Lithionics Battery®

NeverDie® Standard BMS – User Guide

UL Ratings

UL 508	- Contactor
UL 991	- BMS
UL 1998	- BMS
UL 1973	- System

R8.0.8 – 02/14/2019

NEVERDIE®
LITHIUM+ELECTRONICS = LITHIONICS BATTERY

MiniBMS®
TECHNOLOGY

OptoLoop®
TECHNOLOGY

Notice of Copyright

Safety Precautions

- All electrical work should be performed in accordance with local and national electrical codes.
- Voltage is present at the battery terminals, use insulated tools and gloves while working on the system.
- Always turn off equipment connected to the system in addition to turning OFF the Power switch provided on the system to isolate the batteries from other electrical circuits, before performing any repairs or maintenance on the system.
- Always use proper wire sizes to connect the system to inverters, chargers or other equipment.
- Always use crimped connections to connect to the battery terminals.
- Read and follow the inverter, charger or other equipment manufacturers safety precautions prior to connecting the system to that equipment.

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Overview

The main purpose of the NeverDie® BMS is to protect the battery by disconnecting it from the rest of the system when it detects any potentially harmful conditions, as well as provide emergency energy reserve by saving part of the battery's capacity during normal use.

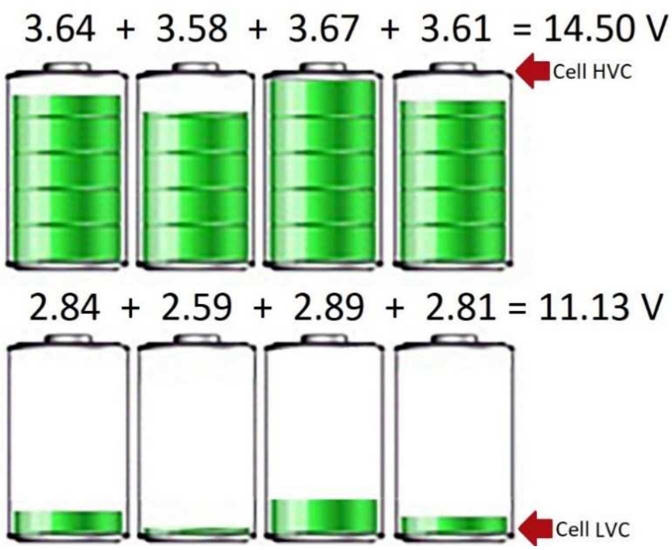
Installation

Since Lithionics Battery offers countless battery configurations, this document will not cover detailed installation steps and assumes that the Battery and BMS are already installed. Please refer to your specific installation guide or contact Lithionics Battery for installation assistance. Typically, the BMS is installed between the battery and the rest of your system, acting as an intelligent power switch. **NOTE: Do NOT attempt to bypass the BMS or tap any loads directly from any battery modules, as it could lead to permanent battery damage and voids your battery warranty!!!**

Definitions

It's important to understand some common terms describing a lithium battery's operation, which are often used in detailed feature descriptions further in this document. It also helps to visualize a charge/discharge graph of a typical lithium battery, to see various voltage points and how they relate to state of charge.

- **VPC – Volts Per Cell**. A Lithium Battery contains several cells connected in series. Battery voltage is a sum of all cell voltages. LiFePO4 chemistry cells are 3.2VPC nominal (i.e. average voltage during discharge). A typical 12V battery has 4 cells in series, also known as a "4S" configuration. Respectively, a 24V battery is 8S, while 48V batteries can be 15S or 16S depending on the model. Since the BMS monitors and acts at the individual cell level as well as pack level, it's more common to refer to cell level voltages, abbreviated as VPC. For example, a fully charged and rested cell is at 3.4VPC, which means a 12V (4S) battery would be resting at 13.6V.



