www.orionbms.com

Wiring & Installation Manual

The Orion BMS 2 by Ewert Energy Systems is the second generation of the Orion BMS. The Orion BMS 2 is designed to manage and protect lithium ion battery packs and is suitable for use in electric, plug-in hybrid, and hybrid electric vehicles as well as stationary applications.

Major key additions in the Orion BMS 2 are:

- Significantly improved cell voltage measurement accuracy & resolution (0.1mV resolution)
- Lighter weight, smaller, and more optimized mechanical design
- Compatibility with both 12-volt and 24-volt power supplies
- Ability to directly drive certain contactors on select outputs (limitations apply)
- Integrated J1772 & CHAdeMO charging interface support
- Significant algorithm improvements
- Expanded diagnostic capabilities
- Significantly improved multi-unit operation with remote modules
- New inputs and outputs
- Up to 8 thermistor inputs now directly on the BMS (previously 4)

Table of Contents

SAFETY: READ THIS FIRST

Important things to read first that will save you time and possibly a battery pack or BMS:

This product is designed to be integrated into an application. Integration must be performed by a qualified person trained in electrical engineering and familiar with the characteristics and safety requirements of lithium batteries. Proper integration, selection of components, wire selection, installation, routing of cables and interconnects, and the determination of the suitability of this product for the application are fully the responsibility of the integrator. Do not use this product if you are unsure if you possess the necessary skills to complete this integration.

1) The **voltage tap connectors must be DISCONNECTED from the BMS when being wired or when wiring is being modified** for personal safety and to prevent damage. **Wiring while connected to the BMS may pose a personal safety hazard and/or fire risk** since the remaining wires within the cell group can become electrically 'hot' due to internal protection diodes. Additionally, wiring with the BMS connected **significantly increases the risk of damage to the BMS**. Damage to the BMS from mis-wiring or misuse is not covered under warranty. **Immediately disconnect the BMS from the battery if the BMS is damaged.**

2) **The BMS must have a means of controlling and shutting off any connected charger, load, source or any other means of charge and discharge.** Two shutoff mechanisms should be present to turn off a charger. The charge safety signal is designed to be used as an emergency backup if a digital CAN control or digital charge enable signal fails. If the charger does not support an analog shutoff, an AC relay can be used in series with the charger power supply. This is the last line of defense if a failure occurs and should not be omitted. **In addition** to the above safety, the battery charger should be programmed such that it does not exceed the maximum pack voltage if a failure occurs.

3) All battery packs must be protected from over-current with a suitable current limiting device such as a fuse. ***If a fuse of safety disconnect is positioned between the first and last cell of a battery pack, it must be wired in certain locations***. Read **Safety Disconnects and Fuse Position** for more information. **Failure to comply may result in catastrophic failure of the BMS from full stack potential present across two adjacent cell taps if a fuse blows or if the safety disconnect is removed and will not provide the required safety isolation. Read the full wiring manual before wiring the BMS, especially the cell tap harnesses.**

4) Always **verify voltage taps are wired correctly** ***before*** plugging them into the Orion BMS. Failure to do so may result in damage to the BMS. ***Damage to the BMS from mis-wiring or misuse is not covered under warranty*** and some incorrect wiring may pose a personal safety risk or fire risk from energy from the battery pack. Please see the section "Verifying the wiring" for methods of testing to ensure the voltage taps are wired properly. Immediately disconnect the Orion BMS from cells if it is incorrectly wired. ***Leaving the Orion BMS connected to cells when incorrectly wired may drain incorrectly wired cells, even when the unit is turned off which may permanently damage connected cells.***

5) Make sure that all cells are connected to the BMS and that all current is measured by the hall effect current sensor. **It is the user's responsibility to ensure the BMS is connected to all cells, to verify the BMS has a method to limit current in and out of the pack, and to determine and supply the correct programming parameters (such as maximum cell voltage, minimum cell voltage, maximum temperature, etc).**

6) Because the Orion BMS is connected to a high voltage battery pack, hazardous voltages and hazardous energies may be present inside the unit. There are no user serviceable parts inside the unit and opening the enclosure will void the warranty. Users should never attempt to repair an Orion BMS unit. Further, a damaged unit or a unit repaired without authorization may pose additional safety risks. **DAMAGED UNITS SHOULD BE IMMEDIATELY DISCONNECTED FROM ALL POWER INCLUDING THE BATTERY PACK AND REMOVED FROM SERVICE. NEVER CONTINUE TO USE A DAMAGED BMS UNIT.** Please contact the factory or your local distributor for repair options. Ewert Energy is not liable for damage caused by user attempted repairs or continued use of a damaged BMS unit.

7) While every effort is made to ensure that the Orion BMS operates properly under all conditions, it is the integrator's responsibility to integrate it properly into the application such that any failure is a safe failure. For more information, please read "Failure Modes" in the operational manual. The integrator is responsible for the determination of suitability of this product for the application, choice of all external components, including, but not limited to, wire, wiring methods, and interconnects, and complying with any regulations, standards, or codes. **This product is not to be used for life support systems, medical applications, manned aircraft, weapons systems, or other applications where a failure could cause damage to property or cause bodily harm or death.**

8) Paralleling separate strings of li-ion batteries together requires special considerations and a method to isolate each string from each other. **The Orion BMS may not be used with parallel string configurations unless specific external safety systems are provided. Engineering work by a qualified electrical engineer is required for use with parallel strings.** Generally, one Orion BMS is required per parallel string (in certain specific cases, it **may** be possible to use a single unit with reduced accuracy when isolation requirements are met). If you are using the Orion BMS in a parallel string setup, please see our documentation about parallel strings (Note: this is different from paralleling cells inside of a single string which is very common).

9) **The BMS chassis must be grounded** to properly bypass electrical noise to the chassis ground. A grounding lug is provided for this purpose. Additionally, external tooth lock washers can be used on mounting screws to ensure good electrical connectivity between the chassis and the Orion BMS. Ground straps should be as short as possible using as large gauge wire as possible.

10) The BMS unit must be programmed in order to function. BMS units ship from the factory with a profile that will not allow charge or discharge for safety reasons. To program, the BMS must be connected to a PC using the CANdapter. For more information on programming, see the software manual.

ALWAYS READ THE MANUAL BEFORE USE.

The most up-to-date Orion BMS manuals can be downloaded at: www.orionbms.com/downloads

Determining which BMS to order

In order to reduce costs, the Orion BMS 2 is offered with different cell group electronics populated. Please carefully read “Wiring the BMS” to accurately determine what size BMS you require for your application. Ideally, the BMS can be the same size as the actual number of cells you have or the next size up. However, depending on the placement of fuses, safety disconnects, and/or any high resistance busbars / wires, it may be necessary or desirable to skip over cell tap positions on the BMS. In those cases, the BMS may need to be sized for more cells than the pack actually has (in some cases, substantially more). For example, a battery pack that has 44 cells may require a BMS that supports 60, 72, or more cells depending on where any high impedance busbars, fuses, or safety disconnects are located. The Orion BMS 2 is available in increments of 12 cells from 24 cells to 180 cells in a single enclosure. A BMS unit sized for a larger number of cells can be used with a smaller number of cells (for example, a 108 cell unit can be used with as few as 4 cells). A larger BMS unit will give more flexibility in wiring and is recommended when the exact configuration is not known. For convenience, a wiring diagram generator tool, which can make recommendations for a minimum BMS configuration based on the location of disconnects and long cables, is available. The tool is available at orionbms.com/downloads.

Orion BMS 2 units can be expanded by adding additional remote modules for up to a maximum of 324 cells. (Note: a maximum battery voltage limitation of 800V applies, which will limit the number of cells in series for most battery types. The BMS supports this many cells in order to allow for cell tap positions to be skipped for fuses and safety disconnects as well as to support low voltage cells such as lithium-titanate.)

The following table shows the standard available ordering options and applies both to the main unit and remote modules. Please note that only the populated cell groups are able to sense cell voltages even if the connectors are present on the unit. Additional custom configurations may be available in higher volumes.

72 Cell Size Enclosure

BMS Size	Cell Groups Populated
24	1, 2
36	1, 2, 3
48	1, 2, 3, 4
48-S*	1, 2 and 4, 5
60	1, 2, 3, 4, 5
72	1, 2, 3, 4, 5, 6

108 Cell Size Enclosure

BMS Size	Cell Groups Populated
84	1, 2, 3, 4, 5, 6, 7
96	1, 2, 3, 4, 5, 6, 7, 8
108	1, 2, 3, 4, 5, 6, 7, 8, 9

180 Cell Size Enclosure

BMS Size	Cell Groups Populated
96 –S*	1, 2, 4, 5, 7, 8, 10, 11
120	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
132	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
144	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
156	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
168	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
180	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

* -S ordering options are arranged differently to provide 2.5kV isolation between cell groups

Included with the standard BMS

- Hardware
- CD with BMS utility software (also can be downloaded from orionbms.com)
- Quick Start Guide with connector pinout diagrams
- Safety “Read First” sheet

Additional items required to operate BMS (not included with base unit)

- CANdatper CAN-to-USB adapter (required for programming and diagnostics only)
- Crimps and connectors or pre-wired harnesses
- Current sensor (required for full functionality of BMS)

Ordering Options

- Number of cells supported (see above)
- Current sensor options: +/- 200A, 500A, 800A and 1000A
- Non-standard CANBUS termination options
- Permanently enabled or permanently disabled isolation fault detection circuit
- With or without support for remote modules
- Pre-assembled wiring harnesses or crimps and connectors are available
- Remote cell tap modules for split battery packs or monitoring larger numbers of cells
- Thermistor expansion module if more than 8 thermistors are needed per unit
- Displays, data loggers, cloud based remote monitoring, and PC interfaces are also available
- See “Purchasing Guide” for details on ordering options

Theory of Operation

The Orion BMS 2 protects and monitors a battery pack by monitoring several sensors and using several outputs to control charge and discharge into the battery. The BMS measures inputs from cell voltage taps, a hall effect current sensor, and thermistors. Using the programmed settings, the BMS then controls the flow of current into and out of the battery pack by broadcasting charge and discharge current limits (via the CANBUS or via analog reference voltages) or by simple on/off digital signals depending on which style is appropriate for the application. The system integrator must provide external controls within the application that respect the current limits set by the BMS to protect the batteries as the BMS does not have integrated switches. During and immediately after charging, the BMS will balance the cells using internal shunt resistors based on the programmed settings.

The Orion unit monitors each individual cell tap to insure that cell voltages are not too high or too low (in accordance with the values programmed). Using the temperatures, cell voltages, the amperage going in and out of the pack (provided by the current sensor), and programmed values in the battery pack profile, the BMS calculates the pack's internal resistance, individual cells' internal resistances, and open cell voltages. From those calculations, the maximum charge and discharge current limits are calculated, and adjustments are made to the pack's calculated state of charge if necessary. These calculations are also used in monitoring the health of the pack. Charge and discharge current limits are provided on the CANBUS and can be programmed to trigger on/off digital outputs to allow or deny charging and discharging of the battery pack.

The BMS also performs other functions such as cell balancing by passively removing charge from cells which are higher than the rest of the battery pack. The BMS will interface with J1772 AC charging stations as well as off-board CHAdeMO chargers.

Additionally, the BMS has many redundant safeties, most of which are transparent to the user. The BMS can be programmed to monitor for a breakdown in isolation between the battery pack and BMS's ground, to detect a failure of the current sensor, and many other internal failures. Please see "failure modes" in the operational manual for more information on failure modes.

Mounting

Physical Mounting

The Orion 2 BMS can be mounted in any orientation. Four to eight mounting slots are provided on the mounting flanges of the BMS depending on the enclosure size of the BMS. The BMS is rated for the automotive temperature range of -40C to +80C and is designed for use in moderately protected locations such as inside the passenger compartment of a vehicle. If the BMS could be exposed to harsh environments such as sprayed liquids, salt spray, or other similar conditions, it must be located inside a suitable protectively sealed rated enclosure. It should be noted that lithium batteries themselves also must typically be protected from these harsh environmental elements, and the BMS is typically located in an adjacent location.

Do not install the BMS or route BMS cell tap cabling on or next to flammable materials such as wood or carpeting or in environments where explosive or combustible gases may be present.

Thermal & Ventilation Information

The Orion BMS requires unobstructed, adequate ventilation and must not be surrounded or sealed by thermal insulating material. Blocking ventilation or thermally insulating the unit may pose a fire hazard.

The BMS is designed to dissipate all heat generated via convection, although a cooling fan may optionally be used. 108 cell size BMS units and smaller generate up to 40 watts of heat, and a 180 cell unit generates a maximum of 60 watts of heat average under normal use while balancing. Under normal conditions, significant amounts of heat are only generated during the balancing phase of charge. Heat dissipation under non-balancing conditions is typically less than 3 watts. The Orion BMS is equipped to measure the internal temperature of the unit and heatsink temperature and will automatically reduce balancing current if the temperature of the heatsink rises above 50 degrees Celsius. Even though the BMS will automatically limit balancing to maintain a specific temperature range, the BMS **must** be installed such that is has adequate ventilation to dissipate up to 40 watts for 108 cell and smaller units and 60 watts for 120 cell and larger units safely without causing dangerous temperature rise. During certain abnormal fault conditions, the unit has the potential to generate as much as 40 watts of heat. Ventilation must be adequate for this amount of heat even though this will not be generated under normal use. Thermal dissipation should be considered if the BMS will be enclosed in a liquid tight enclosure.

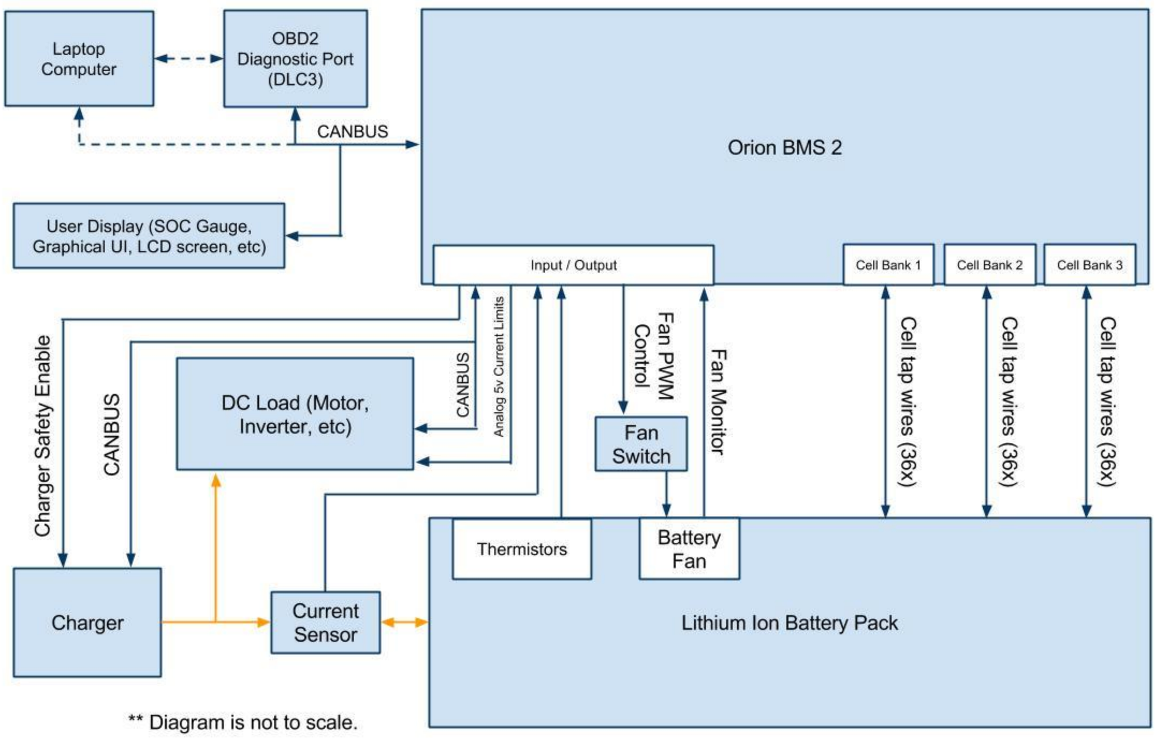
The Orion 2 BMS has a removable heatsink, which may be removed so the unit can be attached to a cold plate or other heatsink. When the stock heatsink is removed, the unit must always meet the minimum heatsink requirements. Care must be taken to ensure good thermal bonds between the BMS chassis and the heatsink. Although unnecessary for most applications, forced cooling such as with fans may be used to lower the thermal impedance. In all cases, the unit must be able to dissipate 40 watts for a 108 cell size and 60 watts for larger units at all times, including when the unit and cooling are off, in the event of abnormal faults. A vehicle chassis should not be treated as a heatsink.

Ground Lug

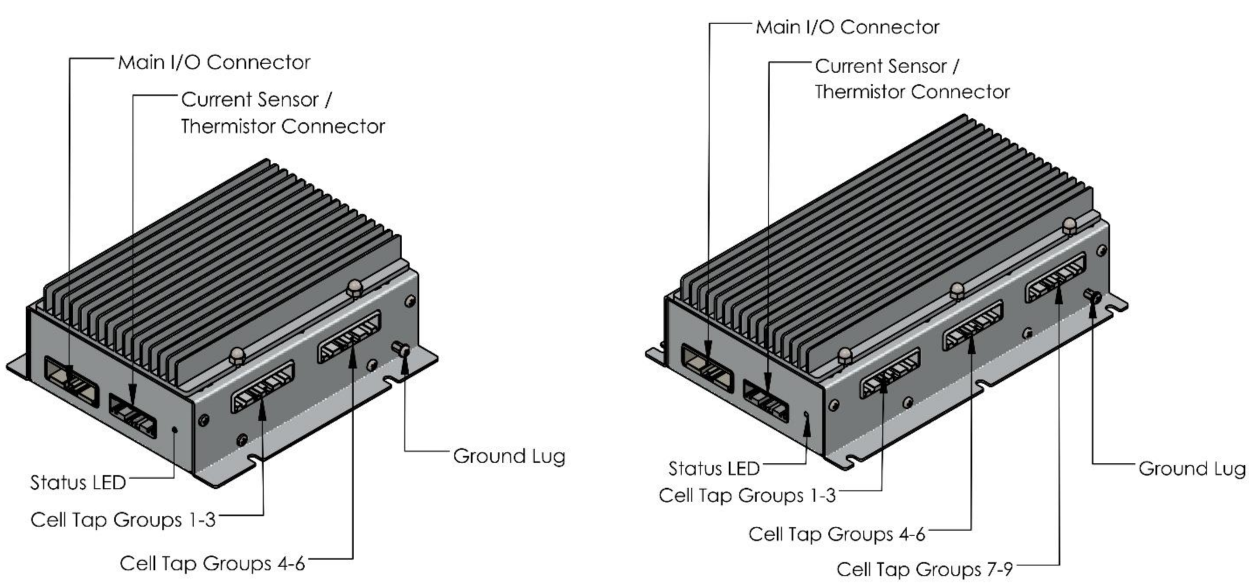
A ground lug is provided on the outside of the enclosure. The BMS bypasses some electrical noise to the chassis ground. **The BMS MUST be grounded to a vehicle chassis or earth ground (if stationary) for proper electrical noise rejection.** In applications which do not have a grounded chassis, the chassis of the BMS must still be grounded for proper noise handling. In most of these cases, the ground lug can be connected to the 12v - 24v power supply negative. If noise persists with the ground lug connected to the negative on the 12v - 24v power supply, it may be necessary to identify the noise source and evaluate a different grounding path.

The voltage of the BMS chassis with respect to the voltage of the 12v – 24v ground may never exceed 50V. When in doubt, ensure that the BMS chassis is grounded to the 12v – 24v power supply negative.

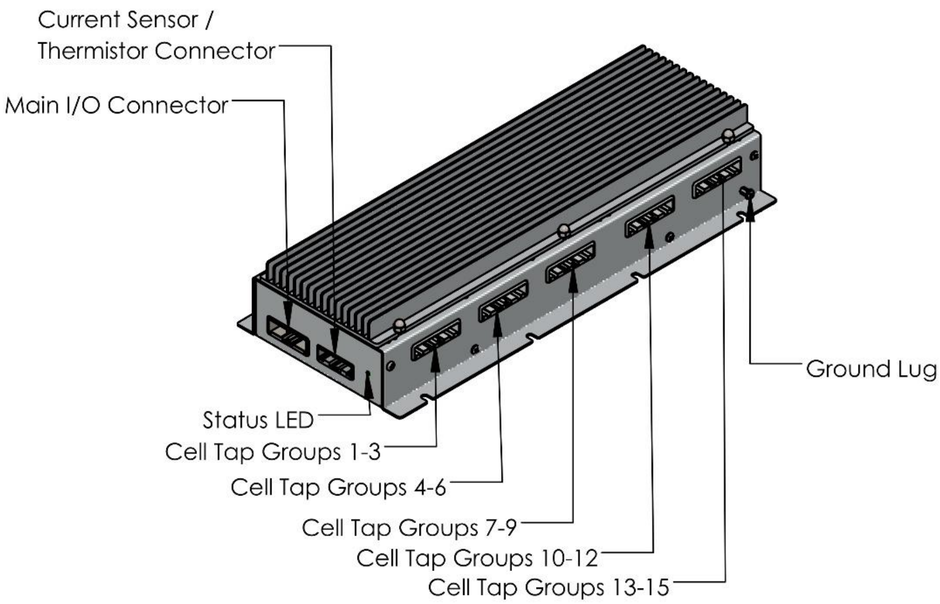
Wiring Overview



Overview of system connections



Connector locations on the 72 and 108 cell Orion BMS 2 units



Connector locations on the 180 cell Orion BMS 2 unit

Connectors, Crimps, and Tooling

For ease of installation, pre-crimped harnesses are available from Ewert Energy, and they are recommended for prototyping and small runs. For larger runs, however, it is usually beneficial to have the harnesses custom manufactured for the exact specifications needed as this reduces waste and assembly time. Contact Ewert Energy Systems for recommendations on cable houses for custom harnesses.

Below is a chart showing the mating connectors, crimps, and official assembly tooling for the connectors used on the Orion BMS 2. Most connectors are TE Connectivity (formerly Tyco) parts:

Connector	Housing	Crimps
Voltage Tap	TE # 1318389-1	TE # 1123343-2 (Gold
Main I/O	TE # 1376360-1	TE # 1123343-1 (Tin)
		Sumitomo # 8240-4892 (Tin)
Current Sensor / Thermistor	JAE # MX34028SF1	JAE # M34S75C4F1

Below are the official hand tools for use in assembling the above connectors:

Crimps	Official Hand Crimping Tool	Official Extraction Tool
TE # 1123343-1 / 1123343-2	TE # 1463260-1*	TE # 1276565-1**
JAE # M34S75C4F1	JAE # CT150-2-MX34	JAE # ET-MX34-1

* This is the official hand crimp tool recommended by TE Connectivity (Tyco). Machine crimp application is strongly recommended. Hand crimping often leads to significantly reduced reliability.
** This is the official pin extraction tool. Other less expensive extraction tools may be usable, such as a modified Molex p/n 11-03-0044.
*** Important: The contact type must match with the BMS. The Orion BMS 2 comes standard with gold plated connectors, but may be special ordered with tinned contacts. If ordered with tinned connectors, use TE #1123343-1 contacts.

Below are the part numbers for the connector mating with the current sensor:

Connector Housing	Crimps	Seals
TE # 1-1456426-5	TE # 1670146-1	TE # 967067-1

Wire Sizes

Connector & Crimp	Wire Gauge
Main I/O 1123343-1 (small crimps)	22 AWG
Main I/O 8240-4892 (large crimps)	18 AWG
Thermistor / Cur. Sensor M34S75C4F1	22 AWG
Voltage Tap 1123343-2	22 AWG*

* For additional wire considerations, please see “Harnesses and Cable Routing” below.

Warning: Always disconnect all power, especially on cell taps, before servicing or altering connectors. Working on a live connector is extremely dangerous and presents a personal safety hazard including burns from arc flash and risk of shock.

Interfacing the Load and Charger with the BMS

The Orion BMS 2 constantly calculates maximum current limits for both charging and discharging. These current limits are based on many parameters including pre-programmed maximum amperages (usually specified by the cell manufacture), temperature, cell health, state of charge, and several other conditions. The current limits are automatically determined based on a calculated algorithm to prevent the cell voltages from dropping below or going above the minimum and maximum cell voltages respectively. More information on how the current limits are calculated can be found in the operational manual.

While the BMS can accurately calculate current limits to keep the connected cells within safe operating parameters, the BMS unit itself cannot directly enforce these current limits (ie: it is up to the load and charger to respect the limits that the BMS sets). For this, the BMS relies on the installer to provide a means to limit charge and discharge current and can only protect cells when this external means of limiting current is properly connected. The BMS must be able to turn off ***all*** charge and ***all*** discharge to the battery pack in order to properly protect the cells. ***Failure to provide an external method to limit charge and discharge current will result in the BMS not being able to protect the connected cells.*** Below are the three main methods of interfacing the BMS to control a load or charge source.

Current Limiting via the digital CANBUS (Controller Area Network)

Many modern chargers, motor controllers, solar/wind charge controllers, and other equipment come with a digital CANBUS interface. This digital protocol usually has a method of communicating maximum current limit(s) to the device. For example, almost all CANBUS enabled battery chargers will listen to the BMS and charge at an amperage not to exceed the amperage the BMS instructs them. Likewise, almost all CAN-enabled motor controllers can be configured to listen to the BMS and limit the amount of current the motor can draw to the amperage that the BMS specifies. Motor controllers that support regenerative braking usually will also listen for a maximum charge current in order to limit regenerative braking amperage.

