

# HARDWARE INSTALLATION MANUAL



## P/N 30-8407 & 30-8408 MINI BMS MASTER MODULE 18 CELL UNSEALED BMS SATELLITE MODULE



### **STOP! - READ THIS BEFORE INSTALL OR USE!**

#### **WARNING:**

IT IS THE RESPONSIBILITY OF THE INSTALLER TO ULTIMATELY CONFIRM THE CONFIGURATION USED FOR ANY PARTICULAR INSTALLATION IS SAFE FOR ITS INTENDED USE. AEM HOLDS NO RESPONSIBILITY FOR ANY DAMAGE THAT RESULTS FROM THE MISUSE OF THIS PRODUCT.

Working on Electric Vehicle tractive systems with high voltage battery packs requires special experience and training. Doing this safely is entirely the responsibility of the installer. AEM has done everything it can to ensure the VCU has appropriate fault detection and failsafe logic but that does not mean that your installation will be safe or that your VCU installation will not interfere with other systems on your vehicle and create a hazardous situation. It is the responsibility of the installer to understand the implications of each stage of tractive system installation and testing, and to know what might be unique about your application that presents an unintended hazard or potential safety issue – and to solve it.

Following is a brief list of recommended practices. This is not a comprehensive list; as noted below, if you are not well-versed in the appropriate installation and testing procedures, you should refer the installation and calibration to a reputable installation facility or contact AEM EV for a referral in your area.

- When access is required near the battery pack, the cell segments must be separated by using an appropriate maintenance disconnect plug.
- When working on the battery pack or tractive system, safety glasses with side shields and appropriate insulated tools must be used.
- Always wear Class 0 gloves rated at 1000V with leather protectors.
- Only use a CAT III rated digital multi-meter (DMM) and test leads.
- When working on the battery pack or tractive system, use the one hand rule: work with one hand keeping the other behind your back whenever possible.
- During initial system power up and testing, the vehicle must be raised off the ground and supported appropriately. Wheels/tires should be removed.
- During the VCU firmware upgrade process, battery cell segments must be separated by using an appropriate maintenance disconnect plug.
- Do not make calibration changes while the inverter PWM is enabled.

## **DANGER!**

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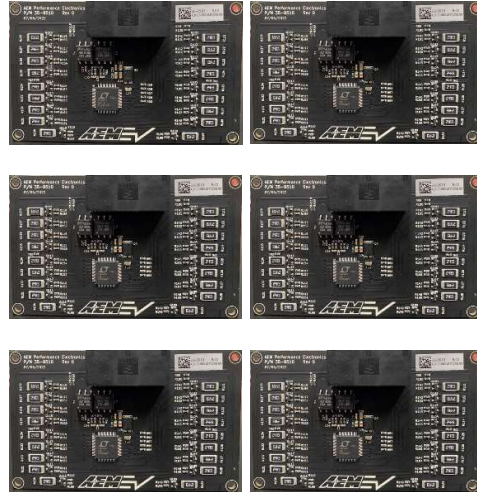
AEM'S Battery Management Systems ("BMS") for electric vehicles work with VERY high voltages, and improper use or installation can result in life-threatening injuries and extensive property damage. USE EXTREME CAUTION at every step of installation, and during use, of the BMS. Incorrect wiring on the high voltage taps may (a) destroy the BMS Module instantly upon connection, (b) destroy the battery if the connection is not broken immediately, and/or (c) start a chain reaction breakdown in the battery cell that can lead to a battery fire, which may destroy the battery, the vehicle and the storage structure the vehicle is housed. In all cases, confirm proper operation of the entire high voltage system, including charging, before leaving a fully-enabled vehicle unattended.

Do not open the BMS Modules as high voltage may be present. If you suspect a Module may be damaged, immediately disconnect the unit and do not use it until it has been inspected by AEM. NEVER ATTEMPT TO USE A UNIT THAT YOU SUSPECT MAY HAVE BEEN DAMAGED. AEM is not liable for continued use of a damaged BMS unit.

All battery packs must have a suitable current limiting fuse. Failure to use a suitable fuse may result in catastrophic failure of the BMS or battery pack.

The Vehicle Control Unit ("VCU") must be in full control of the power connections to the battery and must have the ability to interrupt all connections to the battery in case of an emergency. This includes the Inverter, Charger, DC/DC converter and any other connection to the high voltage battery.

For the VCU to properly determine the maximum safe current flow, the BMS must be connected to all of the battery cells and the current sensor must measure the entire current. The person installing the BMS is responsible for ensuring this is done correctly.



