Users Manual - Circuit Breaker and Switch Simulator

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1 Introduction

1.1 General Unit Description

The unit has the capability to simulate three devices simultaneously, on an individual scale they can be set to either simulate a switch or a breaker. As such the device's application is to test the control system that controls circuit breakers and switches. Where one would usually hook in a physical breaker and/ or switch one can now substitute this device. This removes the necessity of switching on or off a physical system while still providing a basis for testing the control system.

1.2 Dimensions

The case in which the three devices are house is 17.54 inches in length 14.21 inches in width and 7.16 inches in height. The case in which the devices are housed is rugged, dust and water resistant as it is a Pelican case designed for secure storage of fragile equipment.

1.3 Limitations

The device operates under the constraints established by input voltage limitations and intrinsic time delays. The device is also limited by its portable design due to the fragility of its internal construction, and its power requirements.

Input Voltage: Must be limited to a digital signal with a maximum of 140V. Anything beyond that may damage the microprocessor. NOTE: This unit was only tested for 48V, but designed for the specified nominal 125V DC.

Time Delay: Each device has an intrinsic time delay as the electronics and the programming require a minimum of $20ms \pm 10ms$. This means that the minimum time delay that can be set by the user shall not fall below 30ms.

Portability: Although the case is rugged and is designed by the manufacturer to withstand rough conditions, the internal construction that houses all of the components is not specifically designed to withstand a large amount of shock, dust or moisture. As such it is still advised that the device as a whole be handled with care. A second note on portability is that, no matter where the device is taken, it will still require 110V AC power for its operation.

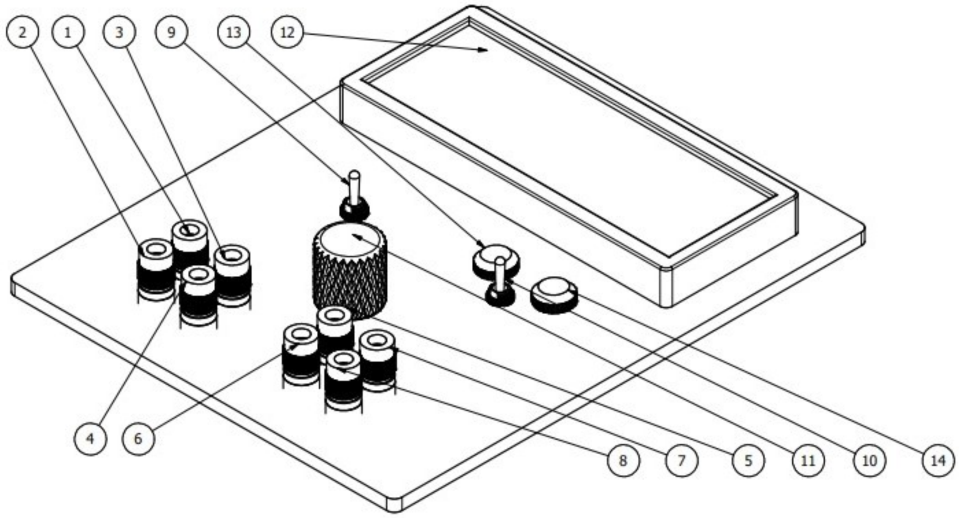
1.4 Documentation

Individual files regarding the programming of the internal Raspberry Pi Zero can be found on the GitHub page along with detailed schematics.

GitHub Link: https://github.com/timkos98/Circuit-Breaker-Switch-Simulator

2 Unit Familiarization

This section and its subsections provide background and definitions of parts and the user interface. They do *not* provide guidance for usage. Details pertaining to the operation of the unit are found in Section 3, "Device Simulator Operation"



User Interface Device List			
#	Type	Documentation Reference	Function
1	Bananna Jack - Red	IN_01_Pos_Open	48V/125V Positve Trip - digital input
2	Bananna Jack - Black	IN_02_Neg_Open	48V/125V Negative Trip - digital input
3	Bananna Jack - Red	IN_03_Pos_Close	48V/125V Positve Close - digital input
4	Bananna Jack - Black	IN_04_Neg_Close	48V/125V Negative Close - digital input
5	Bananna Jack - Red	OUT_01_Pos_Open	52A - dry output contact
6	Bananna Jack - Black	OUT_02_Neg_Open	52A - dry output contact
7	Bananna Jack - Red	OUT_03_Pos_Close	52B - dry output contact
8	Bananna Jack - Black	OUT_04_Neg_Close	52B - dry output contact
9	3-Position switch	UIN_01_Dev_Slct	User selection of simultion type (Left) switch, (center) standby, (right) breaker
10	3-Position switch (auto-return to center)	UIN_02_Ovrd	User manual override - allows manual closing of output relays to either report opened or closed postion to output contacts (left) override to open, (center) functionally unassigned, (right) override to closed
11	Dial with rotation feedback	UIN_03_Dly	User selection of time delay to simulate
12	Multi-Line LCD	DSP_01	4x20 pixel LCD to show simulation details
13	Green LED	IND_01	Indicates green if output is reporting open
14	Red LED	IND_02	Indicated red if output is reporting closed

