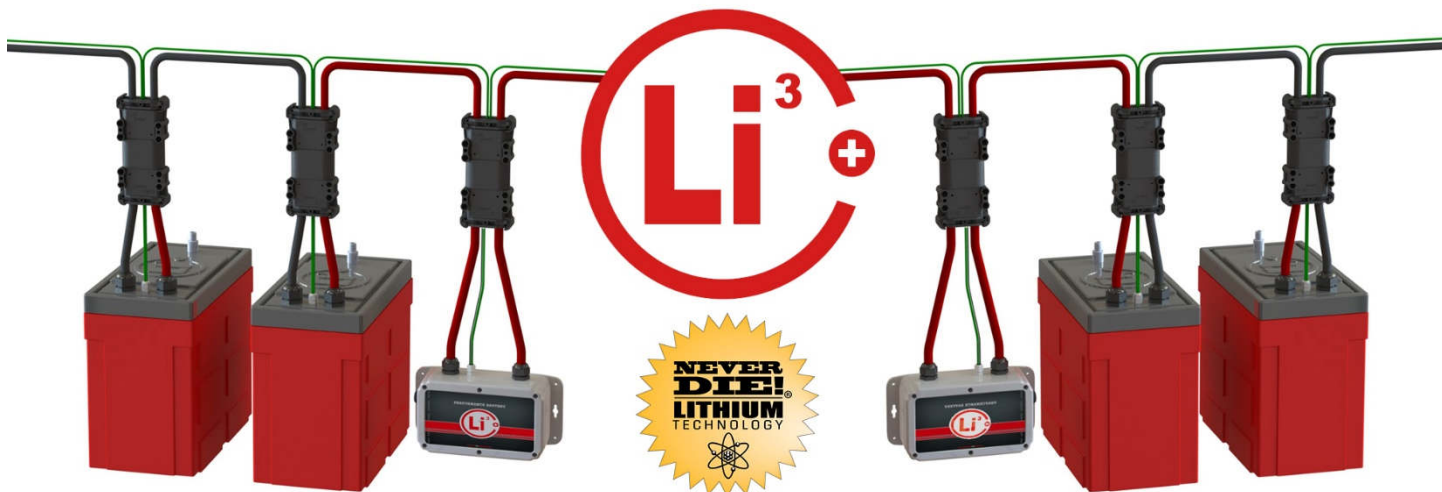


Lithionics Battery



NeverDie® Battery Management System (BMS) Advanced Series



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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.

Included Features

- **OptoLoop® interface.** A uniquely designed continuous opto-isolated loop circuit running through each battery cell's voltage monitor. OptoLoop® alerts the BMS if any single cell is outside of the acceptable voltage range.
- **Power/Storage Mode Switch.** Shuts off battery power in Storage Mode, provides additional safety and compliance with US/DOT regulations for shipping batteries.
- **200A Contactor.** Zero coil energy consumption compared to classic relays which consume over 2 Watts of power continuously.
- **Reset/On/Off button (multifunctional).** Intelligent control of multiple functions, see more details in Product Manual sections below.
- **Coulomb Counter based SOC meter.** Precision SOC measurements using Hall Effect sensor and Coulomb Counter to integrate charge/discharge current over time.
- **Reserve Voltage Cutoff (RVC).** NeverDie® function - 10% energy reserve when you need it most. Configurable reserve level based on true SOC value.
- **Low and High Voltage Cutoff (LVC/HVC).** Pack level and Cell level battery protection from over-charge and over-discharge.
- **External Temperature Sensor.** Factory installed temperature sensor inside the battery module to report actual battery core temperature to the BMS, which can disconnect the battery power in extreme temperature conditions, to prevent battery damage due to overheating or freezing.
- **Field Control Circuit (FCC).** Protects the alternator diodes by safely discharging field energy prior to disconnecting the battery. Disables alternator output when battery detects overcharge, in HVC event.
- **Automatic Charger Detection.** Senses voltage on the load side of the BMS when charge source is present and turns the battery on for charging.
- **Short Circuit Detection.** Disconnects the battery when a short circuit is detected.
- **TVS Flyback Diode.** Protects the BMS from inductive kickback at the load side when the contactor is open.
- **Sealed NEMA Enclosure.** The BMS is housed in a sealed NEMA box for convenient placement near the battery modules.
- **VTE Power Posts.** Heavy duty terminal posts for the battery and load connections.
- **Deep Sleep Mode.** Zero BMS idle load on fully discharged battery.

