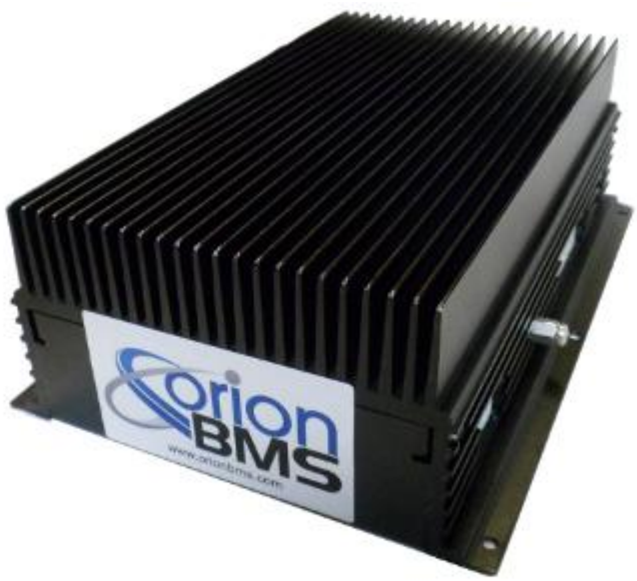
Wiring & Installation Manual

(Document Revision 3)



The Orion BMS by Ewert Energy Systems 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.

This version of the wiring manual has been updated to include new features available on hardware revision D and E. Revision D includes improved robustness for the 12v power supply, boosted robustness of interfaces, 2 new outputs and adds non-volatile memory to eliminate the need for always on power. Revision E has all the features of Revision D and also improves the robustness of the cell tap inputs and prevents damage to the unit from common wiring errors.

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SAFETY: READ THIS FIRST

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

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** 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 way of 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) While the Orion BMS does not require the use of safety disconnects or fuses within the battery pack, if they are positioned in the battery, safety disconnects and fuses must be wired so they fall in specific 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.** If fuses or safety disconnects are used, it is critical to read the entire section on BMS wiring before wiring.

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 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 user's responsibility to integrate properly into the application such that any failure is a safe failure. For more information, please read "Failure Modes" in the operational manual. **The Orion BMS is not to be used for life support systems, medical applications 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. If you are using the Orion BMS in a parallel string setup, please see the section 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-todate Orion BMS manuals can be downloaded at: www.orionbms.com/downloads

Determining which BMS to order

In order to reduce costs, the Orion BMS is offered with different cell groups 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. However, depending on the placement of fuses, safety disconnects or and any high resistance busbars / wires, the BMS may need to be sized for substantially more cells than the pack actually has. For example, a battery that has 48 cells may require a BMS that supports 60 or 72 cells depending on where there any high impedance busbars, fuses or safety disconnects are located. The Orion BMS is available in increments of 12 cells from 12 cells to 180 cells. 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). Multiple units can be connected together in series to support more than 180 cells.

The following table shows the standard available ordering options. Additional custom configurations can be requested

108 Cell Size Enclosure

BMS Size	Cell Groups Populated		BMS Size	Cell Groups Populated
12	1		48-S*	1, 2 and 4, 5
24	1, 2		60	1, 2, 3, 4, 5
24 -S*	1 and 4		72	1, 2, 3, 4, 5, 6
36	1, 2, 3		84	1, 2, 3, 4, 5, 6, 7
36 -S*	1, 2 and 4		96	1, 2, 3, 4, 5, 6, 7, 8
48	1, 2, 3, 4		108	1, 2, 3, 4, 5, 6, 7, 8, 9

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

180 Cell Size Enclosure

BMS Size	Cell Groups Populated
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

Included with the standard BMS

- Hardware
- Voltage tap connectors & crimps (number depends on the number of cells ordered)
- Power connector & crimps
- Current sensor connector & crimps (BMS side); current sensor side included if current sensor is ordered with BMS.
- HV Pack voltage sensor connector & crimps

Ordering Options

- The Orion BMS is available with different number of cell groups populated to reduce costs. For example, a BMS with 72 cells is available such that an application requiring less than that does not require a 108 cell version.
- Non standard CAN termination point options
- Two size enclosures are available - maximum of 108 or 180 cells
- Current sensor options +/- 200A, 500A, 750A and 1000A
- Various thermistor options are available
- Pre-assembled wiring harnesses are available
- Basic displays, data loggers and PC interfaces are also options.
- See “Purchasing Guide” for details on ordering options

Theory of Operation

The Orion BMS protects and monitors a battery pack by monitoring several sensors and uses several outputs to control charge and discharge into the battery. The BMS measures inputs from cell voltage taps, the total pack voltage tap, 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 through broadcasting charge and discharge current limits (via the CAN bus or via analog reference voltages) or via simple on/off digital signals depending on which style is appropriate for the application. The BMS relies on the user to provide external controls 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 in). Using the 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 and individual cell's internal resistance, 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 CAN bus and can be programmed to trigger on/off digital outputs to allow or deny charging and discharging of the battery pack.

Additionally, the BMS has many redundant safeties, most of which are transparent to the user. For example, the BMS monitors each individual cell voltage as well as the total pack voltage. If the two voltages disagree by a set amount (determined in the programmable profile), the BMS will set an error code and go into a fail safe mode. The BMS also 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 BMS can be mounted in any orientation. Six mounting holes are provided on the mounting flanges 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 will be exposed to harsh environments such as sprayed liquids, salt spray or other similar conditions, it must be located inside a sealed rated enclosure.

Thermal Information

While the BMS has a fairly significant looking heatsink, the BMS is designed to dissipate all heat generated via convection in hot environments, and therefore does not generate as much heat as might be expected from such a large heatsink. A 108 cell BMS unit generates a maximum of 40 watts of heat and a 180 cell unit generates a maximum of 60 watts of heat average. Significant amounts of heat are only generated during the balancing phase during charge while heat dissipation under non-balancing conditions is only about 2 - 3 watts. The Orion BMS is equipped to measure the internal temperature of the unit and will automatically reduce balancing current if the temperature rises too high. The thermal dissipation should be considered if the BMS will be enclosed in a liquid tight enclosure.

Ground Lug

A ground lug is provided on the outside of the enclosure. **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 power supply negative. If noise persists with the ground lug connected to the negative on the 12v power supply, it may be necessary to identify the noise source and evaluate a different grounding path.

Wiring Overview

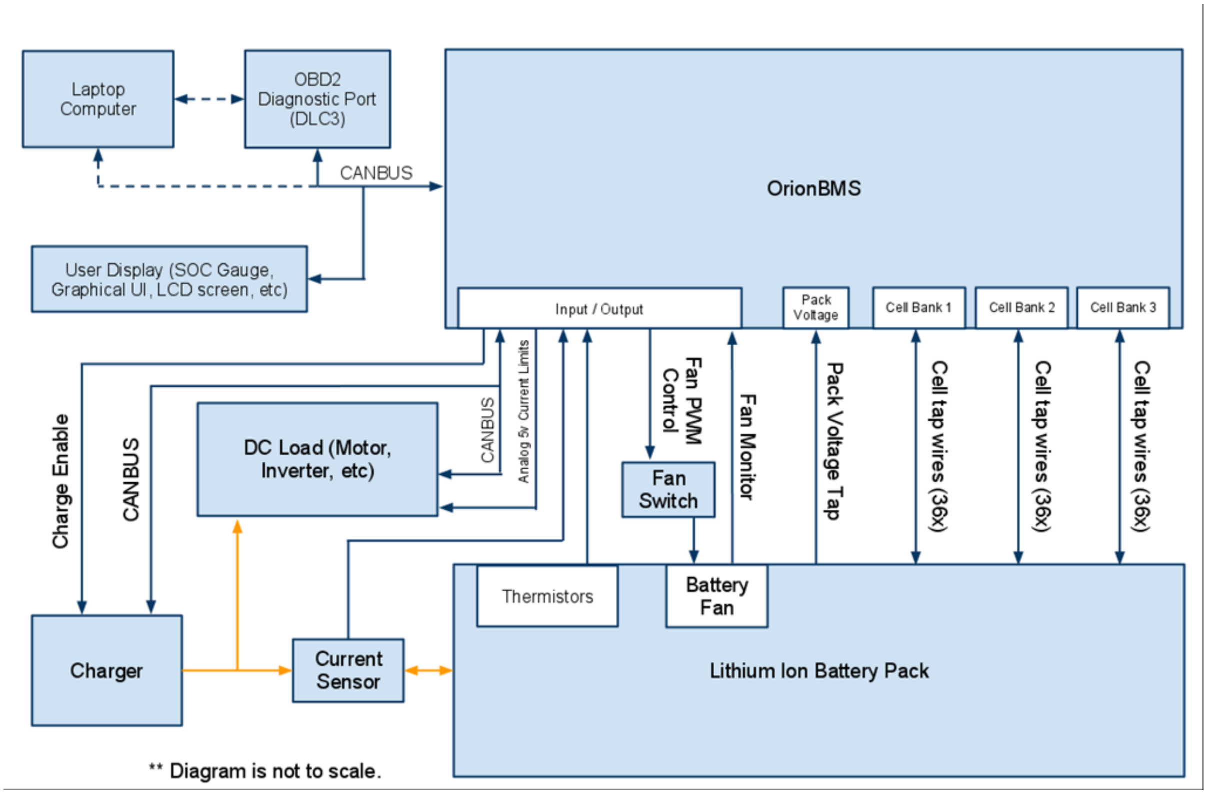


Figure 1: Overview of system connections

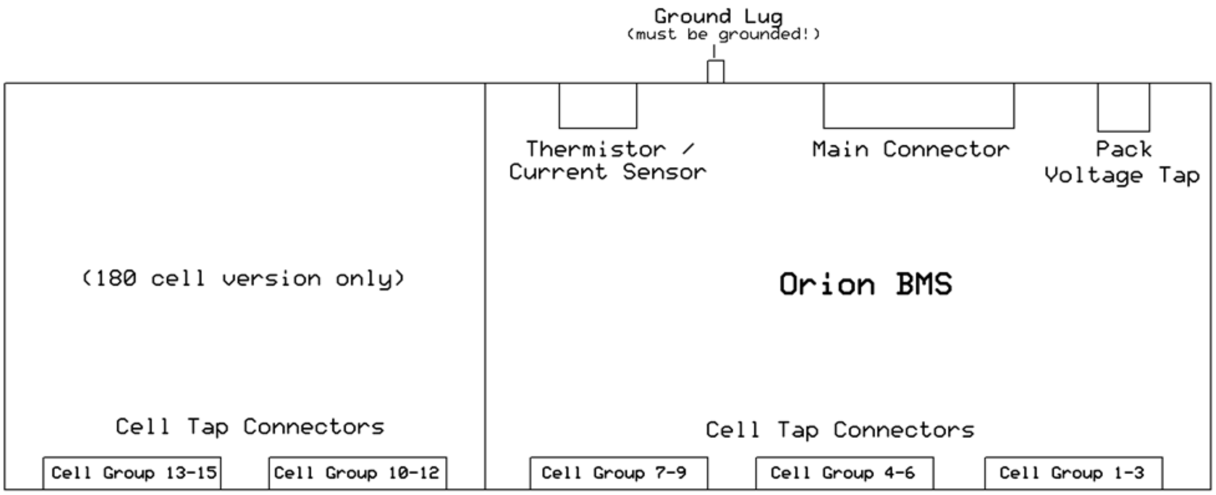


Figure 2: Connector locations on the Orion BMS as looking at the BMS from the bottom

Interfacing the Load and Charger with the BMS

The Orion BMS 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 controlling a load or charge source.

Current Limiting via the digital CANBUS (Controller Area Network)

Many modern chargers, motor controllers, solar/wind inverters, 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 the amperage the BMS instructs them to. 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).

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. 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. See “Wiring the Main I/O” below for more information.

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 3 on / off outputs: Charger safety enable, discharge enable and charge 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.

