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NUVATION BMS™

High Voltage Battery Management System

Installation Guide

2017-12-15, Rev. 1.8

Table of Contents

List of Tables

List of Figures

Important Safety Information

The content in this document must be followed in order to ensure safe operation of the Nuvation High-Voltage BMS™

Do NOT energize the system until all connections to the Cell Interface and Power Interface modules have been made.

Properly insulate or remove any unused wires. Unused wires can couple excessive system noise into the BMS which can disrupt communication and lead to undesirable behaviors.

Insulated handling is required of any connector carrying potentials over 600Vdc relative to chassis.

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

NOTE: The provided module enclosures are not fire enclosures.

WARNING: Depending on battery chemistry, there might be a nominal voltage per cell which adds up in series and is always present. There are many different battery chemistries with different current capacities, and so high voltage with high current capacity may be present while connecting the BMS. You must use proper electrical safety precautions when handling any part of the BMS. Neither Nuvation Energy or any of its employees shall be liable for any direct, indirect, incidental, special, exemplary, personal or consequential harm or damages (including, but not limited to, procurement or substitute goods or services; loss of use, data, or profits; or business interruption) however caused and on any theory of liability, whether in contract, strict liability, or tort (including negligence or otherwise) arising in any way out of the use of this product.

IMPORTANT NOTE: The BMS relies on your system charger to charge the battery cells; do **not** leave your charger off while the BMS is powered from the stack for prolonged periods of time. The BMS should be shut down when the system is in storage to minimize the drain on the cells.

Introduction

Thank you for choosing the Nuvation High-Voltage BMS™.

The Nuvation High-Voltage BMS™ is an enterprise-grade battery management system with features that extend battery life, ensuring pack-level safety, data-analytics, and remote management.

You can take advantage of the highly configurable browser-based user interface and custom-tune the Nuvation BMS™ to your specific target application.

About this Guide

This installation guide provides wiring instructions to connect your Nuvation High-Voltage BMS™ to your system.

Once you have successfully completed the installation process, please follow instructions in the *Nuvation BMS High-Voltage Firmware Reference Manual* for accessing and configuring the user interface.

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

System Overview

Nuvation High-Voltage BMS™ generally includes the following modules:

- 1 Nuvation BMS™ High-Voltage Stack Controller
- 1 Nuvation BMS™ High-Voltage Power Interface
- 1 or more Nuvation BMS™ High-Voltage Cell Interfaces

An example configuration is shown in Figure 1.

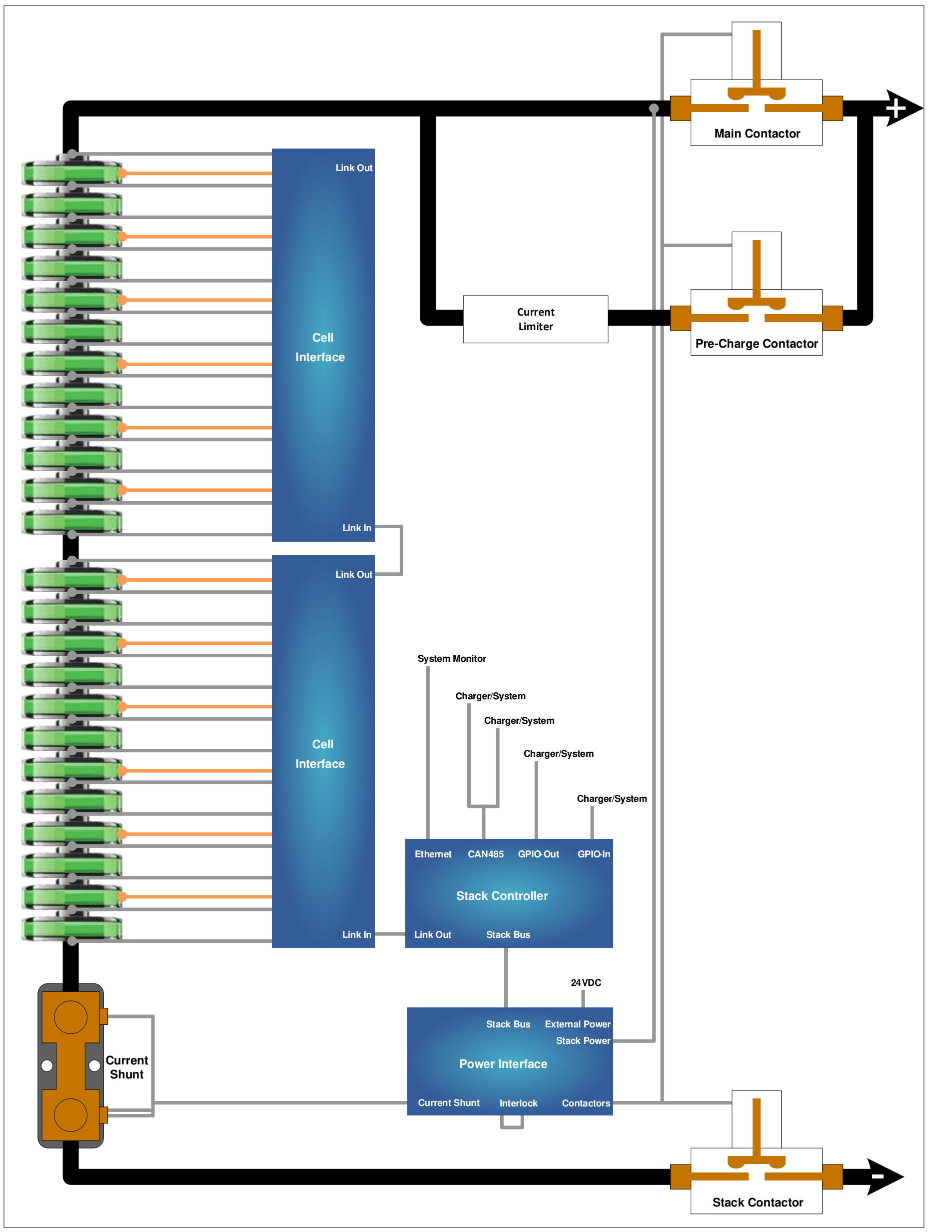


Figure 1: Nuvation High-Voltage BMS™ Example System Diagram

Factory Reset

In the unlikely event the BMS becomes inaccessible due to a forgotten password or invalid network configuration; a factory reset operation must be performed to restore the BMS to the default settings.

Follow the steps below to reset the BMS to factory defaults:

1. Remove External Power from the Power Interface and remove the Link Bus cable from the Stack Controller
2. Connect the Factory Reset cable to the Link Bus connector on the Stack Controller
    - If a Factory Reset cable is unavailable, connect an external 18-24V DC power supply to the Link Bus connector on the Stack Controller
      Note: pin 1 is positive and pin 2 is negative
3. Observe a blinking activity LED on the Stack Controller
4. Connect External Power to the Power Interface
5. Disconnect the Factory Reset cable from the Stack Controller
6. Wait for the blinking activity LED on the Stack Controller to stop blinking
7. Reconnect the Link Bus cable to the Stack Controller

The BMS should now be back to the factory firmware version, default password and default network configuration.

Nuvation High-Voltage BMS™ Modules

The Nuvation High Voltage BMS™ family includes several modules that operate together as a complete system:

- NUV100-SC - Stack Controller
- NUV100-PI - Power Interface
- NUV100-CI-12 - Cell Interface for 12 cells
- NUV100-CI-16 - Cell Interface for 16 cells
- NUV100-CI-4M12 - Cell Interface for 4x12V block

This section describes each module in detail.

Nuvation BMS™ High-Voltage Stack Controller

The Nuvation BMS™ High-Voltage Stack Controller (SC) module monitors and controls all Cell Interface modules in a single battery stack. The built-in Stack Bus receives power and communication from the Power Interface module. The Link Bus provides power and communication for all connected Cell Interface Modules. Ethernet, CAN, RS-485 (Modbus) and USB connections are included. No high-voltage or high-current interfaces are present on the SC, making this module easy and safe to connect to for service operations.

There is only one model of the SC.

Mechanical Dimensions

The overall dimensions of the SC are 104.4mm X 121.58mm X 40.6mm. It comes standard with DIN clips that enable the SC module to be securely mounted to EN50022-compliant DIN rails. The clips add an extra 19.6mm to the overall width of the SC module, bringing it from 104.4mm to 124mm. The clips also hold the module approximately 7mm away from the inside lip of the DIN rail. Extra space should be provided around the module to allow for easy installation/maintenance.

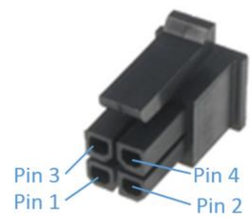
A more detailed mechanical drawing of the SC module is provided in Appendix A: Detailed Mechanical Drawings.

Electrical Connections

The SC module has 7 connectors. Each connector is described in the following sections in detail.

Link Out

The Link Out connector provides power and communication to the Cell Interface modules. The amount of current supplied by this connector is the sum of current consumed by all Cell Interface modules in the system. Connect the Cell Interface module which is measuring the most negative cell in the stack to this connector.



Molex 43025-0400	
Manufacturer	Molex Incorporated
Housing	43025-0400
Housing material	Nylon UL94V-0
Circuits	4
Crimp terminal	43030-0002
Wire gauge range	AWG20-24 stranded

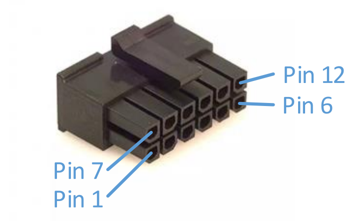
Figure 2: Molex Micro-Fit 3.0 Connector for Connection to Link Bus

Table 1: Link Bus Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	VBUS	DC power from SC, with Fault Pilot Signal	Cell Interface
2	COM	Power return from SC	Cell Interface
3	IPA	Link Bus differential pair plus	Cell Interface
4	IMA	Link Bus differential pair minus	Cell Interface

CAN 485

The CAN 485 connector contains both isolated CAN and non-isolated RS-485 (Modbus) connections. Isolated CAN requires 5.5-12V sourced from an external power supply to operate. 120Ω termination for CAN is added by connecting pins 3 and 9 together. 150Ω termination for Modbus is added by connecting pins 6 and 12 together. Keep the termination wire length short for best results. Connect external equipment to this connector.



Molex 43025-1200	
Manufacturer	Molex Incorporated
Housing	43025-1200
Housing material	Nylon UL94V-0
Circuits	12
Crimp terminal	43030-0002
Wire gauge range	AWG20-24 stranded

Figure 3: Molex Micro-Fit 3.0 Connector for Connection to External CAN and MODBUS

Table 2: CAN 485 Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	-V_isoCAN	Power return from Pin 7	External Equipment
2	CAN_N	CAN bus differential pair negative	External Equipment
3	EXTCAN_TERM1	Termination Resistor; Short to Pin 9 to add 120Ω bus termination	CAN 485 Connector
4	COM	Power return from SC	External Equipment
5	MODBUS_N	MODBUS differential pair negative	External Equipment
6	EXTMOD_TERM1	Termination Resistor; Short to Pin 12 to add 150Ω bus termination	CAN 485 Connector
7	+12V_isoCAN	+5.5~12V isolated CAN bus power	External Equipment
8	CAN_P	CAN bus differential part positive	External Equipment
9	EXTCAN_TERM2	Termination Resistor; Short to Pin 3 to add 120Ω bus termination	CAN 485 Connector
10	+VSYS	+24V Power supply	External Equipment
11	MODBUS_P	MODBUS differential pair positive	External Equipment
12	EXTMOD_TERM2	Termination Resistor; Short to Pin 6 to add 150Ω bus termination	CAN 485 Connector

USB

Contact Nuvation Energy for support if USB connectivity is desired for your specific application.