Optional Features

- **Automatic Generator Start/Restart (AGS/R).** Normally Open dry contacts to signal the generator on/off when battery needs charging. Requires a generator with auto-start function.
- **Alarm Signal Circuit.** Sends an audible or visual alarm signal to get attention when the BMS detects a problem with the battery modules.
- **400A Contactor.** Double the current rating for higher power systems.
- **Dual Contactor.** Separate Charge and Load busses for more complex systems.
- **EURO DIN Advanced connectors.** Improves connection safety by eliminating terminal posts and integrates OptoLoop® connections. Truly Plug and Play battery connections.
- **Pre-charge Relay circuit.** Pre-charges capacitive loads such as inverters or motor controllers to protect the BMS contactor from welding during inrush transient.
- **TSM Charger control.** Controls TSM Chargers over CANBus interface (chargers sold separately).
- **AC power sense for Charge Detection.** Enables charging when AC power is present, but charger must sense the battery to start charging.
- **Remote Reset/On/Off button.** Wiring harness with Reset button for remote battery operations.
- **Round LCD pod.** Round 2" LCD display for panel mount, shows all available battery data such as SOC, Volts, Amps, Watts, etc.
- **Tri-Color LED pod.** Used for simple state of charge indication: Green/Yellow/Red.
- **CANBus Data interface.** Connector for CANBus Data Logging.
- **Serial Data interface.** Connector for UART Serial Interface. Supports conversion to USB or RS232 with separate dongle/adaptor for data logging and BMS configuration.
- **TCP/IP Data interface.** Ethernet network interface for TCP/IP data logging and configuration.
- **DAP (Drive Away Protection).** An extra safety feature for propulsion applications which prevents moving while charging.
- **Bilge Pump Terminal.** A separate dedicated contactor for a bilge pump with energy reserve to run the pump when other loads are turned off.

Custom Features

- **Wi-Fi, Bluetooth, RS485/Modbus interface, etc.** Custom data interfaces and other unique features can be developed for customers with unique requirements. Development / Engineering costs will apply. Contact Lithionics Battery sales team for details.

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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 functions 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.