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

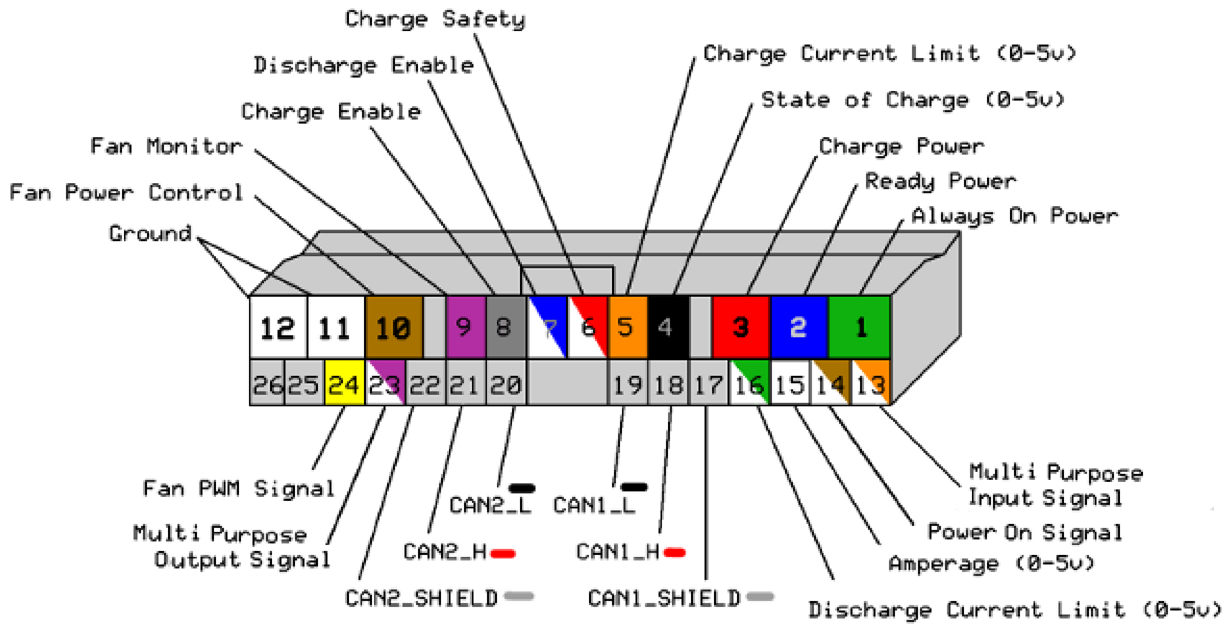


Figure 3: Wire side of Main I/O connector

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. For hardware revisions B & C, this should be connected to a +12v nominal power source which is always powered; otherwise state-of-charge and error code data is reset when power is lost. This power source is optional for revisions D & E as these revisions have non-volatile memory (see “Power Supplies” below for more information). In all cases, the BMS always retains programmed settings across power losses.
READY Power Source	This +12v power source should be connected to a +12v nominal power source whenever the BMS should be active for normal use. This line will cause the BMS to wake up and resume from sleep.
CHARGE Power Source	This power source should be connected to a +12v nominal power source to signal that the BMS should enter charging mode. If this power source is connected while the READY power source is also connected, the BMS will activate the “Charge Interlock” state.
Power Ground (2x)	This is the ground for the supply power sources for the BMS. All three power sources (AM, READY and CHARGE) use this ground. For convenience, two ground pins are provided for tying multiple grounds together, though only one is needed.

Charge Enable Signal (Out)	An open drain digital on/off signal used to signal to a load that the load can charge the battery. This would normally be used to control regenerative braking in an electric vehicle or enable a charge contactor in a stationary application. This signal can be used as a backup to digital CAN communication with a controller. This is a signal current level (100mA max) and should be amplified for controlling large contactors or relays (see electrical specs).
Charge Safety Signal (Out)	An open drain digital on/off signal used as a safety switch for a charger. This signal must be connected to the charger 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 is a signal current level (100mA max) and should be amplified for controlling large contactors or relays (see electrical specs).
Discharge Enable Signal (Out)	An open drain digital on/off signal used to signal to a load that the load can discharge the battery. This would normally be used to control a discharge contactor or to signal to a controller that discharge must be stopped if this signal is not present. This signal can be used as a backup to digital CAN communication with a controller. This is a signal current level (100mA max) and should be amplified for controlling large contactors or relays (see electrical specs).
Fan power signal	This signal is used to turn on a relay to supply the battery cooling fan with power or ground depending on the configuration. This is an on/off line that is turned on only when the fan is active.
Fan PWM signal	This signal is used to control an external switch (MOSFET) to vary the battery cooling fan speed. This PWM signal is between 10% and 90% duty cycle (full range is not used in order to monitor fan performance).
Fan monitor signal	The fan monitor signal is used to monitor the external fan voltage. If the BMS is commanding a certain level of fan power, but the voltage does not match, an error code is set.
CCL/DCL/SOC/AMPS analog 5v outputs	0-5V analog outputs that represent charge, discharge current limits, state of charge and instantaneous amperage.
Multi Purpose Input	This signal is used for firmware revision 2.5 and higher only. This is an input signal 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.
Power Indicator (Rev D & E only)	This output is designed to drive a small LED or signal to other equipment when the Orion BMS is awake and powered. The BMS has a 1k internal resistor on this output.
Multi Purpose Output (Rev D & E only)	The behavior of this multi-purpose output is configured in software for additional functionality. This output is often used to drive an LED to indicate the presence of error codes, but can also be used as a CAN controlled output as well as other functions. Please see the software manual for a complete list of available functions.

Wiring the Main I/O Connector

Power Supplies

12V operating power is supplied to the Orion BMS by three separate power sources - one always on power supply and two primary power supplies. The three power supplies will not backfeed each other due to internal diodes. The Orion BMS consumes approximately 250mA at a nominal 12 volts (9v - 16v range acceptable) for operating current. Operating current may be higher if additional devices are connected to the Orion BMS.

As with all electrical devices, the wires carrying operating current to the Orion BMS unit must be current limited at their source by a fuse (or other current limiting device) to prevent overloading those wires. The fuse (or other current limiting device) must be sized to properly protect both the positive and negative wires. The maximum fuse size which may be used is 15A, but slow blow fuses as small as 500mA may be used.

All three power supplies should be supplied with a nominal 12 volts. Voltages between 9V and 16V are acceptable for continuous operation. On hardware revisions B & C, voltages below 9V will cause some features on the unit to temporarily stop operating until voltages have recovered and voltages above 16v can cause damage to the unit.

Hardware revisions D and newer units have expanded brownout protection. While the startup and continuous operating voltage range remains 9v to 16v, these new hardware revisions can fully operate at voltages as low as 5v for a minimum of 120 seconds, surpassing ISO 7637 "cold crank" requirements. It should be noted that while the unit will fully function at voltages less than 9v for several minutes, the unit is not designed for continuous operation at these lower voltages and an error code will be set by the unit if the voltage is less than 9v for more than 8 seconds. The Orion BMS unit will consume more power when supply voltage drops below 9v. Additionally, these revisions can continue to operate without any power source for up to 100mS (when the starting voltage is 12v or higher when power is removed). As a result of this, "power cycling" the BMS may require 30 seconds or longer.

Hardware revisions D and newer units also feature expanded transient protection. Revision D and E units can **fully operate** through the highest class passenger vehicle load dump ISO 7637 Class IV (87V, 400mS, 0.5 ohm source).

Always On Power Source: This power source is used to retain system memory when the BMS is asleep, as well as being a redundant power supply in case the main power source fails. Hardware revisions B & C require this pin to be connected to an always-on +12v power source for the BMS unit to retain data (state of charge, error codes, battery health information, etc.) in internal memory with the other power sources are disconnected. Hardware revisions D & E can retain data without power in non-volatile memory, making this connection optional for those hardware revisions. In order to take advantage of this non-volatile memory feature and to prevent the BMS from setting error codes, the "disable always-on power supply" option must be selected in the software utility. The always on power source is recommended when possible for revisions D & E and is necessary for applications either requiring a startup time of less than 250mS or requiring redundant power for the BMS. In all revisions of the BMS, programmed settings are retained across power losses.

Internal diodes on this pin cause an additional voltage drop for this supply which is are provided to cause the BMS unit to prefer to draw operating current from the READY or CHARGE power supplies before resorting to the always on (redundant) power supply. While it does not in any way pose a problem to the BMS unit, it is often desirable for power to be supplied by one of the two normal power supplies. To prevent power from being drawn from the always on power supply, the voltage on this line should be lower or up to 1.2 volts higher than the READY or CHARGE power sources. The voltage difference is only necessary to prevent drawing operating current from the always on power source and can be ignored in applications where not required.

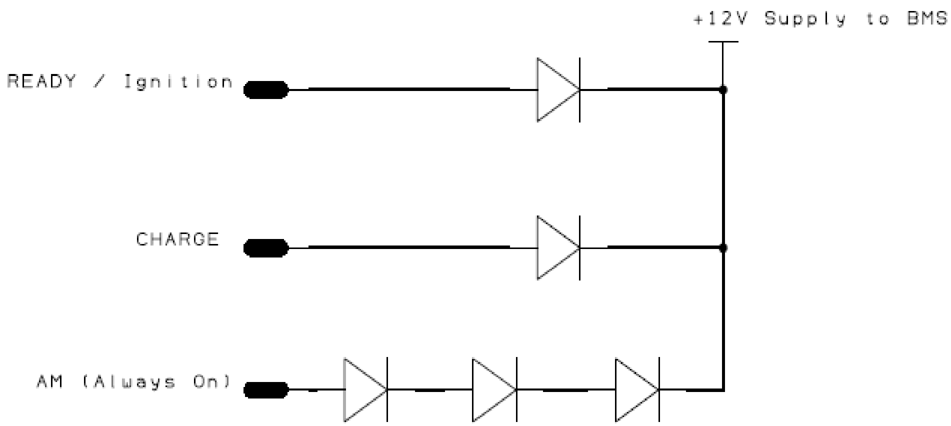


Figure 4: This diagram depicts the internal diodes ***within*** *the Orion BMS unit. No external diodes are required. Note the additional voltage drop present on the Always On supply.*

Ready Power Source: This is the primary power source for the Orion BMS unit. This power source can be thought of as the "Ignition" 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. When power is present at this pin, the BMS will enter charging mode which allows for cell balancing and for the charger safety signal output to be enabled. 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. The voltage on this pin should be higher or up to 1 volt lower than the voltage on the Always On power source in order to prevent the BMS from drawing current from the Always On source if draining an auxiliary battery is a concern.

The BMS will fully operate with both the charge and ready power sources powered at the same time, but as a charge interlock feature for automotive applications, the MIL signal (error indicator) will be turned on which can be used to inhibit a vehicle from driving away while plugged in if both the CHARGE and READY power sources are energized at the same time. However, this will not set an actual DTC error code. All other functionality of the BMS will remain the same. If both CHARGE and READY power sources are energized at the same time, the BMS will allow normal charge and discharge and will also enable the charger safety output and balancing.

Voltages are sensed 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, 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, a diagnostic trouble code (error) will be set on the BMS to alert the operator of the abnormal condition. In applications with revision D units that do not have always on power, this error code is disabled in the software by selecting “disable always-on power supply” option.

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 12v 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: All hardware revisions of the Orion BMS with firmware versions 2.4.10 and newer support a redundant keep-alive option that makes use of the Multi-Purpose Input pin (Main I/O pin 13). 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 pin is designed for a nominal 12v signal. Leave this pin disconnected to disable. This feature is enabled by default in the software profile, but it can be disabled in software if desired.

CAN interfaces

The Orion BMS comes by default with 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 CAN buses with different baud-rates. The CANBUS interfaces can be configured to run at 125, 250, 500 or 1000 Kbps.

CAN interfaces are differential mode buses and require twisted pair wire (2 wires) to communicate. For best operation, shielded twisted pair wire should be used for protection against electrical noise immunity, 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. 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 in very 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, and external CAN isolations device 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 power supply ground and are not electrically isolated from the 12v power supply ground. 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 CAN bus can have many nodes 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 CAN bus cable can be very long (up to about 30 meters for 1mpbs or 100 meters for 500kbps or 500 meters for 125kbps), the taps for additional nodes should be kept less than about 3.5 feet or 1 meter off the main cable. One important note is that if improperly wired (i.e. only one termination resistor on the bus or long taps off the main cable), the bus sometimes may 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!***

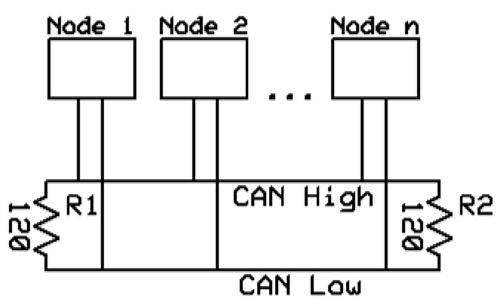


Figure 5: Diagram of a multi-node CAN bus with 120 ohm termination resistors at the ends

For convenience, the CAN1 interface on the Orion BMS (unless specially ordered) has one (1) 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 CAN bus 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.

The two CAN interfaces are functionally the same with the one exception that only the CAN1 interface may be used to perform field updates on the BMS firmware (the BMS profile & settings may be updated from either CAN interface, but the actual firmware software on the BMS can only be updated via CAN1). For this reason, it is recommended that CAN1 be used to interface with any diagnostic connectors or DB9 connectors (to connect to the CANdapter).

After wiring the CAN interfaces, 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 CAN bus. The total resistance should measure 60 ohms (two 120 ohm resistors in parallel = 60 ohms).

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.

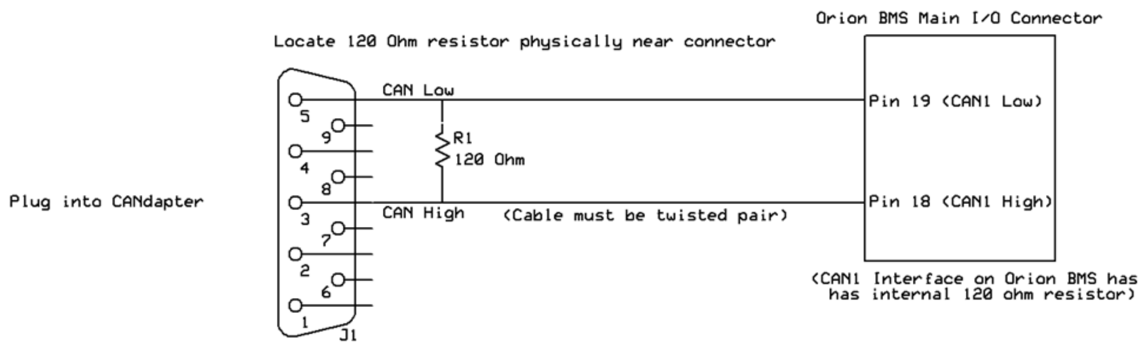


Figure 6: Diagram for connecting the CAN1 interface directly into a DB9 to be connected to the CANdapter

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.

