Experiment BT-3: Voltage Dividers and Loading

Equipment Required

PC or Mac Computer

IX-TA-ROAM recorder, USB cable, power supply

A-BMET-B BMET Trainer Board

C-DIN-BB DIN to Breadboard Cable

C-BNC-BB BNC to Breadboard Cable

A-BMET-EC Electronic Components Set

Jumper Wires

Setup

1. Connect the C-DIN-BB Cable to port A5 on the TA-ROAM. Use extender cables for the yellow and brown leads.
2. Connect the C-BNC-BB Cable to the S1 (LV Stimulator) port on the TA-ROAM.

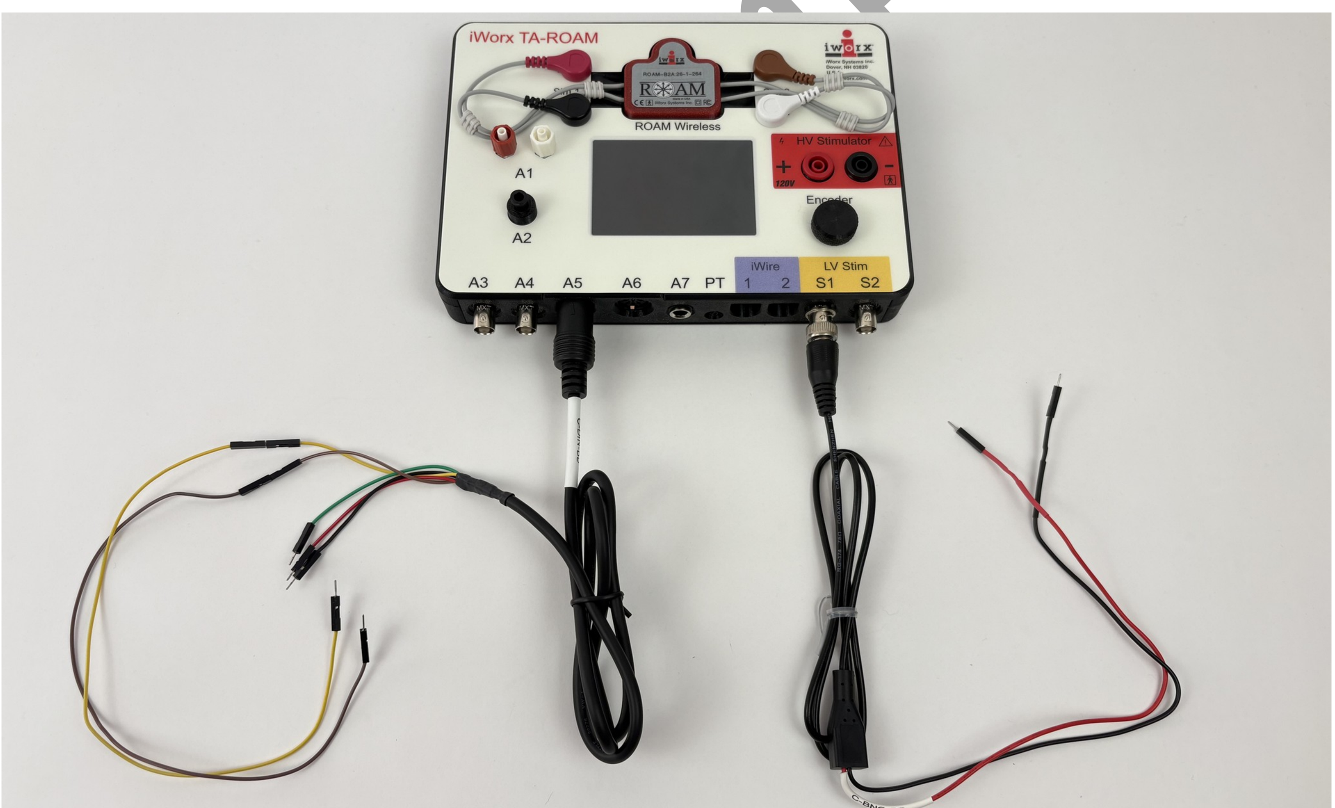

Figure BT-3-S1: IX-TA-ROAM, C-DIN-BB cable (port A5), C-BNC-BB cable (S1).

Experiment BT-3: Voltage Dividers and Loading

Background

Voltage dividers are one of the most common resistor networks in electronics. They are used to create lower voltages for sensors, reference circuits, and signal-conditioning systems found in biomedical equipment.

In previous labs, you used Ohm's Law and analyzed series and parallel resistor circuits. In this lab, you will apply those concepts to predict and measure the output of a voltage divider. You will also investigate loading, which occurs when a connected device draws current and changes the circuit's behavior.

Using the BMET Trainer Board and TA-ROAM system, you will compare calculated and measured voltages and observe how different loads affect voltage-divider performance.

Theory

1. Voltage Division

The purpose of a voltage divider is to take a larger voltage and scale it down. This is important because sometimes the power supply coming in is large (e.g. from a 12V battery), but the component it is going into will be fried with such a large voltage (e.g. a 3.3V microcontroller).

A common voltage divider setup is two resistors in parallel with the output voltage placed between them. Recall that when resistors are connected in series, the input voltage is divided among the resistors (because V_{series} is the sum of each resistor's voltage).

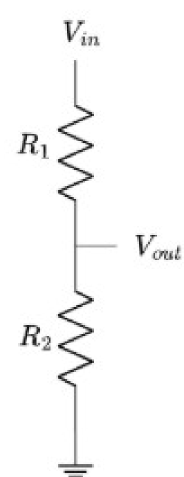

Figure 1. Voltage divider circuit

For a two-resistor divider as the one pictured above, the following formula can be used to find the output voltage:

$$V_{out} = \frac{V_{\text{in}} R_2}{R_1 + R_2}$$

The derivation is shown below, but it is not necessary to know:

Ohm's Law $V = IR$

Voltage difference across the circuit. (Remember that voltage at ground is zero.) $0 - V_{\text{in}} = I(R_1 + R_2)$

Rearrange to isolate current: $I = \frac{-V_{\text{in}}}{R_1 + R_2}$

Find voltage across R_2: $V_{\text{out}} = -IR_2$

Substitute first equation for *I:* $V_{out} = \frac{V_{\text{in}} R_2}{R_1 + R_2}$

2. Loading Effects

Recall that loads are anything that uses energy or power in a circuit. They are necessary because the circuit cannot exist without its components. Unfortunately, **loading effects** can accidentally alter circuits when not accounted for.

Loading effects are typically caused by components drawing current and reducing voltage due to their internal resistance. This can change the circuit's original voltage or current. For instance, loading can be caused by our measurement devices. Even though an ideal voltmeter draws no current, real measurement systems have finite input resistance. Whenever a device is connected to a voltage divider, it slightly alters the circuit and can change the voltage that it measures.

In this lab, we will look at the effects of loading on a voltage divider.

In future labs, we will learn how to avoid loading with tools like buffers.

Pre-Lab Questions

1. A voltage divider contains a 1 kΩ resistor and a 1 kΩ resistor, and has an input voltage of 6 V. Calculate the output voltage.
2. What happens to the output voltage if R_2 becomes larger while the input voltage remains constant?

Experiment BT-3: Voltage Dividers and Loading

Exercise 1: Voltage Divider Introduction

Aim: To understand how voltage dividers split an input voltage between series resistors according to their resistance values.

Approximate Time: 45 minutes

Procedure

1. This section will use Circuit A.
2. Create a voltage divider setup using a 1k Ohm resistor for RA1 and a 5k Ohm resistor for RA2.
3. Place a short at RA5.
4. Supply power and ground to the circuit using the C-BNC-BB cable.
    1. Connect the red lead at INA.
    2. Connect the black lead to one of the GND pins in the Inputs section.
5. Measure the voltage drop using the C-DIN-BB cable.
    a) Connect the + (red lead) to the VCC pin in the Inputs section on the right of the board.
    b) Connect the - (black lead) to the VEE pin.
    c) Connect the ground (green) to a GND pin.
    d) To measure the voltage drop across RA1, place the yellow lead at TPA1 and the brown lead at TPA2.
6. Press the red REC button to start the recording in LabScribe. LabScribe will now supply power to the circuit.
7. Type “RA1” into the Mark box and press ENTER on the computer keyboard to mark the recording.
8. Record for ~10 seconds.
9. Press the STOP button to stop the recording.

10. Repeat the procedure above for RA2 and RA12. To measure the voltage drop across RA2, place the yellow lead at TPA2 and the brown lead at TPA3. To measure the voltage drop across RA12, place the yellow lead at TPA1 and the brown lead at TPA3.

11. Save the data file by clicking File – Save As. Be sure to name the data file appropriately.

12. Calculate what the expected voltage should be, and record these values in the first column in Data Table BT-3-L1. Write the correct units in the table header.

Table BT-3-L1: Data Table for Exercise 1 – Voltage Divider Introduction

Note: V_{out} is the voltage across R_{A2}. V_{in} is the total voltage across both resistors.

Voltages for Various Resistors			
Component	Expected Voltage (_____)	Measured Voltage (_____)	Percent Error (%)
RA1			
RA2			
RA12			

Table BT-3-L2: Data Table for Exercise 1 – Voltage Divider Introduction

Input Voltage Comparison		
Expected V_{in} (_____)	Measured V_{in} (_____)	Percent Error (%)

Data Analysis

1. Scroll to the section of data recorded when the "RA1" mark was made in the recording.

2. Switch into single cursor mode, by clicking on the 1 Cursor icon on the top toolbar. The 1 Cursor icon is located directly to the left of the Preview button. Drag the red cursor so it is on the RA1 mark.
3. Record the value displayed in the Meter dialog window in the Measured Voltage column of Data Table BT-3-L1. This value is also displayed at the right side of the screen, on the channel title.
4. Repeat analysis steps 1-3 for the RA2 and RA12 marks.
5. Verify that $V_{\text{in}} \approx V_{RA1} + V_{RA2}$ and calculate percent error. Complete Data Table BT-3-L2.

Questions

1. Which resistor has the larger voltage drop across it? Why?
2. How does resistance affect voltage division?

Exercise 2: Create a Voltage Divider

Aim: To construct a voltage divider and compare the measured output voltage to the theoretical value.

Approximate Time: 30 minutes

Procedure

1. Repeat the procedure from Exercise 1. Construct a voltage divider using two resistors of your choice.

Table BT-3-L3: Data Table for Exercise 1 – Voltage Divider Introduction

Voltage Divider Data					
R_{A1} resistance (_____)	R_{A2} resistance (_____)	V_{in} (_____)	Measured V_{out} (_____)	Measured V_{out} (_____)	Percent Error (%)

Data Analysis

1. Repeat the data analysis procedure from Exercise 1. Record the values in data table BT-3-L3. Complete the data table.

Questions

1. Between Exercise 1 and Exercise 2, which resistor ratio produced the larger output voltage? Which produced the smaller output voltage? Explain why.

Exercise 3: Introduction to Loading

Aim: To understand how voltage divider circuits behave under loaded and unloaded conditions, and how load resistance affects the output voltage.

Approximate Time: 30 minutes

Procedure

1. Repeat the procedure from Exercise 1. Construct a voltage divider that produces approximately 2.5 V from a 5 V source.
2. Record the output voltage and other values in Data Table BT-3-L4.

Table BT-3-L4: Data Table for Exercise 1 – Voltage Divider Introduction

Voltage Divider Data					
R_{A1} resistance (_____)	R_{A2} resistance (_____)	V_{in} (_____)	Measured V_{out} (_____)	Measured V_{out} (_____)	Percent Error (%)

3. Connect another resistor of 1kΩ between V_{out} and ground to introduce a load as represented by Figure BT-3-S1. (*Hint: This resistor should be at* R_{A3} *or* R_{A4}*.*)

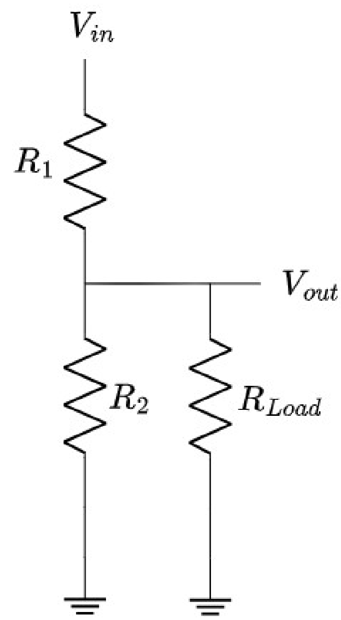

Figure BT-3-S1: Loaded Voltage Divider Circuit

4. Use the parallel resistors formula and voltage divider formula to calculate what V_{out} will now be.
5. Measure V_{out} again and record in Data Table BT-3-L5.

Table BT-3-L2: Data Table for Exercise 1 – Voltage Divider Introduction

Input Voltage Comparison		
Expected V_{out} (_____)	Measured V_{out} (_____)	Percent Error (%)

Questions

1. Did V_{out} increase or decrease when the load was added? Why?
2. Why might loading be important in biomedical instrumentation circuits?

Post-Lab Questions

1. For each scenario below, compare the current through R_{Load} with the current though R_2. Explain what happens to the voltage-divider circuit in each case.

   a) R_{Load} is much larger than R_2

   b) $R_{Load} = R_2$

   c) R_{Load} is much smaller than R_2

   d) $R_{Load} = 0$

2. What is the importance of voltage dividers in electronics? What are some examples of how they may be used?
3. Design a voltage divider that produces approximately 3 V from a 5 V source. Show calculations.
4. Did your measured result always match your experimental results? What are some possible sources of error in this lab?