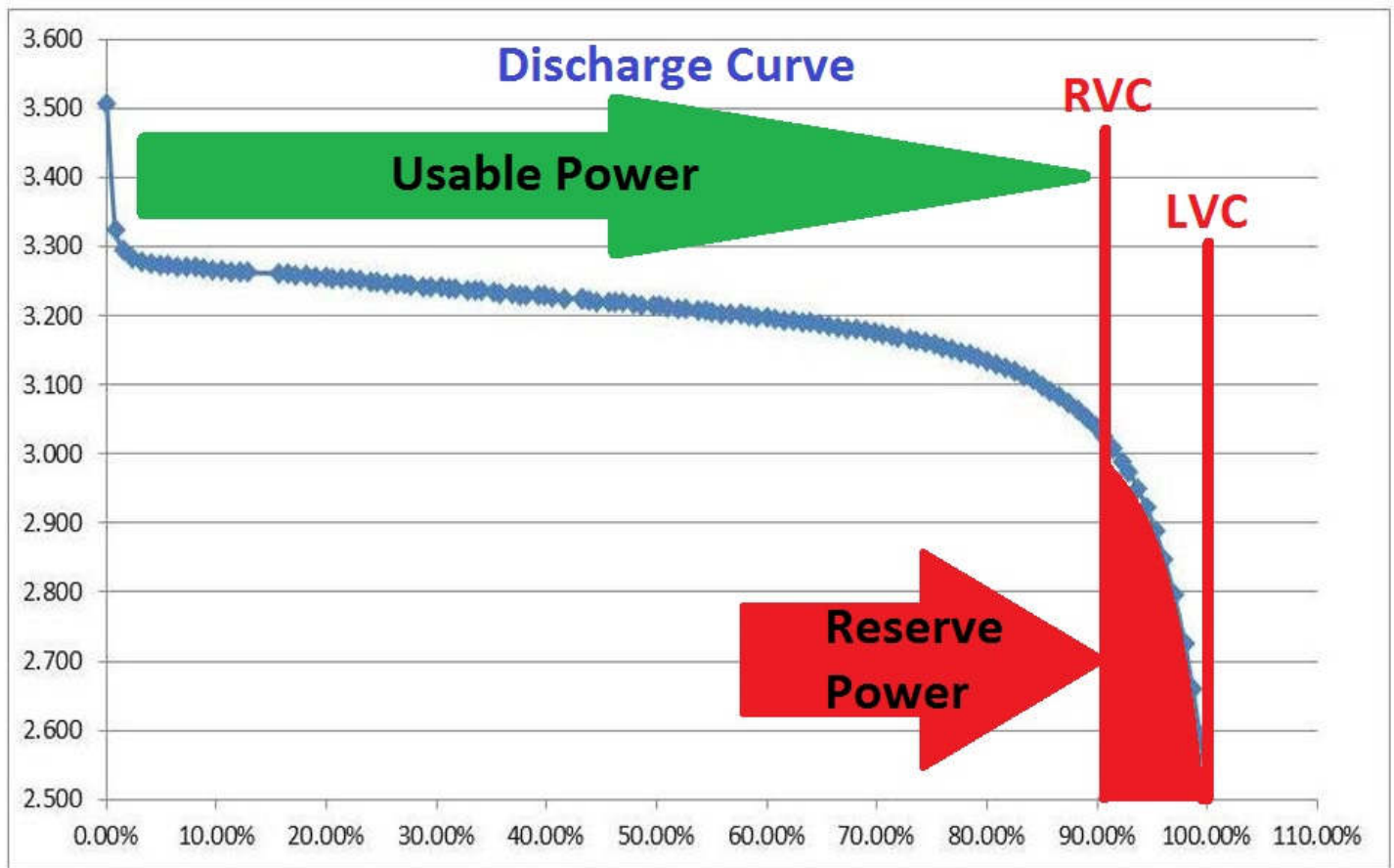
Installation

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 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 will lead to permanent battery damage and void your battery warranty!!!**

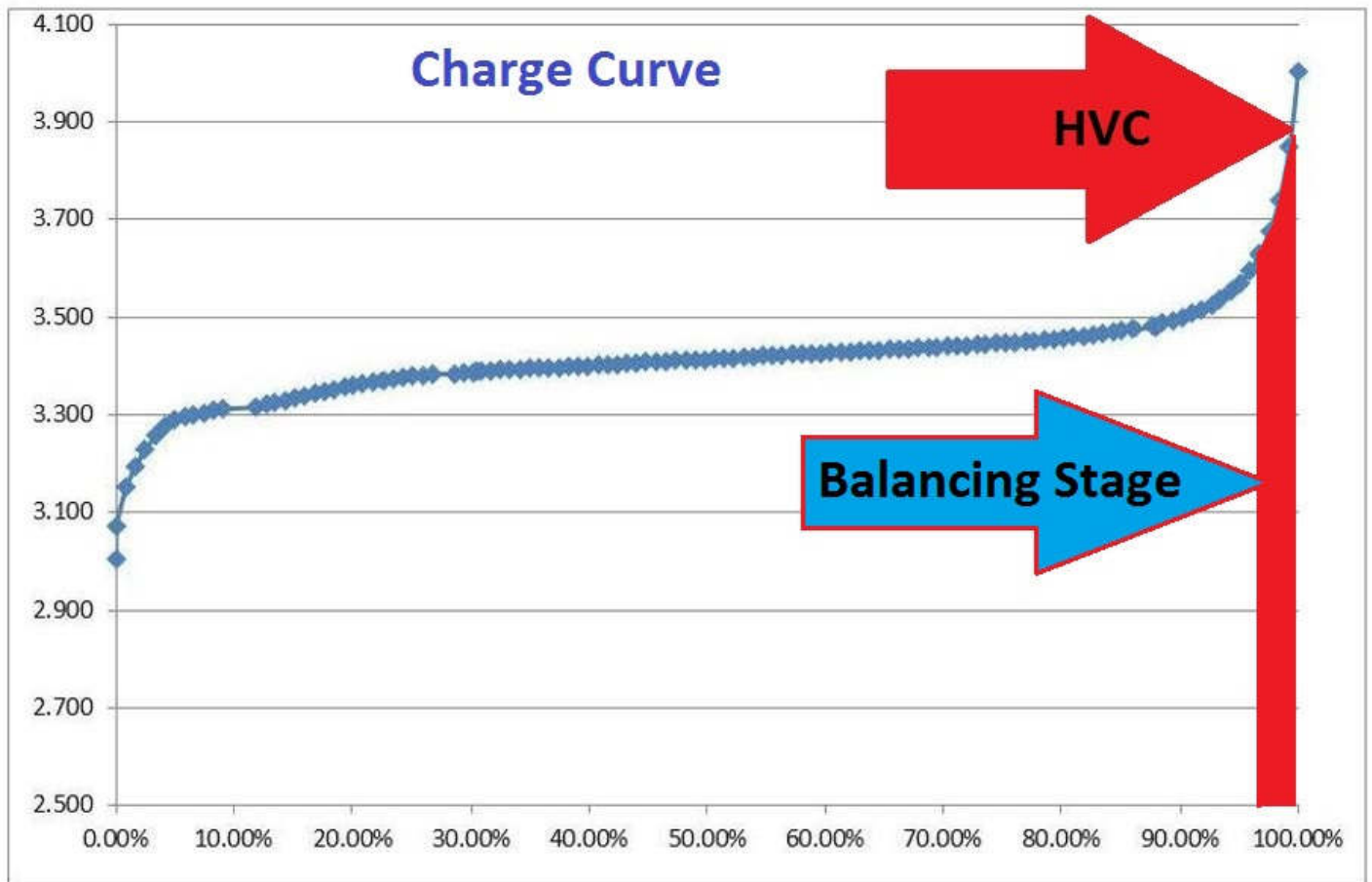
Definitions

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 4S configuration. Respectively, a 24V battery is 8S, while 48V batteries can be 15S or 16S depending on the model. Since BMS monitors and acts at the individual cell 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.
- **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 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 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 larger reserve power capacity if desired.
- **LVC – Low Voltage Cutoff.** Typically set to 2.5VPC. At this voltage the battery is almost fully discharged, so the BMS shuts off the battery to prevent damage due to over-discharge.