Digital signal outputs

The Orion BMS has three signal level digital I/O outputs - Charge Enable, Discharge Enable and Charger Safety. These three 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 and can interface with a wide range of applications using different voltages up to 24V. These three outputs pull low when they are enabled and cannot be inverted in software for safety reasons. This is done such that if the BMS connecter were to become disconnected, the outputs would fail off rather than on. For safety reasons, each of these three outputs feature an analog watchdog circuit which turns the outputs off in the event of a processor malfunction adding an extra layer of safety.

Please note that the output of open drains cannot be directly measured with a multimeter as they do not source voltage. Please see below for more information on testing the outputs.

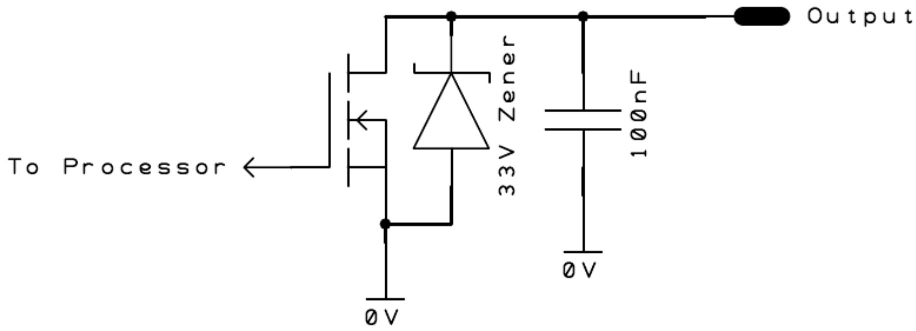


Figure 7: Internal schematic for signal outputs

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 software manual for more details on how the BMS determines when this pin is on or off).

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 software manual for more details on how the BMS determines when this pin is on or off).

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. 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).

Important notes about digital signal outputs - All three of these open drain outputs are capable of directly controlling small relay coils under **100mA** for hardware Revision B & C and up to **175mA** for Revision D & E. 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. Damage can occur to the BMS if higher currents are present which can lead to undefined behavior of these outputs. These outputs should 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 units. These outputs must be amplified for use with large contactors. Revision D & E units have resettable internal fuses on these outputs. However, these over-current protection devices can become damaged from repeated overcurrent 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.***

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 digital signal outputs to sink current due to internal protection diodes (see schematics above).

If additional power is needed or if galvanic isolation is required the digital signal outputs can be used to drive opto-isolators or other loads. Below are sample schematics (Figures 8 and 9) for connecting a relay with a coil less than 100mA (or 175mA for revision D & E) and a sample with an opto-isolator. Please note that the below schematics are for general reference and the suitability of each circuit must be determined by the user.

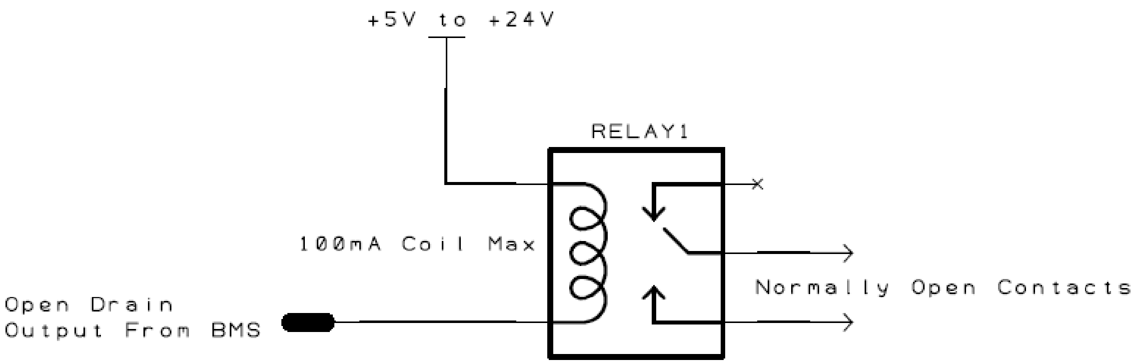


Figure 8: A sample schematic for connecting the open drain outputs with a relay

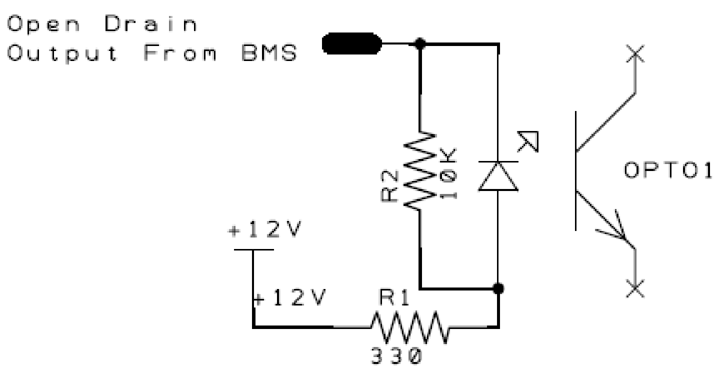


Figure 9: A sample schematic for connecting the open drain outputs with an opto-isolator

If the signals will be used to drive relays with coils larger than 100mA (revision B & C) (175mA for revision D & E), contactors or other loads, an amplification method must be used so that the BMS does not sink more than the maximum allowable current. A common method for this is to use a MOSFET to amplify the signal to provide power to a larger relay or contactor. A schematic is shown below for this method.

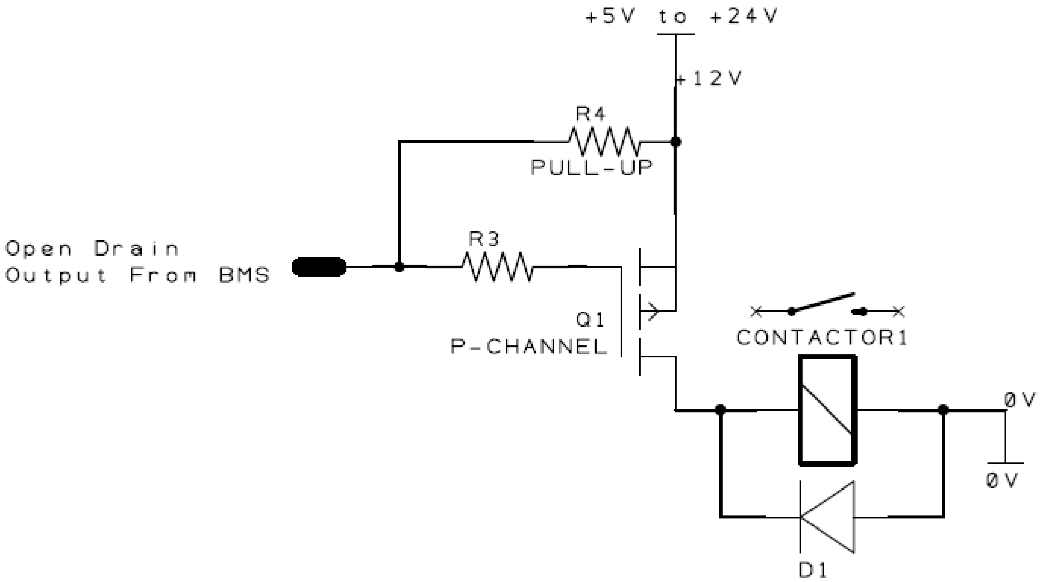


Figure 10: Schematic showing a P-channel MOSFET used to amplify the open drain output

Another method is to use a smaller relay to turn on power for the larger relay/contactor. A schematic for this is shown below.

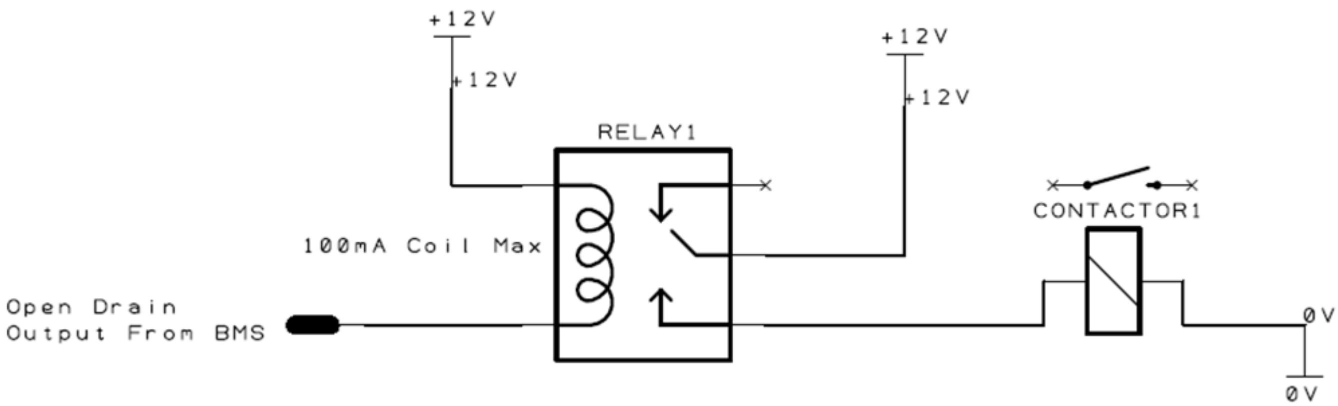


Figure 11: Schematic showing a relay used to control a larger contactor

Checking open drain outputs - Open drain outputs will read zero volts on a voltmeter whether or not they are on since they sink current rather than source it. A simple method for testing the outputs is to connect an LED or small light bulb (under 100mA) between the output pin and +12v (or any voltage between 5V and 24V). If an LED is used, a 330 ohm to 1k ohm series resistor 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.

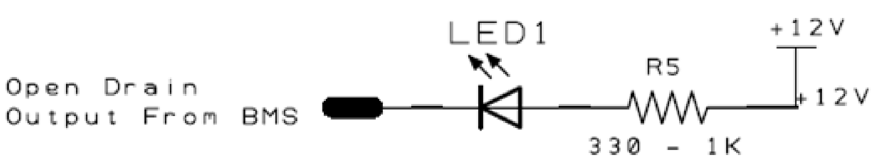


Figure 12: Schematic showing a test circuit which turns on an LED when active

Multi-purpose output (Main I/O pin 23)

This output is an open drain output and is only available on hardware revision D and newer units. The function of this output can be assigned using the setup utility. It is commonly used as an output to signal whether an error code is present and can be used to drive an error LED, such as the LED on the Orion BMS basic display board.

Multi-purpose input (Main I/O pin 13)

This input is a nominal 12v input (it generally registers as “on” at around 5v and can withstand up to 24v). This functionality is available on firmware versions 2.5 and higher. The function of this input can be assigned in the setup utility. It can be used to keep the BMS from going to sleep, even if the READY power source is lost (requires always-on power to function). This pin cannot wake up the BMS. The function of this pin can also be used to select between transmitting different CAN messages (see software manual for more information).

Power indicator output (Main I/O pin 14)

This pin can be used to directly drive an LED to indicate whether the BMS is awake. This output is about 1.2v lower than the input voltage when on and is current limited by an internal 1K series resistor inside the BMS. The maximum diode current is 10mA due to the 1K resistor. The anode of an LED can be directly connected to this pin with the cathode connected to the system ground. This output can also be used to generate a signal for an external controller to assess whether the Orion BMS unit is awake.

Analog 0-5V outputs

The Orion BMS is equipped with four 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, amperage going in and out of the pack, charge current limit and discharge current limit. Each of the 0-5V analog voltage outputs can provide or sink up to 10mA of current. If more current is necessary, an external analog buffer (i.e. 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.

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.

Amperage output (Main I/O pin 15)

This output provides approximate amperage in and out of the battery pack. Since this output can display either positive or negative amperage, 2.5V corresponds to 0 amps. A voltage above 2.5V indicates discharge where-as a voltage below 2.5V indicates charge.

The formula for converting the analog voltage to amperage is as follows:

totalAmpRange = ((sensor_size * 0.25) + sensor_size) * 2)
Amps = ((analog_voltage / 5.0) * totalAmpRange) - (totalAmpRange / 2)

sensor_size = the nominal current rating of the current sensor. This would be 200 for a 200A current sensor or 750 for a 750A current sensor.

While this output is useful for a user display showing the rough amperage in and out of the pack, voltage offset errors and 10 bit resolution make it difficult to use this output for precision amperage measurements. If more precise measurements are necessary, the digital CAN information should be used.

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 should be used in conjunction with the charge 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.

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 should 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.

Fan controller

The Orion BMS 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 base unit supports up to four thermistors directly connected to the BMS. More than 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 Power Control (Main I/O pin 10) pin on the Orion BMS is an open drain output designed to drive loads up to 100mA (up to 175mA for Revision D & E). 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.

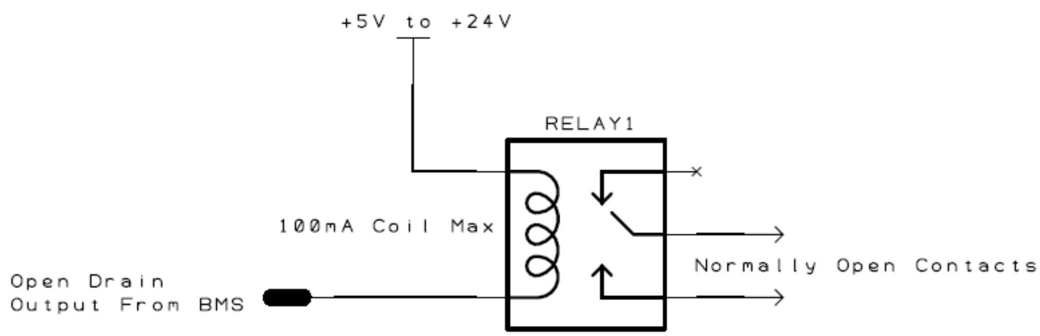


Figure 13: Schematic showing a possible connection for powering a fan in an on/off manner

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.