Ethernet

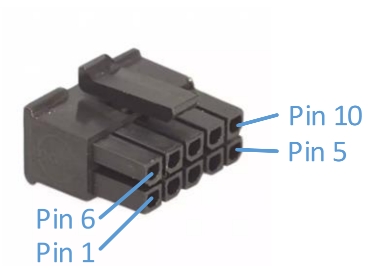
The Ethernet connector is a standard RJ45 Ethernet jack. Connect external equipment to this connector.

Table 3: Ethernet Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	TD_P	Transmit differential pair positive	External Equipment
2	TD_N	Transmit differential pair negative	External Equipment
3	RD_P	Receive differential pair positive	External Equipment
4	NUL45	Unused; connected to Pin 5 and terminated	External Equipment
5	NUL45	Unused; connected to Pin 4 and terminated	External Equipment
6	RD_N	Receive differential pair negative	External Equipment
7	NUL78	Unused; connected to Pin 8 and terminated	External Equipment
8	NUL78	Unused; connected to Pin 7 and terminated	External Equipment

GPIO-Out

The GPIO-Out connector provides four (4) general-purpose outputs. Four (4) independent solid-state relays are used to connect *_A pins to their corresponding *_B pins. Each output is rated for 60VDC, 200mA max., and the signals connected to each output must be within 50VDC from chassis/earth ground. There is no polarity dependency between *_A and *_B pins. Connect external equipment to this connector.



Molex 43025-1000	
Manufacturer	Molex Incorporated
Housing	43025-1000
Housing material	Nylon UL94V-0

Circuits	10
Crimp terminal	43030-0002
Wire gauge range	AWG20-24 stranded

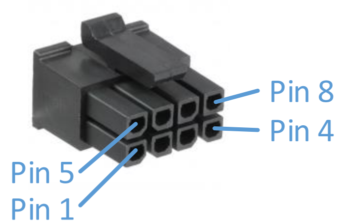
Figure 4: Molex Micro-Fit 3.0 Connector for General Connection to External Equipment

Table 4: GPIO-Out Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	GPO_ISO0_A	Digital Output 0	External Equipment
2	GPO_ISO1_A	Digital Output 1	External Equipment
3	GPO_ISO2_A	Digital Output 2	External Equipment
4	GPO_ISO3_A	Digital Output 3	External Equipment
5	COM	Power return from SC	External Equipment
6	GPO_ISO0_B	Digital Output 0	External Equipment
7	GPO_ISO1_B	Digital Output 1	External Equipment
8	GPO_ISO2_B	Digital Output 2	External Equipment
9	GPO_ISO3_B	Digital Output 3	External Equipment
10	No Connect	Not Connected	No Connect

GPIO-In

The GPIO-In connector provides four (4) general-purpose inputs. Four (4) independent detector circuits are used, driven by an on-board +5V source. Each detector's input is connected to its corresponding pin, and paired with a COM reference pin per input. When switched on by an external connection, each input will source about 12mA to COM. Connect external equipment to this connector; connect a pin to its corresponding COM to turn the input on.



Molex 43025-0800	
Manufacturer	Molex Incorporated
Housing	43025-0800
Housing material	Nylon UL94V-0
Circuits	8
Crimp terminal	43030-0002
Wire gauge range	AWG20-24 stranded

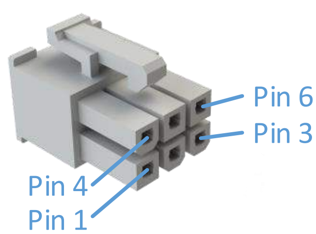
Figure 5: Molex Micro-Fit 3.0 Connector for General Connection to External Equipment

Table 5: GPIO-In Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	COM	Power return from SC for GPI0	External Equipment
2	COM	Power return from SC for GPI2	External Equipment
3	COM	Power return from SC for GPI3	External Equipment
4	COM	Power return from SC for GPI4	External Equipment
5	GPI_ISO0_K	Input detector 0	External Equipment
6	GPI_ISO1_K	Input detector 1	External Equipment
7	GPI_ISO2_K	Input detector 2	External Equipment
8	GPI_ISO3_K	Input detector 3	External Equipment

Stack Bus

The Stack Bus connector accepts power and provides a communication channel from the Power Interface module. The Stack Bus provides 42mA to the SC plus the summation of current consumed by all Cell Interface modules in the system (25mA per CI-12 or 31mA per CI-16). 120Ω termination must be added by connecting pins 1 and 3 together with a short length of wire. Connect the Power Interface module to this connector.



Molex 39-01-2065	
Manufacturer	Molex Incorporated
Housing	39-01-2065
Housing material	Nylon UL94V-0
Circuits	6
Crimp terminal	39-00-0181
Wire gauge range	AWG18-24 stranded

Figure 6: MiniFit Jr Connector for Connection to Stack Bus

Table 6: Stack Bus Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	TERM1	Termination Resistor; Short to Pin 4 to add 120Ω bus termination	Stack Bus Connector
2	STACKBUS_N	Stack bus differential pair negative	Power Interface
3	+VSYS	+24V Power Supply	Power Interface
4	TERM2	Termination Resistor; Short to Pin 1 to add 120Ω bus termination	Stack Bus Connector
5	STACKBUS_P	Stack bus differential pair positive	Power Interface
6	COM	Power return from SC	Power Interface

Nuvation BMS™ High-Voltage Cell Interface

The Nuvation BMS™ High-Voltage Cell Interface (CI) module connects to the battery cells and temperature sensors to monitor and balance the cells, and sends cell data to the SC, to prevent overheating or overcharging.

There are three models of the CI. The CI-12 can monitor up to 12 series-connected cells. The CI-16 can monitor up to 16 series-connected cells. The CI-4M12 can monitor up to 4 series-connected 12V lead-acid cells.

Mechanical Dimensions

The overall dimensions of the CI are 104.4mm X 121.58mm X 40.6mm. It comes standard with DIN clips that enable the CI module to be securely mounted to EN50022-compliant DIN rails. The clips add an extra 19.6mm to the overall width of the CI module, bringing it from 104.4mm to 124mm. The clips also hold the module approximately 7mm away from the inside lip of the DIN rail. Extra space should be provided around the module to allow for easy installation/maintenance.

The CI can also come in a bulkhead-mountable enclosure.

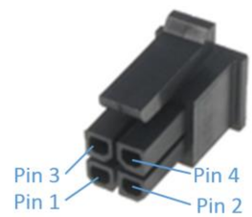
A more detailed mechanical drawing of the CI module is provided in Appendix A: Detailed Mechanical Drawings.

Electrical Connections

The CI module has four connectors. Each connector is described in the following sections in detail.

Link Out

The Link Out connector provides power and communication to the CIs above this CI. The amount of current supplied by this connector is the sum of current consumed by all CIs above this CI. Connect the CI that is measuring the next series-connected cell above the most positive cell connected to this connector.



Molex 43025-0400	
Manufacturer	Molex Incorporated
Housing	43025-0400
Housing material	Nylon UL94V-0
Circuits	4
Crimp terminal	43030-0002
Wire gauge range	AWG20-24 stranded

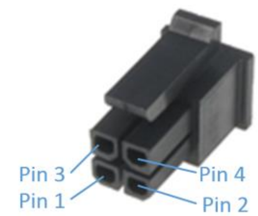
Figure 7: Molex Micro-Fit 3.0 Connector for Connection to Link Bus

Table 7: Link Bus Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	VBUS	DC power from SC, with Fault Pilot Signal	Cell Interface
2	COM	Power return from SC	Cell Interface
3	IPA	Link Bus differential pair plus	Cell Interface
4	IMA	Link Bus differential pair minus	Cell Interface

Link In

The Link In connector provides power and communication to this CI from the CIs below this CI, or from the SC if this CI is measuring the most negative cell in the stack. The amount of current sourced into this connector is the sum of current consumed by this CI and all those above it (which amounts to all CIs if this CI is measuring Cell 1). Connect to the *Link Out* connector on the CI that is measuring the perivous series-connected cell below this CI to this connector, or connect the SC to this connector if this CI is measuring the bottom cell in the stack.



Molex 43025-0400	
Manufacturer	Molex Incorporated
Housing	43025-0400
Housing material	Nylon UL94V-0
Circuits	4
Crimp terminal	43030-0002
Wire gauge range	AWG20-24 stranded

Figure 8: Molex Micro-Fit 3.0 Connector for Connection to Link Bus

Table 8: Link Bus Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	VBUS	DC power from SC, with Fault Pilot Signal	Cell Interface or Stack Controller
2	COM	Power return from SC	Cell Interface or Stack Controller
3	IPA	Link Bus differential pair plus	Cell Interface or Stack Controller
4	IMA	Link Bus differential pair minus	Cell Interface or Stack Controller

Battery Cells

The Battery Cells connector provides cell voltage input and a means for balancing the cells. The cable wire should be rated for at least 750mA to survive worse-case current. Pins 8, 16, 17, and 18 are No Connect in the CI-12 model. Pins 2, 4, 6, 8, 10, 11, 12, 13, 14, 15, 16, and 17 are No Connect in the CI-4M12 model. All unused voltage inputs should be tied to the next highest potential voltage sense input. In this way, all pins should be connected with the exception of pins 8, 16, 17 and 18 in the CI-12 model and pins 2, 4, 6, 8, 10, 11, 12, 13, 14, 15, 16, and 17 in the CI-4M12 model. Connect the battery cell voltage sense leads to this connector.

Molex 43025-1800	
Manufacturer	Molex Incorporated
Housing	43025-1800
Housing material	Nylon UL94V-0
Circuits	18
Crimp terminal	43030-0002
Wire gauge range	AWG20-24 stranded

Figure 9: Molex Micro-Fit 3.0 Connector for Connection to Battery Cells

Table 9: CI-12 Battery Cells Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	CELL0	Bottom reference of CI	Connect to negative terminal of the lowest cell (Cell 1)
2	CELL2	Cell 2 voltage sense	Connect to positive terminal of Cell 2
3	CELL4	Cell 4 voltage sense	Connect to positive terminal of Cell 4
4	CELL6	Cell 6 voltage sense	Connect to positive terminal of Cell 6
5	CELL8	Cell 8 voltage sense	Connect to positive terminal of Cell 8
6	CELL10	Cell 10 voltage sense	Connect to positive terminal of Cell 10
7	CELL12	Cell 12 voltage sense	Connect to positive terminal of Cell 12
8	No Connect	Not Connected	No Connect
9	No Connect	Not Connected	No Connect
10	CELL1	Cell 1 voltage sense	Connect to positive terminal of the lowest cell (Cell 1)
11	CELL3	Cell 3 voltage sense	Connect to positive terminal of Cell 3
12	CELL5	Cell 5 voltage sense	Connect to positive terminal of Cell 5
13	CELL7	Cell 7 voltage sense	Connect to positive terminal of Cell 7
14	CELL9	Cell 9 voltage sense	Connect to positive terminal of Cell 9
15	CELL11	Cell 11 voltage sense	Connect to positive terminal of Cell 11
16	No Connect	Not Connected	No Connect
17	No Connect	Not Connected	No Connect
18	No Connect	Not Connected	No Connect

The following is an example wiring guide for a CI-12 with 12 cells and 8 cells:

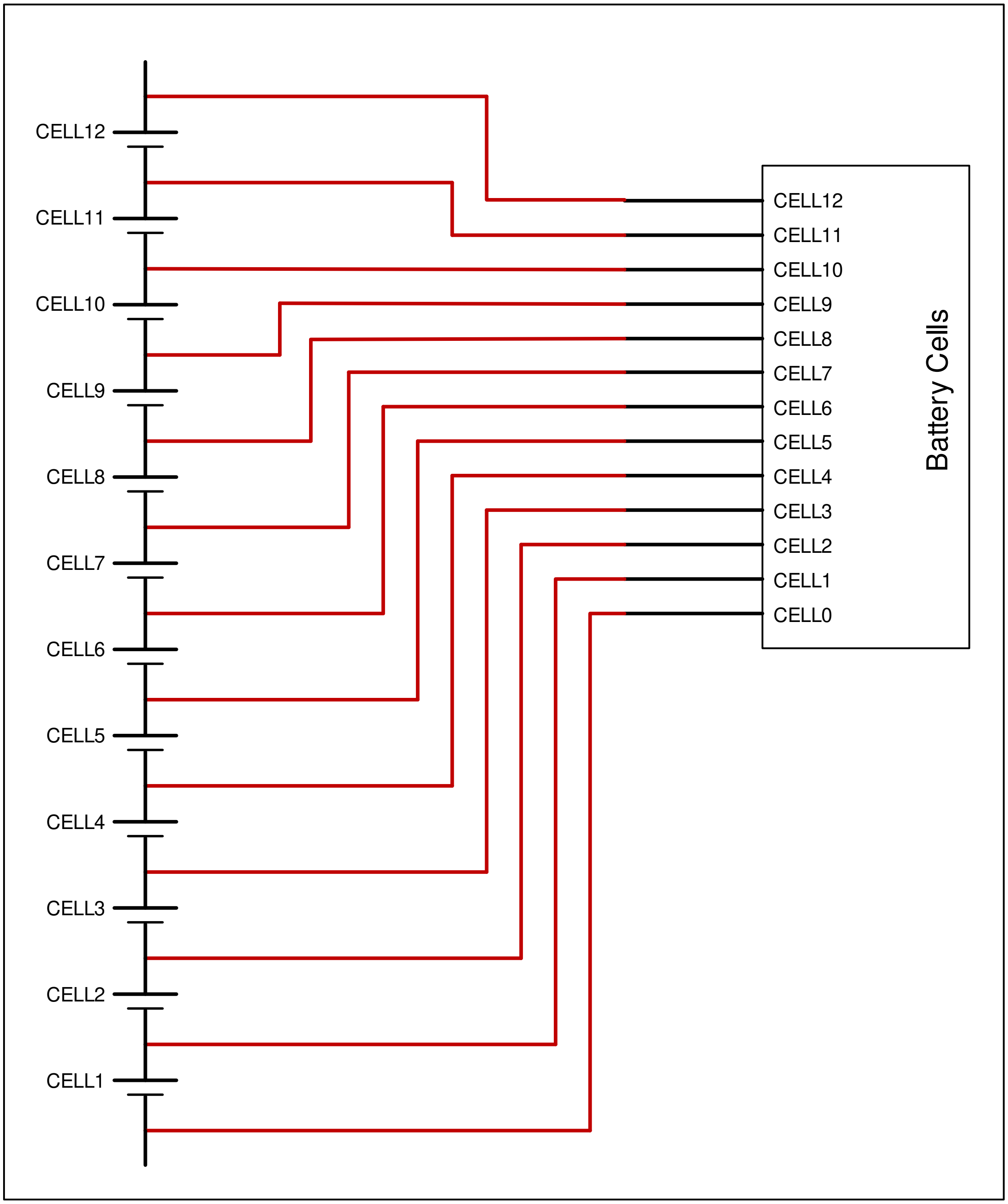


Figure 10: Example CI-12 12cell Wiring Diagram

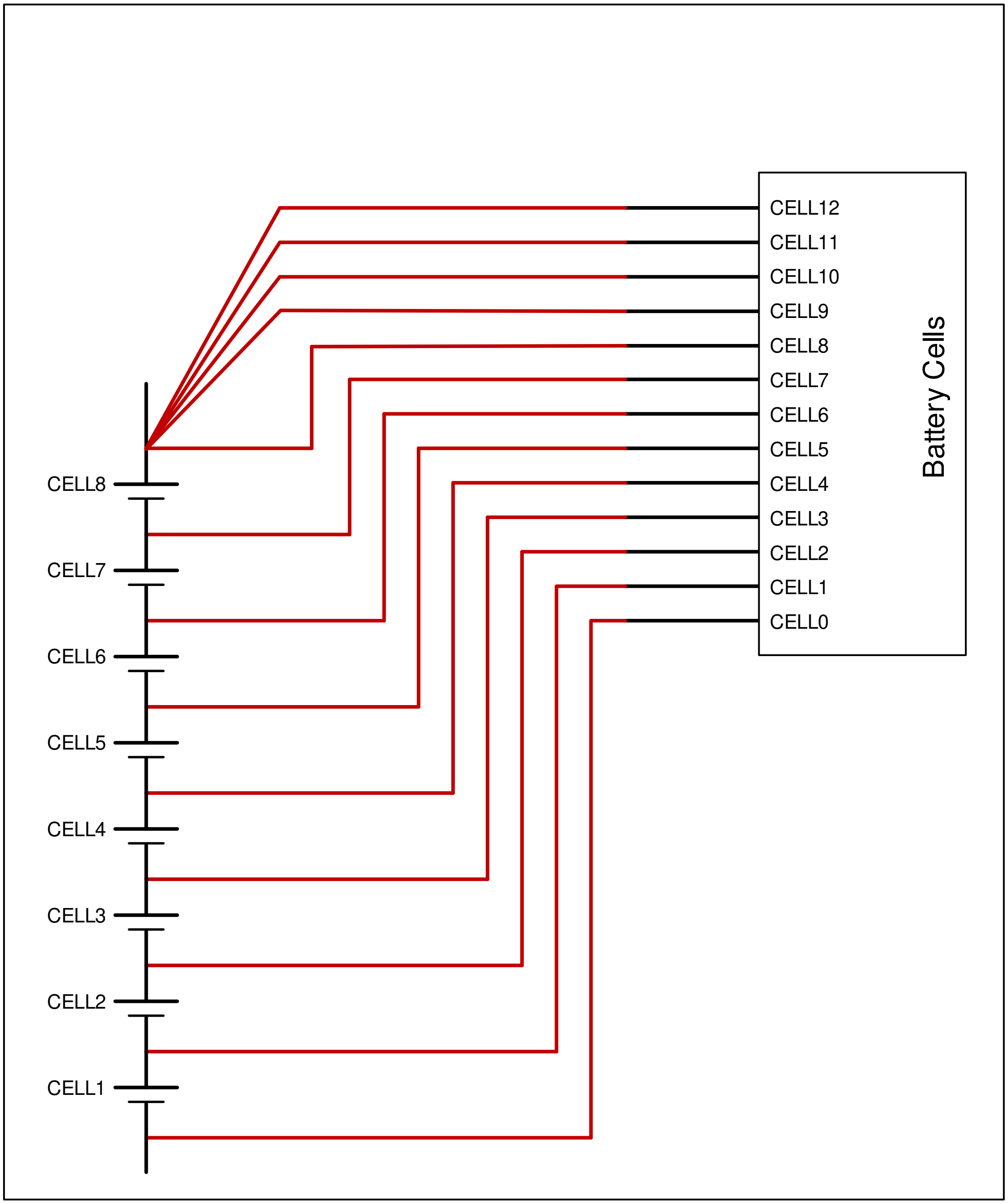


Figure 11: Example CI-12 8cell Wiring Diagram

Table 10: CI-16 Battery Cells Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	CELL0	Bottom reference of CI	Connect to negative terminal of the lowest cell (Cell 1)
2	CELL2	Cell 2 voltage sense	Connect to positive terminal of Cell 2
3	CELL4	Cell 4 voltage sense	Connect to positive terminal of Cell 4
4	CELL6	Cell 6 voltage sense	Connect to positive terminal of Cell 6
5	CELL8	Cell 8 voltage sense	Connect to positive terminal of Cell 8
6	CELL10	Cell 10 voltage sense	Connect to positive terminal of Cell 10
7	CELL12	Cell 12 voltage sense	Connect to positive terminal of Cell 12
8	CELL14	Cell 14 voltage sense	Connect to positive terminal of Cell 14
9	No Connect	Not Connected	No Connect
10	CELL1	Cell 1 voltage sense	Connect to positive terminal of the lowest cell (Cell 1)
11	CELL3	Cell 3 voltage sense	Connect to positive terminal of Cell 3
12	CELL5	Cell 5 voltage sense	Connect to positive terminal of Cell 5
13	CELL7	Cell 7 voltage sense	Connect to positive terminal of Cell 7
14	CELL9	Cell 9 voltage sense	Connect to positive terminal of Cell 9
15	CELL11	Cell 11 voltage sense	Connect to positive terminal of Cell 11
16	CELL13	Cell 13 voltage sense	Connect to positive terminal of Cell 13
17	CELL15	Cell 15 voltage sense	Connect to positive terminal of Cell 15
18	CELL16	Cell 16 voltage sense	Connect to positive terminal of Cell 16

The following is an example wiring guide for a CI-16 with 16 cells and 11 cells:

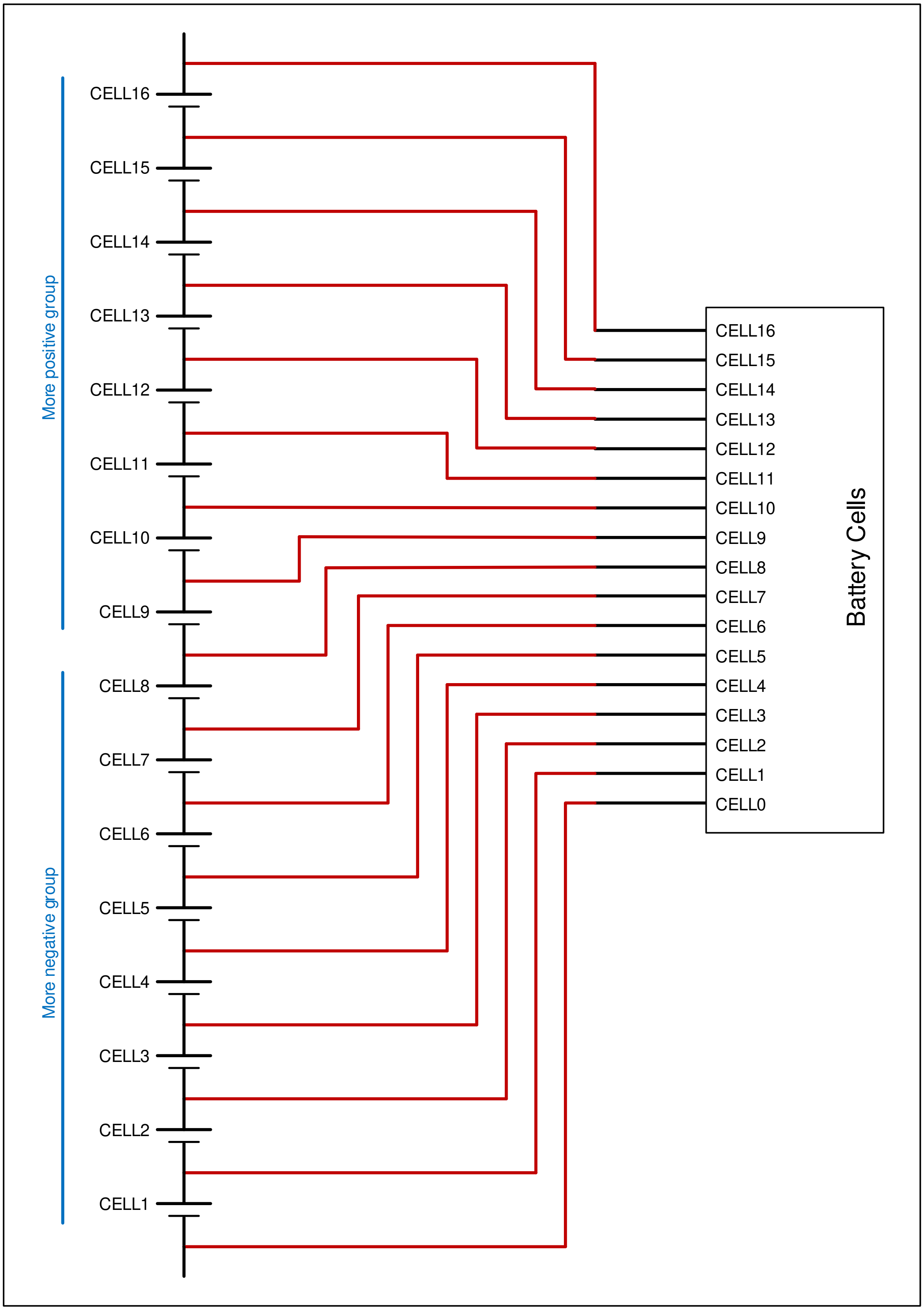


Figure 12: Example CI-16 16cell Wiring Diargam

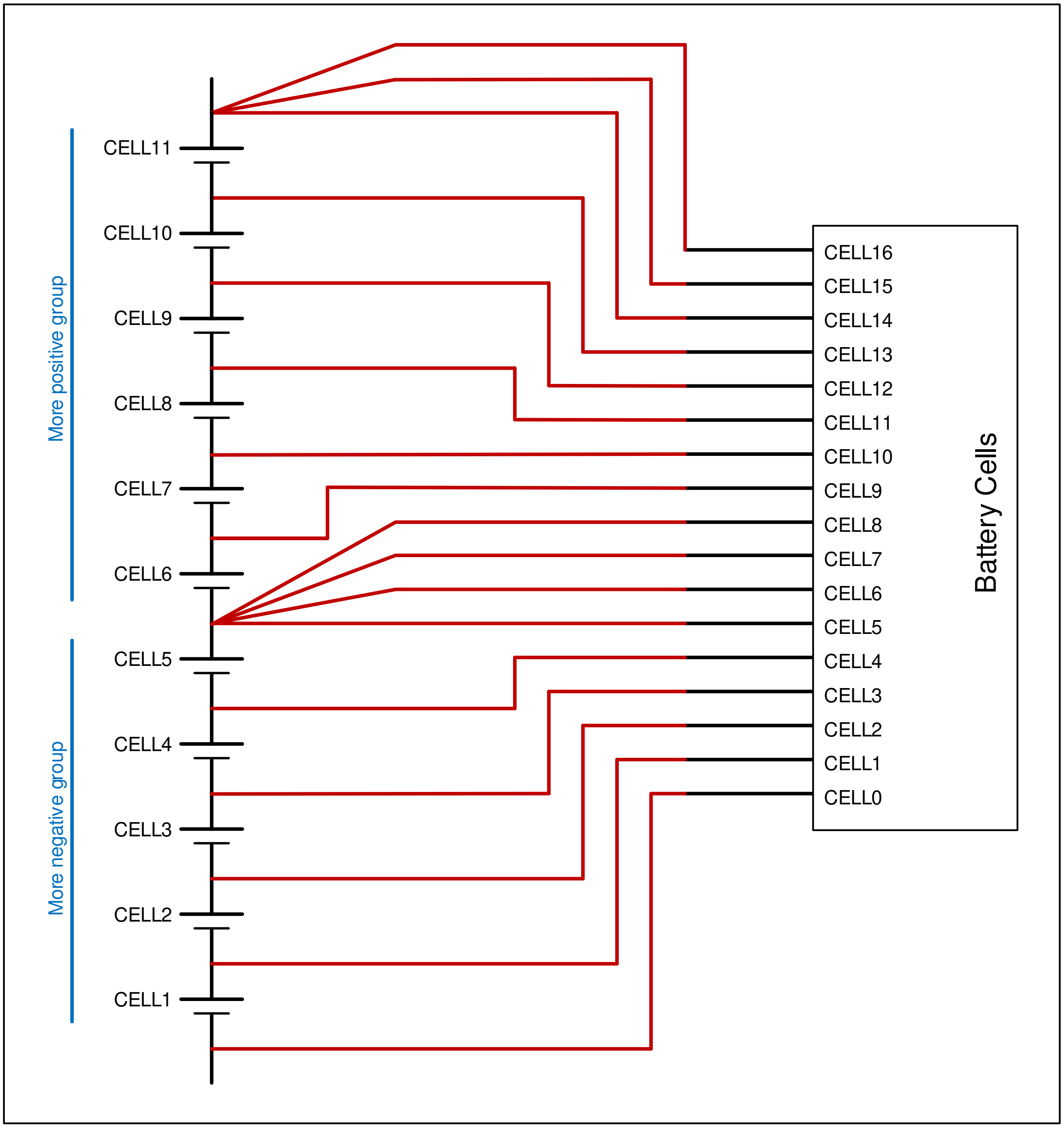


Figure 13: Example CI-16 11cell Wiring Diagram

Table 11: CI-4M12 Battery Cells Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	CELL0	Bottom reference of CI	Connect to negative terminal of the lowest cell (Cell 1)
2	No Connect	Not Connected	No Connect
3	CELL4	Cell 1 voltage sense	Connect to positive terminal of the lowest cell (Cell 1)
4	No Connect	Not Connected	No Connect
5	CELL8	Cell 2 voltage sense	Connect to positive terminal of Cell 2
6	No Connect	Not Connected	No Connect
7	CELL1	Cell 3 voltage sense	Connect to positive terminal of Cell 3
8	No Connect	Not Connected	No Connect
9	No Connect	Not Connected	No Connect
10	No Connect	Not Connected	No Connect
11	No Connect	Not Connected	No Connect
12	No Connect	Not Connected	No Connect
13	No Connect	Not Connected	No Connect
14	No Connect	Not Connected	No Connect
15	No Connect	Not Connected	No Connect
16	No Connect	Not Connected	No Connect
17	No Connect	Not Connected	No Connect
18	CELL16	Cell 4 voltage sense	Connect to positive terminal of Cell 4

The following is a wiring guide for a CI-4M12 with 4 cells and 3 cells:

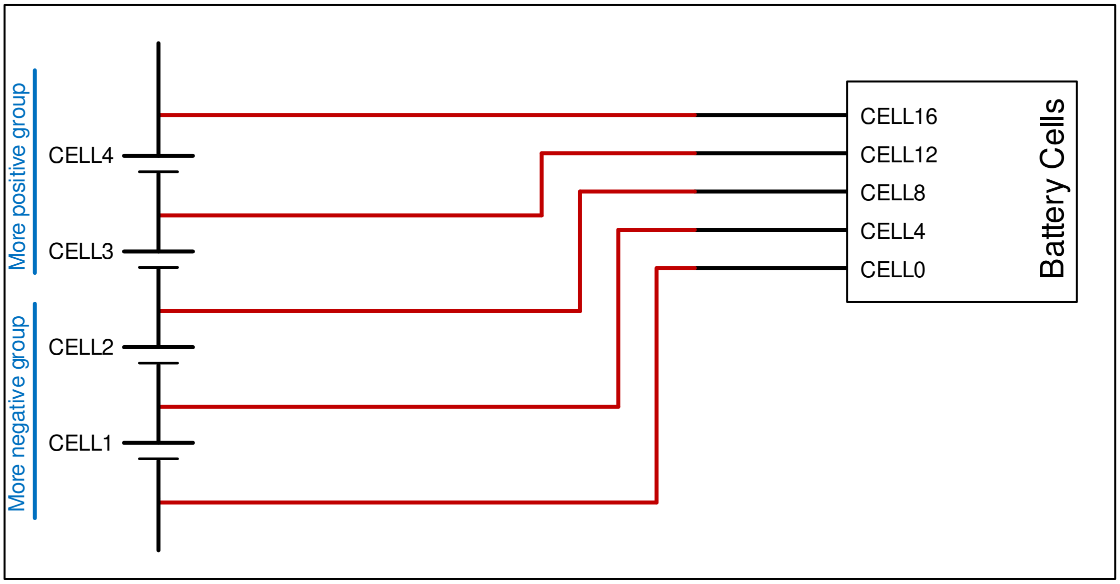


Figure 14: Example CI-4M12 4cell Wiring Diagram

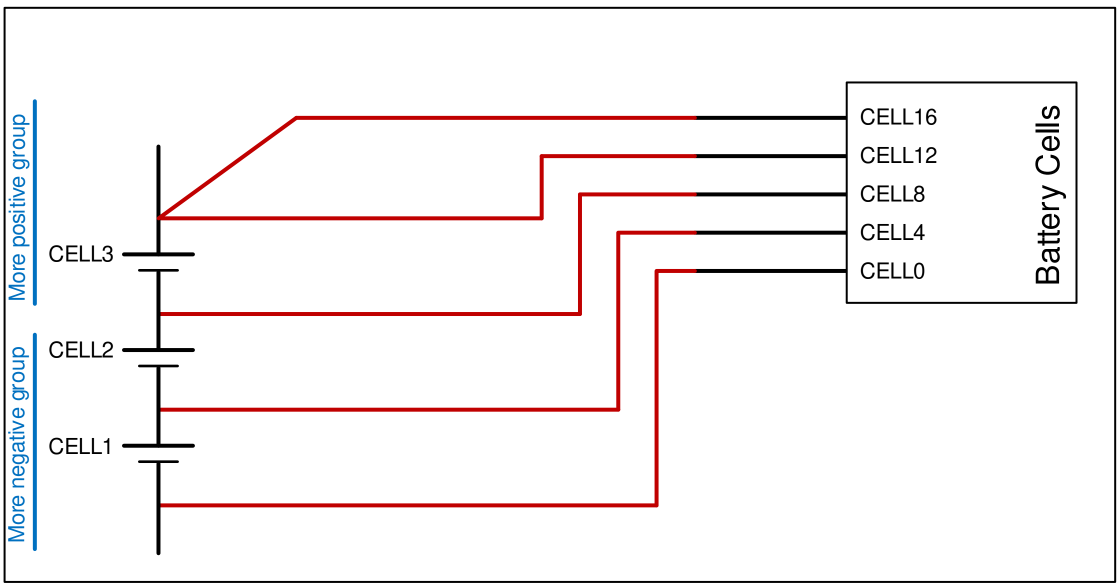


Figure 15: Example CI-4M12 3cell Wiring Diagram

Temperature Sensors

The Temperature Sensors connector provides NTC thermistor inputs for temperature measurement of the cells and/or surrounding area. All signals are referenced to Pin 1 of the Battery Cells connector. The thermistors must be isolated from the cell voltage terminals in such a way that they will not make an electrical connection to a cell terminal in the event of vibration/failures. Connect 10kΩ NTC thermistors to this connector.