The AEM Battery Management System (BMS-18) hardware expansion for the AEM VCU is a modular BMS add-on designed for multicell lithium battery packs. The BMS allows the VCU to monitor all relevant Battery functions and adds the ability for the VCU to interface directly with a J1772 charging plug and allow the VCU to directly control a supported On-Board Charger (OBC).

The BMS expansion cannot operate as a stand-alone system and requires a VCU200 or VCU300 to function. All BMS configuration and communication is performed via the VCUs normal calibration process and the user does not communicate directly with the BMS Modules.

**Specifications**

Parameter	Value
<b>Unsealed BMS Satellite</b>	
18 Cells	0-5v per cell
3 Temperature inputs	Thermistor
<b>Mini BMS Master and Unsealed BMS Satellite System</b>	
Maximum Units	VCU-200 = 1 Mini Master + 6 Unsealed Satellites VCU-300 = 1 Mini Master + 12 Unsealed Satellites. If you are running more than 1 pack in parallel, then multiple masters must be used. Contact AEM for assistance.
Cell Balancing	Passive, up to 165mA per cell
Casing	Mini BMS Master – Plastic Unsealed BMS Satellite – Not Applicable

The BMS is implemented as two different Module types: the Mini BMS Master and the Unsealed BMS Satellite. Each Satellite Module is capable of measuring up to 18 cells and 3 temperatures (thermistors). The Mini Master contains the CAN communication interface and J1772 charging specific connections needed for each battery pack. The VCU talks to the BMS via the Mini Master Module and all battery packs need at least one Mini Master unit. The Unsealed Satellites expand the capability of the Mini Master by an additional 18 cells and 3 thermistors per additional Satellite connected. The Unsealed Satellite Modules are connected to their Mini Master via a high-speed serial interface (isoSPI) that allows additional units to be daisy chained together, adding as many Satellites as necessary for the battery pack configuration.

When the VCU-200 is used, up to Six additional Unsealed Satellites may be connected to the Mini Master, resulting in up to 108 cells and 18 temperatures.

When the VCU-300 is used, up to 12 additional Unsealed Satellites may be connected to the Mini Master, resulting in up to 216 cells and 36 temperatures. Another option available with the VCU-300 based systems is the ability to support 2 Mini Masters, each with up to 6 Unsealed Satellites and have these monitoring parallel battery packs. Contact AEM before using multiple masters in this way.

In addition to battery voltage measurement, the BMS allows the VCU to support for passive cell balancing, calculate the state of charge (SoC), pack health, charge and discharge current limits and more. Refer to the VCU instructions for all the BMS related configurations and settings.

## BMS Architecture

All Unsealed Satellite modules have connections for 18 cell taps, 3 thermistors and the isoSPI channels. The Mini Master module has connections for Power, CAN, and the J1772 charger connections. The Mini Master receives its direction from the VCU over the CAN bus and it forwards them on to the Satellite units over a robust two-wire isoSPI datalink. The Mini Master only has an isoSPI output channel since it is the originator while the Satellites have both an input and an output channel.

## Cell Wiring and Cell Groups

Each Unsealed BMS Module can monitor from 4 and 18 cells wired in series. The cells that are monitored by one Unsealed BMS Module is called a Cell Group.

The first Unsealed Satellite BMS module in the system is always referred to as Group 1. The next module in the system is called Group 2, the next Satellite would be Group 3 and so on. The Group number assignment of a module is defined by the order in which they are attached to the Mini Master.

## Pack & Cell Numbering

Modules are numbered from 1 to 6 on the VCU200 and each Module manages a Cell Group from 4 to 18 cells. A cell may be identified by specifying the Module (Group 1 to 6) and the Cell Number (from 1 to 18) managed by the Module (e.g., Group 2, cell 4).

A basic 18 cell battery connected to a single Unsealed Satellite BMS module requires 19 wires to connect the 18 cells in a Cell Group since you need to connect the ground of the first cell as well. The wires are numbered c0 to c18 with c0 being the ground of the first cell. All cells in a Cell Group must be wired consecutively with the positive terminal of one cell connected to the negative terminal of the next cell.

If fewer than 18 cells are to be monitored, the unused cell inputs should be tied together and all connected together to c18.

A Cell Group **MUST NOT** “span” a circuit protection device (such as a Contactor, Fuse, Service Disconnect or a Circuit Breaker). Wherever a device exists that could ever potentially result in a continuity break you **MUST** locate this between individual BMS modules. The reason for this guideline is that if the fuse blows (or contactor opens, or circuit breaker trips), then the Module may be destroyed because the Module will span the newly open circuit and could be damaged by full pack voltage.

