Rozna ulica 20, 6230 Postojna, Slovenia
e-mail: info@rec-bms.com; www.rec-bms.com

BATTERY MANAGEMENT SYSTEM
Master – Slave configuration

Features:

- robust and small design
- Master + max 15 Slave combination (max 240 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 8 temperature sensors per Slave)
- under temperature charging protection
- passive cell balancing up to 0.9 A per cell with LED indication
- shunt current measurement (resolution 19.5 mA @ ± 500 A)
- 3 galvanically isolated user defined multi-purpose digital inputs/outputs
- 4 programmable relays (normally open and normally closed option)
- 12 V galvanically isolated supply (10.5 – 15 V)
- galvanically isolated RS-485 and CAN communication protocol
- error LED + buzzer indicator
- internal battery powered real time-clock (RTC)
- PC user interface for changing the settings and data-logging (optional accessory)
- LCD touch display for monitoring (optional accessory)
- hibernate switch
- one-year warranty

General description of the BMS

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 battery cell to another and this increases with number of charging/discharging cycles. The Li-ion polymer batteries are fully charged at typical cell voltage 4.16 - 4.20 V. Due to the different capacity this voltage is not reached at the same time for all cells in the stack. The lower the capacity the sooner this voltage is reached. When charging series connected batteries with single charger, the voltage on some cells might be higher than maximum allowed charging voltage at the end of charging. 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 8 sensors may be used. The BMS parameters are listed in table below.

Default Parameter table:

Table 1: Default parameter table.

Parameter	Value	Unit
Chemistry	5 ($LiMnO_2$, NMC)	n.a.
balance start voltage	4.0	V
balance end voltage	4.15	V
maximum diverted current per cell	up to 0.9 (4.3 Ohm)	A
cell over voltage switch-off	4.18	V
cell over voltage switch-off hysteresis per cell	0.03	V
charger end of charge switch-off pack	4.15	V
charger end of charge switch-off hysteresis per cell	0.1	V
cell under voltage protection (CLOW)	3.35	V
cell under voltage protection switch-off	3.25	V
under voltage protection switch-off hysteresis per cell	0.1	V
Max cell difference	0.15	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	-5	°C
Slave 1 100A/50mV voltage to current coefficient	0.01953125	A/V
maximum charging/discharging current per inverter device	100/100	A
charging/discharging coefficients	0.6/1.5	C
Number of inverter devices	1	n.a.
Slave Unit absolute maximum package voltage	68	V
Master Unit power supply voltage	10-15	V
max DC current Relay 1-4 at 100 V DC	0.4	A
max DC current Relay 1-4 at 12 V DC	2	A
max AC current Relay 1-4 at 230 V AC	2	A
optocoupler 1, 2, 4 output max voltage	62	V
optocoupler 2, 4 output max current	15	mA
Slave Unit stand-by power supply	< 90	mW
Slave Unit disable power supply	< 1	mW
Slave Unit cell balance fuse rating (SMD)	2	A
Master Unit stand-by power supply @ 12 V	300	mW
Master Unit disable power supply	0	mW
internal relay fuse (Master Unit)	2 slow	A
cell voltage and temp. measurement refresh rate	2	s
current measurement refresh rate	1	s
Slave Unit dimensions (w × l × h)	190 x 104 x 39	mm
Master Unit dimensions (w × l × h)	190 x 104 x 39	mm
weight	0.650	kg