Molex 43025-1600	
Manufacturer	Molex Incorporated
Housing	43025-1600
Housing material	Nylon UL94V-0
Circuits	16
Crimp terminal	43030-0002
Wire gauge range	AWG20-24 stranded

Figure 16: Molex Micro-Fit 3.0 Connector for Connection to Temperature Sensors

Table 12: Temperature Sensors Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	VBOT	External Temperature Probe Reference 1	10kΩ NTC Thermistor
2	VBOT	External Temperature Probe Reference 2	10kΩ NTC Thermistor
3	VBOT	External Temperature Probe Reference 3	10kΩ NTC Thermistor
4	VBOT	External Temperature Probe Reference 4	10kΩ NTC Thermistor
5	VBOT	External Temperature Probe Reference 5	10kΩ NTC Thermistor
6	VBOT	External Temperature Probe Reference 6	10kΩ NTC Thermistor
7	VBOT	External Temperature Probe Reference 7	10kΩ NTC Thermistor
8	VBOT	External Temperature Probe Reference 8	10kΩ NTC Thermistor
9	TEMP1_R	External Temperature Probe Input 1	10kΩ NTC Thermistor
10	TEMP2_R	External Temperature Probe Input 2	10kΩ NTC Thermistor
11	TEMP3_R	External Temperature Probe Input 3	10kΩ NTC Thermistor
12	TEMP4_R	External Temperature Probe Input 4	10kΩ NTC Thermistor
13	TEMP5_R	External Temperature Probe Input 5	10kΩ NTC Thermistor
14	TEMP6_R	External Temperature Probe Input 6	10kΩ NTC Thermistor
15	TEMP7_R	External Temperature Probe Input 7	10kΩ NTC Thermistor
16	TEMP8_R	External Temperature Probe Input 8	10kΩ NTC Thermistor

Nuvation BMS™ High-Voltage Power Interface

The Nuvation BMS™ High-Voltage Power Interface (PI) module connects directly to high-voltage and high-current components. It accepts an external power input, provides power conditioning for all Nuvation BMS modules and power for the contactors. The SC controls all operations on the PI via the Stack Bus.

There is only one model of the PI.

Mechanical Dimensions

The overall dimensions of the PI are 174.40mm X 121.58mm X 48.60mm. It comes standard with DIN clips that enable the PI module to be securely mounted to EN50022-compliant DIN rails. The clips add an extra 19.6mm to the overall width of the PI module, bringing it from 174.40mm to 194mm. The clips also hold the module approximately 7mm away from the inside lip of the DIN rail. Extra space should be provided around the module to allow for easy installation/maintenance.

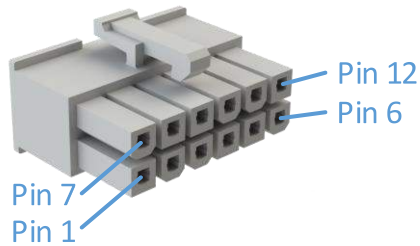
A more detailed mechanical drawing of the PI module is provided in Appendix A: Detailed Mechanical Drawings.

Electrical Characteristics

The PI module has seven connectors. Each connector is described in the following sections in detail.

Contactors

The Contactors connector provides high-current outputs for controlling high-current contactors. Each output is capable of sourcing maximum continuous 2.8A. When powering the contactor drivers from the internal 24VDC supply, +VINT, the combined current cannot be more than 3A minus 25mA for the PI, minus 42mA for the SC and minus the combined current consumed by the CIs (22mA per CI). If powering the contactor drivers from an external power source via +VCOIL, the combined current cannot be more than 2.8A continuously. Connect up to four (4) high-current contactor coils to this connector.



Molex 39-01-2125	
Manufacturer	Molex Incorporated
Housing	39-01-2125
Housing material	Nylon UL94V-0
Circuits	12
Crimp terminal	39-00-0181
Wire gauge range	AWG18-24 stranded

Figure 17: MiniFit Jr Connector for Connection to Contactors

Table 13: Contactors Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	COIL1_HI	Positive Coil 1	Contactor 1 positive coil connection
2	COIL2_HI	Positive Coil 2	Contactor 2 positive coil connection
3	COIL3_HI	Positive Coil 3	Contactor 3 positive coil connection
4	COIL4_HI	Positive Coil 4	Contactor 4 positive coil connection
5	No Connect	Not Connected	No Connect
6	COM	Negative reference for external supply	External Power Supply
7	COM	Negative Coil 1	Contactor 1 negative coil connection
8	COM	Negative Coil 2	Contactor 2 negative coil connection
9	COM	Negative Coil 3	Contactor 3 negative coil connection
10	COM	Negative Coil 4	Contactor 4 negative coil connection
11	+VINT	PI Power Supply	Connect to Contactors connector Pin 12 if driving contactor coil from PI power supply
12	+VCOIL	12~24V Contactor Coil Power Supply	Connect to external power supply or Contactors connector Pin 11 if driving contactor coil from PI power supply

The following is an example 2 contactor implementation with 24V coils that are powered from the PI:

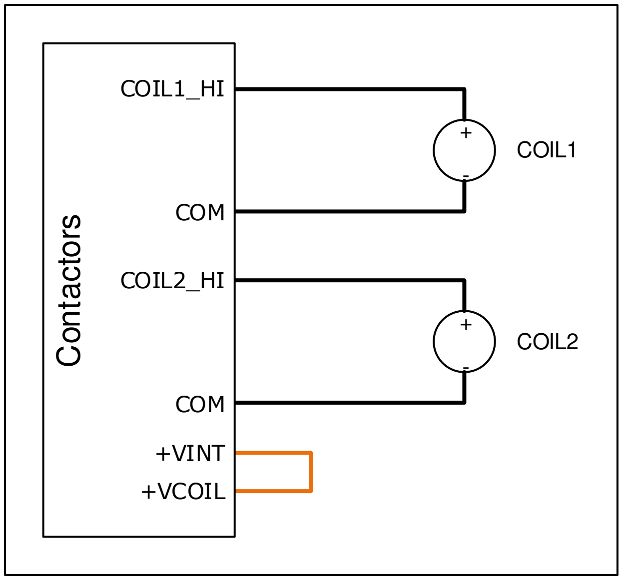


Figure 18: Example 2-coil Wiring Diagram

The following is an example 4 contactor implementation that is powered from an external power supply:

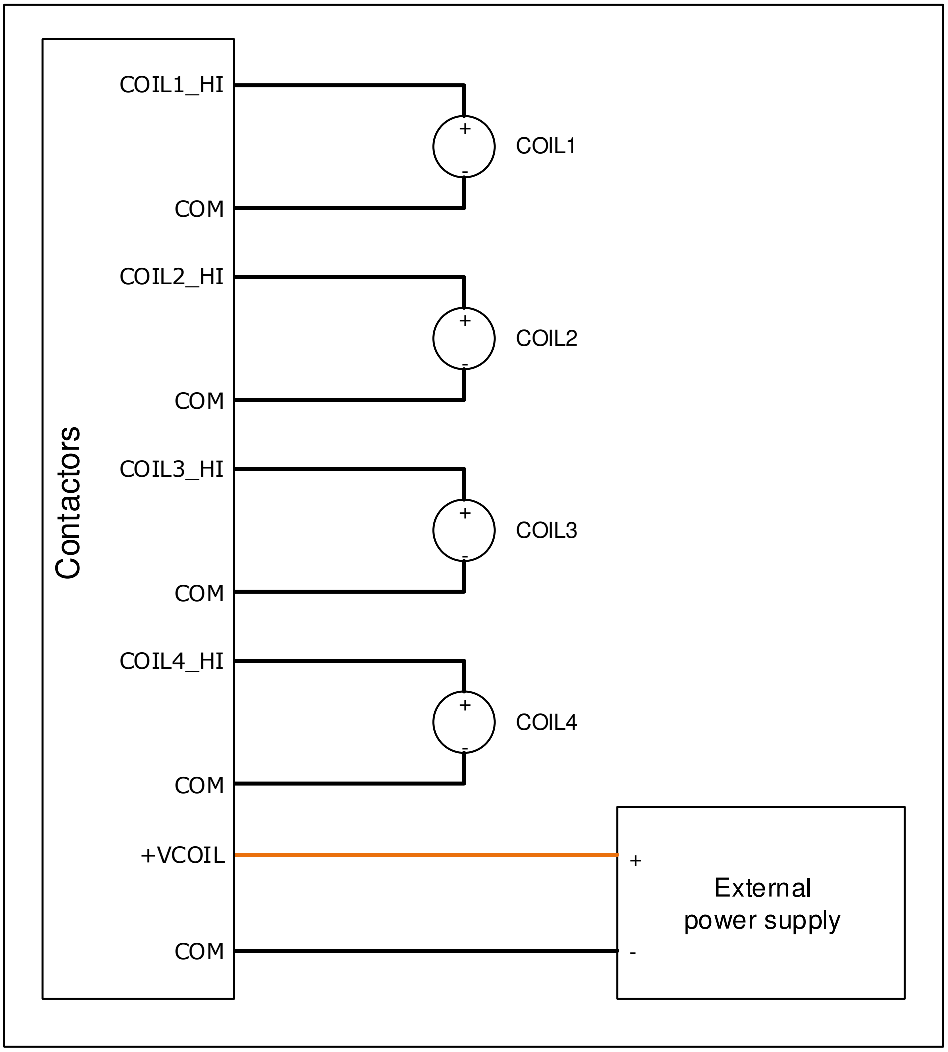


Figure 19: Example 4-coil Externally Powered Wiring Diagram

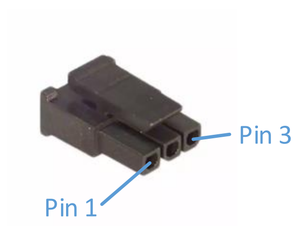
Interlock

The Interlock connector provides a means to set the high-current contactor behaviour, as outlined in Table 14. Using a physical switch/relay instead of a jumper is a convenient way to implement an interlock switch that de-energizes the system contactors. It is recommended to connect pins 2 and 3 as this will enable the hardware redundant fault signalling feature to de-energize system contactors in the event of a PI failure.

Table 14: Interlock Options

Interlock Connection		Function
1 & 3	2 & 3	
open	open	System contactors are de-energized
open	closed	System contactors are controlled by BMS software, but de-energized if hardware-based fault signaling detects a fault
closed	open or closed (does not matter)	System contactors are controlled by BMS software; hardware-based fault signaling mechanism will not de-energise system contactors
Note: Pin 3 is electrically connected to chassis ground.		

Connect a jumper or external interlock switch to this connector.



Molex 43645-0300

Manufacturer	Molex Incorporated
Housing	43645-0300
Housing material	Nylon UL94V-0
Circuits	3
Crimp terminal	43030-0002
Wire gauge range	AWG20-24 stranded

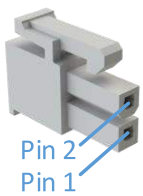
Figure 20: Molex Micro-Fit 3.0 Connector for Connection to Interlock

Table 15: Interlock Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	R_OVERRIDE_ENA#	Active-low; Allows BMS software to control contactors	Interlock Connector Pin 3
2	R_DRV_ENA#	Active-low; Allows internal hardware fault detection to override BMS software control of contactors	Interlock Connector Pin 3
3	COM	Power return from PI	Interlock Connector Pin 1 or Pin 2

External Power

The External Power connector accepts power from an external power supply to allow the BMS to function without deriving its power directly from the battery stack. The external supply can be either 9-24VAC or 13-34VDC and must be isolated from chassis and COM grounds. There is no polarity dependency between PWR2_A and PWR2_B pins. Connect an external power supply to this connector.