Interfacing with external devices via CANBUS has some significant advantages and is generally the preferred method of controlling external devices whenever a CAN interface is available (with a few exceptions). Because CAN is a digital protocol, the BMS can accurately and quickly specify the current limit to the device. This is particularly useful for applications where a gradual reduction of power either at the end of discharge or end of charge is beneficial or necessary and takes full advantage of the Orion BMS's capabilities. For example, if the BMS is being used in a vehicle, it is desirable for the vehicle to gradually slow down when the battery is exhausted rather than suddenly cut out when the battery is depleted. This also allows a greater portion of the battery to be used. Gradual current limiting is necessary to fully charge a battery pack to 100% state of charge (although in most applications it is desirable only to charge to a maximum of 95% for lifespan reasons, which may not require gradual tapering of the charge in lithium batteries). Although CAN is a precise and robust way to control loads, it is a digital communication system and communication failures must be handled appropriately. Because of this, an analog backup is usually necessary.

The Orion BMS utility has built-in support for many CAN enabled chargers and motor controllers and has an extremely programmable CAN interface which can be programmed for devices that are not already integrated.

Current limiting via the analog voltage outputs.

The Orion BMS is equipped with two analog voltage outputs which can be used to communicate the amperage limits to external devices. Pin 16 (Discharge Current Limit or DCL) and Pin 5 (Charge Current Limit or CCL) are both outputs which range from 0 to 5 volts and provide an analog representation of the maximum current limits (0V = 0%, 5V = 100% of the maximum limit). If a motor controller does not support CAN, but has a 5V potentiometer for a throttle, it may be possible to use the 0-5V output from the BMS to limit the maximum voltage on the potentiometer and therefore effectively limit current. Interfacing charge and discharge limits with a vehicle is usually handled by communicating with a motor controller. Integrating directly with a throttle is not recommended. The BMS can interface with devices requiring a 0-10V signal with the addition of external op-amp circuit to translate the voltage.

Important: Whenever the 0-5V analog outputs are used for controlling current, they must be used in conjunction with the charge or discharge enable outputs from the BMS as a backup to ensure the BMS can fully turn off the device since the analog 0-5V outputs are not watchdog backed and could potentially lock at a certain voltage in a failure. See “Wiring the Main I/O” below for more information.

Important: Care must be taken to ensure that interfacing with the device is done in a manner where a single failure will not lead to dangerous situations. This is particularly important if interfacing with a throttle to ensure that no fault could lead to unintended acceleration or other unintended consequences. The integrator is solely responsible for integrating the BMS with the application in a safe manner.

Current limiting via an on/off signal from the BMS.

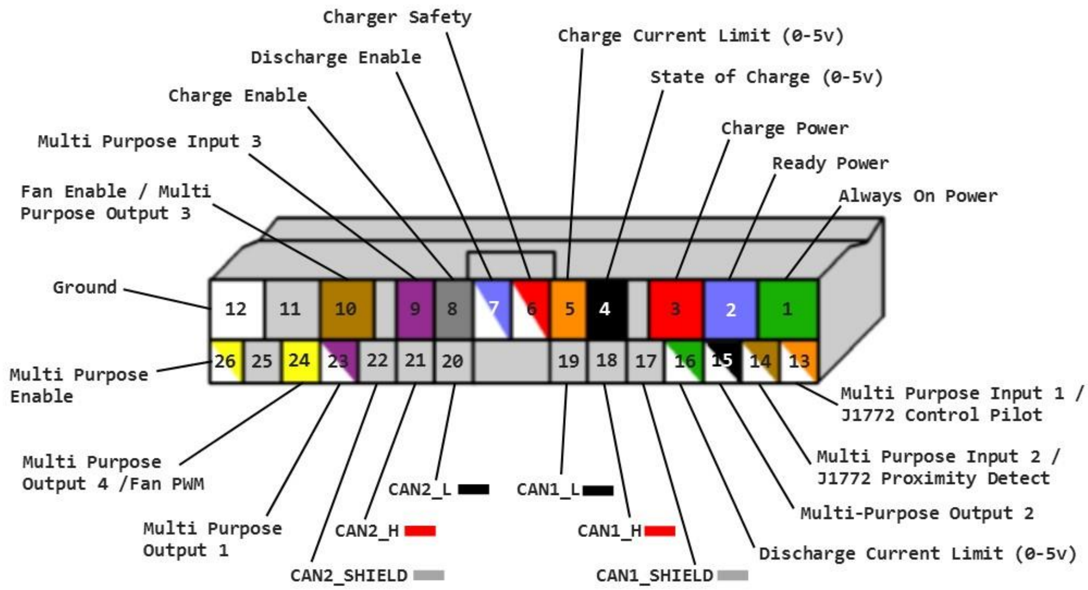
The simplest method to control a load or charger is by using the on / off outputs. These outputs will turn on when charge or discharge are allowed based on the present conditions. Unlike the other above methods of controlling external devices, these outputs are either on or off and cannot gradually taper charge or discharge (though they can be used in conjunction with the other methods). There are 4 on / off outputs: charger safety enable, discharge enable, and charge enable, and a programmable multipurpose enable. Charger safety enable is used to control a battery charger; discharge enable is used to control a load such a motor controller or AC inverter; and charge enable is used to turn off intermittent charging currents such as charge from regenerative braking or intermittent charge sources such as solar or wind energy.

More information about how the outputs are wired and how they function can be found later in this manual as well as in the operational manual. Information on changing the setting for when these outputs are on can be found in the software manual.

Notes for specific applications

Application notes are available for integrating with many common motor controllers and chargers and include information, tips and recommended wiring specific to those devices. Application notes can be viewed at http://www.orionbms.com/application-notes/

Main Input/Output (I/O) Connector



Wire side of Main I/O connector

Signal Name	Description
CAN1_H, CAN1_L	First CAN interface with high and low signal lines. With the default ordering option, this interface **includes** a termination resistor.
CAN2_H, CAN2_L	Second CAN interface with high and low signal lines. With the default ordering option, this interface is **without** a termination resistor.
Always On (AM) Power Source	Always on battery source. **This power source is optional for the Orion BMS 2.** BMS settings and collected data are retained in non-volatile memory when all power is lost (see “Power Supplies” below for more information). **This power source is required for J1772 support**, if redundant power supplies are to be used, or if very fast startup times are required.
READY Power Source	This power source should be connected to a 12v - 24v nominal (9v – 30v actual) power source whenever the BMS should be active for normal use. This line will cause the BMS to wake up and resume from sleep. For electric vehicles, this would usually be tied to the keyed ignition. This power source may be powered at the same time as the CHARGE power source.
CHARGE Power Source	This power source should be connected to a 12v - 24v nominal (9v – 30v actual) power source to signal that the BMS is in a defined charging period (such as when the vehicle is parked and plugged in). This is often powered thorough an AC-DC power supply off the grid power. If this power source is connected while the READY power source is also connected, the BMS can optionally activate the “Charge Interlock” state which may be used to prevent discharge while charging. The charge interlock feature can be disabled in the settings if desired. This power source may be always powered when

	used in energy storage applications (see “charge power source” below for more details)
Power Ground	This is the ground for the supply power sources for the BMS. All three power sources (AM, READY and CHARGE) use this ground. Only pin 12 is ground.
Charge Enable Signal (Out)	This output is an on/off signal used to control an intermittent charging source, such as regenerative braking in an electric vehicle or a solar or wind charging source. This signal can be used as one of the primary controls or as a backup to digital CAN communication with a controller (note that two or more methods must always be provided for shutting down a charger for safety). This output is an open drain output, meaning that it does not source voltage, but rather pulls down to ground when on. This output is able to directly drive certain types of contactors (see below for important limitations and more information).
Charge Safety Signal (Out)	This output is an on/off signal used to control a battery charger during defined periods of charging such as would be present in an electric vehicle while parked and charging. This signal must be connected to the charger (if supported) or be connected to a relay which enables AC power to the charger such that the lack of this signal will cause the charger to be inactive. This signal can be used as one of the primary controls or as a backup to digital CAN communication with a controller (note that two or more methods must always be provided for shutting down a charger for safety). This output is an open drain output, meaning that it does not source voltage, but rather pulls down to ground when on. This output is able to directly drive certain types of contactors (see below for important limitations and more information).
Discharge Enable Signal (Out)	This output is an on/off signal used to signal to a load that the battery is able to be discharged. This would normally be used to control a motor controller in an electric vehicle or to shut off other loads. This signal can be used as one of the primary controls or as a backup to digital CAN communication with a controller. This output is an open drain output meaning, that it does not source voltage, but rather pulls down to ground when on. This output is able to directly drive certain types of contactors (see below for important limitations and more information).
Multi-Purpose Enable	This is a user selectable on/off output which can be used to control a load or source, as well as many other functions based on various user defined criteria. If this output is used as a primary control method to control a load or charger, the corresponding charge enable, discharge enable, or charger safety must also be used in conjunction with this output. One of the selectable outputs for this pin is a system contactor enable output that can serve as a backup switch for other primary control mechanisms. This output is an open drain output, meaning that it does not source voltage, but rather pulls down to ground when on. This output is able to directly drive certain types of contactors (see below for important limitations and more information).
Multi-Purpose Output 1	The function of this output is user definable. This is an open drain output which pulls down to ground when on. Please see the software manual for a

	complete list of available functions. This output is NOT watchdog backed and may remain on when certain faults occur. This output should not be used as the sole control for limiting charge or discharge.
Multi-Purpose Output 2	The function of this output is user definable. This is an open drain output which pulls down to ground when on. Please see the software manual for a complete list of available functions. This output is NOT watchdog backed and may remain on when certain faults occur. This output should not be used as the sole control for limiting charge or discharge.
Fan Enable / Multi-Purpose Output 3	The function of this output is user definable. If the fan control is enabled, this pin will be used to provide an on/off signal to a battery cooling fan. This is an open drain output which pulls down to ground when on. Please see the software manual for a complete list of available functions. This output is NOT watchdog backed and may remain on when certain faults occur. This output should not be used as the sole control for limiting charge or discharge.
Fan PWM Signal / Multi-Purpose Output 4	The function of this output is user definable. If the variable speed PWM fan control is enabled, this signal is used to control an external switch (MOSFET) to vary the battery cooling fan speed. The PWM signal is between 10% and 90% duty cycle (full range is not used in order to monitor fan performance). This is an open drain output which pulls down to ground when on. When used to drive a MOSFET for PWM, a pull-up resistor is required (see below for more information). This output is NOT watchdog backed and may remain on when certain faults occur. This output should not be used as the sole control for limiting charge or discharge.
Multi-Purpose Input 1 / J1772 Control Pilot	This is a user definable input that can have multiple different input functions such as redundant keep-awake power signals, clearing DTC fault codes, and other functions. Please see the software manual for a complete list of available functions. If J1772 support is enabled, this pin is connected to the J1772 Control Pilot.
Multi-Purpose Input 2 / J1772 Proximity Detect	This is user definable input that can have multiple different input functions such as redundant keep-awake power signals, clearing DTC fault codes, and other functions. Please see the software manual for a complete list of available functions. If J1772 support is enabled, this input is connected to the J1772 Proximity Detect.
Multi-Purpose Input 3 / Fan Monitor Signal	The function of this pin is user definable. If the fan monitor is selected, this pin is used to monitor the external fan voltage to ensure proper operation of the cooling fan.
CCL/DCL/SOC analog 5v outputs	0-5V analog outputs that represent charge, discharge current limits, and state of charge. These outputs are sometimes used to interface with motor controllers or gauges. See below for important information.

Wiring the Main I/O Connector

Power Supplies

12 – 24 volt nominal operating power is supplied to the Orion BMS by three separate power sources - two primary power supplies and one optional always on power supply.

The three power supplies will not back-feed each other due to internal diodes contained within the BMS (external diodes are not required). The Orion BMS 2's typical awake power consumption is shown below. Actual power consumption will vary depending on features used and actual number of cells connected. Due to the switching mode power supply inside the BMS, the actual current will vary with respect to the input voltage. Actual voltages between 8v – 30v are acceptable for operating power. Operating current may be higher if additional devices are connected to the Orion BMS.

Typical power consumption table with all cells connected.

BMS Size	Typical Power Consumption
36	1.5 watts
72	1.8 watts
108	2.1 watts
180	2.8 watts

Fusing

Important: As with all electrical devices, the wires carrying operating current to the Orion BMS unit **must** be current limited at their source, including wires feeding current to relays driven by the BMS. Any circuit connecting to the BMS must be current limited with an appropriately sized fuse (or other current limiting device) to prevent overloading wires in the event of a short. The external fuse must be sized properly to protect the conductors and must specifically have a DC voltage rating of no less than the maximum possible working voltage and an appropriate DC interrupting current rating for the application.

The maximum fuse size permitted for the CHARGE or READY power, any of the open drain output pins, or multi-purpose input pins is 5A, but smaller fuses may be used.

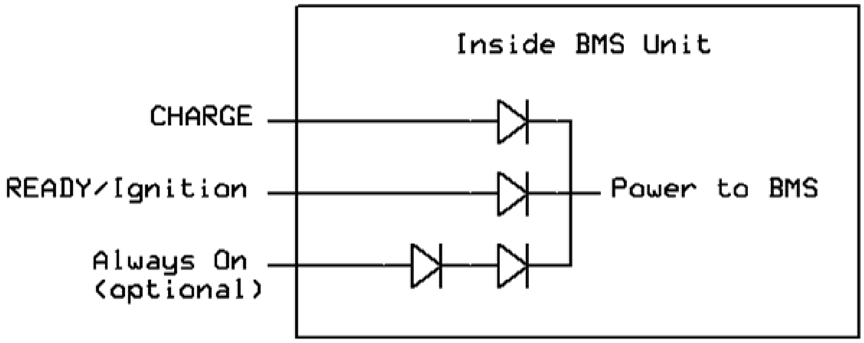
All three power supplies accept a nominal 12 - 24 volts DC. Voltages between 9V and 30V are acceptable for continuous operation. The Orion BMS 2 has expanded brownout protection, allowing the BMS to fully operate at voltages as low as 5v for at least 120 seconds, surpassing ISO 7637-2 "cold crank" requirements (pulse 4 with 12v parameters). It should be noted that, while the unit will fully function at voltages between 5v and 9v for several minutes, the unit is not designed for continuous operation at these lower voltages, and a fault code will be set by the unit if the voltage is less than 9v for more than 8 seconds. Long term use at these voltages may lead to reduced reliability. The Orion BMS unit will consume more power when supply voltage drops below 9v. Additionally, the unit can operate without any power source for up to 100mS (when the starting voltage has been 12v or higher for at least 20 seconds before power is removed). As a result of the internal capacitors, “power cycling” the BMS may require 30 seconds or longer.

The Orion BMS 2 can **fully operate** through the highest class passenger vehicle load dump for 12V and 24V passenger vehicles (ISO 7637-2 pulse 5a, Class IV 174V, 350mS, 1 ohm source repeated 5 times). More powerful transients or repeated exposure to transients at this level may damage the BMS. While the BMS has protection and the ability to operate through transients such as those defined in pulses 1, 2a, 2b, 3a, 3b and 5a in ISO 7637-2, if the BMS is powered at a voltage above 30V for a longer period of time, the BMS may enter into a protective shutdown mode to protect the power supply. The BMS may take several minutes to reset after such a condition.

Always On Power Source: Always on power is optional on the Orion BMS 2 and is only required when certain specific features or tight startup times are needed. All data is retained in non-volatile memory, meaning that the BMS will not lose data or settings if this power is not supplied or if power to this pin is interrupted. This power supply is required in order to make use of the J1772 feature, is required if very fast startup times (close to 20mS) are needed, and is required if using the keepalive redundant power feature. When the always on power is available, the BMS will also remain alive for approximately 1.5 seconds after READY and CHARGE power are lost, allowing data to be supplied briefly longer which may allow more graceful shutdown for some applications. If the always on power is not supplied, the BMS may take up to 200mS to power up and initialize.

If the always on power source is not used or energized by the application, it should be disabled in the configuration settings (so no fault will occur if the BMS detects that it is not energized.) This is done by un-checking the “Clear Fault Codes when Always-On power source is lost” option on the Fault Settings tab of the BMS Profile Settings window. Additionally, unchecking this option will prevent the BMS from automatically clearing fault codes when the Always-On power is not energized so that faults will be stored over complete power loss.

Internal diodes on the always on power input cause additional voltage drop for this power source. This is done in order to cause the BMS to prefer drawing operating current from the READY or CHARGE power supplies, if available, rather than the always on power supply. This is done for applications where the always on power source is connected to an aux battery, and it is not desirable to drain the aux battery when another power source is available. To prevent power from being drawn from the always on power supply, the voltage on this line should be the same or lower than the READY or CHARGE power source voltages. The voltage consideration is only necessary to prevent drawing operating current from the always on power source and can be ignored in applications where not relevant.



*This diagram depicts the internal diodes **within** the Orion BMS unit. **No external diodes are required**. Note the additional voltage drop present on the Always On supply.*

Ready Power Source: This is the primary power source for the Orion BMS unit. This power source can be thought of as the "ignition" or "keyed ignition" power source when the BMS is used in automotive applications. When power is present at this source, the BMS will "wake up" and allow both normal charge and discharge. When powered only by this power source (i.e. Charge power is not present), the BMS will not engage the charger safety output (usually used to control a battery charger) and will not allow cell balancing.

Charge Power Source: This power source should be energized when the battery is being charged in a defined charging phase such as an electric car that is parked and charging. When power is present at this pin, the BMS will enter charging mode which allows for cell balancing and enables the charger safety signal output. For most applications, this is used when the BMS is in a defined charging phase from AC power. Because of this, CHARGE power is normally provided by a small AC / DC power adapter powered off the mains. This is designed to prevent discharge to on-board auxiliary batteries. Since the BMS will draw current from the highest voltage power source present, if the Always On power is used, it may be desirable to use the same or a slightly higher voltage than the Always On power source. This will prevent the BMS from drawing current from the Always On source and is important if draining an auxiliary battery is a concern.

The BMS will fully operate and will enter charging mode when both the CHARGE and READY power sources are powered at the same time. However, when both the CHARGE and READY are powered at the same time, the BMS will enter into charge interlock mode if enabled in the settings. Charge interlock is designed to help prevent a vehicle from driving away while plugged in by prohibiting discharge when CHARGE power is also present (see discharge enable relay settings in the BMS utility). If the charge interlock detection feature is enabled, the BMS will set a temporary fault code when both CHARGE and READY are powered simultaneously (this will also occur if the J1772 inlet is connected while the BMS is in READY mode). The charge interlock fault is automatically cleared when the condition clears. If the charge interlock detection feature is disabled in the settings, there will be no functional impact from having both READY and CHARGE power present at the same time, and the BMS will behave as it would in charging mode.

Voltages are monitored by the BMS at each of the power sources, including the always on source. If power is present only on the always on power source, while CHARGE and READY are both off, the

BMS will enter a low power sleep mode within a few seconds. If power is present at either the CHARGE or READY power sources, but not at the always on power source, the BMS will operate normally. However, depending on a programmable setting, a diagnostic trouble code can be set on the BMS to alert the operator that the always on power is missing. In applications that do not use always on power, this error code can be disabled in the software by un-checking the “Clear Fault Codes when Always-On power source is lost” option on the Fault Settings tab of the BMS Profile Settings window.

In some applications such as non-automotive applications where the BMS is powered by a single power supply or an automotive application with a secondary charger or DC-DC converter topping off the auxiliary battery, it may be more convenient to wake the BMS up using a low current signal rather than supply the full operating current. In this situation, a 1K resistor can be put in series with the CHARGE or READY power supplies. The BMS will detect the voltage at the power source pins, but will be unable to draw operating current from the power source pins due to the 1K series resistor. While this method will not provide redundant power supplies to the BMS, it will wake up the BMS and cause it to draw operating current from the always on power source and may be more convenient for some applications.

Redundancy Power Option: The Orion BMS 2 supports a redundant keep-alive option that makes use of a Multi-Purpose Input pin. This option is designed to keep the BMS “awake” in the event that a power failure occurs to the Ready or Charge power source, but not to the always on power source. Applying a voltage to this pin will not wake up the BMS if it is already asleep, but it will prevent the BMS from going to sleep if it is already active. This feature can be enabled in the BMS settings.

CAN interfaces

The Orion BMS has two separate CAN (controller area network) interfaces - CAN1 and CAN2. The two interfaces are not connected internally and can operate at different baud rates and can transmit and receive different messages. This is particularly useful if the application has multiple CANBUS devices with different baud-rates. The CANBUS interfaces can be configured to run at 125, 250, 500 or 1000 Kbps.

CAN interfaces are high speed differential mode buses and require twisted pair wire (2 wires) to communicate. For best operation, a shielded cable should be used for protection against electrical noise, particularly when used in vehicles or around other noisy devices. For convenience, two locations are provided on the Orion BMS connector to terminate the shields on the cables. Shields should only be connected in one location to prevent ground loops, so if the shield grounding locations are used on the Orion BMS connector, the shields should not be connected anywhere else. Some applications may require grounding of the shields in locations other than the Orion BMS connector to properly divert noise, and it is the integrator’s responsibility to determine if this is necessary. While it is necessary for the wires to be outside of the shield for a short distance at any connectors, the amount of non-shielded, non-twisted wire should be kept as short as possible, ideally a couple inches or less as even very short sections of exposed CANBUS wiring can cause communication errors in high noise environments.

Any external devices connected to the Orion BMS’s CAN interface must share a common ground with the BMS (Main I/O connector pin 12). This is important as differences in ground potentials can damage the CAN transceivers on the BMS and on other devices. If it is not possible to use the same ground, external CAN isolations devices must be used. **Please note that while the low voltage electronics in the BMS are electrically isolated from the battery pack, the CAN transceivers are referenced to the 12v – 24v power supply ground and are not electrically isolated from the 12v – 24v power supply ground or from each other**. If the BMS is connected to motor controllers, chargers, or other devices which do not offer isolation between the high voltage battery pack and the CANBUS (or any other low voltage signals that are connected to the BMS), an external CANBUS isolator is required for safety and for the protection of the equipment. For more information, please see "Internal Isolation" below for an isolation diagram.

Controller Area Networks (CAN) require exactly two 120 ohm termination resistors on the 2 physical ends of the bus to operate properly. A CANBUS can have many nodes (devices) attached to a single bus. If only two nodes are attached, they should be at the physical ends of the cable with a termination resistor as close to each end as possible. If additional nodes are used, they should "T" off the main wire. While the entire CANBUS cable can be very long (up to about 30 meters for 1mpbs,100 meters for 500kbps, or 500 meters for 125kbps), the taps for additional nodes must be kept less than about 3.5 feet or 1 meter off the main cable. It is important to note than an improperly wired CANBUS (e.g. only one termination resistor on the bus or long taps off the main cable) may sometimes appear to work, but may then fail or suffer reliability problems at a later time when exposed to more significant noise. ***The bus must be properly terminated even if it appears to work with just one termination resistor as this will affect the reliability of the network! Please ensure proper termination on the CANBUS even if the bus appears to be working.***

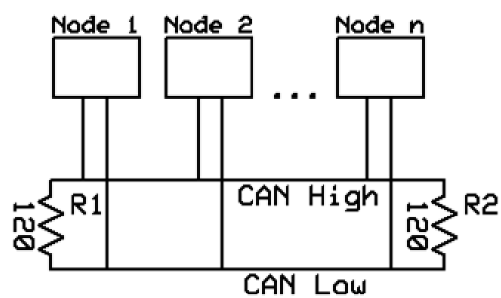


Diagram of a multi-node CANBUS with 120 ohm termination resistors at the ends

For convenience, the CAN1 interface on the Orion BMS 2 (unless specially ordered) has one (1) 120 ohm terminator resistor built into the unit, whereas the CAN2 interface does not, allowing the default Orion BMS unit to be easily integrated either at the physical end of a bus (CAN1 interface) or in the middle of an existing bus (CAN2 interface). Since the BMS includes one of the two necessary termination resistors, at least one additional termination resistor is required on the network so that the CANBUS has exactly two termination resistors (termination resistors are not required on an interface if it is not used). Some other devices such as motor controllers may have integrated termination resistors. Please consult the manual for other devices to determine if they have termination resistors. The Orion BMS can be special ordered with specific termination resistors loaded or unloaded, but this must be done at the time of ordering. Besides the different stock termination, the two CAN interfaces on the Orion BMS 2 are functionally the same. The BMS profile & settings and firmware may be updated from either CAN interface (this differs from previous models in which the CAN1 was the only interface on which a firmware update could be applied).

After wiring the CAN interfaces, it is possible to verify proper termination by using an ohm-meter to check the resistance between CAN_H and CAN_L. In order to verify the resistance, ***all*** power must be removed from all devices on the CANBUS. The total resistance should measure 60 ohms (two 120 ohm resistors in parallel = 60 ohms). If the resistance measures 40 ohms or lower, too many termination resistors are present. If it reads 120 ohms or no resistance, too few are present.

Wiring the CANdapter (for programming)

The following diagram is provided for connecting the Orion BMS's CAN1 interface directly to a DB9 that can connect to the CANdapter for programming. Other nodes may be added to the CAN1 bus, but this drawing does not show that configuration.

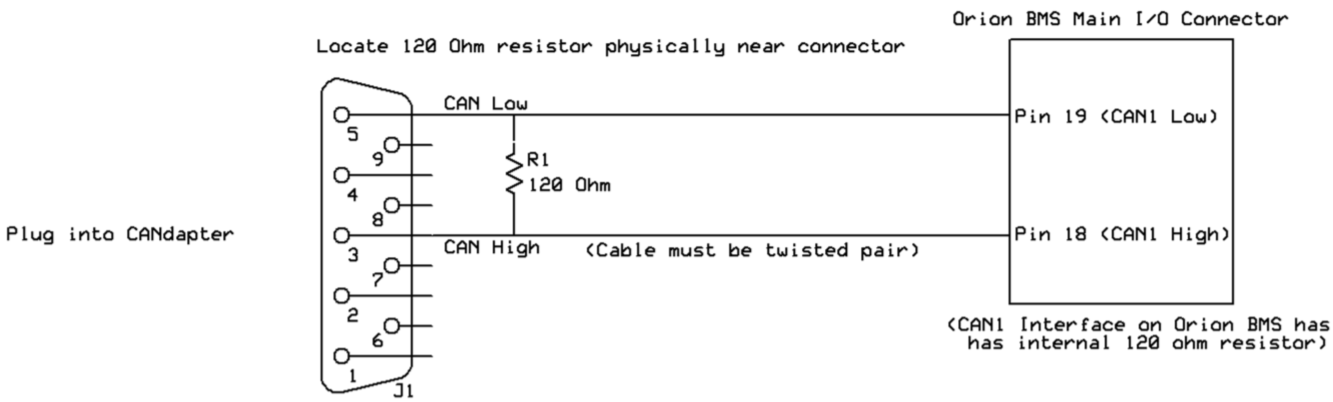


Diagram for connecting the CAN1 interface directly into a DB9 to be connected to the CANdapter

In some applications, it may be desirable to connect the Orion BMS to a diagnostic connector for easy programming or diagnostics. Any style of connector suitable for differential mode digital communications can be used as a diagnostic port including a DB9 connector (as pictured above) and OBD-2 connectors.

