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Nuvation Energy G5 Cell Connection Tester

NUVP-G5-CCT-24 Product Manual

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Table of Contents

The content in this document must be followed in order to ensure safe operation of Nuvation Energy BMS.

The G5 High-Voltage BMS is to be installed in a location with restricted access. Only **skilled persons** may install or service a system containing hazardous voltages that may be present when the system is energized.

Do **NOT** energize the G5 Cell Connection Tester until all connections to the cable harness have been made.

Verify the voltage difference between any two connections to the G5 Cell Connection Tester is less than 103.2 V **before** connecting the cable harness to the tester. The G5 Cell Connection Tester is only designed to be robust to wiring errors within a group of cells monitored by a single G5 Cell Interface module.

When probing the G5 Cell Connection Tester test points, ensure that the multimeter probe does not contact multiple test points. The G5 Cell Connection Tester does not provide any input protection between the Cell Voltage Inputs and the test points.

The G5 Cell Connection Tester discharges the battery cells that it is connected to; do not leave the G5 Cell Connection Tester connected for prolonged periods of time.

Insulated handling is required of any connector carrying potentials over 60 V DC relative to chassis.

Please be aware of high voltages present in your system and follow all necessary safety precautions.

The provided module enclosures are not fire enclosures.

1. Introduction

Thank you for choosing Nuvation Energy.

Designed specifically for lithium-ion battery chemistries, the Nuvation Energy new fifth-generation Battery Management System supports up to 1500 V DC battery stacks and modules that use cells in the 1.6 V - 4.3 V range. The G5 High-Voltage BMS offers cutting edge features such as continuous cell balancing and the ability to manage 24 battery cells with each series connected G5 Cell Interface module.

The G5 Cell Connection Tester is a companion tool that can be used to detect wiring errors that could damage a G5 Cell Interface module.

1.1. About this Manual

This *Nuvation Energy G5 Cell Connection Tester: NUVP-G5-CCT-24 Product Manual* is a comprehensive manual, providing guidance on operating the Nuvation Energy G5 Cell Connection Tester.

We thrive on your feedback and what we build is driven by your input.
Please submit support tickets to support@nuvationenergy.com.

2. Product Overview

The Nuvation Energy G5 Cell Connection Tester (NUVP-G5-CCT-24) is a Nuvation Energy G5 High-Voltage BMS companion tool used to detect wiring errors in a *Cell Voltage and Temperature* harness that could damage a G5 Cell Interface.

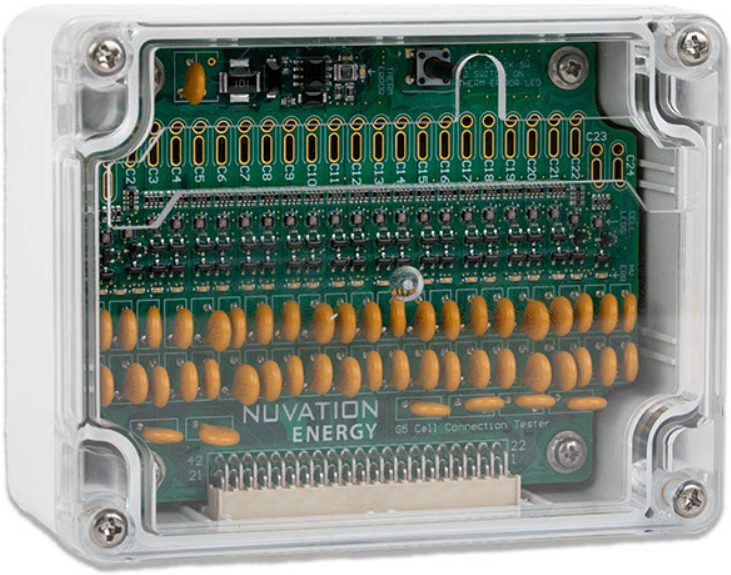


Figure 1. G5 Cell Connection Tester.

The external interfaces to this module are:

- Cell Voltage and Thermistor Connector
- Cell Voltage LEDs
- Cell Test Points
- Cell High Voltage Error LEDs
- Thermistor Error LED
- Thermistor Error Detection Self Check Switch

The G5 Cell Connection Tester connects to the battery stack-referenced signals through high voltage rated connectors. Safety precautions are required to handle and connect cables into this module.

2.1. Functional Overview

The G5 Cell Connection Tester provides a few external interfaces to determine if the connected cable harness can be connected to a G5 Cell Interface module without damaging it. If not, these interfaces can be used to characterize the wiring error.

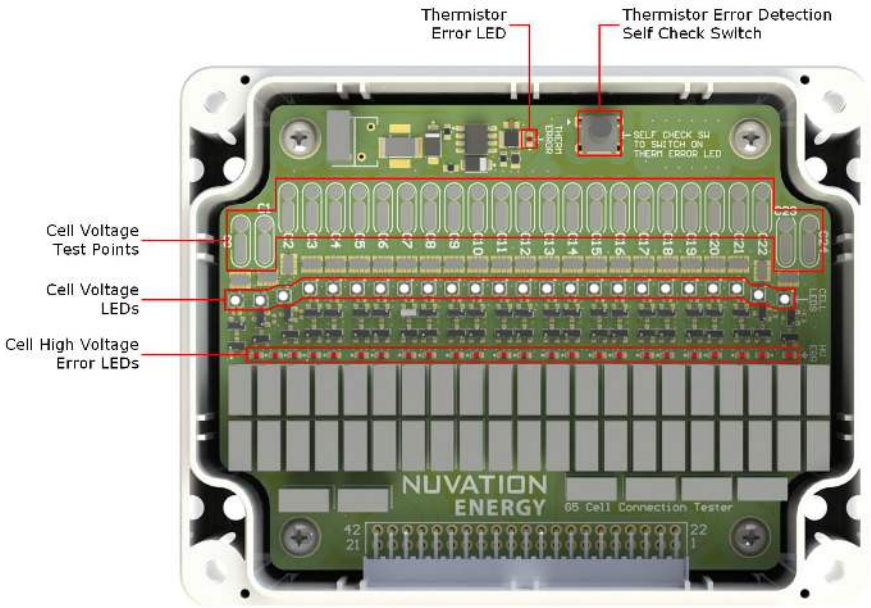


Figure 2. G5 Cell Connection Tester External Interfaces

Cell Voltage LEDs

Each Cell Voltage Input is associated with a Cell Voltage LED. If there is an undervoltage or negative voltage condition on a Cell Voltage Input, its Cell Voltage LED will be off. The Cell Voltage LED's color changes from red to white as its Cell Voltage Input increases from 1.6 V to 4.3 V.

Cell High Voltage Error LEDs

Each Cell Voltage Input is associated with a Cell High Voltage Error LED. If there is an overvoltage condition on a Cell Voltage Input that is significant enough to damage a G5 Cell Interface Module, its Cell High Voltage Error LED will be on.

Cell Voltage Test Points

Each Cell Voltage Connection passes through to an accessible test point on the G5 Cell Connection Tester. These test points are designed so that standard multimeter probes can be used to measure each Cell Voltage Input.

Thermistor Error LED

There is one Thermistor Error LED, which will be on if any Thermistor Input is shorted to a Cell Voltage that is significant enough damage a G5 Cell Interface Module.