System Overview

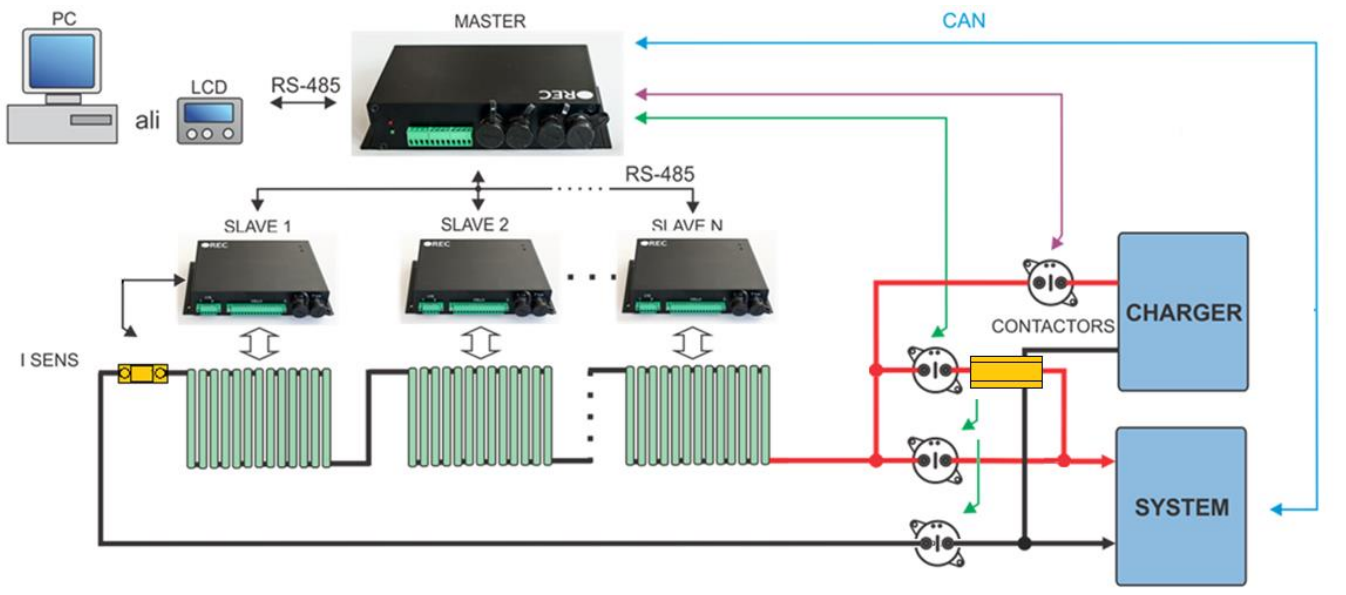

Figure 1: System overview.

Slave Unit

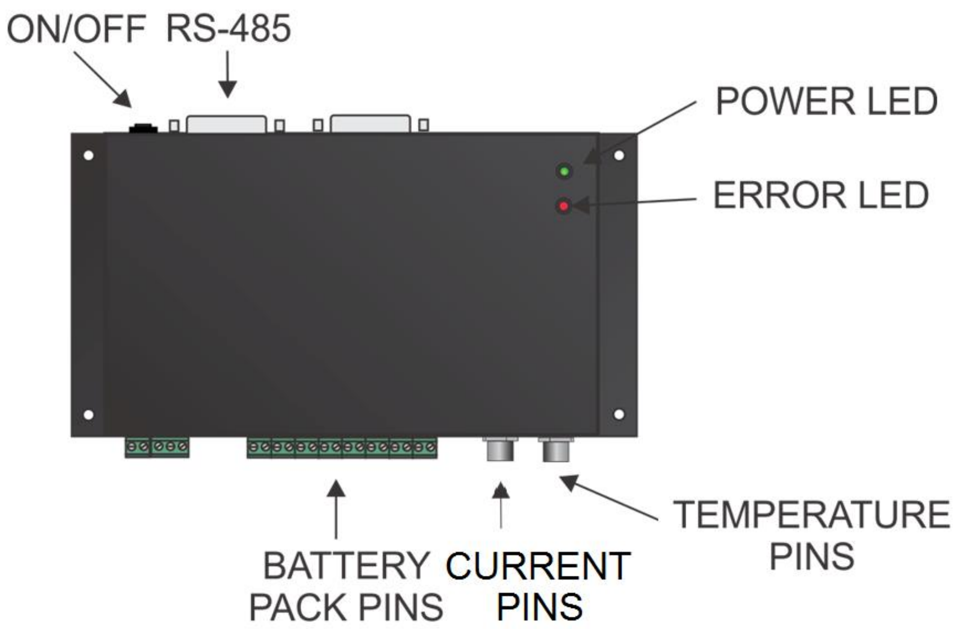

Figure 2: Slave Unit function overview.

Slave Unit Connection Table

Table 2: Slave Unit connection table.

Pins	Connection	Description
Temp. pins		
1	DALLAS 18B20 temp. sensor pins	+5 V
2	DALLAS 18B20 temp. sensor pins	GND
3	DALLAS 18B20 temp. sensor pins	1-wire digital signal
Current. Pins*		
1	Shunt Kelvin sens negative	Shunt negative
2	Shield	GND
3	Shunt Kelvin sens positive	Shunt negative
Cells pins		
1	Cell 1 ground	Analog signal
2	Cell 1 positive	Analog signal
3	Cell 2 positive	Analog signal
4	Cell 3 positive	Analog signal
5	Cell 4 positive	Analog signal
6	Cell 5 positive	Analog signal
7	Cell 6 positive	Analog signal
8	Cell 7 positive	Analog signal
9	Cell 8 positive	Analog signal
10	Cell 9 positive	Analog signal
11	Cell 10 positive	Analog signal
12	Cell 11 positive	Analog signal
13	Cell 12 positive	Analog signal
14	Cell 13 positive	Analog signal
15	Cell 14 positive	Analog signal
16	Cell 15 positive	Analog signal
17	Cell 16 positive	Analog signal
I/O pins		
1	-	-
2	-	-
3	-	-
4	-	-
5	-	-

***Slave with address 1 only. Connect as close to battery as possible. Do not put the fuse between.**

Setting number of cells and the RS-485 address

Number of cells connected to the Slave 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.

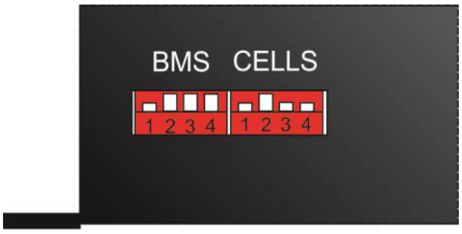

Figure 3: Address and cell selection DIP Switches.