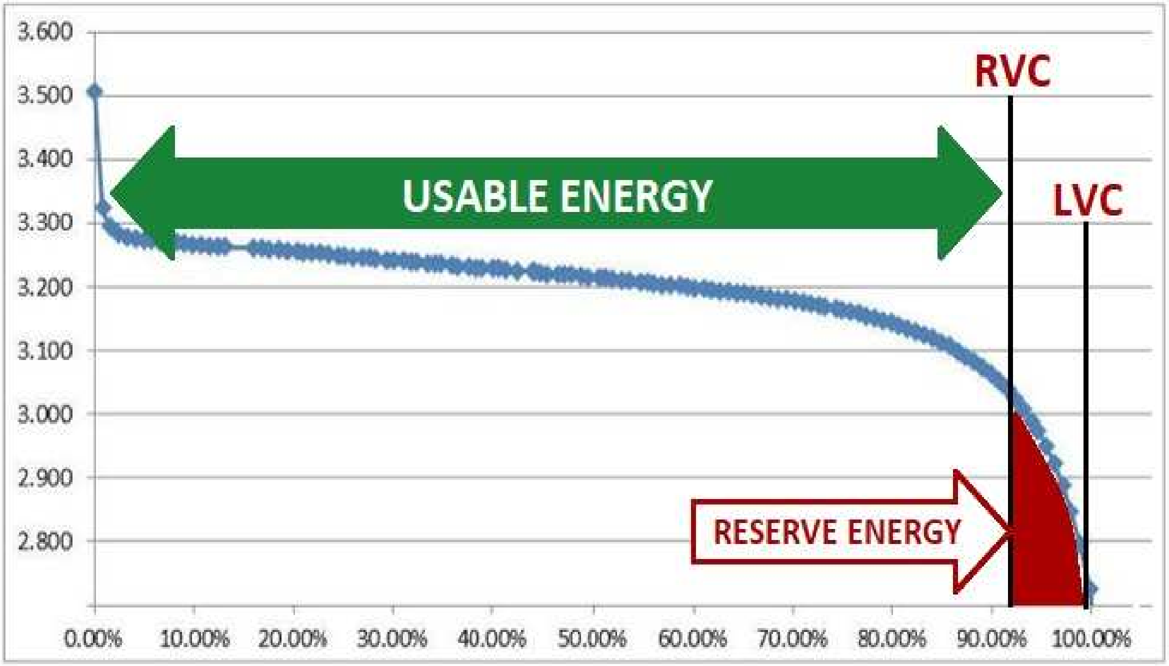
Picture on the left illustrates the cell level and the pack level voltages. Due to manufacturing tolerances and environmental factors individual cell voltages may not always be the same, so the BMS must employ both cell level (MiniBMS®) and pack level (NeverDie® BMS) triggers for protection events such as HVC and LVC. Our BMS also works to minimize those voltage differences in a process called "balancing", which occurs at the end of each full charge cycle.
Pack level triggers are more conservative than cell level triggers to allow for some natural imbalance in cell voltages at the top and the bottom of the charge/discharge cycle. BMS events are triggered on both cell level and pack level, whichever happens first.

In a 12V battery, for example, pack level and cell level triggers are:
HVC Pack Level = 14.80 V
HVC Cell Level = 3.75 VPC
LVC Pack Level = 11.60 V
LVC Cell Level = 2.50 VPC

- **Charge / Discharge Curve**. One of the main advantages of a Lithium battery compared to a Lead Acid battery its flat charge/discharge curve. This means that the battery voltage stays relatively constant for most of the charge/discharge cycle, with sharp "knees" on both ends where voltage rises and drops very fast. Constant voltage means stable power is supplied to loads, making them operate more efficiently. However, this also renders voltage-based SOC (state-of-charge) measurement useless. Voltage based SOC estimates can only be done at the upper and lower "knees" where voltage change is more pronounced. See the Charge and Discharge Curves below with explanations of usable and reserve power.

- **RVC – Reserve Voltage Cutoff**. Typically set to 3.0VPC on voltage based BMS triggers. At this level the BMS would shut off the battery power allowing the NeverDie® Reserve Power capacity to be stored in the battery for an emergency, such as engine cranking. The areas shaded red in the picture below represent the Reserve Power.

