



BMS16 v2

8-16 cell Lithium Battery Management System

Introduction

The ZEVA BMS16 is an integrated battery management system for lithium battery packs containing 8-16 cells in series and 5-1200 Ah capacity. It is suitable for both electric vehicle and battery storage applications. The BMS16 includes an internal power supply to allow it to run directly from the battery pack, internal shunt resistors for automatic pack balancing, dual solid state relay outputs for switching power contactors to protect charging and discharging of batteries, built-in current shunt interface for measuring current and calculating battery state of charge, and a CAN bus port for optional colour touchscreen interface or integration with third party control systems.

The BMS16 Monitor provides information such as voltage, current, power, battery state of charge, and all individual cell voltages. It can also be used for configuring the operating parameters of the BMS16. It may be installed up to 50m from the BMS16 (if correct shielded twisted pair cable is used).

Battery management systems are the last line of defence for your battery pack. In normal circumstances it should not interfere with the battery pack's operation, only intervening when something goes wrong and protection is required.

Safety Warning

Although 8-16 cell lithium battery packs do not involve lethal voltages, they frequently involve dangerous amounts of current and power. Proper precautions and electrical safety procedures should always be observed. Please read this manual carefully to ensure correct installation and operation. If you are unsure of anything, please contact us before proceeding.

We have endeavoured to make a safe and reliable product which performs as described, however since ZEVA has no control over the integration of its products into a battery system, we can assume no responsibility for the final safety or functionality of the completed installation. It is up to the end user to determine the suitability of the products for the purpose employed, and the end user assumes all risks associated. Products should only be installed by suitably qualified and experienced persons, and should always be used in a safe and lawful manner.

Specifications

- Number of cells: 8-16
- Battery types: LiFePO₄, LiCo, LiMn, NMC, etc
- Accuracy: Within 0.002V per cell
- Battery capacity: 5-1200Ah
- Current measurement: 0-500A via shunt interface, 0-1200A with external sensor
- Dimensions: 120x80x16mm, 2x Ø4mm mounting holes 116mm apart
- Outputs: Dual solid state relays, 100V 2A max, internally fused
- Power consumption: Approx 30mA when running (with both output relays closed and a monitor connected to the CAN bus), 8mA when sleeping

Installation

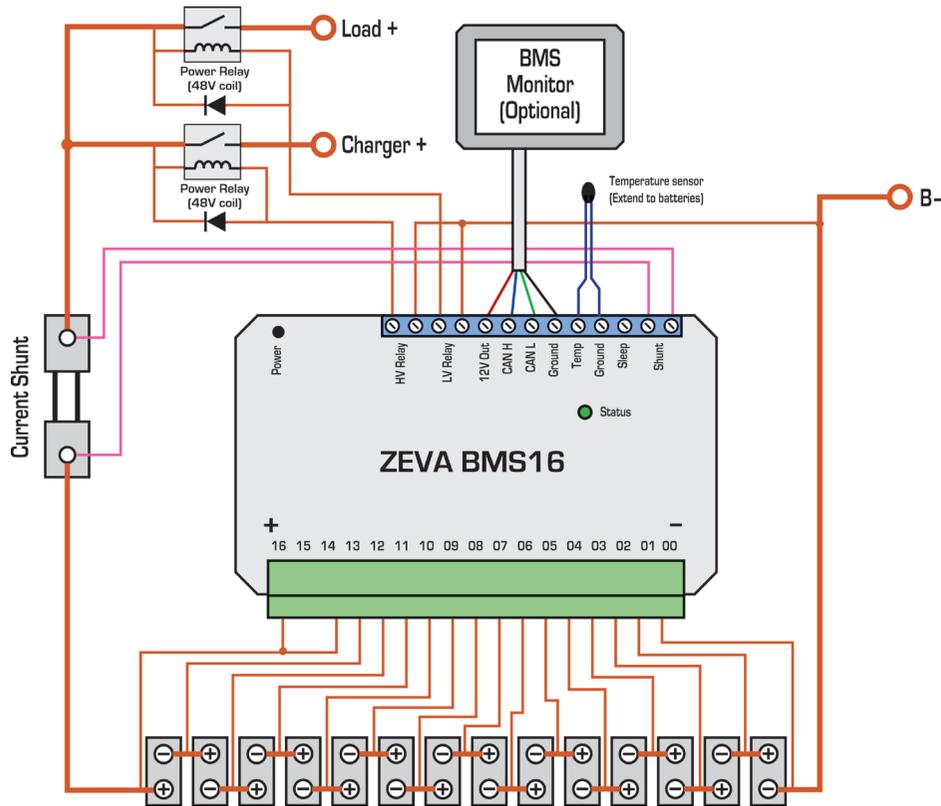
The BMS16 should be mounted securely using screws through the holes on the case flanges. Install the BMS16 in a location protected from direct sun and water, and close to the cells if possible to minimise cell wiring lengths (under 1m recommended).