- **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.



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 alleviated.

When the BMS is initially powered on by the Power switch, it performs health checks across the OptoLoop® and also 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 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. Some applications may require dual stage Power Up, where BMS waits for a separate command to close the contactor. This mode can be enabled in the BMS configuration if desired.

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 Reset button for 3 seconds or by sending the **\$BATOFF** command via its data interface.

Below is a detailed description of all 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.

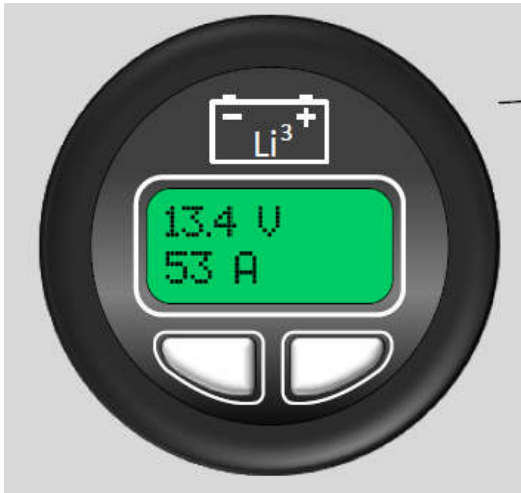
- **Power On/Off** – when the BMS is turned off via the Power Switch, it will automatically open the contactor, disconnecting the battery power output. The battery can also be disconnected by holding the Reset button for 3 seconds, or by sending **\$BATOFF** command via its digital interface. Short press of Reset button will turn the battery back on and allow use of battery power.
NOTE: 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 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 Reset button for 5 seconds while powering on the BMS with the Power Switch. 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 500ms prior to opening main contactor, allowing alternator field to collapse 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 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 Reset 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 properly fused and does not rely on the BMS alone for short circuit protection!

- **Automatic Generator Start/Restart (AGS/R)** – 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 Lvl” level set in BMS Configuration, whichever comes first. The AGS/R circuit will open when the voltage rises above 3.5VPC after 15-minute delay, which simulates a Constant Voltage charge stage. You can also manually turn AGS/R circuit on and off by briefly pushing Reset button while the battery is turned on.
- **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 have to 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 Reset button or the data stream command **\$BATOFF**. This is a safety feature to prevent chargers from outputting voltage when the battery is disconnected.
- **Deep Sleep mode** – When battery power is turned off the BMS enters deep sleep mode, turning off power to all peripheral interfaces and reducing power consumption to around 1mA. It will wake up from this mode when charging voltage is detected or if Reset button is pressed to turn on the battery power.
- **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, power cycle the BMS with the Power Switch or hold down Reset 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 any cell reports either a HVC or LVC condition over the OptoLoop® interface.
- **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.

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. If they are ever accidentally modified a record of the default values is included in this manual for your reference. 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.

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 Gauge. Each of the 6 bars corresponds to approximately 17% of capacity.
- **100% BAT** – Digital Battery gauge. BAT level is derived from SOC minus the MinSOC setting explained in the Settings section below, allowing for a hidden reserve
- **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 Tmp** – Instant temperature reading. Can be set to C or F in the Config menu. Temperature data comes from external sensor if present, or from BMS internal sensor if external sensor is not present.
- **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 with 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.

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.

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:

B1H00000V0000F000S000DOA00000W000000T000R000000

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: B1H00010V0135F100S100DOA00000W000000T077R008080

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

EXAMPLE: B1,H10,V135,F100,S100,DO,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

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 of data. In CANBus stream it's located in the first 3 bytes of the message ID = 0x18FF98FA (Battery State). See CANBus documentation for details.

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

Description of System Status bits:

HEX Digit 6				HEX Digit 5				HEX Digit 4				HEX Digit 3				HEX Digit 2				HEX Digit 1			
23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Bit 0 – High Voltage State. Indicates that battery voltage is above HVC, typically 3.70VPC.

Bit 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.

Bit 2 – NeverDie Reserve State. Indicates that battery is in the NeverDie Reserve State, allowing access to reserve energy.

Bit 3 – OptoLoop® Cell Loop 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.

Bit 4 – Reserve Voltage Range. Indicates that battery voltage is below RVC, typically 3.0VPC.

Bit 5 – Low Voltage State. Indicates that battery voltage is below LVC, typically 2.6VPC.

Bit 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.

Bit 7 – Power Off State. Indicates that battery was turned off by a command or a button press.

Bit 8 – 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.

