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BATTERY MANAGEMENT SYSTEM
5 – 16S

Features:

- robust and small design
- 5 – 16 cells
- single cell voltage measurement (0.1 – 5.0 V, resolution 1 mV)
- single cell - under/over voltage protection
- single cell internal resistance measurement
- SOC and SOH calculation
- over temperature protection (up to 3 temperature sensors)
- under temperature charging protection
- passive cell balancing up to 0.9 A per cell
- shunt current measurement (resolution 19.5 mA @ ± 500 A)
- galvanically isolated user defined multi-purpose digital input/output
- programmable relay (normally open)
- galvanically isolated RS-485 communication protocol
- CAN communication
- error LED + buzzer indicator (option)
- PC user interface for changing the settings and data-logging (optional accessory)
- hibernate switch
- one-year warranty
- **NEW**: reduced 1 s measuring interval
- **NEW**: balancing transistors defect check @ restart
- **NEW:** EEPROM memory data corruption check @ restart
- **NEW:** cell's voltage RMS voltage measurement
- **NEW:** self calibration @ restart
- **NEW:** BMS shutdown @ 0.98 x minimum cell disconnect threshold
- **NEW:** Ah counting

General Description of the BMS Unit:

Battery management system (BMS) is a device that monitors and controls each cell in the battery pack by measuring its parameters. The capacity of the battery pack differs from one cell to another and this increases with number of charging/discharging cycles. The Li-poly batteries are fully charged at typical cell voltage 4.10 - 4.20 V or 3.5 – 3.6 V for $LiFePO_4$. Due to the different capacity this voltage is not reached at the same time for all cells in the pack. The lower the cell's capacity the sooner this voltage is reached. When charging series connected cells with a single charger, voltage on some cells might be higher than maximum allowed voltage. Overcharging the cell additionally lowers its capacity and number of charging cycles. The BMS equalizes cells' voltage by diverting some of the charging current from higher voltage cells – passive balancing. The device temperature is measured to protect the circuit from over-heating due to the passive balancing. Battery pack temperature is monitored by Dallas DS18B20 digital temperature sensor/s. Maximum 3 temperature sensors per BMS unit may be used. Current is measured by low-side shunt resistor. Battery pack current, temperature and cell's voltage determine state of charge (SOC). State of health (SOH) is determined by comparing cell's current parameters with the parameters of the new battery pack. The BMS default parameters are listed in Table 1.

Default Parameters:

Table 1: Default BMS parameter settings.

parameter	value	unit
balance start voltage	3.95	V
balance end voltage	4.12	V
maximum diverted current per cell	up to 0.85 (4.7 Ohm)	A
cell over voltage switch-off	4.18	V
cell over voltage switch-off hysteresis per cell	0.04	V
charger end of charge switch-off pack	4.123.60	V
charger end of charge switch-off hysteresis	0.1	V
charger end of charge SOC hysteresis	5	%
cell under voltage protection switch-off	3.0	V
cell under voltage protection when BMS switches-off after 30s	3.0*0.98	V
cell under voltage protection alarm	3.1	V
under voltage protection switch-off hysteresis per cell	0.15	V
cell under voltage protection switch-off timer	4	s
cells max difference	0.15	V
BMS maximum pack voltage	**68.0**	**V**
BMS over temperature switch-off	55	°C
BMS over temperature switch-off hysteresis	5	°C
cell over temperature switch-off	55	°C
under temperature charging disable	-1	°C
max DC current relay @ 60 V DC	0.7	A
max AC current relay @ 230 V AC	2	A
BMS unit stand-by power supply	< 90	mW
max DC current @ optocoupler	15	mA
max DC voltage@ optocoupler	68	V
BMS unit disable power supply	< 1	mW
BMS unit cell balance fuse rating (SMD)	2	A
internal relay fuse (Master unit)	2 slow	A
dimensions (w × l × h)	190 x 104 x 39	mm
weight	0.650	kg
IP protection	IP32	

System Overview:

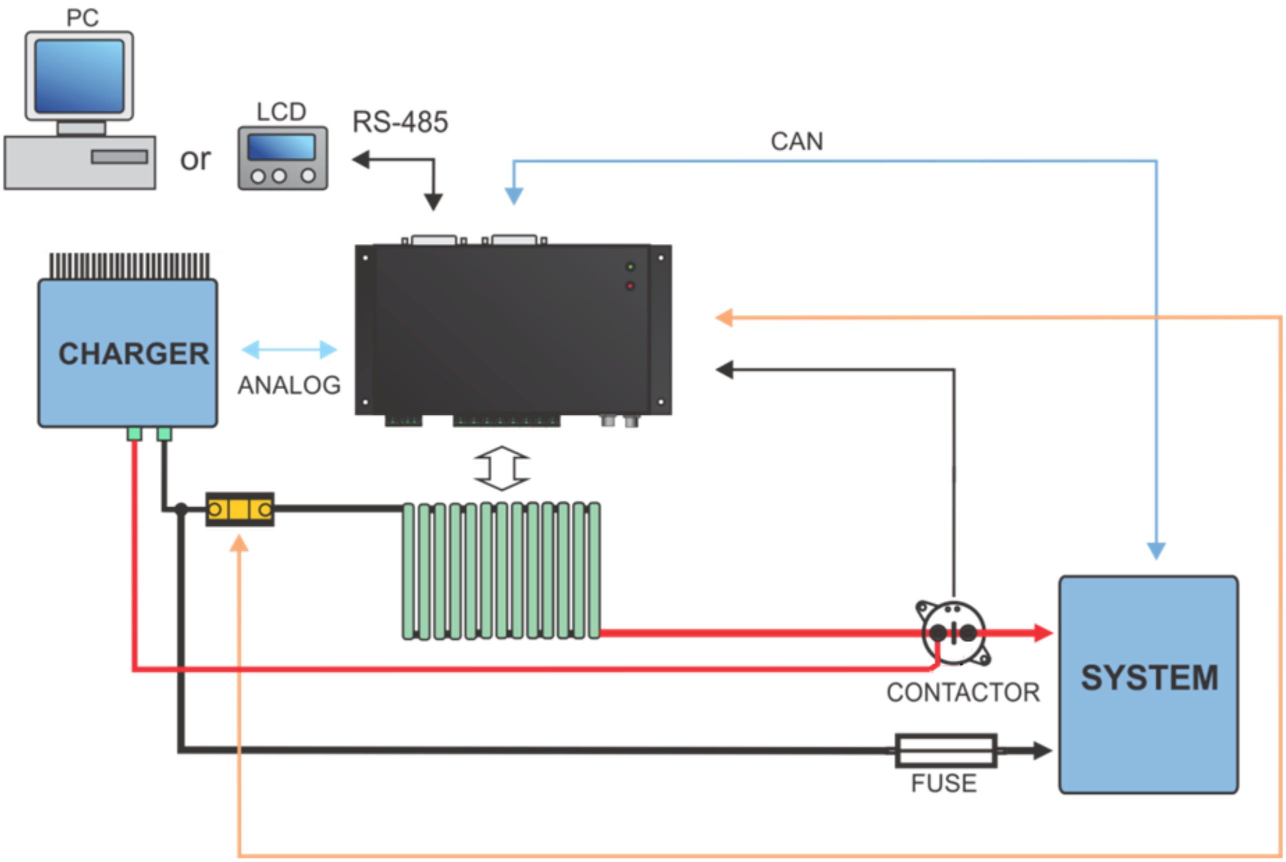

Figure 1: System overview.

BMS Unit Connections:

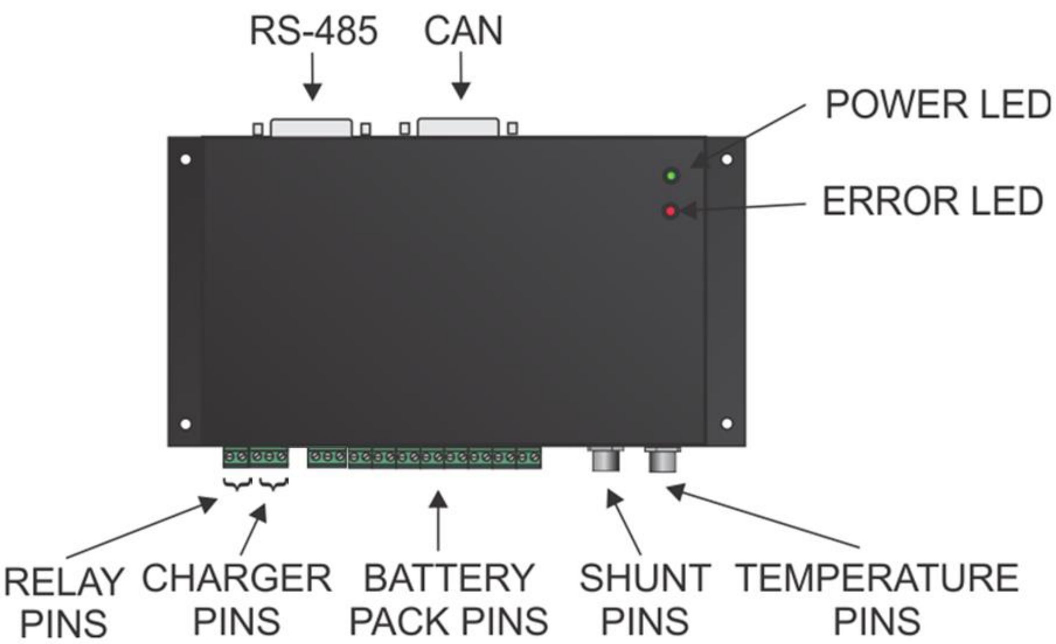

Figure 2: BMS unit function overview.

Table 2: BMS unit connections.

connection	description	
Temperature connector	DALLAS 18B20 temp. sensor pins (pin 2)	GND + shield
Temperature connector	DALLAS 18B20 temp. sensor pins (pin 3)	1-wire digital signal
Temperature connector	DALLAS 18B20 temp. sensor pins (pin 1)	+ 5 V
Current connector	+ Shunt (pin 3)	Analog signal
Current connector	- Shunt (pin 1)	Analog signal
Current connector	Shield (pin 2)	Analog signal
7	Cell 1 ground	Analog signal
8	Cell 1 positive	Analog signal
9	Cell 2 positive	Analog signal
10	Cell 3 positive	Analog signal
11	Cell 4 positive	Analog signal
12	Cell 5 positive	Analog signal
13	Cell 6 positive	Analog signal
14	Cell 7 positive	Analog signal
15	Cell 8 positive	Analog signal
16	Cell 9 positive	Analog signal
17	Cell 10 positive	Analog signal
18	Cell 11 positive	Analog signal
19	Cell 12 positive	Analog signal
20	Cell 13 positive	Analog signal
21	Cell 14 positive	Analog signal
22	Cell 15 positive	Analog signal
23	Cell 16 positive	Analog signal
24	Charger control optocoupler collector	Open collector
25	Charger control optocoupler emitter	AGND
26	-	-
27	Internal Relay	Main relay control (via pre-charge)
28	Internal Relay	Main relay control (via pre-charge)

Setting Number of Cells and the RS-485 Address:

Number of cells connected to the BMS unit is selected via CELL DIP Switch pins at the back of the unit. Binary addressing is used to enable setting up to 16 cells with 4 DIP Switches.

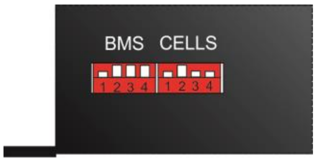

Figure 3: Address and cell selection DIP Switches.

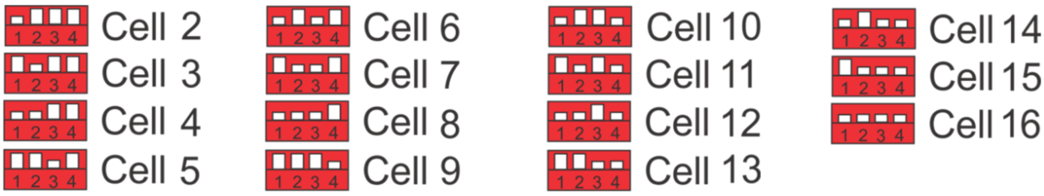

Figure 4: Number of cell selection description.

