123\SmartBMS gen2 manual

rev 6

Albertronic BV
The Netherlands
E-mail: info@123electric.eu
www.123electric.eu

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Albertronic BV
The Netherlands
E-mail: info@123electric.eu
www.123electric.eu

Introduction

After the introduction of affordable LiFePO4 batteries, off-grid solutions became feasible. It is vital that such batteries are charged very carefully. In other words, they can easily be over-charged, or over-discharged. Cell temperature and current are also very important, in order to guarantee a long life.

The 123\SmartBMS Battery Management System (or BMS) is primarily intended for prismatic cells, but can also be adapted by the end-user for other cell shapes, provided the cell voltage is in the working voltage range of the cell modules. For more info about the working voltage range, see section “Specifications”.

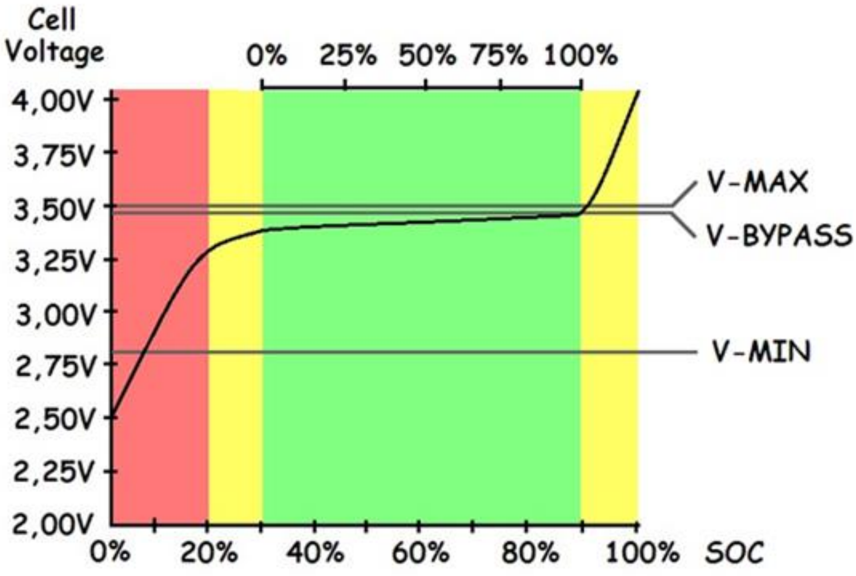
Keep the batteries in perfect condition

The drawing below shows that your expensive batteries are in good hands with 123\SmartBMS.

To keep batteries in the best condition, it is necessary to constantly monitor the voltage and temperature of individual cells. The voltage should stay within specified limits to prevent damage to the cells. Keeping the batteries in a safe operating temperature also prevents possible damage.

The width of the green (safe) area can be set by changing the threshold voltages V-min, V-bypass (balance threshold voltage) and V-max. For more info about this, see section "The App".

Conclusion: the upper limit is safe-guarded by entering V-max / V-bypass, and the lower limit by V-min.



A LiFePO4 cell voltage vs. SOC curve. The voltage is dependent on the percentage energy left in the cell (SOC).

Albertronic BV
The Netherlands
E-mail: info@123electric.eu
www.123electric.eu

Package contents

The standard 4 cells/12V package contains:

- IN Cell Board
- OUT Cell Board
- 2 Cell Boards
- 2 Current sensors
- Piece of 0,75 mm² wire for the interconnections
- Connector unlock tool

Specifications

All specifications measured at 3.3V cell voltage and slow message cycle (1x per second).

Description	Value / range
General specifications	
Operating voltage range	2.0V to 5.0V
Operating temperature range	-40 to 85°C
Voltage measurement accuracy	± 20mV
Temperature measurement accuracy	± 5°C
Balancing current	1A
Number of Cells	2 to 255
Board type dependent specifications	
"Between" module current average	<1.0mA
IN module current average with 1 current sensor	<2.0mA
IN module current average with 2 current sensors	<2.9mA
OUT module current average with standby Bluetooth	<2.0mA
OUT module current average when device connected to Bluetooth	<9.0mA
Maximum current through charge / load relay on OUT board	1A

Current measurement specifications

Current sensor type	Measurement resolution	Blindspot when on
25A	0.125A	± 0.25A
50A	0.25A	± 0.5A
100A	0.50A	± 1.0A
250A	1.25A	± 2.5A
500A	2.5A	± 5.0A
1000A	5A	± 10A
2000A	10A	± 20A

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The Netherlands
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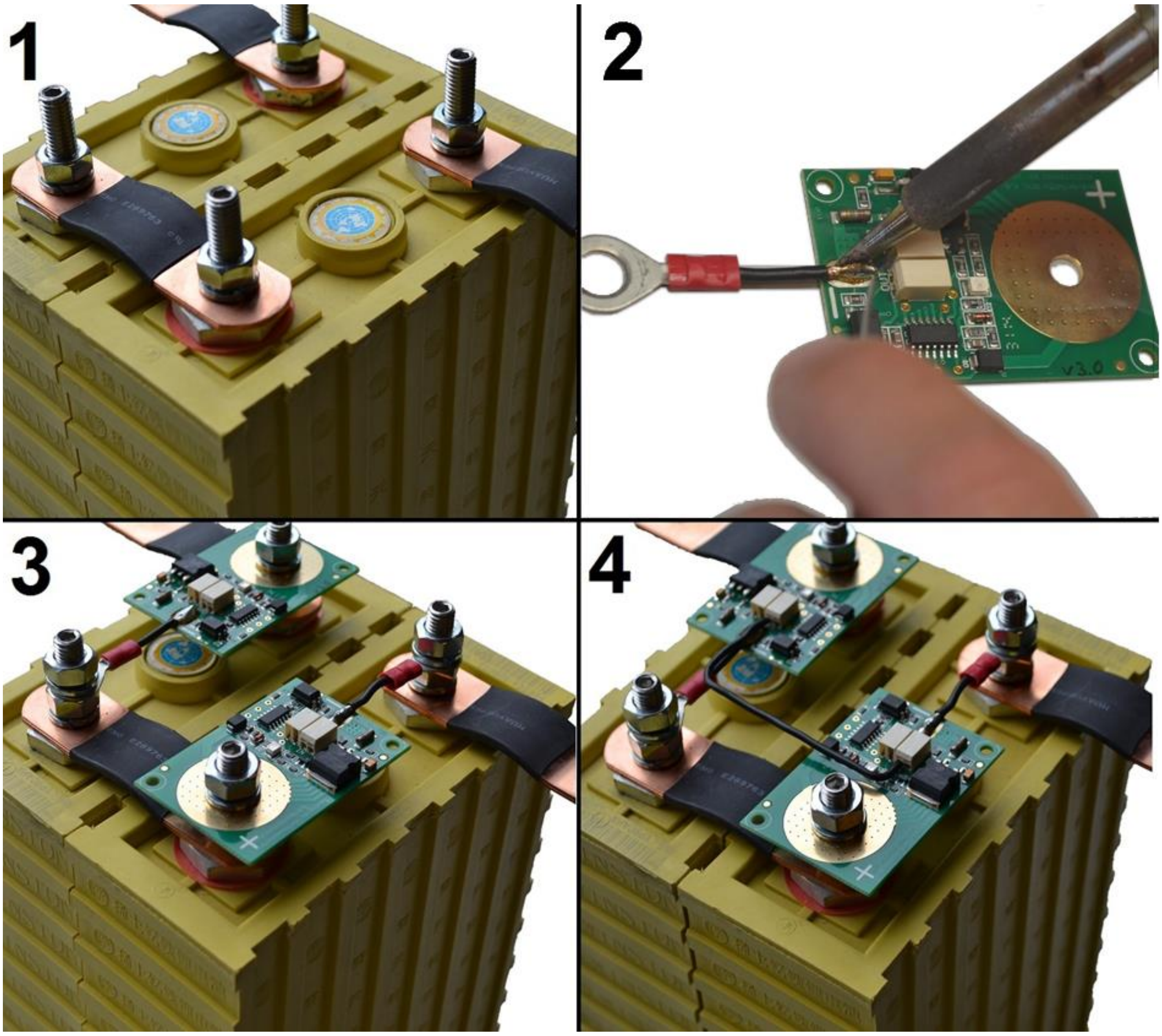
Placing the cell modules

