



Lithionics Battery®

NeverDie® Advanced BMS – User Guide

UL Ratings

UL 508 - Contactor

UL 991 - BMS

UL 1998 - BMS

UL 1973 - System



NEVERDIE®
LITHIUM+ELECTRONICS = LITHIONICS BATTERY

MiniBMS®
TECHNOLOGY

OptoLoop®
TECHNOLOGY

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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. Additional function of the Advanced BMS is to gather battery data and send it over a digital interface to a computer system for data logging and analysis, as well as display real time data.

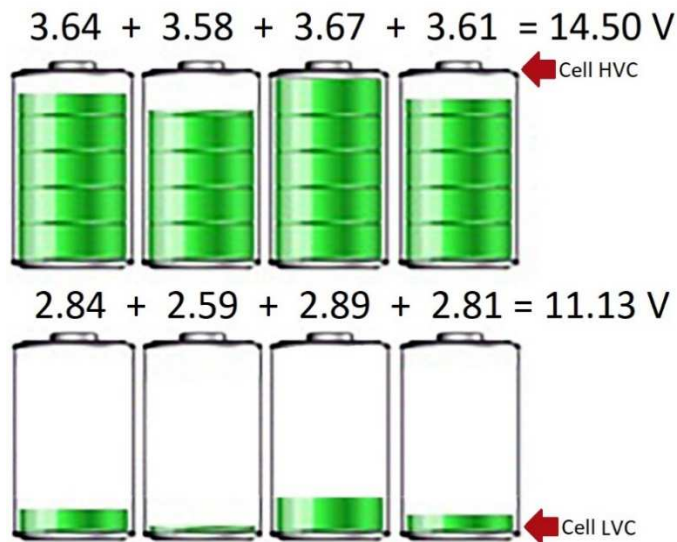
Installation

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 module 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.



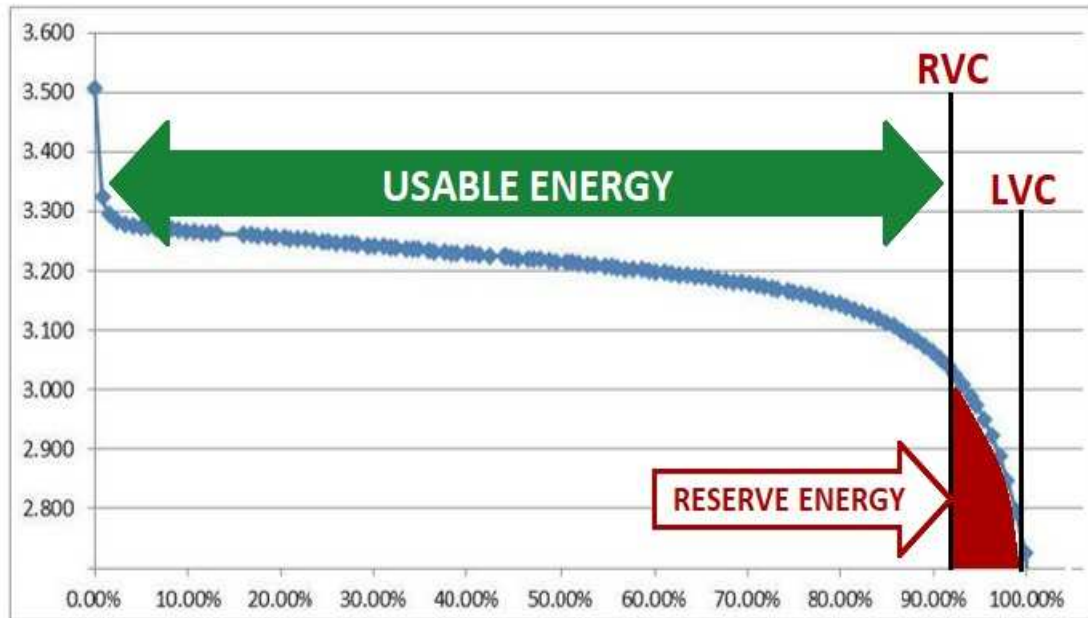
Picture on the left illustrates the cell level and the pack level voltages. Due to manufacturing tolerances and environmental factors individual cell voltages may not always be the same, so the BMS must employ both cell level (MiniBMS®) and pack level (NeverDie® BMS) triggers for protection events such 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 is its flat charge/discharge curve. This means 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. In Advanced

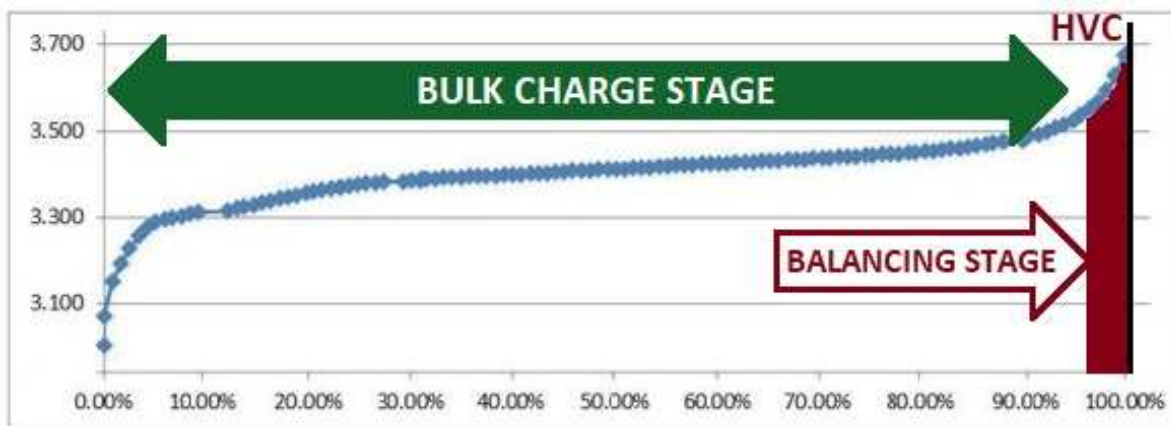
Series BMS, the RVC level can also be set based on true SOC measurement, using a Coulomb counter, which also allows for a larger reserve power capacity if desired.