Figure 1: Overview of the individual device simulator

The device consists of three simulation devices that are to be used completely independent of one another. Individually considered, their operation is demonstrated in the following section. Device operation is the same from one device to the next.

2.1 Indicator lights

These are located above the override switch and are shown by items #13 and #14 in Figure 1). When the green light (item #13) is illuminated, the device is simulating a trip/ open mode which is also the default for any of the device simulators on startup. When the red light (item #14) is illuminated, the device is simulating a closed position.

2.2 Displays

The unit houses 3 device simulators, as such there are three displays that will display information and instruction once the device has gone through its boot up sequence. See Figure 2 for a photo of how an active (device on) display may appear for a single simulator device. On an individual device simulator basis, the screen displays information in the order as shown:

Line 1: Simulation type

Line 2: A note on how to cycle between that delays that can be adjusted

Line 3: The currently set **Open Delay**

1. The character in the square brackets shows the status of the selection
2. The number to the right of the status is the corresponding value of the Open Delay

Line 4: The currently set **Close Delay**

1. The character in the square brackets shows the status of the selection
2. The number to the right of the status is the corresponding delay value

Figure 2: Simulator display example image

The status character located between square brackets can only be one of: **L, 1, 2,** or **3**. Their respective meanings are shown below.

- `[L]` = value is locked
- `[1]` = left most digit is unlocked
- `[2]` = middle digit is unlocked
- `[3]` = right most digit is unlocked

2.3 Simulation modes

Each device of the three simulators included in the package may be individually adjusted as described in this and the following sections. As a brief overview: Setting into "switch" mode will put the delay units into seconds (s) whereas "breaker" mode will have units of milliseconds (ms). The values that are set in either mode are saved between cycling from **breaker** to **switch** or vice versa, so they only have to be set once if it is desired to frequently cycle between the two.

2.3.1 Switch

Placing the device selector switch (item #9 in Figure 1) in the left position places the device in the **switch** simulation mode. In this position, the units of the configurable time delay are set to seconds. The delay time in this mode may only be configured to be between 0.02s to 9.99s. The value that is set for the time delay is then saved for the **switch** simulation and is not changed when switching to **breaker** simulation mode.

2.3.2 Breaker

Placing the device selector switch (item #9 in Figure 1) in the right position places the device in the **breaker** simulation mode. In this position, the units of the configurable time delay are set to milliseconds. The delay time in this mode may only be configured to be between 20ms to 999ms. The value that is set for the time delay is then saved for the **breaker** simulation and is not changed when switching to **switch** simulation mode.

2.4 Unlocking and Adjusting delay values

Pushing down on the dial will unlock the delay values digit by digit. The [L] signifies the locked position and then, moving from left to right, [1] signifies that the first digit of the number is unlocked and can be adjusted. [2] signifies that the second digit can be adjusted, and [3] signifies that the last, or furthest right, digit can be adjusted. Once all of the digits have been moved through in the Open Delay line another press of the dial will unlock the first value of the Close Delay line, in which an identical process as the above may be followed to lock in the desired close delay.

2.5 Trip and Close Overrides

The trip and close overrides are accessible through the toggling of the manual override switch (item #10 in Figure 1).

Trip (open): Accessed when the the manual override switch is toggled to the left position. When this is toggled the device will enter open position and will remain there until either a close override is applied or the switch is returned to ”auto” mode and the device reacts to an input signal.

Auto-mode: Accessed when the manual override switch is toggled to the center position. In this mode the delays that have been set by the user will be applied to the output upon detection of an input signal.

Close: Accessed when the manual override switch is toggled to the right position. When this is toggled the device will enter closed position and will remain there until either a trip/open override is applied or the switch is returned to ”auto” mode and the device reacts to an input signal.