Please be aware that your battery-pack contains a large amount of energy, which can be potentially dangerous. Use isolated spanners, to prevent any short circuits. High inrush currents, causing arcing (sparks) and ultra-high electromagnetic levels, can easily damage electronic circuits.

We therefore strongly recommend to always FIRST connect the so called "large current connections" in a new setup, and THEN separately connect the BMS-boards.

A good way of doing this is indicated on photo number one. After thorough cleaning of the cell-poles, the copper strips are bolted-on. Don't forget to also attach wires to the first and last cell in the same way, and connect these to the solar panels, MPPT, charger and the load.

If the positive (+) hole on the cell module is too small, you can make this hole bigger with a drill. Make sure to remove the drilling dust afterwards to prevent short circuits or other unintended behaviour.



Mounting the IN Module

Start to mount the IN-Board on the first cell. It is important this is the cell on the minus (-) side of the battery pack. Solder a wire on the solder pad of the IN-Board. (Photo 2) Connect this wire to the minus (-) side of the cell. After the IN-Board is connected the LED will start blinking every second, this shows the IN-Board is trying to send out data messages to the following cell board.

Install a current sensor in the incoming power line (solar panels, PMMT, charger) and connect this current sensor to the IN-Board connector”J1” marked “I-1”. Install the other current sensor in the power line of the consumers (inverter) and connect this sensor to the IN-Board connector ”J2” marked “I-2”. Make sure the arrow on the current sensor is pointing in the right direction. The direction where the current is flowing (see picture on the following page).

Both current sensors can measure bidirectional currents. It is also possible to only use 1 current sensor instead of 2. This may be needed if you have a combined inverter/charger with a shared power cable to both inverter and charger. The BMS will work fine with 1 current sensor. The drawback is that you cannot measure incoming and outgoing currents independently, but only see the current going in or out the battery pack. When connecting only 1 sensor, connect this to J1 of the IN board.

Mounting the cell Modules

After the IN-Board was installed, please proceed by the cell boards. Now, prepare the BMS-boards as shown on photo number two. Use thick solid-copper wire for this, for optimum accuracy. (the bypass-current has to flow through these wires)
Take your time: the result has to look good.

The BMS module always has to be mounted on the 'plus' pole of the cell. This '+' is also indicated on the cell modules. Connect all the modules as shown in photo number three.

Mounting the OUT module

On the last cell (+ side of the battery pack) the OUT-Board has to be installed. This works the same way as the other cell boards. It’s normal you will hear some clicking relays when you power up the OUT board.

The OUT board has two signal relays to switch enable/disable signals or power relays. For more information about this, see section “Controlling external components”.

Cell boards interconnections

After all cell boards are installed the interconnection can be made. Start the interconnection of the IN-Board to the following cell board. Make a connection from the single connector marked “OUT” on the IN-Board to the double connector position 1 Marked “IN” on the following cell board. Please be careful while you’re doing this, prevent short circuits. After you have made the interconnection between the IN-Board and the first cell board you will notice the green LED on the next cell board will flash as well every second. This confirms the cell board was correct installed and the interconnection between the cell boards are made correct. Now go on with the other cell boards. **Make connections from the double connector position 1 marked "OUT" to the next cell board connector position 1 market "IN". Be careful when inserting the cable, do not use excessive force.** If the flashing LEDs stop somewhere in the middle of the cell chain there is an error, in this case check the wiring.

A four cells (12 volt) system needs three connections:

IN-Board	J4 "OUT"	→	Cell-Board	"IN" position 1
Cell-Board	"OUT" position 1	→	Cell-Board	"IN" position 1
Cell-Board	"OUT" position 1	→	OUT-Board	J1 "IN"