The BMS16 has a pluggable screw terminal block for the cell connections, with the most negative point of the battery pack connected to terminal **00**, and successive positive terminals connected to **01–16**. Wire gauge around AWG20-26 is recommended for sufficient mechanical strength and suitable current rating. We recommend wiring up the plug and verifying all voltages before connecting to the BMS. The plug requires a significant amount of force to fully engage; ensure it is plugged all the way in for reliable connections.

If you need to disconnect the cell plug from the BMS, significant force is required for removal as well. For easier removal, a flat blade screwdriver may be used to lever the positive end of the plug out first, which should then be loose enough to remove by hand.

Ensure that all wiring is secured so it will not become damaged from vibration or abrasion.

Optionally small fuses (~1A) may be used to protect wiring, best installed close to each cell terminal. Device power is always taken from the most positive input **16**. If using the module with fewer than 16 cells, simply add a short jumper wire from your most positive cell terminal to **16**. An example wiring diagram for 14 cells is shown below.

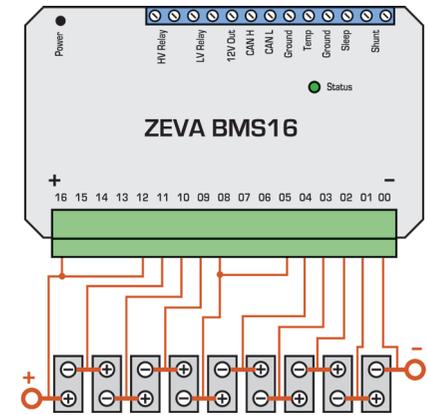


Relay outputs are floating / isolated, and have a maximum rating of 60V and 1.3A continuous. Be sure to include a flyback diode (if not built in to the relay/contactor) to suppress inductive voltage spikes from switching the relay coil. In installations with a single "battery enable" relay, the LV and HV relays may be wired in series such that either an over-voltage or under-voltage condition will open the relay to isolate the battery pack.

Once your wiring is complete, press the power button on the top left of the case, and the status LED should come on. A green light indicates all cells are within correct voltage range, and both relay outputs will be closed circuit. A steady red light indicates one or more cells are over-voltage, and the HV Relay outputs will be open circuit. A blinking red light indicates one or more cells are under-voltage, and the LV Relay outputs will be open circuit. Green/red flashing indicates an over-temperature shutdown.