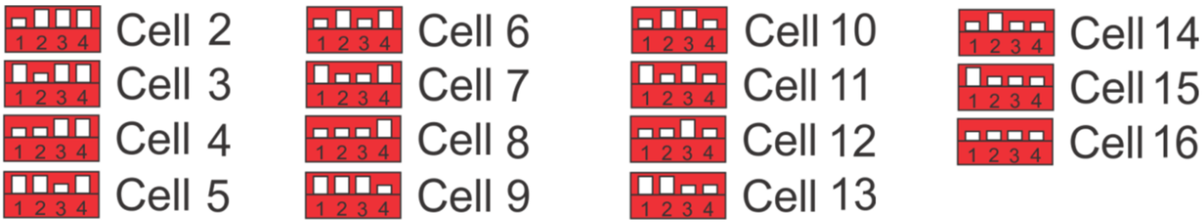

Figure 4: Number of cell selection description.

Slave 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 Slave Units are used distinguished addresses should be set to avoid data collision on the RS-485 communication bus!**

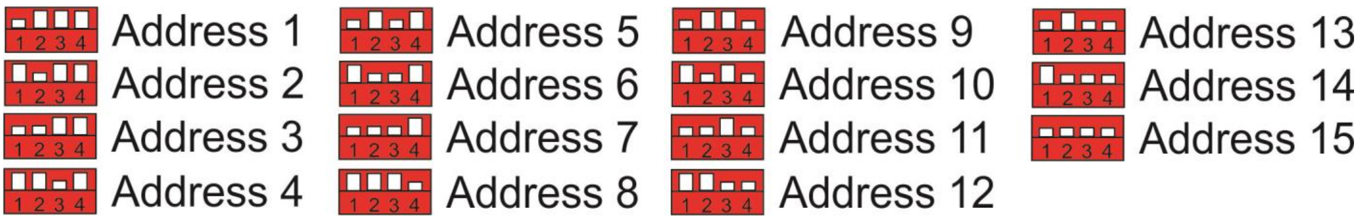

Figure 5: Slave Unit address selection description.

Slave Unit Cell Connector

Connect each cell to the Slave Unit cell connector plug. Use silicon wires with cross section of 0.5-1 mm^2. **! Before inserting the cell connector check voltages and polarities with voltmeter of each connection!**

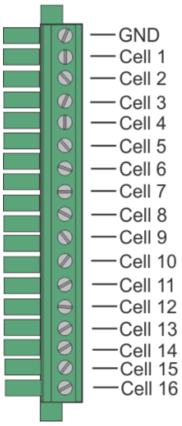

Figure 6: Battery pack cell connection.

Slave 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!**

If multiple Slave Units are used in series, care should be taken how to connect each. Two separate wires should be wired to the same cell: first wire for the lower Slave Unit as the end-cell voltage potential, and second wire as GND potential for the higher Slave Unit. See Fig. 7 ! **Do not bypass the higher cell!**