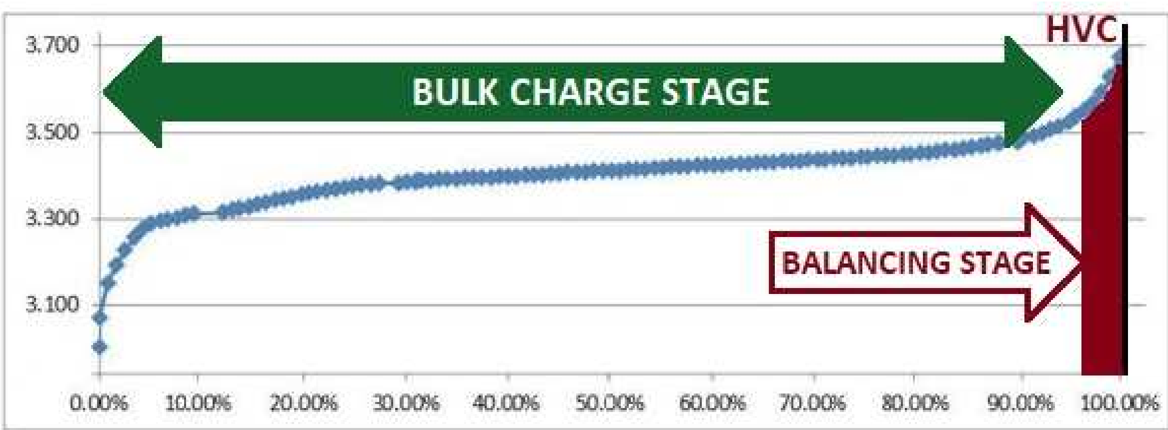
- **LVC – Low Voltage Cutoff**. Typically set to 2.9VPC at the pack level and 2.5VPC at the cell level. At this voltage the battery is almost fully discharged, so the BMS shuts off the battery to prevent damage due to over-discharge. To compensate for voltage sag under heavy load, LVC is reduced by 0.1VPC per 1C rate of discharge, up to 0.3VPC limit at 3C rate.



Discharge Curve

- **HVC – High Voltage Cutoff**. Typically set to 3.75VPC. At this voltage level the cell is not taking any more charge, so voltage rise becomes exponential and if left unchecked would cause permanent damage to the battery. The BMS shuts off the battery when any cell reaches this level, allowing voltage to rest down.

- **Balancing Stage**. As the battery nears the end of charge the cells enter the upper knee of the charge curve, where voltage rise becomes faster and faster. Due to individual manufacturing differences between cells, some cells reach this stage earlier than others, causing voltage imbalances between cells. While not harmful in the short term, in the long term such an imbalance will become more and more pronounced which eventually reduces the useful capacity of the battery. To counteract this process the BMS performs cell balancing by slightly discharging the higher voltage cells (a process called "shunting"), this allows the lower cells time to catch up. This process is similar to "equalization" in a Lead Acid battery but requires more precision and controlled by the BMS on an individual cell level.