Bit 9 – AUX Contacts Error. In case of contactor welding, this bit will indicate discrepancy between expected and actual state of contactor. It also sets Bit 6 – Battery Protection State.

Bit 10 – 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.

Bit 11 – 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.

Bit 12 – AC Power Present. Indicates that BMS detected AC power presence, so BMS expects charging to begin shortly. This optional feature requires special wiring inside BMS unit to connect to AC grid.

Bit 13 – 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.

Bit 14 – 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.

Bit 15 – External Temp Sensor Error. Indicates a problem with external temperature sensor installed inside the battery module. Temperature data from this sensor is used to cutoff battery power under extreme temperatures.

Bit 16 – AGSR State. State of optional AGSR Control circuit, used to start/stop generators when BMS is wired into supported generator’s auto start interface.

Bit 17 – High Temperature State. Temperature detected by external sensor exceeded allowed threshold.

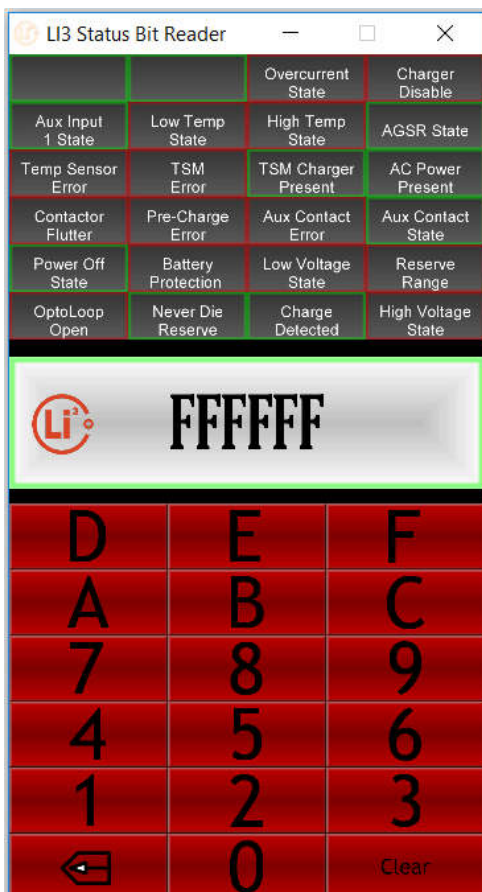
Bit 18 – Low Temperature State. Temperature detected by external sensor is below allowed threshold.

Bit 19 – Auxiliary Input 1 State. Reflects the state of AUXIN1 input, which is optional and application specific.

Bit 20 – 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.

Bit 21 – Overcurrent State. BMS detected current higher than preset limit.

Bit 22 – Bit 23. Not used, reserved for future functions.



Lithionics Battery has developed the **Li3 Status Bit Reader** application for Windows and Android platforms, which 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 these applications from <http://www.lithionicsbattery.com/user-guides/>

Each bit description is color coded in green or red border, 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. To enter the new value, click Clear button first, then enter the new value.

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)

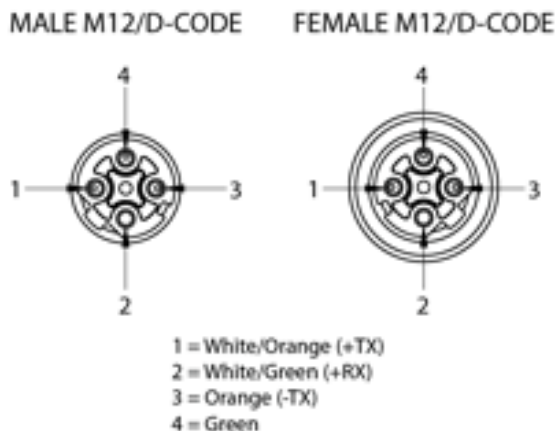
Source Port – **48879** (0xBEEF)

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 Termite 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. **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 69 (0x45) 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. Per RV-C specs address 70 (0x46) can also be used.
2. **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.
3. **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=0x45, but can be changed in config
DM_RV	0x1FECA	Diagnostic data as defined in RV-C specs
PRODUCT_ID	0xFEEB	Will fit in 3 frames – INITIAL_PACKET + Li3*BMS*v714**
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](http://www.lithionicsbattery.com/user-guides/) from <http://www.lithionicsbattery.com/user-guides/>

BMS Commands Processing

During normal operation the BMS can receive and process certain commands from Serial, Ethernet or CANBus interfaces. CANBus command codes are described in the above chapter. Serial or Ethernet commands must be formatted as text strings starting with “\$” and end with CR+LF termination. Following commands are supported by BMS:

- **\$STREAMOFF** – Turns off data stream.
- **\$STREAMON** – Turns on data stream.
- **\$POLL** – Poll data one time while continuous data stream is turned off.
- **\$BATOFF** – Turns off battery power. This command opens the main contactor, same as a long press of the Reset button.
- **\$BATON** – Turns on the battery power. This command closes the main contactor, same as a short press of the Reset button.
- **\$CHARGEON** – If the battery is over-discharged with the Cell Loop open, this command forces the contactor to latch ON to allow charging to begin. The BMS then expects a voltage rise to qualify that it is being charged.
- **\$TRACEON** – Turns on additional data string in the serial output, with extra data points useful in advanced troubleshooting.
- **\$TRACEOFF** – Turns off additional data string in the serial output.