The “Fan PWM Signal” (Main I/O pin #24) provides the PWM signal. The PWM signal is signal level and is current limited by an internal 300 ohm resistor. In BMS hardware revisions B and C, the output is a totem pole output driving both 0V and 5V. This output has been changed in revision D and newer to an open drain output in order to accommodate a wide range of voltages up to 24V. A simple pull-up resistor can be added to the output for backwards compatibility if necessary. The frequency of the PWM signal and polarity of the signal can be altered in the profile.

If the PWM method is used, the “Fan Monitor” (Main I/O pin 9) pin can be used to monitor a voltage from 0 to 12V 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.

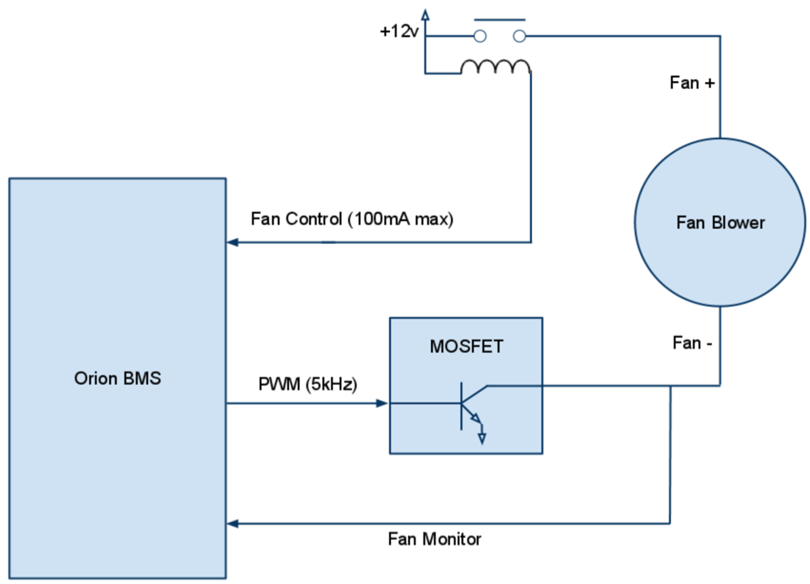


Figure 14: General fan circuit diagram.

Wiring the Current Sensor / Thermistor Connector

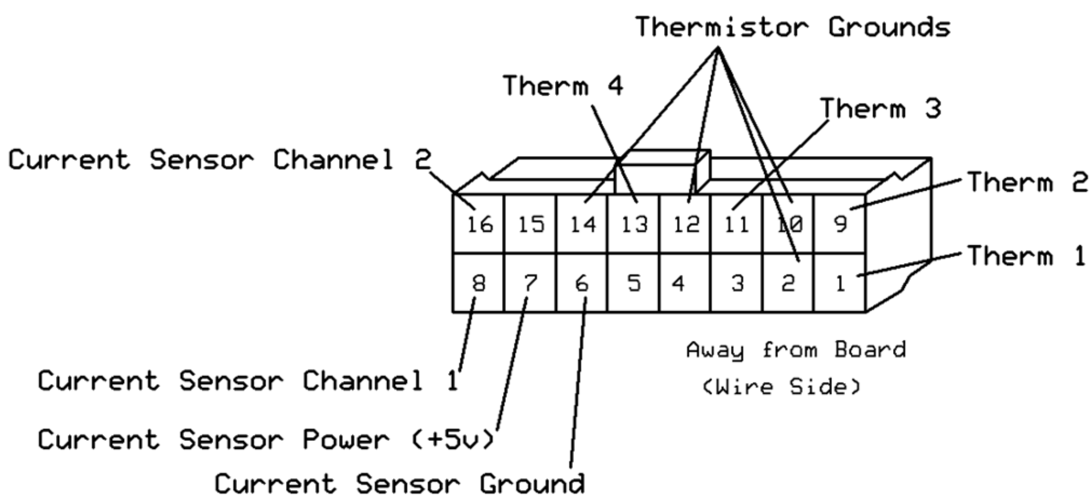


Figure 15: Wire side of Current Sensor / Thermistor Connector

Signal Name	Description
Thermistor GND (4x)	One leg of each of the four 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.
Thermistor 1, 2, 3, 4	Thermistors returns (non-grounded lead of the thermistor). These thermistors are embedded into the battery pack to provide the BMS with the general temperature of the pack.

	One of these thermistors can 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 Vdd	+5v supply provided to the external hall effect current sensor.
Current Sensor Chan. 1	First current sensor channel. This is the more sensitive of the two channels and measures the smaller current range.
Current Sensor Chan. 2	Second current sensor channel. This is the less sensitive of the two channels, but the one that measures the full current range.

Current Sensor & Thermistor Taps

The current sensor wiring harness consists of four wires for the standard current sensor options. The standard current sensor options are actually a combination of two current sensors in one for redundancy and accuracy. Current sensor wires should be kept as short as possible, ideally less than 18" in length. While it is possible to extend the wires if needed, longer wires will reduce the accuracy and make the sensor more susceptible to electronic noise. For this reason, these wires should be kept as short as possible.

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. See the image below for possible locations.

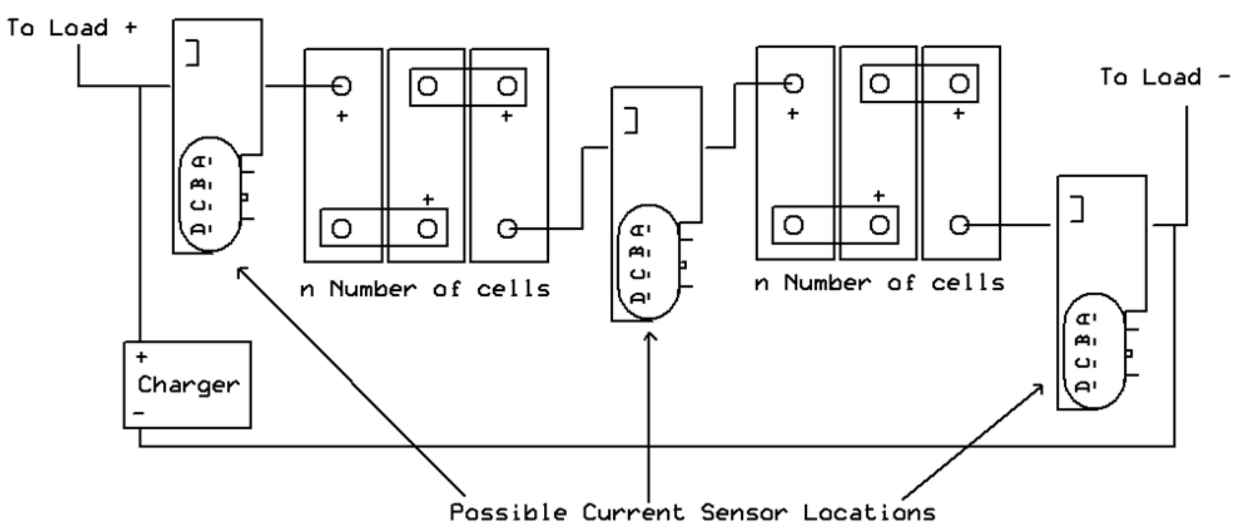


Figure 16: Schematic showing possible locations of hall effect current sensor

It is important that the Orion BMS unit is setup showing current in the proper direction or otherwise many of the calculations will show up incorrect. The above diagram shows the standard orientation of the current sensors. The current sensor direction can be inverted in the Orion BMS profile (using the BMS utility software), so it is not particularly important that it is physically installed in one direction or another. 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.

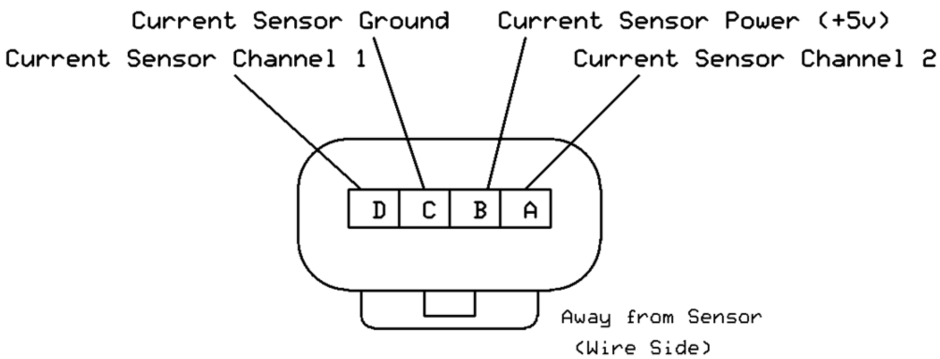


Figure 17: Wire side of connector which attaches to the current sensor. Looking into the current sensor.

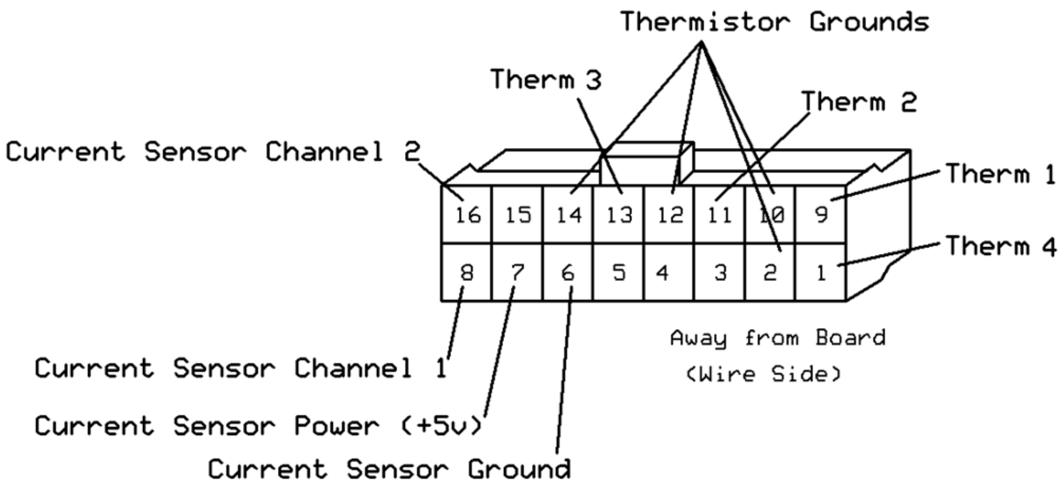


Figure 18: Wire side connector which attaches to the Orion BMS unit

Above are two diagrams (Figures 17 and 18) showing the wiring between the connector attaching to the current sensor and the thermistor / current sensor connector on the Orion BMS unit.

The Orion BMS main unit can have up to four thermistors directly connected to the unit. These four thermistors are designed to provide the BMS with a representative idea of the pack temperature. The four 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 should 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.

One of the four thermistors on the base unit can be selected as an intake air thermistor (any of the four thermistors can be configured for this in the software profile). This 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.

If monitoring more than four temperatures is necessary, an external thermistor expansion module is available which can monitor up to eighty additional thermistors per module with up to ten modules connected (up to 804 thermistors total), which should be sufficient for most applications.

The thermistors are 10K NTC thermistors with a B25/50 value of 3380K. Other B values can be used, though the accuracy will be reduced. Custom configurations for B values may be available for high volume applications requiring a different B 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 and the order of thermistor ground pins does not matter. All thermistor common wires can be connected to a single thermistor ground pin if helpful for cable routing.

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 can be taped or glued to cells. Some thermistors are attached to ring terminals and can be screwed onto battery terminals. Care must be taken if the thermistors are attached to ring terminals to ensure that they have sufficient electrical isolation from the battery pack. Insufficient isolation can cause catastrophic damage to the BMS unit.

Wiring the Pack Voltage Sensor Connector

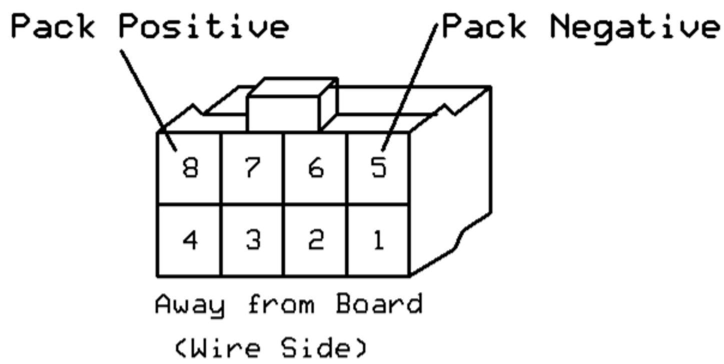


Figure 19: Wire side of pack voltage sensor connector

NOTE: Follow the above diagram instead of the pin numbers listed on the connector.

Signal Name	Description
Pack Negative	Negative pack voltage sensor. This should be connected to the negative output from the battery pack.
Pack Positive	Positive pack voltage sensor. This should be connected to the positive output from the battery pack.

Both the negative and positive pack voltage sensors are used to redundantly monitor the total pack voltage and monitor for isolation faults.