2.6 Output terminal behavior

The right cluster of Banana jacks are the output sets. These contacts are dry contacts and are either in a closed or open position at all time.

The left set (item #5 and #6 in Figure 1) correspond to the behaviour of the 52A auxiliary contacts found on breakers and switches. This means that they follow the status of the device that is being simulated.

The right set (item #7 and #8 in Figure 1) correspond to the behaviour of the 52B auxiliary contacts found on breakers and switches. This means the they follow the opposite of the status of the device that is being simulated.

3 Device Simulator Operation

The following sections describe the steps that need to be taken to adjust the individual device simulators for a certain application.

3.1 Interfacing with the Device Simulators

Attaching connections to the device simulators can be done one of two ways: Through the use of Banana jacks or by using the screws clamp functionality of the binding posts. To access the screen connectors simply rotate any one of the jacks counterclockwise to loosen and clockwise then to tighten.

3.2 Adjusting the Time Delay

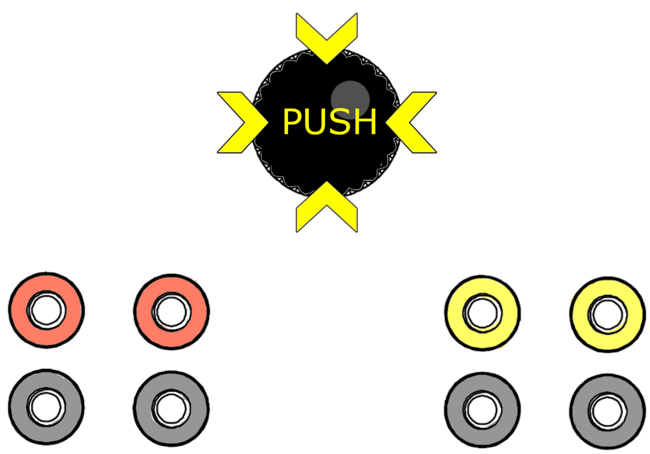


Figure 3: Cycling between digits

1. Use the dial depress function to change the status of the selection until it is indicating that you have selected the correct digit of the delay that you want to change (Figure 3).
2. Rotate the dial clockwise to increase the value of the digit (Figure 4) or counterclockwise to decrease the value of the digit (Figure 5).

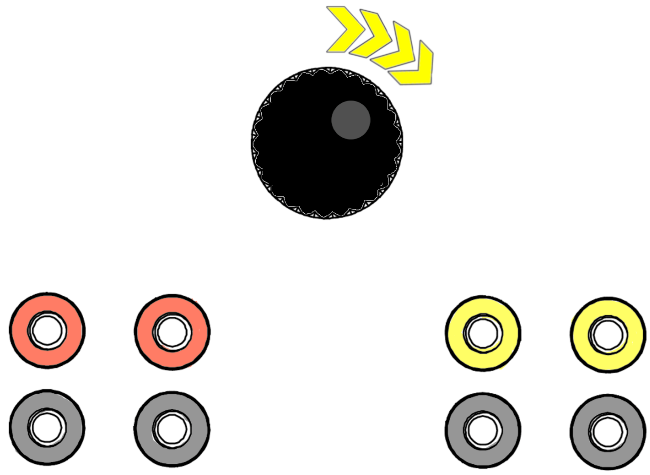


Figure 4: Increasing the digit

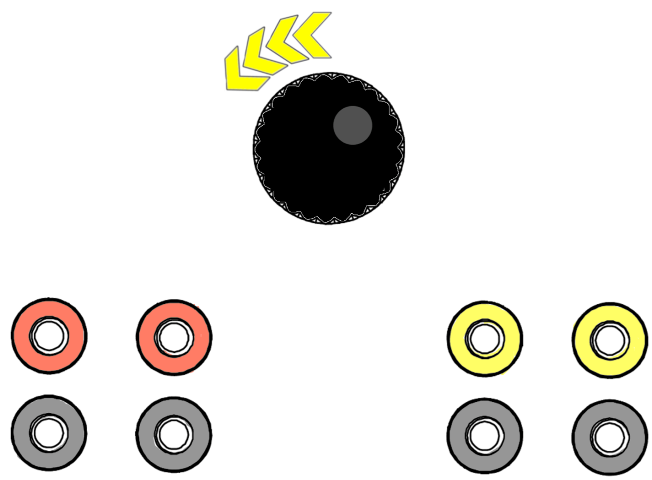


Figure 5: Decreasing the digit

*Keep in mind that there is no limit on the digits so even if you have selected the second digit, for example, turning clockwise past 9 will result in an increase of the first digit.