Thermistor Error Detection Self Check Switch

To verify the health of the Thermistor Error Detection circuit, there is a Self Check Switch. When a cable harness is connected to the G5 Cell Connection Tester, press this button and verify that the Thermistor Error LED is on.

3. Operating Limits

Exceeding the maximum ratings will damage the G5 Cell Connection Tester.

Symbol	Parameter	Min	Typ	Absolute Max	Units
	Input Specifications				
$V_{(n)} - V_{(CI\_REF1-)}$	Voltage between any connection and CI_REF1-	0	-	103.2	V DC
$V_{(n)} - V_{(m)}$	Voltage between any two cell and/or temperature connections	-103.2	-	103.2	V DC
$I_{(cell)}$	Cell input current	-	-	362	mA DC
$I_{(temp)}$	Temperature input current	-	-	2	mA DC
	Thermal Specifications				
T_a	Operating Temperature	5	25	40	°C
	Storage Temperature	-30	25	60	°C
	Humidity Specifications				
RH	Operational RH	5	-	85	%
	Storage RH	5	-	85	%
	Shock and Vibration Specifications				
Vertical	Vertical Random Vibration (SAE J2380)	-	-	10	m/s^2
Longitudinal	Longitudinal Random Vibration (SAE J2380)	-	-	10	m/s^2
Transverse	Transverse Random Vibration (SAE J2380)	-	-	10	m/s^2
Pulse Vibration (Shock)	On each axis (SAE J2464)	-	-	245	m/s^2

4. Mechanical Overview

The overall dimensions of the G5 Cell Connection Tester are 115 mm x 90 mm x 55 mm.

The G5 Cell Connection Tester weighs approximately 250 g. It does not include mounting features and is not intended to be permanently installed in an end-application.

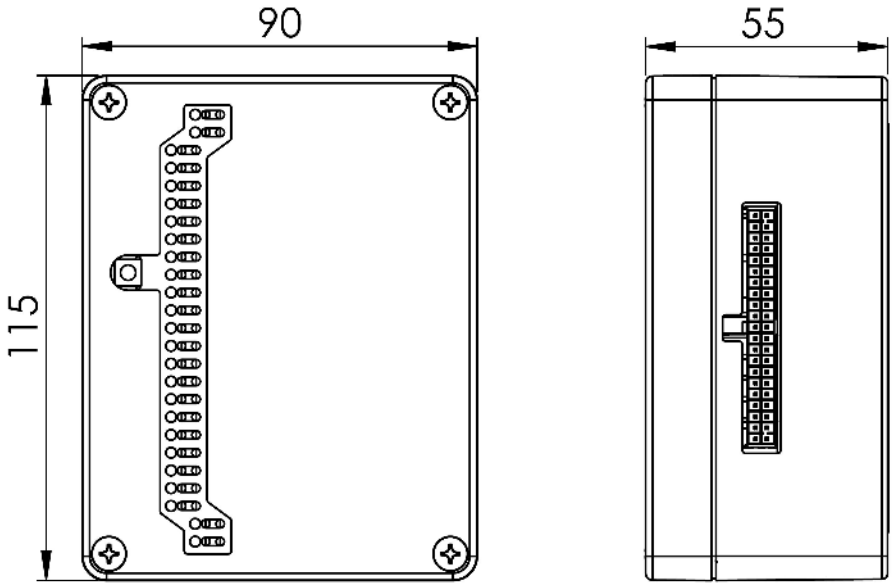


Figure 3. Mechanical Drawing of G5 Cell Connection Tester

Please contact support@nuvationenergy.com for access to CAD files.

5. Operating Instructions

5.1. Electrical Overview

The G5 Cell Connection Tester connects to the battery stack-referenced signals through high-voltage rated connectors. Safety precautions are required to handle and connect cables into this module.

Verify the voltage difference between any two connections to the G5 Cell Connection Tester is less than 103.2 V **before** connecting the cable harness to the tester. The G5 Cell Connection Tester is only designed to be robust to wiring errors within a group of cells monitored by a single G5 Cell Interface module.

A G5 Cell Interface connects to battery stack-referenced signals through its Cell Voltage and Temperature Cable. The cell voltage wires in this cable connect to the battery voltage sense leads to provide cell voltage inputs and a means for balancing the cells. The temperature wires in this cable provide 10 kΩ NTC thermistors for temperature measurement of the cells and/or surrounding area. It is recommended to use thermally conductive/electrically non-conductive epoxy to adhere the thermistors to the cells.

To use the G5 Cell Connection Tester, connect a Cell Voltage and Temperature cable to the battery cells. All 25 battery voltage sense leads must be connected to cell terminals, and up to 8 thermistors can be installed in the system. After installing this cable, connect it to the G5 Cell Connection Tester.

Please refer to the *Nuvation Energy G5 High-Voltage BMS: NUVG5 Product Manual* for more information about wiring and installing a Cell Voltage and Temperature Cable.

5.2. Connecting the Cable

Step 1: Wire the cable

Attach the voltage sensing ends of the cable to the battery cells and attach the thermistor sensors to monitoring locations.

Please refer to the *Nuvation Energy G5 High-Voltage BMS: NUVG5 Product Manual* for detailed instructions on wiring the Cell Voltage and Temperature Cable.

Table 1. G5 Cell Interface: Cell Voltage and Temperature Cable

Figure 4. Voltage and 2 Temperature Sensors Cable (NUVW-C23A15-020)

Figure 5. Voltage and 8 Temperature Sensors Cable (NUVW-C24A15-020)

Step 2: Connect cable to G5 Cell Connection Tester

Plug in the connector end of the G5 Cell Interface *Cell Voltage and Temperature* cable to the G5 Cell Connection Tester.

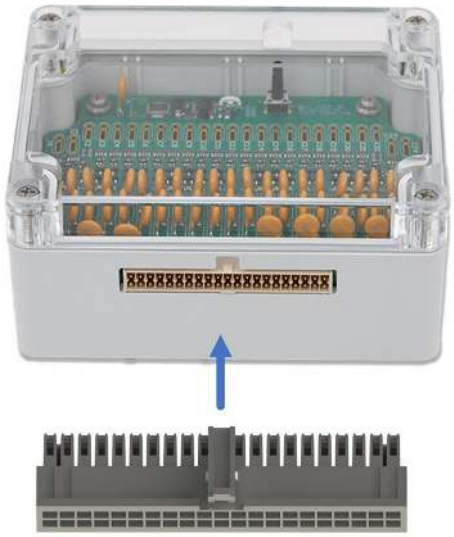


Figure 6. Connect *Cell Voltage and Temperature* cable

5.3. Verifying the Cable

The following checks must pass to verify that the *Cell Voltage and Temperature* cable is OK to connect to the G5 Cell Interface.

Overview of verification checks

- Check 1: Verify each Cell Voltage LED for a connected cell is **ON** and displays the appropriate color for the voltage input.
- Check 2: Verify each Cell Voltage LED for an unused cell is **OFF** and the input measures 0 V on a voltmeter.
- Check 3: Verify all High Voltage Error LEDs are **OFF**.
- Check 4: Verify the Thermistor Error LED is **OFF**.
- Check 5: Verify the Thermistor Error LED turns **ON** when Self Check is toggled.