- **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 could 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

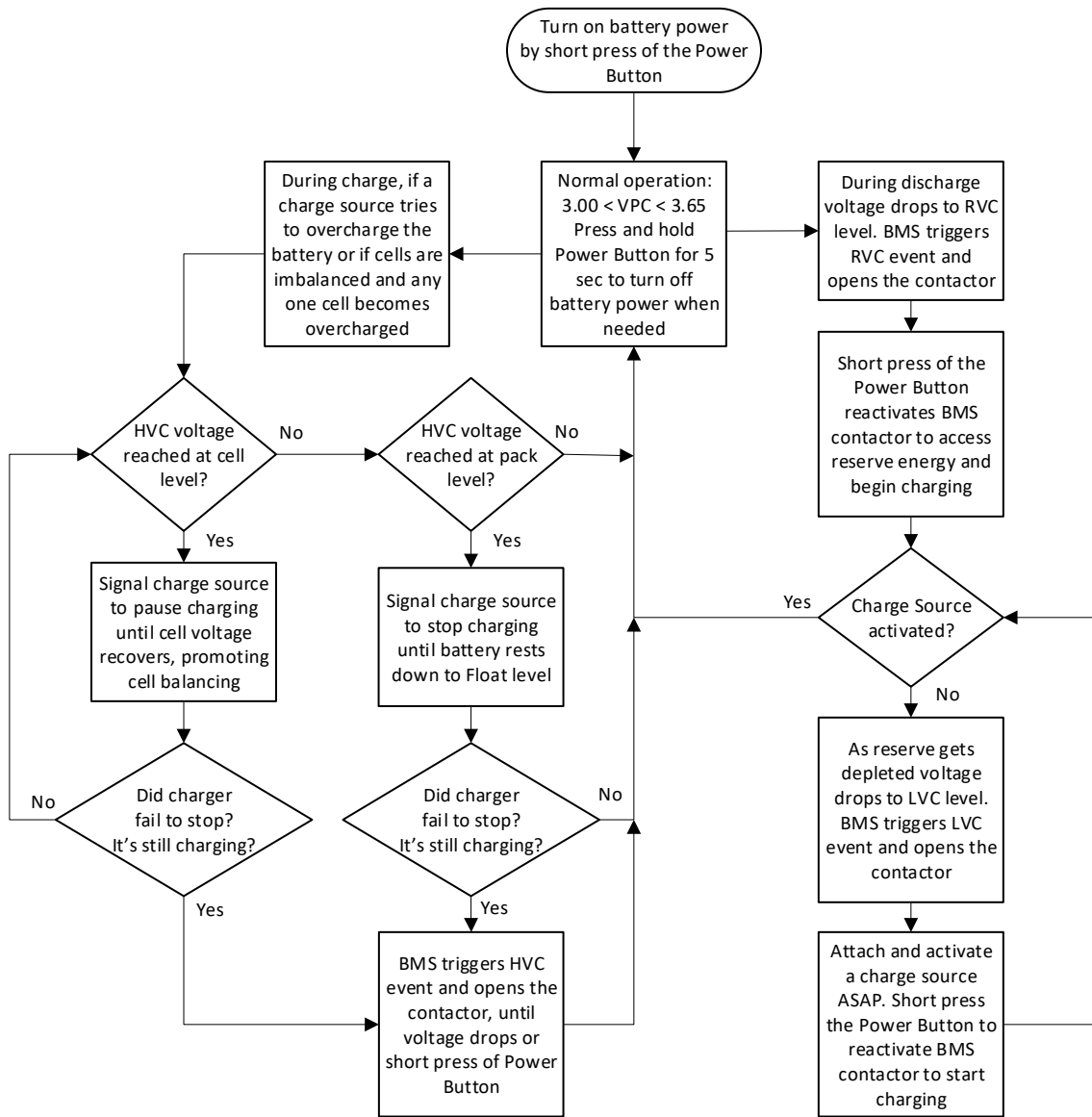
BMS Operation

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. **NOTE: The NeverDie® BMS does not need to intervene if the battery is cycled normally. Lithium battery can be charged at any SOC level and does not need to be regularly depleted. For best life cycle the battery should be normally operated between 20% and 95% SOC, with regular, but not excessive charging to 100% SOC to promote balancing and avoid SOC drift.**

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 Advanced BMS Functions chapter for details of those functions.



BMS Operation flowchart

SOC Gauge operation

The Advanced Series BMS includes an integrated SOC Gauge, designed to track battery state of charge (percent of usable energy left in the battery) as well as other useful data parameters. Tracking state of charge is accomplished by a Coulomb counter, based on an internal, high sensitivity hall-effect sensor. The SOC Gauge data will only be correct if the configuration parameters are set correctly, which are pre-set initially by Lithionics Battery, but are user adjustable with supporting hardware. The SOC Gauge will also track and display live amperage (A), live wattage (W), battery voltage (V), temperature (F/C), amp hours (Ah), watt hours (Wh), time remaining (d/h), etc. The meter will be most accurate if the battery is fully charged on a regular basis. If the battery is always partially charged, then the SOC meter reading may drift in the long term and will become less accurate. When the most accurate measurements are required it is recommended to perform a full charge at least weekly.



SOC Data can be observed on the optional LCD Display pod or extracted from the BMS data interface.

LCD pod has a backlight feature, which activates for 30 seconds after each button press, to better see the data in the dark environment. After 30 seconds backlight turns off to avoid light pollution if LCD is installed in the sleeping compartment.