On/Off Outputs

The Orion BMS 2 has 8 on/off outputs. All 8 of these outputs are open drain outputs which means that they do not source any current or voltage, but rather pull down to ground and sink current when they are turned on. While this may seem like an odd way to interface with the BMS, this method provides greater flexibility as it can interface with a wide range of applications using different voltages up to 24V nominal (30V max). More information on how these outputs operate, how to measure them and general wiring information can be found after the descriptions.

Pin	Pin Name	Watchdog?	Contactor Support?	Max Cont. Current	Max Pulse Current
8	Charge Enable	Yes	Yes*	500mA	4A for 150mS*
7	Discharge Enable	Yes	Yes*	500mA	4A for 150mS*
6	Charger Safety	Yes	Yes*	500mA	4A for 150mS*
26	Multi-Purpose Enable	Yes	Yes*	500mA	4A for 150mS*
23	MPO1	No	Relay, Signal Level Only	175mA	N/a
15	MPO2	No	Relay, Signal Level Only	175mA	N/a
10	MPO3 (Fan Control)	No	Relay, Signal Level Only	175mA	N/a
24	MPO4 (Fan PWM)	No	Relay, Signal Level Only	175mA	N/a

*Only when used with approved contactors with economizers, limit 2 contactors per BMS. See below for important information & compatible contactors.

Charge Enable Output (pin 8) - This pin is used in both READY or CHARGE mode and is turned on (pulled low) as soon as the BMS has gone through self-checks and determined that the battery is able to be charged. This output will turn off (float high) if the BMS determines that the battery can no longer accept a charge or if the maximum charge amperage is exceeded (please see the operational and software manuals for more details on how the BMS determines when this pin is on or off). This output can be turned back on again automatically when certain criteria set in the software are met. If the BMS turns this output off (and if the charger safety output is also off), but still measures current flowing into the battery pack afterwards, a critical fault code will be set on the BMS resulting in the disabling of all charge and discharge and the multi-purpose enable output until the BMS has been reset as a safety feature.

Important note: **In addition** to using this output, any charge source (i.e. charger or regen controller) should be set such that it will shut off in the even the maximum pack voltage is reached as a secondary precaution against overcharge. While this is an important backup, never rely solely on the pack voltage to turn off charge sources and always ensure the BMS can turn off all charge sources.

Discharge Enable Output (pin 7) - This pin is used in both READY or CHARGE mode and is turned on (pulled low) as soon as the BMS has gone through self-checks and determined that the battery is able to be discharged. This output will turn off (float high) if the BMS determines that the battery can no longer provide current or if the maximum discharge amperage is exceeded (please see the operational and software manuals for more details on how the BMS determines when this pin is on or off). This output can be turned back on again automatically when certain criteria set in the software are met. If the BMS turns this output off, but still measures current flowing out of the battery pack afterwards, a critical fault code will be set on the BMS resulting in the disabling of all charge and discharge until the BMS has been reset.

Important note: **In addition** to using this output, any load should be set such that it will shut off in the event the minimum pack voltage is reached as a secondary precaution against over-discharge. An entire lithium ion battery pack can be destroyed in a single cycle from over-discharge. While this is an important backup, never rely solely on the pack voltage to turn off loads and always ensure the BMS can turn off all loads.

Charger Safety Output (pin 6) - This pin is used only in CHARGE mode and is used to control when a charger is turned on. Once the CHARGE power supply is detected by the Orion BMS, the BMS will go through self-checks and ensure that the battery can accept a charge. **The charger safety output will not turn on unless CHARGE power is applied to the BMS.** Once the BMS passes all the tests, this output is turned on (pulled low) to enable the charger. Once the battery has reached its maximum voltage, this output is turned off (float). This output can optionally be turned back on again during balancing, if the battery pack drops below a certain state of charge, or at set intervals when certain criteria set in the software are met. If the BMS turns this output off (and if the charge enable output is also off or disabled, but the BMS still measures current flowing into the battery pack afterwards, a critical error will be set on the BMS resulting in the disabling of all charge and discharge until the BMS has been reset. The status of this pin can be transmitted to a charger digitally via the CANBUS, though an analog backup shutoff must be present for a charger.

Important safety note: At least two shutoff mechanisms should be present to turn off a charger. The charger safety signal may to be used as a backup if a digital CAN control or digital charge enable signal fails. If the charger does not support an analog shutoff, an AC rely can be used in series with the charger power supply. This is the last line of defense if a failure occurs and should not be omitted. **In addition** to the above safety, the battery charger should be programmed such that it does not exceed the maximum pack voltage if a failure occurs. While this is an important backup, never rely solely on the pack voltage to turn off chargers! Always ensure that the BMS is able to turn off all connected chargers.

Multi-Purpose Outputs

Multi-Purpose Enable Output (pin 26) - This pin is used in both READY and CHARGE modes and is turned on (pulled low) based on a user specified function. While this pin has many user assignable functions, it is commonly used for controlling a backup charge source or a system level contactor which can be used to shut down a system in the event of a serious fault such as the failure of a primary control mechanism (analog or CANBUS), over/under temperature, or over/under voltage. Please see the operational and software manuals for more details on the possible settings for this output. This pin is backed by a watchdog which will shut this output off (float high) in the event of a processor failure or certain critical BMS faults. For safety reasons, the polarity of this pin cannot be inverted.

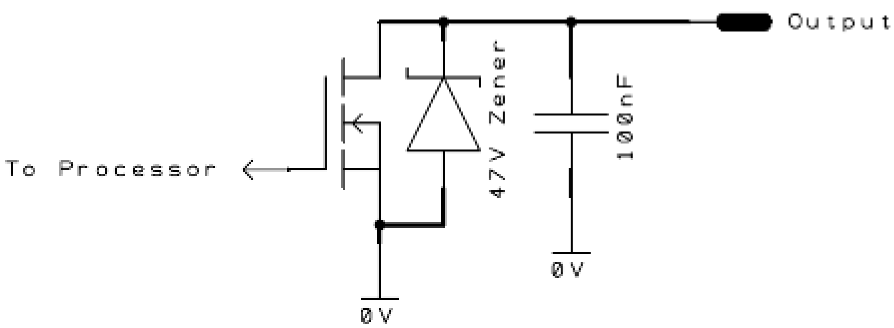
Important note: If this pin is used to control charge or discharge in any way, the appropriate charge enable, discharge enable, or charger safety output must also be used to ensure safe operation in the event that this output is incorrectly programmed.

MPO1 (Pin 23), MPO2 (Pin 15), MPO3 (Pin 10) & MPO4 (Pin 24) - The function of these multi-purpose outputs can be assigned to a wide variety of functions ranging from turning on or off at a certain state of charge, temperature, cell voltages, fault status, CANBUS controlled output, idle time, etc. These outputs are all open drain outputs (meaning they pull to ground when they are on and float when they are off) and can directly drive relays or small loads up to 175mA. The polarity of these outputs may be flipped in software. **These outputs (MPO1, MPO2, MPO3, MPO4) do not have**

watchdog protection and may not turn off during certain faults. If these outputs are used to control charging or discharging in any way, they must be used in conjunction with charge enable, discharge enable, or charger safety outputs from the BMS.

While all of the multipurpose outputs can be used for general purpose functions, if the fan output is used, it requires the use of 2 specific pins. If the fan controller is used, MPO3 will be used to control the fan on or off and if variable speed PWM is enabled, MPO4 will be dedicated for this purpose.

How open drain outputs work - Open drain outputs are designed to provide the grounding leg of a circuit. They can be thought of as a switch that connects the pin to ground when they are turned ON. By providing ground rather than positive voltage, the outputs are able to work with a wide range of voltages up to 30v. When the outputs are on, they will pull down to ground. When they turn off, they will float high. Because they do not source voltage at any time, the output of open drains cannot be directly measured with a multimeter as they do not source any voltage to measure. Please see below for more information on testing the outputs.

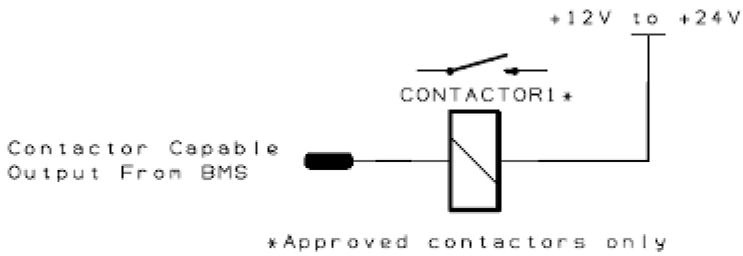


Simplified internal schematic for on / off outputs

Important notes about digital signal outputs - All of the open drain outputs are capable of directly driving relays up to **175mA**. Select outputs, as noted in the above table, support **500mA** loads and direct connection to certain models of contactors with built in economizers (see below for more information and limitations). The BMS has internal protection from the back EMF generated by the relay coils. Additional clamping diodes can be added if desired for additional protection (not recommended for contactors with economizers). Damage to the BMS can occur if higher currents are present, which can lead to undefined behavior of these outputs including the possibility of the output shorting on. While the 500mA outputs are rated to directly drive certain contactors, the 175mA outputs may not be used to directly drive large contactors. Some large contactors have a DC:DC converter attached to reduce average power consumption, but they still require a large inrush current to turn on initially. This large inrush current can damage the BMS unit. These outputs must be amplified for use with large contactors. The unit has resettable internal fuses on these outputs. However, these over-current protection devices can become damaged from repeated over-current or sustained over-current events. ***Always monitor the first charge and discharge cycle manually and ensure that the BMS has proper control over the loads and sources of current to and from the battery. If you receive a***

charge, discharge, or charger safety relay fault error, immediately investigate to ensure over-charging or over-discharging is not occurring.

***Driving Contactors* -** Four of the BMS outputs support directly driving select contactor models. Those outputs are Charge Enable, Discharge Enable, Charger Safety, and Multipurpose Enable. They support standard relays up to 250mA coils or approved contactors with economizers. While all four of these outputs are able to drive contactors, only two contactors may be connected to the BMS at any time. This is necessary to keep the maximum current through the ground pin sufficiently low. Additionally, only certain contactor models are supported and only contactors with economizers built in.



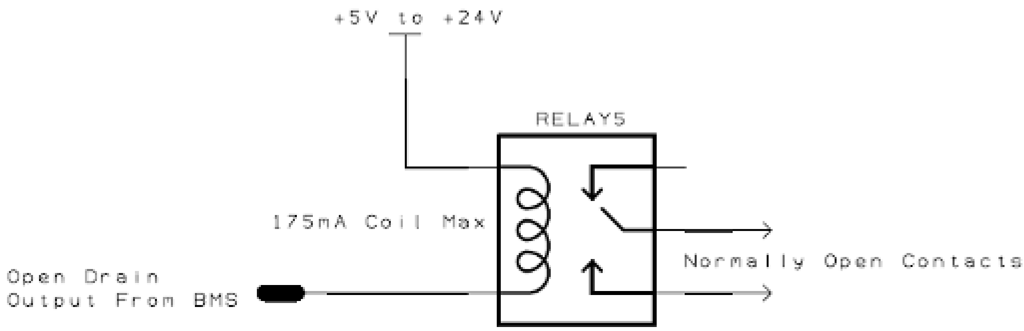
The following contactors are approved for direct use with the Orion BMS 2 (compatible pins only):

Manufacture	Part Number
Tyco Electronics (TE)	EV200xAxxA
Gigavac	GV200Mx

(x's indicate compatible ordering options variations)

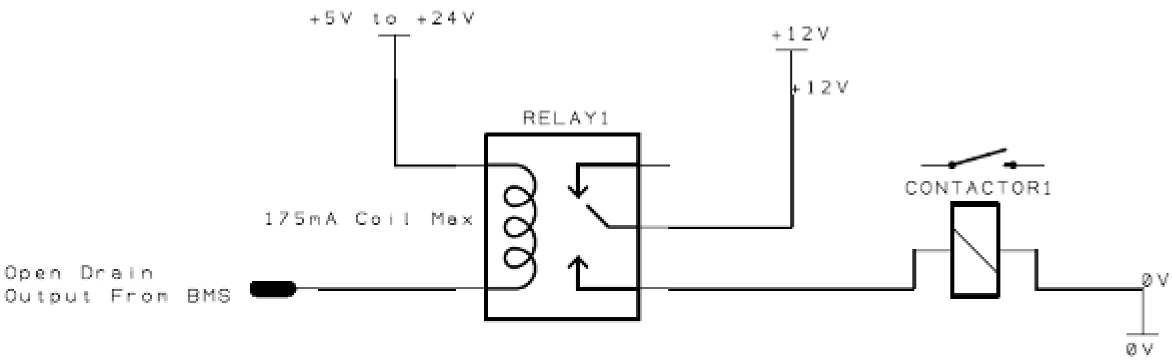
Regardless of the load the outputs are driving, care must be taken to avoid differences in ground potentials between the Orion BMS unit and other parts of the application. A difference in ground potentials can cause the on / off open drain outputs to sink current due to internal protection diodes, effectively causing them to turn on when they should be off (see schematics above). Care must also be taken to ensure that the voltage on these pins never exceeds 40V, even very briefly. A voltage exceeding 40V will damage the unit and may cause these pins to short ‘ON’.

If additional power is needed, outputs can be amplified. The on/off outputs can be used to drive relays to provide additional power. Below are sample schematics for connecting a relay with a coil less than 175mA and a sample with an opto-isolator. While the user must determine the suitability of the relays, TE part numbers T9AP1D52-12 (single pole, 30A) and T92P11D22-12 (double pole, 30A contacts) are examples of relays compatible with the Orion BMS 2. Please note that the below schematics are for general reference and that the suitability of each circuit must be determined by the user.



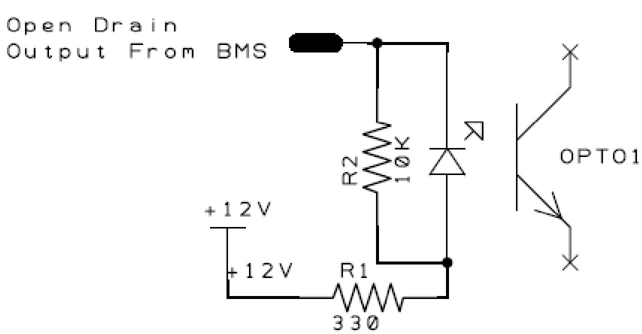
A sample schematic for connecting the open drain outputs with a relay

If the 175mA outputs will be used to drive relays or contactors with coils larger than 175mA (or other loads greater than 175mA), an amplification method must be used so that the BMS does not sink more than the maximum allowable current. A common and simple method is to use a smaller relay to turn on power for the larger relay/contactor. A schematic for this is shown below.



Schematic showing a relay used to control a larger contactor

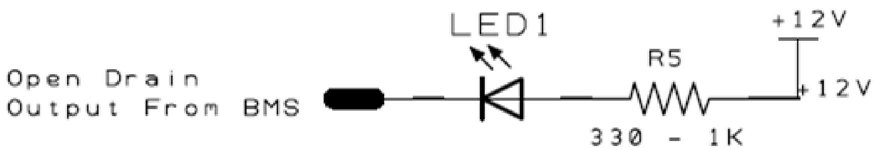
Other methods may also be used including the use of an amplifying MOSFET. Care must be taken when using a MOSFET as MOSFETs may fail in a shorted ON position and must be sufficiently protected from transients. If only signal-level currents are needed and galvanic isolation is required, an optical isolator can be used as shown below.



A sample schematic for connecting the open drain outputs with an opto-isolator

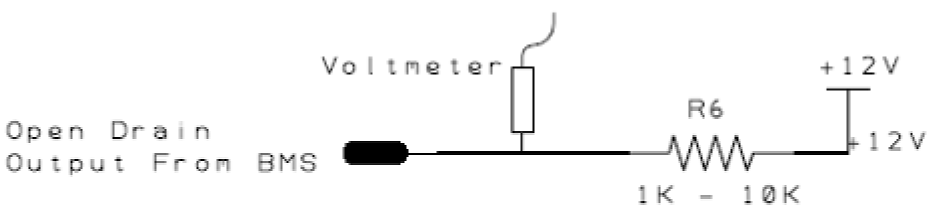
Solid State Relays – While it is possible to drive a solid state relay with the Orion BMS, ***solid state relays (SSRs) are not recommended*** when driving critical circuits due to the fact that they tend to fail in an ON position and are very susceptible to electrical noise and transients. Because of the potential failure modes and susceptibility to EMC, the possible failure of an SSR must be analyzed. If one is being used to control charge or discharge, it **must** be used in conjunction with another non-discrete switch (i.e. not a MOSFET or SSR). Additionally, a resistor and capacitor must usually be placed across the control / gate pins for increased electrical noise immunity, reducing the likelihood that the SSR will turn on due to noise.

***Checking open drain outputs* -** Open drain outputs will read zero volts on a voltmeter whether or not they are on as they sink current rather than source it. A simple method for testing the outputs is to connect an LED (or small light bulb under 175mA) between the output pin and +12v (or any voltage between 5V and 24V). If an LED is used, a series resistor (typically between 330 - 2k) must be used to limit current through the diode. When the output is on, the LED or bulb will illuminate. A schematic for this is pictured below.



Schematic showing a test circuit which turns on an LED when active

Alternatively, a multi-meter can be used in conjunction with a pull-up resistor as shown below. When the output is OFF, the multi-meter will read your supply voltage (12v in the example), and when the output is ON, it will read approximately 0 volts.



Configuration to allow testing the output using a voltmeter

Multi-Purpose Inputs

The Orion BMS 2 has 3 multi-purpose inputs which can be used for various user configurable signals to the BMS. Two of these pins are used for J1772 if it is enabled.

These inputs accept a nominal 12v – 24v (6v – 30v acceptable) input. The function of these inputs can be assigned in the setup utility. They can be used to keep the BMS from going to sleep, even if the READY power source is lost (requires always-on power to provide redundant power). With the exception of the J1772 circuit, these pins cannot wake up the BMS. The function of these pins can also be used to select between transmitting different CAN messages, clear fault codes, and various other functions (see software manual for more information).

Analog 0-5V outputs

The Orion BMS is equipped with three analog 0 to 5V voltage outputs designed to aid in integrating the Orion BMS with non-digital applications including voltage based displays. The outputs include pack state of charge, charge current limit, and discharge current limit. They are often used to provide current limits to motor controllers (for discharge or regenerative braking) when CANBUS controls are not available. They can also be used to drive gauges or displays such as the Basic Display.

Each of the 0-5V analog voltage outputs can provide or sink up to 10mA of current, though the current should be kept as low as possible to minimize voltage drop. If more current is necessary or if a different voltage range is necessary, an external analog buffer or op-amp must be used to amplify the signal. The analog voltages are generated inside the Orion BMS unit by a digital-to-analog converter. Do not use these signals as the sole means to control charge or discharge as the digital-to-analog converter is not watchdog backed. If these outputs are used to limit charge or discharge current, always use them in conjunction with one of the charge enable, discharge enable, or charger safety outputs.

State of charge output (Main I/O pin 4)

This output provides the calculated state of charge. 0V corresponds to 0% state of charge and 5V corresponds to 100% state of charge. This output often is used to display state of charge for applications when digital communications are not available. It can also be used to provide data to the basic display board. For information on connecting the basic display, please refer to the basic display manual, which can be found at www.orionbms.com.

Charge current limit (Main I/O pin 5)

This output provides an analog representation of the maximum current that the battery can accept at any given time. 0V corresponds to 0 amps and 5V corresponds to the maximum amperage set in the profile for this specific output (please see the software manual for information on setting this maximum value).

While this output can be reliably used to limit current, it must be used in conjunction with the charge enable signal output (Main I/O pin 8) or charger safety (Main I/O pin 6), which provides an analog watchdog shutoff circuit. Although unlikely, it is possible for the digital-to-analog converter to fail leaving the voltage in an undefined state. The charge enable or charge safety outputs can provide a shutoff in the event this were to happen.

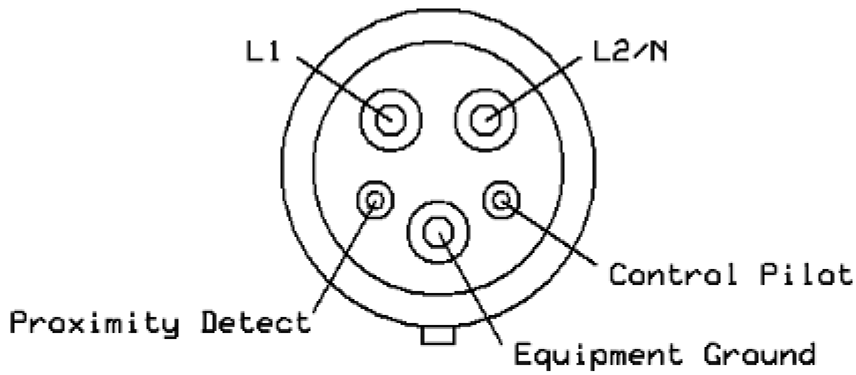
Discharge current limit (Main I/O pin 16)

This output provides an analog representation of the maximum current that the battery can discharge at any given time. 0V corresponds to 0 amps and 5V corresponds to the maximum amperage set in the profile for this specific output (please see the software manual for information on setting this maximum value).

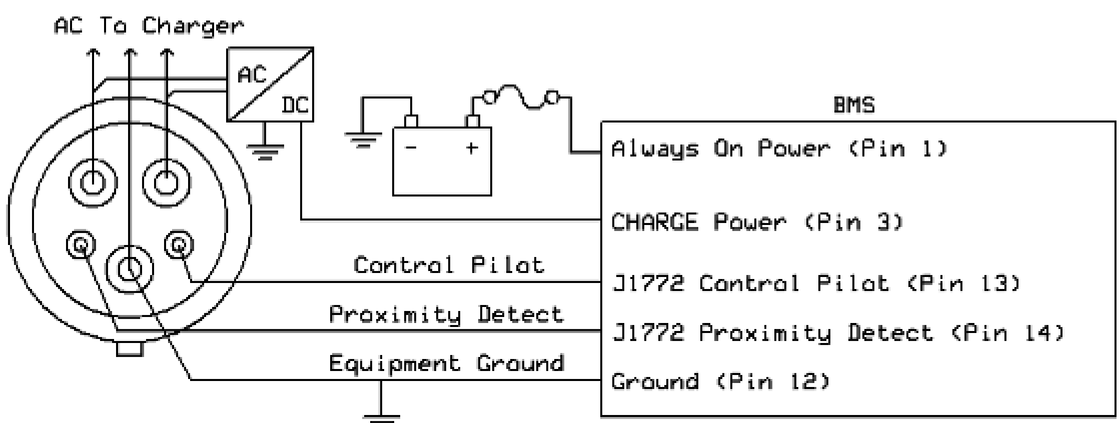
While this output can be reliably used to limit current, it must be used in conjunction with the discharge enable signal output (Main I/O pin 8) which provides an analog watchdog shutoff circuit. Although unlikely, it is possible for the digital-to-analog converter to fail leaving the voltage in an undefined state. The discharge enable output can provide a shutoff in the even this were to happen.

J1772 Interface

The Orion 2 can directly interface with a J1772 vehicle charging inlet to enable level 1 and level 2 AC charging (J1772 DC fast charging is not supported). This feature must be enabled in the software, and the level of support varies by charger from simple on/off control to variable current limiting based on the provided EVSE (charging station) capabilities.



J1772 Vehicle Side Connector Pinout



J1772 connections to the BMS (AC wiring is simplified, fuses may be required)

Wiring the J1772 involves connecting 2 wires and ensuring that the J1772 earth ground is connected to the BMS ground. **Ensuring that the J1772 ground pin is connected to the BMS ground is essential for proper operation!** If the ground becomes disconnected, the J1772 will not work. The BMS must receive CHARGE power when power is present on the inlet. This can often be accomplished by using a small 12-24V power AC to DC power supply as shown below. Always on power (Main I/O Pin 3) is required to bootstrap the process when using J1772 since the BMS must be able to sense the inlet even when it is not on. Ensure that all power sources share the same ground. When enabled in software, the J1772 uses multi-purpose inputs #1 and #2 as shown above.

Proper fusing is necessary for the AC circuits. J1772 allows for a supply circuit anywhere from 6 amps to 80 amps, so it is possible for the inlet to be connected to an 80A circuit. For this reason, the input must be treated as an 80A circuit even though it may not be supplied with that amount of current at all times. Wires, chargers, and any other devices connecting to the J1772 AC power inside the vehicle should each be fused at an appropriate level based on the maximum possible amperage used. For example, if an AC charger is designed to be connected to a 20A circuit and this charger will be interfaced with J1772, the AC coming from the J1772 must be fused in accordance with the charger specifications (in this case likely at 20 amps). If multiple loads are connected, such as a battery charger and a small AC / DC adapter, the line may need to be fused at different amperages for each load (e.g. if a battery charger requires a 40A circuit, but an AC – DC adapter is designed for a maximum circuit size of 15 amps). The AC input should be fused as close to the J1772 inlet as possible. In order to ensure that wires are properly protected from over-current, the fuses must be upstream of any reduction in wire size. As always, the wires must be appropriately sized for the current. Always consult electrical codes and applicable standards. DC power supplies to the BMS must also be fused (see the section "Fusing" above for BMS power supply fusing requirements).