HV Pack Voltage Sense Connector

The pack voltage sensor consists simply of one wire going to the total pack negative and the other to the total pack positive. This connector is used for redundant voltage monitoring for error detection as well as for isolation fault detection. These wires should be connected as close to the battery terminals as possible to avoid voltage drop. The BMS must always be able to read a pack voltage while operating; otherwise an error will be set.

If multiple Orion BMS units are being used in series, the total pack voltage sensor connection should be connected only to the portion of the pack that the BMS is controlling.

Wiring Voltage Taps

READ THIS ENTIRE SECTION BEFORE WIRING.

Several precautions need to be taken for the BMS to function properly, accurately and safely. While the Orion BMS does not require the use of in-pack safety disconnects or fuses, **if safety disconnects or fuses are used, they must be placed in certain locations.** Please see "Safety Disconnect and Fuse Locations."

Each BMS is designed to handle up to nine (108 cell version) or fifteen (180 cell version) groups of 4 - 12 cells. **For the purpose of this document, a cell refers to one or more cells directly paralleled together.** 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.

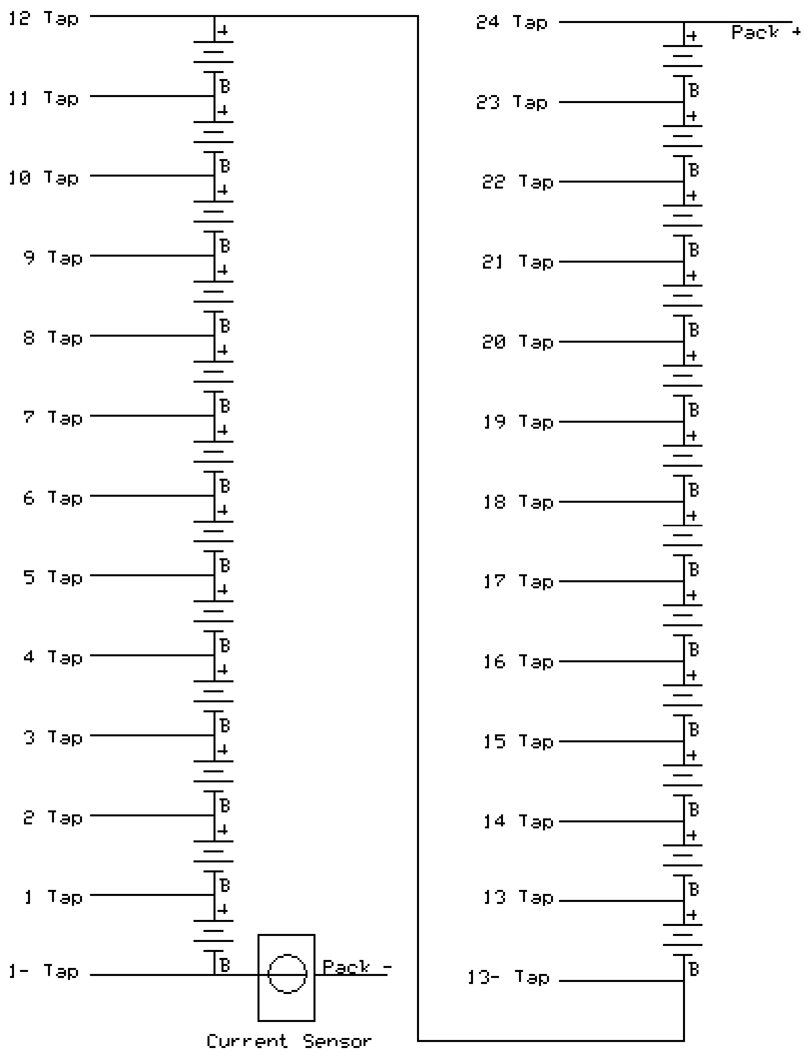


Figure 20: Same wiring diagram for a 24 cell pack

Voltage Tap Connector Pinouts

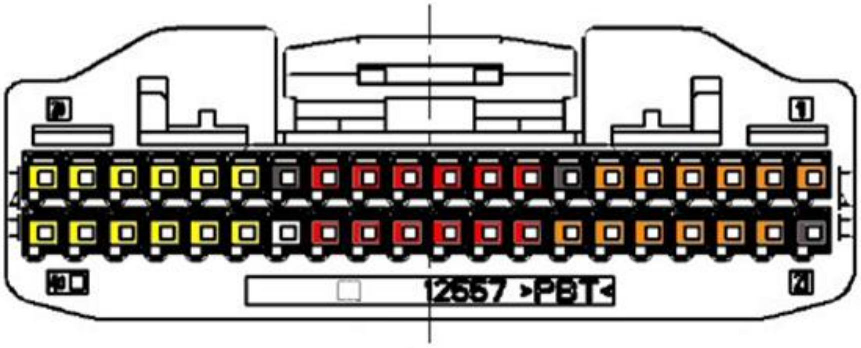
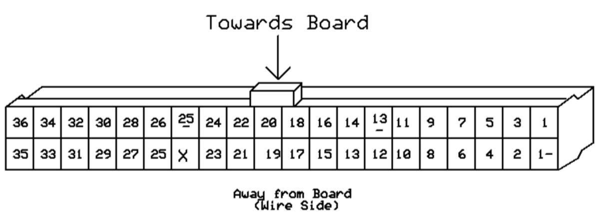
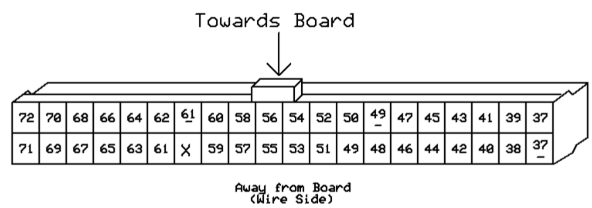


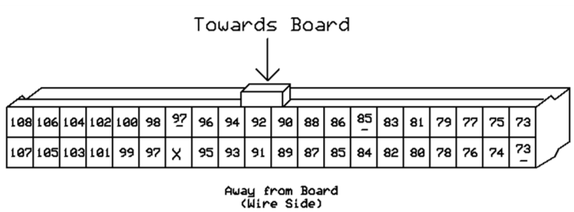
Figure 21: Diagram of the pre-wired harness connector. Cell Groups 1 in orange, 2 in red and 3 in yellow. Cell group ground wires are in black. Looking at the wire side of the connector looking into the ECU.



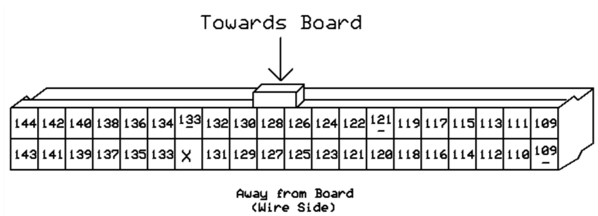
Cell group 1-3 connector



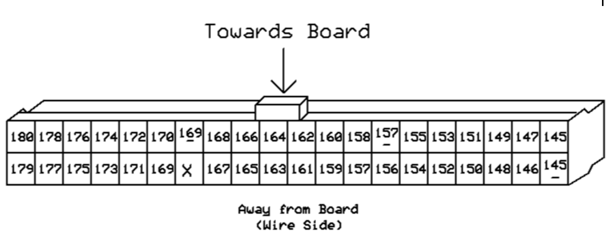
Cell group 4-6 connector



Cell group 7-9 connector



Cell group 10-12 connector (180 cell version)



Cell group 13-15 connector (180 cell version)

Safety Disconnects and Fuse Position

While the Orion BMS does not require the use of safety disconnects or fuses in line with the battery pack, the Orion BMS has locations specifically designed to facilitate disconnects and fuses if they are used. 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.

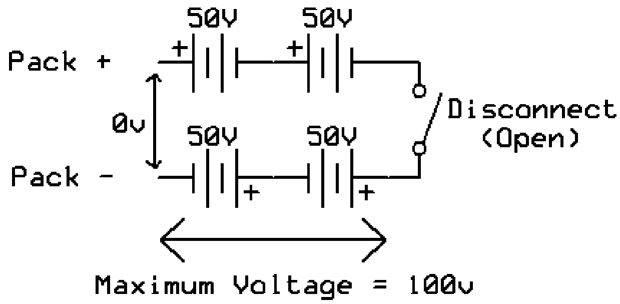


Figure 22: Illustration of a properly functioning safety disconnect or fuse

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 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.

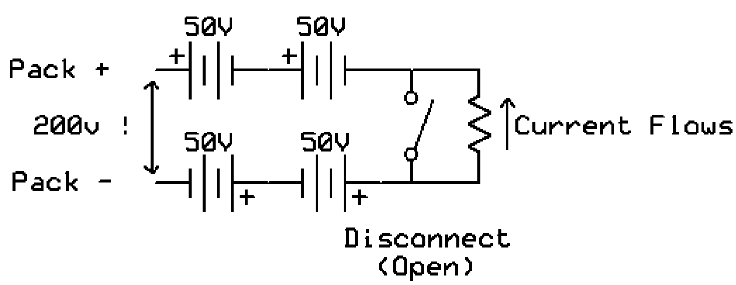


Figure 23: Illustration of a safety disconnect with a dangerous alternative current path

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 voltage 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 recommended 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 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 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 or fuses are used within a battery pack the Orion BMS must be wired such that the fuses 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 are located 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 cell numbers 36 and 37 since cells and cell groups can be skipped with the Orion BMS wiring.

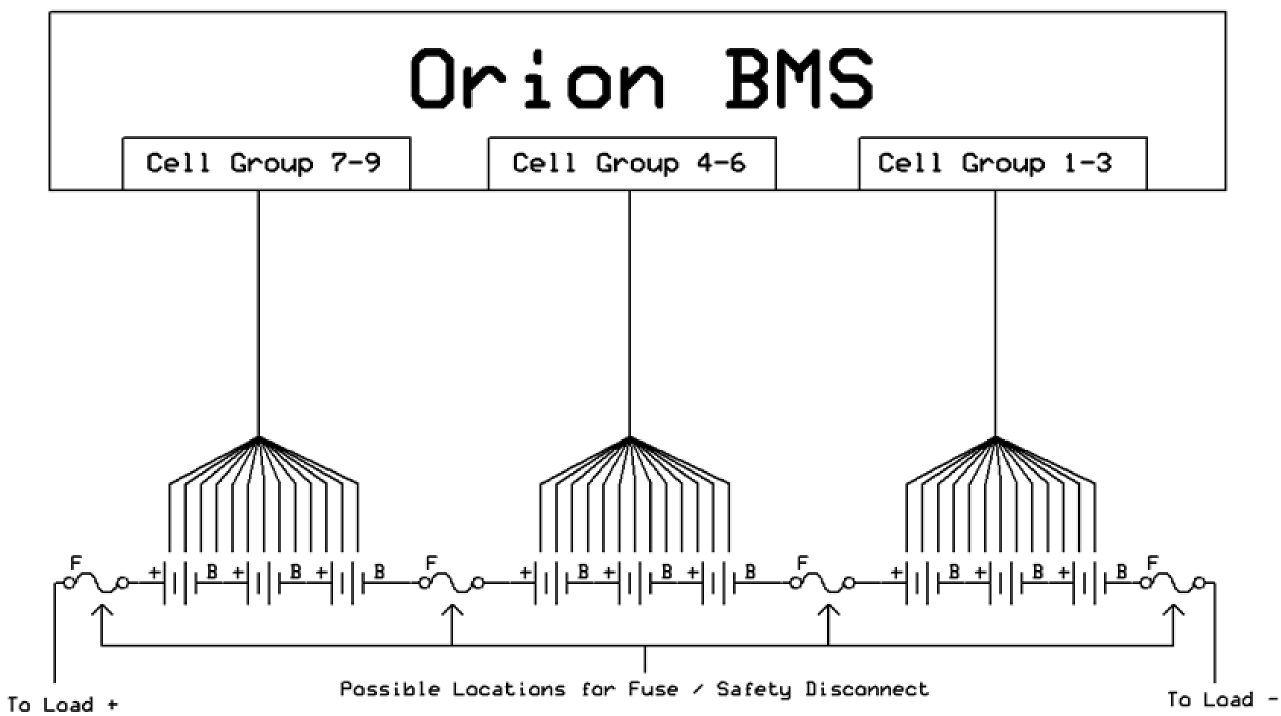


Figure 24: Possible locations for Fuse / Safety Disconnect

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 24-S or 48 cell or higher model BMS would be necessary even though only 12 actual cells are present. In this case, a 24-S model is the lowest cost option. Placing safety disconnects or fuses in the ideal locations provided by the Orion BMS is usually the most cost effective method.