Charge Curve

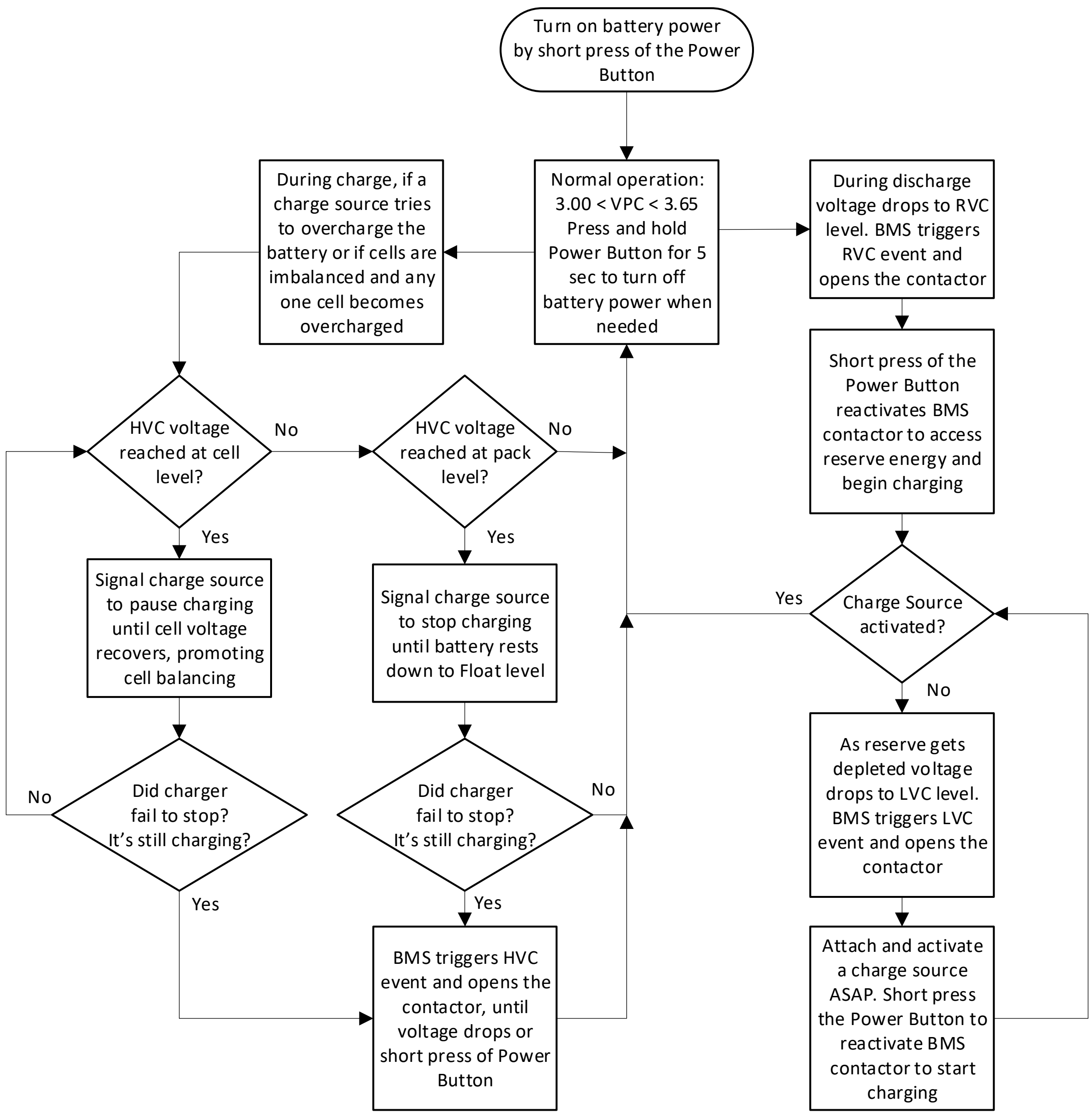
BMS Operation

The NeverDie® BMS operates by monitoring the voltage and temperature data from each individual cell and battery pack as a whole. Cell data is then passed on to the BMS via a unique single-wire interface called OptoLoop®. Such an interface allows for a flexible distributed design for battery packs of various voltages and capacities. OptoLoop® works by establishing circuit continuity which passes thru all individual BMS monitoring boards installed on each cell inside the battery modules. When continuity is broken by any cell board or wiring fault, the main BMS unit will open the main contactor as well as not allow it to close until the fault is resolved.

Below flowchart depicts typical BMS operation cycle when battery is fully depleted or at risk of overcharge by a rogue charge source. The NeverDie® BMS does not need to intervene if the battery is cycled normally.

For simplicity reasons this flowchart only shows basic protective BMS functions based on voltage triggers. Additional BMS functions based on temperature triggers and other advanced functions based on SOC triggers are not shown in this flowchart.

Please refer to Standard BMS Functions chapter for details of those functions.



BMS Operation flowchart

LED Indicators

NeverDie® BMS has an LED indicator integrated into the Power/On/Off/Re-Set button on the unit itself and in some cases, there are also optional remote LED indicators. There can be one or two remote LEDs, for Power On/Off/Alarm status and Low Battery status. Please refer to your specific installation to check which LEDs, if any, you have available in your system.

- **Power On/Off/Alarm** – This LED indicator is integrated into the Power Button or could be a separate remote LED, depending on specific installation. LED is off when BMS is turned off and battery power is disabled. LED is on when BMS is on and battery power is on. LED flashes rapidly when BMS is in alarm state and battery power is disabled. LED blinks briefly when BMS is on and sending telemetry data, but battery power was turned off by operator, usually this is only available in the dual stage power up mode.
- **Low Battery** – This optional LED indicator is typically installed at the control panel, so the operator can see when the battery is getting low and needs to be charged. LED turns on when battery goes below approx. 20% SOC based on the pack voltage trigger of 3.05VPC. When charging is in progress LED will turn off after voltage rises above 3.30VPC.

BMS Troubleshooting

Module(s) Voltage. Most Lithionics Battery systems are built as modular assemblies, with series/parallel connected battery modules and an external NeverDie® BMS enclosure. In such a modular architecture, troubleshooting comes down to simply checking voltages of individual modules, and, checking continuity of all connections. A healthy and well-maintained battery would exhibit the same or very similar voltages on all modules of the same configuration, so if you see one module's voltage is significantly different from the other modules, it could indicate an imbalance in the State of Charge between modules, which causes unexpected BMS events, since BMS protects the individual cells in the difference modules. **When contacting Lithionics Battery for support, please write down the exact voltages of each battery module and note if the measurement was taken at the end of charge or discharge, or somewhere in between.**

Negative Reference wire. Make sure the BMS negative reference wire has a good solid connection to the battery's most negative terminal. The BMS uses this wire for its own power as well as voltage measurements. If there is a poor or loose connection, the BMS will have unpredictable behavior. For systems utilizing the Anderson Power Products EURO DIN connector, the negative reference wire is integrated into the wire harness provided with the system.