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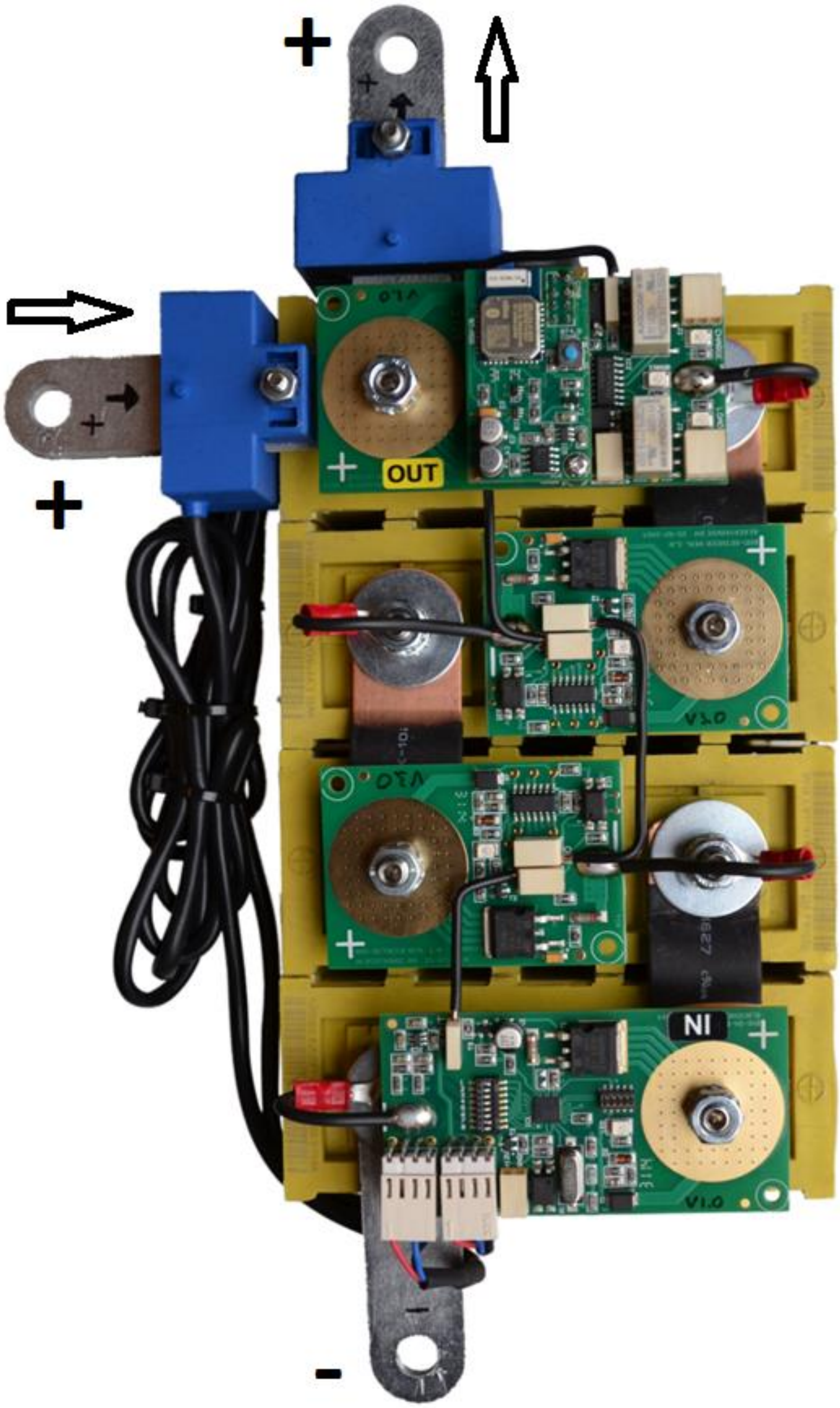
The picture below will show a basic setup of a 4 cell battery pack.

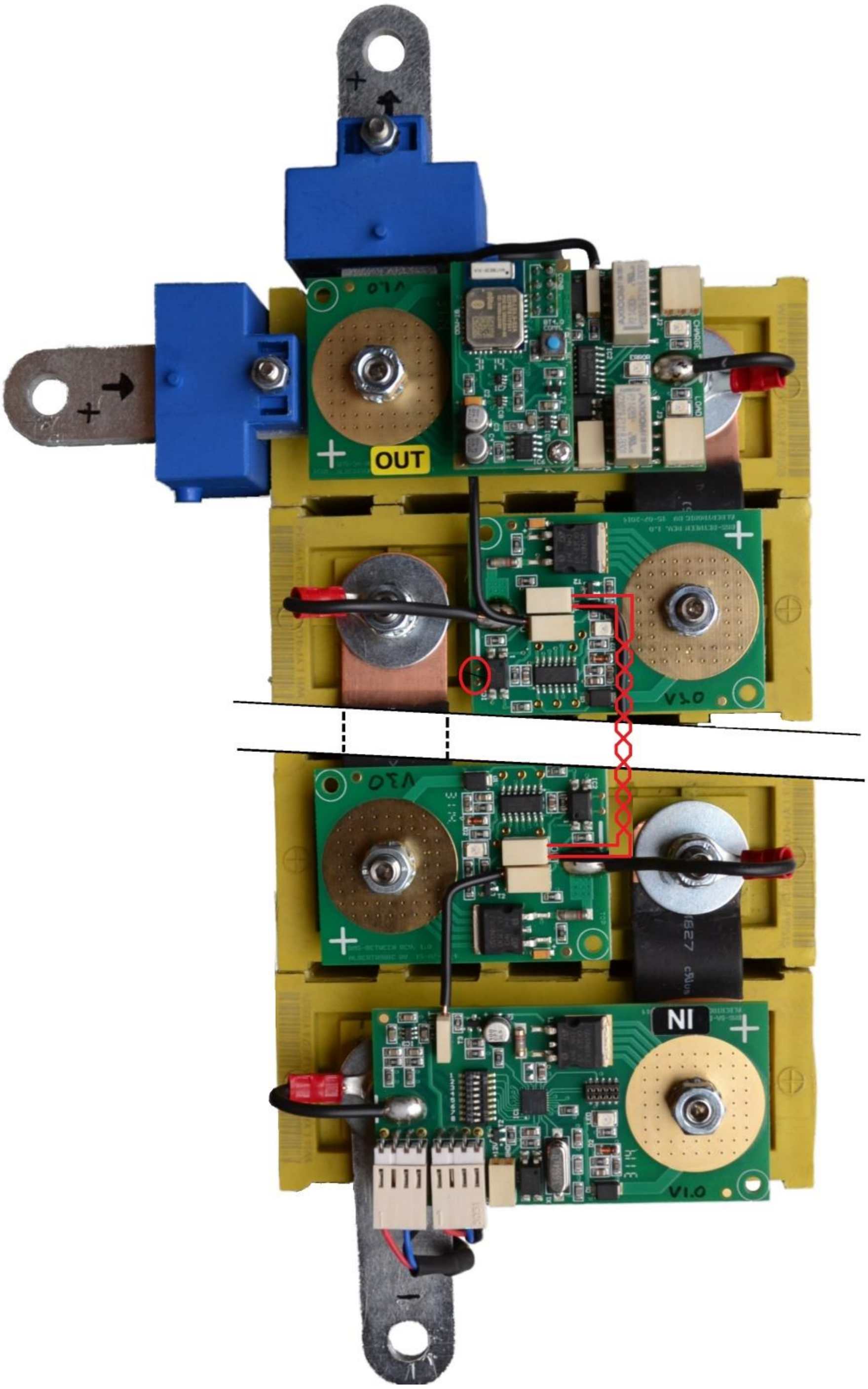


Separate battery sections

When the battery pack has separated battery banks the interconnection has to be changed to prevent interference from other components in the system. The data connection has to be galvanic isolated. This can be done by the following procedure:

1. Cut of the PCB track between the two gold dots (red circled in the picture above).
2. Use a twisted pair cable and use both terminals.