BMS unit address is selected via Address DIP Switch pins (BMS) at the back of the unit. Binary addressing is used to enable setting up to 15 addresses with 4 DIP Switches. **! If multiple BMS units are used distinguished addresses should be set to avoid data collision on the RS-485 communication bus!**

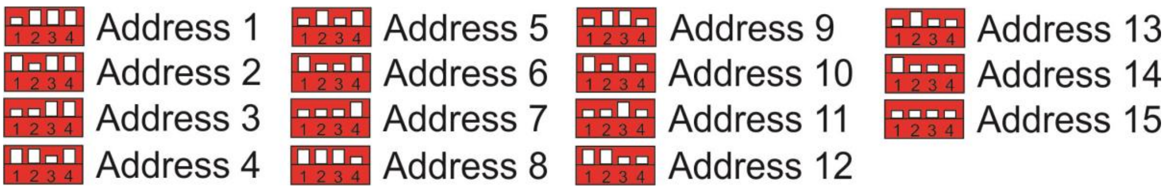

Figure 5: BMS unit address selection description.

BMS Unit Cell Connector:

Connect each cell to the BMS unit cell connector plug. Use silicon wires with cross section of 0.5 – 1mm^2 **! Before inserting the cell connector check voltages and polarities with voltmeter of each connection!**
! If working on cells connections –BMS's cells connector should be unplagued otherwise the BMS is damaged !

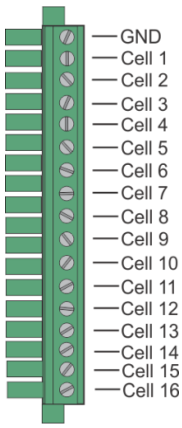

Figure 6: Battery pack to BMS connection.

BMS Unit Power Supply:

BMS unit is always supplied from the 16-th cell connection. **! When less than 16 cells are used in the battery pack, an additional wire with Pack + voltage should be connected to the cell 16 connector !**

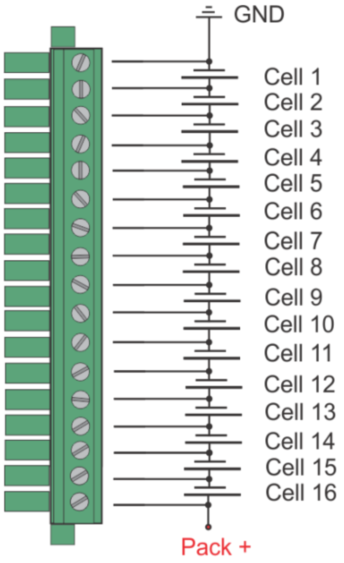

Figure 7: BMS unit power supply.

BMS Unit Connection Instructions:

Connect the BMS unit to the system by the following order described in Fig. 8. It is important to disable all the BMS functions by turning enable switch OFF before plugging any connectors. **All cells should be connected last and simultaneously**. When all the system components are plugged in, the enable switch can be turned ON and the BMS unit starts the test procedure.

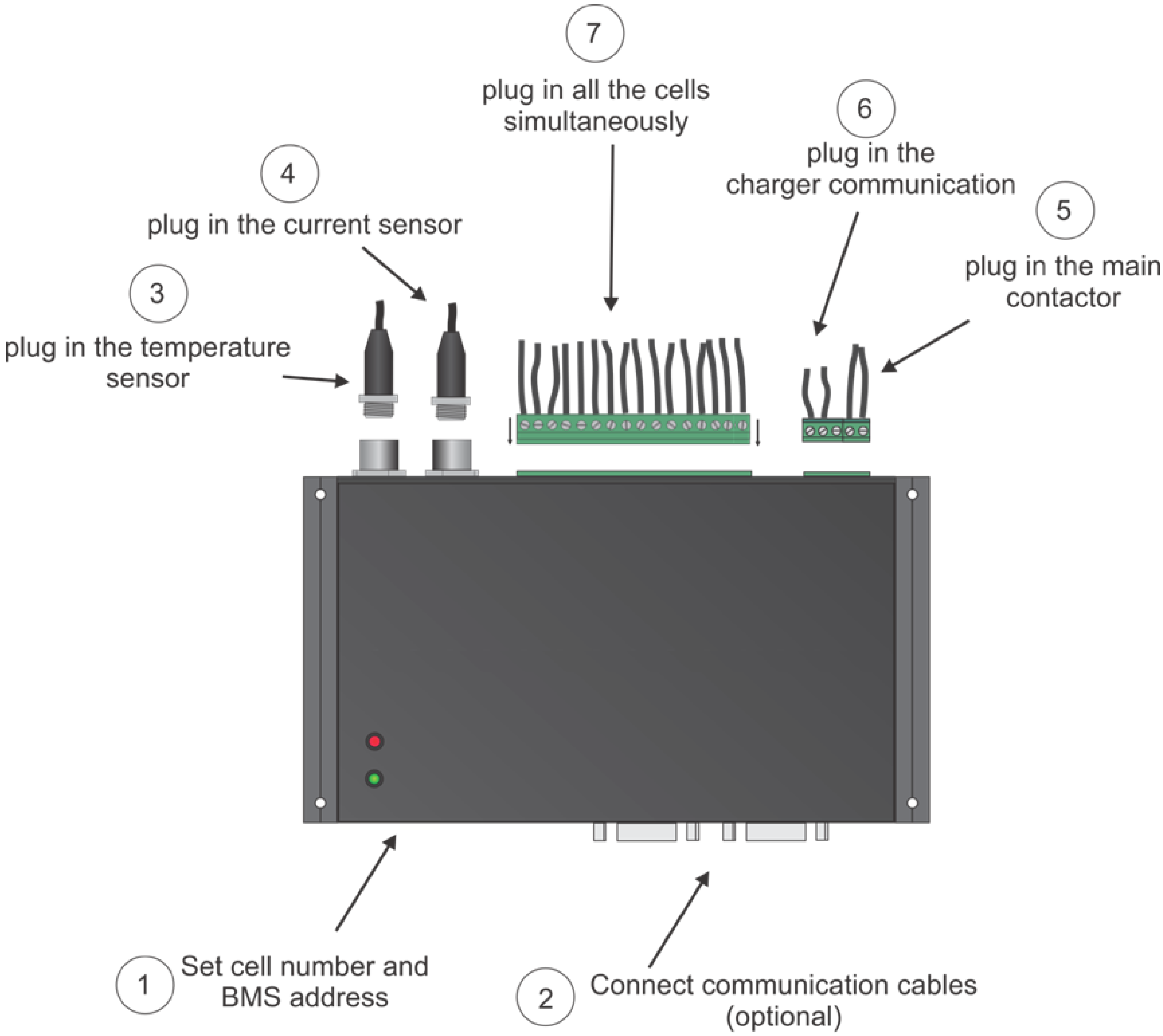

Figure 8: BMS connection order.