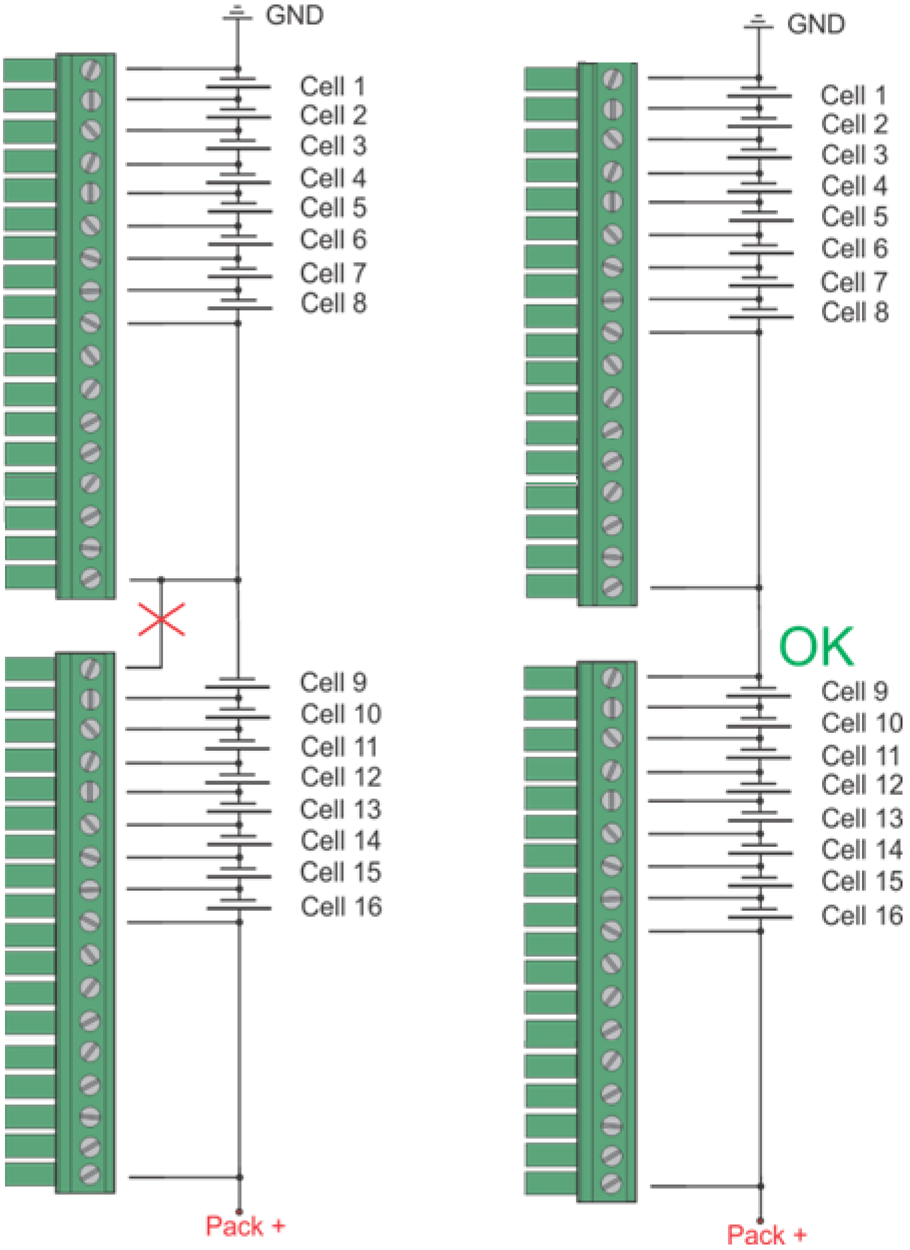

Figure 7: Multiple Slave Units for series cell connection.

Slave Unit Connection Instructions

Connect the Slave 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 second to last and simultaneously**. When all the system components are plugged in, the enable switch can be turned ON and the Slave Unit starts the test procedure.

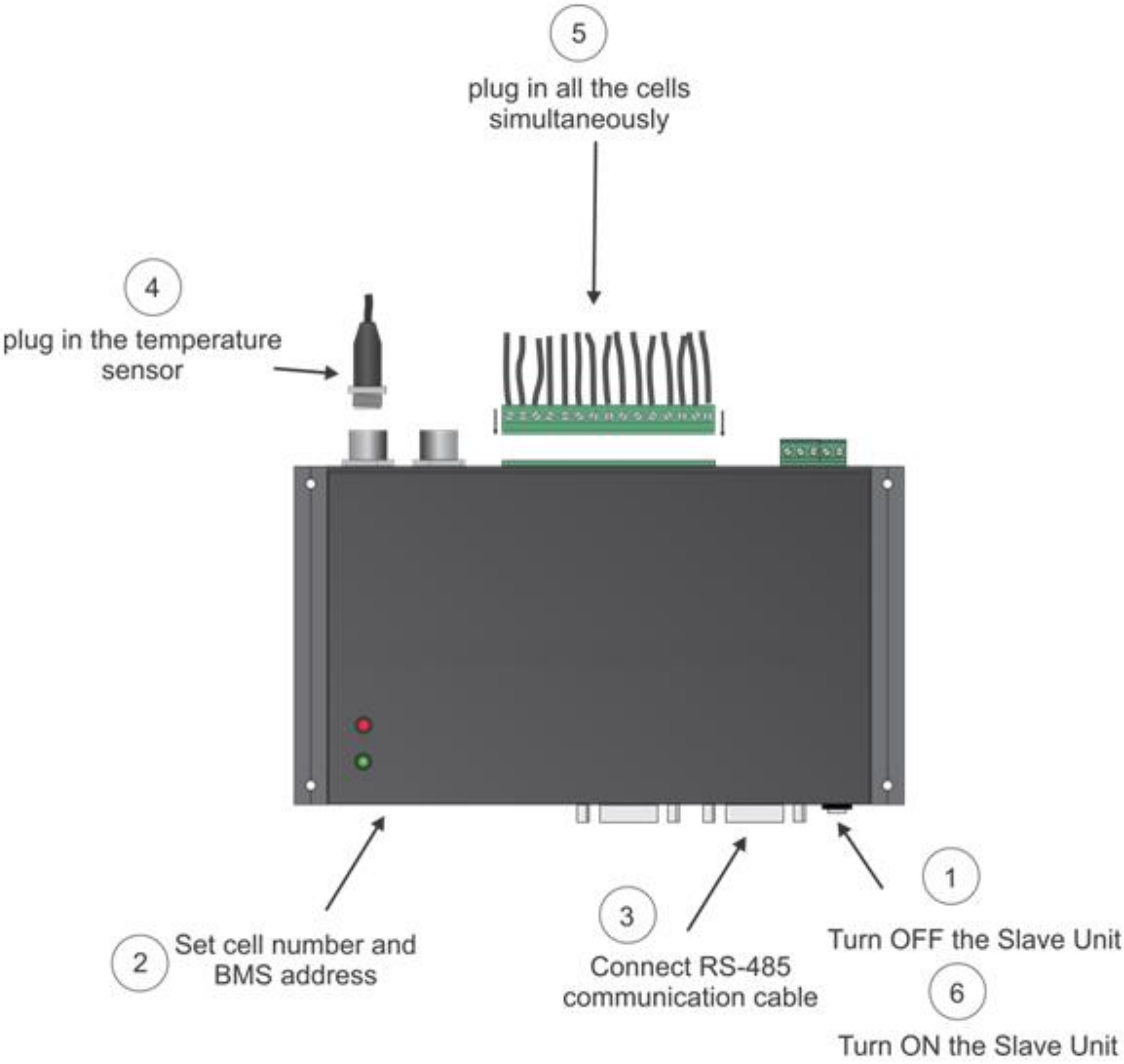

Figure 8: BMS connection order.