Any devices connecting to the J1772 AC power must be able to accept 120V AC nominal and 208V – 240V AC nominal. Since the J1772 inlet can be connected to a level 1 (120V AC) or Level 2 (208 – 240V AC) in an unpredictable manner, all devices must automatically adjust to the supplied voltage without user intervention.

It is essential that all loads connected to the J1772 charging station (EVSE) respect the AC current limit set by the EVSE. The BMS can be configured to allow or deny charging based on the J1772 AC current limits. For example, if the vehicle's charger is a simple charger that only operates at one speed and requires 12 amps, but the EVSE indicates it can only source 8 amps, the BMS can deny charging until the vehicle is connected to an EVSE that is able to supply at least 12 amps. For supported CANBUS enabled chargers that provide certain data on the CANBUS, the BMS can also calculate a DC charging current limit based on the J1772 AC limit received from the EVSE. This configuration allows the vehicle to charge at any station, even if the station cannot supply sufficient power to allow the charger to run at maximum power.

Only small loads other than a battery charger should be connected to the J1772. Inrush must be kept to a minimum, and chargers must stop charging immediately when the BMS commands them to stop to prevent wear and tear on EVSE contactors. Do not use J1772 with non-isolated chargers.

It is the sole responsibility of the integrator to research and comply with all applicable laws, regulations, standards, and codes for the specific application.

CHadeMO Interface

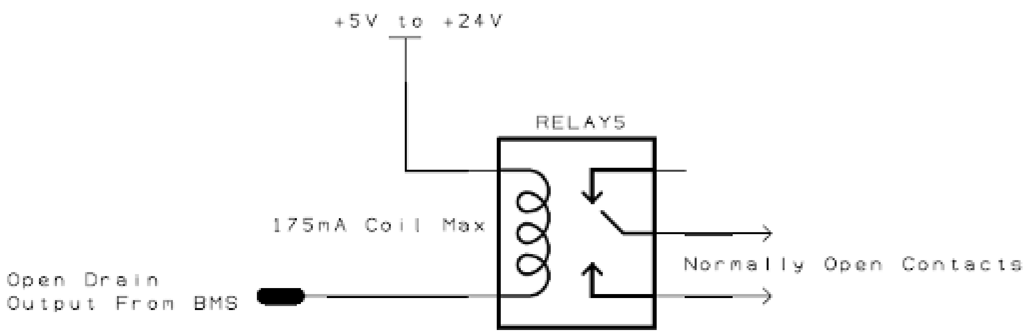
Support for CHAdeMO is largely provided through the 2nd CANBUS interface. See our application note on www.orionbms.com for interfacing with CHAdeMO chargers for information on wiring for CHAdeMO.

Fan controller

The Orion BMS 2 features a thermal management system consisting of thermistors for measuring battery temperature (and optionally for measuring intake air temperature), an on/off output and PWM output designed to control a fan and a voltage monitoring circuit designed to ensure that a fan is operating properly.

The Orion BMS 2 base unit supports up to eight thermistors directly connected to the BMS. 800 additional thermistors can be connected to the Orion BMS using thermistor expansion modules. For more information on the thermistors, please see the “Current sensor / thermistor connector” section.

Fans and liquid cooling systems can be controlled in an on/off or variable speed manner by the Orion BMS. The simplest method of connecting a fan is the on/off approach. The Fan Enable (Main I/O pin 10) pin on the Orion BMS is an open drain output designed to drive loads up to 175mA. In most instances, this output is connected to a relay coil or MOSFET which then supplies power to the battery fan. Below is a schematic (Figure 13) showing a possible connection for powering a fan in an on/off manner.



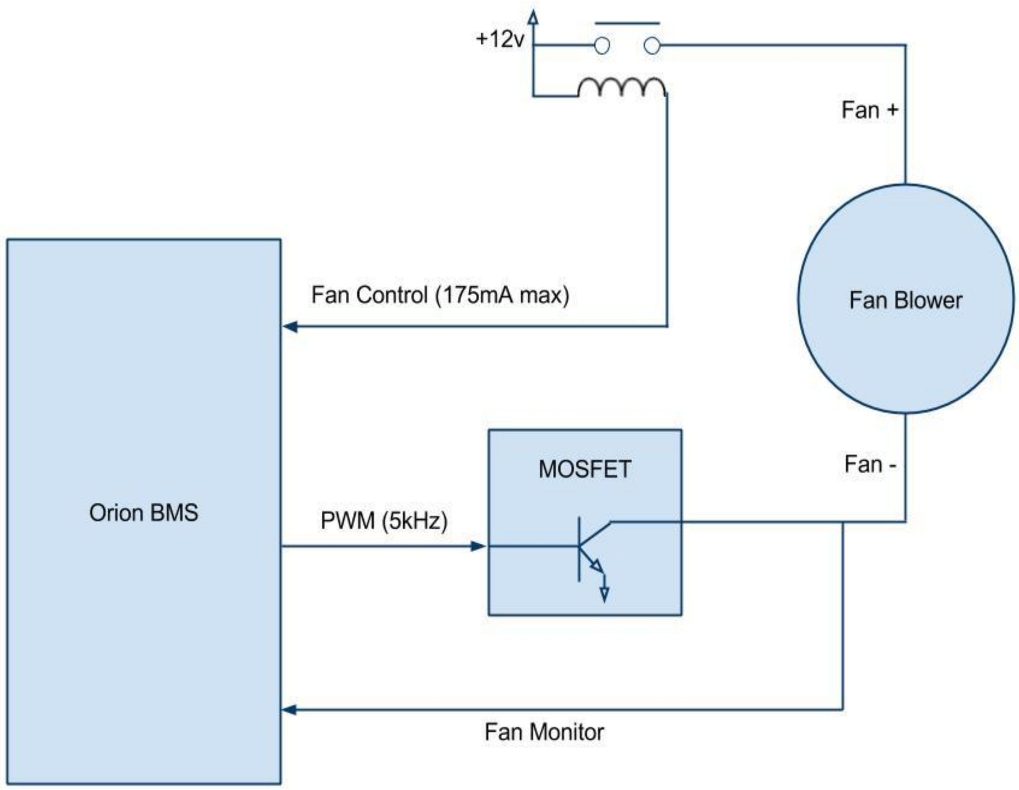
Schematic showing a possible connection for powering a fan in an on/off manner

A PWM output is also provided to provide variable speed fan controls. The PWM output can be used to drive a compatible fan or liquid cooling system. Care must be taken in selecting a fan or motor that is compatible with PWM. It may be necessary to convert the PWM signal to a DC voltage for some fans, and the required switching frequencies may not be compatible with the Orion BMS 2.

The “Multi-purpose #4 / Fan PWM Signal” (Main I/O pin 24) provides the PWM signal if enabled. The PWM signal is signal level and is an open drain output to accommodate a wide range of voltages up to 24V. If this output is used to drive a MOSFET or if a high / low signal is needed, a pull-up resistor will be necessary on the output. The frequency of the PWM signal and polarity of the signal can be altered in the BMS settings profile.

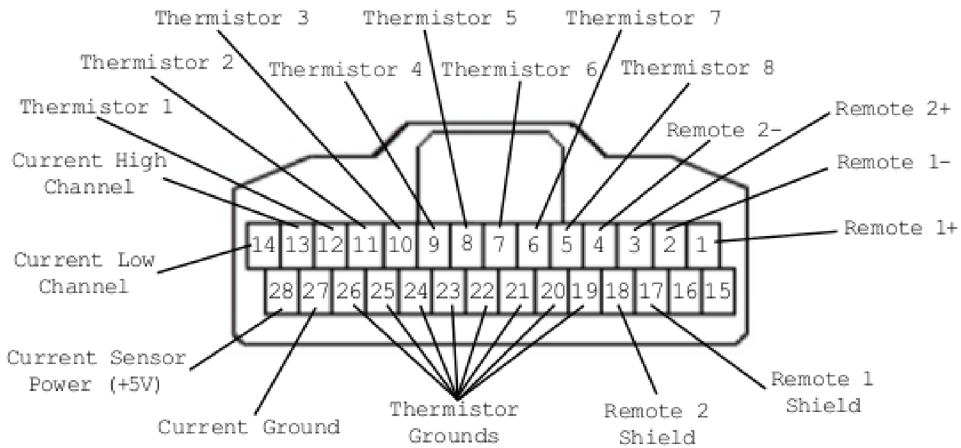
If the PWM method is used to variably control the speed of the fan, the “Multi-Purpose Input #3 / Fan Monitor” (Main I/O pin 9) pin can be used to monitor a voltage from 0 to 30V to detect fan failures. The fan monitor feature can be setup in software to verify that the voltage present at the fan monitor pin matches the expected voltage for the desired fan speed. The fan monitor polarity is invertible in software. Please see the software manual for more information about setting up voltages and error thresholds the fan monitor feature.

Below is a simplified overview of the fan circuit using PWM and the fan monitor feature. This is one example, but there are many other ways of using the thermal interface. This example is for 12v. Higher voltages may require a level shifting drive circuit to prevent damage to the MOSET gate. Transient protection is also necessary to protect the MOSFET.



General fan circuit diagram.

Wiring the Current Sensor / Thermistor / Remote Connector



Wire side of Current Sensor / Thermistor / Remote Connector looking into the BMS

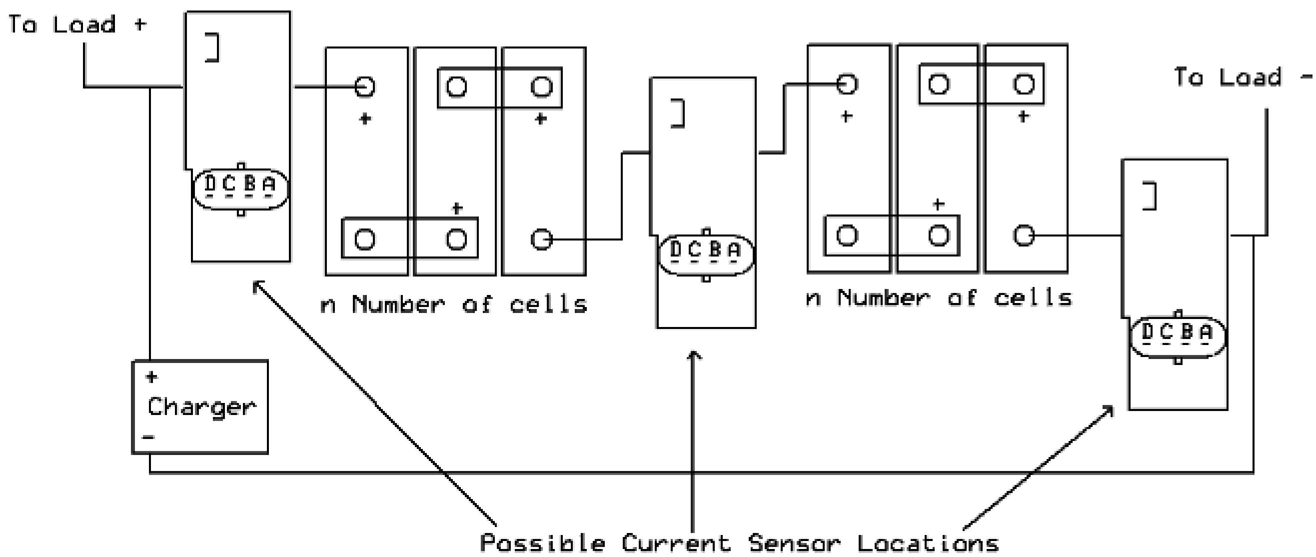
Signal Name	**Description**
Thermistor Grounds (8x)	One leg of each of the thermistors should be grounded to one of these grounds. Any thermistor can be grounded to any of the available thermistor ground pins, order does not matter and all can optionally be grounded to one pin. The use of thermistors is optional, but recommended.
Thermistor 1 - 8	Non-grounded lead of the thermistors. These thermistors are embedded into the battery pack to provide the BMS with the general temperature of the pack. One of these thermistors can optionally be used as an air intake temperature sensor to measure ambient air temperature for more intelligent control of the fan (selected in software).
Current Sensor +5v	+5v supply provided to the external hall effect current sensor.
Current Sensor Ground	The ground for the current sensor.
Current Low Channel	Connect to the low channel output from the current sensor.
Current High Channel	Connect to the high channel output from the current sensor.
Remote 1+ & Remote 1-	Positive and negative data wires that connect to remote BMS cell tap module 1 (available only if ordered with this feature). Use only shielded twisted pair cable for this.
Remote 2+ & Remote 2-	Positive and negative data wires that connect to remote BMS cell tap module 2 (available only if ordered with this feature). Use only shielded twisted pair cable for this.
Remote 1 & 2 Shield	These pins can be used to terminate the shield of the twisted pair cable. The shields should only be grounded at one location. If they are connected here, do not connect the shields in any other location.

Current Sensor & Thermistor Taps

The standard current sensors sold with the Orion BMS 2 are actually a combination of two current sensors built into a single unit for improved accuracy. One of the current sensor channels is smaller than the other and is used for measuring small currents while the other is used for measuring larger currents. The BMS will also cross check the two sensor channels to ensure that both line up and are producing matching data.

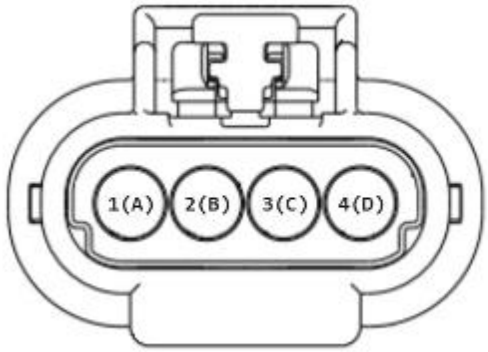
The current sensor wiring consists of four wires. One +5V voltage reference for the sensor, a ground, and 2 analog voltage returns (each voltage return will be 2.5V with no current flowing through the sensor). Each wire simply connects from the BMS unit to the current sensor. These wires should be kept as short as possible, ideally less than 18” in length. While it is possible to extend the wires if needed, testing was performed with 18” lengths, and longer wires may reduce the accuracy and make the sensor more susceptible to electronic noise. No other loads or taps should be placed on these wires.

The hall effect current sensor can be located anywhere along the high power path. It can be on the positive or negative side of the battery or anywhere in the middle, provided that all current passes through the sensor. If placed on an end of the battery pack, ensure all current passes through the sensor as shown below. See the image below for possible current sensor placements.



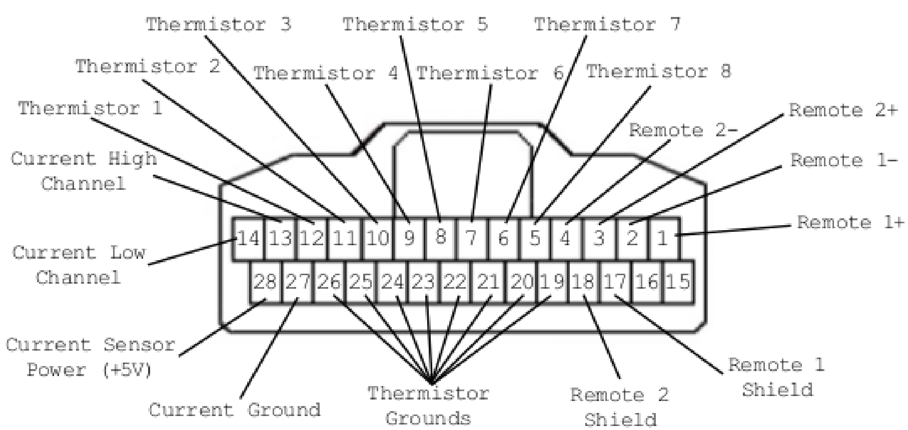
Schematic showing possible locations of hall effect current sensor

The above diagram shows the standard orientation of the current sensors. If the current sensor is installed backwards, the current sensor direction can simply be inverted in the Orion BMS profile using the BMS utility software. For this reason, it is not particularly important which direction it is physically installed. It is, however, very important that the BMS setting match the installed orientation. Otherwise many of the calculations which depend on measured amperage will show up incorrectly. In the initial setup of the unit, the direction of current should be verified by using the Orion BMS utility to ensure proper configuration. Current going into the battery pack (charging) should show up as negative current, and current leaving the battery pack (discharging) should show up as positive current in the BMS utility.



Pin	Description
1 (A)	+5V Current Sensor Power
2 (B)	Current High Channel
3 (C)	Current Sensor Ground
4 (D)	Current Low Channel

Wire side of connector which attaches to the current sensor. Looking into the current sensor.



Wire side connector which attaches to the Orion BMS unit

Above are two pinouts showing the wiring between the connector attaching to the current sensor and the connector attaching to the Orion BMS unit.

Thermistors - The Orion BMS 2 has provisions for eight thermistors to be connected directly to the unit. These thermistors monitor the temperature of the cells and provide the BMS with a representative idea of the pack temperature. The thermistors should be spread throughout the battery pack in a manner which provides the most representative temperatures possible. If the battery pack is split into multiple physical locations, at least one thermistor, ideally more, must be placed in each physical location. If the battery pack is in one physical location, sensors should be scattered through different areas of the pack such as the middle and outer portions of the pack such that they provide an accurate sampling of the battery temperatures.

In certain applications, more than eight thermistors may be required. It is the responsibility of the system integrator to determine how many thermistors are needed to measure the temperature of the battery pack. If monitoring more than eight temperatures is necessary, an external thermistor expansion module, which can monitor up to eighty additional thermistors per module with up to ten modules connected, is available. If the external thermistor expansion module is used, it is recommended to connect as many representative thermistors as possible directly to the main Orion BMS unit and then connect additional thermistors to the expansion modules such that the BMS can still sense temperatures even if there is a loss of communication with the thermistor expansion module.

Thermistors can be attached to the battery cells in different ways depending on the type of cell. The thermistors sold with the Orion BMS have epoxy coated beads at the ends. They are often taped or glued to cells. Other thermistors (sourced separately) are attached to ring terminals and can be installed onto battery terminals. While these are sometimes required or desired, we strongly discourage attaching thermistors directly to electrically live battery terminals. ***In all cases, care must be taken to ensure that thermistors are sufficiently electrically isolated from the battery pack. The thermistor measurement pins are NOT electrically isolated from any other pin on the Thermistor or Main I/O connectors, and a breakdown in isolation may cause a short!*** The integrator is responsible for ensuring proper isolation and any necessary fusing for protection against shorts. Insulation must be designed to withstand and survive all anticipated environmental factors such as temperature changes, condensation, abrasion and vibration without compromising insulation integrity. Insufficient isolation can cause shorts outside the BMS and/or catastrophic damage to the BMS unit. Fuses to guard against shorts on the thermistors may be necessary in some applications.

Connected thermistors must be 10K NTC thermistors. The thermistors sold with the BMS have a B25/50 value of 3380K. Other 10K NTC thermistors with different B values can be used as the B value can be programmed on the Orion BMS 2, though all thermistors connected to the BMS must be of the same value. One end of the thermistor is connected to the appropriate thermistor pin and the other is grounded to one of the thermistor ground pins. As thermistors are resistive, polarity does not matter. The order of thermistor ground pins also does not matter as they are all connected together internally. All thermistor common wires can be connected to a single thermistor ground pin if helpful for cable routing. **The thermistor wires can be extended if necessary** since the additional resistance of the wire is very small compared to the resistance of the thermistor.

One of the eight thermistors on the base unit can be selected as an intake air thermistor (any of the eight thermistors can be configured for this in the software profile). This feature allows the BMS unit to monitor the incoming air temperature to determine if cooling would be effective or not by comparing the intake temperature with the battery temperature. If cooling is needed and the BMS determines that the intake temperature is higher than the battery temperature, it can prevent the fans from turning on since the fans would not be effective in cooling the battery in that case. It also allows the BMS to turn on the fans when heating is desired if the intake temperature is higher than the battery temperature in colder climates. Care should be taken in using warming fans to ensure that relatively warmer air with a higher humidity content will not cause condensation to form on batteries or other sensitive parts including live electrical connections, causing rust or corrosion, etc. The multi-purpose outputs from the BMS can be used to control battery warming equipment in some cases, which may provide better protection against condensation.

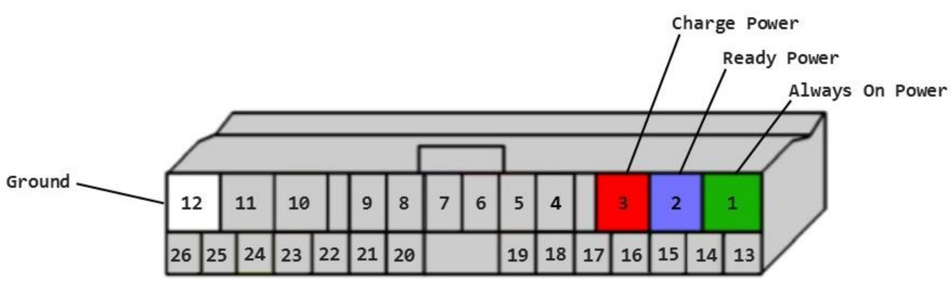
Remote Cell Tap Modules

The Orion BMS 2 supports up to 2 remote cell tap modules. Remote modules range in size from 24 to 180 cells. These modules are designed to be used in situations where battery packs are split up in multiple physical locations or in situations where more than 180 cell taps are needed (Note: 800V absolute maximum battery pack voltage limitations apply, which may limit the number of cells in series). More cell taps may be needed in the event that some cell tap positions needed to be skipped or when the BMS is used with lower voltage cells such as lithium titanate. With the Orion BMS 2, these remote modules do not require an additional current sensor and do not use either of the CANBUS interfaces on the main unit.

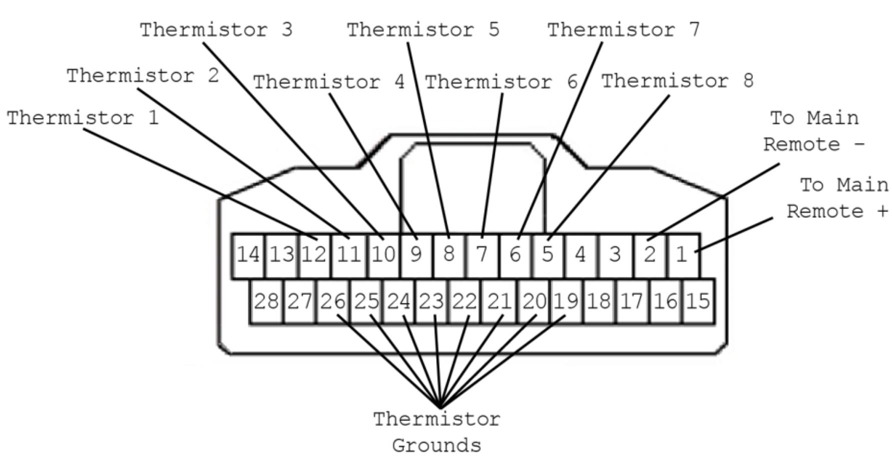
Remote modules require only a small number of connections – power, ground, data connection, and thermistors (optional). It is very important that the power and grounds for the main unit and any remote units be connected directly together because power must come up at exactly the same time for the main unit and any remote units. Grounds (both chassis ground and power supply negative ground) must also be the same in order to prevent ground loops and potential noise issues. Two data wires (Remote+ and Remote-) are used to connect to each of the remote boards. Only shielded twisted pair cable may be used for connecting the data pins from the main unit to the remote. The shield for the remote module data cables should be terminated at one end only.

If more than one remote module is used, the module with the largest number of cells connected to it should be put in as remote #1 as this will improve the cell polling time of the overall system.

Each remote module supports up to 8 additional thermistors (optional). The thermistors are wired the same way as on the main unit.



Wire Side of Remote Module Main I/O



Wire side of Remote Current Sensor / Thermistor / Remote Connector looking into the BMS

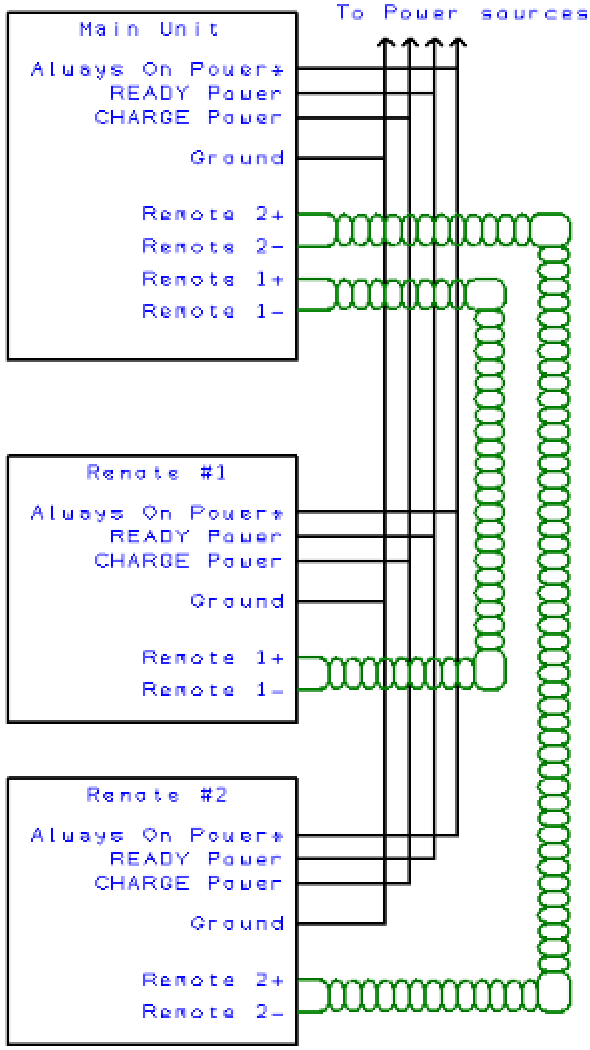


Diagram showing the wiring connections between the main unit and remote modules

Wiring Voltage Taps

READ THIS ENTIRE SECTION BEFORE WIRING.