OptoLoop® connections. Each battery module has a normally-closed (N.C.) OptoLoop® (a.k.a. Cell Loop) output composed of 2 light green-colored 18-gauge wires. These wires are "daisy-chained" from one battery module to the next. The OptoLoop® connection starts and ends at the NeverDie® BMS unit. If there is ever a fault in any battery module, then its Cell Loop will go to an open-circuit condition which communicates the fault to the NeverDie® BMS. This simple open/closed circuit fault makes diagnosing a battery system very easy. To check the continuity of the OptoLoop® connection on each module, disconnect the light green wires from the adjacent modules and check for continuity between the 2 wires using a DVM set to continuity checking mode, which beeps when there is continuity between probes. Also check for overall continuity across all modules at the BMS connection points. The BMS must sense continuity of the OptoLoop® in order to operate properly. The Opto-Loop connections points are normally either Delphi Weatherpack connectors or located in 2 small signal pins of the Anderson EURO DIN connector plug.

Standard BMS functions

When the BMS is initially powered on by the Power button, it performs health checks across the OptoLoop® and also checks the pack level voltage. If all health checks are successful, BMS will close the main contactor and allow use of the battery power.

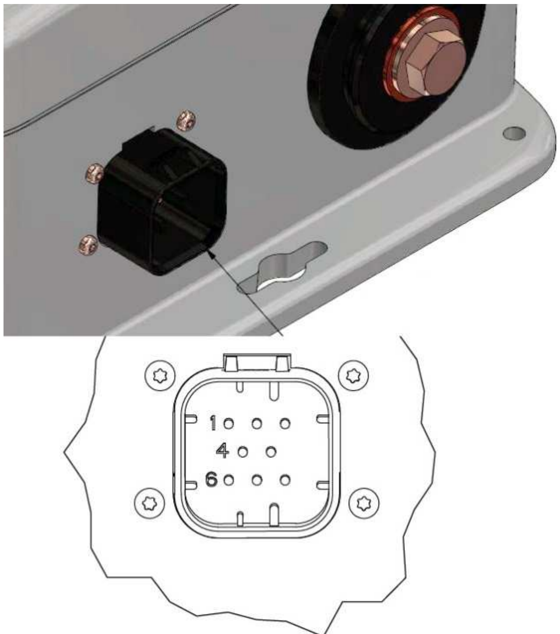
When the main contactor is closed, and the battery is being charged or discharged, the BMS is always monitoring battery health parameters and will open the contactor if any trouble is detected. You can also open the contactor by holding the Power button for 3 seconds.

Below is a detailed description of standard BMS features and how they affect the state of the contactor.

- **Power On/Off** – Briefly press the Power button to turn on the BMS and enable battery power. The battery can be turned off by holding the Power button for 3 seconds.
  NOTE: Always turn off the battery power when placing the battery into storage or for removal and/or transporting of the battery, as well as making any wiring changes!