When disconnecting the unit from the battery pack, the procedure should be followed in reverse order.

RS-485 Communication Protocol:

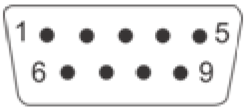

Figure 9: RS-485 DB9 connector front view.

Table 3: RS-485 DB9 connector pin designator.

Pin	Designator
1	-
2	GND
3	B + TERMINATION 470 OHM
4	A + TERMINATION
5	-
6	GND BMS
7	-
8	-
9	-

Galvanically isolated RS-485 (EN 61558-1, EN 61558-2) serves for logging and changing BMS parameters. Dedicated PC BMS Control Software or another RS-485 device may be used for the communication.

Messages are comprised as follows:

STX, DA, SA, N, INSTRUCTION- 4 bytes, 16-bit CRC, ETX

- STX start transmition <0x55> (always)
- DA - destination address <0x01> to <0x10> (set as 6)
- SA - sender address <0x00> (always 0)
- N – number of sent bytes
- INSTRUCTION 4 bytes for example.: 'L','C','D','1','?', - (combined from 4 ASCII characters, followed by '?', if we would like to receive the current parameter value or ' ','xx.xx' value in case we want to set a new value
- 16-bit CRC, for the whole message except STX in ETX
- ETX - end transmition <0xAA> (always)

Dataflow:

- Bit rate: 56k
- Data bits: 8
- Stop bits: 1
- Parity: None
- Mode: Asynchronous

Table 4: RS-485 instruction set.

INSTRUCTION	DESCRIPTION	BMS ANSWER
'*','I','D','N','?'	Identification	Answer "REC - BATERY MANAGEMENT SYSTEM"
'L','C','D','1','?'	Main data	Returns 7 float values LCD1 [0] = min cell voltage, LCD1 [1] = max cell voltage, LCD1 [2] = current, LCD1 [3] = max temperature, LCD1 [4] = pack voltage, LCD1 [5] = SOC (state of charge) interval 0-1-> 1=100% and LCD1 [6] = SOH (state of health) interval 0-1-> 1=100%
'L','C','D','3','?'	Main data	Returns 8 unsigned char values LCD3 [0] = min cell BMS address, LCD3 [1] = min cell number, LCD3 [2] = max cell BMS address, LCD3 [3] = max cell number, LCD3 [4] = max temp. sens. BMS address, LCD3 [5] = max temp. sens. number, LCD3 [6] = Ah MSB, LCD3 [7] = Ah LSB,
'C','E','L','L','?'	Cell voltages	BMS first responds with how many BMS units are connected, then it sends the values of the cells in float format
'P','T','E','M','?'	Cell temperatures	BMS first responds with how many BMS units are connected then it sends the values of the temperature sensors in float format
'R','I','N','T','?'	Cells internal DC resistance	BMS first responds with how many BMS units are connected then it sends the values in float format
'B','T','E','M','?'	BMS temperature	BMS first responds with value 1, then it sends the values of the BMS temperature sensor in float format
'E','R','R','O','?'	Error	Responds with 4 bytes as follows ERRO [0] = 0 – no error, 1 – error ERRO [1] = BMS unit ERRO [2] = error number (1-13) in ERRO [3] = number of the cell, temp. sensor where the error occurred
'E','R','R','D','?'/ 'E','R','R','D',' ','xxx'	Sends back the error number	Returns unsigned char value
'B','V','O','L', '?'/ 'B','V','O','L', ' ','xxx'	Cell END balancing	Returns float voltage [V]
'C','M','A','X','?'/ 'C','M','A','X',' ','xxx'	Max allowed cell voltage	Returns float voltage [V]
'M','A','X','H', '?'/ 'M','A','X','H', ' ','xxx'	Max allowed cell voltage hysteresis	Returns float voltage [V]
'C','M','I','N', '?'/ 'C','M','I','N', ' ','xxx'	Min allowed cell voltage	Returns float voltage [V]
'M','I','N','H', '?'/ 'M','I','N','H', ' ','xxx'	Min allowed cell voltage hysteresis	Returns float voltage [V]
'T','M','A','X', '?'/ 'T','M','A','X', ' ','xxx'	Maximum allowed cell temperature	Returns float temperature [°C]
'T','M','I','N', '?'/ 'T','M','I','N', ' ','xxx'	Minimum allowed temperature for charging	Returns float temperature [°C]
'B','M','I','N', '?'/ 'B','M','I','N', ' ','xxx'	Balancing START voltage	Returns float voltage [V]