The picture below will show a setup with separated battery banks.



IN-Board 'option switch' function s

Settings

The option switches can be changed when the system is active.
The table below shows you the functions of the option switches.
Important: Don't use switch number 8, this will overwrite hidden factory settings.

Switch	1	2	3	4	5	6	7	Function
	Fast message	V-Bypass	Blind spot	Set zero	Mode	V-Bypass		
	OFF							Message every 1,0 sec.
	ON							Message every 0,5 sec.
			OFF					Blind spot around zero AMP disable
			ON					Blind spot around zero AMP enable (recommended)
				OFF				Auto zero inactive
				ON				Auto zero active
					OFF			Normal mode (recommended)
					ON			Critical mode
		OFF				OFF	OFF	V-Bypass 3,4 Volt
		OFF				OFF	ON	V-Bypass 3,5 Volt
		OFF				ON	OFF	V-Bypass 3,6 Volt
		OFF				ON	ON	V-Bypass 3,7 Volt
		ON				OFF	OFF	V-Bypass 4,0 Volt
		ON				OFF	ON	V-Bypass 4,1 Volt
		ON				ON	OFF	V-Bypass 4,2 Volt
		ON				ON	ON	V-Bypass 4,3 Volt

Option switch nr 1: The frequency of the cell board messages can be changed by these option switch. For fastest information set the switch to ON, for saving energy set the switch to OFF.

Option switch nr 3: Temperature fluctuations and current measurement errors can give a false current reading when there is no current flowing through the sensor. This can lead to miscalculations in the SOC calculations. With this switch ON, small (false) measured currents will be seen as 0 ampere.

Option switch nr 4: When the current sensors need to be calibrated follow the next procedure: Make sure there is running absolutely no current through the current sensors during the zero calibration procedure. On the IN module you will find the option switches. Set option switch number 4 to the ON position. Now the “Auto zero” procedure will be active. The currents on the App screen will show 0 Amps in a couple of seconds. Set the option switch number 4 back to the OFF position again.

Option switch nr 5 (v1.5+): OFF (recommended): the BMS works in normal mode. The SOC is reset to 100% when all cell voltages are at or above Vbypass. The relays are controlled by the BMS charge/discharge algorithm. Please see section "Algorithm" for more info.

ON: the BMS does not act on SOC anymore and only switches the relays off in critical conditions like communication error, too low voltage, too high voltage, too low temperature and too high temperature. The SOC is reset to 100% if the total pack voltage is at or above Vbypass x Number of cells. This mode is handy when using a combined charger/inverter with only one or no enable/disable signals.

Option switch 2, 6 and 7: Set option switch 2, 6 and 7 in the right positions for the Bypass voltage you like. See table for details.

Hidden factory settings

The settings below are normally pre-programmed during the production.
For programing other current sensors or change the number of cells follow the next procedure:

Set all switches below in the right positions for current sensor and number of cells and toggle switch 8 ON and OFF again.
If your number of cells is not in the list, select the next higher value in the list. This will not have any drawbacks.
The hidden settings are now stored in the BMS. Set the switches back in the original positions.
Please be aware it could be necessary to follow the current sensor calibration procedure again.

Switch	1	2	3	4	5	6	7	Function
	Current sensor			Number of cells				
	OFF	OFF	OFF					25 Amp
	OFF	OFF	ON					50 Amp
	OFF	ON	OFF					100 Amp (default)
	OFF	ON	ON					250 Amp
	ON	OFF	OFF					400 Amp
	ON	OFF	ON					500 Amp
	ON	ON	OFF					1000 Amp (version 1.4 or higher)
	ON	ON	ON					2000 Amp (version 1.4 or higher)
				OFF	OFF	OFF	OFF	4 Cells
				OFF	OFF	OFF	ON	8 Cells
				OFF	OFF	ON	OFF	12 Cells
				OFF	OFF	ON	ON	16 Cells
				OFF	ON	OFF	OFF	20 Cells
				OFF	ON	OFF	ON	24 Cells
				OFF	ON	ON	OFF	28 Cells
				OFF	ON	ON	ON	32 Cells
				ON	OFF	OFF	OFF	48 Cells
				ON	OFF	OFF	ON	64 Cells
				ON	OFF	ON	OFF	80 Cells
				ON	OFF	ON	ON	96 Cells
				ON	ON	OFF	OFF	128 Cells
				ON	ON	OFF	ON	156 Cells
				ON	ON	ON	OFF	204 Cells
				ON	ON	ON	ON	255 Cells

The App

First connection

Go to the App store for Apple devices and search for “123SmartBMS”. Install the 123SmartBMS App on your Apple device. For Android devices go to the Play store and search for “123SmartBMS”. Install the App on your Android device. Enable the Bluetooth functionality of your device.

Start the App, You will see an overview of an off-grid system. Tab the screen to show the title bar on the top of the screen. Tab settings to open the settings section.

Tab on the discovered 123SmartBMS device to make a connection. The App will ask for a password, this password is stored in the BMS to prevent anybody with a Bluetooth device can control your BMS. The standard password is “1234”. After the connection has been made it’s time to configure the system.

To disconnect, tap again on the BMS ID with the check mark next to it.

Settings

Solar peak power: Set the maximum power of your incoming energy source, for example solar panels. If the system contains 10 solar panels of 250 Watt each, the total power of 2,50 kW has to be configured.

Inverter peak power: Set the maximum power of the consumers, for example an inverter. When your inverter can supply 5 kilo Watt, 5,00 kW has to be configured.

Battery capacity: The battery capacity can of course be set to the total capacity of the battery pack. We advise however to take only 75% of the rated capacity, to comply with cell aging and temperature effects.

Example: If you use four 200 Ah cells → 4 x 200 x 3,2 = 2560 Wh. In this case we advise to use a value of 2560 x 0,75 = 1920 Wh → 1,9 kWh.

Change PIN: It is recommended to change the password of the BMS to prevent intruders can sabotage the system. Tab the “change PIN” line and follow the instructions.

Clear energy counters: Totals of incoming and outgoing energy will be stored into the BMS. If you like to set these total counters to zero, tab the “Clear energy counters” line and follow the instructions.