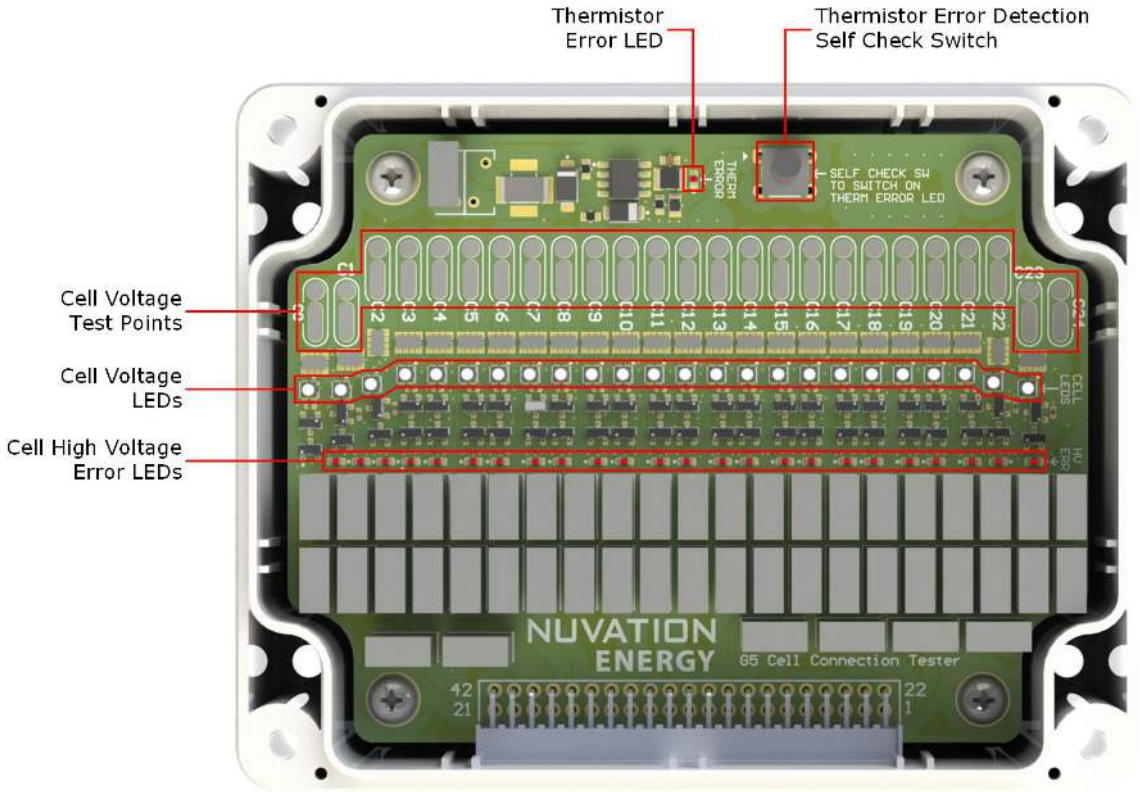


Figure 7. G5 Cell Connection Tester External Interfaces

Troubleshooting failures

If the *Cell Voltage and Temperature* cable doesn't pass the verification, please see Section 5.4, "Reviewing a Failed Cable Harness" for troubleshooting steps.

The operation of the G5 Cell Connection Tester along with the verification checks is described in the flowchart below:

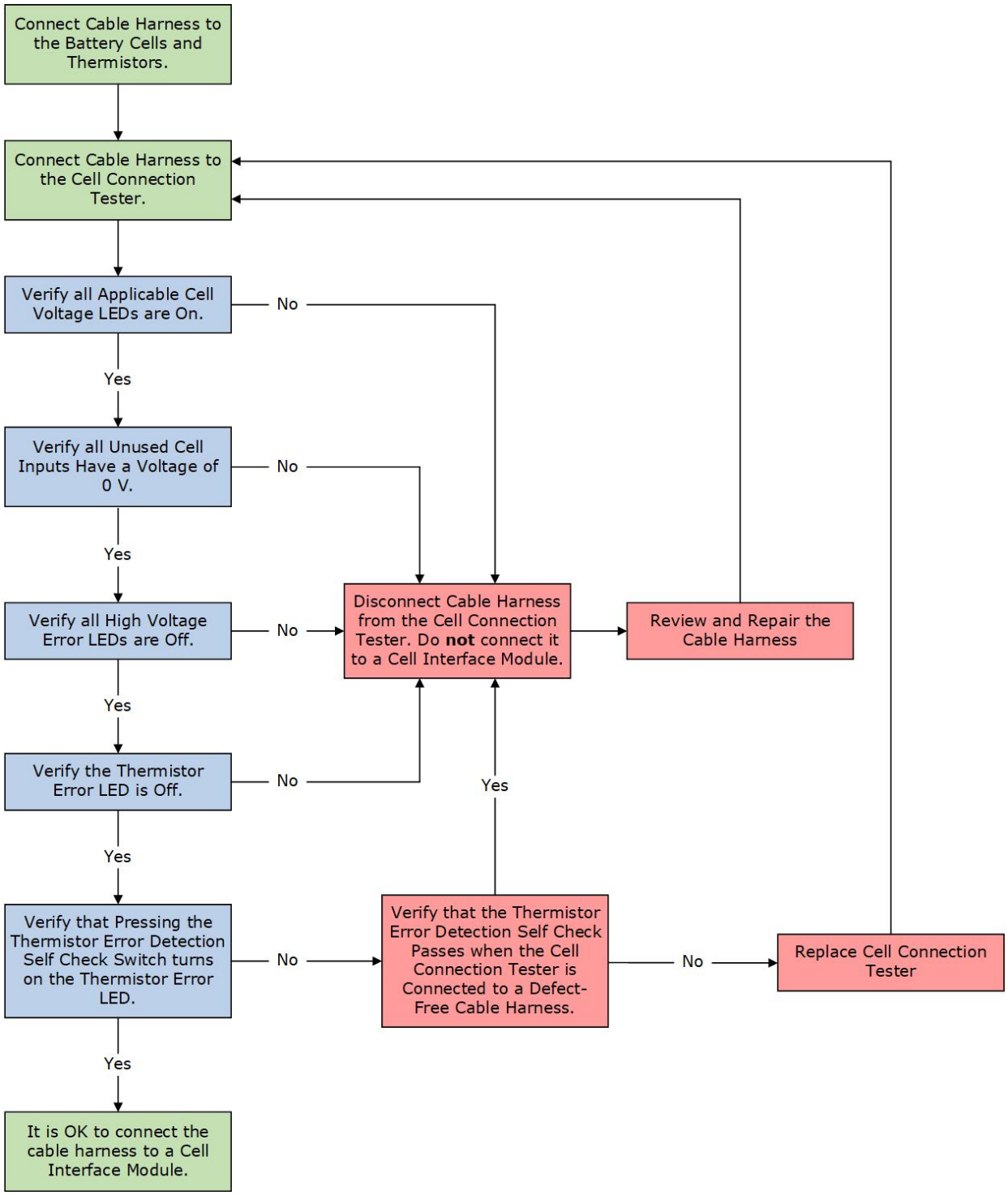


Figure 8. G5 Cell Connection Tester Operation Flowchart

5.3.1. Check 1: Verify applicable Cell Voltage LEDs are On

Each Cell Voltage Input is associated with a Cell Voltage LED. Verify that for each connected battery cell, its associated Cell Voltage LED is on and has an appropriate color. The Cell Voltage LED's color changes from red to white as its Cell Voltage Input increases from 1.6 V to 4.3 V. If there is an undervoltage or negative voltage condition on a Cell Voltage Input, its Cell Voltage LED will be off.