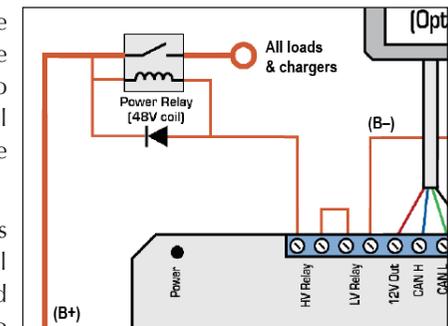
Packs Smaller Than 12 Cells

Internally the BMS16 uses two voltage sampling chips which are connected to up to 8 cells each, one spanning terminals **00** to **08** and the second from **08** to **16**. These samplers require a minimum of 4 cells each for reliable operation, so for packs with fewer than 12 cells, some unusual wiring is required. The most positive four cells should be connected between **08** to **12**, with a jumper from **12** to **16** (since the BMS draws power from **16** to power itself). Then the remaining cells are connected from **00** up, with a wire jumper from the most positive terminal in this group up to **08**. An example case for a 9-cell pack is shown right.



Protection Using a Single Contactor

It is possible for the BMS to control a single contactor to protect against both under-voltage and over-voltage conditions concurrently. To achieve this, the HV Relay and LV Relay terminal pairs should be wired in series, as per the diagram, right.



Note that in this configuration, if the BMS opens the main contactor due to an under-voltage cell for example, the battery pack will also be isolated from any charging sources so will be unable to charge (and correct the under-voltage condition) until the system is reset manually. For this reason it is important in this case that BMS intervention is an exceptional circumstance, and under normal operation chargers and loads will not cause any cells to exceed safe range.

Current Shunt

The BMS16 may be supplied with either a 100A, 200A or 500A shunt, which should be installed in the positive wire from the battery. The shunt is connected via two wires to the associated terminals on the BMS16. For best performance, twisted pair wire is recommended. The sample wire from the anode / positive side of the shunt (closest to the +ve terminal of the battery) should be connected to the left-hand terminal (as shown on the wiring diagram, left). By default, discharge amps are shown positive, though this can be reversed in settings if preferred. If your polarity seems to be reversed (e.g discharge current is causing SoC to increase), simply swap the two shunt wires into the BMS.

Note that the zero point of the current sensor is calibrated when the BMS is turned on, so for accurate current measurement it is essential that no current is flowing at this time. (In a correct installation it will be zero since the BMS should have control over all loads and charging sources and will not enable them until after shunt calibration.) It is also essential that there are no contactors or switches between the battery positive and the current shunt as these could change the voltage levels at the shunt when they open/close, throwing out zero point calibration.

Temperature Sensing

A temperature sensor may be connected to the BMS16 between the Temp and Ground inputs. The scaling is calibrated for a 100Kohm NTC thermistor with B25/100 value of 4540K. These are available from us, or most large electronics vendors.

It is recommended that the temperature sensor is installed somewhere near the middle of the pack, since this is typically the warmest location. Wires on the sensor may be extended as long as necessary. Temperature limits may be adjusted in settings, to warn if the temperature exceeds safe range, restrict charging if the battery is too cold, or shut everything down if the battery gets too hot.

Sleep Mode

The BMS16 has a Sleep terminal which may be used to put the device into a lower power standby mode by connecting a wire from it to a Ground terminal. It is most commonly used in mobile applications, when the vehicle is neither being driven or being charged. (Stationary applications typically run 24/7 so the Sleep terminal is often unused.)

Sleep mode will shut down the CAN bus and turn off both relay outputs. The device continues to monitor cell voltages and shunt current, and will turn itself off completely if any cells get extremely low.

Automatic Pack balancing

In battery packs built from many cells, optimum performance is attained when all cells are at the same State of Charge, also known as pack balance. The BMS16 uses a system known as “shunt balancing”, which switches on resistors across any cells which are above a threshold voltage to reduce their charge and bring them into line with other cells.

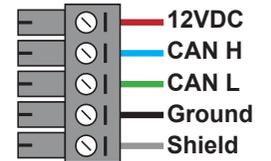
By default the BMS16 uses a dynamic balance threshold, where any cells more than 1mV above the average receive balancing. The threshold may also be set manually – if so it is best to set it to the average maximum charge voltage, so that only cells above average at the end of a charge receive balancing. Manually setting a shunt threshold below the maximum charge voltage is not recommended since it may result in all balancers running concurrently, which actually negates the effect and generates extra heat. Balancing can also be disabled.