3. Continue cycling through the digits until the first selection status indicates that **Open Delay** is locked and the last line, **Close Delay** is unlocked.

4. Adjust each digit to your liking.

5. Once the adjustment has completed return all delay back into their locked position or continue past this point by depressing the dial once more to restart the adjustment process

3.2.1 Resetting the Time Delay

Depress and hold down the dial in (Figure 3) for more than *2 seconds*. This will reset all values in the current simulation back to their predefined default values.

3.3 Simulating a Switch

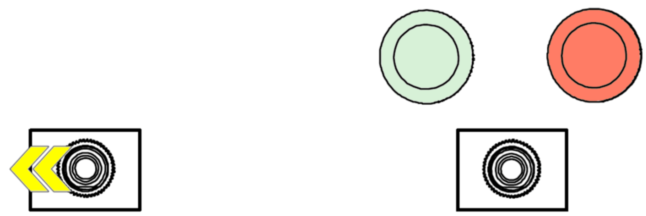


Figure 6: Simulating a Switch

1. Place device selector switch in left position (Figure 6).
2. Adjust delay to desired value (see section 3.2).

Once the above steps have been completed the device simulator will already be ready to receive and react to an input signal.

3.4 Simulating a Breaker

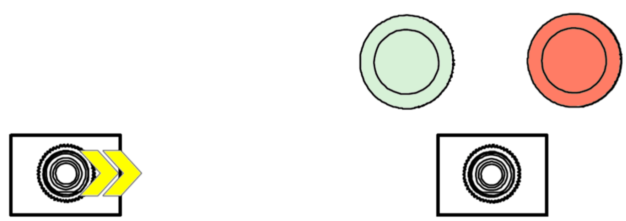


Figure 7: Simulating a breaker

1. Place device selector switch in right position (Figure 7).
2. Adjust delay to desired value (see section 3.2)

Once the above steps have been completed the device simulator will already be ready to receive and react to an input signal.

3.5 Initiating Overrides

Trip (open): Push override switch into left position and release. The green indicator light should confirm that the device simulator is now in open position (Figure 8).

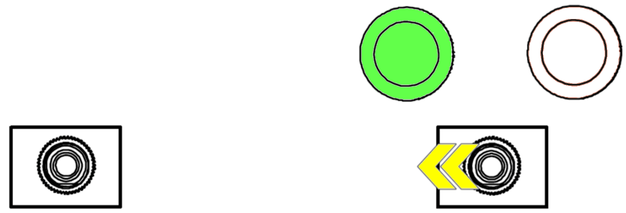


Figure 8: Initiating Trip (open) Override

Auto-mode: Default operation mode when override switch is in center position.

Close: Push override switch into right position and release. The red indicator light should confirm that the device simulator is now in closed position (Figure 9).

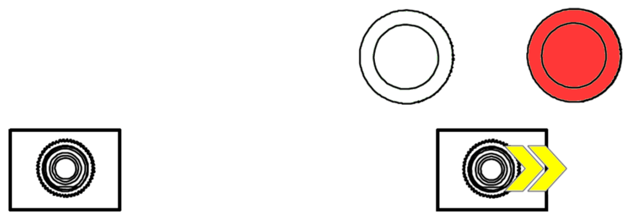


Figure 9: Initiating Close Override

4 Maintenance

In general there is no regular upkeep required. However this is a prototype that could be sensitive to rough conditions. In the case that functionality seizes please follow the instructions in the below found sections.

4.1 Opening the Unit

Before opening the unit ensure that it is disconnected from mains voltage and there are no connections made to the inputs or outputs of the device simulators

Tools required:

- 3mm Allen Wrench

There are four allen head screws that have to be removed before the Plexiglas and electronics can be lifted out of the case. When viewing from a top down angle, two of the screws can be found along the bottom edge of the Plexiglas and two along the top edge.

After removing the screws, carefully lift out the Device Simulator cluster by the two nobs located toward the left and right edges. **Be careful not to yank on any of the cable trees that my still be attached to the case!**

4.2 Replacing Fuses

There are 4 fuses in total that can be replaced or checked directly on the backside of the unit's case.