BMS Configuration

The BMS stores a number of configuration parameters in its EEPROM memory. These parameters configure the BMS for a particular battery size, voltage and application. Normally Lithionics Battery ships every BMS unit pre-configured for the particular 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 into 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 20 seconds 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.

Ah PackSize - 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 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

3.65V per cell. So a 12V (4 cell) battery is $4 \times 3.65 = 14.6V$, subtract .2V for charger accuracy tolerance = 14.4V full voltage setting. You may also calculate your maximum voltage by the following table:

Nominal Voltage	Full Voltage Setting
12.8V AKA "12V"	14.4V
16V	18.0V
25.2V AKA "24V"	29.0V
38.4V AKA "36V"	43.6V
51.2V AKA "48V"	58.2V
64.0V	72V
76.8V AKA "72V"	87V
89.6V	102V
102.4V AKA "96V"	116V

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.

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 3.0VPC. This allows NeverDie® Reserve feature on Advanced Series BMS to act on both voltage trigger and SoC level trigger, whichever comes first.

AGSR Lvl – AGSR level. This percentage value determines the minimal Bat Gauge level at which the Automatic Generator Start/Restart circuit is triggered. AGS/R circuit triggers on voltage set to 3.05VPC, or the Low Bat level, whichever comes first, hence allowing flexible control of generator starting point.

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

ChargeEff – Charging Efficiency. This percentage value slows down the rate of SoC climb during the charge to compensate for battery losses during discharge cycle. Recommended setting is 98%. In applications with high discharge rates, energy losses are more pronounced, so this value must be set lower to more accurately report SoC and BAT Gauge values during partial charges. This setting must be tuned experimentally for best accuracy. Ideal setting will cause SoC to reach 100% at approximately the same time as charger is finishing up the full charge.

DeadZone – Dead Zone. Due to thermal drift in Hall Effect sensors when temperature fluctuations are wide and fast, BMS might report non-zero current reading when no current is present. Dead Zone value allows ignoring small current readings when they are likely false (when small reading fluctuates between zero and non-zero values). Default value 0.3A is recommended for best zero-point stability.

IdleLoad – 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 ON would turn off the battery while leaving reserve charge, which can be accessed by pressing the reset button. When set to OFF entire battery charge is available without leaving any reserve. When set to EXT (Extended) amount of reserve charge is increased on voltage based triggers.

Configuring the BMS using Serial or TCP/IP interface

Entering Setup Mode: Upon initial power-up the BMS will be in data mode, so it will be sending data to the Serial or TCP/IP interface. Connect to the BMS using terminal software like Termiter, so you can send text commands to the BMS. You can ignore the incoming data and type in the following command and then press Enter to send it – **AT+SETUP**. If the command is accepted the unit will respond with **OK** and will stop sending data, expecting the next set of AT commands. Below is the listing of all commands. You do not have to send all the commands, only those which require changes to corresponding parameters. Once all changes have been sent, complete setup by sending the command – **AT+END**.

NOTE: If BMS does not respond to AT commands, make sure Termiter is configured to append CR-LF characters to the end of sent commands. The BMS requires that all commands end with CR-LF termination, or 0x0D 0x0A in ASCII code.

When using the Ethernet TCP/IP interface, once in setup mode the BMS will reset its IP configuration to the default listed in the above chapters of this document, so it can communicate with the Serial-Ethernet Gateway. It still stores previously configured IP parameters and will revert to them once exited out of setup mode (**AT+END**) back to data mode. This feature allows communication with the BMS even when its stored IP parameters are unknown or invalid, but requires use of the Serial-Ethernet Gateway with a crossover cable, to ensure matching IP parameters during setup mode.

NOTE: When using IP settings that are different than the defaults, polling data will NOT be received via the Ethernet TCP/IP configuration interface. Although polling data is not received, the BMS will still respond to the Setup Mode and Data Mode Commands listed below.

Listing of all AT commands: The commands listed below must be followed by a new value after “=” sign. If the new value is outside of the expected range an error message will be sent. If the new value is accepted and OK message will be sent as confirmation. For example, sending command **AT+AH=100** will set Pack AmpHours to 100AH. Only integer values are accepted, for example **AT+V=142** will set Full Voltage to 14.2V in 64V range system, but 142V in 350V range system. To list all stored values, use the **AT+LIST** command. A detailed explanation of each value is outside of the scope of this section. Please refer to the earlier chapter for a detailed explanation of each value.