Molex 39-01-2025	
Manufacturer	Molex Incorporated
Housing	39-01-2025
Housing material	Nylon UL94V-0
Circuits	2
Crimp terminal	39-00-0181
Wire gauge range	AWG18-24 stranded

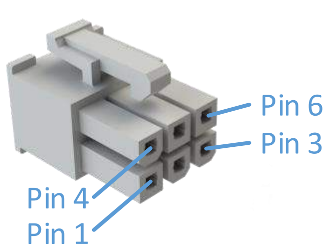
Figure 21: MiniFit Jr Connector for Connection to External Power

Table 16: External Power Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	PWR2_A	External Power Supply Input	External Power Supply
2	PWR2_B	External Power Supply Input	External Power Supply

Stack Bus

The Stack Bus connector provides power and communication to the SC module. The Stack Bus provides 42mA to the SC plus the summation of current consumed by all CI modules in the system (up to 25mA per CI12 or 31mA per CI-16). 120Ω termination must be added by connecting pins 1 and 3 together with a short length of wire. Connect the SC module to this connector.



Molex 39-01-2065	
Manufacturer	Molex Incorporated

Housing	39-01-2065
Housing material	Nylon UL94V-0
Circuits	6
Crimp terminal	39-00-0181
Wire gauge range	AWG18-24 stranded

Figure 22: MiniFit Jr Connector for Connection to Stack Bus

Table 17: Stack Bus Connector Pin Assignment

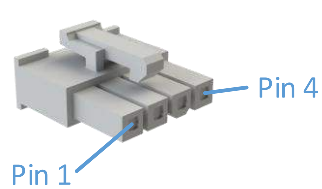
Pin	Connection	Description	Connected to Device
1	TERM1	Termination Resistor; Short to Pin 4 to add 120Ω bus termination	Stack Bus Connector
2	STACKBUS_N	Stack bus differential pair negative	Stack Controller
3	+VSYS	+24V Power Supply	Stack Controller
4	TERM2	Termination Resistor; Short to Pin 1 to add 120Ω bus termination	Stack Bus Connector
5	STACKBUS_P	Stack bus differential pair positive	Stack Controller
6	COM	Power return from PI	Stack Controller

Thermistor

Contact Nuvation Energy for support if temperature compensation of the high-current shunt is desired for your specific application.

Current Shunt

The Current Shunt connector provides a current shunt input for current measurement of the high-voltage stack. For best results, minimize the cable length used between the shunt and the connector. Use a twisted pair for the differential shunt voltage sense wires. The differential voltage across the shunt must never exceed 1V under any circumstance. Choose the resistance value accordingly. Connect the current shunt to this connector.



Molex 39-01-4041

Manufacturer	Molex Incorporated
Housing	39-01-4041
Housing material	Nylon UL94V-0
Circuits	4
Crimp terminal	39-00-0181

Wire gauge range	AWG18-24 stranded

Figure 23: MiniFit Jr Connector for Connection to Current Shunt

Table 18: Current Shunt Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	No Connect	Not Connected	No Connect
2	VSHUNT_REF	Voltage reference for voltage measurement	Load side of current shunt
3	VSHUNT_LOAD	Differential voltage input; Load side	Load side of current shunt
4	VSHUNT_BAT	Differential voltage input; Battery side	Battery side of current shunt

An example high-current shunt wiring diagram is shown below:

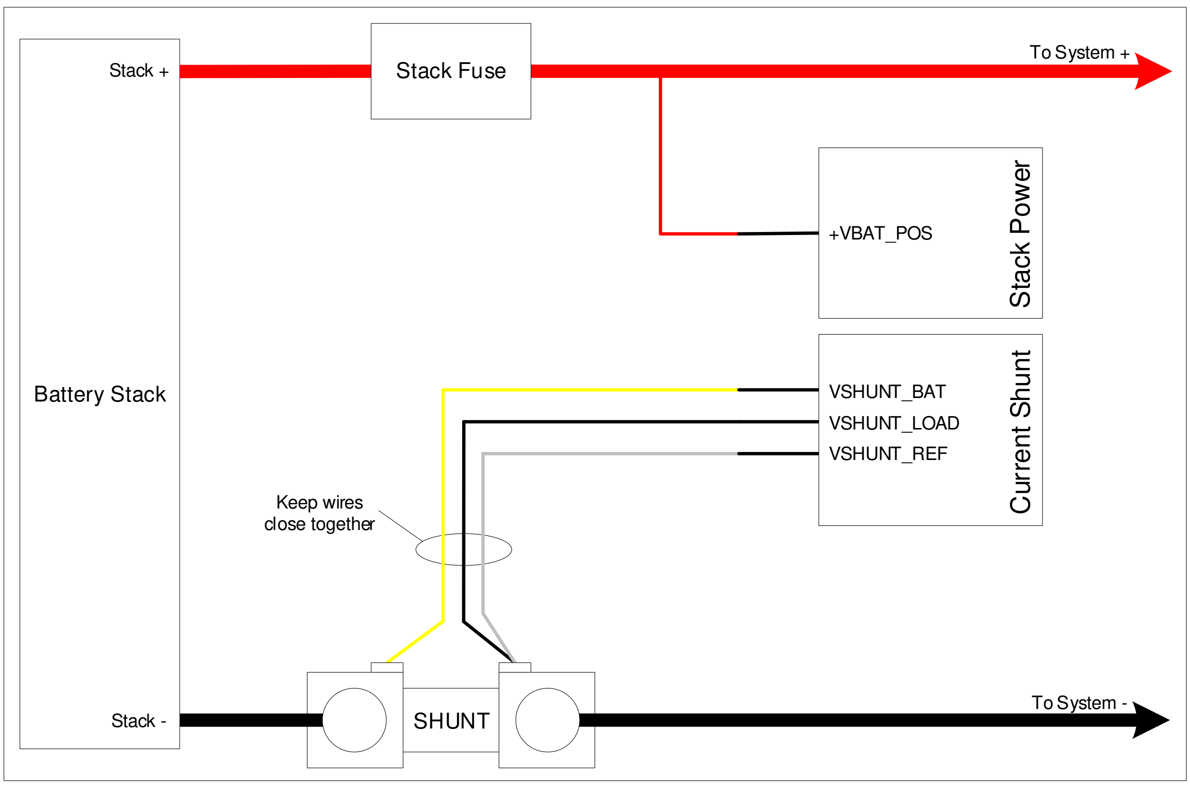
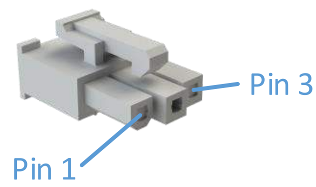


Figure 24: Example High-Current Shunt Wiring Diagram

Stack Power

The Stack Power connector is used to provide an overall stack voltage measurement. Connect the overall battery stack positive terminal to this connector.



Molex 39-01-4031	
Manufacturer	Molex Incorporated
Housing	39-01-4031
Housing material	Nylon UL94V-0
Circuits	3
Crimp terminal	39-00-0181
Wire gauge range	AWG18-24 stranded

Figure 25: MiniFit Jr Connector for Connection to Stack Power

Table 19: Stack Power Connector Pin Assignment

Pin	Connection	Description	Connected to Device
1	+VBAT_POS	Overall Stack Positive	Connect to most positive terminal of the battery stack
2	No Connect	Not Connected	No Connect
3	No Connect	Not Connected	No Connect

Nuvation BMS Best Practices

This section describes important concepts which need special attention to achieve a reliable installation.

Grounding

It is assumed that the Nuvation BMS will be attached electrically to an earth or local chassis ground point, via the DIN rail grounding provision (#8-32 , ¼" Hex-head drive, earth grounding screw), and the mounting brackets on the BMS component enclosures.

Voltages and signals on the Stack Bus and Link Bus cables are chassis/earth ground referenced. In addition, the Stack Controller's USB port, non-isolated RS485, and GPIO-In signals; and the Power Interface's Contactor coils and Interlock signals are chassis/earth ground referenced.

All connections to the battery stack are isolated from chassis ground. This includes the Current Shunt, Thermistor, and Stack Power connections on the Power Interface; and the Battery Cells and Temperature Sensors connections on the Cell Interface, and Ethernet and CAN interfaces on the Stack Controller.

It is acceptable, as may be required in some cases, for the battery stack to be ground-referenced at some single point. However, a 24VRMS AC or 24VDC power supply connected to the Power Interface's External Power connection must be isolated from earth/chassis ground, with a working isolation voltage of at least 60Vrms for all Power Interface models.

Protective earthing conductors must be attached to each DIN enclosure at the designated ground screw location on the DIN clip. Furthermore, the DIN rail itself should be connected to earth ground. 14AWG wire with a jacket color appropriate for indicating it is a protective earthing conductor must be used. An example of this grounding scheme is shown below:

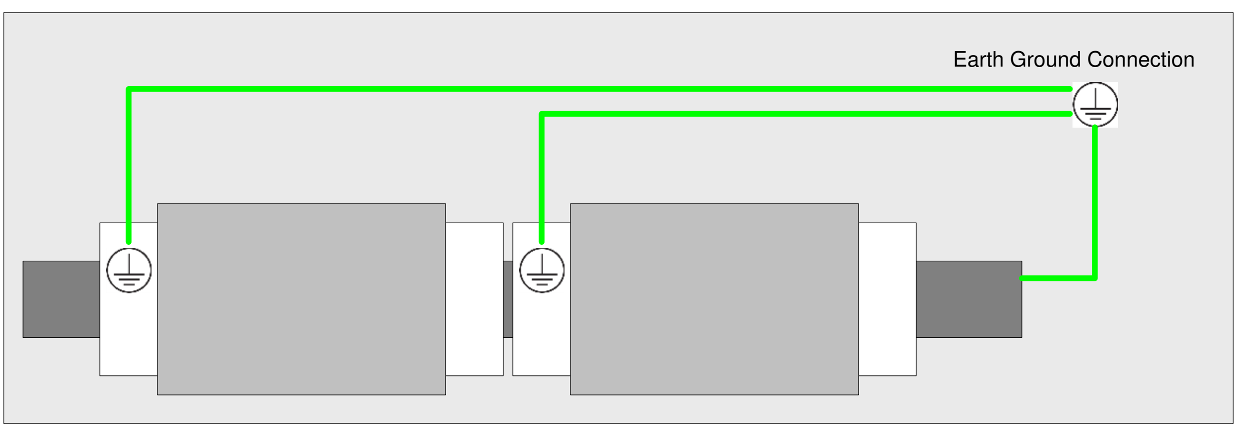


Figure 26: Example Earth Ground Wiring Diagram

Excess Cable Management

During the first prototype system build, it is possible to encounter cable lengths that are too long for your system. Leaving the excess cable length unmanaged can result in a messy system installation.

If reducing the cable length is not feasible or if there is no time to physically modify the lengths, a common solution is to wrap the excess cable length in a coil and fasten the wire loop in the cabinet. This basic tactic has the undesirable effect of creating an air-core transformer which will couple EMI into the cable extremely well.

The best solution to cable length management is to bundle the excess length in a figure-8 pattern. This prevents the bundle from turning into an air-core transformer since the direction of current in one side of the figure-8 turns opposite to the current in the other side. It is recommended to use the figure-8 method if physically reducing the cable length is not possible.