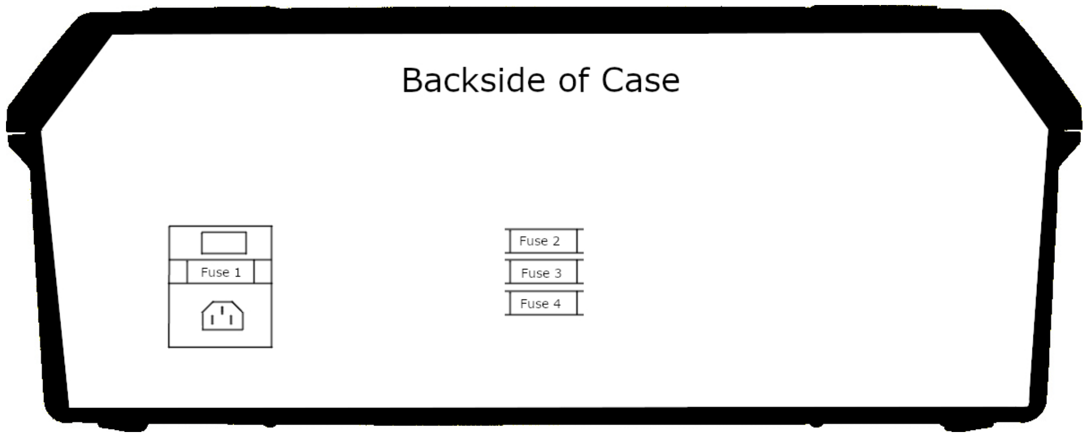


Figure 10: Backside view of Fuse locations

4.3 Replacing or Upgrading Microprocessor

The Raspberry Pi may be conveniently replaced or upgraded. As of the Raspberry Pi 4, the pin assignments for all Raspberry Pi models are identical (see Figure 11); therefore, they need only to be unplugged and substituted with their replacement models.

The device simulators are equipped with Raspberry Pi 3 B microprocessors at the time of this document's creation.

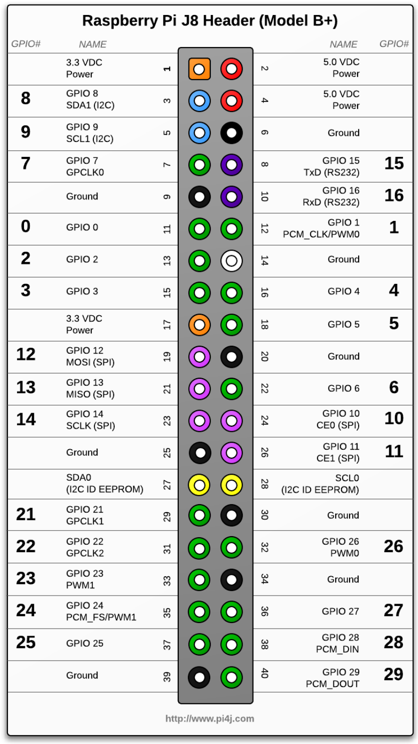


Figure 11: Raspberry Pi Pinout
SOURCE: https://pi4j.com/1.2/images/j8header-3a-plus.png

5 Troubleshooting

5.1 Single Device Simulator Not Turning On

Some steps to troubleshoot for this issue include:

- Turn on and off the device
- Checking the rear fuses on the case
- Searching for visual damage to any components through the plexiglass
- Opening the case and visually inspecting for any burnt wires or burnt sections on the circuit board or device wiring

5.2 Device Simulator Frozen

The quickest way to rectify this issue in the short term is to restart all three simulator devices via the on/off switch located on the back of the unit casing. The likely cause of this issue is from a data over-flow in the Raspberry Pi.

If this problem persists, consult Section 6.1.

5.3 Device Type Adjustable but Unresponsive to Delay Adjustments and Input Signals

This specific problem was only encountered during the testing of the simulator devices using a lower-grade microprocessor. It is unlikely to occur, but should this situation be encountered, it may be traced back the interrupt-handler in the source code.

Also, see Section 6.

6 Possible improvements

6.1 Programming

The source code for the device simulators may be improved in the following ways:

- Using a real-time operating system
- Translating the existing source code to C or C++

6.2 Microprocessor

The Raspberry Pi microprocessors for each of the device simulators may be switched out and upgraded with more current versions as they become available. These upgraded models will likely improve performance, such as shortening the simulator devices' startup time.

6.3 Voltage Regulation

The addition of active input voltage regulation would ensure that the Raspberry Pi does not get any over-voltage on the IO pins. Anything above 3.3V runs a high risk of damaging the Pi.

Appendix

A Schematic