'C','H','A','R', '?'/ 'C','H','A','R', ' ','xxx'	End of charging voltage per cell	Returns float voltage [V]
'C','H','I','S', '?'/ 'C','H','I','S', ' ','xxx'	End of charging voltage hysteresis per cell	Returns float voltage [V]
'I','O','F','F','?'/ 'I','O','F','F',' ','xxx'	Current measurement zero offset	Returns float current [A]
'T','B','A','L','?'/ 'T','B','A','L',' ','xxx'	Max allowed BMS temperature	Returns float temperature [°C]
'B','M','T','H','?'/ 'B','M','T','H',' ','xxx'	Max allowed BMS temperature hysteresis	Returns float temperature [°C]
'V','M','A','X','?'/ 'V','M','A','X',' ','xxx'	Number of exceeded values of CMAX	Returns integer value
'V','M','I','N','?'/ 'V','M','I','N',' ','xxx'	Number of exceeded values of CMIN	Returns integer value
'M','A','X','T','?'/ 'M','A','X','T',' ','xxx'	Number of exceeded values of TMAX	Returns integer value
'C','Y','C','L','?'/ 'C','Y','C','L',' ','xxx'	Number of battery pack cycles	Returns integer value
'C','A','P','A','?'/ 'C','A','P','A',' ','xxx'	Battery pack capacity	Returns float capacity [Ah]
'I','O','J','A','?'/ 'I','O','J','A',' ','xxx'	Voltage to current coefficient	Returns float value
'R','A','Z','L','?'/ 'R','A','Z','L',' ','xxx'	Package cell difference	Returns float voltage [V]
'C','H','E','M', '?'/ 'C','H','E','M', ' ','xxx'	Li-ion chemistry	Returns unsigned char value
'S','O','C','S','?'/ 'S','O','C','S',' ','xxx'	State of charge	Returns/accepts float SOC [0-1.0]
'R','E','L','V','?'/ 'R','E','L','V',' ','xxx'	cell under voltage protection switch-off	Returns float voltage [V]
'R','E','L','H','?'/ 'R','E','L','H',' ','xxx'	cell under voltage protection switch-off hysteresis	Returns float voltage [V]
'R','E','L','T','?'/ 'R','E','L','T',' ','xxx'	Timer for min cell < RELV before under-voltage relay turns off	Returns unsigned char value (1-200 means 2-400 s)
'C','R','E','F','?'	Reference calibration – read only	Returns float voltage [V](4.996 typ.)
'O','D','D','C','?'/ 'O','D','D','C',' ','xxx'	Odd cells calibration coefficient	Returns float value (0.0003 typ.)
'E','A','V','C','?'/ 'E','A','V','C',' ','xxx'	Even cells calibration coefficient	Returns float value (0.0003 typ.)
'S','O','C','H','?'/ 'S','O','C','H',' ','xxx'	Charger SOC hysteresis	Returns float value 0 - 0.99

Parameter accepted and changed value is responded with 'SET' answer.

Example: proper byte message for 'LCD1?' instruction for BMS address 1 is:
<0x55><0x01><0x00><0x05><0x4C><0x43><0x44><0x31><0x3F><0x013><0x15><0xAA>
RS-485 message are executed when the microprocessor is not in interrupt routine so a timeout of 350 ms should be set for the answer to arrive. If the timeout occurs the message should be sent again.

CAN Communication Protocol:

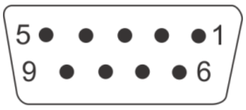

Figure 10: CAN DB9 connector front view.

Table 5: CAN DB9 connector pin designator.

Pin	Designator
1	TERMINATION
2	CANL +TERMINATION
3	GND
4	
5	-
6	GND
7	CANH
8	-
9	

Bitrate: 250 kbs
11-bit identifier: 0x031 and 0x032
Default settings TX only
8 byte message structure:

Table 6: CAN message structure description for ID=0x031

Byte	Description	Type	
1	State of charge [%]	Unsigned char	0-200 LSB = 0.5 % SOC
2	Battery pack voltage high byte	Unsigned integer	0-65535, LSB = 2 mV
3	Battery pack voltage low byte		
4	Battery pack current high byte	Signed integer	−32768 to 32767 LSB = 20 mA
5	Battery pack current low byte		
6	Battery pack max temperature	Signed char	-127 to 127 LSB = 1° C
7	Error number	Unsigned char	0-15
8	Number of the cell or temp. sensor where the error occurred	Unsigned char	0-16

Table 7: CAN message structure description for ID=0x032.

Byte	Description	Type	
1	High cell voltage high byte	Unsigned integer	0-65535, LSB = 1 mV
2	High cell voltage low byte		
3	Low cell voltage low byte	Unsigned integer	0-65535, LSB = 1 mV
4	Low cell voltage low byte		
5	High cell number	Unsigned char	1-16
6	Low cell number	Unsigned char	1-16
7	Battery pack min temperature	Signed char	-127 to 127 LSB = 1° C
8	State of health [%]	Unsigned char	0-200 LSB = 0.5 % SOH

CAN message is sent every second with refreshed values. **Short pins 1 and 2 for CAN communication termination to enable proper BMS operation without self-restart.**

BMS Unit Start Test Procedure:

When the BMS is turned ON it commences the test procedure. BMS checks if the user tries to uplod a new firmware by turning on the Power LED. After the timeout Red error LED turns on to signal the system’s test procedure. The procedure starts by testing balancing switches, BMS address and cells number, temperature sensor/s detection, self calibration, EEPROM memory parameters, buzzer and internal relay. The test completes in 10 seconds. In case of no Errors red LED turns off and the BMS unit starts working in normal mode.

In case of Address=0 or cell number <4, error 6 informs the user to properly set the DIP switches. BMS has to be turned off before the pins are changed.
In case if the BMS does not detect any temperature sensors on the bus, error 8 appears.
Error 10 indicates that the self calibration rutine detected error while calibrating due to reference failure.
Error 15 indicates balancing transistor/s failure.

BMS Unit LED Indication:

Power LED (green) is turned on in 2 s intervals, if the BMS is powered. Error LED (red) is turned on in case of system error. Number of Error LED blinks/sound alarm indicates Error number.

BMS Unit Low Voltage Disable:

If the lowest cell’s voltage drops under MIN Vcell ('C','M','I','N') set value (2.9 V per cell default), the BMS signals Error 2. If the lowest cell’s voltage drops further under the relay under-voltage threshold ('R','E','L',’V') for more than set Timer for min cell ('R','E','L',’T') internal relay turns off. This feature prevents switching off the system at higher load spikes. When the lowest cell’s voltage drops further under the relay under-voltage threshold ('R','E','L',’V') x 0.98 for more than 30 s, BMS goes to sleep.

Cell Voltage Measurement:

Cell voltages are measured every second. The cell measurement algorithm performs several measurements to digitally filter the influence of 50, 60, 100 and 120 Hz sinus signal. Each cell voltage is measured after the balancing fuse, in case the fuse blows BMS signals error 10 to notify the user.

BMS Cell Balancing:

Cells are balanced passively by a 4.7 Ω power resistor. Since the balancing resistors dissipate a lot of heat, there must be an additional temperature measurement inside the enclosure of the BMS unit to prevent overheating the integrated circuits. If the BMS temperature rises above the set threshold, charging and balancing is stopped. BMS error 5 is indicated until the temperature drops under the set hysteresis.

Balancing START Voltage:

If errors 2, 4, 5, 8, 10, 12 are not present, highest cell voltage rises above Balancing START voltage and current is > 0.2 A (charging stage) the BMS initiates balancing algorithm. A weighted cell voltage average is determined including cells’ DC internal resistance. Balancing algorithm calculates the voltage above which the cells are balanced. The lowest cell voltage is taken into account determining balancing voltage.