Figure 9. Cell Voltage LED Color Spectrum

If the G5 Cell Connection Tester is connected to a group of 24 battery cells, all 24 LEDs should be on, as shown in Figure 10, "Expected LEDs with 24 4.3 V Cells". With a cell voltage of 4.3 V, these LEDs will all be bright white.

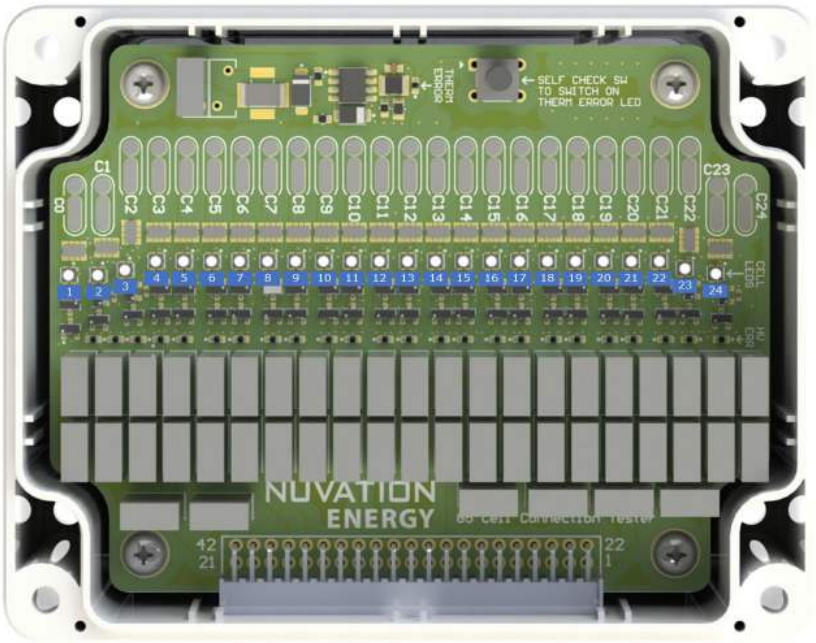


Figure 10. Expected LEDs with 24 4.3 V Cells

If the G5 Cell Connection Tester is connected to a group of 20 battery cells, the CELL10, CELL11 and CELL12 wires should all be connected to the positive terminal of battery cell 10. Likewise, the CELL22, CELL23 and CELL24 wires should all be connected to the positive terminal of battery cell 20.

This example, assuming that the group of cells all have voltages of 1.6 V, is shown in Figure 11, "Expected LEDs with 20 1.6 V Cells":

- Cell Voltage LEDs 1 through 10 are expected to be on (red as the cell voltages are 1.6 V)
- Cell Voltage LEDs 11 and 12 are expected to be off (cell voltages are 0 V)
- Cell Voltage LEDs 13-22 are expected to be on (red as the cell voltages are 1.6 V)

- Cell Voltage LEDs 23 and 24 are expected to be off (cell voltages are 0 V)

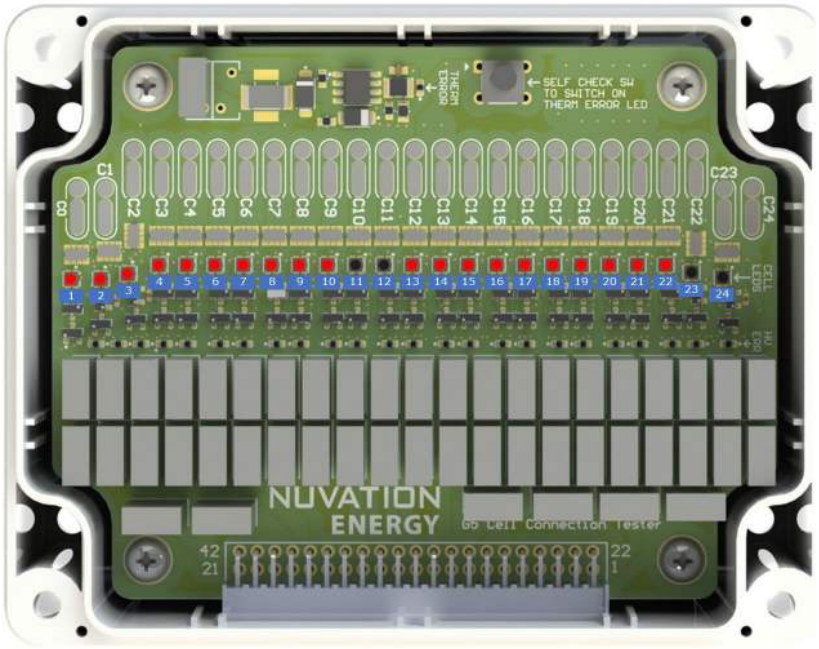


Figure 11. Expected LEDs with 20 1.6 V Cells

Figure 12, "Expected LEDs with CELL2 and CELL3 Swapped" shows the setup described above, with the CELL2 and CELL3 cell voltage inputs swapped. In this case, Cell Voltage LED 3 is unexpectedly off, indicating that CELL3 is experiencing an undervoltage or negative voltage condition. This error must be corrected before connecting the cable harness to a G5 Cell Interface module.

- Cell Voltage LED 1 matches the expected state shown in Figure 11, "Expected LEDs with 20 1.6 V Cells"
- Cell Voltage LED 2 is more yellow than expected:
  - CELL2 is connected to the positive terminal of battery cell 3
  - CELL1 is connected to the positive terminal of battery cell 1
  - CELL2 – CELL1 = 2 x 1.6 V = 3.2 V
- Cell Voltage LED 3 is off:
  - CELL3 is connected to the positive terminal of battery cell 2
  - CELL2 is connected to the positive terminal of battery cell 3
  - CELL3 – CELL2 = -1.6 V
- Cell Voltage LED 4 is more yellow than expected:
  - CELL4 is connected to the positive terminal of battery cell 4
  - CELL3 is connected to the positive terminal of battery cell 2
  - CELL4 – CELL3 = 2 x 1.6 V = 3.2 V
- Cell Voltage LEDs 5 through 24 match the expected states shown in Figure 11, "Expected LEDs with 20 1.6 V Cells"