The LCD Display pod has a 2-line screen capable of showing 2 data points independently. Pressing the left button scrolls through the available data points on upper line, pressing right button scrolls through the available data points on the lower line. Any combination of data is possible on these 2 lines. The following list explains all available data points:

- **E ■■■■■■ F** – Graphical representation of the Battery State of Charge Gauge. Each of the 6 bars corresponds to approximately 17% of capacity.
- **100% SOC** – Digital Battery State of Charge gauge.
- **23.4 A** – Amperage. Instant current reading. The “+” sign in front of the value indicates charging current. No sign indicates discharging current.
- **20000 W** – Instant Wattage reading. This power value is derived by multiplying current and voltage together. This is useful to estimate how much instant power is passing through the battery circuit. This value can be manually converted to horse power by the formula: $HP=Watts/745.7$
- **39.6 V** – Instant battery voltage reading.
- **82F t1** – Instant temperature reading. Can be set to C or F in the Config menu. Temperature data comes from Temperature Intervention Sensors, or from BMS internal sensor if external sensors are not present. “t1” indicates how many sensors are present, up to 8 sensors are supported in large systems with multiple battery modules.
- **100.0 Ah** – Remaining Amp Hour capacity of the battery.
- **3960 Wh** – Remaining Watt Hour capacity of the battery. The Watt Hour value is derived by multiplying the Amp Hour value and the Pack Voltage together. This value will be changing dynamically as voltage fluctuates under load.
- **D 22.5h** – Remaining time at current load level until battery is depleted. This value will be changing dynamically if load current changes over time. When battery is charging first letter will change from D to C and displayed value will indicate remaining time to full charge. Time counter label automatically scales to days (d) or hours (h).
- **R000000** – System Status Bits value. See chapters below for detailed explanation of this value.
- **T0001234** – Total number of AmpHours consumed from the battery since day of manufacture. This value helps estimate battery State of Health by extrapolating its discharge cycles over the life of the battery.

NOTE: During initial BMS power up the LCD display will show Last Recorded Fault code and BMS firmware version for 5 seconds, before switching to normal operating mode. This information is critical for troubleshooting purposes, please collect this information and pass to your support contact whenever working on any battery issues.

System Status bits

One of the data values in the BMS Data Stream is called System Status, where each bit represents one of the basic conditions of a battery system in real time. In Serial/Ethernet streams this value is labeled 'R', located at the end of the data string, it's 6 characters long and coded in Hexadecimal digits '0-F'. Each HEX digit represents 4 bits of binary data, for a total of 24 bits or 3 bytes of data.

NOTE: Some of the bits represent optional BMS features, which might not be enabled in your system. Last 2 bits are currently unused.

BMS System Status Code Flags - 3-byte value			
Byte	Bit	Name	Value Definition
0	0	High Voltage State	Indicates that battery voltage is above HVC, typically 3.70VPC.
	1	Charge Source Detected	Indicates that charge voltage was detected on the far side of the contactor, allowing contactor to close even when battery is in Low Voltage state. This bit resets when battery reaches Nominal voltage.
	2	NeverDie Reserve State	Indicates that battery is in the NeverDie Reserve State, allowing access to reserve energy.
	3	OptoLoop is Open	Indicates that Cell Loop is open, which means one or more cells is out of normal voltage range, or broken Cell Loop wiring between battery modules and/or NeverDie BMS unit.
	4	Reserve Voltage Range	Indicates that battery voltage is below RVC, typically 3.0VPC.
	5	Low Voltage State	Indicates that battery voltage is below LVC, typically 2.9VPC.
	6	Battery Protection State	Indicates that battery is recovering from abnormal event, such as short circuit, pre-charge failure, or contactor failure. See additional bits below for more details.
	7	Power Off State	Indicates that battery was turned off by a command or a button press.
1	0	AUX Contacts State	State of Auxiliary contacts inside the contactor, reflects actual physical state of the main contactor. This optional feature requires special model of the contactor with AUX contacts.
	1	AUX Contacts Error	In case of contactor welding, this bit will indicate discrepancy between expected and actual state of contactor. It also sets Battery Protection State bit.
	2	Pre-charge Error	Indicates that Pre-charge function failed to detect voltage rise on the load side of BMS, which could mean a short circuit condition or other issues with load wiring. It also sets Bit 6 – Battery Protection State. This optional feature requires Pre-charge relay and resistor to be installed inside the BMS unit.
	3	Contactor Flutter	If BMS contactor changes state 10 times over 5-minute period, BMS enters Power Off state and sets this bit, so troubleshooting can be performed. This condition could be caused by wiring problems or other hardware issues and requires service attention.
	4	AC Power Present	Indicates that BMS detected AC power presence, so BMS expects charging to begin shortly. This optional feature requires AC/DC supply wired to the BMS unit to connect to AC grid.
	5	TSM Charger Present	Indicates that CAN message from TSM charger was detected on CANBus interface. This indicates TSM charger is present and has AC power. Used for troubleshooting TSM chargers.
	6	TSM Charger Error	Message received from TSM charger indicating an issue with the charger. Further analysis of CAN data from the charger is needed to determine exact nature of the problem.
	7	Temperature Intervention Sensor Error	Indicates a problem with temperature intervention sensor installed inside the battery module. Temperature data from this sensor is used to cutoff battery power under extreme temperatures.
2	0	AGSR State	State of optional AGSR Control circuit, used to start/stop generators when BMS is wired into supported generator's auto start interface.
	1	High Temperature State	Temperature detected by Temperature Intervention Sensor exceeded allowed threshold.
	2	Low Temperature State	Temperature detected by Temperature Intervention Sensor is below allowed threshold.
	3	AUXIN1 State	Reflects the state of AUXIN1 input, which is optional and application specific.
	4	Charge Disable State	Signals any charge source to stop charging the battery while this bit is set. This state is determined by BMS logic based on multiple factors including cell level and pack level protective functions.
	5	Over-current State	BMS detected current higher than preset limit.

Bluetooth Telemetry



Lithionics Battery has developed the **Lithionics Battery Monitor** application for iOS and Android mobile platforms, which allows real time monitoring of battery data if the BMS is equipped with the **optional** Bluetooth BLE module. However, the Status Code Reader function can be used even without this optional module.