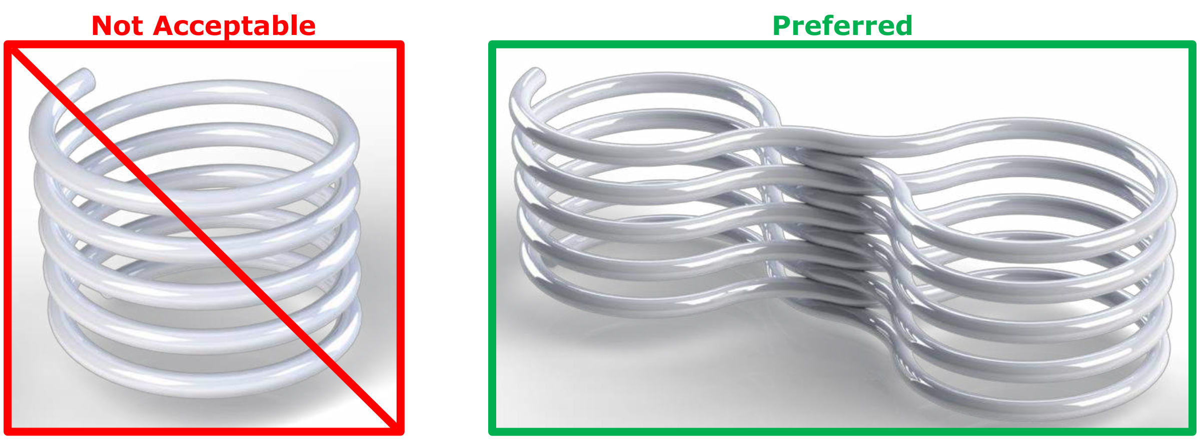


Figure 27: Excess Cable Management Examples

System Noise

High-power inverters generate a lot of system noise, especially on the DC bus. This is due to the industry standards for AC harmonics and EMC on the grid-side which require the DC bus to help filter out the harmful emissions. Unfortunately, that means the battery cells, and the BMS, experience extreme levels of noise.

The most harmful emissions on the DC bus are between the DC bus and earth. This is due to the slew-rate of the switching devices implemented in the inverter (usually IGBTs). The slew-rate is impacted by a many elements, and the emissions can be minimized by carefully grounding the installation so that the return-path for the high-frequency switching noise can be kept small.

The BMS has many faults and informative registers to determine if the system has a high level of noise that is impacting the BMS. The communication faults are:

```
sc_fault_linkbus_wdt.trig
sc_fault_stackbus_rxwdt.trig
sc_fault_stackbus_txwdt.trig
sc_fault_pi_afe_rx.trig
sc_fault_pi_afe_wdt.trig
sc_fault_wdt.trig
```

The informative communication error registers are:

```
sc_linkbus_packets.operation_read_errors
sc_linkbus_packets.operation_validate_errors
sc_stackbus.rxerrrate
sc_stackbus.txerrrate
pi_afe.rx_err_rate
pi_afe.tx_err_rate
```

The system controller heartbeat should also be coming through as expected, and can be verified by reading the register:

```
controller_heartbeat.value
```

In a correctly wired system, a communication fault points to elevated system noise that is disrupting communications. If the system grounding scheme cannot be improved, there are still a few techniques within the BMS/Battery area to try to decrease the amount of noise.

DC Filtering

A DC filter can be installed between the DC bus and the inverter or between each DC battery stack and the common DC bus in a multi-stack system. Schaffner FN 2200 is an example DC filter which has been known to decrease the amount of harmful emissions on the DC bus. An example filter installation is shown below:

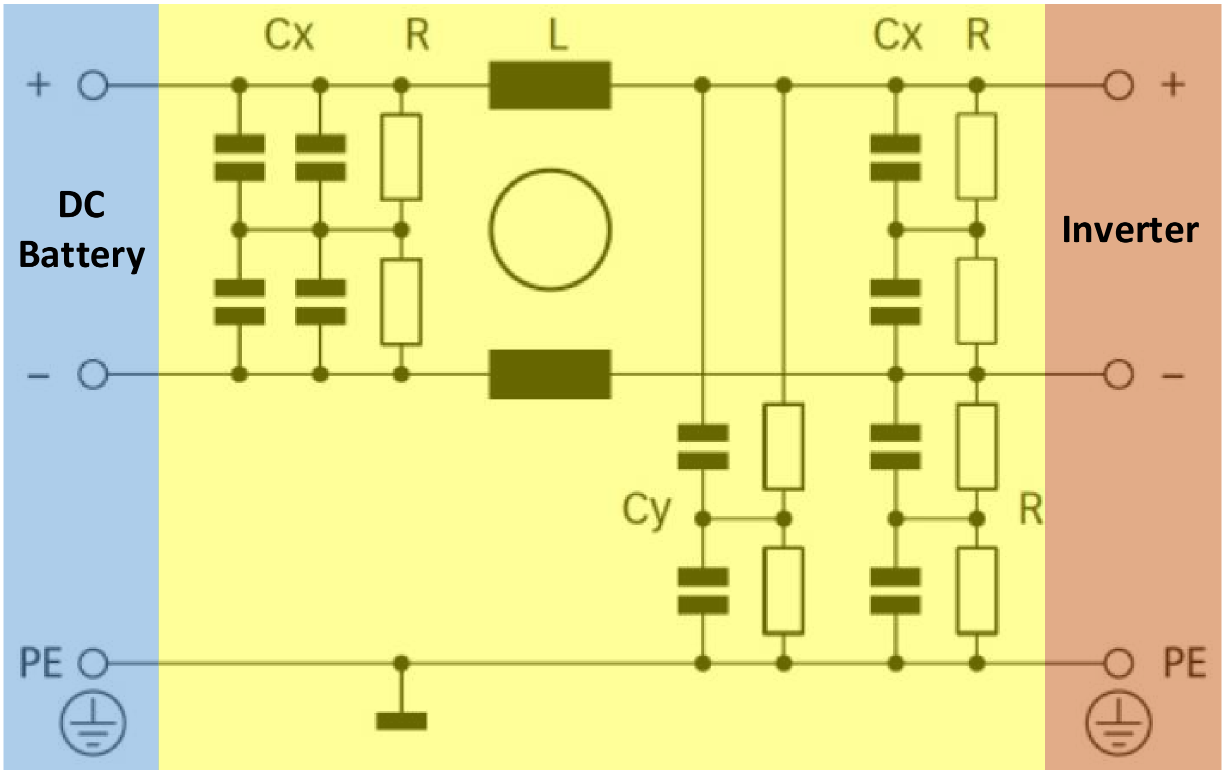


Figure 28: Example DC Filter Schematic

When using DC filters, please be aware that it shunts high-frequency noise to earth. If the inverter is not driving an insulated neutral system, there will be high current pulses flowing in the system earth which can trip ground fault detectors. It might be necessary to install an isolation transformer between the inverter and the grid to remove the high current pulses.

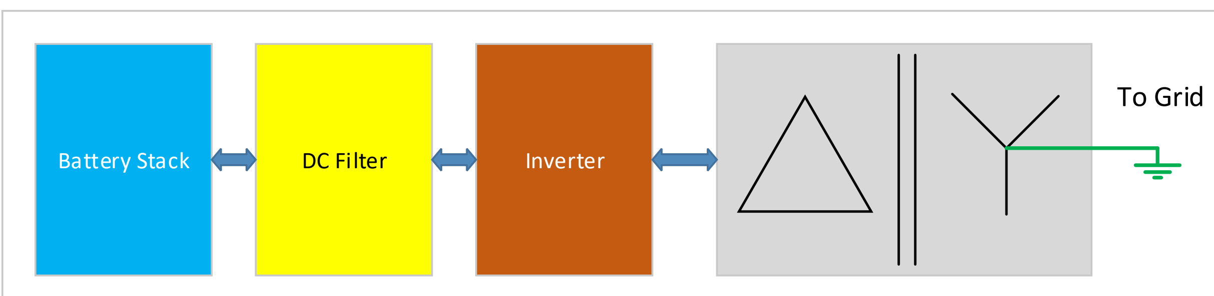


Figure 29: Example Isolation Transformer Installation Diagram

SC Grounding

If sc_stackbus communication faults are occurring, it might be alleviated by providing a dedicated ground connection for the SC. In the typical installation, the SC is grounded through the PI via the Stack Bus cable. By providing a direct connection to ground, any noise entering the SC from the Link Bus cable will not flow through the Stack Bus cable. Connect one of the following pins to earth:

- Link Out pin 2
- CAN485 pin 4
- GPIO-Out pin 5
- GPIO-In pin 1, 2, 3 or 4

Link Bus Power

While the communication interface between the SC and the CIs is a daisy-chain, the power supplied to the CIs from the SC is a bus. This results in the power twisted pair in the Link Bus cable carrying power up the entire length of the chain. This provides a decent medium to couple system noise into the Link Bus which can result in sc_linkbus communication faults.

In systems where the cells can provide the necessary minimum operating voltage to the CI, Link Bus power can be disabled if the observed impact on performance is acceptable. The power twisted pair must be disconnected in the Link Bus cable, so all Link Out and Link In connectors on the SC and CI must have pins 1 and 2 unpopulated. Also, the BMS must be configured to disable power to the Link Bus, by setting this register to 0:

```
sc_linkbus.power_mode = 0
```