Balancing END Voltage:

If errors 2, 4, 5, 8, 10, 12 are not present, the cells above balancing END voltage are balanced regardless the battery pack current. A special charging-balancing algorithm is programmed. If the highest cell's voltage rises above the middle value between end of charge voltage and maximum cell's voltage the charger is turned off. BMS measures the weighted average value of the battery pack and sets this value as balancing voltage END. BMS balances all the cells that are above this value. When the highest cell is balanced down below this value, the charger is enabled again. Process is repeated until all the cells are @ end of charge voltage.

Cell Internal DC Resistance Measurement:

Cell internal DC resistance is measured as a ratio of a voltage change and current change in two sequential measurement cycles. If the absolute current change is above 15 A, cells internal resistance is calculated. Moving average is used to filter out voltage spikes errors. A time interval current-drop is introduced in the battery pack charging current to perform the cell internal DC resistance measurement.

Battery Pack Temperature Measurement:

Battery pack temperatures are measured by Dallas DS18B20 digital temperature sensors. Up to eight sensors can be used in parallel. BMS should be turned off before adding additional sensors. If the temperature sensors wiring is placed near the power lines a shielded cables should be used.

BMS Current Measurement:

A low-side shunt resistor current measurement is used. A 4-wire Kelvin connection is used to measure the voltage drop. As short as possible **shielded cable** should be used to connect the power shunt and BMS. The battery pack current is measured every second. A high precision ADC is used to filter out the current spikes. The first current measurement is timed at the beginning of the cell measurement procedure for a proper internal DC resistance calculation. Shunt connection is shown in Fig. 11.

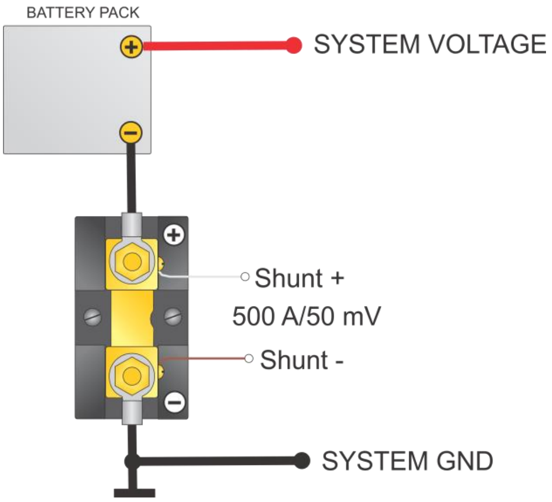

Figure 11: Shunt resistor connection.

Table 8: Shunt resistor connection.

Pin	Signal
1	- Shunt
2	Shield
3	+ Shunt

Voltage-to-current Coefficient:

Different size and resistance shunts can be used, since the voltage-to-current coefficient can be changed in the BMS Control software as 'I','O','J','A',' ','xxxxx'

Current is calculated by the voltage drop at the shunt resistor. 1 LSB of the 18 bit ADC represents different current values according to the shunt resistance. The LSB coefficient can be calculated as:

$$k_{LSB} = 0.01171875 \cdot \frac{0.05\text{ V}}{300\text{ A}} \cdot \frac{I_{\text{currentx}}}{V_{\text{dropx}}}$$

where the V_{dropx} represents the voltage drop on different shunt resistor at current I_{currentx}.

ADC has a pre-set gain of 8. With a maximum input voltage difference of 0.256 V.

Battery pack SOC Determination:

SOC is determined by integrating the charge in-to or out of the battery pack. Different Li-ion chemistries may be selected:

Table 9: Li-ion chemistry designators.

Number	Type
1	Li-Po High power
2	Li-Po High capacity
3	Winston/Thunder-Sky/GWL
4	A123
5	Li-NMC

Temperature and power correction coefficient are taken into consideration at the SOC calculation. Li-Po chemistry algorithms have an additional voltage to SOC regulation loop inside the algorithm. Actual cell capacity is recalculated by the number of the charging cycles as pointed out in the manufacturer's datasheet.

When BMS is reconnected to the battery pack, SOC is set to 50 %. SOC is reset to 100 % at the end of charging. It can be set to desired value by RS-485 communication protocol by 'S','O','C','S',' ','x.xx' instruction (0.0-1.0).

Chargers Enable Connection via external relay:

Charger is controlled by internal Darlington open collector optocoupler. When the charger should be enabled the optocoupler output transistor is closed. Due to the Darlington output and additional reverse protection diode there is 0.9 V voltage drop between the transistor's collector and emitter. Charger can be driven directly by the optocoupler @ AUX input or by a small external relay (coil up to 15 mA, 68 V). Connection schematic with 12 V relay coil is shown in Fig. 12. A special ON/OFF charging algorithm is used. When the highest cell reaches mean value between the maximum cell voltage and end of charge voltage, charger is stopped. BMS sets balance voltage end to minimum cell voltage. When the highest cell is balanced bellow this value, charger is enabled again. When the last cell reaches End of Charge value, BMS stops charging, sets SOC to 100% and sets charging and SOC charging hysteresis.

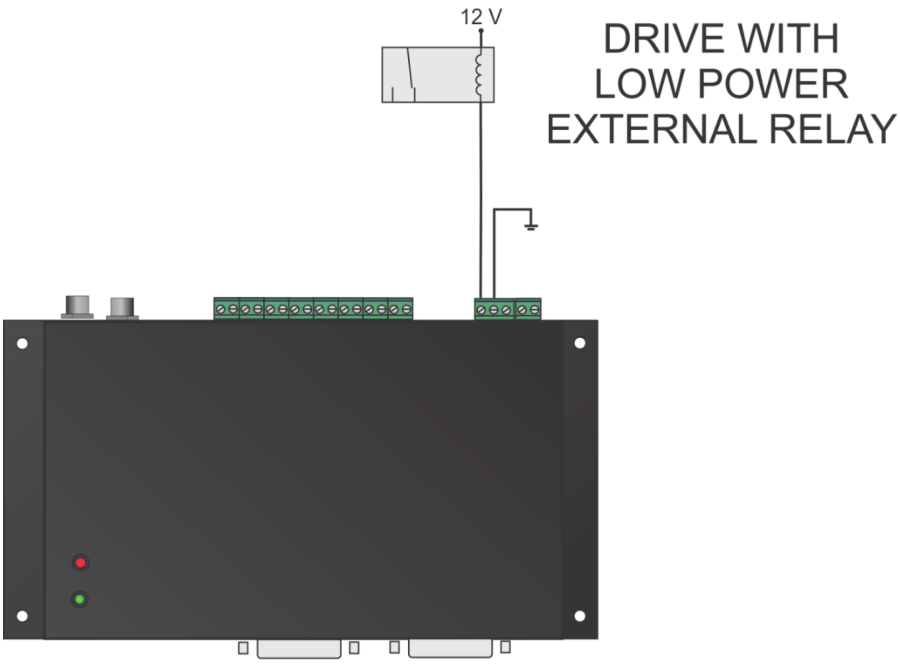

Figure 12: External relay connection schematics.