The Status Code Reader function makes it easy to visualize status of each bit by typing in the System Status value and observing color coded table of bit values, see example below. You can download this application from Apple and Google application markets on your iPhone, iPad, Android phone or tablet.

Each active bit description is color coded in green or red, where green indicates informational bits and red indicates faults or critical conditions requiring attention, such as immediate need to charge the battery.

NOTE: All 6 digits of the “R” value must be entered, including leading zeroes to trigger decoding function.

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 and can be based on pack voltage trigger of 3.05VPC or Coulomb counter value of 20%, whichever comes first. When charging is in progress LED will turn off after voltage rises above 3.30VPC and Coulomb counter value is above 20%.

BMS Troubleshooting

Last Recorded Fault Code. When BMS is powered on, the LCD display shows the last recorded fault code and the firmware version for 5 seconds, before it switches to normal data display. If you missed it, you can power cycle the BMS again and take a snapshot of the LCD display during first 5 seconds. **When contacting Lithionics Battery for support, please write down this last recorded trouble code and the firmware version and pass this information to your support contact.**

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.

Decoding Critical Fault states and possible corrective actions. Table below lists most critical fault codes and possible solutions.

Status Code Flag	BMS Protective Function	Activation Trigger	Possible root cause and corrective action
High Voltage State	High Voltage Cutoff	Battery Voltage => 3.70 VPC	One or more charge source(s) is overshooting target charge voltage. Check your charge source settings and try to slightly reduce charge voltage. Confirm by measuring voltage with DVM at battery terminals. Charge sources could be alternator regulator, solar charge controller, inverter/charger, etc.
Low Voltage State	Low Voltage Cutoff	Battery Voltage <= 2.90 VPC	Battery has been deeply discharged, completely depleted. Immediately start charging with any available charge source and stop any loads to prevent further discharge until battery reaches nominal voltage. If necessary, short press Power button to wake-up the BMS to start charging.
Reserve Range	NeverDie Reserve	Voltage <= 3.00 VPC	Battery has been discharged to approx. 10% SOC and turned off to preserve remaining charge. Short press Power button to turn the battery power back on to access remaining reserve, but also start charging the battery with any available charge source ASAP.
		Battery Gauge <= 10%	
OptoLoop Open	OptoLoop Cell Monitor	Cell Voltage > 3.75 VPC	Cell level monitoring circuit indicates one or more cells are out of normal operating range. Check continuity of OptoLoop monitoring circuit between the BMS and battery module(s). If battery is also in LVC or HVC states, follow corrective actions for those states, otherwise contact your battery supplier for support.
		Cell Voltage < 2.50 VPC	
High Temp State	High Temperature Cutoff	Battery Discharge Temp > 131 F	Battery temperature is too high. Try to cool down the battery by increased airflow, avoid direct sunlight, reduce charge/discharge rate to prevent internal heat buildup.
		Battery Charge Temp > 113 F	
Low Temp State	Low Temperature Cutoff	Battery Discharge Temp < -4 F	Battery temperature is too low. Try to warm up the battery by any available heat source. Be careful to avoid overheating or melting of the battery casing.
		Battery Charge Temp < 32 F	
Overcurrent State	Overcurrent Protection	Battery Current > 400 A* *Actual value depends on specific battery model and capacity	Battery current exceeded allowed safety rating. Reduce loads to bring the current down to rated levels. Short press Power button to reset the protection state.
Aux Contact Error	Contact State Fault	Contact State Mismatch	Possible damage detected inside BMS contactor, such as tack welded contacts due to surge or inrush of current. Hold Power button for 10 sec to turn the BMS off, then short press to restart the BMS to see if problem clears up. If problem persists, contact your battery supplier for support.
Contact Flutter	Contact Flutter protection	10 cycles in 10 min	Frequent repeated cycling of BMS contactor could indicate a wiring issue or other defect in the system, so BMS stops operating until issue is investigated and resolved. Hold Power button for 10 sec to turn the BMS off, then short press to restart the BMS to see if problem clears up. If problem persists, contact your battery supplier for support.
Temp Sensor Error	TIS Quantity Enforcement	TIS count < TIS config	Possible wiring issue with Temperature Intervention Sensor circuit between the BMS and battery module(s). Check for proper connection, restart the BMS to see if problem clears up. If problem persists, contact your battery supplier for support.
Pre-Charge Error	Pre-charge relay-resistor circuit	Load Voltage does not rise to Battery Voltage within 5 seconds	When optional Pre-Charge feature is enabled, voltage at inverter DC terminals is expected to rise fast to battery voltage at initial BMS power up. If additional DC loads prevent expected voltage rise, BMS throws this error. Contact your battery supplier for advise on changing Pre-Charge settings or reduce initial DC load to allow completion of Pre-Charge sequence.
Battery Protection	Battery Safety Protection	Combined with other protective functions	This state is typically combined with other protective states to lock the BMS in the safe mode requiring manual intervention and investigation. Check for other fault flags and problems, then try to restart the BMS to clear the fault state.

Advanced BMS functions

When the BMS is initially powered on by the Power button, it performs health checks across the OptoLoop® and checks the pack level voltage and the State of Charge (SOC). The BMS then begins to transmit digital data onto its available interfaces, such as CAN, RS232 or TCP/IP, depending on the specific BMS configuration. 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.

Below is a detailed description of advanced BMS features and how they affect the state of the contactor. Some features depend on setup parameters which are described in detail in the Configuration section of this user guide.