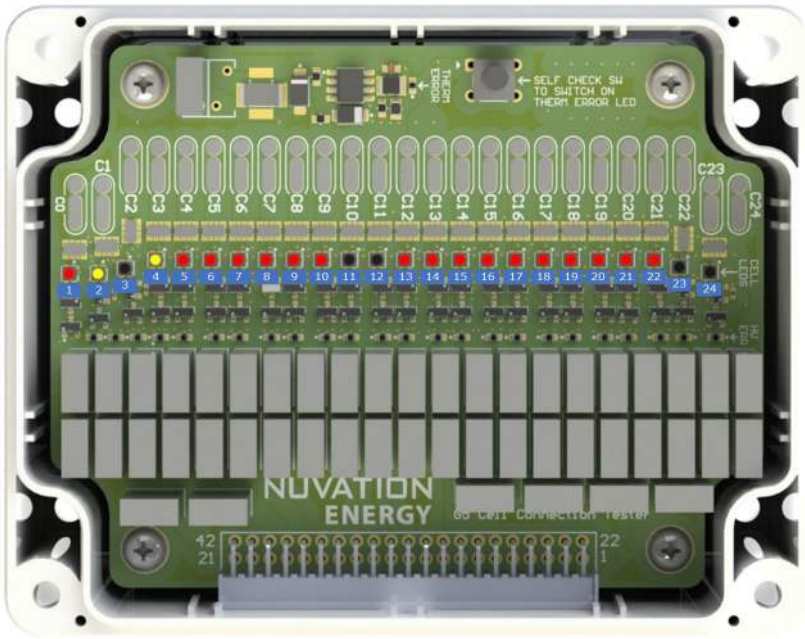


Figure 12. Expected LEDs with CELL2 and CELL3 Swapped

While all Cell Voltage LEDs will be off if their cell input is experiencing an undervoltage or negative voltage condition, the first or last Cell Voltage LED could also be unexpectedly off due to an open wire fault. For instance, in Figure 13, "Expected LEDs with CI_REF1- Open Wire Fault", CI_REF1- has an open wire fault, meaning that the G5 Cell Connection Tester is not connected to the negative terminal of battery cell 1. Likewise, the last LED would be off if there was no connection between the G5 Cell Connection Tester and the positive terminal of the final battery cell.

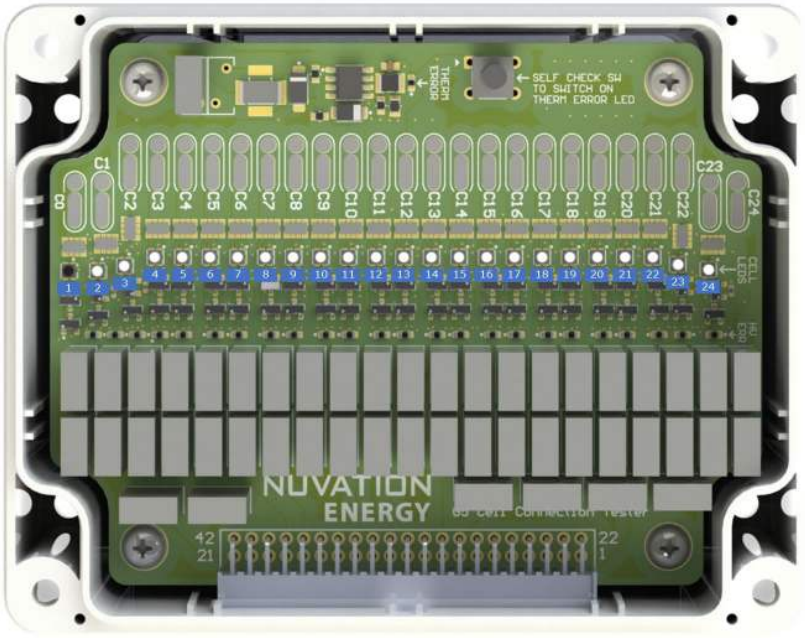


Figure 13. Expected LEDs with CI_REF1- Open Wire Fault

5.3.2. Check 2: Verify Unused Cell Inputs are 0 V

The Cell Voltage LEDs can be off if there is an undervoltage or negative voltage condition on the associated Cell Voltage Input. When a G5 Cell Interface module is configured to monitor less than 24 cells, some cells are unused, meaning that they have an expected cell voltage of 0V. This means that there is no change in LED state if one of these unused inputs is incorrectly wired to have a negative voltage condition. A voltmeter should be used to verify that any unused cell inputs are the expected 0V.

Figure 14, "Voltmeter Check with 20 Installed Cells" shows the 4 voltage measurements required if the G5 Cell Connection Tester is connected to a group of 20 battery cells. In this case, the CELL10, CELL11 and CELL12 wires should all be connected to the positive terminal of battery cell 10. Likewise, the CELL22, CELL23 and CELL24 wires should all be connected to the positive terminal of battery cell 20. If one or more measurement is not 0V, the cable harness has an error that must be corrected before it is connected to a G5 Cell Interface module.

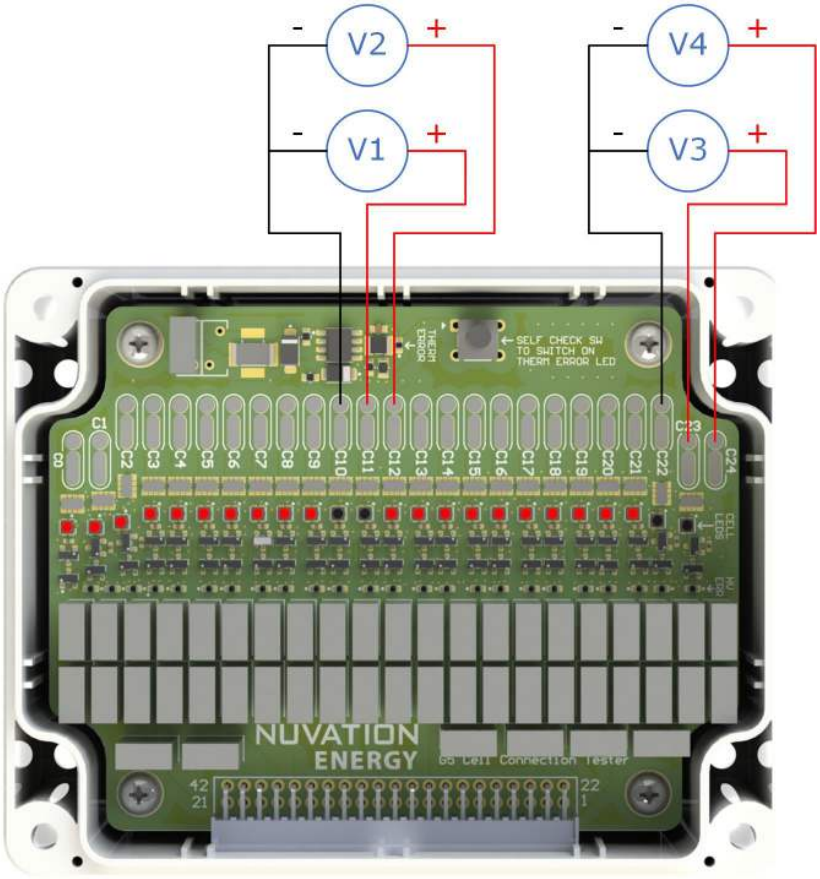


Figure 14. Voltmeter Check with 20 Installed Cells

5.3.3. Check 3: Verify Cell High Voltage Error LEDs are Off

Each Cell Voltage Input is associated with a Cell High Voltage Error LED. If there is an overvoltage condition on a Cell Voltage Input that is significant enough to damage a G5 Cell Interface Module, its Cell High Voltage Error LED will be on.

Figure 15, "All Cell High Voltage Error LEDs are Off" shows a G5 Cell Connection Tester with no Cell High Voltage Error LEDs turned on.