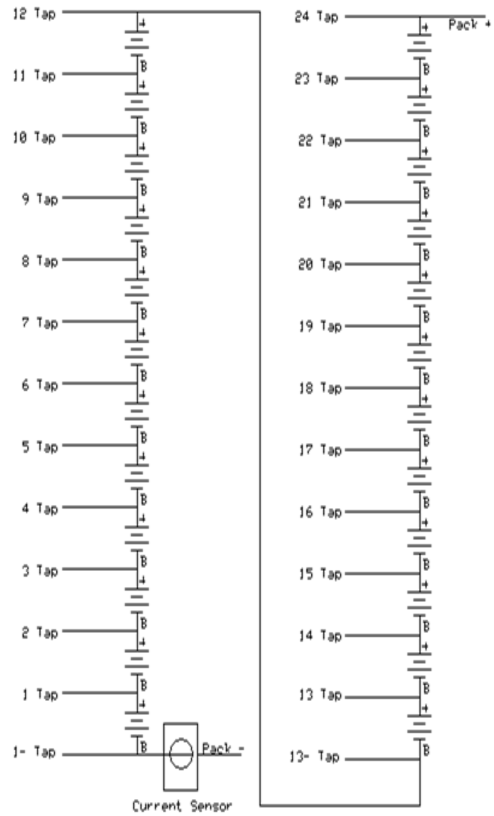
Several precautions need to be taken for the BMS to function properly, accurately, and safely. All battery packs must be suitably protected against over-current by an external means such as a fuse. While pack fuses are always necessary to protect the battery pack from over-current and shorts, **if a safety disconnect or fuse is placed mid-pack, between the first and last cell, they must be wired in certain locations to prevent catastrophic damage to the BMS in the event that they blow or are opened manually.** Please see “Safety Disconnect and Fuse Locations.”

WARNING: Never alter any battery wiring, including tightening cell terminals, while the BMS is connected. Disconnect the cell tap connectors from the BMS before altering wiring, and do not reconnect them until all wiring alterations have been made and the harnesses have been tested.

The cell tap connections on the BMS are organized into 'groups' of between 4 and 12 cells each. Each connector on the BMS supports up to 3 cell groups. The number of connectors and groups populated on the BMS depends on the size of the BMS that is purchased. For example, a 108-cell BMS has 3 connectors and supports 9 cell groups (12 cells * 9 groups = 108 cells). A 24-cell BMS has 1 connector and supports 2 groups. For a full list of size options, please refer to the chart at the beginning of this document under “Determining which size BMS to order.”

For the purpose of this document and as far as the BMS is concerned, a cell refers to one or more cells directly paralleled together. Cell tap wires run from each cell (or group of cells directly paralleled together) back to the BMS for the purposes of monitoring voltages and balancing cells.

Below is the standard wiring diagram for cell taps. One cell tap is provided for each cell with one negative tap for each group of 12 cells (in this case 1- and 13-). Cells are numbered from the lowest stack potential to the highest stack potential (starting at the pack negative and working up in number towards pack positive). The following example is for a 24 cell pack. (Note: see further down in this section for information about how to connect unused wires if less than 12 cells are in a group.)



Wiring diagram for a 24 cell pack

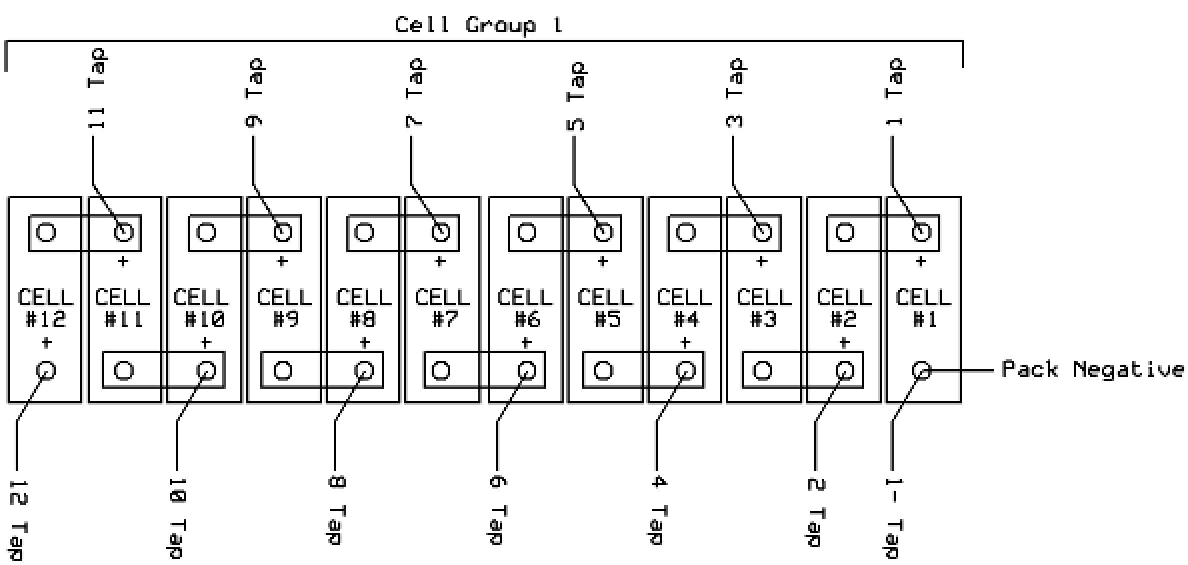


Diagram showing cell tap connections for prismatic cells (12 cells in series)

Voltage Tap Connector Pinouts

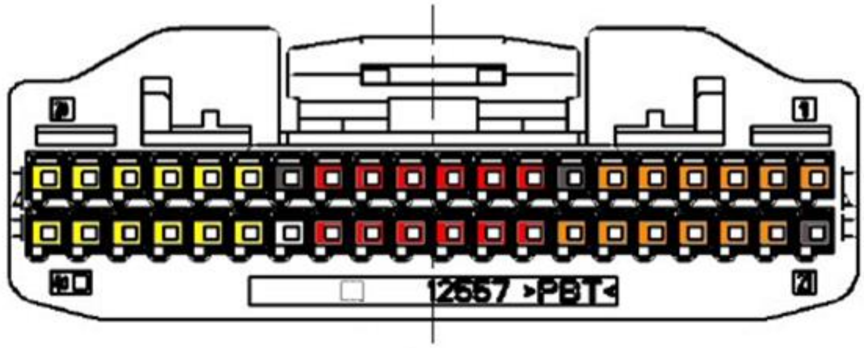
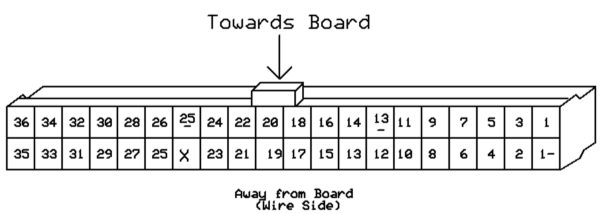
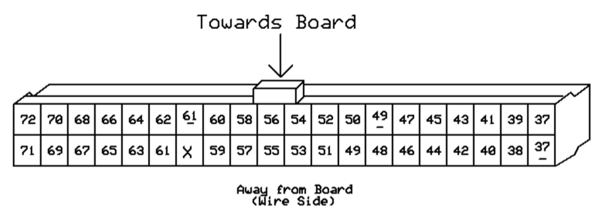


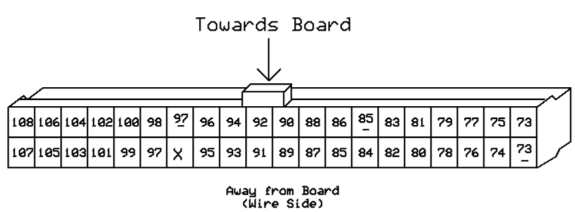
Diagram of the pre-wired harness connector. Cell Groups 1 in orange, 2 in red and 3 in yellow. Cell group ground wires are in black. Looking at the wire side of the connector looking into the ECU.



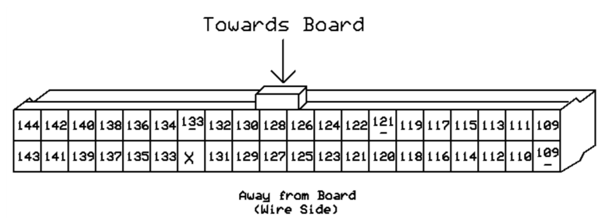
Cell group 1-3 connector



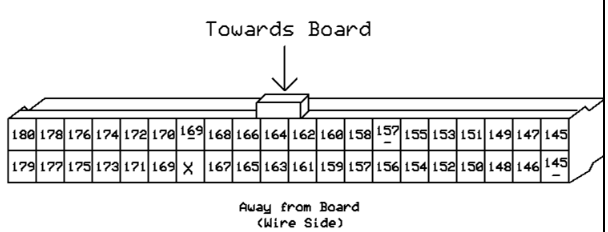
Cell group 4-6 connector



Cell group 7-9 connector



Cell group 10-12 connector (180 cell version)



Cell group 13-15 connector (180 cell version)

Important note about connectors: Unless specially ordered, the Orion BMS 2 comes with gold plated contacts on the voltage tap connectors which are more resistant to long term fretting and corrosion. Previous generations of the Orion BMS used tinned contacts which are not compatible. ***Tinned contacts cannot be mated to gold contacts because of interactions between the two types of metals which will lead to degraded connection reliability***. If the BMS is being upgraded from a previous generation which used tinned connectors, the Orion BMS 2 can be special ordered with tinned connector headers.

Harnesses and Cable Routing

Prewired cell tap harnesses, which are typically used for low volume builds or for prototypes, are available. In larger volumes it is often most economical to make the harnesses to the exact specifications needed to reduce wasted cable (connector specifications and part numbers can be found earlier in this document). The pre-wired cell tap harnesses available with the BMS come in various lengths and use 22AWG UL style 11028 wire. The wire is rated for 600V and -40 to +105 degrees C. Because of the mppe style insulation, it is physically thinner than comparably rated PVC wire and has about 10x the abrasion resistance of standard PVC wire. It may be possible to use other 22AWG wire styles for the cell tap connections, but this determination is solely the responsibility of the integrator.

Each of the individual cell tap wires may be cut down to size, and a suitable terminal (usually a ring terminal) can be crimped to the end. Machine crimping with the proper tool is recommended as hand crimping or crimping with tools not designed for the specific crimp tend to be unreliable.

Wires must be routed in such a manner that they do not chafe or rub against any materials that could cause abrasion, potentially leading to shorts. High voltage wires including tap wires should be routed in different harnesses away from low voltage wires to reduce the likelihood of shorting. Additionally, cell tap wires should not be routed next to flammable materials, should be suitably protected from damage, and should be kept inaccessible from people other than qualified service personnel. We recommend routing cell tap wires away from high power cables or other high noise sources when possible.

Order of Cell Tap Connectors

While the connectors have 2.5kV isolation between them, and in previous version of the Orion BMS, the order did not matter, the Orion BMS 2 uses cell tap 1- (the cell tap connected to the negative most terminal in the battery pack) to optionally measure breakdown in isolation (isolation fault detection). Because of this, ***the negative-most cell connector must be plugged into connector 1 on the BMS for proper operation of the isolation fault detection system.*** Inadvertent connection of the wrong connector to connector 1 for short periods of time should not harm the BMS, but may cause isolation fault detection to operate incorrectly. The order of the cell taps on remaining connectors can be swapped if desired.

Safety Disconnects and Fuse Position

While the Orion BMS does not require safety disconnects or fuses to be between the first and last cells in a pack, the Orion BMS has locations specifically designed to facilitate mid-pack disconnects and fuses if they are used. Pack fuses which protect the battery pack from over-current during shorts are always required. Please see below for more information.

Many times with high voltage or high amperage battery packs, it is highly desirable for safety reasons to have a disconnect and/or fuse(s) located in the middle of the battery pack. In this case, removing the safety disconnect or fuse effectively splits the battery pack into two smaller packs making servicing safer by reducing the maximum voltage present and reducing the potential across the positive most and negative most terminals to zero (assuming proper isolation). Often times, fuses are integrated into the safety disconnects since they are often used in conjunction with each other.

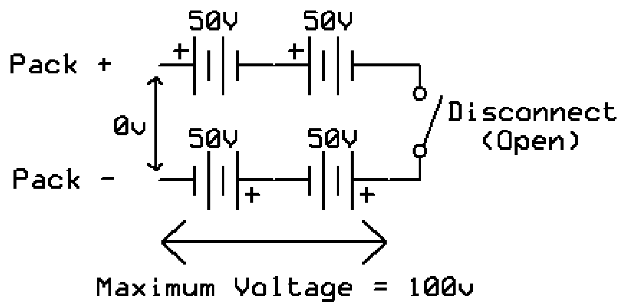


Illustration of a properly functioning safety disconnect or fuse

The above schematic shows the advantage of a mid-pack safety disconnect. The disconnect essentially splits the 200 volt nominal battery pack into two smaller 100v sections, thereby theoretically reducing the voltage at the pack terminals to zero volts and limiting the maximum voltage in the pack to roughly half the nominal voltage.

Isolation is critical if a safety disconnect is used. If there is not sufficient isolation or if there is an additional path around the safety disconnect or fuse, current can still flow around the disconnect or fuse, and high voltage can be present at the battery pack's terminals as pictured below. The resistor in the following schematic represents leakage current from a breakdown in insulation, arcing across an insufficient insulation barrier or another current path such as through protection diodes inside the Orion BMS. Even if the effective resistance is in the 100's of kilo-ohms, the voltage at the terminals of the pack can present a shock hazard as the full voltage of the battery pack may be present.

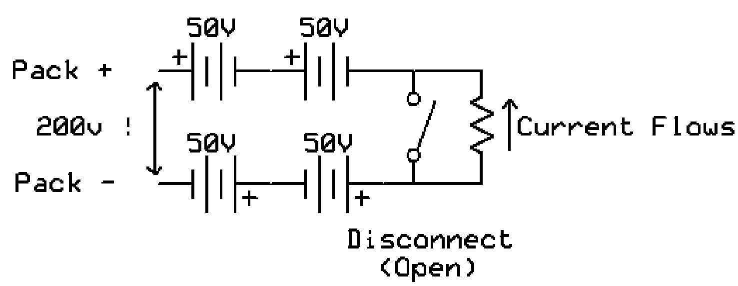


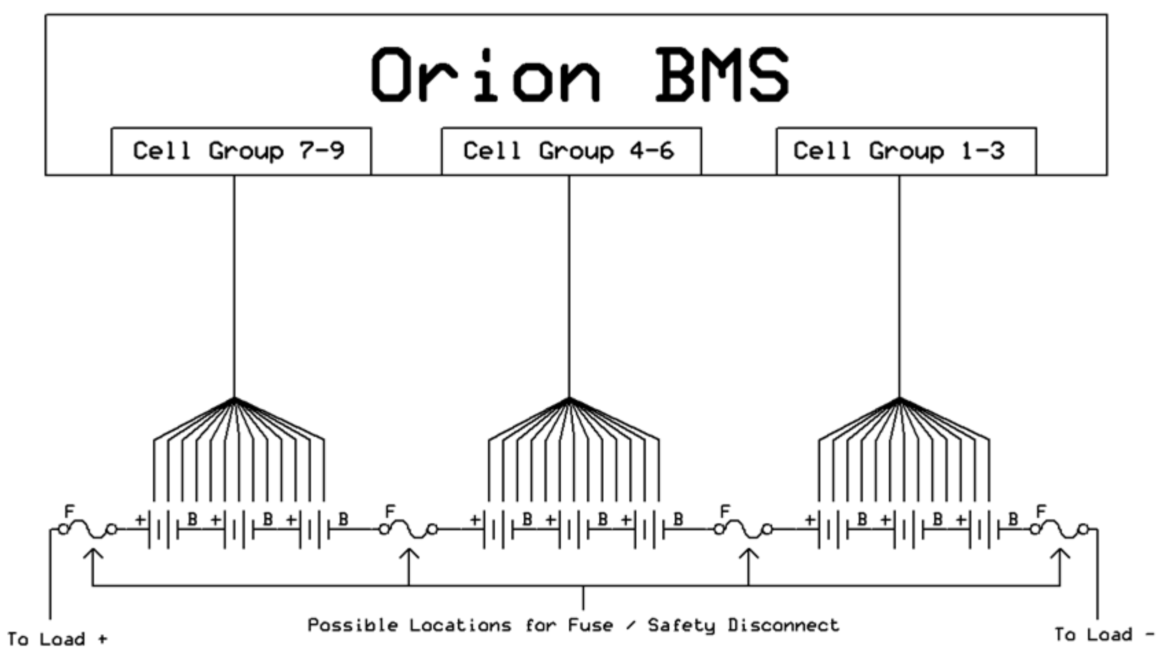
Illustration of a safety disconnect with a dangerous alternative current path

The Orion BMS was designed with support for safety disconnects and fuses inside the pack at certain intervals. 2.5kV safety isolation is provided between each battery cell tap connector on the Orion BMS (each connector can handle 36 cells, so isolation barriers are on multiples of 36 cells). This is done such that safety disconnects can be connected in a way where no current can flow around the safety disconnect or fuse. While the Orion BMS also has nominal isolation between each individual cell group, it is not sufficient for safety disconnects or fuses since the total stack voltage of the battery could be present across those terminals in the event of a short, which could potentially arc over the nominal isolation barrier. Additionally, if a fuse blows due to over-current, stray inductance from the battery cables can cause significant voltage transients which can also arc over smaller isolation barriers.

The Orion BMS has internal protection diodes within each cell group that can pass current from one cell to another if the voltage of the adjacent cell is more than 5V or less than 0V. **If a safety disconnect or fuse is incorrectly wired to the Orion BMS such that it is in the middle of a cell group (12 cells), if the fuse blows or the safety disconnect is removed, current can flow through the Orion BMS, bypassing the safety disconnect or fuse leading to dangerous conditions.** This can cause high voltage to be present at the terminals of the battery pack when there should be no voltage present and force large currents and high voltage to flow through the Orion BMS and cell tap wires, damaging the BMS unit. Catastrophic damage to the BMS is possible and damage from incorrect wiring is not covered by the warranty.

If safety disconnects, contactors, or fuses are used within a battery pack the Orion BMS must be wired such that the fuses, contactors, or safety disconnects fall between the connectors (between taps 36 and 37 or 72 and 73 or 108 and 109 or 144 and 145). ***Failure to do this may result in damage to the BMS and will not provide the required isolation across the safety disconnect.*** The Orion BMS does not require the use of safety disconnects or pack fuses in the pack and if your application does not use a safety disconnect or a fuse inside the battery pack then this does not apply. Please see the "Isolation" section below for more details and a diagram of the isolation provided by the Orion BMS.

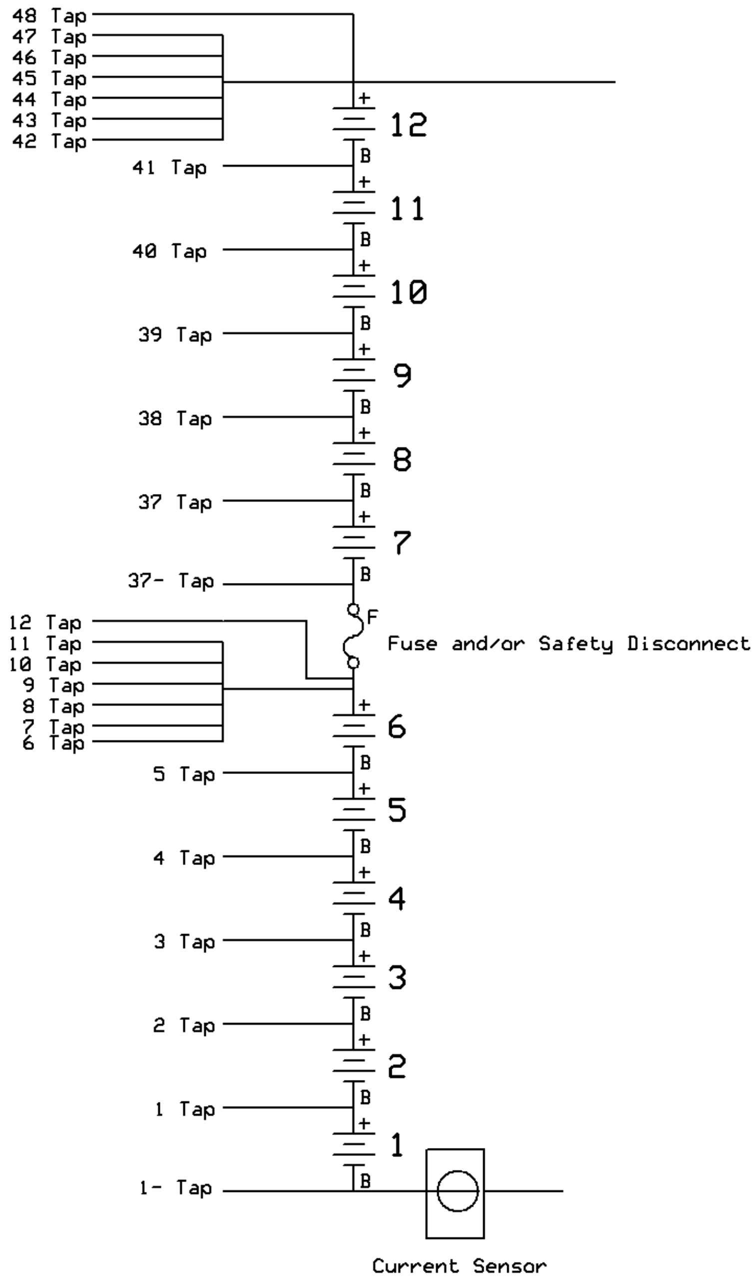
The diagram below visually shows locations where safety disconnects and fuses can be located with respect to the connectors on the Orion BMS (108 cell unit shown). While the disconnect and fuses need to be wired such that they fall between the cell voltage tap connectors (on a multiple of 36 cells) to maintain safety isolation, safety disconnects do not need to be located between the actual cell numbers 36 and 37 since cells and cell groups can be skipped with the Orion BMS wiring.



Possible locations for Fuse / Safety Disconnect

If safety disconnects and fuses are used and cannot be located on multiples of 36 cells, cell positions on the BMS must be left unpopulated such that the safety disconnects fall between a multiple of 36 cells on the BMS. Safety disconnects or fuses can be used on the positive most or negative most terminals of the battery pack, provided that the Orion BMS voltage taps are all on the battery side of the fuse or disconnect and cannot provide a path for current to flow around the disconnect or fuse.

The following wiring diagram shows the proper wiring technique if a pack with 12 cells is wired with a safety disconnect between cells 6 and 7. Note that for this example, a 48 cell or higher model BMS would be necessary even though only 12 actual cells are present. In some cases, the “-S” cell tap configurations may provide a lower cost option, and in larger volumes, customized configurations may be available. Placing safety disconnects or fuses in the ideal locations provided by the Orion BMS is usually the most cost effective method when possible.



Sample wiring diagram for a 12 cell pack a safety disconnect between cells 6 and 7

Notes on Busbars

Busbar types will vary from battery pack to battery pack, but the quality of the busbar is very important for reliability and safety. Much more goes into engineering a busbar than one might expect. Only approved, professionally manufactured busbars should be used to connect cells together. **Do not use aluminum busbars or aluminum wire for any cables. Do not use homemade busbars.** In most cases, busbars must be somewhat flexible (such as braided flat cable or strips with bends in them). This is usually necessary as to not transmit vibration to the cell terminals as well as for reliability from temperature cycling. Busbar / interconnect metal finish is also very important for long term reliability. Bare, unplated copper busbars have been known to corrode or oxidize quickly, which can lead to high resistance connections between cells resulting in reduced reliability.

Paralleled Cells

Lithium cells can almost always be paralleled directly together to essentially create a larger cell. This is useful when a cell manufacturer does not manufacture the cell size needed or when there are certain physical constraints. The method of paralleling cells directly together as shown below is generally the simplest method of increasing the capacity of the battery pack when larger cells are not available.