- **Dual Stage Power-Up** – Some applications may require dual stage Power-Up, where BMS waits for a separate command to close the contactor. This mode allows BMS to be powered up and transmit telemetry data independent of battery power On/Off state. It could be useful in remote or industrial applications where BMS telemetry is critical even when battery power is turned off. This mode can be enabled in the BMS configuration if desired, using command **\$PWRUP=0**
- **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, or by sending **\$BATOFF** command via its digital interface. If BMS is configured for dual stage power up, then first button press will turn on the BMS and second press will turn on the battery power. In this mode the BMS is powered off by holding Power button for 10 seconds while turning off the battery power.
NOTE: Some high voltage battery systems have a separate latching BMS Power Switch used to stop quiescent load from internal DC/DC converter. Always turn off the BMS with the Power Switch 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 reaches the RVC level, which allows the battery to store energy reserve. The RVC level is defined either by voltage (typically 3.0VPC or 3.1VPC) or by SOC percentage set in the BMS Configuration, whichever comes first. Once the battery is in the RVC state you can access the reserve capacity by a short press of the Reset button or by sending the **\$BATON** command via digital interface. 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.
- **Over-Current Protection** – The BMS will limit maximum continuous charge or discharge current to enforce safe operating limits as stated in the battery datasheet. If BMS detects continuous current above preset limit for over 2 minutes, BMS will open the contactor to prevent potentially unsafe operation. **NOTE: This function does not replace the safety requirement of fusing power circuits. Make sure battery is always properly fused according to local electrical safety code.**
- **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!
- **Automatic Generator Start/Restart (AGSR On/Off)** – if your BMS is wired to your generator’s start circuit, it will close the circuit to start the generator when voltage drops below 3.05VPC or BAT percentage drops below the “AGSR On” level set in BMS Configuration, whichever comes first. The AGSR circuit will open when the voltage rises above 3.5VPC after 15-minute delay, which simulates a Constant Voltage charge stage. You can also set “AGSR Off” level in the BMS Configuration if your application requires only partial generator-based charge, which can be later supplemented by solar or other renewable energy sources. This allows for maximum fuel saving and reduced wear on the generator.
- **Pre-charge Control** – This optional feature requires hardware implementation inside of the BMS unit. The purpose of this feature is to reduce inrush current when closing the contactor into a capacitive load, such as an inverter or motor controller. When the BMS is commanded to close the contactor, it will first close a small pre-charge relay in series with a pre-charge resistor, which limits the current to a safe low level. Such a small current will safely charge the capacitive load, reducing voltage across main the contactor, then the BMS will close the main contactor without high inrush current. Pre-charge timing and voltage threshold are configurable, allowing fine tuning of the process in complex systems with mixed capacitive and resistive loads. If at the end of pre-charge timer voltage threshold has not been reached, BMS will not close the contactor and will set **PRECHARGE_ERROR** status flag for troubleshooting purposes. This protects the system in case of pre-charge circuit failure or short circuit at the Load side of the BMS. **NOTE: If load resistance is very low (such as a high-power resistive load bank) then the BMS will mistake it for a short circuit. In this case you must disable the pre-charge control feature as it was not designed for resistive loads.**
- **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.
- **Charger OFF control** – When BMS is wired to control a charger, it will disable the charger when battery power is commanded OFF with a long push of the Power button or the data stream command **\$BATOFF**. This is a safety feature to prevent chargers from outputting voltage when the battery is disconnected.
- **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.

- **Alarm Circuit** – An optional wiring circuit from the BMS which can provide an audible or visual alert when BMS detects any trouble with the battery.
- **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.

BMS Configuration

The BMS stores several configuration parameters in its EEPROM memory. These parameters configure the BMS for a specific battery size, voltage and application. Normally Lithionics Battery ships every BMS unit pre-configured for the specific battery, but in some cases the customer may need to make changes to those parameters to better match their individual system requirements. The BMS configuration can be done over a Serial or TCP/IP data interface, by entering SETUP mode and using AT commands. If you do not have a data interface connected, but have an LCD display, most parameters can be changed using the 2 buttons on the LCD Display.

Configuring BMS using LCD Display Unit

To enter the BMS Configuration Menu press and hold both buttons on the LCD Display simultaneously for 6 seconds. The BMS will enter SETUP mode and will display the first configuration parameter and its current value.

-Press the left button to scroll through the range of values.

-Press the right button to lock the value and move to the next parameter screen.

NOTE: If no button(s) are pressed within 5 minutes then Setup Mode will time-out and switch to display mode automatically.

Below is the listing of all setup screens and their variable descriptions. The factory default values are recorded for you at the end of this document for your reference.

Pack Size - Battery pack Amp Hour capacity. Settings are from 1Ah to 3000Ah. 0-50Ah are in 1 Ah increments. 50Ah-3000Ah are in 10 Ah increments.

Full Vlt – Full Voltage. Set this to the maximum per-cell voltage your battery reaches at the end of charge. This will be used to sync the SoC meter’s 100% reading when the battery reaches this voltage level. Typically, this value is 3.55V per cell. So, a 12V (4 cell) battery is $4 \times 3.55 = 14.2V$. When battery reaches this voltage at the end of charge cycle, the SOC value will reset to 100%.

NOTE: If you notice that your SoC meter value never reaches 100% at the end of charge cycle, you may need to slightly lower Full Vlt value to what the voltage reading is on LCD Display at the moment when the charger turns off. This value must be higher than the resting voltage of the battery since the charger’s end voltage is higher than its resting voltage. Typical value range should be between 3.50 and 3.60 VPC.

Min SOC – Minimal State of Charge. This percentage value sets the “Empty Battery” level, a.k.a. Reserve Capacity, so the user can go by a BAT Gauge reading and not completely deplete the battery, to preserve its lifecycles. For example, if this value is set to 20%, then BAT Gauge will report 0% when SoC is still at 20%. If you desire to use your battery to its full capacity and/or want the BAT Gauge to reflect true SoC, then set this value to zero.

In addition, when RVC Mode is enabled, BMS will turn off battery power when SoC reaches this preset level, assuming it comes before battery voltage reaches RVC level, typically 3.00VPC. This allows NeverDie® Reserve feature on Advanced Series BMS to act on both voltage trigger and SoC level trigger, whichever comes first.

AGSR On/Off – AGSR trigger points. These percentage values determine the minimal and the maximum Bat Gauge levels at which the Automatic Generator Start/Restart circuit is triggered on and off. AGSR On circuit also triggers on voltage set to 3.05VPC, hence allowing flexible control of generator starting point. The circuit also triggers off when voltage reaches 3.50VPC with 15min delay. AGSR On value must be non-zero to activate this feature. Setting AGSR On to zero disables the AGSR feature completely.