V min: If one of the cells gets below this minimum cell voltage threshold the “Vl“ warning indicator on the battery details screen is switched on. The “allow to discharge” relay to control external devices will be switched off.

V max: If one of the cells gets above this maximum cell voltage threshold the “Vh“ warning indicator on the battery details screen is switched on. The “allow to charge” relay to control external devices will be switched off.

V bypass: This is the balancing voltage where you want all the cells to end up. Above this voltage the cell modules start to dissipate 1 ampere to balance the cells. This setting can be changed with the option switched on the IN-board and will only be displayed.

T min: If one of the cells gets below this minimum cell temperature threshold the "Tl" warning indicator on the battery details screen is switched on. Both relays to control external devices will be switched off.

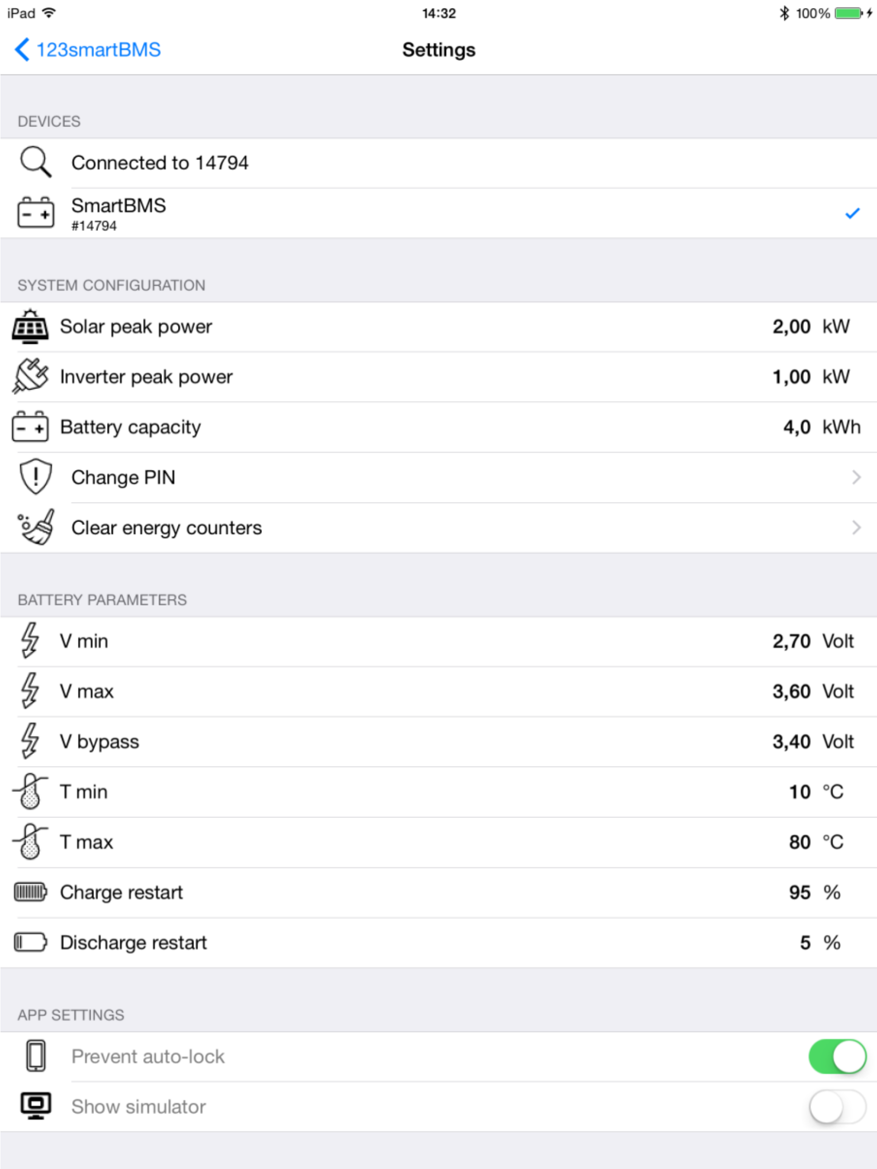
T max: If one of the cells gets above this maximum cell temperature threshold the "Th" warning indicator on the battery details screen is switched on. Both relays to control external devices be switched off.

Charge restart: The charge relay switches ON again if the capacity is below the programmable "Charge restart" and the BMS is in "Normal mode". This is to prevent toggling relays.

Discharge restart: The load relay will be switched on again if the capacity is above the programmable "Discharge restart" and the BMS is in "Normal mode".

Prevent auto-lock: Enabling this function prevent the device goes into sleep mode.

Show simulator: If you don't have an 123\SmartBMS but you like to discover the App, you can run a simulator.



After the settings has been done, Tab the "< 123SmartBMS" button to show up the overview.

Dashboard

The overview dashboard shows you all information you like to know.

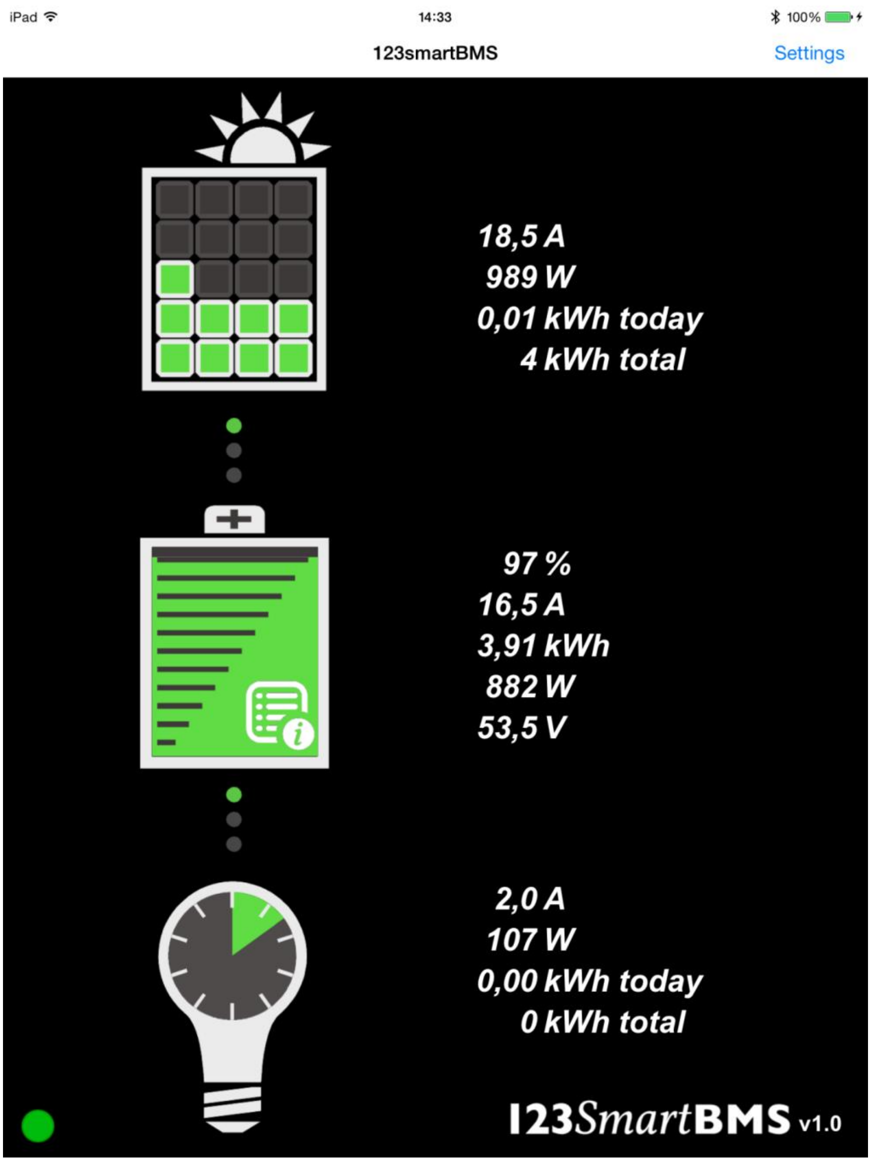
The Solar panel shows the status of the incoming energy, next to this graphic presentation you will find details like: Incoming charge current, Incoming power, harvest energy today, total of harvest energy.