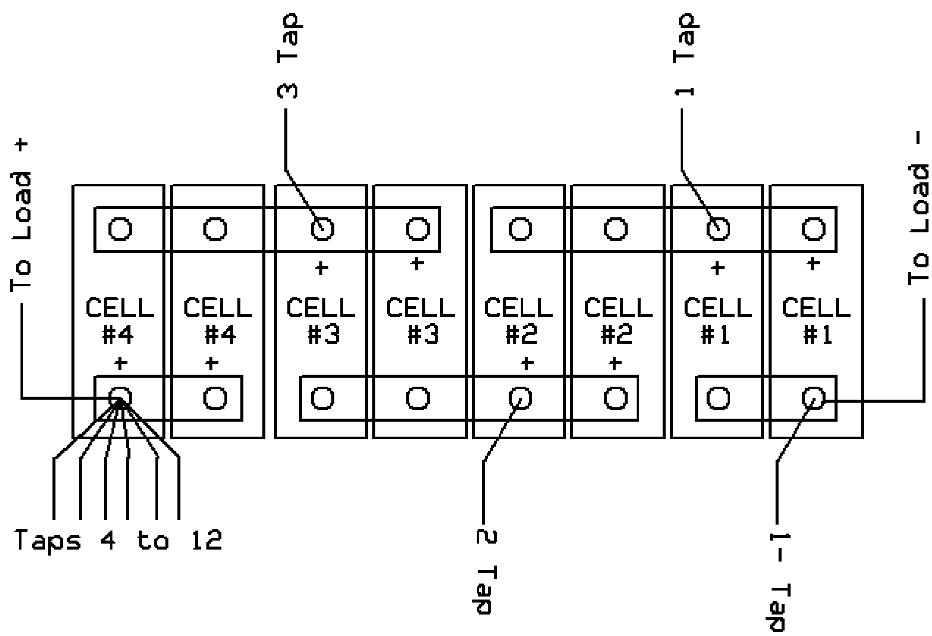
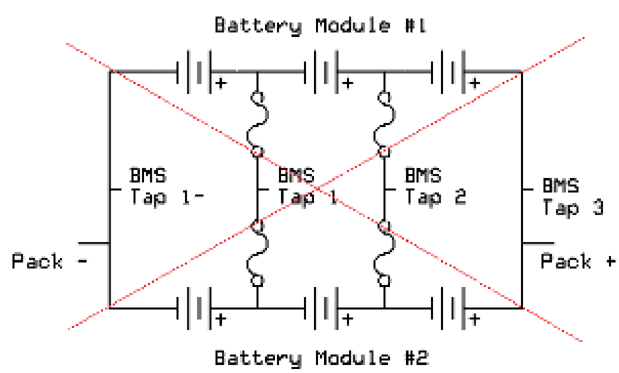


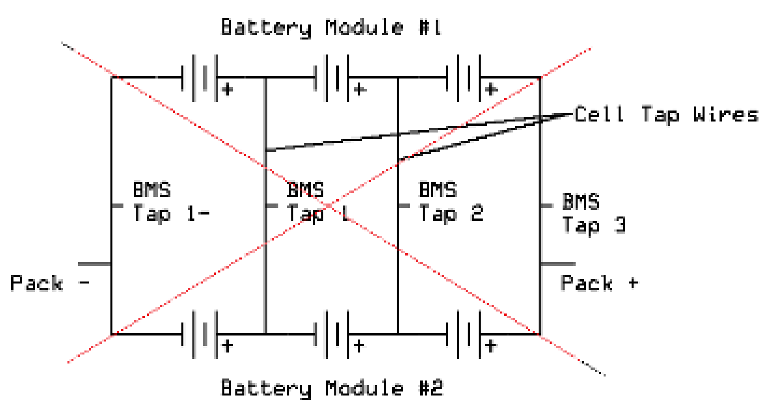
Diagram showing cells paralleled directly together

Even though there are twice the number of cells in the above diagram, the Orion BMS treats two or more cells that are directly paralleled together as a single cell for the purpose of managing the battery pack. In this case, the BMS will "see" the two paralleled cells as a single cell with twice the capacity and half the internal resistance of a single cell. Since there is a busbar between the two positive and two negative terminals of each of the cells, the voltage of both cells is forced to be equal. Therefore, monitoring the voltage of either cell will show the same results (less the very negligible difference in voltage caused by voltage drop on the busbar).

In the event that one of the cells develops a reduced capacity or high resistance (as is typical for aged or failed cells), the stronger cell will take more of the load and essentially prop up the weaker cell. In that event, the BMS is able to see a decrease in the overall capacity or an overall increase in resistance. With two cells paralleled together, a single weak cell can affect the resistance up to 50% and the capacity up to 50%. If three cells are paralleled, a single bad cell can affect the resistance and capacity of the total paralleled block up to 33% (with four cells paralleled, up to 25%, and so forth). As more cells are paralleled, a single failure becomes more difficult to detect, but redundancy is also increased since a single cell failure will have less of an impact on the overall performance of the battery. Cells directly paralleled with each other will automatically balance each other since they are permanently connected. This only applies when cells are directly paralleled together and placed in a single string and does not apply when parallel strings are used.

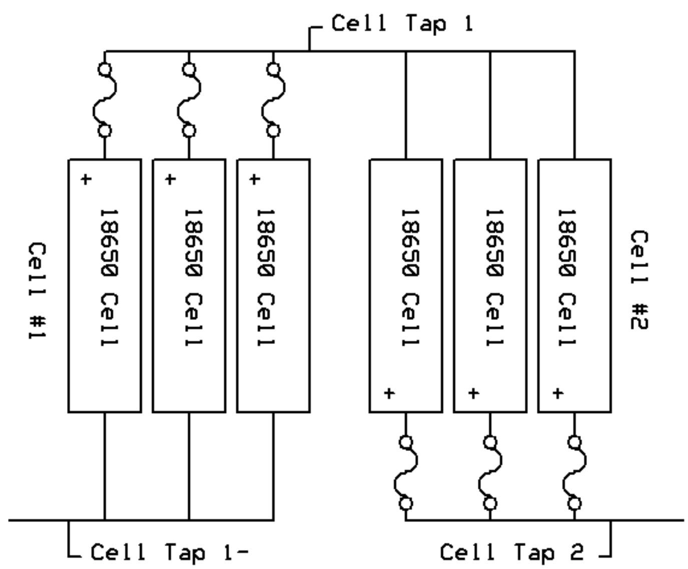
Very Important: When cells are paralleled directly together, the busbar connecting the cells together must be capable of handling the full pack amperage. Only rated busbars should be used for this purpose. Due to the possibility that large amperages up to and exceeding the full pack amperage can pass through the paralleling connection in certain conditions, ***cell tap wires may never be used to parallel cells in separate battery modules together! Using cell tap wires to parallel modules can result in burnt wires and fire risk due to over-current.*** **Even when fuses are placed in series with cell tap wires to limit currents, they may not be used to parallel cells in separate modules.** This is due to the fact that if one of the fuses blows, the paralleled cells' voltages are no longer forced to be the same and the BMS will be unable to monitor or protect one or more of the cells with the blown fuse, leaving those cells unprotected and vulnerable to overcharge. **The following configurations are prohibited:**





Prohibited, unsafe configurations using cell tap wires to parallel cells

Important Note: While most lithium batteries can be directly paralleled together, check with the cell manufacturer to ensure that the cells can be safely paralleled and to see if there are any specific requirements for the specific cells used. In some cases (such as with some 18650 style cells), cell manufacturers may require individual fuses or fusible link wire to connect the cells to the common busbar to prevent over current through a single cell in the event of a cell failure or an internal short within a cell. In those cases, if a fuse blows, it will remove the specific shorted cell from the circuit entirely while leaving the remaining cells unaffected. Consult with the cell manufacturer to determine if such a design is necessary. In cases where this design is used, care must be taken to ensure that a cascading failure of fuses does not occur to cause a break in the continuity of the stack. This is very important for preventing catastrophic failures and damage to the BMS. At a minimum, **the main pack fuse must be rated for a lower amperage and faster blow time than the sum of the fuses on the individual cells. This is important to ensure that in the pack fuse will blow rather than the individual cell fuses in the event of a short at the pack.**



Allowed configuration for individual fuses on cell (commonly used for 18650 cells)

Note: 18650 style cells can be very dangerous to work with due to the proximity of electrically hot terminals and the often non-isolated metal enclosure. They should only be used when proper equipment is used to assemble the battery pack and by persons qualified to do so. Proper battery pack design is essential for use with 18650 style battery packs, and this work should be performed by an engineer familiar with 18650 style cells.

Note: Paralleled cells may require the use of larger busbars to connect the cells together. Large busbars often increase the amount of stray inductance and capacitance in the busbar, which may increase the amount of EMF. When large busbars are used with rapidly changing currents, especially with DC to AC inverters or inverter chargers, additional steps may need to be taken to mitigate the additional EMF. See our application note on using the Orion BMS with DC to AC inverters for more information.

Paralleled String Configuration

Paralleling strings together greatly increases the complexity of managing the battery pack, because different currents will flow through each string. This configuration should be avoided unless there is a specific reason to use this configuration. Paralleling strings often yields lower overall reliability, overall lower capacity, and lower power than paralleling cells directly together and forming a single string. In this setup, each string must essentially be treated as its own battery pack with its own BMS. **Paralleling separate strings of li-ion batteries together requires special considerations including an automatic method to isolate each string from each other among other requirements.** **Additional engineering and additional safety systems are required for this configuration. The Orion BMS may not be used with parallel string configurations unless specific external safety systems are provided.** **Engineering work by a qualified electrical engineer is required for use with parallel strings.** Please see our document on Parallel Strings for more important information. In the example below, 2 strings of 8 cells each are placed in parallel.

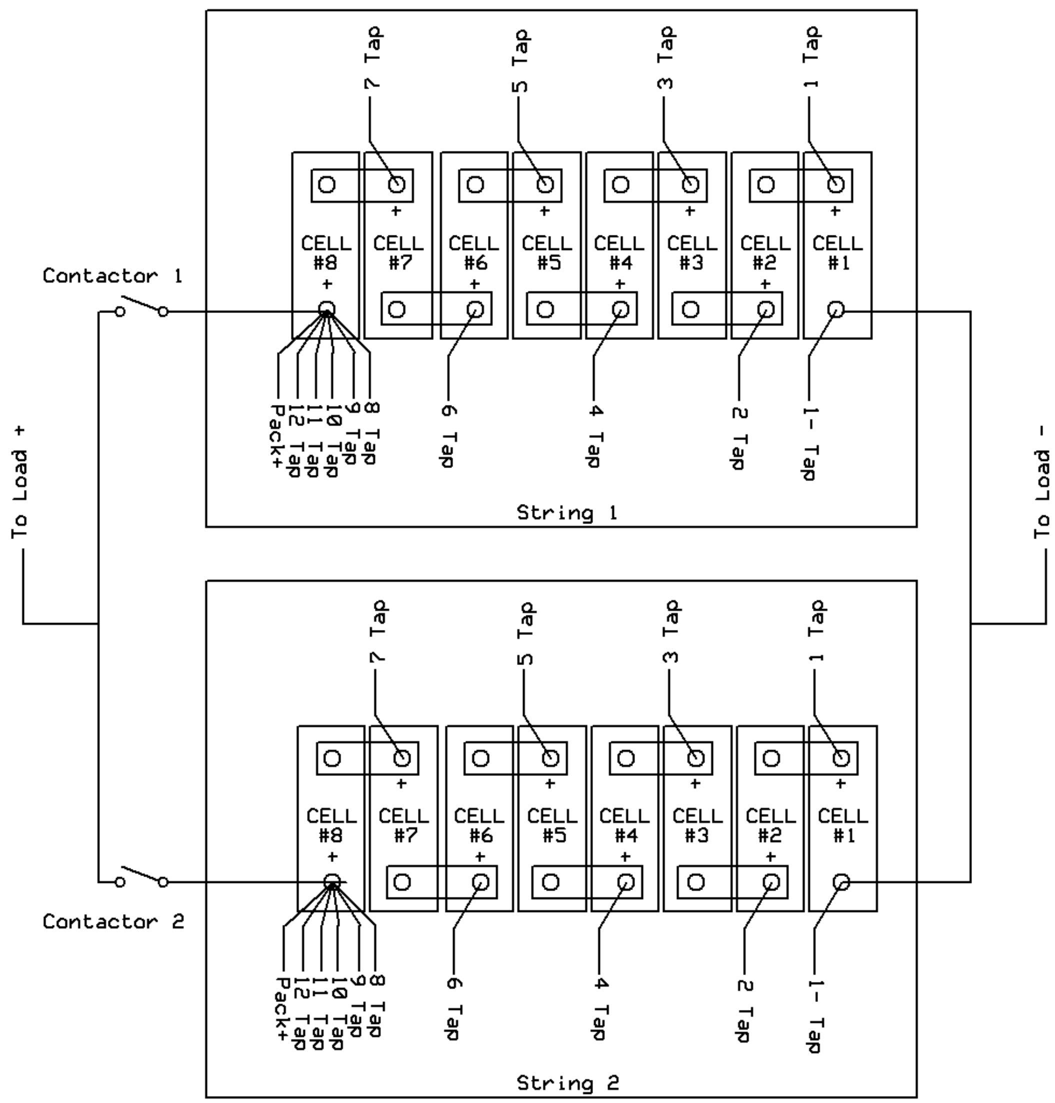
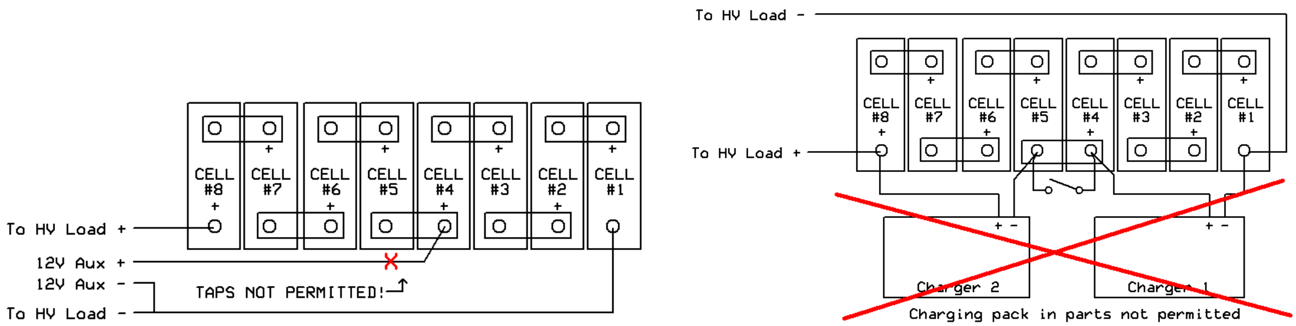


Diagram showing parallel strings

Equal currents for all cells

In order to properly maintain cell balance and to provide proper protection to the battery pack, all cells being monitored by the Orion BMS must have equal currents at all times. Tapping a battery pack mid-way to obtain a lower auxiliary voltage is not permitted. Tapping off only some of the cells for a lower voltage will cause cell imbalance and the BMS may not be able to fully protect all cells.

Charging separate sections of the battery independently or simultaneously with different chargers is also not permitted as different parts of the battery pack will see different currents. If other battery monitoring systems are also connected to the battery pack, they must pull exactly the same current from each cell in the pack.



Examples showing that the batteries should not be tapped mid-pack or charged with different chargers.

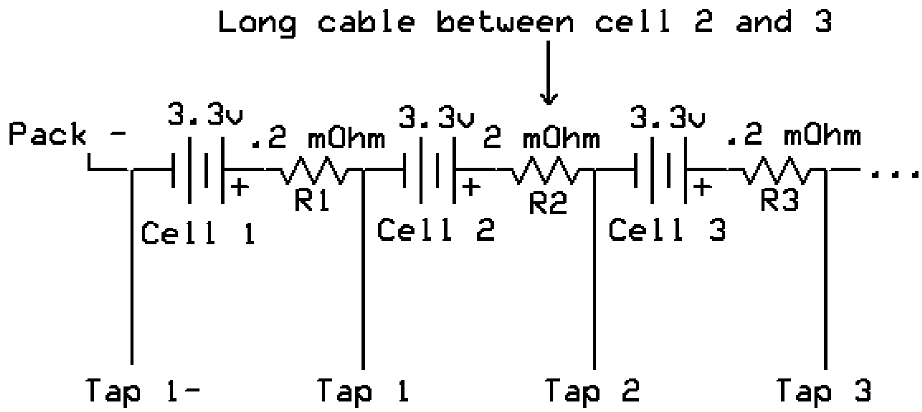
Wiring for high impedance cables and busbars

Voltage measurements are taken by the Orion BMS with respect to the next lowest cell or the negative wire in each cell group. For example, when the Orion BMS measures cell 1's voltage, it measures the voltage between tap 1- and 1. For cell 2, the voltage is measured between tap 1 and tap 2 to determine cell 2's voltage.

While battery cables and busbars may be very large and have a minimal resistance, all cables have some electrical resistance. The cell taps by necessity will see the additional resistance from busbars, battery interconnects, and cables unless they fall between cell groups (12 cells). The diagram below shows the first three cells wired in a group.

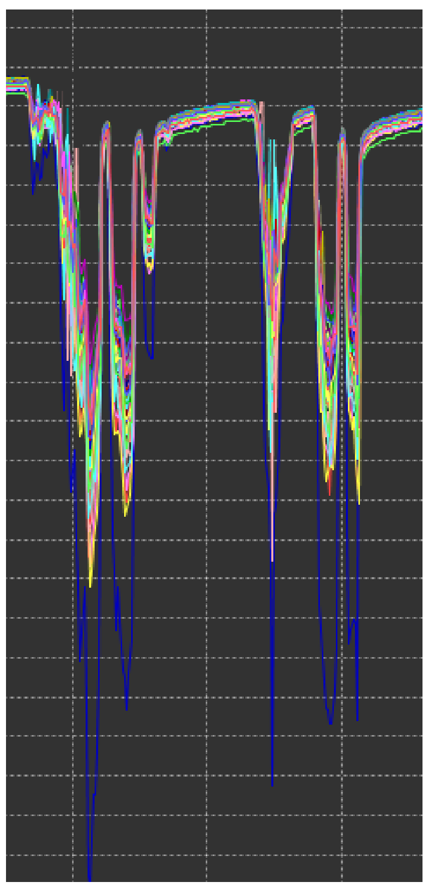
If cell voltages are measured by the Orion BMS with no current flowing through the circuit, the voltages measured are exactly the voltage of the cells. When a current is running through the pack, the measured voltage of each cell will drop (or increase) due to the internal resistance of the cells and the measured voltage (instantaneous voltage) and the open cell voltage of the cells will be different. Appendix A of the operational manual has a more detailed description of how this works.

Because of the way the cells are connected, the differences in resistance from one interconnect to another will be reflected in the instantaneous voltage measurements and would show up to the Orion BMS as extra resistance for that particular cell. In the example below, all of the cells have a resistance of 3 mili-ohms, but due to the busbar resistances, the BMS sees the extra 2 mOhm resistance for a total of 5 mOhm on cell 2. Even though cell 2 is still healthy, it appears to be a weak cell without any compensation. This is where busbar compensation comes in.



Example of differences in resistance due to busbar resistance

For cables or connections with relatively lower resistance, this extra resistance can be compensated out by the BMS using “busbar compensation” (see the software manual for information on setting up busbar compensation). For high resistance busbars / cables (or higher amperage applications), it is possible for the voltage drop (or voltage increase if the battery is being charged) to be large enough that it can cause the voltage at the tap to exceed 5V or drop below 0V (which are the maximum and minimum voltages for the Orion BMS). If the voltage can swing outside those maximum voltages, even briefly, the Orion BMS must be wired such that the cable falls between a cell group break (every 12 cells) and be wired such that voltage drop induced by the busbar cannot be seen by the Orion BMS.



Voltage drop under load from an uncompensated high impedance busbar (blue)

Maximum voltage swing can be calculated if the maximum cell voltage, resistance of the busbar / cable and maximum amperage are known using the following formulas. Please keep in mind that the resistance of the busbar or cable must include the resistance of the terminal and any crimps. Headroom must be left for possible small increases in resistance due to eventual corrosion, etc.

Peak_voltage = Vmax_cell + (Rbusbar * Imax_charge) (Peak_voltage must be < 5v)
Lowest_voltage = Vmin_cell - (Rbusbar * Imax_discharge) (Lowest voltage must be >0v)

In the above example, if the example cells have a maximum voltage of 3.65v (Vmax_cell) and a minimum of 2v (Vmin_cell) and a maximum amperage of +/-200A (Imax_charge and Imax_discharge), the peak voltage with the given 2 mOhm cable would be 4.05v and the lowest voltage 1.6v. These voltages are within the limits and busbar compensation could be used. **While there are exceptions, the general rule of thumb is that any cables longer than approximately 4 feet (1.2 meters) should not be compensated with busbar compensation.** In these cases, the cable should wired such that it falls between a cell group or connector either by skipping cell taps or re-locating the cable. In some cases depending on the gauge, cables shorter than 4 feet cannot be compensated.

Busbar compensation works only when DC loads and sources are connected to the battery. **Busbar compensation cannot be used when fast pulsing currents such as those generated by most AC inverters or AC inverter/chargers are connected** (see 'using the Orion BMS with AC inverters' for more information on integration with AC inverters). Unfiltered high frequency inverters which place a significant AC component on the DC bus or excessively noisy motor controllers / inverters may also be problematic for busbar compensation due to back EMF. In such cases, busbar compensation cannot be used, and cables must be installed between cell groups. If the noise causes skin effect, filtering may be necessary to be able to use with the Orion BMS.

Although busbar compensation is able to compensate out extra resistance from short cables, for best results, we recommend placing any cables between cell groups whenever possible.

Skin effect issues due to AC currents

The vast majority of motor controllers available on the market provide some amount of filtering on the DC bus in order to limit radiated and conducted emissions. While most motor controllers generate high levels of noise, the noise generally does not lead to a significant AC component on the DC bus. A small minority of motor controllers lack adequate internal bulk capacitance and filtering and actually produce a high frequency AC component on the DC bus.

The Orion BMS is extremely resistant to electrical noise (EMI) and has been tested in real world situations to operate successfully with this excessive noise. However, a strong high frequency AC component can create a “Skin Effect” on the cables connecting the batteries. Skin effect is where eddy currents form within the cables and effectively cause only the outside portion of the wire to carry current, effectively increasing the resistance of the wire.

Although the Orion BMS has been tested extensively to operate and measure voltages properly in these extremely harsh noise environments, the BMS may correctly measure unpredictably changing resistance values since the effective resistance of the cable is changing considerably with respect to amplitude and frequency. The Orion BMS bases many calculations on the measured resistance of the cells, including open cell voltage calculations which are used for determining maximum current limits and determine when cells are weak. If a significant skin effect is present, it can introduce inaccuracies with some calculations even though the Orion BMS continues to operate.

The overwhelming majority of motor controllers have adequate filtering to reduce conducted emissions to levels that prevent a skin effect from forming. For the small number that do not, the skin effect can be mitigated somewhat by using suitable rectangular busbars or straps rather than round cables. In an environment where a skin effect forms, any round cables should be wired such that they fall between a cell groups since the BMS cannot effectively compensate them out. Additionally, it may be possible to add external filtering to the motor controller to suppress the conducted emissions generated by the motor controller to a tolerable level. Extremely high amounts of AC noise can also cause back EMF from stray inductance in the cabling. If this occurs, the emissions will need to be limited to a safe level.

DC to AC Inverters and Inverter Chargers

With good layout and standard busbars, the Orion BMS 2 can generally be used with most single phase DC to AC inverters. However, there are several considerations that need to be taken into account. DC to AC inverters (or inverter chargers) can lead to a significant AC component (sinewave like current pulses) being present on the DC bus. Many AC inverters will pull current from the battery pack in a rectified sine wave at twice the frequency of the AC sine wave (i.e. 120Hz for a 60Hz inverter or 100Hz for 50Hz inverter.) If multiple synchronized inverters are present or when multiple phases are present on the same battery pack, these frequencies can overlap, sometimes leading to significantly higher frequencies. These frequencies can lead to skin effect (described above).

When high frequencies are present, the physical layout of the battery pack and interconnections becomes very important. Even very small amounts of stray inductance in cabling or interconnects can begin to cause back EMF. If EMF or skin effect are present, filtering at the inverter or an alternative cell tap configuration may be necessary. More information, including how to interface and control a DC to AC inverter (or inverter/charger) can be found in our “Using the Orion BMS with DC to AC inverters” application note, which can be found at orionbms.com.

Transients

Transients on the battery pack must be limited to reasonable levels. This is important both for the protection of the BMS as well as the protection of the attached lithium cells. Lithium cells exposed to extreme transients may short and enter thermal runaway. Extreme transients are often generated by the combination of rapid changes in current and stray inductance. These usually occur when bulk capacitors in motor controllers or chargers are switched into circuit or by other rapid changes in current such as from a blowing fuse or sudden connection of current. Transients from normal switching from contactors can be limited by using proper pre-charge circuits and limiting slew rates for motor controllers. The use of multiple chargers with series diodes is not permitted for use with the Orion BMS as these configurations can cause significant damaging transients. **The Orion BMS 2 may not be used with multiple chargers in series.**

Excessive transients may cause damage to the Orion BMS unit or to connected lithium ion cells. In the event of excessive transients, the Orion BMS unit and lithium cells should be inspected or tested for damage as damage can lead to safety risks. The Orion BMS 2 has protection against moderate transients on the high voltage measurement circuits. Severe transients may cause the internal fuses to blow, and repeated exposure to transients may eventually damage the BMS.

If a unit has been damaged by transients, it must be disconnected immediately from service and repaired or replaced. Never continue to use a damaged unit.

Wiring Errors

Wiring errors can cause serious damage to the Orion BMS that is not covered under warranty. The Orion BMS has internal fuses on each cell tap wire to protect the BMS and connected wiring from excessive currents. The unit can withstand certain minor wiring errors such as accidentally swapping the order of two cells or even wiring cells in the reverse order for short periods of time. The internal fuses are designed to blow with voltages more than +/- 24v (though there are some rare situations where fuses can still blow at lower voltages and some situations where they won't blow until voltages are higher. The Orion BMS 2 can withstand wiring errors only for a short period of time and repeated or prolonged exposure to these errors may cause permanent damage. ***If units are wired improperly, small currents may flow through the BMS. An incorrectly wired unit should not be left connected to the battery pack for more than 5 minutes as it will eventually drain and can destroy cells connected to it.*** If there is question as to whether the harnesses are wired properly, do not leave them connected to a unit for any length of time. The Orion BMS units may report an "open wire" fault, "wiring fault", or "low cell fault" if incorrectly wired.