- **AT+VR** – Voltage Range. Set to 0 for 64V range, 1 for 350V range, 2 for 600V range.
- **AT+AH** – Pack capacity in AmpHours. Valid range 1 to 3000. Use 1AH increments.
- **AT+V** – Full Voltage. Valid ranges 0 – 640. In 64V range system use 0.1V increments.
- **AT+MSOC** – Min SOC. Valid range 0 – 80. Percentage value.
- **AT+DIR** – Current sensor direction. Set to 0 for Reversed or 1 for Normal.
- **AT+AGSR** – Low BAT trigger level. Valid range 0 – 80. Percentage value.
- **AT+TU** – Temperature Units. Set to 0 for Celsius or 1 for Fahrenheit.
- **AT+CE** – Charge Efficiency. Valid range 50 – 100. Percentage value.
- **AT+DZ** – Dead Zone. Valid range 0 – 9. Use 0.1A increments.
- **AT+TM** – Test Mode. Set to 0 for OFF or 1 for ON.
- **AT+ST** – Sensor Type. Set to 1 for 600A square, 2 for 800A round, 3 for Y-splitter with 600A square
- **AT+ICAL** – Current Calibration. Valid range -125 to 125. Must be set experimentally to match trusted tools.
- **AT+VCAL** – Voltage Calibration. Valid range -125 to 125. Must be set experimentally to match trusted tools.
- **AT+IL** – Idle Load. Valid range 0 – 20. Use 10mA increments.
- **AT+BATID** – Battery ID. Valid range 1-9.
- **AT+CCNT** – Cell Count. Valid range 4-100.
- **AT+DTYPE** – Data Type. Set 0 for fixed data length, 1 for comma delimited format (CSV), 2 for fixed CSV.
- **AT+RVC** – Enable or Disable RVC (Reserve Voltage Cutoff) 0 for Off 1 for On.
- **AT+ALARM** – Enable or Disable Alarm function. Set 0 for Off, 1 for On.
- **AT+CHGCUR** – TSM Charger bulk current level.
- **AT+AUXCONT** – Aux contacts mode.
- **AT+PRCHTIME** – Pre-charge timing. Valid range 0-80. Use 125ms increments.
- **AT+PRCHVLT** – Pre-charge voltage threshold. Valid range 0-200. Use 1V increments.
- **AT+POWERUP** – 0 – single stage, 1 – dual stage Power Up mode.
- **AT+CONTCFG** – Contactor config. 0 – single, 1 – two in parallel, 2 – dual channel (charge/load)
- **AT+CANRATE** – Sets baud rate for CANbus interface. 0 - 125kbps, 1 - 250kbps, 2 - 500kbps
- **AT+CANS** – Sets source address for RV-C support. Default value 0x45 (69) is defined by RV-C protocol.
- **AT+FINSTAGE** – Final charge stage time limit. 0-disabled, 1-8 number of hours in final charge stage.
- **AT+VDROP** - 0-disabled, 1-250 distance in feet of 4/0 cable between BMS and battery modules.
- **AT+SIP** – Source IP address. Example - AT+SIP=192.168.0.254
- **AT+SMASK** – Source Mask.
- **AT+SGW** – Source Gateway.
- **AT+DIP** – Destination IP address.
- **AT+DPORT** – Destination port in decimal form. Example AT+DPORT=65261

NOTE: The below commands do not have any values. These commands execute actions as described below.

- **AT+LIST** – Lists all stored values.
- **AT+RESET** – Resets IP parameters to factory defaults and creates a new MAC address where the last 4 digits are randomly generated.
- **AT+END** – End Setup mode and resume to normal Data mode.
- **AT+SETUP** – Halt normal operation and enter Setup mode.

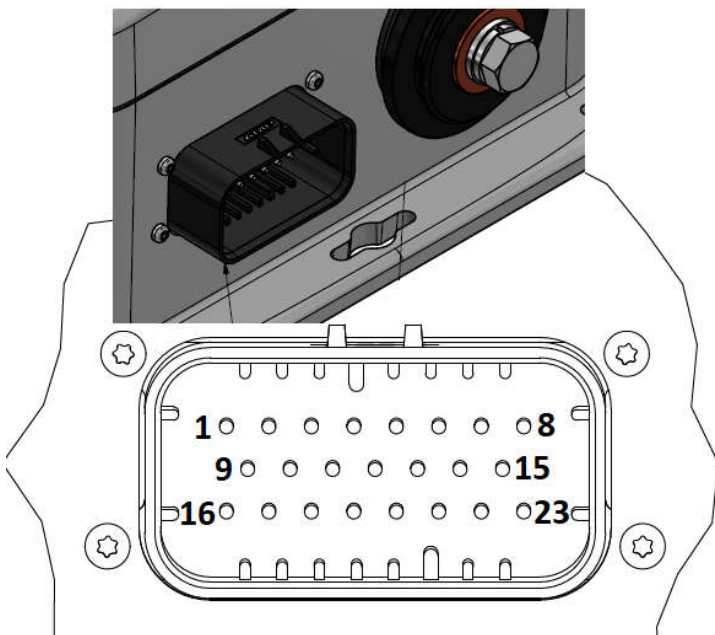
BMS Troubleshooting

Modules Voltages. Most Lithionics batteries are built as modular assemblies, with series connected battery modules and a BMS box. In such a modular architecture, troubleshooting comes down to 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 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.