The shunt balancers are quite small and can take a long time to correct large imbalances. If possible it is recommended to manually balance your cells prior to initial pack assembly (e.g

by charging each cell individually, or wiring them all together in parallel to equalise with each other). However the shunts will get an unbalanced pack incrementally closer to balanced each charge, and once balanced are able to maintain balance with minimal effort.

CAN Bus Wiring

The BMS16 has four screw terminals for connecting CAN bus wiring: 12V Out, CAN H, CAN L and Ground. The monitor CAN plug uses a Molex Eurostyle screw terminal. These connectors require some force to plug in, so make sure the plug is fully inserted for a reliable connection. Wiring for the Eurostyle connector is shown right.



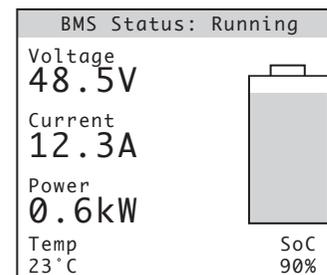
Wire gauge around 20-24AWG is recommended for appropriate current rating and mechanical strength. For best noise immunity in high EMI environments, shielded twisted pair cable is recommended, with two conductor pairs – one pair for CAN signals, and one pair for bus power. The shield can be connected to the Ground terminal at the BMS. We use and recommend Belden 8723 wire, or equivalent.

For optimum performance, CAN buses should be wired as a single daisy chain of devices (without branching), and terminated at both ends of the bus with a 120Ω resistor across the CAN H and CAN L lines. The monitor includes termination resistor built-in. Note that the CAN bus is referenced to the battery negative and is *not* isolated from the main battery pack.

The 12V Out terminal is limited to 200mA current and is primarily intended for powering CAN devices such as a monitor, but may also be used to power other small 12V devices such as solid state relays.

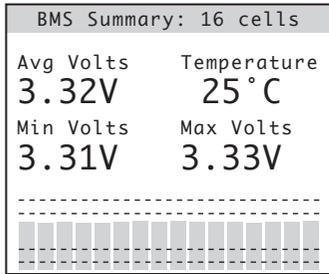
BMS16 Monitor

The BMS16 Monitor is an optional colour touchscreen which may be used to remotely interact with the BMS16. The Monitor displays various pages of information:



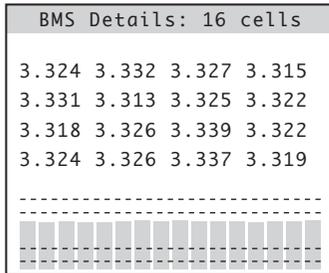
The BMS Status page is the standard display when the system is running, showing pack voltage, current, power, temperature, battery state of charge. This will only be shown if a current sensor is present.

Tapping the panel on the left or right side will toggle between the different display pages.



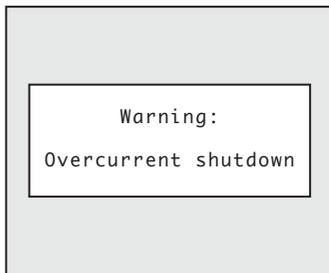
The BMS Summary page shows the average, minimum and maximum cell voltages, and the temperature sensor, plus a bar graph overview of all cells across the bottom.

If no current sensor is present, this will be the default page, and Pack Voltage will be shown instead of Average Voltage.

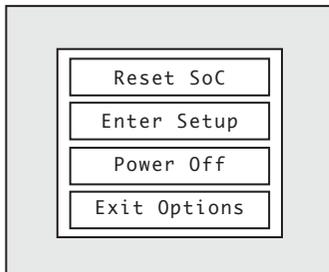


The BMS Details page shows all individual cell voltages, plus a bar graph below. Dotted lines on the graph show HV and LV thresholds plus hysteresis.