The battery shows the SOC (state of charge) of the battery pack. Next to this graphic presentation you will find details like: State of charge percentage, Incoming / outgoing current of the battery, Stored power in kWh, Incoming / outgoing power, Total battery pack voltage.

If the BMS is newly mounted on the battery pack, the SOC may not show 100% while the cells are full. Charge the battery pack until all cell voltages are above Vbypass. The SOC will then be set to 100%. This SOC recalibration happens every time the battery pack is fully charged.

The light bulb shows the status of the outgoing energy, next to this graphic presentation you will find details like: consumed current, consumed power, consumed energy today, total of consumed energy.

When you Tab the “i” sign off the battery you will enter the battery details section.



Battery details

The battery details shows you detailed info of the battery pack. Cell voltage and temperature of each cell will be shown. Please be aware the temperature during bypass mode is much higher than the really cell temperature. Green values are in the safe range, yellow values shows balancing cells and red values are out of the safe range cells (above V max or below V min for example)

On top of the screen five warning lights will show critical errors. “E” Cell board communication error, “Vh” Exceeding maximum cell voltage, “Vl” Exceeding minimum cell voltage, “Th” exceeding maximum cell temperature, “Tl” exceeding minimum cell temperature.


iPad
15:06
100%
123smartBMS
Status
E
Vh
Vl
Th
Tl
#001 3.385 V +26 °C
#002 3.410 V +46 °C
#003 3.370 V +26 °C
#004 3.400 V +26 °C
#005 3.395 V +35 °C
#006 3.410 V +45 °C
#007 3.405 V +45 °C
#008 3.410 V +45 °C
#009 3.400 V +35 °C
#010 3.395 V +35 °C
#011 3.405 V +44 °C
#012 3.405 V +43 °C
#013 3.405 V +46 °C
#014 3.405 V +45 °C
#015 3.400 V +41 °C
#016 3.395 V +25 °C

Controlling external components

On the OUT Module you will find two bi stable signal relays to control external components of your off-grid system. This can be “solar chargers”, “Maximum power point trackers”, “inverters”, etc. An example is the “enable” pin on many Victron inverters. The maximum current through the signal relays is specified in section “Specifications”.

Charge relay

There is one relay to control incoming energy components of the system, like MPPT, solar charger et. This relay is called the “CHARGE” relay. When charging is allowed the green CHARGE LED next to the CHARGE relay will flash every second.

When charging is allowed Pin 1 and 2 of the CHARGE relay contacts (see OUT Board details) are closed (pin 2 & 3 are open).

When charging is NOT allowed Pin 2 and 3 of the CHARGE relay contacts are closed (pin 1 & 2 are open).

Note: when switching inductive loads like a relay/contactor, make sure there is a protection against flyback of the coil. A simple example is the flyback diode parallel to the coil.

Load relay

The other relay is to control outgoing energy components of the system, like inverters or other consumers. This relay is called the “LOAD” relay. When discharging is allowed the green LOAD LED next to the LOAD relay will flash every second.

OUT Board v2.x

When discharging is allowed pin 2 and 3 of the LOAD relay contacts (see OUT Board details) are closed (pin 1 & 2 are open).

When discharging is NOT allowed pin 1 and 2 of the LOAD relay contacts are closed (pin 2 & 3 are open).

OUT Board v1.x

When discharging is allowed pin 1 and 2 of the LOAD relay contacts (see OUT Board details) are closed (pin 2 & 3 are open).

When discharging is NOT allowed pin 2 and 3 of the LOAD relay contacts are closed (pin 1 & 2 are open).

Note: when switching inductive loads like a relay/contactor, make sure there is a protection against flyback of the coil. A simple example is the flyback diode parallel to the coil.

Switching combined charger/inverter

It is possible to use a combined charger/inverter. Just use 1 current sensor and connect this sensor to J1. Make sure to run the current cable the right way through the current sensor. When charging, you should see a positive current in the app next to the battery icon. When discharging, you should see a negative current.

- **<u>Combined charger/inverter with two enable/disable signals, one for charger and one for inverter</u>**

  You can keep the BMS in “normal mode” and use the charge relay for the enable/disable signal of the charger and the load relay for the enable/disable signal of the inverter.

- **<u>Combined charger/inverter with 1 enable/disable or no enable/disable signal</u>**

  In ”normal mode” the BMS will switch off the charge relay when the battery pack is full. However, this would mean the shared power will be switched off and the user is not able to discharge. For this case the BMS can be configured in “critical mode”. The BMS will only switch the power off in case there is a critical error condition. Connect the charge and load relay of the BMS in series to get a combined charge/load signal. Now you can switch a power relay or the enable/disable signal of the device.
  The charger/inverter floating voltages need to match the battery pack to operate correctly.