## Status LED

The Master has a Status LED which will inform the user of the current operating state of the BMS. The following blink patterns are supported:

LED	Status
Green	All OK
Green Blink	All OK, Balancing
Off	Powered Down
Yellow	VCU Keepalive Timeout
Yellow 200ms blink every 8 secs	Dozing (BMSM powered up / VCU keepalive timeout)
Red / Yellow	Thermal Shutdown
Red	LTC Diagnostic Failure
Red 200ms Blink	IsoSPI error detected (PEC error or “no reply”)

## Connector

Mini BMS Master Module	
Harness/Mating Connector	TE DTM06-12SA
Terminal	TE 1062-20-0222
Blanking Plug	TE 0413-204-2005
Unsealed BMS Satellite Module	
Harness/Mating Connector	TE 1-1827863-5
Terminal	TE 1871303-1
Required Single Wire*	TE M22759/32-22-9
Required IsoSPI Twisted Pair Wire*	TE M27500/22SB2U00

**\*Thin-walled wire is required for the Unsealed BMS Satellite Module Connector, TXL wire will not work.**

A wiring kit is available separately from AEM (P/N 30-3717, Unsealed BMS Wiring Kit). It contains 1x mating connector, 25 x Pre-Terminated Single Thin-Walled wires 36" long, 2 x Pre-Terminated Twisted Pair Thin-Walled Wires 120" long.

## Pin Out

Mini BMS Master			Unsealed BMS Satellite		
Pin	Desc	Notes	Pin	Desc	Notes
1	Perm 12 volts	Permanent +12V	A1	T1 (-)	Temp sensor 1 ground
2	Ground	12V Ground	A2	T2 (-)	Temp sensor 2 ground
3	CANH	CAN High	A3	T3 (-)	Temp sensor 3 ground
4	CANL	CAN Low	A4	Cell 0 (-)	Group Cell ground
5	IPO	IsoSPI Plus Out	A5	Cell 2 (+)	Group Cell 2 voltage
6	IMO	IsoSPI Minus Out	A6	Cell 4 (+)	Group Cell 4 voltage
7	J1772 Prox	PP Pin on J1772 Conn.	A7	Cell 6 (+)	Group Cell 6 voltage
8	J1772 CP	CP Pin on J1772 Conn.	A8	Cell 8 (+)	Group Cell 8 voltage
9	VCU Wake	VCU/BMS Wake in/out	A9	Cell 10 (+)	Group Cell 10 voltage
10	Serial Ground	Serial Ground Reference	A10	Cell 12 (+)	Group Cell 12 voltage
11	RX Serial	Serial Receive	A11	Cell 14 (+)	Group Cell 14 voltage
12	TX Serial	Serial Transmit	A12	Cell 16 (+)	Group Cell 16 voltage
			A13	Cell 18 (+)	Group Cell 18 voltage
			A14	IMO	IsoSPI Minus Out
			A15	IPO	IsoSPI Plus Out
			B1	TH1 (+)	Temp sensor 1
			B2	TH2 (+)	Temp sensor 2
			B3	TH3 (+)	Temp sensor 3
			B4	Cell 1 (+)	Group Cell 1 voltage
			B5	Cell 3 (+)	Group Cell 3 voltage
			B6	Cell 5 (+)	Group Cell 5 voltage
			B7	Cell 7 (+)	Group Cell 7 voltage
			B8	Cell 9 (+)	Group Cell 9 voltage
			B9	Cell 11 (+)	Group Cell 11 voltage
			B10	Cell 13 (+)	Group Cell 13 voltage
			B11	Cell 15 (+)	Group Cell 15 voltage
			B12	Cell 17 (+)	Group Cell 17 voltage
			B13		"---"
			B14	IMI	IsoSPI Minus In
			B15	IPI	IsoSPI Plus In

## Power Wiring

The Master is powered from the 12v Perm Power (Pin 1) and is awakened with +12v on the VCU wake pin (pin 9). The individual modules are powered from their HV pack connections. When "on", the Master consumes approximately 20mA of 12V. The Perm Power connection must remain powered with +12v at all times, regardless of the vehicle operating state otherwise the J1772 charging will not function properly.

