Now set the DMM range to the continuity setting. Measure the continuity between different sets of pins/holes/points on the breadboard to determine which groups of pins are connected and which are not. Lack of continuity will be read as an open circuit by the DMM, with no beeping sound. A beep from the DMM will indicate that the two points are electrically connected.

*Below is an image of a solderless breadboard, similar to what you are using in class.* ***Draw lines on this image showing how the holes are interconnected.*** *The lines represent wires/metal that are underneath the board. A line connecting several holes means these holes are electrically connected.*

*A breadboard line of electrically connected holes is called a “node”. In a circuit, each two-terminal circuit element (resistor, measuring meter, etc.) should be connected between two different nodes. You can connect two separate nodes with a wire to short them, thereby combining the two nodes into a single node.*

*Useful tips:* ***When you construct a circuit on a breadboard, plan out the nodes first.*** *Then place elements between different nodes. Also, the long nodes at the top and bottom of the breadboard are utilized as* ***power rail*** *and* ***ground rail****. Power rail should be connected to the power supply’s power channel (red). Ground rail should be connected to the power supply’s ground channel (green).*

Part 1 – drawing nodes and rails on a breadboard



*As you start constructing the circuits on the breadboard for the experiments below, think about why the nodes of a breadboard are laid out the way they are. It will help you develop the skill of constructing circuits accurately and efficiently.*

**Part 2: Basic Series Measurements, Voltage Division Rule (VDR)**

Construct this circuit by following the steps below. This may appear very detailed at first, but it is necessary when you first learn how to construct circuits. Later, when you become more proficient, you may develop your own style of constructing circuits.

A diagram of a circuit

Description automatically generated

1. First, configure the power supply to use either channel 1 or 2 to output 10V to the breadboard, and limit the amperage to 0.1A=100mA. This means OCP (Over-Current Protection) must be set to “On” at 0.1A. Make sure to connect the green ground pin of the power supply to the black negative output of the power supply. Why is it important limit the amperage and check ground connections before powering on a circuit?
2. Use jumper wires (aka hookup cables) to transfer the power from the power supply posts to the breadboard pins at the top of the board. Don’t connect the resistors yet. Measure the open-circuit voltage to confirm that the 10V supply voltage is being transferred. Write down the actual voltage being supplied to the breadboard. Then turn off the power supply channel 1 or 2 that you are using.
3. Use DMM to measure the actual resistance of a nominal 1kOhm resistor, and a nominal 5kOhm resistor. Calculate the theoretical equivalent series resistance RS,thy using the measured resistor values. Recall that resistors in series add together.
4. Make sure the power supply channel (1 or 2) is turned off! This is a good practice as you insert elements onto a breadboard to construct a circuit. You don’t want the breadboard to be energized when you are placing wires and elements on it. Insert the 1kOhm and 5kOhm resistors into the breadboard to complete the circuit. Check the breadboard to make sure that you have three nodes and two elements in this circuit. It is a good practice to check your breadboard circuit after you have constructed it, to see that your actual circuit agrees with your planned circuit.
5. Make sure you physically disconnect the power supply from the breadboard, and then use DMM to measure the experimental equivalent series resistance RS,expt. Record the measured series-resistance value. *An important note is that if the power supply is physically connected to the breadboard, then the series-resistance you measure will not be correct.* How does this measured series-resistance compare to the theoretical series-resistance (in part c)? Why must the power supply be physically disconnected from the breadboard when you measure the series-resistance value (hint: the power supply has its internal resistance)?
6. Connect the power supply back to the breadboard, and turn on the power supply channel to energize the circuit. Now measure the voltage across each resistor. What is the voltage across the 1kOhm resistor? What is the voltage across the 5kOhm resistor? Record these two voltages. Do these two resistor voltages add up to the power supply voltage?
7. Now measure and record the source current using the DMM. To measure current using the DMM, the current must pass through the DMM. To measure a current through a node, you must (1) separate that node into two sub-nodes, and (2) connect the DMM between the two sub-nodes. Also, remember that a DMM probe should be inserted into the proper current-measuring hole of the DMM. **If you are still not sure about how to measure a current, you need to ask the lab instructor to show you before taking this measurement. Otherwise, you may short out the 10V source or cause the fuse inside the DMM to fail.**
8. Using the measured supply voltage and the measured current reading, calculate the equivalent series resistance RS,Ohm using Ohm’s law. How does this value compare to the values found from part 2c and 2e? Record your values in the table below:

Part 2 – resistors in series

|  |  |
| --- | --- |
|  | Series-resistance (kOhm) |
| Theoretical: add two measured resistances |  |
| Actual: measure the series-resistance |  |
| Ohm’s law: voltage divided by current |  |

1. Fill out the datasheet (see Appendix). Explain the three voltages (total voltage, voltages of R1, R2) with the voltage division rule (VDR).

Part 2 – resistors in series, VDR

|  |  |
| --- | --- |
| Vs (DMM) |  |
| R1 (DMM) |  |
| R2 (DMM) |  |
| R1+R2 (theoretical calc.) |  |
| R1+R2 (DMM) |  |
| R1+R2 (Ohm’s law calc.) |  |
| V1 (DMM) |  |
| V2 (DMM) |  |
| V1+V2 (DMM) |  |
| Source current Is (DMM) |  |

**This circuit building of Part 2 is optional (not graded):** Construct the following circuit on a breadboard. If you can’t find a resistor with the exact nominal value (e.g., 2.5kOhm), use the closest resistor you can find. Record the actual voltage that is being supplied by the power supply (should be close to 10V, but may not be exactly 10V).

A diagram of a circuit

Description automatically generated

j. What values would you estimate for the voltage drop across each of the three resistors V(R1), V(R2), and V(R3)? Explain your reasoning with the voltage division rule (VDR).

k. Calculate V(R1) using VDR, based on the measured actual resistor values and the actual power supply voltage. This is your theoretical voltage value. Then measure V(R1) with DMM, How do they compare?

l. Since R2 = R3 = ½ R1, VDR predicts that (1) V(R2)=V(R3) and (2) V(R1)=V(R2)+V(R3). Measure actual voltages V(R2) and V(R3) to verify these predictions. How does your theoretical estimation compare with actual measurement?

**Part 3: Basic Parallel Measurements, Current Division Rule (CDR)**

Construct this circuit by following the steps below.

A diagram of a circuit

Description automatically generated

1. Before you construct the circuit, measure the source voltage that is being supplied from the power supply. Record that source voltage. Use DMM to measure the actual resistance of the1kOhm and the 10kOhm resistors, and record these values. Calculate the theoretical equivalent parallel resistance RP,thy using the measured resistor values. 1/Req = 1/R1 + 1/R2
2. With the power supply channel turned off, place the resistors onto the breadboard to complete the circuit. Now physically disconnect the power supply from the breadboard, and then measure the experimental equivalent parallel-resistance RP,expt using a DMM. If the power supply is physically connected to the breadboard, then the parallel-resistance you measure will not be correct. How does this value compare to part a?
3. Connect the power supply back to the breadboard. Turn on the power supply channel to energize the circuit, and measure the current flowing from the power source using the DMM. Record this source current. Review part 2 about how you should measure a current through a node. **Be very careful not to short out the supply - it will blow the fuse. If you are unsure, please ask for a demo on how to do this. It’s OK to ask more than once!**
4. Using the measured supply voltage and the measured current, calculate the equivalent parallel-resistance RP,Ohm using Ohm’s law. How does this value compare to 3a and 3b?

e. Now measure the current in 1kOhm branch and 10kOhm branch. Does the sum of the two branch currents equal the source current? How is the main current distributed among the two branch currents?

f. Fill out the datasheet below, and explain the three currents (main current, two branch currents with the current division rule (CDR).