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

Slave Unit Test Procedure

When the Slave Unit is turned ON it commences the test procedure. Red error LED turns on to signal the system's test procedure. The procedure starts by testing Slave Unit balancing switches. The test completes in 5 seconds, red LED turns off and the Slave Unit starts working in normal mode if there is no error and at least one temperature sensor is detected. Slave Unit goes to idle mode to conserve power consumption and waits for the Master Unit instructions.

Slave Unit LED Indication

While the Slave Unit measures the cell voltage, current, cell temperature and BMS temperature Power LED (green) is turned on at each Slave module simultaneously. Error LED (red) is turned on in case of system error.

Master Unit

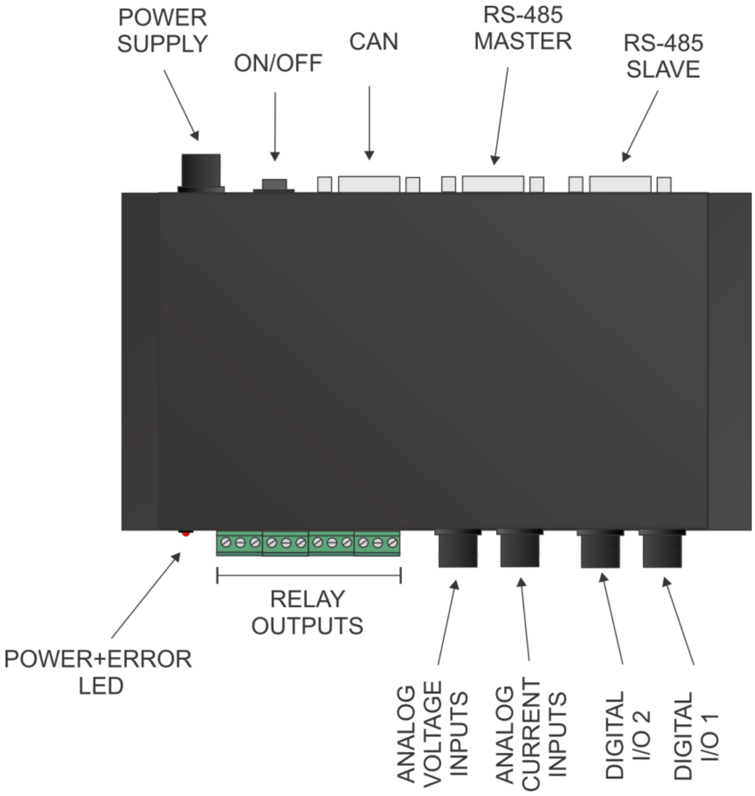

Figure 9: Master Unit function overview.

Table 3: Digital I/O 1.

Pin	Connection	DESCRIPTION
1	Optocoupler 2 emitter	Not programmed
2	Optocoupler 1 emitter	Not programmed
3	Optocoupler 1 open collector	Not programmed
4	Optocoupler 2 open collector	Not programmed

Table 4: Digital I/O 2.

Pin	Connection	DESCRIPTION
1	Optocoupler 4 emitter	Not programmed
2	-	-
3	-	-
4	Optocoupler 4 open collector	Not programmed

Table 5: Analog current measurement connections.

Pin	Connection	DESCRIPTION
1	No connection	Not programmed
2	No connection	Not programmed
3	No connection	Not programmed
4	No connection	Not programmed

Table 6: Analog voltage measurement connections.

Pin	Connection	DESCRIPTION
1	-	-
2	Vin 1 -	Not programmed
3	Vin 1 +	Not programmed
4	-	-

Table 7: Relay Outputs.

Pin	RELAY	Connection	Polarity	Protection
1	RELAY_1	Charger enable relay	NO	
2		Charger enable relay	Signal	Fuse 2A Slow
3		-	NC	
4	RELAY_2	Battery pack HV - relay	NO	
5		Battery pack HV - relay	Signal	Fuse 2A Slow
6		-	NC	
7	RELAY_3	pre-charge relay 4 s	NO	
8		pre-charge relay 4 s	Signal	Fuse 2A Slow
9		-	NC	
10	RELAY_4	Battery pack HV + relay	NO	
11		Battery pack HV + relay	Signal	Fuse 2A Slow
12		-	NC	

Power Supply

Connect the power supply at the back side of the Master Unit. Supply voltage is limited to 10.5 – 15 V DC by internal protection circuit. Power consumption differs according to the switched on relays or I/O. If no relay is turned on, the BMS Master Unit consumes about 300 mW of power @ 12 V. Power supply entry is isolated from the rest of the circuit by internal isolative DC-DC converter.

Figure 10: Master Unit back plate power supply pins.

Table 8: Master Unit power supply connections.

Pin	Connection	Protection
1	GND	
2	+ 12 DC (10.5 – 15 V)	Under-voltage/overvoltage + over-current protection

Master Unit Analog Voltage Inputs (no-function)

Master Unit has an analog voltage input that is able to measure up to maximum 530 V DC. Input voltages are subtracted and translated to circuit ground. Input impedance toward the internal ground is 1 MOhm at both poles. Signal is filtered by low-pass filter (-3dB @ 0.6 Hz).

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: Programmed Chemistry types.