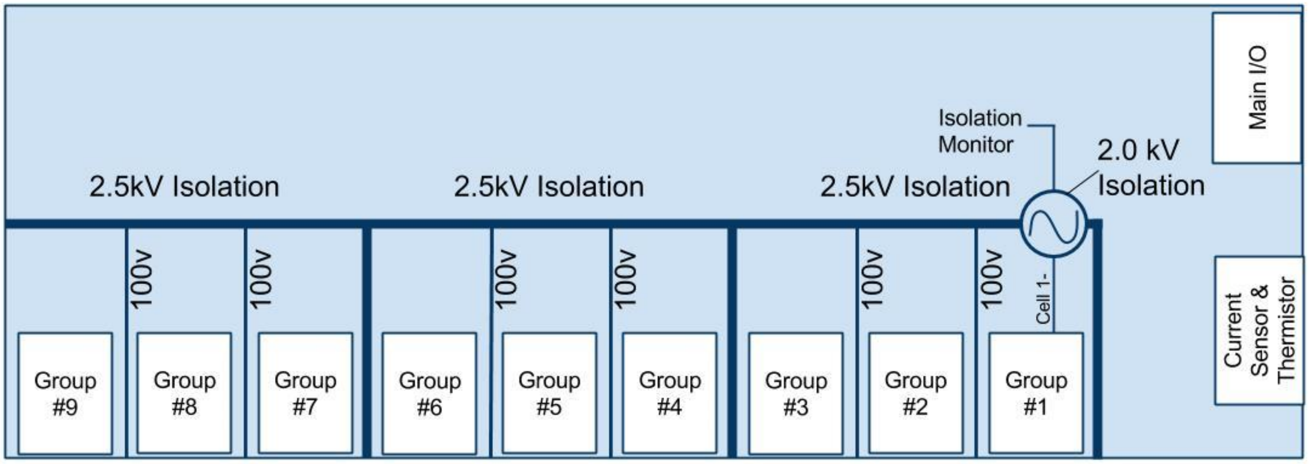
Voltage tap harness lengths

Standard pre-wired voltage wiring harnesses are available for the Orion BMS in 6 foot and 12 foot lengths. The length of the tap harness very slightly affects the accuracy of the voltage readings by the Orion BMS. Wires can be cut down to size to reach the particular cell they need to reach. Wires, even within the same cell group or connector can be cut to different lengths without significantly impacting voltage readings. Wire lengths beyond 36 feet are not recommended.

Cable Length	Additional Error
6 foot	0
12 foot	+/- 0.10mV
18 foot	+/-0.15mV
24 foot	+/-0.23mV
30 foot	+/-0.32mV
36 foot	+/-0.44mV

The values in the table above are approximate values and may be affected by other factors such as temperature and resistance of crimp and ring terminals.

Internal Isolation



Isolation Diagram for 108 cell system (180 cell version can be extrapolated).

The Orion BMS provides 2.5kV isolation between cell voltage taps and control electronics as well as between groups of 36 cells. Isolation between cell groups on the same connector (e.g. between groups 1, 2 and 3) is a nominal 100v isolation which is an ideal placement of high resistance busbars or cables between cells, but cannot be used for a safety disconnect or fuse since it is not rated to withstand the full stack voltage.

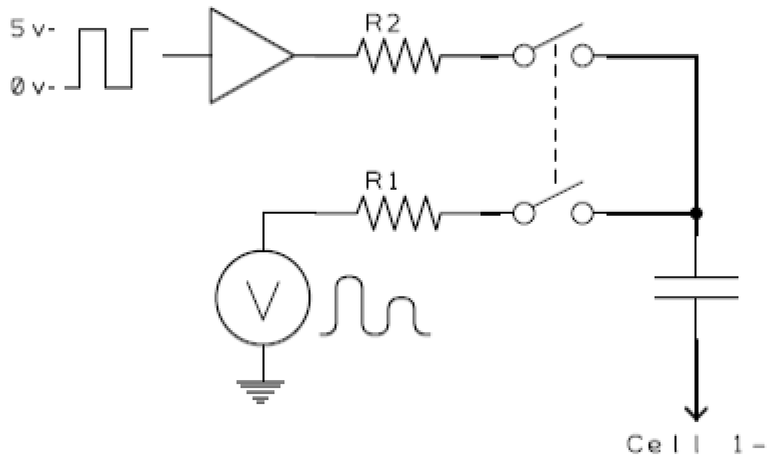
Note that units configured with less than 108 cells do not have all nine groups populated. For 120 - 180 cell units, the same pattern of isolation continues with groups #10, 11, 12, 13, 14 and 15 with 2.5kV isolation between groups 9 and 10 and 12 and 13.

Please note that the CAN transceivers inside the BMS are referenced to the 12v-24v ground (Main I/O pin 12) and are not electrically isolated from each other. While most motor controllers and chargers isolate the CANBUS from the battery pack, if the BMS is used with a motor controller, charger, or other device which does not have a CANBUS interface that is isolated from the battery pack, an appropriately rated CANBUS isolation device must be used.

Note: The BMS's isolation fault detection circuit may cause a small amount of 'leakage' current to flow from cell tap 1- to the chassis ground through the isolation capacitors if the isolation fault detection circuit is enabled.

Isolation Fault Detection Circuit

The Orion BMS 2 has an integrated isolation fault detection circuit to detect a breakdown in insulation between the high voltage battery pack and the 12v – 24v power supply. The BMS measures isolation by transmitting a weak 5V AC signal across an isolation capacitor and measuring the degradation of the AC signal. A simplified schematic of the isolation fault detection circuit is included below.



Simplified isolation fault detection schematic

Isolation is measured from the 12v – 24v power supply negative to cell tap 1- (negative most cell in the battery pack). ***For the isolation fault detection circuit to work properly, cell 1 must be the most negative cell in the battery pack such that cell tap 1- is connected to pack negative.*** Since the measurements are made against the 12v – 24v power supply negative, and most isolation faults occur to the vehicle or equipment chassis, the chassis must be connected to the 12v negative to properly measure a breakdown in insulation.

Only one isolation fault detection system can be installed on a DC bus at any given time as the detection circuit AC signal will conflict with other systems and produce invalid results. If the BMS will be used in a system where other isolation fault detection systems are used, the circuit must be physically disabled. The Orion BMS 2 contains a latching relay that can be used to physically disconnect the circuit. This relay is designed to be operated during setup and is not designed to be switched on and off regularly during operation. While the latching relay is periodically pulsed to ensure it is in the desired state, the relay status can be flipped if the unit is exposed to very large g forces due to mechanical shock, such as if the unit is dropped in the correct orientation. The BMS may be ordered with the isolation fault detection circuit permanently enabled or permanently disabled, which is recommended if the feature will always be used or will not be used (in larger volumes there are cost savings for ordering without this feature.) **If the BMS is expected to be used in environments where mechanical shock is possible or likely, the unit should be ordered with the circuit permanently enabled or permanently disabled.**

This is a very common method for measuring breakdown in isolation between a battery pack and a chassis. With this method, the isolation capacitors will have a very small leakage current. This small leakage may cause voltage to be measured between the battery pack and the chassis. Although the voltage can be measured, the current is very weak.

Maximum Number of Cells (Maximum System Voltage)

The Orion BMS has a maximum operating voltage of 800v. The total voltage of the attached battery pack may not exceed 800V for any period of time, even when remote modules are used. While the BMS unit can support up to 324 cells in series, this number is typically limited by the overall system voltage. The BMS unit supports this many cells for the purposes of allowing the use with low voltage cells (such as lithium-titinate) and for the purpose of allowing cell taps to be skipped for the placement of cables, fuses, disconnects, contactors, etc.

Cell Groups with fewer than 12 cells

Each cell group must have a minimum of 4 cells and up to 12 cells, with a minimum voltage of 11v per group. If fewer than 12 cells are used, each cell tap wire must still be connected to maintain proper operation and accuracy (see below for more information). The minimum number of cells is determined by the voltage of the cells. The minimum voltage to meet accuracy specifications is 11V per group. Although the BMS may continue to read cell voltages below these voltages, the accuracy may be degraded at those voltages. See the table below for determining the minimum number of cells based on the worst case minimum cell voltages.

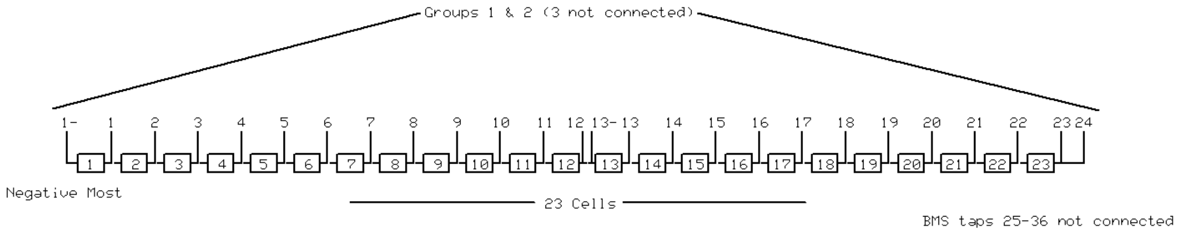
Cell Min. Voltage	Min. cells in a group
1.8V	7
2.0V	6
2.5V	5
2.8V	4
3.0v	4

Rules for fewer than 12 cells

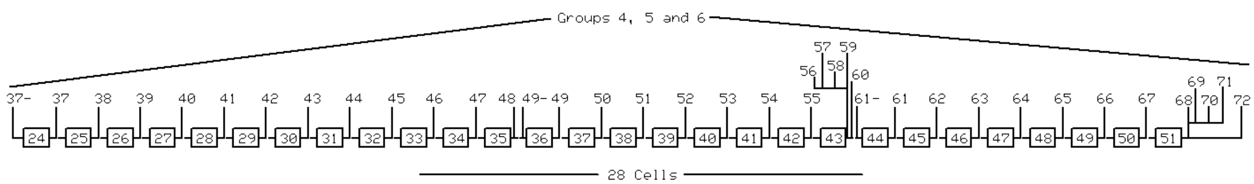
- If fewer than 12 cells are populated in a group, unused cell taps must all be connected to the highest potential cell in that group. For example, if 6 cells are populated in a group, taps 6 – 12 all must be connected to the positive tap on cell 6.*
- No cell group may have fewer than 4 cells connected (higher minimums may apply if a cell's minimum voltage is below 2.8v). If a group of cells ends up with fewer than 4 cells, some cells must be skipped in one of the other groups and wired into the group with less than 4 to ensure that a minimum of 4 cells are present.
- Cell Groups must have a minimum normal working voltage of 11 volts (2.8v per cell for 4 cells) and an absolute minimum voltage of 10v. Accuracy of voltage measurements is decreased when the group voltage is below 11 volts.
- If a cell group has 0 cells connected (the group is skipped entirely), all wires from that group may be left disconnected.

*In this example, cell tap positions 6-12 can optionally be combined into a single wire that runs to the terminal to reduce the number of wires entering the battery area. For cell tap wire lengths over 16 feet, the 12th cell tap wire in a group should run directly to the highest potential cell using a separate wire to improve accuracy of the voltage reading on the 12th cell.

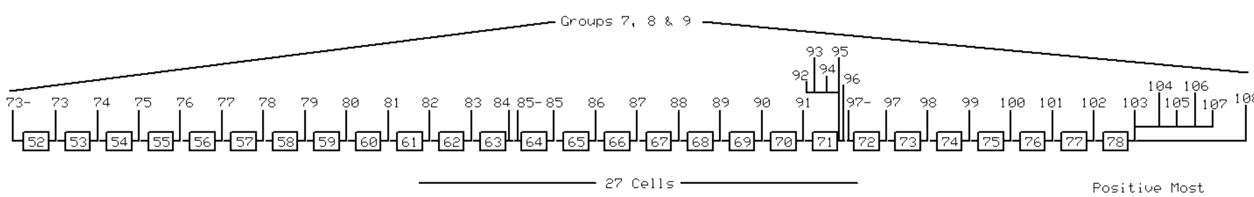
Example: A battery pack of 78 cells is divided into three sections with a fuse and a long, high impedance cable located between cells 23 / 24 and 51 / 52. 23 cells are in the first section, 28 in the 2nd section and 27 in the third section.



In the first section of this example battery, cell group one is wired normally with 12 cells. Group 2 is wired with 11 cells and because of that, BMS tap #23 and #24 are tied to the same cell (cell #23). Because 2.5kV isolation is required between cell #23 and cell #24, group 3 is skipped and left disconnected and the next section starts with group 4.



In the second section of this battery, group 4 (starting with BMS tap #37-) is wired normally starting with cell #24 and has all 12 cells connected. Since the 2nd section has 28 cells and 12 cells have already been connected, that leaves 16 cells left to connect to groups 5 and 6. If 12 cells were connected to group 5, 4 cells would be left for group 4 which is the minimum number of cells per group allowed. While that would be suitable and meet the minimum criteria, the best solution is to split the remaining cells between the 2 groups with 8 cells per each group to ensure that the 11 volts per group minimum is always met. The unused BMS taps are tied to the same potential as shown.



The third section is similar to the 2nd section, but with 37 cells. Group 7 is wired normally with all 12 cells, which leaves 15 cells in the section. If group 8 were wired with 12 cells, there would be only 3 cells left for group 9, which is below the minimum required. In this instance cell group 8 must have no more than 11 cells such that enough cells are left for group 9.

Fuses on voltage tap wires

The Orion BMS has internal fuses on each of the positive cell tap wires. While these fuses protect the BMS and guard against excessive current flowing through the internal protection diodes and are designed to blow if the maximum voltages are exceeded, **the fuses do not protect against two tap wires that short together outside the BMS or short at the BMS connector**, or provide protection against excessively high cell tap voltages. While many major OEM vehicle manufacturers have carefully calculated and rely upon the fusing characteristics of the cell tap wires, this approach requires engineering work by a qualified electrical engineer and extensive testing and is never appropriate for cells incapable of producing large enough currents to fuse wire. Fuses on cell taps are recommended as the above technique requires must testing and engineers. **Some applications will require the use of fuses on the cell taps, and it is the sole responsibility of the integrator to determine if these external fuses are needed. It is the sole responsibility of the integrator to research and comply with all applicable laws, regulations, standards, and codes for the specific application.**

If external cell tap fuses are used, they should be as close to the cell terminals as possible, kept as low resistance as possible within reason, and be rated no larger than 5A. Fuses must always be rated for the maximum possible DC working voltage with a suitable DC interrupting current rating for the application. Certain electrical codes or regulations may dictate the maximum fuse size, and it may be smaller than 5A depending on wire gauge and other considerations. Fuses should be selected to have the lowest possible resistance to prevent degrading the cell voltage measurement accuracy. Series resistors are not permitted as current limiting devices for cell tap wires as they may over-heat or limit current to insufficient levels to blow internal fuses on the BMS, which may lead to dangerous situations in addition to causing voltage measurement inaccuracies.

Note: The fuses inside the BMS unit are designed to blow only in the event of over-voltage or reverse voltage on adjacent cell taps (see “Why Fuses Blow” below for more information). Adding external fuses to the cell taps will not prevent the fuses inside the BMS from blowing in the event of an over-voltage situation, and if an external fuse blows due to over-voltage, the BMS must still be inspected for damage by a factory authorized repair center.

Fuses may also be necessary on thermistors to protect against a possible short between a thermistor and a terminal of a battery. It is the sole responsibility of the integrator to determine if fuses are necessary on the cell tap wires.

Verifying Cell Voltage Tap Wiring

The wiring must be verified prior to connecting any of the wiring harnesses to the Orion BMS. Improper wiring can cause damage to the BMS unit, catastrophic failure or even personal safety risks depending on the extent of the wiring mistake.

The most important connectors to verify are wired correctly are the cell voltage tap harnesses. There are two methods for doing this.

The first is the tap validation tool which is available for rental or purchase. The tool can be connected to the wiring harness already connected to the battery pack and will verify that cells are wired in the correct order and can detect most wiring mistakes. The verification tool is designed to withstand incorrectly wired harnesses without damage. **It is strongly recommended to use the verification tool before plugging the harness into the Orion BMS since it is very easy to make an error wiring the harness and it may not be obvious. Mis-wired voltage tap harnesses can cause significant damage to the Orion BMS that is not covered under warranty.** Please refer to the cell tap validation tool manual for more information on proper testing.

Wiring can also be verified by carefully using a multimeter (the use of the tap validation tool is the recommended method). **Care must be taken not to short any pins with the multimeter given the size of the connector pins. Personal safety equipment including protective eye-wear and gloves and arc-flash resistant clothing should be worn for protection in the event of an arc flash.** In order to avoid two probes on the connector, the negative probe should be attached to the negative-most terminal of the negative-most cell in the pack rather than on the connector. Then, being careful not to short pins or touch the probe, carefully measure each of the pins on the connector starting with the pin for 1-. On the first connector, the 1- pin should read 0V since the negative probe of the multimeter should be connected to the same cell. Pin 1+ should read the voltage of the first cell (3.3V for example); pin 2 should read the sum of the first two cells (6.6V for example) and so forth. The connection for cell 12 and 13- should read the same voltage since they are connected to the same potential and the same is true for every multiple of 12.

When connecting the harness to the BMS for the first time, (after first verifying correct wiring), first adjust the cell population settings in the BMS software so the BMS is aware which cells it should be expecting to see. Once you have uploaded the profile to the BMS (see the software manual for more information on this), use the live cell voltages screen to verify that all cell voltages are reading correctly. Then verify on the diagnostic trouble code screen that no “open wire faults,” “wiring faults,” “low cell faults,” or “high cell faults” are present on the BMS. Open wire or wiring faults indicate that the BMS has detected a problem with the cell tap wiring. ***If any errors are found or if cell voltages are not matching properly, do not leave the BMS connected to the pack for long periods of time as it may drain cells and cause damage to them.***

Disconnect Cell Taps While Altering Battery Wiring

Any time battery wiring is altered in any way, the cell taps on the Orion BMS MUST be fully disconnected from the BMS.

Why Orion BMS Internal Fuses Blow

The Orion BMS has an internal fuse for each of the cell voltage tap wires. These fuses are designed to blow in over-voltage and reverse-voltage conditions. The BMS also contains resettable fuses which protect against certain kinds of temporary lower voltage wiring faults. In **most** cases where the over voltage or reverse voltage conditions are less than 24 volts for less than 5 minutes, the resettable fuses will reset to normal after the fault is cleared. In situations where faults result in higher voltages across two cell taps, the standard fuses are designed to blow. If this occurs, the BMS must be returned for service. Sufficient current to blow the standard fuses will only flow through the tap wires during an over-voltage or reverse-voltage condition.

Below is a diagram showing a sample 48 cell battery pack connected to an Orion BMS unit. The internal fuses and protection diodes inside the unit are depicted below. In the diagram, all cell tap voltages are within 0 – 5 volts with respect to the next lower cell. As a result, none of the zener diodes conduct and no significant current is flowing through the BMS. Since no current is flowing, all fuses remain in a closed state.

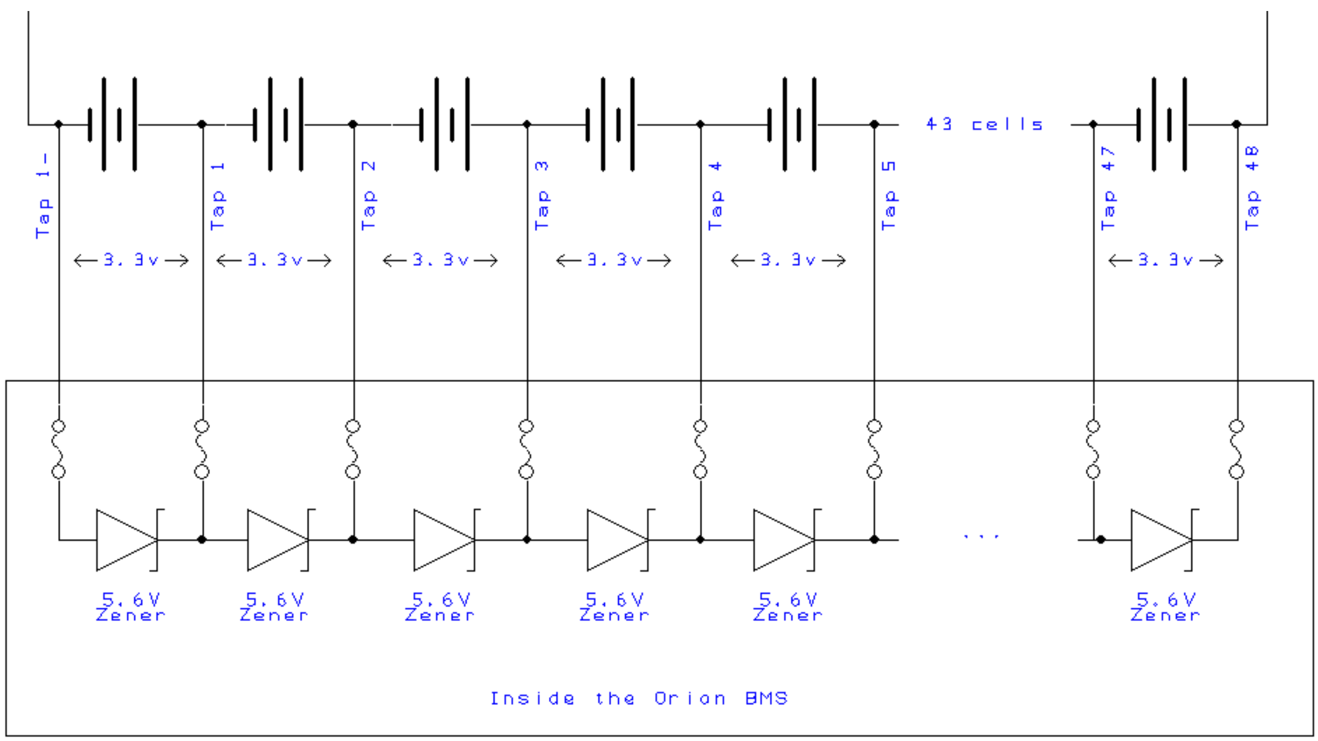


Diagram showing Orion BMS fuses

What causes the fuses to blow?

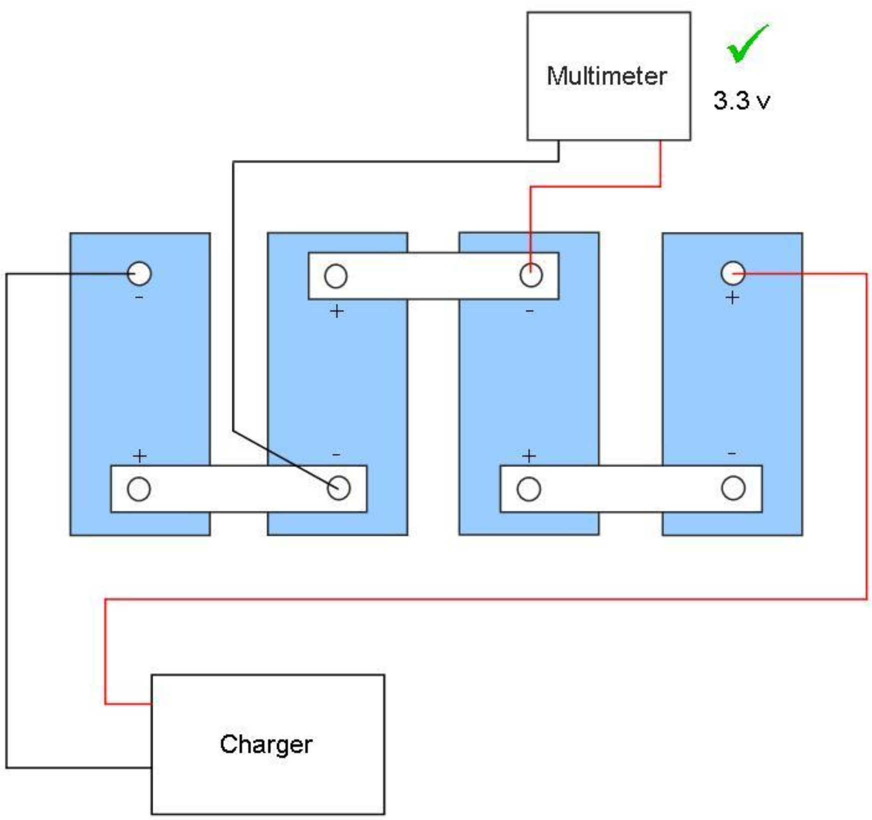
The only time the internal fuses on the tap wires will open is from an over-voltage or reverse-voltage condition. When an over-voltage or reverse-voltage condition occurs, the zener diodes will begin to conduct, causing current to flow through the tap wires and causing the fuses on the taps to blow. This is necessary in order to protect the voltage measurement electronics from damage. Over-voltage and reverse-voltage conditions are both with respect to the adjacent lower cell tap and the adjacent higher cell tap. There are many situations that can lead to over-voltage and reverse-voltage occurring, some of which may be unexpected. While the following few pages are not an exhaustive list, they cover the most common causes.

Reason: Altering wiring with the BMS connected (or loose busbar)

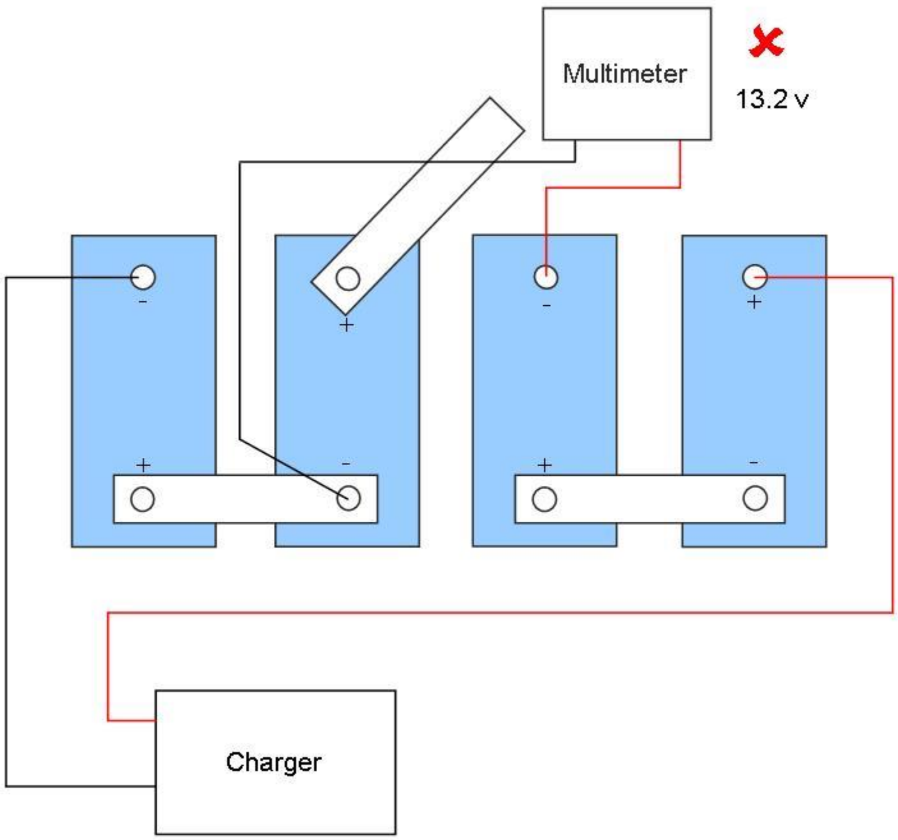
By far, the most common cause of blown fuses and/or more serious damage to the Orion BMS is when battery pack wiring is altered with the Orion BMS still connected. While it may seem counter-intuitive, removing a busbar with the BMS cell tap wires connected can result in the voltage of the entire battery pack across two adjacent cell tap wires due to capacitors in a battery charger, resistance from a connected load (motor controller, DC:DC converter, lighting, etc.), stray capacitance, a breakdown in isolation within the battery pack, or other such causes. Since these voltages are well beyond the maximum rated voltage between two cell taps, damage to the unit is likely to occur.