Temp Unit – Temperature Units. Set this to Fahrenheit (F) or Celsius (C).

Idle Load – Idle Load (mA). This setting represents the constant idle load current powering the BMS system. This can be measured with a digital multi-meter in DC amperage mode in series with the BMS’s negative reference wire. Allowed range is 0mA – 200mA. Since idle current is usually too low to register by internal hall-effect sensor, but still affects SoC reading over long time periods when battery sits idle, setting this value allows for better long-term accuracy of SoC counter.

Alarm – Alarm function. Turns ON or OFF an Alarm function, which drives internal buzzer as well as AUXOUT2 external relay circuit when BMS is in Alarm state.

RVC – NeverDie Reserve function. Default setting STD (Standard) would turn off the battery while leaving reserve charge, which can be accessed by pressing the reset button. When set to EXT (Extended) amount of reserve charge is increased on voltage-based triggers.

Serial Data Interface

Lithionics Battery offers several options to connect your BMS serial port to a standard PC interface such as USB or RS232. Please refer to Appendix B for technical details. Once connection is made and COM port is initialized there will be a continuous stream of data packets with 1 second time interval between each packet. Each data packet is an ASCII string of 47 characters, containing 10 data fields. Each field starts with a label character and is followed by a numeric data of constant length, padded by leading zeroes. Each string is terminated by return and new line characters, bytes 0x0D and 0x0A.

Example of Serial Data packet:

B1H00000V0000F000S000D0A00000W000000T000R000000

Serial Data packet fields:

B – Battery address, typically 1, in multi-battery systems this will represent battery order – 1-digit long

H - AmpHours remaining, in 0.1Ah resolution, i.e. 123 = 12.3Ah – 5-digit long

V – Volts, in 0.1V resolution, i.e. 123 = 12.3V – 4-digit long

F - Bat Gauge, in percent, i.e. 100 = 100% – 3-digit long

S - SoC percent, in percent, i.e. 100 = 100% – 3-digit long

D – Current direction, 1 – charging, 0 – discharging – 1-digit long

A - Amps instant, in 0.1A resolution, i.e. 123 = 12.3Amp – 5-digit long

W - Watts instant, in 1W resolution, i.e. 20000 = 20000W – 6-digit long

T – Temperature, in degrees, units depends on setup parameter – 3-digit long

R – System Status – 6-digit long, see details below

NOTE: Two additional data formats are available by setting DTYPE value in Config mode. All 3 formats have the same data fields in the same order, with same line termination, the difference is only in delimiters.

DTYPE=0 – fixed length data fields with labels as described above.

EXAMPLE: B1H00010V0135F100S100D0A00000W000000T077R008080

DTYPE=1 – variable length data fields with labels, comma delimited, with label “E” indicating end of string

EXAMPLE: B1,H10,V135,F100,S100,D0,A0,W0,T77,R008080,E

DTYPE=2 – fixed length data fields without labels, comma delimited

EXAMPLE: 1,00010,0135,100,100,0,00000,000000,077,008080

TCP/IP Data Interface

If your BMS is equipped with the optional TCP/IP Data Interface, you can connect the BMS to your LAN and transmit data to any IP based host. The TCP/IP interface supports Auto Negotiation (Full/Half duplex and 10/100 Mb speed). Data is transmitted over a UDP socket in a text string with CR+LF termination. The data format is the same as RS232 Serial Data, see above chapters. The data string is inserted into a UDP packet and sent to the destination IP address. The receiving host would listen on UDP socket, get the data string and break it down into the individual data fields.

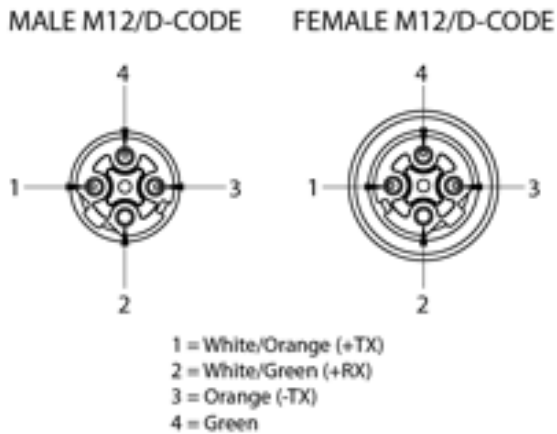
BMS is shipped with default IP configuration described below:

- IP Address – **192.168.0.254**
- Subnet Mask – **255.255.255.0**
- Gateway – **192.168.0.1**
- Destination IP – **192.168.0.255** (broadcast to local LAN)
- Source Port – **48879** (0xBEEF)
- Destination Port – **65261** (0xFEED)



To change the BMS' IP configuration for your network you must use the Serial-Ethernet Gateway Configuration device (**Lithionics Part# 50-196**) which can be used with a Windows PC to communicate with the BMS over a crossover RJ45 cable. This allows you to avoid connecting the BMS to a live network, which might have different IP addressing, and also to allow the use of a simple serial terminal for configuration, rather than writing custom software to handle UDP socket communications. This device has a USB Serial port based on the common FTDI chipset, so it's recognized as a COM port by Windows host. Free terminal software Terminate can be used to communicate to the BMS thru the Gateway device, see RS232 Data Interface section above for details. Once the BMS is configured with the desired IP addressing it can be connected to a live network for real time data processing.

BMS Ethernet TCP/IP Physical Interface: Typically, the physical interface is an M12 D-Coded connector which is an industrial weather resistant standard for an Ethernet connection. If your network connection requires a RJ45 plug, use a conversion cable from M12 to RJ45.