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

SOC is reset to 100% at the end of charging and Power LED turns ON until charger hysteresis is present. When the BMS senses that the whole capacity was emptied from the battery pack a cycle is added. This means that ten 10 % discharges would also result in one battery cycle.

System Error Indication

System errors are indicated with red error LED by the number of ON blinks, followed by a longer OFF state. Red LED switch-off indicator turns on in case of:

Table 10: System error description.

Number of ON blinks	ERROR	BMS	TO-DO
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 (2 s error hysteresis cell over voltage switch-off hysteresis). Main contactors is disconnected, charging 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 (2 s error hysteresis + cell under voltage hysteresis is applied). Main contactors are disconnected. Charging is enabled.	• Plug in the charger.
3	Cell voltages differs more than allowed (cells differ more than set).	Main contactors are connected.	
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 (2 s error hysteresis + cell over temperature hysteresis is applied). All contactors are disconnected.	• Examine the battery pack if this occurs frequently.
5	BMS temperature is too high (BMS over temperature switch-off).	Due to extensive cell balancing the BMS temperature rose over upper limit (2 s error hysteresis + 5 °C temperature hysteresis). Main contactors are connected. Charging 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 Slave Unit was changed from the default manufacturer settings. All contactors are disconnected.	• 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). Main contactors are connected, Charging 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. All contactors are disconnected.	• Turn-off the Master and Slaves Units by enable switch and try to re-plug the temperature sensor connector. Turn Slave Unit back ON and restart the Master Unit. If the BMS still signals error 8, contact the service. The temperature sensors should be replaced.
9	Communication error.	Main contactors are disconnected. All outputs are disconnected	• Turn OFF Master and all Slave Units. Turn ON Slave Units and Master Unit. • Check the Master –Slave connection cable + remote ON/OFF cable • Check the Slave Unit voltage (is it below set threshold voltage) • If the error repeats, contact the service.
10	Cell in short circuit or BMS measurement error.	Single or multiple cell voltage is close to zero or out of range, indicating short circuit, blown balance fuse or measuring failure. All contactors are disconnected.	• Restart the Slave and Master Unit. • Check the cells connection to the BMS Slave Units. • If the same error starts to signal again contact the service.
11	Main contactors are in short circuit.	If the main contactors 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 contactors by turning it ON and OFF for three times. All contactors are disconnected.	• Restart the Master Unit.
12	Error measuring current.	Current sensor is disconnected or not working properly. All contactors are disconnected.	• Turn-off the BMS by enable switch and try to 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.	All contactors are disconnected.	• Use PC interface to set proper cell chemistry.
14	Reserved	-	-
15	Balancing transistor failure	Main contactors are connected. Charging is enabled.	• Restart the Slave and Master Unit. • Check the cells connection to the BMS Slave Units. • If the same error starts to signal again contact the service.

16	TWI internal communication error (Slave/Master)	All contactors are disconnected.	• Restart the Slave and Master Unit. • Check the cells connection to the BMS Slave Units. • If the same error starts to signal again contact the service.

RS-485 Communication Protocol

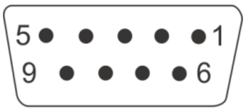

Figure 11: RS-485 DB9 male connector front view.

Table 11: RS-485 DB-9 connections.

Pin	Designator
1	-
2	A + termination
3	B + termination
4	AGND
5	-
6	-
7	-
8	-
9	+5 V

BMS Unit is programmed as a Slave Unit and responds only when asked. Galvanically isolated RS-485 (EN 61558-1, EN 61558-2) serves for logging and changing BMS parameters. Dedicated PC software BMS Master Control 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 if 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, Little endian format

Table 12: RS-485 instructions description.

INSTRUCTION	DESCRIPTION	BMS ANSWER
'*','I','D','N','?'	Identification	Answer "REC - BATERY MANAGEMENT SYSTEM"
'L','C','D','1','?'	Main data	Returns 28 in the first message and then 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 2	Returns 8 in the first message and then 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 in the first message and then sends 4 bytes as follows ERRO [0] = 0 – no error, 1 – error ERRO [1] = BMS unit ERRO [2] = error number (1-15) in ERRO [3] = number of the cell, temp. sensor where the error occurred
'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
'T','H','I','S','?'/ 'T','H','I','S',' ','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
'P','A','R','V', '?'/ 'P','A','R','V',' ','xxx'	Number of inverter/charger devices	Returns unsigned char value
'S','O','C','H', '?'/ 'S','O','C','H',' ','xxx'	Charger SOC hysteresis	Returns float value 0.0-1.0
'S','O','C','S', '?'/ 'S','O','C','S',' ','xxx'	SOC manual reset	Returns float value 0.0-1.0
'F','U','S','E', '?'/ 'F','U','S','E',' ','xxx'	First use byte for Error Log reset	Returns float value 0,1. Set it to 0 and restart the Master BMS for Error Log delete
'E','R','R','L', '?'/	Returns error log data (FIFO register of the last 12 errors). By sending the same instruction the data pointer shifts from the last error entry to the first error entry, then it starts all over again	Returns “xx,zz; hh:mm:ss;dd.mm.yyyy” xx-error number zz-number of the cell/temp sensor
'C','L','O','W','?'/ 'C','L','O','W',' ','xxx'	Relay under voltage switch off	Returns float voltage [V]
'C','H','A','C','?'/ 'C','H','A','C',' ','xxx'	Charging coefficient (0-3C)	Returns float value 0-3.0 (default 0.6)
'D','C','H','C','?'/ 'D','C','H','C',' ','xxx'	Discharging coefficient (0-3C)	Returns float value 0-3.0 (default 1.5)
'M','A','X','C', '?'/ 'M','A','X','C', ' ','xxx'	Max allowed charge current per inverter device	Returns float current [A]
'M','A','X','D', '?'/ 'M','A','X','D', ' ','xxx'	Max allowed discharge current per inverter device	Returns float current [A]