It is very important, both for safety and for the health of the BMS, that all cell tap wires are always disconnected before any modifications are made to the wiring of the battery pack. We recommend designing the battery box enclosure to require the cell taps to be disconnected before the battery wiring can be modified or applying warning stickers throughout the battery pack indicating that the BMS must be disconnected before the battery pack is serviced.

The below example shows a 13.2 volt battery pack. A volt meter is measuring 3.3v from cell tap #1 to #2 in the example.



The next diagram shows what happens when the busbar is disconnected. As the busbar is now open, battery voltage is no longer present at the battery charger, but the internal capacitors in the charger are still charged at the pack voltage (13.2 volts) and have no place to discharge. Because of this, the full battery voltage is present across cell tap #1 and #2 (the multimeter leads in the diagram). Because the voltage is now the full battery voltage, the zeners inside the BMS break down and conduct, causing the fuses inside the BMS to blow.



In the above example, the total pack voltage is only 13.2 volts, which would likely not damage an Orion BMS 2 unit unless left in this configuration for a period of time greater than 5 minutes. If this same scenario were to occur on a higher voltage battery pack, internal fuses on any revision of the Orion BMS 2 will blow as the voltage would exceed 24 volts. The below electrical diagram shows the same situation, only with a larger 158v battery pack. When the voltage between the cell taps rises rapidly, the zener diodes inside the BMS begin to conduct, discharging the battery charger's capacitors, resulting in blown fuses. In this case, it is possible to blow all fuses within a particular cell group. Typically current will first flow through the two closest cell taps as it is the path of least resistance (black line in the following diagram) and then seek alternative paths as fuses blow (light purple line.)

When voltages between 2 cell taps to the BMS exceed 60V, more substantial damage to the BMS than blown fuses may occur, which may increase the cost of repairs.

It is important to note that a battery charger or load does not need to be connected to the battery pack to cause high voltages between cell taps when a busbar is removed. Isolation faults, built up charge against the chassis (stray capacitance), or capacitors on snubber circuits can all be enough to cause damage. Damage from this scenario can be prevented by ensuring that the cell tap harnesses are fully disconnected from the BMS before any wiring is altered on the battery pack. This damage can be caused by not only intentional re-wiring of the battery pack, but by loose, corroded, or high resistance cell interconnection busbars, cables, etc. Intermittent or high resistance cell interconnections also pose a fire risk from arcing and must be avoided by using proper connection techniques.

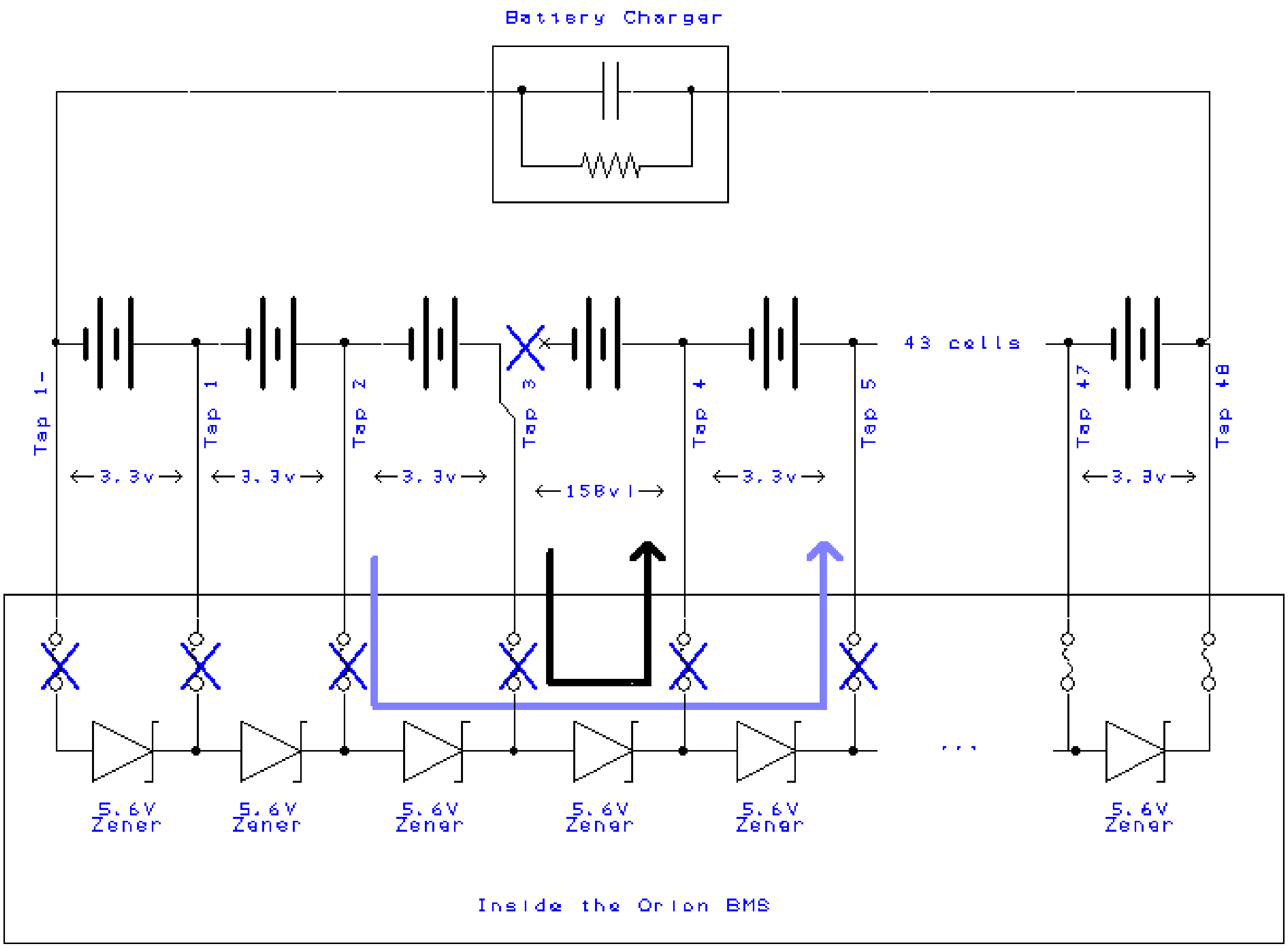
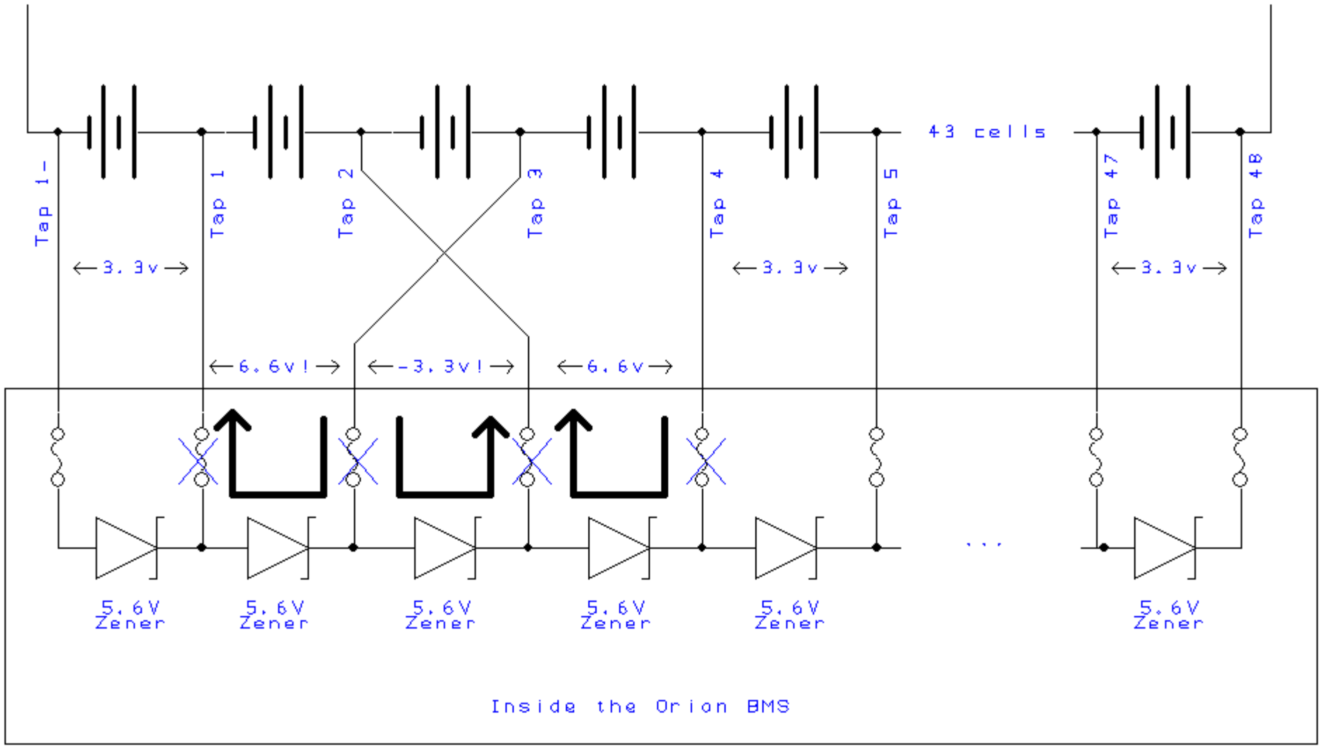


Diagram showing battery pack with blown fuses

Reason: Cell tap wires reversed

While Orion BMS 2 units are designed to survive a single tap wire reversed for short periods of time, the unit may not survive for longer times or if multiple wires are crossed. Never leave a BMS unit connected with reversed tap wires. Even though the BMS may survive, this condition will the drain attached cells and may cause damage to the BMS.



Schematic showing battery pack with reversed cell taps

In the above schematic, cell taps 2 and 3 are reversed. This leads to 6.6v between cell taps 1 and 2 and 3 and 4 with a reverse voltage between taps 2 and 3. In this case, 4 of the zener diodes will conduct and current will flow through the tap wires. This condition leads to up to 4 fuses blown (but may be as few as 2 fuses depending on the order that they blow.) For Orion BMS 2 units, fuses will generally reset to their normal state once the above fault is fixed for this particular situation.

Reason: Accidental contact to cell tap

If a cell tap wire accidentally comes into contact with a different voltage cell while the harness is plugged into the BMS unit, significant voltage may be present. This can also happen if a tap wire is cut or abrades and shorts to another wire or another terminal. Cell tap wiring must not be altered with the BMS connected both for safety reasons and to prevent damage to the BMS. Care must also be taken to route the cabling in such a way that it cannot abrade or be cut by objects.

Reason: Transients (and shorts within the high voltage battery pack)

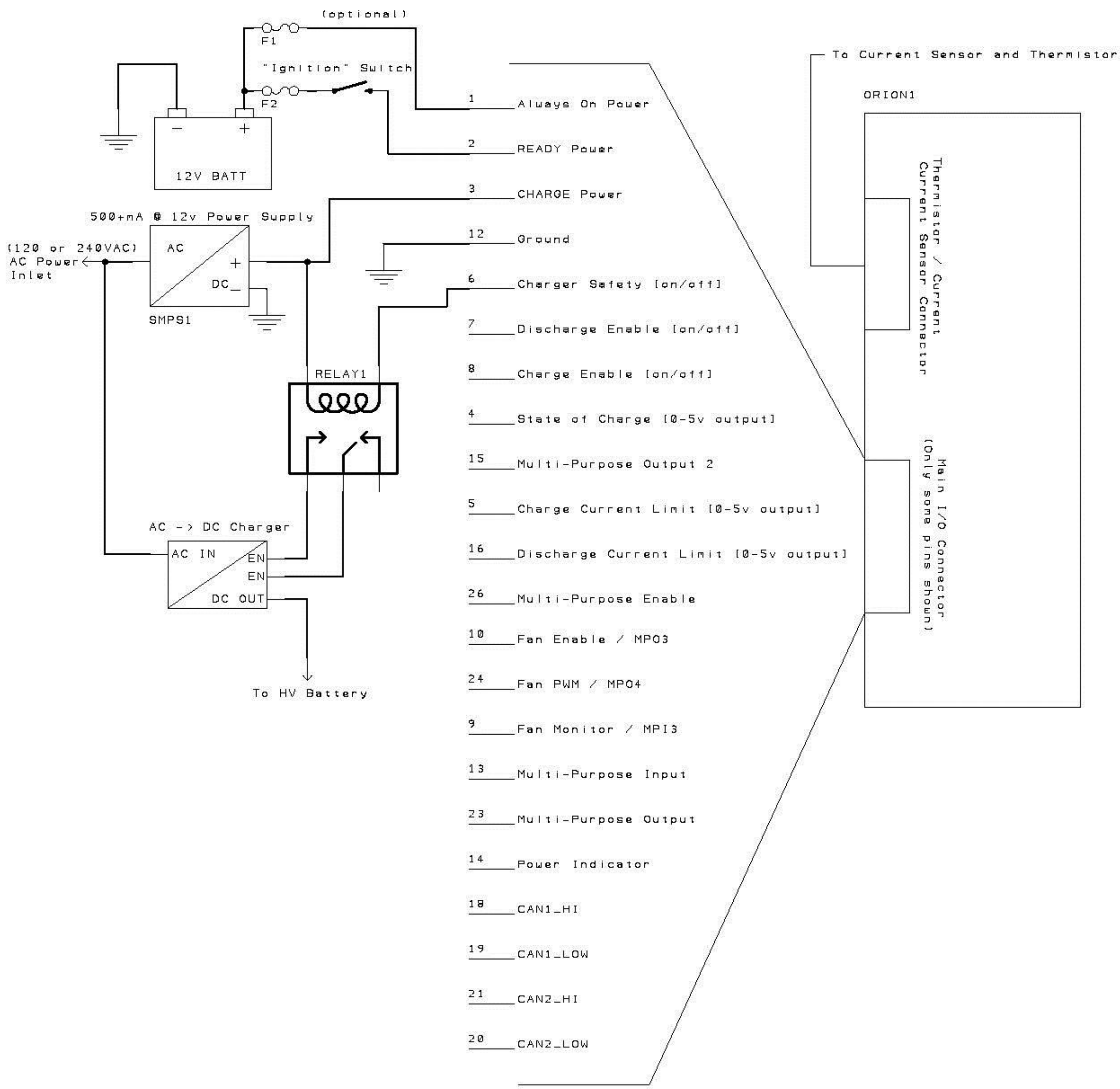
Transients may also cause fuses to blow inside the BMS. Transients are very rapid voltage spikes that can occur as a result of switching loads, rapid changes in current or other causes. Small transients occur regularly due to loads switching on and off, and the BMS is designed to withstand these common transients. Very large transients, typically caused by shorts within a battery pack or by hard switching very large loads combined with stray cable inductance, can be very high voltage and can cause damage, not only to the BMS, but also to lithium-ion cells.

Reason: Extremely weak cell, internal cell failure (fairly rare)

When current is flowing through the battery pack, high resistance connections within the battery pack can cause “voltage drop” that will cause higher or lower voltages at certain cell taps. This most commonly occurs with extremely weak cells or faulty cells which have become internally open. This failure is fairly rare. If cells have become over-discharged or over-charged, the cell impedance will become very high. The BMS will not allow charge or discharge if it detects a seriously under-charged or over-charged cell. However, if the user ignores the BMS and continues to charge or discharge, the cell can cause significant voltage drop (or in some cases reverse voltages) that can cause fuses to blow.

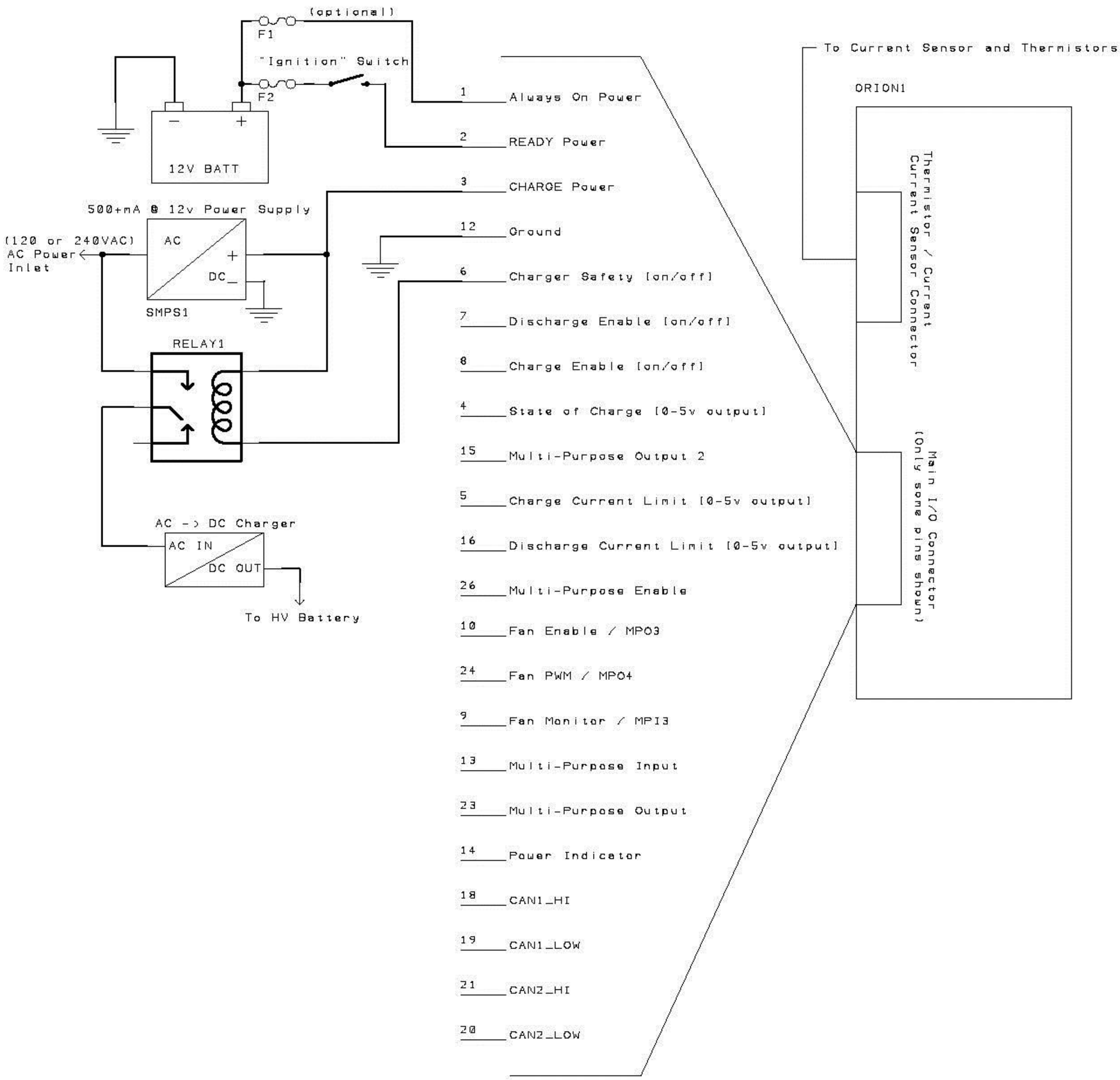
Example Wiring

Battery charger without CAN: Controlling charger with enable capabilities



In the above schematic, the battery charger is controlled using its enable circuitry. When the vehicle is plugged into AC power, the AC/DC power supply is energized and produces 12v which turns on the Orion BMS unit in charge mode. The BMS runs through its safety checks and when it determines it can accept charge, the charger safety output is turned on (brought to ground). This energizes the coil on RELAY1 and shorts the enable pins on the charger turning the charger on. When the BMS determines the battery is full or an error has occurred, it will turn off the charger safety output, which de-energizes RELAY1 shutting off the charger. The relay coil must be less than 175mA (or be an approved contactor as described in On/Off outputs above). For wiring examples for specific chargers, please review the app-notes at www.orionbms.com.

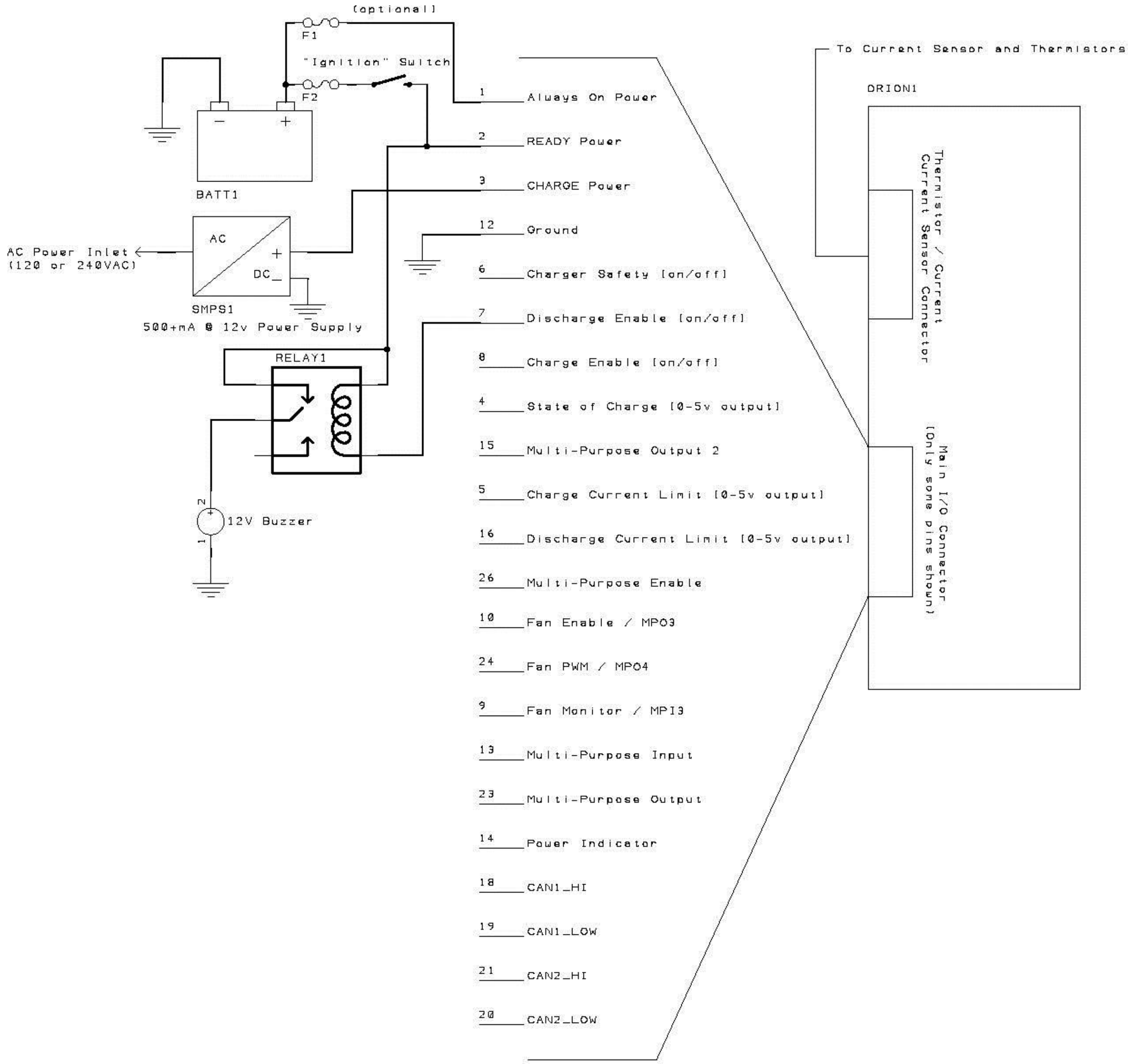
Battery charger without CAN: Controlling charger without enable capabilities



The above drawing is similar to the first diagram, but this charger does not have an enable input. In this case, a relay is used to control the AC power to the charger. With this method, almost any battery charger can be used with the Orion BMS. Note that the charger must be programmed to turn off completely if pack voltage reaches a voltage just slightly higher than the maximum possible pack voltage. This is a secondary layer of safety in the event that the relay fails or if the BMS fails to turn the charger off for any reason. The relay coil must be less than 175mA and must interrupt both AC lines if it could be used with 208 / 240v charging.

Over-Discharge or Under-Voltage Buzzer

Note: This approach is commonly requested, but it is not recommended since it relies on human intervention to prevent over-discharge of cells.



In the above schematic, a buzzer will sound if the battery pack becomes over-discharged or if the load is too high (either due to over-amperage or under-voltage of a cell). The buzzer will only sound when the “ignition” circuit is on. When the BMS receives power to the READY power supply, it quickly goes through safety checks and verifies that the battery pack can be discharged. Once this finishes (usually a few tenths of a second), it will turn on the discharge enable output. When this happens, RELAY1 will energize, breaking the circuit powering the buzzer and turning the buzzer off. If a fault or under-voltage condition occurs, the BMS will turn off the discharge enable output, de-energizing RELAY1 and turning on the buzzer. The buzzer will briefly sound when first turning on. The relay coil must less than 175mA.