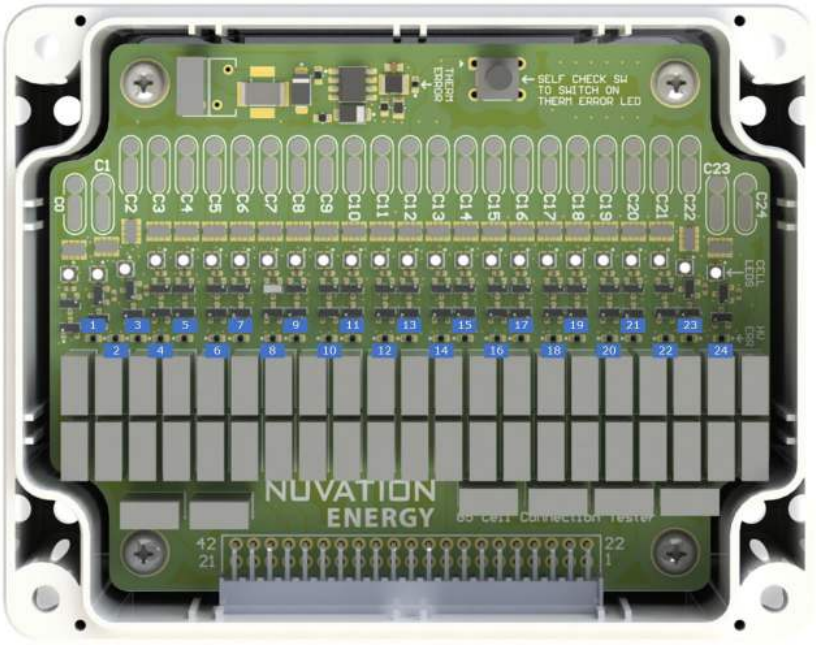


Figure 15. All Cell High Voltage Error LEDs are Off

Figure 16, "Cell 14 High Voltage Error LED On" shows a G5 Cell Connection Tester with an overvoltage condition on its Cell 14 input, as indicated by the Cell 14 High Voltage Error LED being on. This error must be corrected before connecting the cable harness to a G5 Cell Interface module.

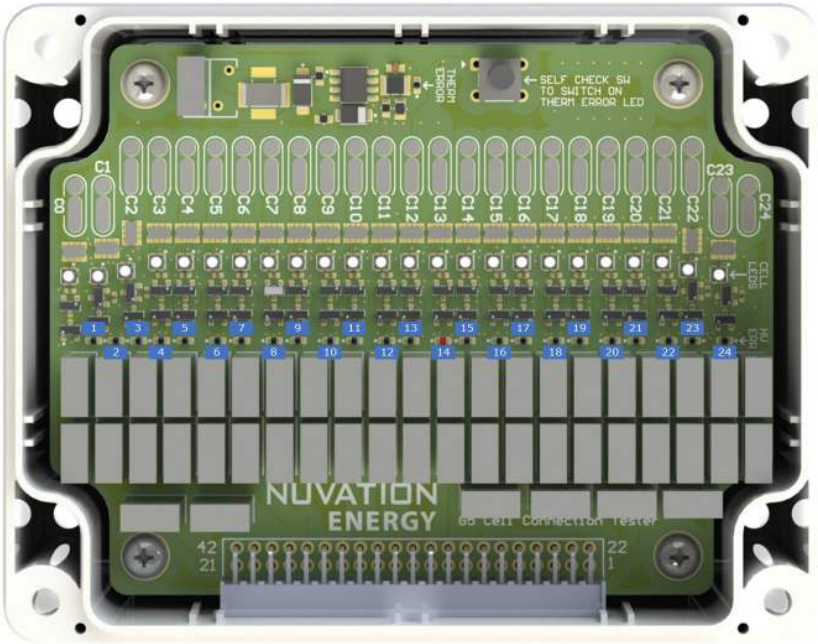


Figure 16. Cell 14 High Voltage Error LED On

5.3.4. Check 4: Verify Thermistor Error LED is Off

There is one Thermistor Error LED, which will be on if any Thermistor Input is shorted to a Cell Voltage that is significant enough damage a G5 Cell Interface Module. Verify that this LED is off when the cable harness is connected to the G5 Cell Connection Tester, as shown in Figure 17, "Thermistor Error LED is Off".

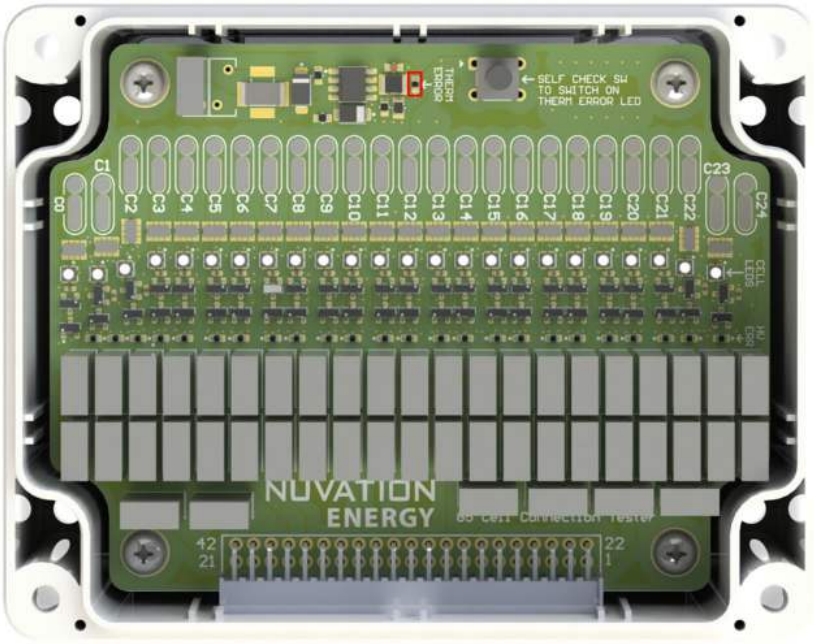


Figure 17. Thermistor Error LED is Off

Figure 18, "Cell Connection Tester with Thermistor Shorted to a Cell Input" shows a G5 Cell Connection Tester where one of the thermistor inputs are shorted to a cell input, as indicated by the Thermistor Error LED being on. This error must be corrected before connecting the cable harness to a G5 Cell Interface module.