Pre-charge Circuit (optional):

Pre-charge circuit is used to fill the input capacitors of the System. When the BMS turns the internal relay, battery voltage starts to charge the capacitors via 33 Ohm power resistors inside the pre-charge circuit. After 4 s, the contactor is turned ON. Fig. 13 below shows how to connect the pre-charge circuit in the system.

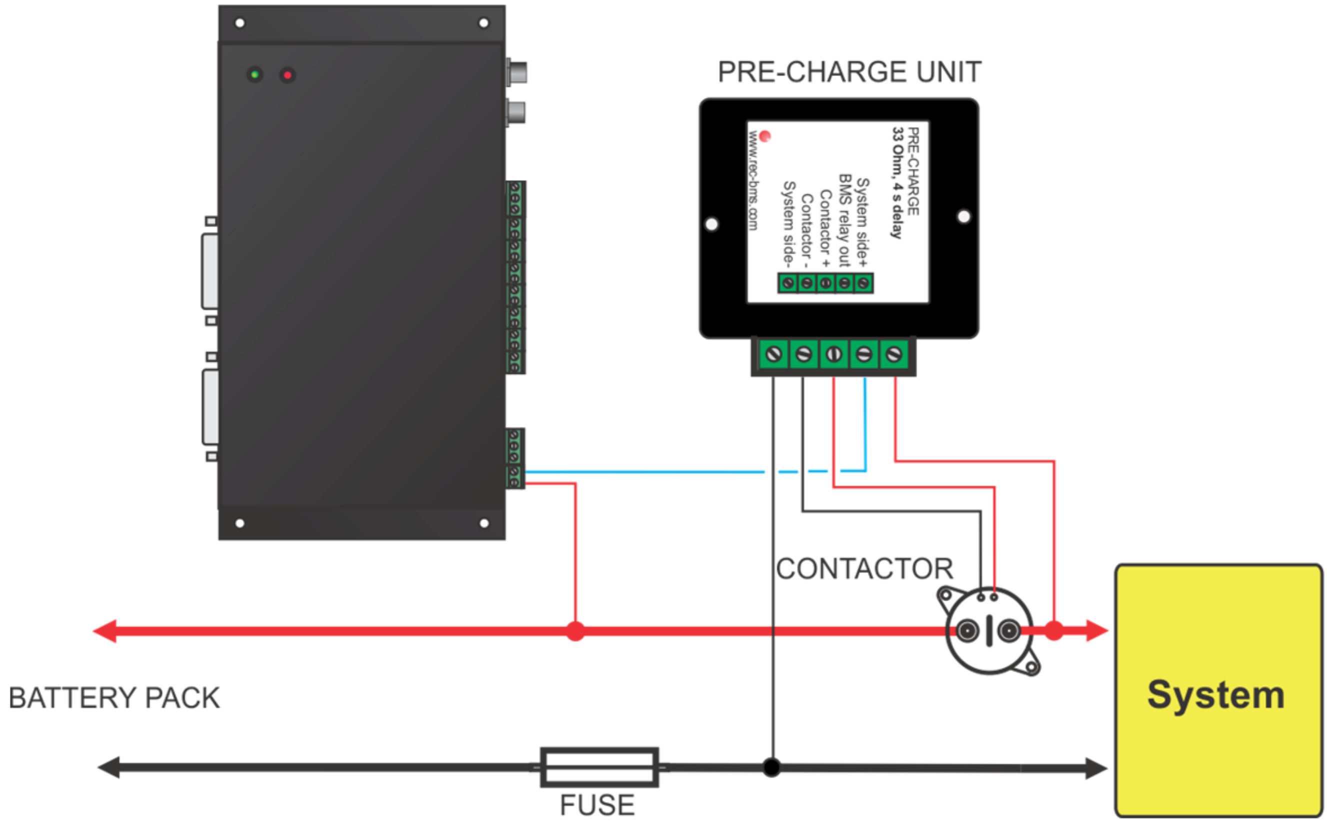

Figure 13: Pre-charge circuit connection schematics.

System Error Indication:

System errors are indicated with red error LED by the number of ON blinks, followed by a longer OFF state.

Table 10: BMS error states.

Number of ON blinks	ERROR	BMS	OWNER
1	Single or multiple cell voltage is too high (cell over voltage switch-off).	BMS will try to balance down the problematic cell/cells to safe voltage level (10 s error hysteresis + single cell voltage hysteresis is applied). Internal relay is opened, charger is disabled.	• Wait until the BMS does its job.
2	Single or multiple cell voltage is too low (cell under voltage protection switch-off).	BMS will try to charge the battery (10 s error hysteresis +single cell voltage hysteresis is applied). Internal relay is opened to disable discharging (if cell's voltage is below CLOW for more than TREL), charger is enabled.	• Plug in the charger.
3	Cell voltages differs more than set.	BMS will try to balance the cells (10 s error hysteresis + 20 mV voltage difference hysteresis). Internal relay is closed, charger is enabled.	• Wait until the BMS does its job. If the BMS is not able to balance the difference in a few hours, contact the service.
4	Cell temperature is too high (over temperature switch-off).	Cells temperature or cell inter-connecting cable temperature in the battery pack is/are too high. (20 s error hysteresis 2°C hysteresis). Internal relay is opened, charger is disabled.	• Wait until the pack cools down.
5	BMS temperature is too high (BMS over temperature switch-off).	Due to extensive cell balancing the BMS temperature rose over upper limit (10 s error hysteresis + 5 °C temperature hysteresis). Internal relay is closed, charger is enabled.	• Wait until the BMS cools down.
6	Number of cells, address is not set properly.	Number of cells at the back of the BMS unit was changed from the default manufacturer settings. Internal relay is opened, charger is disabled.	• Set the proper number of cells, address.