Appendix A: Detailed Mechanical Drawings

Nuvation BMS™ High-Voltage Stack Controller

Nuvation BMS™ High-Voltage Stack Controller with DIN Enclosure

Weight: 525g

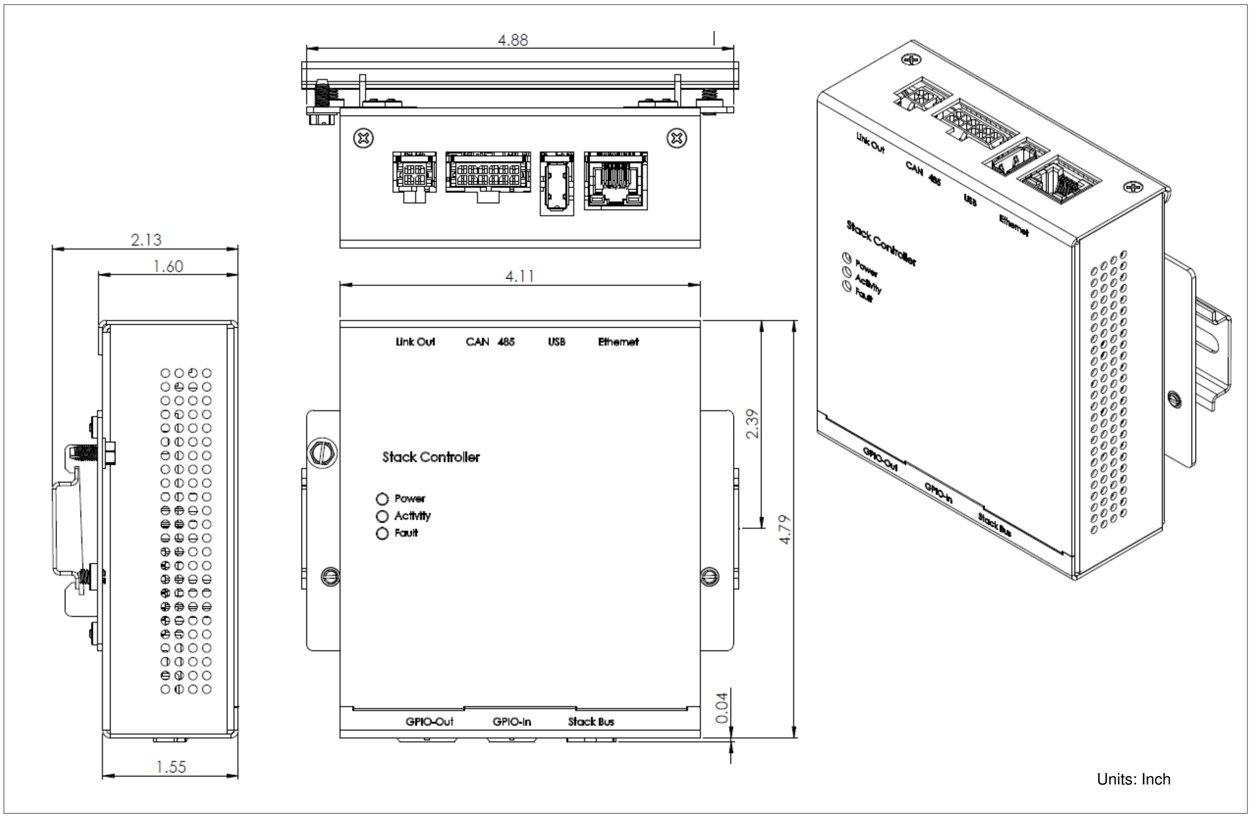


Figure 30: Nuvation BMS™ High-Voltage Stack Controller Mechanical Drawing

Nuvation BMS™ High-Voltage Cell Interface

Nuvation BMS™ High-Voltage Cell Interface with DIN Enclosure

Weight: 540g

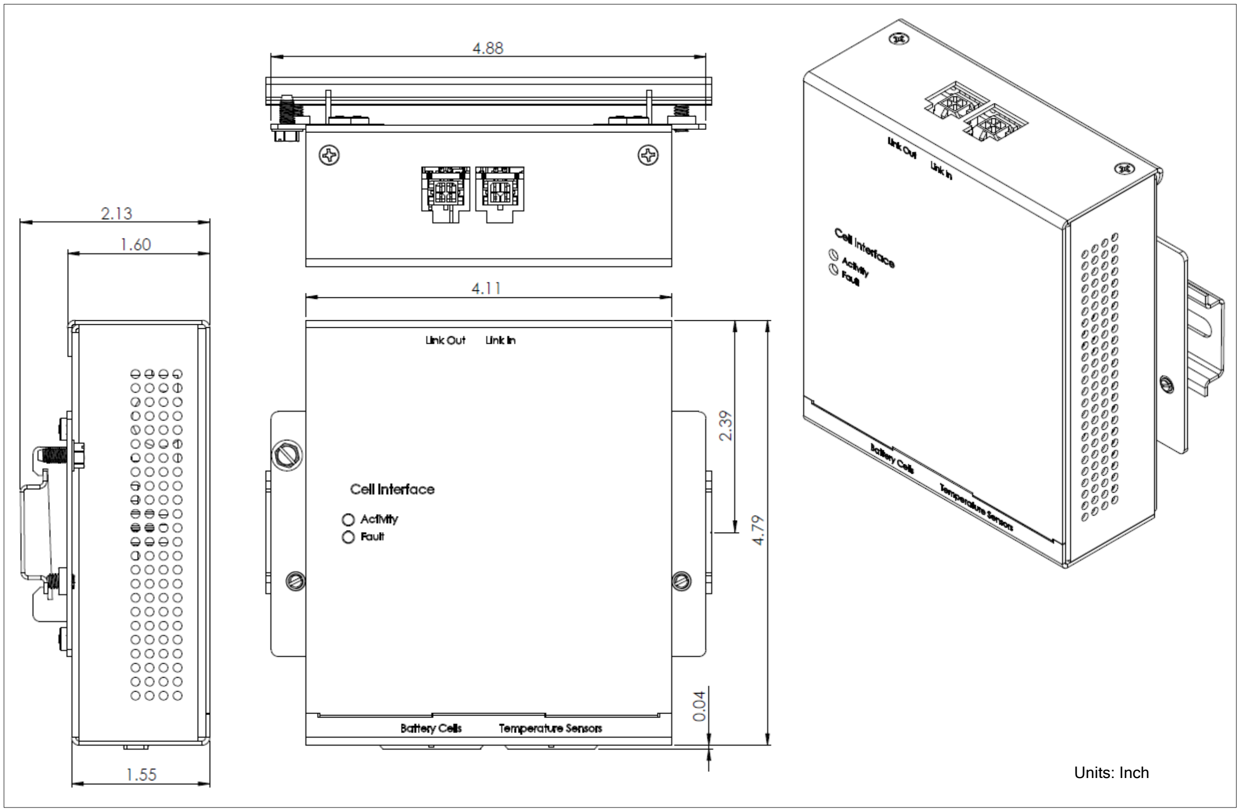


Figure 31: Nuvation BMS™ High-Voltage Cell Interface Mechanical Drawing

Nuvation BMS™ High-Voltage Cell Interface with Bulkhead Enclosure

This enclosure has five metal walls, leaving the bottom of the unit fully exposed. It must be mounted to a metal bulkhead panel so that the panel will become the missing side. The module will produce up to 24W (32W if it is the CI-16 model) during cell balancing. A portion of this heat will be transferred to the bulkhead.

Weight: 450g

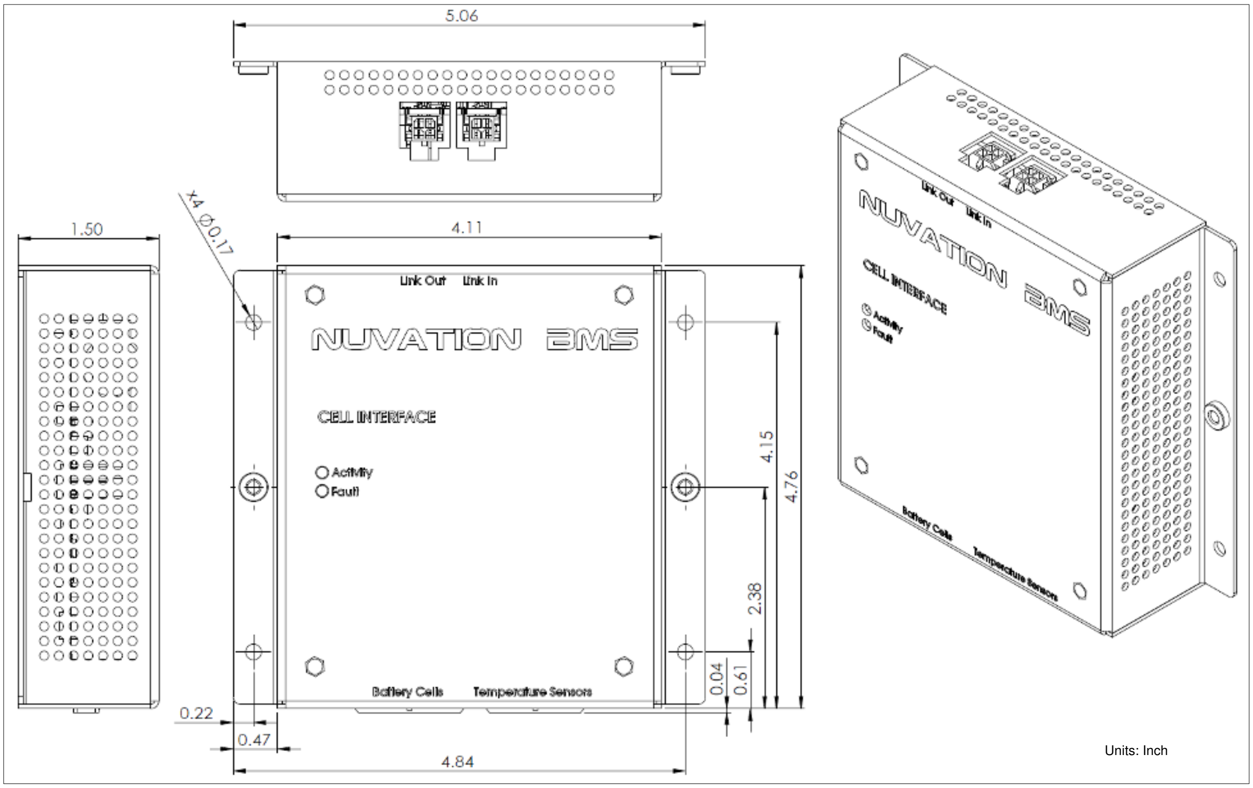


Figure 32: Nuvation BMS™ High-Voltage Cell Interface with Bulkhead Enclosure Mechanical Drawing

Nuvation BMS™ High-Voltage Power Interface

Nuvation BMS™ High-Voltage Power Interface with DIN Enclosure

Weight: 915g

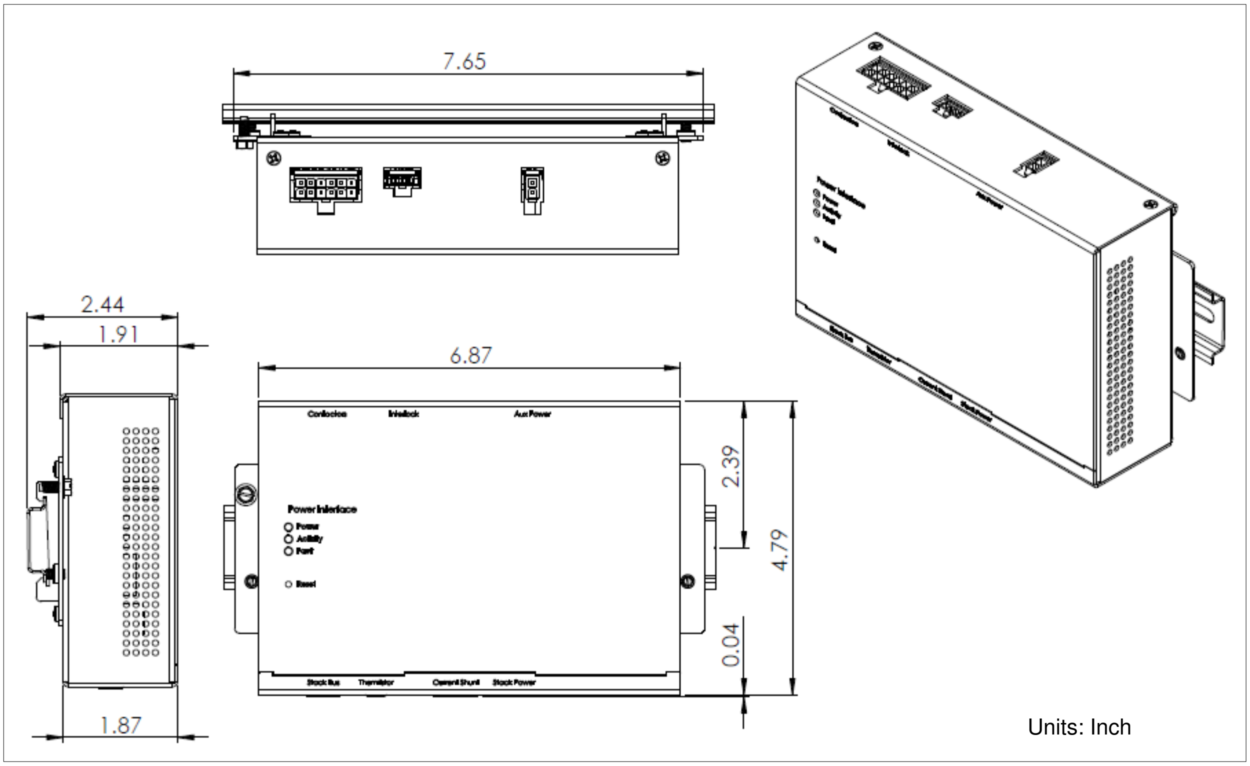


Figure 33: Nuvation BMS™ High-Voltage Power Interface Mechanical Drawing