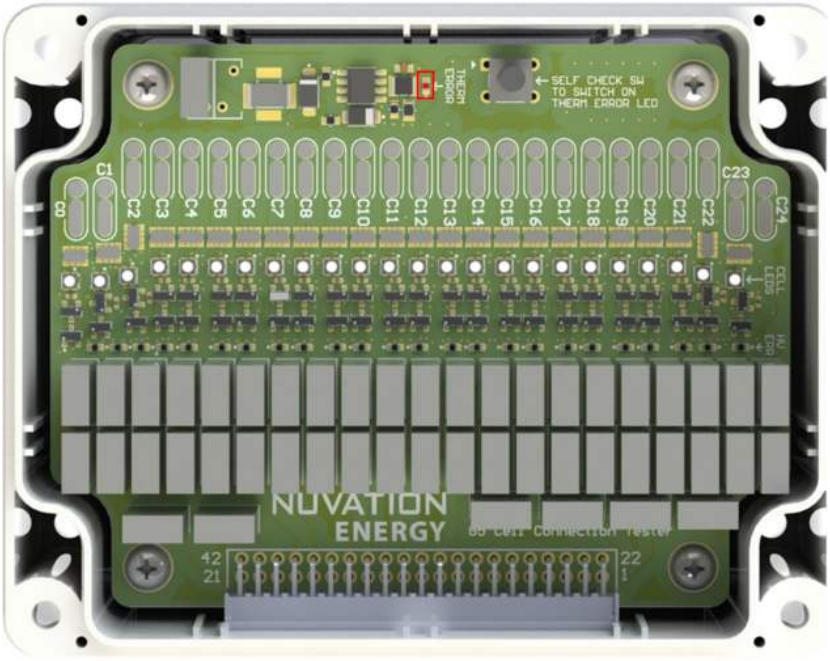


Figure 18. Cell Connection Tester with Thermistor Shorted to a Cell Input

5.3.5. Check 5: Verify Thermistor Error Detection Self Check Passes

To verify the health of the Thermistor Error Detection circuit, there is a Self Check Switch. To complete this self check protocol, verify that when the Self Check switch is pressed, the Thermistor Error LED switches on. This step should be completed on all cable harnesses that pass the previous checks, before they are connected to a G5 Cell Interface module.

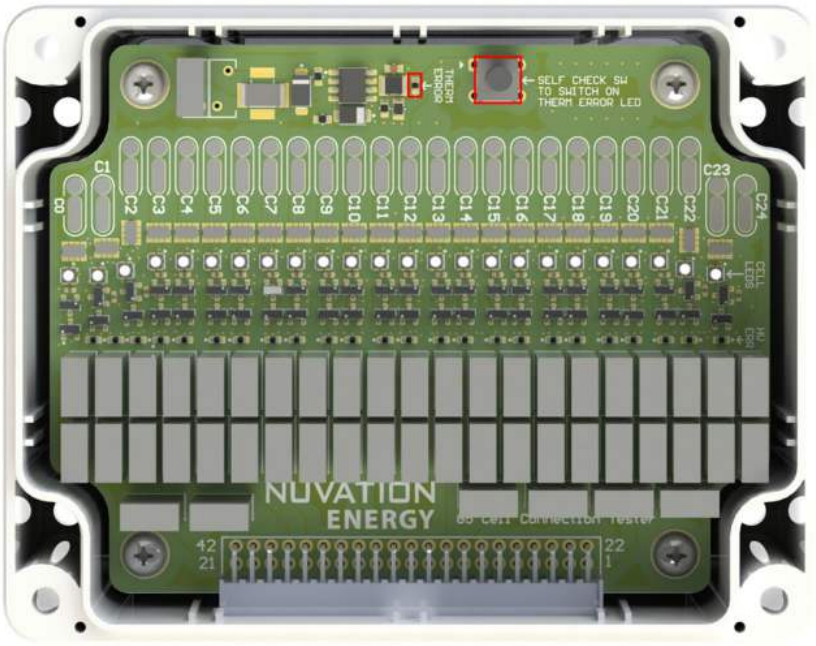


Figure 19. Expected Behavior with Self Check Switch Not Pressed

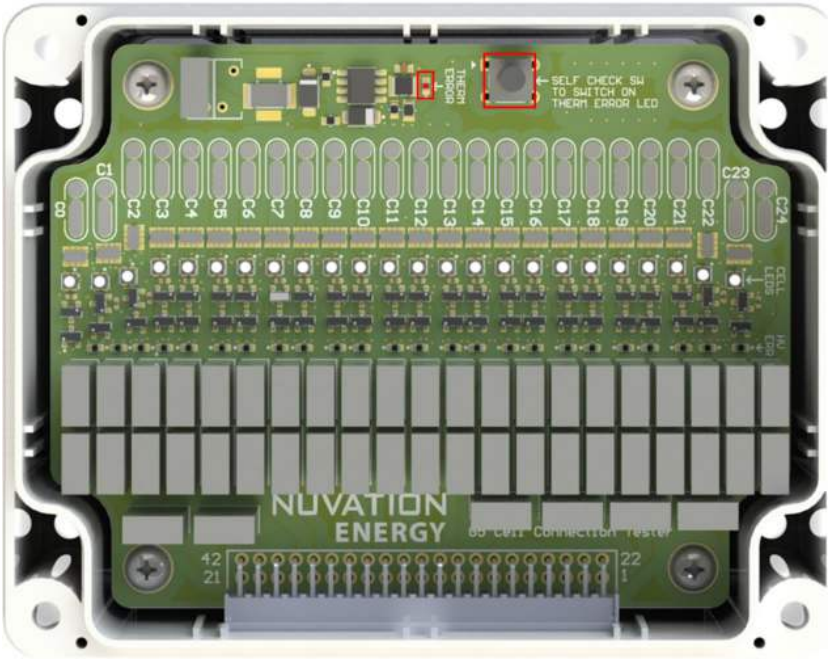


Figure 20. Expected Behavior with Self Check Switch Pressed

If the Thermistor Error LED does not switch on when the Self Check Switch is pressed, connect the G5 Cell Connection Tester to a cable harness that is known to be defect-free. If the G5 Cell Connection Tester's Self Check passes on the defect-free cable harness, review and repair the original cable harness. Otherwise, re-test the cable harness on a different G5 Cell Connection Tester.

5.4. Reviewing a Failed Cable Harness

The G5 Cell Connection Tester provides 25 test points, to assist with identifying wiring errors with the cell voltage inputs. Each test point directly connects to one of the Cell Voltage inputs.

> When probing the G5 Cell Connection Tester's test points, ensure that the multimeter probe does not contact multiple test points. The tester does not provide any input protection between the Cell Voltage Inputs and the test points.

It is recommended to use hook style test leads when probing the G5 Cell Connection Tester's test points.

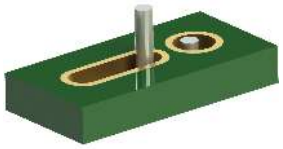


Figure 21. Hook Lead Probing G5 Cell Connection Tester

The test point designated C0 connects to the CI_REF1- input, while the test points designated C1 – C24 connect to the CELL1 – CELL24 inputs. To measure the voltage of the CELL14 input, place the voltmeter's negative lead on the C13 test point, and positive lead on the C14 test point, as shown in Figure 22, "Measuring CELL14 Voltage".