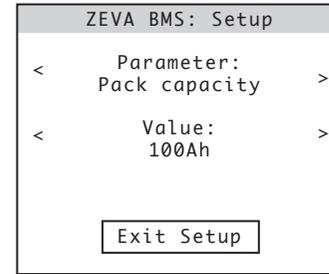
Graph bars will be green when a cell is in range, blue for under-voltage, red for over-voltage, and orange if a cell is currently being shunt balanced.



If the BMS detects an error, this warning page will be displayed. In most cases, the error can be acknowledged/reset by tapping the screen.



You can bring up the options menu by touching and holding for 1 second. From here you can do a manual reset of the State of Charge (back to 100%), enter the Setup mode, switch the display off, or command the BMS16 to turn off.



If you choose Enter Setup, the Monitor can be used to modify settings for the BMS16. The top row selects the parameter, and the bottom row adjusts the value, in both cases by touching the left or right arrows on each side. Once finished, touch Exit Setup and the new parameters will be transmitted to the BMS16.

List of Settings

The following table describes the parameters available in the Settings page.

Name	Range	Description
Pack capacity	5-1200Ah	The rated capacity of your traction battery pack, in Amp-Hours.
SoC warning	0-100%	The BMS16 can raise a warning when the battery's State of Charge reaches a predetermined minimum level. (Use 0% to disable.)
Full voltage	1-70V	The BMS uses a "full voltage" threshold (combined with low charge current) to detect charge completion and automatically re-synchronize the SoC to 100% when pack voltage exceeds this value. Typically set value to just below your peak charge voltage.
Warn current	0-1200A	The BMS16 will provide a warning if the current in or out of the battery exceeds this threshold. Set to 1210A to disable (will display as "off").
Trip current	0-1210A	The BMS16 will automatically shut down the battery pack if current exceeds this threshold (for over 1 second continuously). Note: This should not replace a physical fuse, but can be used as a "first line of defence". This is considered a serious error which will require the device to be power cycled to reset.
Num cells	8-16	The number of cells the BMS should expect to see in the battery pack. Warning: If this is set incorrectly, some cells may not be monitored.

Shunt size	None, 100, 200 or 500A	Selects the size of current shunt connected to the BMS's shunt interface terminals, for correct current scaling. (75mV shunts only.) This should be set to "None" if you have no shunt connected, or are using an external current sensor on the CAN bus.
Min voltage	1.50-4.00V	The minimum voltage any single cell should be allowed to reach. If any cell goes below this threshold, the LV output relay will go open circuit.
Max voltage	2.00-4.50V	The maximum voltage any single cell should be allowed to reach. If any cell goes above this threshold, the HV output relay will go open circuit.
Balance voltage	2.00-4.50V, Dynamic or Off	The voltage threshold where shunt balancing will occur. Balancing should only be performed on cells which are higher than average, so typically set this to the average maximum charge voltage of each cell (i.e max charge voltage divided by number of cells). Set to 4.51V for dynamic balance voltage or 4.52V for Off.
BMS hysteresis	0.00-0.50V	<i>Applies to Stationary Mode only.</i> Adds hysteresis to min/max voltage reset thresholds, so that charge and load relays are not switched on and off too rapidly. For example, after an under-voltage trip, the LV relay won't be re-enabled until the cell recovers to 0.2V above Min Voltage.
BMS min temp	-41C to 100C	The minimum allowable temperature for the battery pack. If a temperature below this threshold is detected, a warning will be generated and charging will be disabled. Set to -41C to disable (will show as "Off")