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

Example: proper byte message for 'LCD1?' instruction for BMS address 1 is:
<0x55><0x01><0x00><0x05><0x4C><0x43><0x44><0x31><0x3F><0x46><0xD0><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

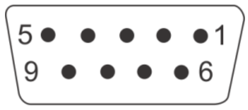

Figure 12: CAN DB9 connector front view.

Bit-rate: 250 kbs
11-bit identifier: 0x031, 0x032, 0x033 and 0x034
Default settings TX only
8 byte message structure

Terminate the CAN line by shorting PIN 1 and 2 and prevent BMS reset!

Table 13: CAN DB9 connector pin designator.

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

Table 14: 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 = 20 mV
3	Battery pack voltage low byte		
4	Battery pack current high byte	Signed integer	−32768 to 32767 LSB = 50 mA
5	Battery pack current low byte		
6	Battery pack max temperature	Signed char	-127 to 127 LSB = 1° C
7	State of health [%]	Unsigned char	0-200 LSB = 0.5 % SOC
8	Error number	Unsigned char	0-17

Table 15: CAN message structure description for ID=0x032.

Byte	Description	Type	
1	Slave module number with error	Unsigned char	0-15
2	Slave module with error element number	Unsigned char	0-16
3	Contactor status	Unsigned char	0 – disconnected, 1-pre-charge, 2 - connected
4	Low cell voltage high byte	Unsigned integer	0-65535, LSB = 1 mV
5	Low cell voltage low byte		
6	High cell voltage high byte	Unsigned integer	0-65535, LSB = 1 mV

7	High cell voltage low byte		
8	Battery pack min temperature	Signed char	-127 to 127 LSB = 1° C

Table 16: CAN message structure description for ID=0x033.

Byte	Description	Type	
1	Low cell position - Slave	Unsigned char	0-15
2	Low cell position on the Slave	Unsigned char	0-16
3	High cell position - Slave	Unsigned char	0-15
4	High cell position on the Slave	Unsigned char	0-16
5	Max temperature position - Slave	Unsigned char	0-15
6	Max temperature position on the Slave	Unsigned char	0-4
7	Min temperature position - Slave	Unsigned char	0-15
8	Min temp position on the Slave	Unsigned char	0-4

Table 17: CAN message structure description for ID=0x034.

Byte	Description	Type	Property
1	Charge voltage high byte	Unsigned integer	LSB = 0.1 V
2	Charge voltage low byte		
3	Max charging current high byte	Signed integer	LSB = 0.1 A
4	Max charging current low byte		
5	Max charging current high byte	Signed integer	LSB = 0.1 A
6	Max charging current low byte		
7	Discharge voltage high byte	Unsigned integer	LSB = 0.1 V
8	Discharge voltage low byte		

CAN message is sent every 500 ms. **If the BMS is not connected to any other device using the CAN interface, it is required to short pins 1 and 2 for proper signal line termination. Otherwise the BMS will enter a self-restarting loop.** BMS will calculate a max charge current and max discharge current from the maximum cell and minimum cell voltage and cells temperatures. BMS will not communicate to the charger.

Battery Pack's Charging Algorithm

The communication between the REC BMS and the system is established through the CAN bus. All the parameters that control the charging/discharging behavior are calculated by the BMS and transmitted in every measurement cycle.

The charging current is controlled by the *Maximum charging current* parameter. It's calculated as *Charging Coefficient('C','H','A','C') x Battery capacity.* The parameter has an upper limit which is defined as *Maximum Charging Current per Device ('M','A','X','C') x Number of Devices ('P','A','R','V').*

When any cell reaches the voltage interval between *Balance Voltages Start* and *Balance Voltage End*, the charging current starts to ramp down to *1.1 A x Number of Devices* until the last cell rises to the *End of Charge Voltage*. At that point the Maximum charging voltage is set to Number of cells x (*End of Charge Voltage per cell* - end of charge hysteresis *per cell)* and the charger is disabled also via the BMS I/O interface. End of Charge, SOC hysteresis and End of charging cell voltage hysteresis prevent unwanted switching. SOC is calibrated to 100 % and Power LED lights ON 100 %. Charger turn-off can also be caused by some of the systems errors (See System Errors indication chapter). SOC is calibrated to 96 % at the 0.502 x value between *Balance Voltages Start* and *Balance Voltage End*.