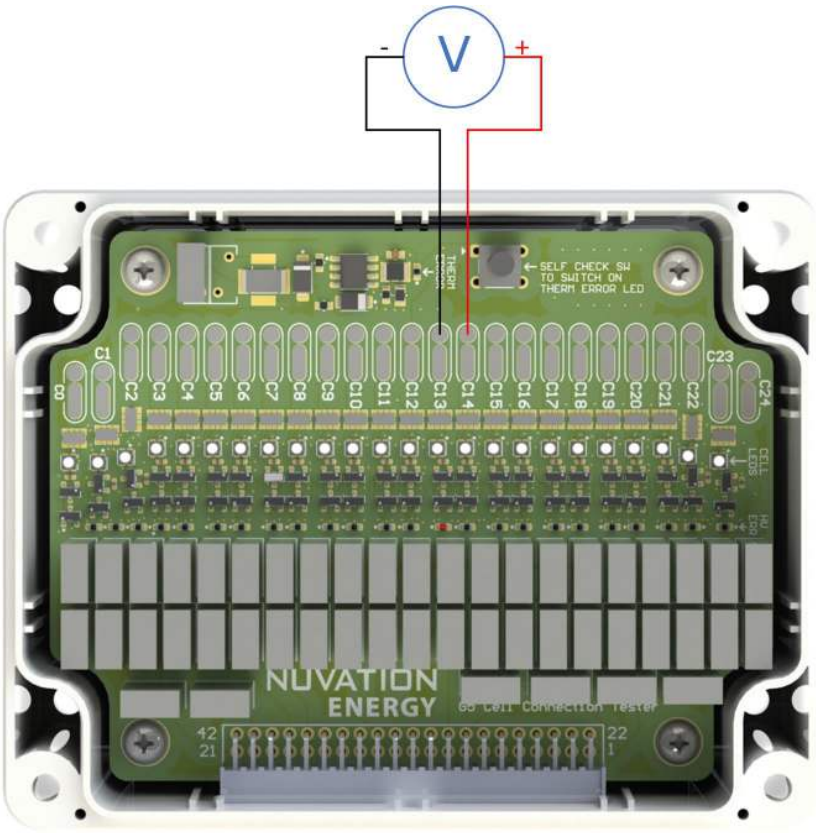


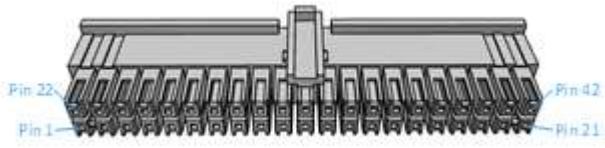
Figure 22. Measuring CELL14 Voltage

6. Ordering Information

Product Part Number	Product Name
NUVP-G5-CCT-24	Part, G5 Cell Connection Tester, 24 channel

This product is available for purchase online at https://nstore.nuvationenergy.com.

Appendix A: G5 Cell Interface Cell Voltage and Temperature Connector



Samtec IPD1-21-D-K	
Manufacturer	Samtec Incorporated
Housing	IPD1-21-D-K
Housing material	Nylon UL94V-0
Circuits	42
Crimp terminal	CC79L-2024-01-L
Wire gauge range	AWG20-24 stranded

Table 2. Cell Voltage and Temperature Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	CELL23+	Cell 23 voltage sense	Connect to positive terminal of Cell 23
2	CELL24+	Cell 24 voltage sense	Connect to positive terminal of Cell 24
3	*Reserved – Do not populate*		
4	TEMP1	External temperature probe input 1	10 kΩ NTC Thermistor #1
5	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #1
6	TEMP2	External temperature probe input 2	10 kΩ NTC Thermistor #2
7	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #2
8	TEMP3	External temperature probe input 3	10 kΩ NTC Thermistor #3
9	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #3
10	TEMP4	External temperature probe input 4	10 kΩ NTC Thermistor #4
11	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #4
12	TEMP5	External temperature probe input 5	10 kΩ NTC Thermistor #5
13	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #5
14	TEMP6	External temperature probe input 6	10 kΩ NTC Thermistor #6
15	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #6
16	TEMP7	External temperature probe input 7	10 kΩ NTC Thermistor #7
17	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #7
18	TEMP8	External temperature probe input 8	10 kΩ NTC Thermistor #8
19	TCOM	External temperature probe reference	10 kΩ NTC Thermistor #8
20	CI_REF1-	Bottom reference of G5 Cell Interface	Connect to negative terminal of the lowest cell (Cell 1)

Pin	Connection	Description	Connected to Device
21	CELL1+	Cell 1 voltage sense	Connect to positive terminal of the lowest cell (Cell 1)
22	CELL22+	Cell 22 voltage sense	Connect to positive terminal of Cell 22
23	CELL21+	Cell 21 voltage sense	Connect to positive terminal of Cell 21
24	CELL20+	Cell 20 voltage sense	Connect to positive terminal of Cell 20
25	CELL19+	Cell 19 voltage sense	Connect to positive terminal of Cell 19
26	CELL18+	Cell 18 voltage sense	Connect to positive terminal of Cell 18
27	CELL17+	Cell 17 voltage sense	Connect to positive terminal of Cell 17
28	CELL16+	Cell 16 voltage sense	Connect to positive terminal of Cell 16
29	CELL15+	Cell 15 voltage sense	Connect to positive terminal of Cell 15
30	CELL14+	Cell 14 voltage sense	Connect to positive terminal of Cell 14
31	CELL13+	Cell 13 voltage sense	Connect to positive terminal of Cell 13
32	CELL12+	Cell 12 voltage sense	Connect to positive terminal of Cell 12
33	CELL11+	Cell 11 voltage sense	Connect to positive terminal of Cell 11
34	CELL10+	Cell 10 voltage sense	Connect to positive terminal of Cell 10
35	CELL9+	Cell 9 voltage sense	Connect to positive terminal of Cell 9
36	CELL8+	Cell 8 voltage sense	Connect to positive terminal of Cell 8
37	CELL7+	Cell 7 voltage sense	Connect to positive terminal of Cell 7
38	CELL6+	Cell 6 voltage sense	Connect to positive terminal of Cell 6
39	CELL5+	Cell 5 voltage sense	Connect to positive terminal of Cell 5
40	CELL4+	Cell 4 voltage sense	Connect to positive terminal of Cell 4
41	CELL3+	Cell 3 voltage sense	Connect to positive terminal of Cell 3
42	CELL2+	Cell 2 voltage sense	Connect to positive terminal of Cell 2

Appendix B: Battery Topology Terminology

Energy storage systems are hierarchical in nature. Nuvation Energy has adopted the following definitions for battery pack topology:

Cell

A Cell is the smallest unit of energy storage distinguishable by the Battery Management System. One Cell, as defined from the perspective of the BMS, may actually consist of one or more electrochemical cells connected in parallel. This subtlety is reflected in the nomenclature for completeness. For example, a "1p" Cell refers to a single electrochemical cell, while a "2p" Cell refers to two electrochemical cells connected together in parallel. From the perspective of the BMS, these topologies appear identical except for the capacity of the Cells.

Group

A Group is a set of Cells connected in series and managed together. For example, 12 "1p" Cells in series are referred to as a "12s1p" Group, while 16 "2p" Cells in series are referred to as a "16s2p" Group. Grouping of Cells is highly application-specific and is defined in how BMS hardware interfaces are physically wired up to Cells.

Stack

A Stack is one or more Groups connected in series. For example, five "14s2p" Groups connected in series could be described as a "5g14s2p" Stack. However, it is far more common to describe it as a "70s2p" Stack.

Bank

A Bank is one or more stacks connected in parallel. For example, three "70s2p" Stacks connected in parallel are referred to as a "3x70s2p" Bank.

Pack

A Pack is one or more Banks connected in series.

From time to time Nuvation Energy will make updates to products in response to changes in available technologies, client requests, emerging energy storage standards, and other industry requirements. The product specifications in this document, therefore, are subject to change without notice.