7	The temperature is too low for charging (under temperature charging disable).	If cells are charged at temperatures lower than operating temperature range, cells are aging much faster than they normally would, so charging is disabled (2 °C temperature hysteresis). Internal relay is opened, charger is disabled.	• Wait until the battery's temperature rises to usable range.
8	Temperature sensor error.	Temperature sensor is un-plugged or not working properly (6 s error hysteresis). Internal relay is opened, charger is disabled.	• Turn-off BMS unit and try to re-plug the temp. sensor. If the BMS still signals error 8, contact the service. The temperature sensors should be replaced.
9	Communication error.	(RS-485 Master-Slave communication only).	
10	Cell in short circuit or BMS measurement/calibration error.	Single or multiple cell voltage is close to zero or out of range, indicating a blown fuse, short circuit or measuring failure (10 s error hysteresis + 10 mV voltage difference hysteresis). Internal relay is opened, charger is disabled.	• Turn-off the BMS and check the cells connection to the BMS and fuses. Restart the BMS. • If the same error starts to signal again contact the service.
11	Main relay is in short circuit.	If the main relay should be opened and current is not zero or positive, the BMS signals error 11. When the error is detected, the BMS tries to un-shorten the main relay by turning it ON and OFF for three times. Internal relay is opened, charger is enabled.	• Restart the BMS unit. If the same error starts to signal again contact the service.
12	Error measuring current.	Current sensor is disconnected or not working properly. Internal relay is opened, charger is disabled.	• Turn-off the BMS and check the sensor connections, re-plug the current sensor connector. Turn BMS back ON. If the BMS still signals error 12, contact the service.
13	Wrong cell chemistry selected.	In some application the chemistry pre-set is compulsory.	• Use PC Control Software to set proper cell chemistry.

14	EEPOM data corruption	EMC interference can change the data in the EEPROM memory. When the BMS is switched on all the data is checked. If corrupted data is found, BMS sets its values to default and signals error 14. Internal relay is opened, charger is disabled.	• Use PC Control Software to reset the parameters.
15	Balancing transistors failure	Single or multiple transistors for balancing failure detection Internal relay is opened, charger is disabled.	• Restart the BMS unit. If the same error starts to signal again contact the service.

BMS Unit Dimensions:

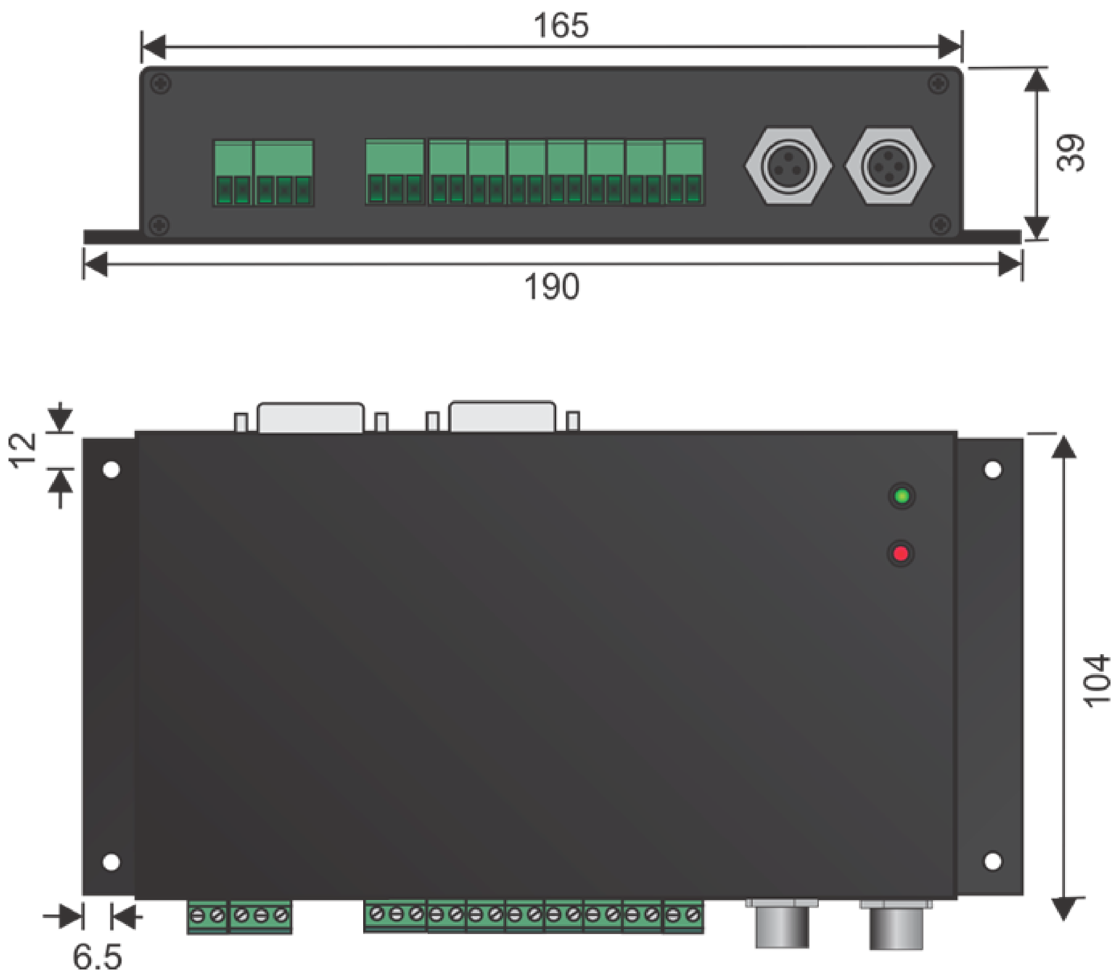

Figure 14: BMS dimensions.

BMS unit can be supplied without the enclosure, if an application is weight or space limited. The dimensions of the BMS without the enclosure are 160 mm x 100 mm x 27 mm. Sufficient contact surface for cooling the balancing resistors should be provided (aluminum recommended).