Part 3: parallel-resistance, CDR

|  |  |
| --- | --- |
| Vs (DMM) |  |
| R1 (DMM) |  |
| R2 (DMM) |  |
| R1 // R2 (theoretical calc.) |  |
| R1 // R2 (DMM) |  |
| R1 // R2 (Ohm’s law calc.) |  |
| Is (DMM) |  |
| I1 (DMM) |  |
| I2 (DMM) |  |

Explain the three currents Is, I1, I2 with CDR:

To explore the general form of CDR based on conductance G, construct the following circuit. You may use the previously constructed circuit, and simply add a 5k resistor as an additional parallel branch.

A diagram of a circuit

Description automatically generated

g. Without making any calculations, what approximate value would you estimate for each of the three branch current through each resistor? Explain your reasoning.

h. Calculate the currents i1, i2, and i3 using the CDR from the measured values of R1, R2, R3, and the measured source current iS. Then use DMM to measure the individual branch currents i1, i2, and i3.

i. Fill out the following data tables based on your calculations and measurements.

Part 3 CDR – Theoretical calculation of conductance G based on actual values of R1, R2, R3

|  |  |  |  |
| --- | --- | --- | --- |
| R1 meas (kOhm) |  | G1 (mMoh) |  |
| R2 meas |  | G2 |  |
| R3 meas |  | G3 |  |

Part 3 CDR – Current division calculation vs. measurements

|  |  |  |  |
| --- | --- | --- | --- |
| Is calc (mA) |  | Is meas (mA) |  |
| I1 calc |  | I1 meas |  |
| I2 calc |  | I2 meas |  |
| I3 calc |  | I3 meas |  |

Write down the general form of CDR based on conductance G:

**When you return a resistor to its drawer, please use DMM to verify that the drawer has the same nominal value as the resistor. Otherwise the other users may get the wrong resistor. Thank you!!!**

**Appendix: summary of data tables**

Part 1 – answer the following questions

|  |  |
| --- | --- |
| Resistor color band | Resistor value (Ohm or kOhm) |
| What is red, red, red? |  |
| What is Brown, Black, orange? |  |
| What is Orange, green, black? |  |

Part 1 – measuring resistance

|  |  |
| --- | --- |
| Nominal value (Ohm) | Measured value (Ohm) |
| 1k |  |
| 5k |  |

Part 1 – drawing nodes and rails on a breadboard

A white rectangular object with holes

Description automatically generated

Part 2: series-resistance, VDR

|  |  |
| --- | --- |
| Vs (DMM) |  |
| R1 (DMM) |  |
| R2 (DMM) |  |
| R1+R2 (theoretical calc.) |  |
| R1+R2 (DMM) |  |
| R1+R2 (Ohm’s law calc.) |  |
| V1 (DMM) |  |
| V2 (DMM) |  |
| V1+V2 (DMM) |  |
| Source current Is (DMM) |  |

Explain the three voltage values V1, V2, and Vs with VDR:

Part 3: parallel-resistance, CDR

|  |  |
| --- | --- |
| Vs (DMM) |  |
| R1 (DMM) |  |
| R2 (DMM) |  |
| R1 // R2 (theoretical calc.) |  |
| R1 // R2 (DMM) |  |
| R1 // R2 (Ohm’s law calc.) |  |
| Is (DMM) |  |
| I1 (DMM) |  |
| I2 (DMM) |  |

Explain the three currents Is, I1, I2 with CDR:

Part 3 CDR – Theoretical calculation of conductance G based on actual values of R1, R2, R3

|  |  |  |  |
| --- | --- | --- | --- |
| R1 meas (kOhm) |  | G1 (mMoh) |  |
| R2 meas |  | G2 |  |
| R3 meas |  | G3 |  |

Part 3 CDR – Current division calculation vs. measurements

|  |  |  |  |
| --- | --- | --- | --- |
| Is calc (mA) |  | Is meas (mA) |  |
| I1 calc |  | I1 meas |  |
| I2 calc |  | I2 meas |  |
| I3 calc |  | I3 meas |  |

Write down the general form of CDR based on conductance G: