Experiment BT-4: Pull-Up and Pull-Down Networks

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.

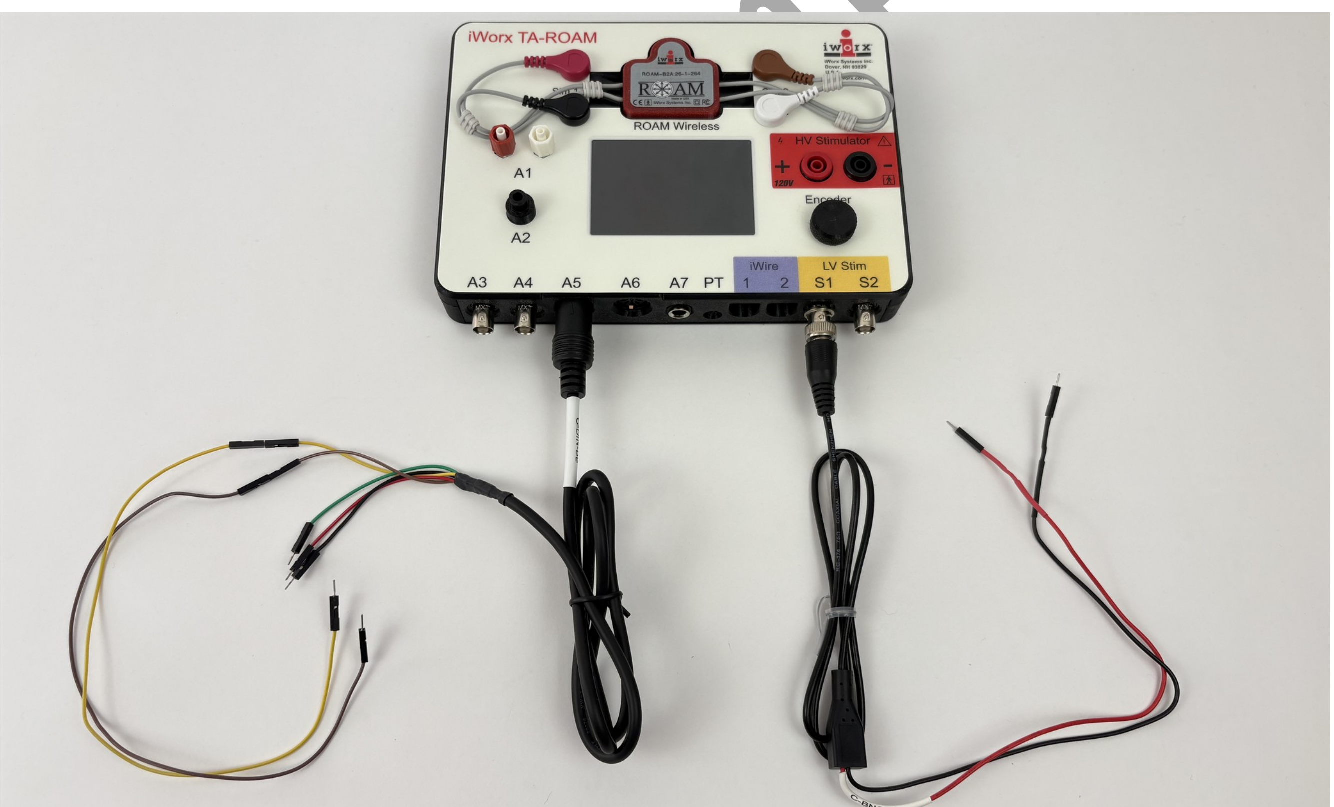

Figure BT-4-S1: IX-TA-ROAM, C-DIN-BB cable (port A5), C-BNC-BB cable (S1).

Experiment BT-4: Pull-Up and Pull-Down Networks

Background

In previous labs, you explored how voltage, current, and resistance behave in basic circuits. However, many electronic systems also rely on digital signals to transmit information. These signals can represent only two states: ON or OFF, HIGH or LOW, and 1 or 0.

For digital circuits to operate reliably, every input must be connected to a known voltage level. Otherwise, the input may change unpredictably by picking up electrical noise in its surroundings. These unconnected inputs, or floating inputs, can overwrite or corrupt the information being transmitted in digital logic signals.

One common method for ensuring stable digital signals is the use of pull-up and pull-down resistor networks. These circuits establish a default logic state while still allowing switches, sensors, or other devices to change the signal when needed. Pull-up and pull-down networks are widely used in microcontrollers, communication interfaces, and digital control systems.

In this lab, you will investigate how pull-up and pull-down networks behave.

Theory

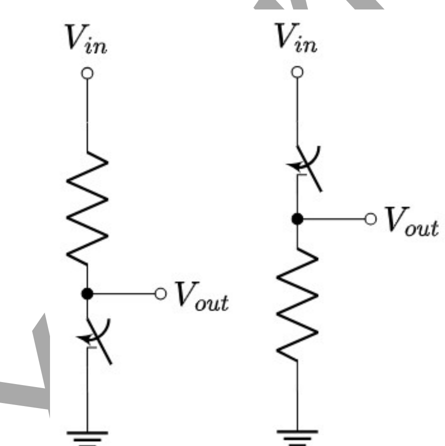

Figure 1: Left: A switch pulled down by a resistor. Right: A switch pulled up by a resistor.

One difference between pull-up and pull-down resistors is where they are connected, as shown in Figure 1. Both serve to stabilize signals by eliminating floating nodes.

1. Pull-Up Resistors

Pull-up resistors are located between the input and the output.

For the pull-up resistor network in Figure BT-4-S1, we will first consider what happens when the switch is open. This creates an open circuit at the bottom, causing all of the current to flow from V_{in} to V_{out}, making the state at V_{out} "high".

When the switch is closed, there is a short circuit to ground. This causes V_{out} to be zero volts since it is now at the same node as ground. As a result, the output is "low".

2. Pull-Down Resistors

A pull-down resistor connects a node to ground.

In the pull-down circuit in Figure BT-4-S1, when the switch is open, V_{out} has a path to ground and it is not receiving any power. This causes it to have zero volts, so it is "low".

When the switch is closed, the input is shorted to the output. This causes them to be equal, so the output is "high".

3. Switches

Figure 2. Switch symbol

Like the light switches in your house, the switches on your board have two settings: on and off. To turn them on, flip the switch closer to the word "ON".

On simply means short circuited (connected), and *off* means open circuited (disconnected).

Pre-Lab Questions

1. What are the two possible logic states in a digital circuit, and what voltage levels do they generally represent?
2. What is a floating input, and why can a floating input cause problems in a digital circuit?
3. In a pull-up network, what logic state would you expect at the output when the switch is open? What about when the switch is closed? Explain why.
4. In a pull-down network, what logic state would you expect at the output when the switch is open? What about when the switch is closed? Explain why.
5. What is the difference between an open circuit and a short circuit?
6. Why is a resistor used in a pull-up or pull-down network instead of connecting the input directly to the power supply or ground?

Experiment BT-4: Pull-Up and Pull-Down Networks

Exercise 1: Investigating a Floating Node

Aim: To understand the behavior of a floating node and why undefined input voltages can lead to unreliable circuit operation.

Approximate Time: 20 minutes

Procedure

1. Locate Circuit B on your board.
2. Create a floating node circuit.
   a) Short circuit the switches by setting them to “on” (flip them up, not down).
   b) Leave RB as an open circuit.
3. Provide an input of 5V using the C-BNC-BB cable.
   a) Connect the red lead to INB.
   b) Connect the black lead to one of the GND pins in the Inputs section.
4. Measure the output using the C-DIN-BB cable.
   a) Connect the + (red lead) to the VCC pin in the Inputs section on the right.
   b) Connect the - (black lead) to the VEE pin.
   c) Connect the ground (green) to a GND pin.
   d) Connect the brown lead to the IN- pin.
   e) Measure the output by connecting the yellow lead at each test point (TPB1, TPB2, and TPB3). Start with the yellow lead connected to TPB1.
5. Press the Preview button in LabScribe (icon that resembles an eye). The preview button is primarily used to display and monitor data acquisition in real-time without actually recording or saving that data to your computer's disk. The voltage reading will be visible in the Meter dialog box to the left of the screen.
6. Observe the measured voltage for 15-20 seconds.

7. Stay in preview mode and move the yellow lead to the second test point, TPB2.
8. Observe the measured voltage for 15-20 seconds.
9. Stay in preview mode and move the yellow lead to the third test point, TPB3.
10. Observe the measured voltage for 15-20 seconds.
11. Observe output differences between each test point.

Questions

1. Did the voltage remain constant for each test point?
2. Why might a floating node be undesirable in biomedical equipment?
3. What external factors could influence the voltage?

Exercise 2: Pull-Up Network

Aim: To understand how a pull-up resistor establishes a defined logic state and prevents a floating input when a switch is open.

Approximate Time: 20 minutes

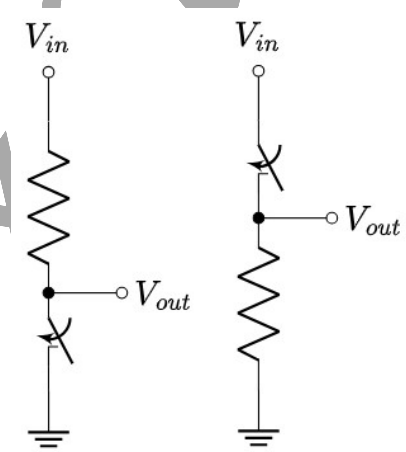

Figure BT-4-S1: Left: A switch pulled down by a resistor. Right: A switch pulled up by a resistor.

The pull-up circuit for this exercise is the same as the one in Figure BT-4-S1.

1. Keep the yellow lead connected to TPB3.
2. Add a 10kΩ resistor at RB as your pull-up resistor. In pull-up circuits, we always want the resistor directly connected to the input, so SW1 should be short-circuited (on) for all of this exercise.
3. Start with the SW2 switch open for now (OFF).
4. Press the red REC button in LabScribe to supply power to the circuit.
5. Place a mark in the recording "switch open".
6. Record for 15-20 seconds.
7. Close the SW2 switch (ON).
8. Place a mark in the recording "switch closed".
9. Record for 15-20 seconds.
10. Press STOP to stop the recording.
11. Save the data file by clicking File – Save As. Be sure to name the data file appropriately.

Data Analysis

1. Scroll to the section of data where the "switch open" mark was placed.
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 mark.
3. Record the value displayed in the Meter dialog window in the Measured Voltage column of Data Table BT-4-L1. This value is also displayed at the right side of the screen, on the channel title.
4. Scroll to the section of data where the "switch closed" mark was placed.
5. Drag the red cursor so it is on the mark.
6. Record the value displayed in data table BT-4-L1. Add the correct units in the column title.

Table BT-4-L1: Data Table for Exercise 2 – Pull-Up Network

Vout: Pull-Up Resistor	
Condition	Measured Voltage (_____)
Switch Open	
Switch Closed	

Questions

1. Which logic state corresponds to the open switch?
2. Which logic state corresponds to the closed switch?
3. Why is the resistor necessary?

Exercise 3: Pull-Down Network

Aim: To understand how a pull-down resistor establishes a defined logic state and prevents a floating input when a switch is open.

Approximate Time: 20 minutes

Procedure

1. Connect the yellow lead to TPB2.
2. Reconfigure the circuit as a pull-down network with a 10kΩ pull-down resistor.

Hint: The resistor should always be connected from the output node directly to ground, so decide which switch to keep closed.

3. Leave the other switch open (OFF).
4. Press the red REC button in LabScribe to supply power to the circuit.
5. Place a mark in the recording “switch open”.

6. Record for 15-20 seconds.
7. Close the switch (ON).
8. Place a mark in the recording “switch closed”.
9. Record for 15-20 seconds.
10. Press STOP to stop the recording.
11. Re-save the data file.

Data Analysis

1. Scroll to the section of data where the “switch open” mark was placed.
2. Switch into single cursor mode. Drag the red cursor so it is on the mark.
3. Record this value in data table BT-4-L2.
4. Scroll to the section of data where the “switch closed” mark was placed.
5. Drag the red cursor so it is on the mark.
6. Record this value in data table BT-4-L1. Add the correct units in the column title.

Table BT-4-L2: Data Table for Exercise 3 – Pull-Down Network

Vout: Pull-Up Resistor	
Condition	Measured Voltage (_____)
Switch Open	
Switch Closed	

Questions

1. Compare the behavior to Part B.

2. Which logic state corresponds to the open switch?
3. Which logic state corresponds to the closed switch?

Exercise 4: Effect of Resistor Value

Aim: To understand how the value of a pull-up resistor affects circuit current, power consumption, and output voltage.

Approximate Time: 30 minutes

Procedure

1. Construct a pull-up network. Ensure the yellow pin is at the correct test point location.
2. Locate a 1 kΩ resistor, a 10 kΩ resistor, and then a 100 kΩ resistor.
3. Place the 1kΩ resistor for RC1.
4. Press the red REC button in LabScribe to supply power to the circuit.
5. Place a mark in the recording "1k".
6. Record for 15-20 seconds.
7. Press STOP to stop the recording.
8. Repeat steps 3-7 for the 10kΩ resistor and the 100kΩ resistor.
9. Be sure to re-save the data file.

Data Analysis

1. Scroll to the section of data where the "1k" mark was placed.
2. Record this value in data table BT-4-L3.
3. Repeat steps 1 and 2 for the 10kΩ and 10kΩ resistors.
4. Calculate current through each resistor when the switch is closed, and record these values in data table BT-4-L3.

Table BT-4-L3: Data Table for Exercise 4 – Effect of Resistor Value

Output Voltages of Pull-Up Network according to Various Resistor Values			
Resistor Value (_____)	Open-Switch Voltage (_____)	Closed-Switch Voltage (_____)	Closed-Switch Current (_____)
1			
10			
100			

Questions

1. Did the output voltage change significantly?
2. Which resistor consumes the least power, given that P = IV, where P is power, I is current, and V is voltage?
3. Why might extremely large pull-up resistors be undesirable?

Challenge Problem (Optional)

A pull-up resistor of 47 kΩ is connected to a 5 V supply.

1. Calculate the current when the switch is closed.
2. Calculate the power dissipated by the resistor.
3. Would this resistor consume more or less power than a 10 kΩ pull-up resistor?

Show all work.

Post-Lab Questions

1. What is a floating node?
2. How do we avoid having floating nodes?

3. Why might we sometimes want a pull-up resistor and other times want a pull-down resistor?
4. What would happen if a switch directly connected +5 V to ground without a resistor?
5. Compare the advantages and disadvantages of using 1 kΩ, 10 kΩ, and 100 kΩ pull resistors.
6. Describe one biomedical device that could benefit from pull-up or pull-down networks.
7. Explain how pull-up and pull-down resistors improve reliability in electronic systems.