Battery Pack's Discharging Algorithm

Calculated maximum discharging current is sent to the system by CAN communication in every measurement cycle. When the BMS starts/recovers from the error or from Discharging SOC hysteresis, maximum allowed discharging current is set. It is calculated as discharging coefficient ('D','C','H',’C') x Battery capacity. If this value is higher than maximum discharging current per device ('M','A','X',’D') x number of devices ('P','A','R',’V'), maximum discharging current is decreased to this value. When the lowest open circuit voltage cell is discharged bellow the set threshold 'C','L','O',’W', the maximum discharging current starts to decrease down to 0.05 C (5 % of Capacity in A). After decreasing down, maximum allowed discharging current is set to 0 A. SOC is reset to 3 % and Discharging SOC hysteresis is set to 5 %. If the cell discharges bellow Minimum Cell voltage ('C','M','I','N'), BMS signals Error 2 and SOC is reset to 2 %. If the Charger/inverter is connected to the grid maximum allowed discharge current is drawn from the grid. Otherwise 100 % load current is drawn from the battery until maximum allowed discharging current is set to 0 A.

Slave Unit Dimensions

BMS Slave 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. A sufficient contact surface for balancing resistors should be provided. The PCB has four 3.2 mm mounting holes. The enclosure is made of black anodized aluminum.

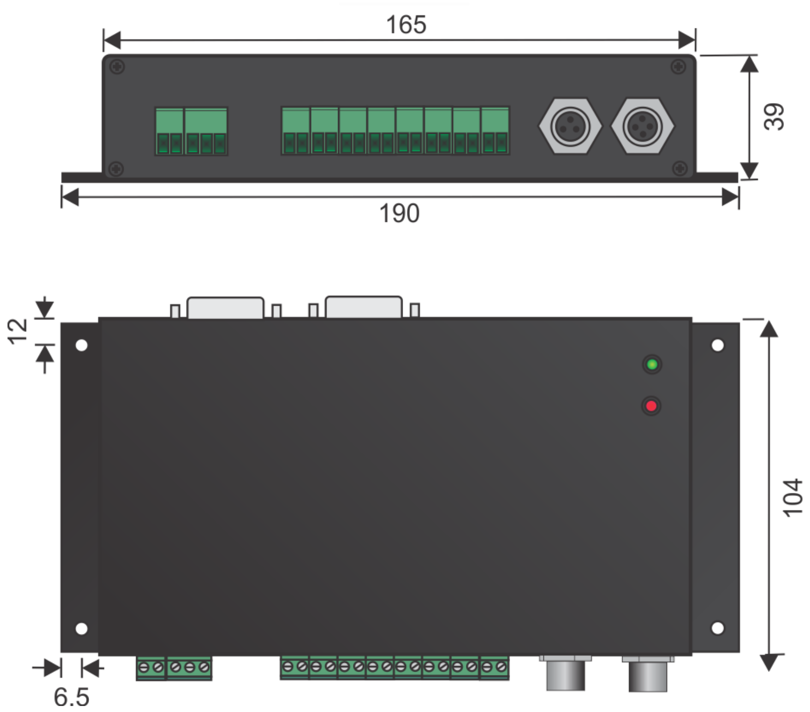

Figure 13: BMS Slave Unit dimensions.

BMS Master Unit Dimensions

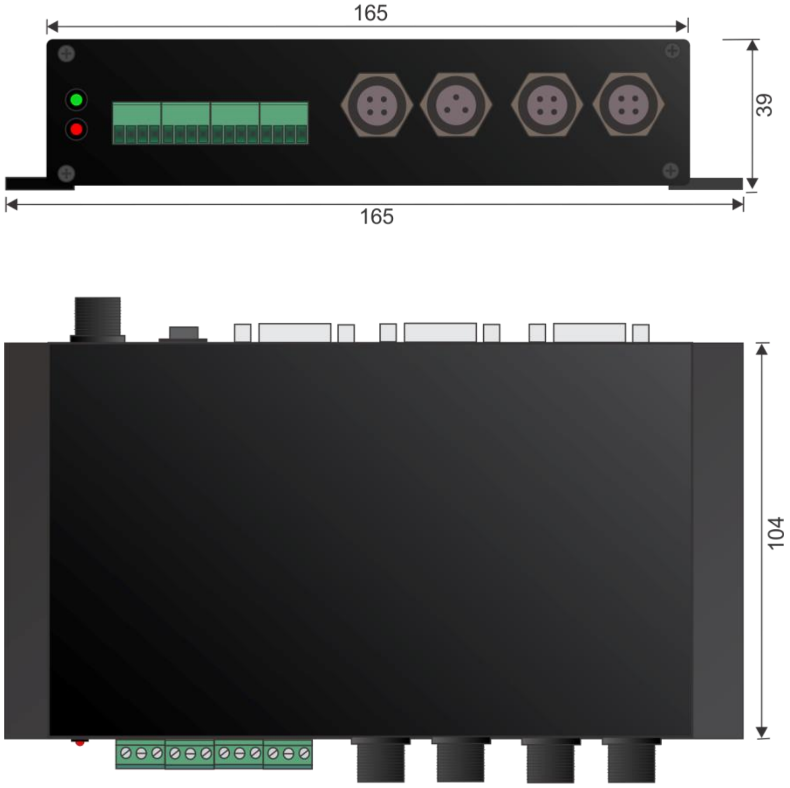

Figure 14: BMS Master Unit dimensions.