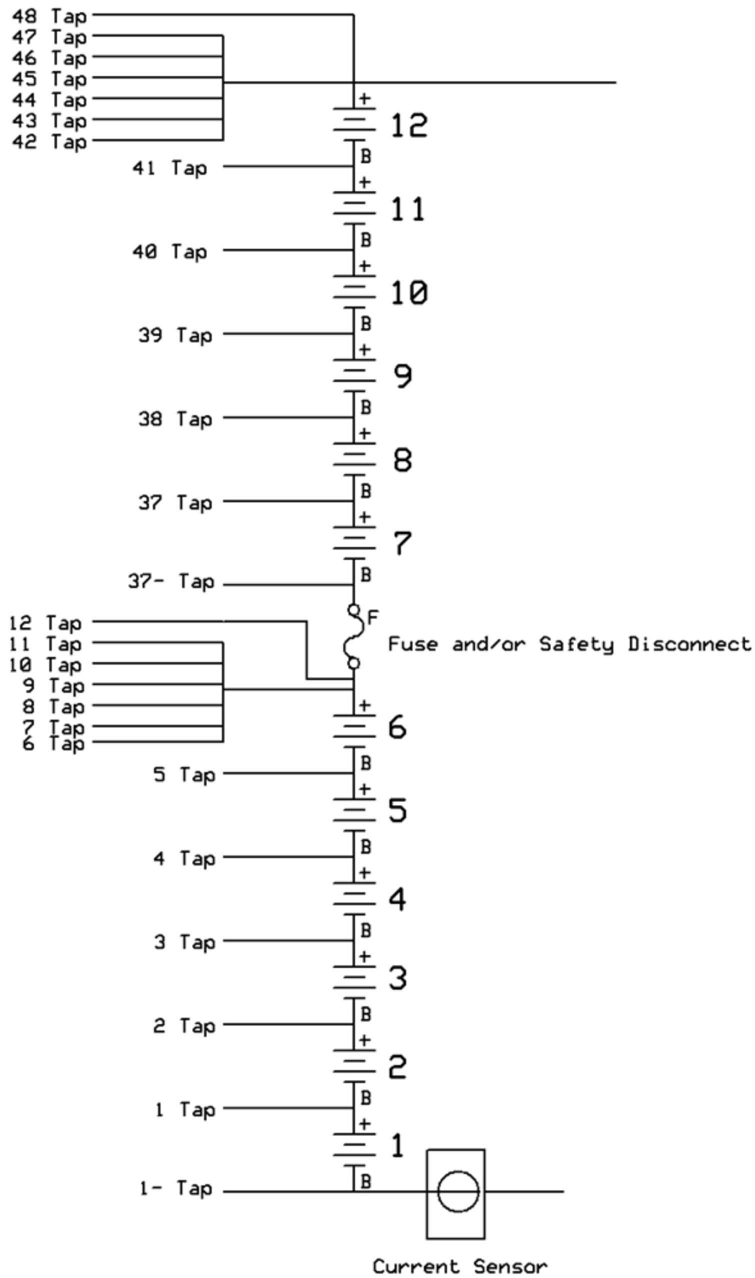


Figure 25: Sample wiring diagram for a 12 cell pack a safety disconnect between cells 6 and 7

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. Likewise, 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.

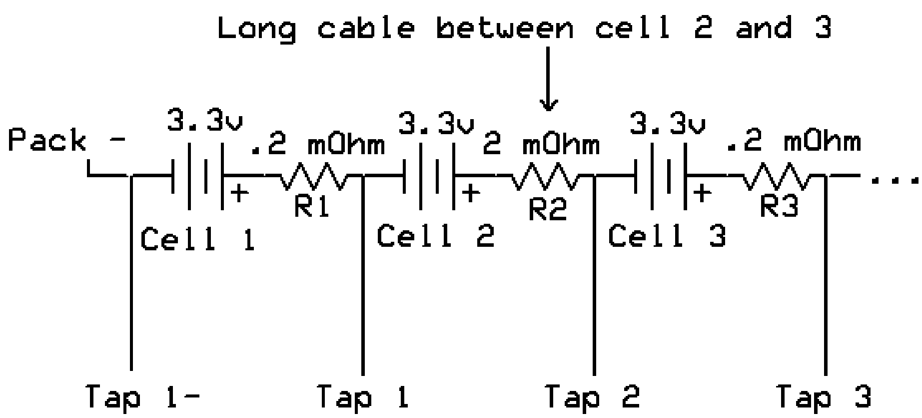


Figure 26: Example of differences in resistance due to busbar resistance

For 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, 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.

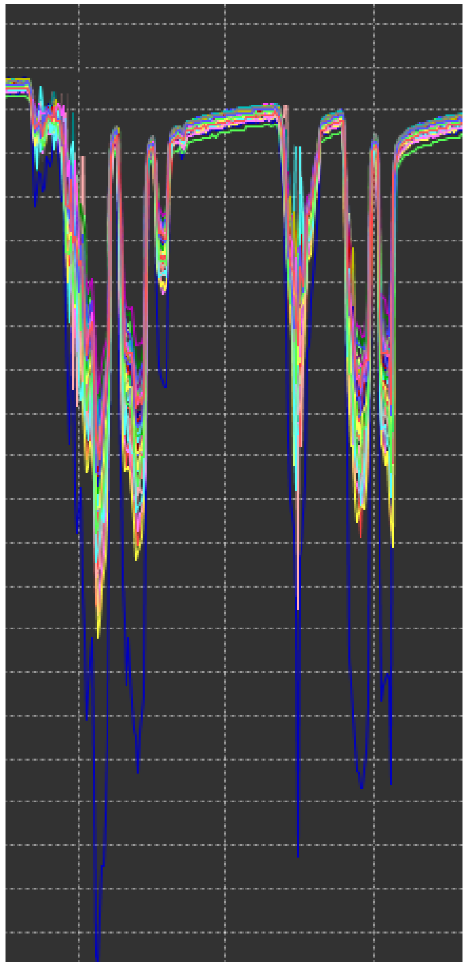


Figure 27: Voltage drop under load from an uncompensated high impedance busbar (blue)

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.

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 carries 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.

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 recommended for use with the Orion BMS as these configurations can cause damaging transients.

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.

All versions of the Orion BMS have protection against moderate transients on the high voltage measurement circuits. Hardware revisions B, C & D have TVS diodes and internal fuses to protect against transients. Severe transients may cause the internal fuses to blow and transients > 30 volts on one cell may cause more significant damage that requires the unit to be returned for service. Damage to the BMS unit may also occur if the total group voltage exceeds 80V (>6.5v on all cell inputs). Hardware revision E has a wider survivable voltage range and can therefore survive larger transients, but transients still must be limited for the safety of the lithium cells.

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. All revisions of the Orion BMS have internal fuses on each cell tap wire to protect the BMS and connected wiring from excessive currents. The BMS units also have protection diodes which on revision B, C & D are designed to cause the internal fuses to blow when voltage measured between any two cells is less than 0v or greater than 5v. When this happens, the BMS may report an “open wire fault” or “wiring fault”. These fault codes can also indicate a wire that is simply not connected to a cell or loosely connected to a cell.

Revision E units have been upgraded to withstand certain minor wiring errors such as accidentally swapping the order of two cells or even wiring cells in the reverse order. 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. Revision E units can withstand wiring errors only for a short period of time and repeated exposure to wiring errors or extended wiring errors may cause permanent damage. ***If revision E 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 voltage wiring harnesses are available for the Orion BMS in 6 foot and 12 foot lengths. The length of the tap harness slightly affects the accuracy of the voltage readings by the Orion BMS. By default, Orion BMS units are calibrated for 6 foot lengths of wire. For revision B, C & D, the maximum (uncompensated) recommended length of wire is 12 feet, although it can be used with longer cables with reduced accuracy. Revision E was improved to allow for cable lengths up to 30 feet. For high volume applications, the BMS units can be specially calibrated for other lengths.

Cable Length	Rev B, C & D Additional Error	Revision E Additional Error
6 foot	0	0
12 foot	+/- 2.1mV	+/- 0.7mV
18 foot	+/- 4.2mV	+/-1.5mV
24 foot	Not recommended	+/-2.3mV
30 foot	Not recommended	+/-3.2mV
36 foot	Not recommended	+/-4.0mV

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

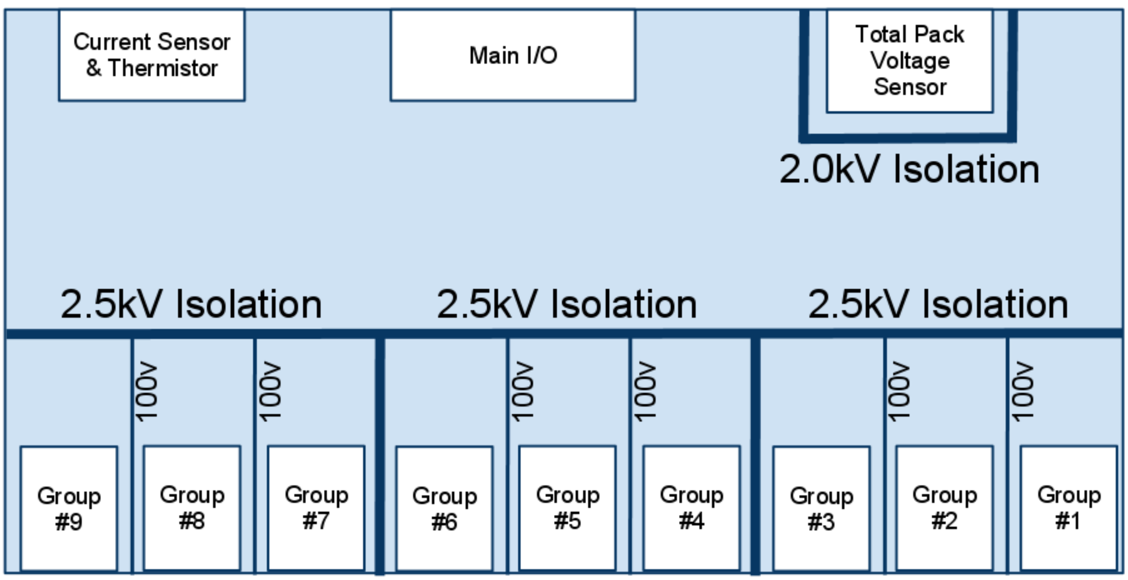


Figure 28: Isolation Diagram for 108 cell system (180 cell version can be extrapolated).

The Orion BMS provides 2.5kV isolation between cell voltage taps and control electronics as well as between groups of 36 cells. The total pack voltage sensor is isolated from all other electronics by 2.0kV DC isolation. Isolation between cell 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 ground (Main I/O pin 12) and are not electrically isolated from each other.

Cell Groups with fewer than 12 cells

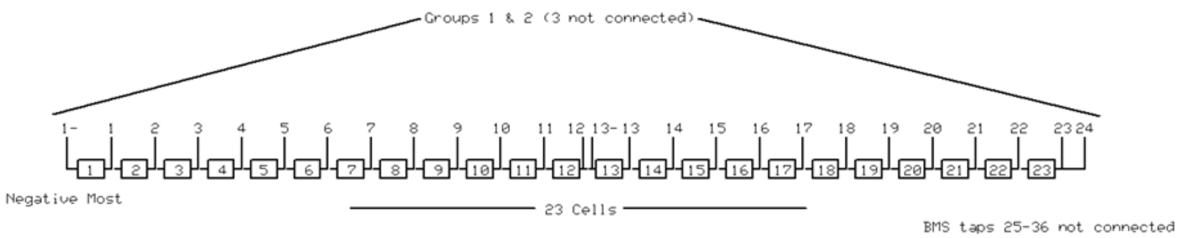
Each cell group must have a minimum of 4 cells and up to 12 cells, with a minimum voltage of 13V per group. If fewer than 12 cells are used, each wire must still be connected to maintain proper operation and accuracy.

Rules for fewer than 12 cells

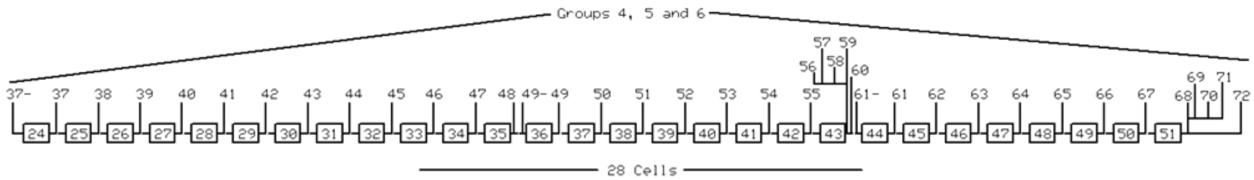
- If fewer than 12 cells are populated in a group, unpopulated cells must all be connected to the highest potential cell in that group. For example, if 6 cells are populated in a group, taps 6 - 12 are all connected to the positive tap on cell 6.*
- No cell group may have fewer than 4 cells connected (higher minimums may apply if nominal voltage is lower than standard li-ion cells). If the last group of cells has fewer than 4 cells, some cells must be skipped in the previous group and wired into the last group to ensure that a minimum of 4 cells are present in the last group.
- Cell Groups must have a minimum normal working voltage of 10 volts (2.5v per cell for 4 cells) and an absolute minimum voltage of 8V. Accuracy of voltage measurements is decreased when the group voltage is below 10 volts.

*In this example, cell tap positions 6-11 could be combined into a single wire that runs to the terminal to reduce the number of wires entering the battery area. However, for revision A, B, C and D units, the 12th cell tap should run directly to the highest potential cell using a separate wire to avoid an approximately 5-7mV error in measurement on the last cell in the group. This is also recommended for revision E when used with tap wires longer than 6ft. In all cases, the simplest approach is to run all wires to the terminal.

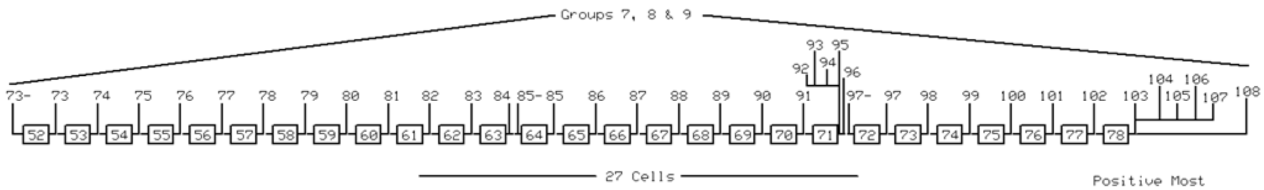
Example: A battery pack of 78 cells is divided into three sections with a fuse and a long, high impedance cable located between cells 23 / 24 and 51 / 52. 23 cells are in the first section, 28 in the 2nd section and 27 in the third section.