Algorithm

SOC calculation

The SOC is calculated by constantly measuring the in- and outgoing currents and integrating these currents. This is called Coulomb counting. The SOC is recalibrated every time the pack is full. This is done to reduce SOC calculation deviations.

In BMS “normal mode”, the SOC is set to 100% when all cell voltages are >= V-Bypass.
In BMS “critical mode”, the SOC is set to 100% when the total pack voltage is >= V-Bypass x total number of cells. In other words, when the average cell voltage is >= V-bypass.

Charge and discharge/load relay

The tables below display the conditions for each relay to switch on or off, depending on the selected mode.

Normal mode

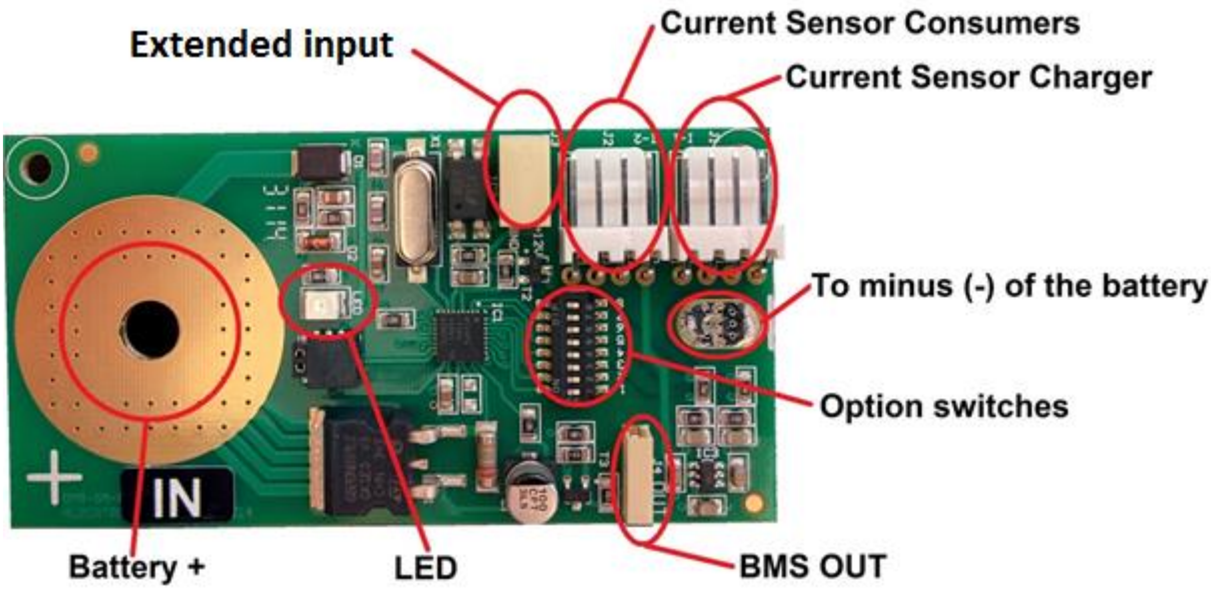
Charge		Discharge/load	
Enable	***Disable***	***Enable***	***Disable***
All cell voltages < V-bypass	Cell voltage >= V-max	All cell voltages > V-min	Cell voltage <= V-min
AND SOC < charge restart	All cell voltages >= V-bypass	**AND** SOC >= discharge restart	
AND cell temperature > T-min	Cell temperature < T-min	**AND** cell temperature > T-min	Cell temperature < T-min
AND cell temperature < T-max	Cell temperature > T-max	**AND** cell temperature < T-max	Cell temperature > T-max
AND cell communication	No cell communication	**AND** cell communication	No cell communication

Critical mode

Charge		Discharge/load	
Enable	*Disable*	*Enable*	*Disable*
All cell voltages < V-max	Cell voltage >= V-max	All cell voltages > V-min	Cell voltage <= V-min
AND cell temperature > T-min	Cell temperature < T-min	**AND** cell temperature > T-min	Cell temperature < T-min
AND cell temperature < T-max	Cell temperature > T-max	**AND** cell temperature < T-max	Cell temperature > T-max
AND cell communication	No cell communication	**AND** cell communication	No cell communication