CANBus Data Interface

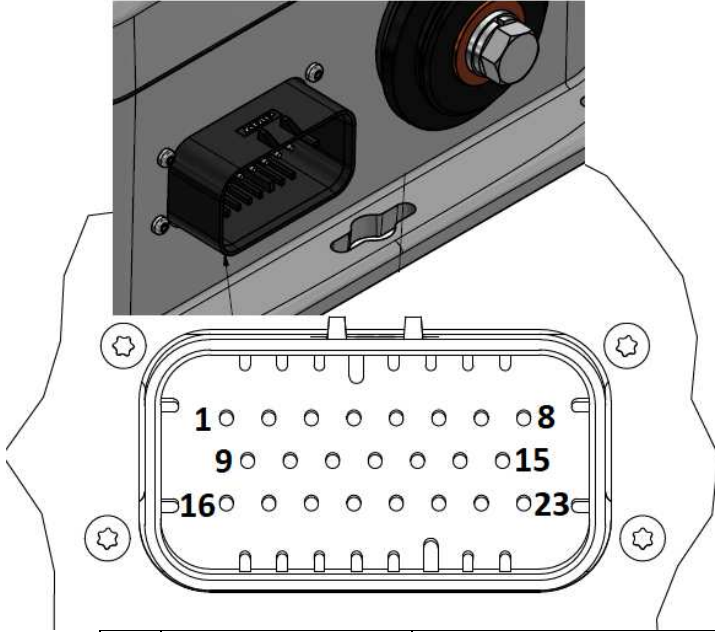
If your BMS is equipped with the optional CANBus interface, you can connect the BMS to any CANBus compatible receiver and read BMS data messages. The following messages have been defined for Advanced Series BMS. Default bus speed is 250kbps but can be configured for 125kbps or 500kbps if required. Messages use 29-bit addressing and 8-byte data frames (CAN 2.0B). Messages are formatted for compatibility with RV-C protocol, which is also partially compatible with J1939, NMEA2000 and XanBus networks. The CANBus electrical interface circuit is galvanically isolated from the battery pack to prevent ground loops and allow multiple BMS units on the same bus. For additional protocol details see RV-C Application specs at <http://www.rv-c.com/>

1. **Termination.** CANBus network requires 120 Ohm termination resistors connected to each end of the bus. BMS has one integrated resistor, so BMS can be installed at one end of CAN network. If your CAN network has it's own termination resistors, or if you have multiple BMS units, consult with Lithionics Battery or your dealer on removal of integrated resistor.
2. **Node addressing.** Due to resource limitations BMS will not support dynamic address assignments at this time. Source Address (SA) will be configurable via BMS configuration interface and default value will be set to 70 (0x46) per RV-C specs for a BMS device. If multiple BMS devices are present on the network, then integrators can change SA from default value to another appropriate value.
3. **Instance addressing.** Many data messages include an instance number, allowing multiple instances of a device class to coexist on the network. Instance will be configurable as BATID in the BMS configuration interface with default value set to 1. If multiple BMS devices are present on the network, then integrators can change the instance number from default value to another appropriate value according to RV-C specs.
4. **Supported messages.** Below messages will be supported by the BMS as defined in the RV-C Application specs. Last 2 messages are proprietary for Lithionics BMS status reports and future development.

Message	DGN / PGN	Notes
REQUEST	0xEA00	BMS listens and responds to these messages
ADDRESS_CLAIM	0xEE00	BMS will claim preset SA=0x46, but can be changed in config
DM_RV	0x1FECA	Diagnostic data as defined in RV-C specs
PRODUCT_ID	0xFEED	Identification message Li3*8***
DC_SOURCE_STATUS_1	0x1FFFD	provides battery Voltage and Current data
DC_SOURCE_STATUS_2	0x1FFFC	provides battery Temperature and SOC data
DC_SOURCE_STATUS_3	0x1FFFB	provides remaining Ah capacity
DC_SOURCE_STATUS_4	0x1FEC9	provides desired charger state and charge specs
DC_SOURCE_STATUS_6	0x1FEC7	provides HVC and LVC status
DC_SOURCE_STATUS_11	0x1FEA5	provides more status bits, total Ah capacity and current Power
DC_SOURCE_COMMAND	0x1FEA4	accepts ON/OFF/Charge-ON commands
PROP_LITHIONICS_COMMAND	0xEF45	accepts request for proprietary status data
PROP_LITHIONICS_STATUS	0xEF##	provides proprietary status bits and other data

For detailed description of messages and data encoding, download a document - **NeverDie BMS Advanced CANbus protocol.pdf** from <http://www.lithionicsbattery.com/user-guides/>

AMPSEAL Connector



The NeverDie® BMS has a 23 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.

NOTE: Some pins are part of optional BMS features and may not be enabled on your BMS unit. Please check with your battery supplier or Lithionics Battery regarding available features in your BMS unit.