BMS max temp	0-101C	The maximum allowable temperature for the battery pack. If a temperature above this threshold is detected, a warning will be generated and chargers and loads will both be disabled. Set to 101C to disable (will show as "Off")
Charger voltage	0-70V	For CAN integration with TC Chargers only. The maximum voltage that the BMS will instruct the charger to reach.
Charger current	0-100A	For CAN integration with TC Chargers only. The maximum current that the BMS will instruct the charger to reach.
Stationary mode	No/Yes	Whether the BMS behaviour should be set for stationary applications. Please see "Stationary Mode" section for further explanation.
Reverse current display	No/Yes	By default, the BMS16 displays discharge amps as positive / charge amps negative. If preferred, you can reverse the display so that discharge amps are negative / charge amps are positive.
Night Brightness	0-100%	Adjusts the brightness of the LCD display in low light mode, to reduce screen glare at night. Toggle between full brightness and night brightness by swiping a finger up/down.
Buzzer On	Yes/No	Selects whether the Monitor should sound the buzzer for alerts. (Safest to leave this on.)
Use Fahrenheit	Yes/No	Changes display of temperature units to Fahrenheit instead of Celcius.
SoC Display	Percent or Amp-Hours	The battery State of Charge value displayed on the Monitor can either be shown as a percentage of full charge, or as the number of amp-hours remaining.

Stationary Mode

The BMS16 has two main modes of operation, either normal (for mobile / EV applications) or Stationary Mode (for off grid / backup battery type applications). In normal mode, if an under- or over-voltage is detected, the LV or HV output relay will be disabled respectively, and will remain off until the device is either power cycled or (more commonly) they are re-enabled whenever the device wakes from sleep.

In Stationary mode, the outputs will automatically reset if the voltage recovers sufficiently. The BMS Hysteresis setting is used to adjust the amount that the voltage needs to recover before outputs are re-enabled. For example, if the HV output has been disabled due to an over-voltage cell, a Hysteresis setting of 0.2V will prevent the output from re-enabling until the high cell has fallen more than 0.2V below the Max Voltage setting. *Note: Systems supplied prior to May 2019 also had the hysteresis amount added to the trip threshold, not just subtracted from the reset threshold. Be sure to test your trip thresholds to confirm safe behaviour.*

Common settings for LiFePO4 cells are a *Min Voltage* setting of 2.50V, *Max Voltage* of 3.80V, and *Hysteresis* of 0.40V, giving a 2.5V-2.9V band for the Main Ctr output and 3.4V-3.8V band for the Charge Enable output. LiCo cells have a more linear charge curve so typically need a smaller hysteresis band around 0.10V, with a *Min Voltage* setting of 3.00V and a *Max Voltage* setting of 4.2V.

LED Status Codes

The BMS has a bicolour (red/green) LED which it uses to display its operating status. The table to the right summarises the colour codes for the possible statuses indicated.

Status	Colour
Running (no errors)	Green
Sleeping	Blinking green
Under-voltage trip	Flashing red
Over-voltage trip	Steady red
Thermal trip	Flashing red/green

BMS Power Consumption Protection

An inherent problem with any BMS which powers itself from the cells it is monitoring is that the BMS itself can slowly discharge the cells, which can eventually flatten cells – particularly if powering contactors or monitors, and no charging source is present for an extended period. To prevent possible damage, the BMS16 is able to switch of its own power supply if any cells get critically low (under 2.0V). If your BMS has turned off due to a critically low cell, simply attach a charging source to the batteries then press the power button to re-enable the BMS.

Tech Support and Warranty Information

All ZEVA products are covered by a 12 month warranty against manufacturing faults or failures under normal operating conditions. The warranty does not cover misuse of the product, including but not limited to: excessive voltage or reversed polarity on terminals, short circuits on outputs, opening of housings and/or modification of internal electronics, severe impact damage, submersion in water.

We have taken great care to design a safe and reliable product, but faults can happen. If you believe your product has a fault, please contact us via our website to discuss. If it is determined that a hardware fault is the likely cause, we will provide an RMA number and return address to proceed with repairs.

If you have any questions not covered by this manual, please contact us via our website:

<http://www.zeva.com.au>