- **Reserve Voltage Cutoff (RVC)** – NeverDie® function. During discharge the BMS will open its contactor, disconnecting the battery power when battery voltage reaches the RVC level (typically 3.0VPC or 3.1VPC), which allows the battery to store energy reserve. Once the battery is in the RVC state you can access the reserve capacity by a short press of the Reset button. If desired, the RVC function can be disabled by setting **RVC=0** in the BMS' Configuration.
- **Low Voltage Cutoff (LVC)** – During discharge the BMS will open its contactor when the battery reaches the LVC level. LVC is monitored on both pack level and cell level, using the OptoLoop® interface. The contactor remains open until the BMS detects a charge voltage, at which point the contactor will close to allow charging. The BMS will monitor the initial charge for expected voltage rise and will open the contactor again if voltage rise is not detected within 20 minutes, or immediately if voltage continues to fall below LVC level. Some charging sources require to "see" the battery before allowing charging, in which case LVC lockout can be temporarily overridden by holding down the Power button for 10 seconds while powering on the BMS. This override will allow the contactor to close so charging can begin. If voltage rise is not detected within 20 minutes or voltage continues to fall below LVC level, the contactor will open again to protect the battery.
- **High Voltage Cutoff (HVC)** – During charging the BMS will open the contactor if any cell signals HVC voltage level via the OptoLoop® interface. This should not happen during normal operation if charging sources are setup with correct voltage levels. Once the charge voltage is removed, battery voltage will slowly lower to resting level, typically 3.4VPC. If your charging source has a "float" mode, it should be set to 3.4VPC, which is a resting voltage of a fully charged cell. If your charger has a control interface connected to the BMS, then the BMS will force the charger to stay off until voltage drops below this "float" level.
- **Temperature Based Cutoff** – when temperature inside the battery goes below or above preset safe limits BMS will open the contactor to prevent further use of the battery until temperature returns under safe limits. Different temperature limits are enforced for charging and discharging due to nature of Lithium chemistry. Discharge safe range is -4F to 131F, charge safe range is 32F to 113F.
- **Field Control Circuit (FCC)** – if your BMS is wired to your alternator's field or regulator circuit, it will disable the alternator's output by opening this circuit when HVC condition is detected, to protect the battery from being overcharged. The BMS will open this circuit 2 seconds prior to opening main contactor, allowing alternator field to discharge which protects the alternator's diodes from potential damage. This circuit can also be used to disable other charge sources, such as solar controllers or inverter/charger's charge function.
- **Short Circuit Protection** – The BMS will detect a possible short circuit event if the battery voltage drops below 1.75VPC, immediately disconnecting the contactor. The contactor will stay open until the BMS is power cycled or Power button is held down for 10 seconds to reset the BMS, or charge voltage is applied to the BMS.
  NOTE: The lithium battery is capable of significant power output and may maintain the voltage level during a short circuit event, producing a very large current, capable of melting or welding connection points and damaging cables and connectors. Even if the BMS detects short circuit and tries to open the contactor, the contactor itself might weld under such a very large current. Make sure the battery connection is always properly fused and does not rely on the BMS alone for short circuit protection!
- **Auxiliary Contacts** – This feature is part of the special type of contactors used inside the BMS unit, which has mechanically coupled aux contacts on the same arm as the main contacts. This allows monitoring for possible welding of the contactor in high power systems. The BMS monitors the state of aux contacts when changing state of the main contactor to make sure there is a match between actual and the expected state of the contactor. If there is a mismatch, the BMS will attempt to unstick the contactor by repeatedly pulsing the coil up to 10 times. If not successful, the BMS will set the **AUX_ERROR** status flag for troubleshooting purposes. During normal operation the BMS will set **AUX_STATE** flag to indicate current state of aux contacts, which can be interpreted as the actual state of the main contactor.
- **Contactor Flutter detection** – if any abnormal condition, such as loose wiring or faulty equipment causes the BMS to turn contactor on/off 10 times in a 10-minute period, then the BMS will enter the Power Off state, preventing contactor flutter. Once the problem is investigated and addressed, hold down Power button for 10 seconds to reset the BMS, to return to normal operation.
- **Lockout Voltage detection** – if an incorrectly configured charge source, such as solar controller or inverter/charger set to higher battery voltage is applied to the BMS, it will detect wrong voltage range and will prevent from closing the contactor, protecting the battery from wrong charge source.

AMPSEAL Connector



The NeverDie® Standard BMS has an 8 pin AMPSEAL Connector on its side wall (for internal BMS models, this is located on the lid on most batteries), which can be used to wire BMS's auxiliary circuits to other components in the energy storage system. This allows implementation of additional BMS functions listed below. The scope of this document is only to list AMPSEAL pins and their functions. Please contact your battery supplier or Lithionics Battery for specific wiring diagrams and technical assistance to make sure these pins are used as intended and prevent internal damage to the BMS unit. Pay close attention to electrical specs and fusing requirements for each circuit.

Pin	Function	Description	Details
1	Reset Button 1	Reset button wire 1	15V 5mA normally open push button circuit
2	Remote_LED_Pos	Remote LED 15V Positive wire	15V 20mA LED driver, internally PTC fused
3	CAN Low	isolated CANBus Low signal	5V isolated CAN_L signal - TI ISO1050 IC
4	Remote_LED_Neg	Remote LED 15V Negative wire	LED return, tied to battery negative
5	CAN High	isolated CANBus High signal	5V isolated CAN_H signal - TI ISO1050 IC
6	Reset Button 2	Reset button wire 2	15V 5mA normally open push button circuit
7	FCC 1	Alternator Field Control Circuit wire 1	dry contact, up to 24VDC 2A, needs ext. fuse
8	FCC 2	Alternator Field Control Circuit wire 2	dry contact, up to 24VDC 2A, needs ext. fuse