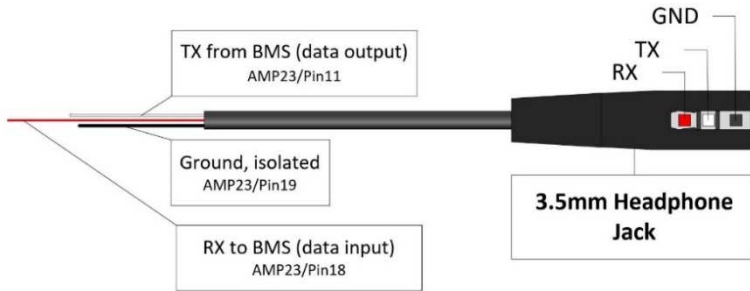
Pin	Function	Description	Details
1	FCC 1	Alternator Field Control Circuit wire 1	dry contact, up to 24VDC 2A, needs ext. fuse
2	AGSR 2	Automatic Generator Start/Restart wire 2	dry contact, up to 24VDC 2A, needs ext. fuse
3	AGSR 1	Automatic Generator Start/Restart wire 1	dry contact, up to 24VDC 2A, needs ext. fuse
4	+12V Supply	Pre-charge/Alarm output 12V supply positive	15V 500mA load limit, internally PTC fused
5	Pre-charge Out Neg	Pre-charge output negative wire	low side protected FET switch, 1A load limit
6	Alarm Out Neg	Alarm output negative wire	low side protected FET switch, 1A load limit
7	+12V Ext Pwr Input	AC sense / External power positive wire	BMS ext. power, needs 11-18VDC 3A supply
8	GND	Common Ground for all non-isolated circuits	Tied to battery negative with 8A internal fuse
9	FCC 2	Alternator Field Control Circuit wire 2	dry contact, up to 24VDC 2A, needs ext. fuse
10	CAN High	isolated CANBus High signal	5V isolated CAN_H signal - TI ISO1050 IC
11	UART TX	isolated serial UART TX signal	0-5V CMOS/TTL signal, isolated from battery
12	Analog BAT% Output	analog 0-5V BAT% Output signal	0-5V analog signal, 1mA load, not isolated
13	LED-Pod Green	Tri-Color LED Pod - Green signal	15V 50mA LED driver, internally PTC fused
14	Charger Relay 2	Charger Interlock relay wire 2	dry contact, up to 48VDC 100mA, needs ext. fuse
15	Reset Button 1	Reset button wire 1	15V 5mA normally open push button circuit
16	CAN/UART +5V	isolated CANBus 5V power	5V 50mA isolated supply for PC interface dongle
17	CAN Low	isolated CANBus Low signal	5V isolated CAN_L signal - TI ISO1050 IC
18	UART RX	isolated serial UART RX signal	0-5V CMOS/TTL signal, isolated from battery
19	CAN/UART GND	isolated CANBus/Serial ground	isolated ground for PC interface, CAN shield drain
20	LED-Pod Red	Tri-Color LED Pod - Red signal	15V 50mA LED driver, internally PTC fused
21	AUX Input	Auxiliary input signal	15V 5mA input for custom BMS functions
22	Charger Relay 1	Charger Interlock relay wire 1	dry contact, up to 48VDC 100mA, needs ext. fuse
23	Reset Button 2	Reset button wire 2	15V 5mA normally open push button circuit

Serial Port Connector

The BMS is equipped with AMPSEAL 23-pin connector, which includes pins for UART serial port. These pins are wired to a standard 3.5mm phone jack, which is used to connect to a UART-USB dongle, commonly available from suppliers like Mouser, Digikey, Allied, etc. This allows you to connect the BMS to a laptop via USB port used as a virtual COM port. Here is the link to the USB dongle at Mouser:

<https://www.mouser.com/ProductDetail/TTL-232R-5V-AJ?R=0virtualkey0virtualkeyTTL-232R-5V-AJ>

And a pinout of the 3.5mm jack to BMS Ampseal 23-pin connector

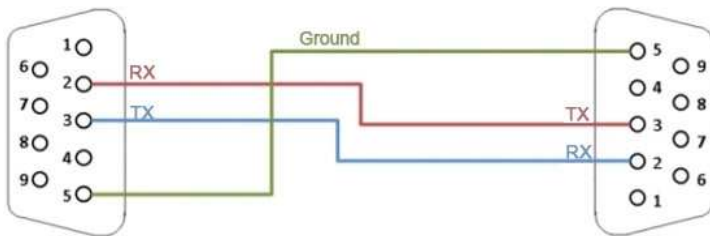


NOTE: If your BMS is equipped with a Bluetooth module, then external Serial Port is disabled. Since Bluetooth operates over serial port internally, only one option can be enabled, either wired Serial Port or wireless Bluetooth module. Specific configuration is assigned during BMS manufacturing and cannot be changed by a customer. Please contact Lithionics Battery or your dealer for details.

If your BMS is equipped with the optional RS232 Serial Data interface, then either a typical DB9 connector or more industrial M12 3-Pin A-Code connector can be used as the data cable. You can connect the Serial Data cable between the BMS and a Computer to communicate with the BMS. You can use a commonly available RS232 to USB adapters when connecting to PCs without a native RS232 port. We recommend adapters based on the “FTDI” brand chipset, which are robust and have native driver support in popular PC Operating Systems.

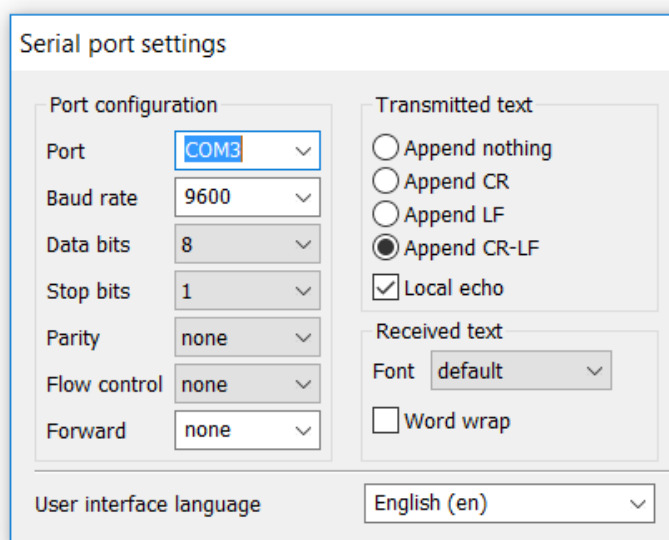
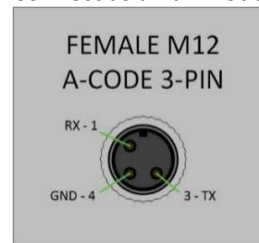
DB9 Pin-out:

Connect as a null modem cable



M12 A-code 3-Pin Pin-out:

Connect as a null modem cable



Any terminal emulator software with COM port support can be used to communicate with BMS. We recommend free software called Terminate, which allows data logging and has bidirectional command interface:

http://www.compuphase.com/software_terminate.htm

Download “complete setup” version to be able to save data log files for later analysis.

In the Terminate configuration screen set the port parameters as shown in the screenshot, selecting the COM port number which is connected to BMS. It’s critical to set “Transmitted text” parameters exactly as shown here to communicate with the BMS successfully.