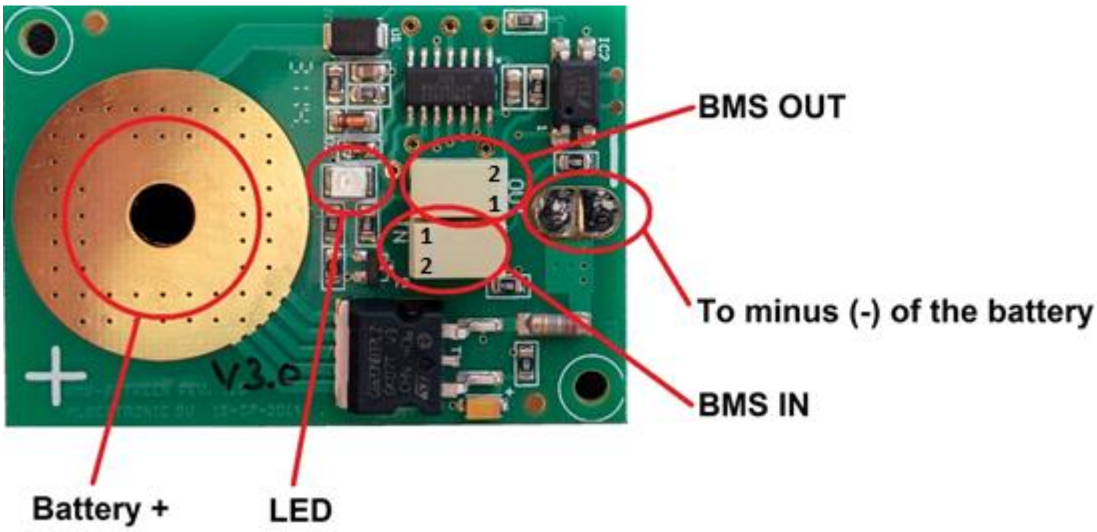
Module details

In Board



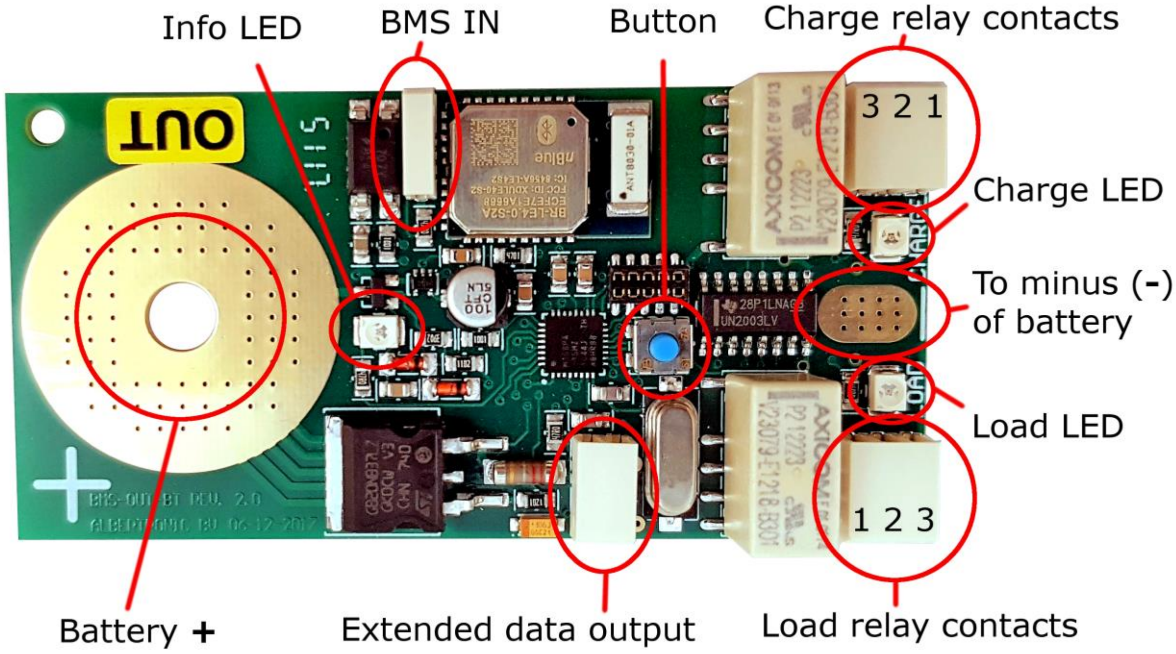
Battery +	Mount hole for the 'plus'-pole of the cell.
LED	Indicator LED, Flashes when active, continuous ON when the bypass mode is active.
BMS OUT	Interconnection connector for the data link to the next cell board.
Option switches	See page 7.
To minus (-) of the battery	Solder a wire on the solder pad and connect this wire to the minus (-) side of the cell.
Current sensor charger	Connector for the current sensor of the incoming current (solar).
Current sensor consumers	Connector for the current sensor of the outgoing current (consumers).
Extended data output	Data output for external modules to receive information about the battery pack.

Between Boards



Battery +	Mount hole for the 'plus'-pole of the cell.
To minus (-) of the battery	Solder a wire on the solder pad and connect this wire to the minus (-) side of the cell.
LED	Indicator LED, Flashes when data will be received / send, continuous ON when the bypass mode is active.
BMS IN	Data input from the previous cell board or IN-Board. Use the inner connector hole marked with the text IN.
BMS OUT	Data output to the next cell board or OUT-Board. Use the inner connector hole marked with the text OUT.

Out Board



Battery +	Mount hole for the 'plus'-pole of the cell.
To minus (-) of the battery	Solder a wire on the solder pad and connect this wire to the minus (-) side of the cell.
Info LED	Indicator LED. Flashes when BMS data is received and load and charge relays are off, continuous ON when the bypass mode is active.
Load LED	Flashes when load relay is active and BMS data is received.
Charge LED	Flashes when charge relay is active and BMS data is received.
BMS IN	Interconnection connector for the data link to the previous cell board.
Button	Button for Bluetooth configuration and password reset.
Charge relay contacts	Relay for cutting off chargers, MPPT, solar chargers etc. In case of full batteries.
Load relay contacts	Relay for cutting off consumers like inverters, etc. In case of empty batteries.
Extended data output	Data output for external modules.

Frequently asked questions

No communication

No battery data on the app and the “E” sign will light ON in the battery details tab of the App. Check the flashing LED’s on the string of cells. The position where the LED’s stop flashing is the location of the problem. Check wiring or replace cell modules.

Forgot my password

Press and hold the Bluetooth button for 5 seconds, the password will be set the standard “1234”.

Bluetooth does not work

Make sure your phone supports Bluetooth 4.0 LE. The following steps can help to connect to the BMS.

1. Restart the App and check in de Settings screen if the BMS appears.
2. Restart your phone and open the App to check again.
3. If you have OUT board version <1.8, press the blue OUT board button and retry.
4. Try a different phone, download the 123SmartBMS app and check if you see the BMS in the device list.
5. Disconnect the OUT Module of the battery cell. Close the App. Press and hold the Bluetooth button while you re-connect the OUT Module on the cell. The OUT module will take approximately 10 seconds to reconfigure the Bluetooth. Now open the app again and check if the device appears in the Settings screen.

Only one current sensor or cable

It is possible to only use 1 current sensor, the BMS will also work perfectly fine. Using one sensor will use less power on the IN board. The drawback is that you cannot measure incoming and outgoing currents independently, but only see the current going in or out the battery pack.
Connect the current sensor to J1 on the IN board and make sure to see a positive current in the App next to the battery icon when charging and a negative current when discharging.

Current sensor is not zero in idle mode

Make sure there is running absolutely no current through the current sensors during the zero calibration procedure. On the IN module you will find the option switches. Set option switch number 4 to the ON position. Now the “set to zero” procedure will be active. The currents on the App screen will show 0 Amps in a couple of seconds. Set the option switch number 4 back to the OFF position again. Also set option switch number 3 to ON as the blind spot is recommended.

Albertronic BV
The Netherlands
E-mail: info@123electric.eu
www.123electric.eu

Multiple battery cells or packs parallel

There is a difference between placing multiple cells parallel or packs parallel.

- **Multiple cells parallel**

You can safely place multiple cells parallel and only need 1 BMS cell module per parallel group. For instance: a 12V LiFePO4 pack consists of 4 cell groups in series. In case you have 8 cells, the pack is configured as 2P4S (groups of 2 cells parallel, then these parallel groups in series). In this case you only need 1 BMS for 4S (4 cell groups).

- **Multiple battery packs parallel**

When you have to connect multiple packs parallel, you need 1 complete BMS per pack. You can connect the signal relays on each OUT board in series. For instance: with 3 packs parallel, you can run the charging signal through from the first OUT board Charge relay to the second Charge relay and through the third Charge relay. This signal can switch an enable/disable or power relay. The same goes for the Load relays in series.

Albertronic BV
The Netherlands
E-mail: info@123electric.eu
www.123electric.eu