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 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 13 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. While many major OEM vehicle manufacturers do not fuse the cell voltage taps, fuses are always a good idea and can be added for additional protection if desired. If additional fuses are used, they should be kept as low resistance as possible within reason. Fuses sometimes have relatively high resistance and the additional resistance can reduce the accuracy of monitoring the cells.

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” or “wiring faults” (and “low cell” faults for revision E) are present on the BMS. Open wire or wiring faults indicate that the BMS has detected a problem with the cell tap wiring. ***If 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.***

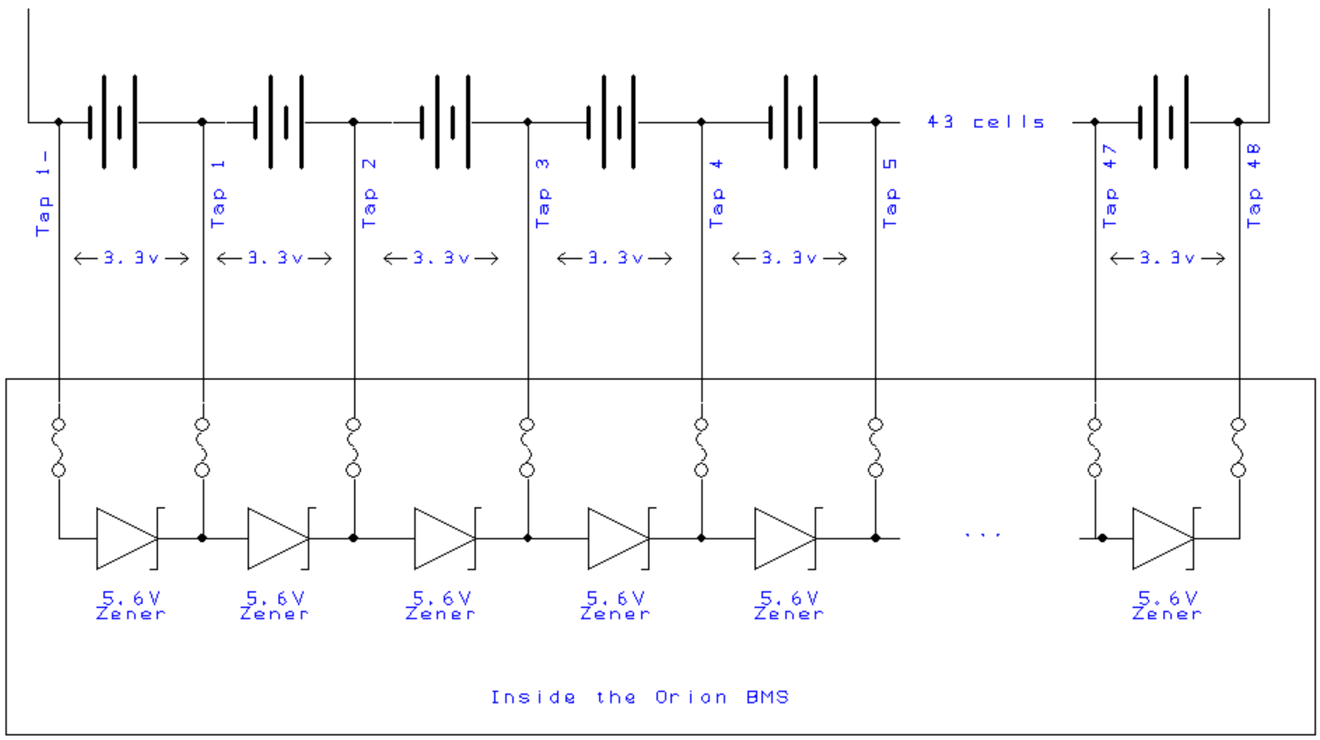
Disconnect Cell Taps While Altering Battery Wiring

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. Sufficient current to blow the 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.



What causes the fuses to blow?

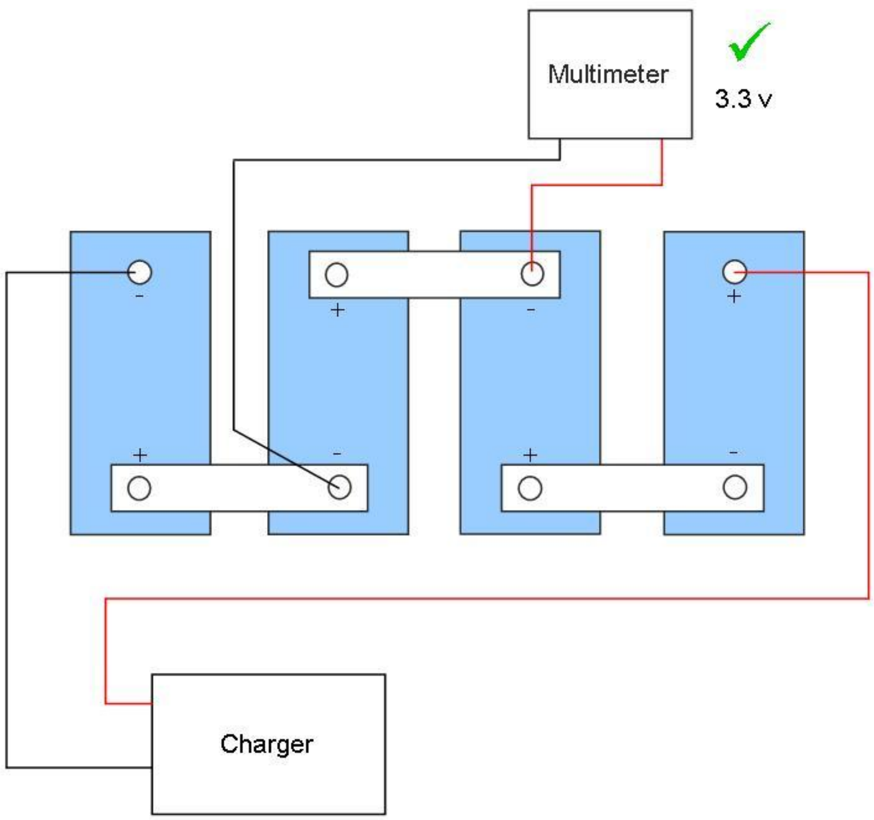
The only time the internal fuses on the tap wires will open is from an over-voltage or reverse-voltage condition. When an over-voltage or reverse-voltage condition occurs, the zener diodes will begin to conduct, causing current to flow through the tap wires and causing the fuses on the taps to blow. 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)

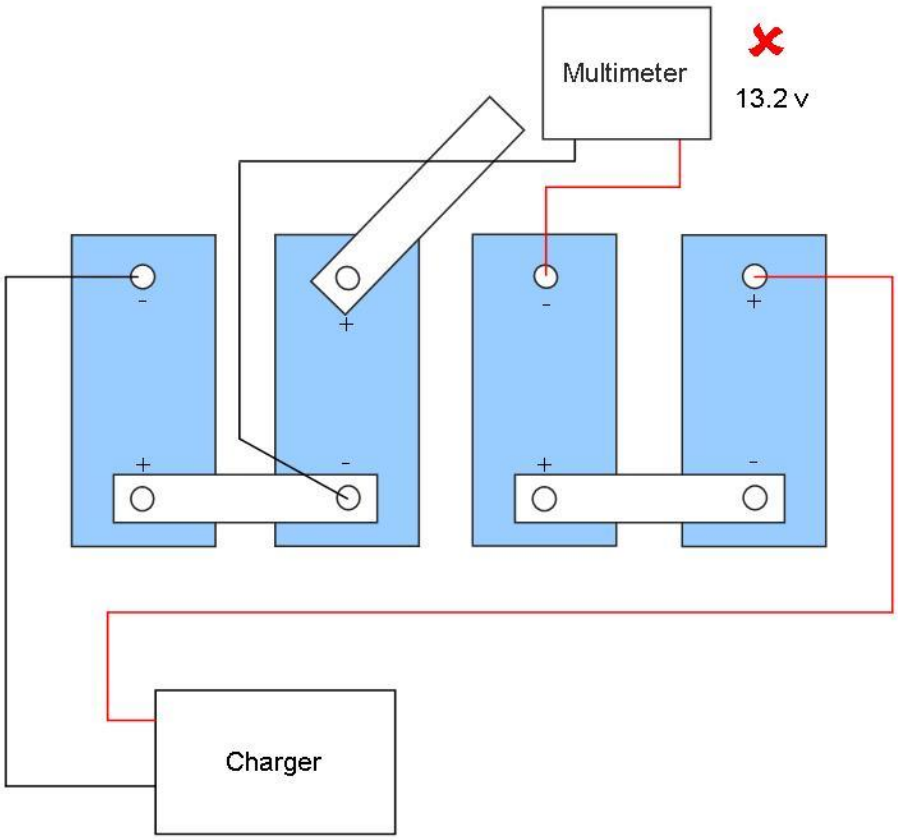
By far, the most common cause of blown fuses and/or more serious damage to the Orion BMS is when battery pack wiring is altered with the Orion BMS still connected. While it may seem counter-intuitive, removing a busbar with the BMS cell tap wires connected can result in the voltage of the entire battery 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.



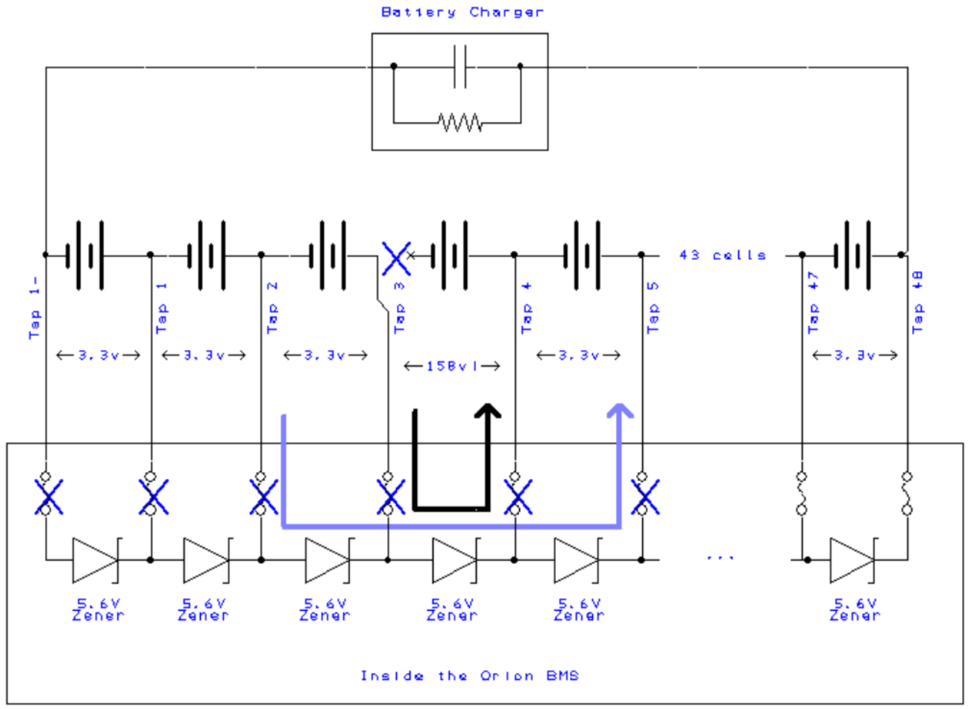
The next diagram shows what happens when the busbar is disconnected. As the busbar is now open, battery voltage is no longer present at the battery charger, but the internal capacitors in the charger are still charged at the pack voltage (13.2 volts) and have no place to discharge. Because of this, the 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 blow fuses in a revision C or D unit, but likely would not damage a revision E unit. If this same scenario were to occur on a higher voltage battery pack, internal fuses on any revision of the Orion BMS 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.)

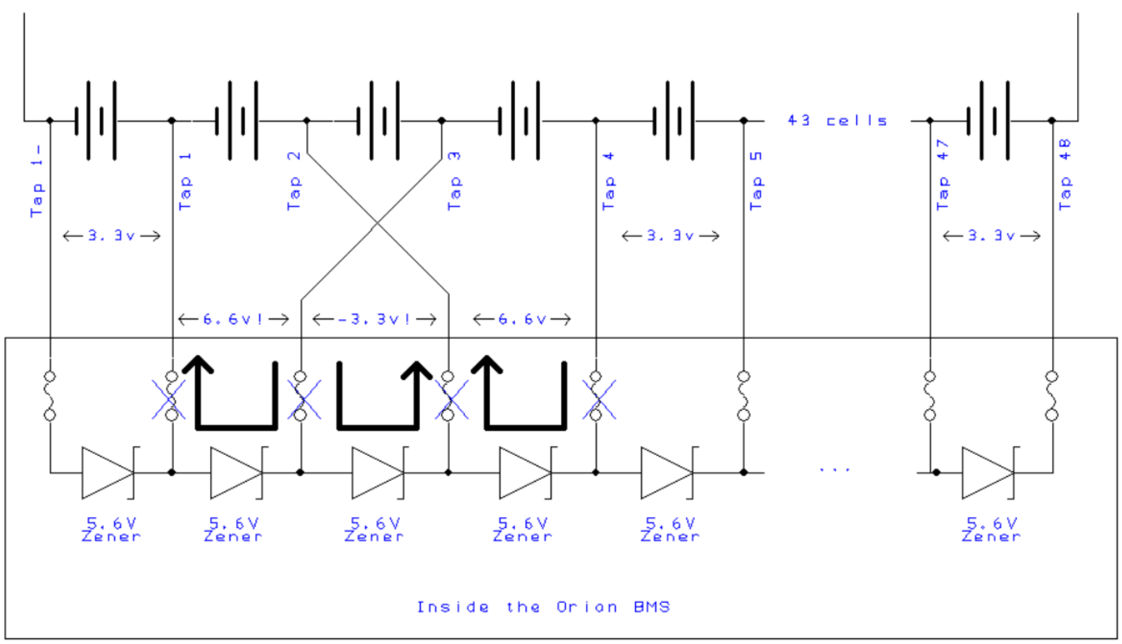
When voltages between 2 cell taps to the BMS exceed 60V, more substantial damage to the BMS than blown fuses may occur.