OptoLoop® connections. Each battery module has a normally closed 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.

Appendix A: AMPSEAL Connector



NeverDie® BMS has a 23 pin AMPSEAL Connector on its side wall, 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.

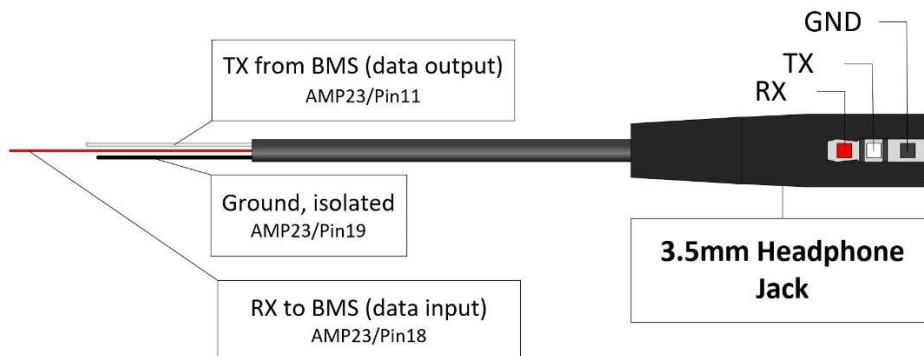
Pin	Function	Description	Details
1	FCC 1	Alternator Field Control Circuit wire 1	dry contact, up to 24VDC 2A, needs ext. fuse
2	AGSR 2	Automatic Generator Start/Restart wire 2	dry contact, up to 24VDC 2A, needs ext. fuse
3	AGSR 1	Automatic Generator Start/Restart wire 1	dry contact, up to 24VDC 2A, needs 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	5V 20mA 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	5V 20mA 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

Appendix B: Serial Port Connector

Latest versions of the BMS are 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

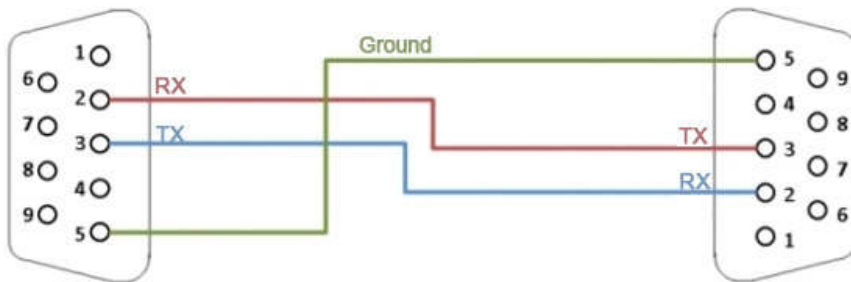


If your BMS is equipped with the optional RS232 Serial Data interface, then either a typical DB9 connector or more industrial M12 3-Pin A-Code connector can be used as the data cable. You can connect the Serial Data cable between the BMS and a

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.

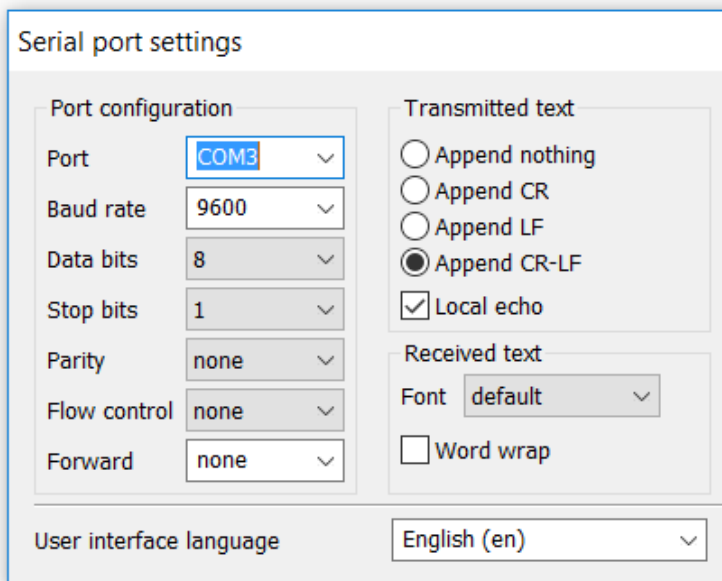
DB9 Pin-out:

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.