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 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. Additionally, this can be caused by intentional re-wiring of the battery pack or by loose busbars (which also pose a fire risk from arcing.)



Reason: Cell tap wires reversed

For revision C & D units, reversed cell tap wires will lead to a blown fuse. While revision E 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.



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 revision E units, fuses will generally reset to their normal state once the above fault is fixed.

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, 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.

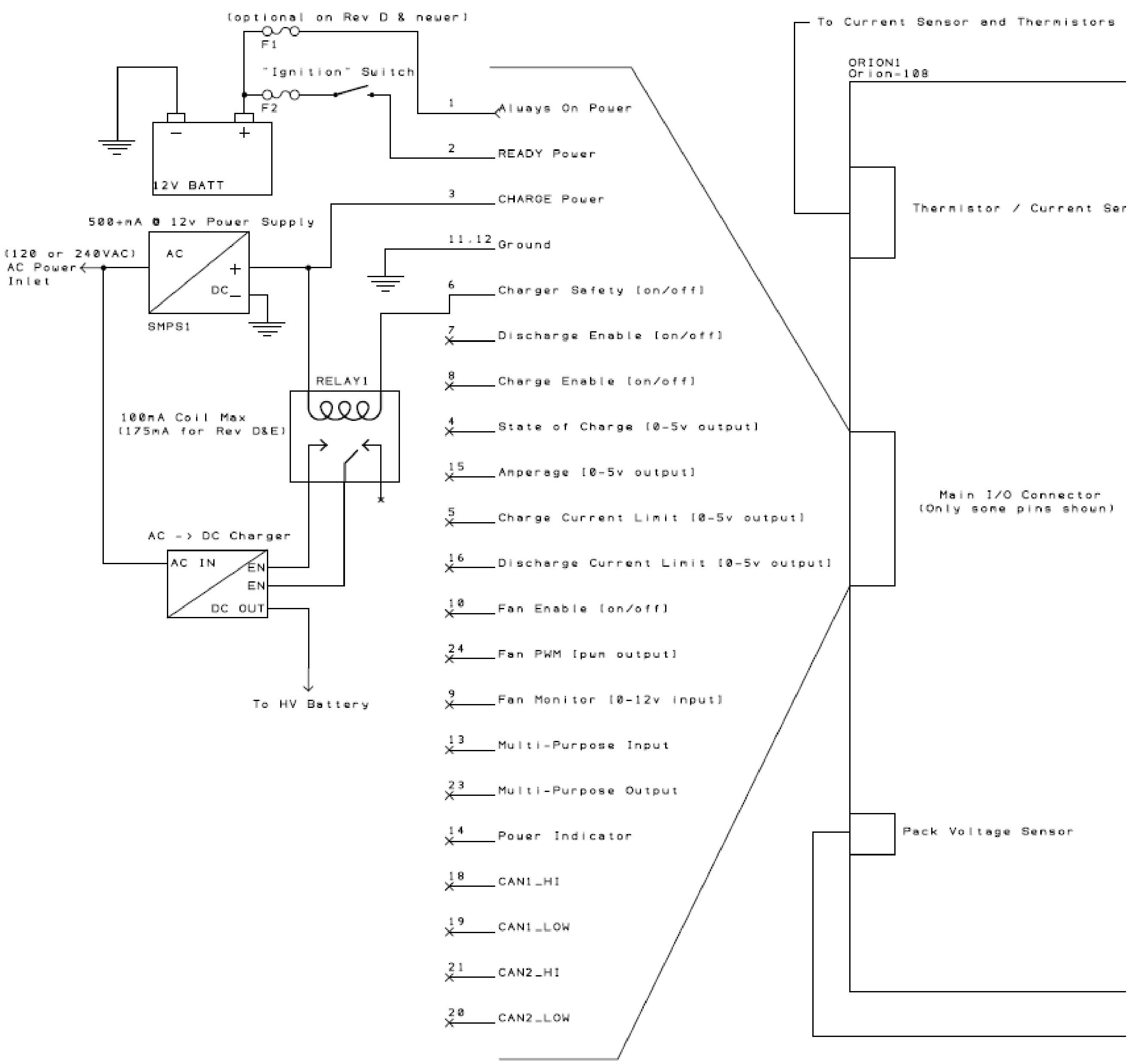
Differences between Revision E and previous revisions

Revisions C & D of the Orion BMS contain standard fuses. Once these fuses blow in these units, the unit must be serviced and the fuses replaced. Fuses in these units will blow if voltages exceed 5.5v or if there is reverse voltage below 0v.

Revision E of the Orion BMS also contain standard fuses, but these units also contain additional 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 10 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.

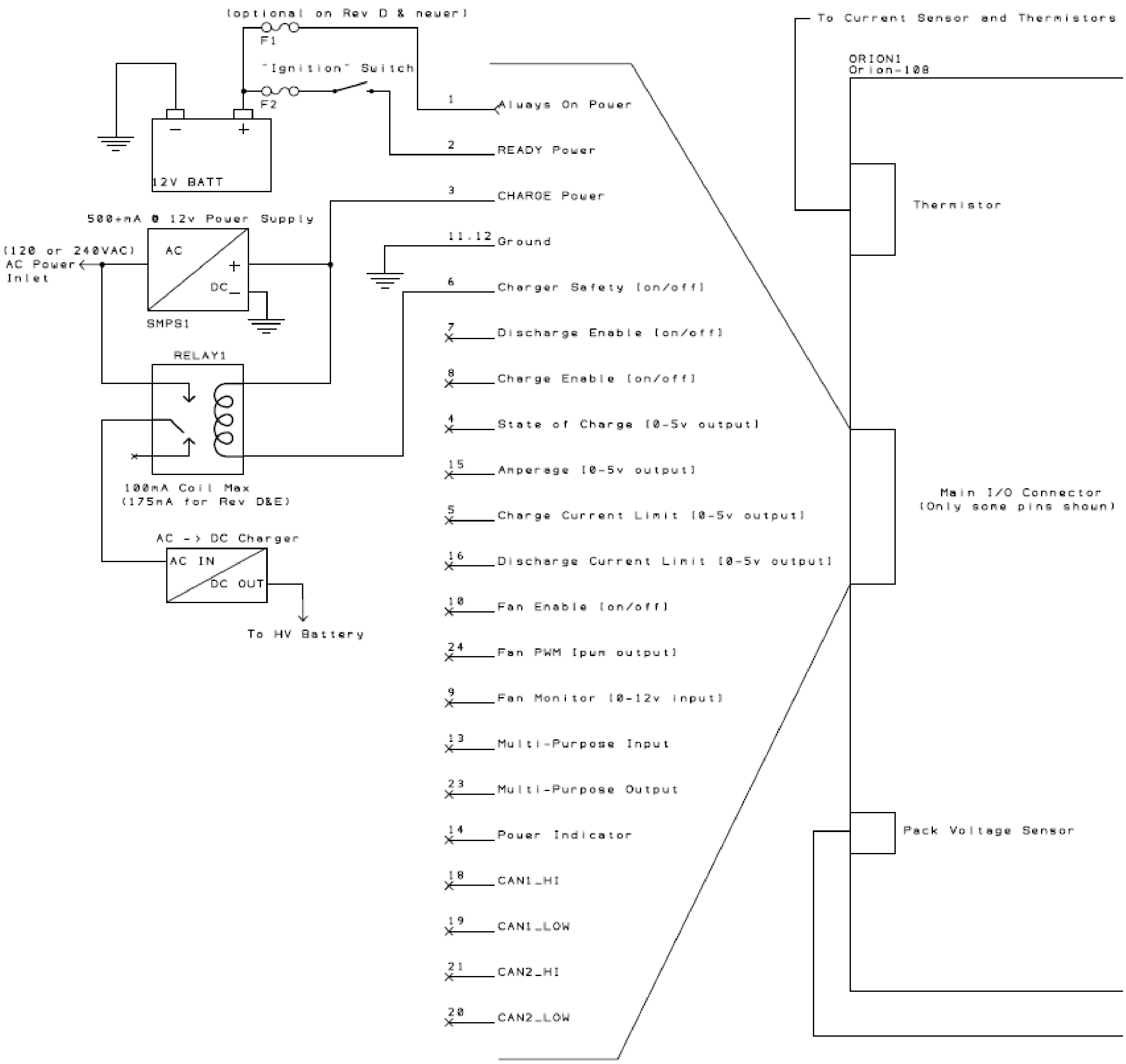
Example Wiring

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. Note that the relay coil must be rated 100mA or less for Orion BMS revisions A, B & C or less than 175mA for revisions D & E. For wiring examples for specific chargers, please review the app-notes at www.orionbms.com.

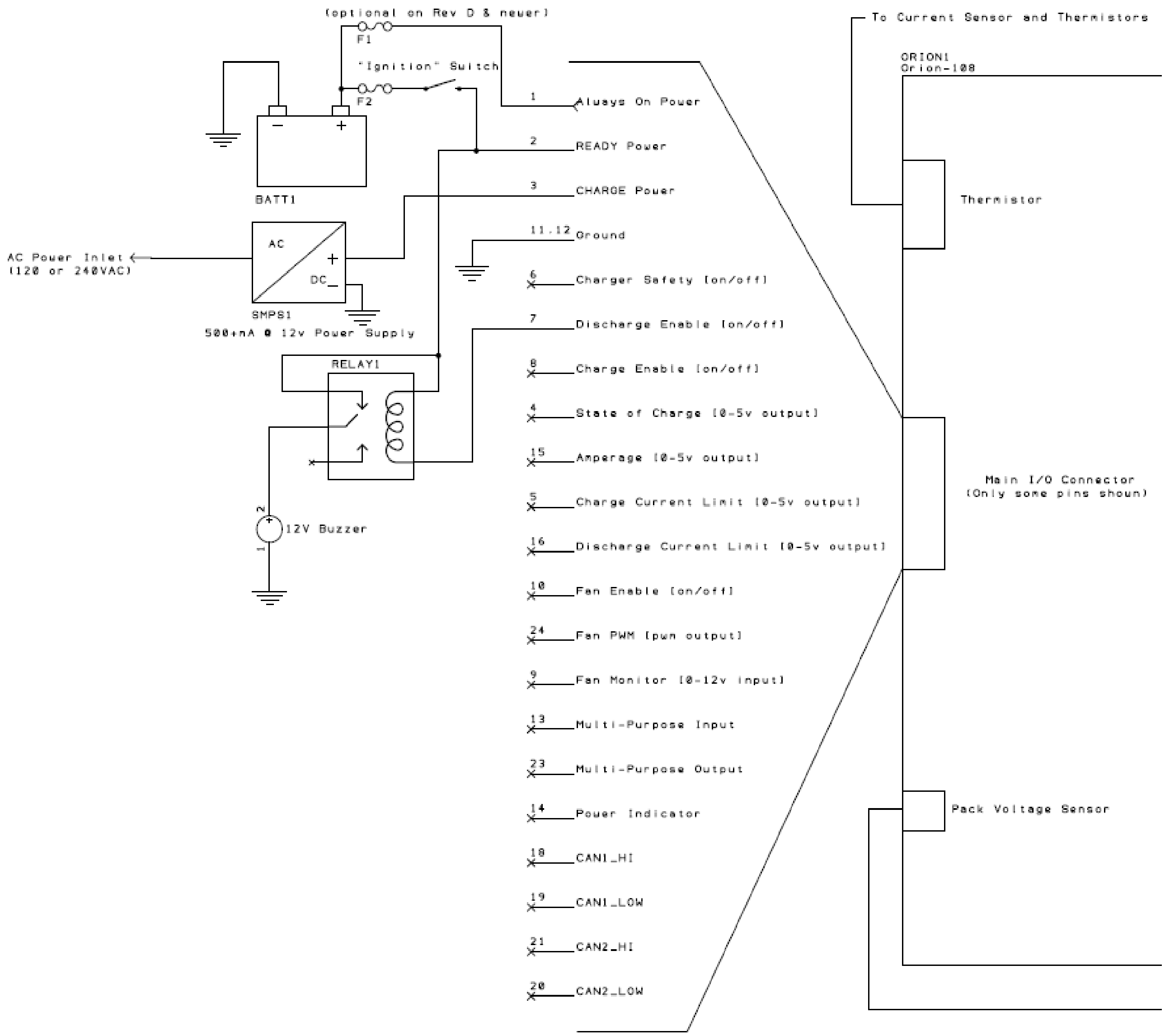
Battery charger without CAN: Controlling charger without enable capabilities



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 should 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.

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 be rated < 100mA for Rev A, B & C or less than 175mA for revision D & E.