## Wake Function

The VCU/BMS Wake (pin 9) is a bidirectional input/output that both wakes up the BMS and also allows the BMS to wake up the VCU. This is needed since there are times when the VCU is asleep and the cockpit wake switch is off but the J1772 charging needs to wake up the VCU and initiate charging. This input should be connected to the VCU Wake pin as well as the cockpit +12v wake switch. ***It is CRITICAL that no other devices are connected to this wake switch and it should not be treated like an "ignition switch" that supplies power to other devices. The BMS communicates with the VCU over this pin when charging and any external load will prevent proper operation.***

## CAN Wiring

CAN is provided at the CANH and CANL connections. The BMS Master uses a CAN data rate of 500Kbs and does not have an internal termination resistor. CAN wiring should be kept short and the conductors should be twisted. Wiring should be placed away from the motor and controller and parallel runs next to the traction cabling should be avoided.

The possible CAN connections to the different VCUs is as follows:

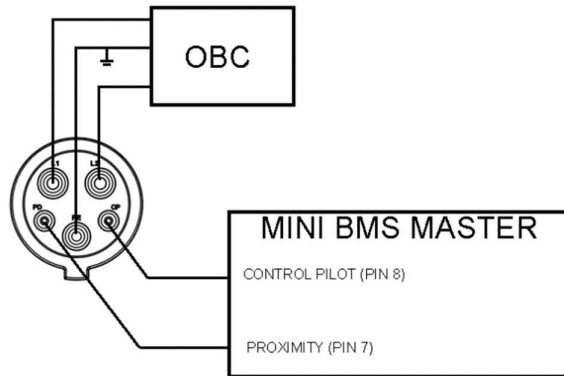
BMS Mini Master	VCU-200	VCU-300
CANH Pin 3	CAN 4+ Pin J2-F1	CAN 3+ Pin K77
CANL Pin 4	CAN 4- Pin J2-E1	CAN 3- Pin K78

## isoSPI Satellite System Wiring

The isoSPI datalink wiring **must be twisted pair** and connects to the IPO and IMO (IP<sub>out</sub> and IM<sub>out</sub>) signals (IPO pin 5, IMO pin 6). These signals are connected to the corresponding IPI and IMI (IP<sub>in</sub> and IM<sub>in</sub>) signals (IPI pin B15, IMI pin B14) on the next module downstream. The instructions flow **out** of the Master and **in** to the Satellites. If there are no more devices in the chain you simply leave the last IPO and IMO disconnected, there is no termination required.

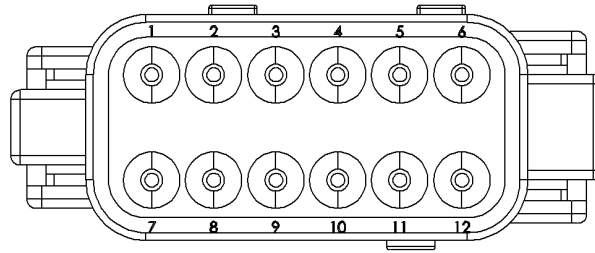
## J1772 Charging

The BMS/VCU combo can control the J1772 Charge Port. Connect J1772 CP (Pin 8) to the CP terminal on the J1772 connector. Connect J1772 Prox (Pin 7) to the PP terminal on the J1772 connector. Connect L2, L2 and PE to the On-board Charger and you must also tee-off the PE connection to the vehicle ground as well or the Proximity signal will not read correctly.



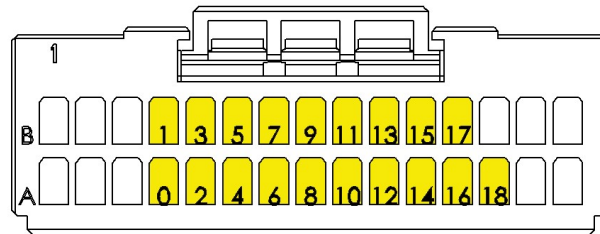
J1772 Charging Connections

Mini Master BMS



Mini Master BMS Connections as viewed from the wire entry side of the Connector

Unsealed Satellite BMS



Unsealed Satellite BMS Connections as view from the wire entry side of the Connector.

When wiring the cell harness connector, remember that Cell 0 is the ground of Cell 1 and that all cells within a group must be connected in series with voltage increasing. Each cell group has 19 connections to connect to the 18 cells in the group. If fewer than 18 cells are to be monitored, then the unused cell inputs should all be connected with the highest actual cell.

Once the cell group is wired, use a voltmeter to verify that cells are connected with the proper polarity, and that they are in series. Verify that voltage difference between adjacent cells is correct. Also verify that if fewer than 18 cells are used in the group that the top cells all have identical voltage readings.

**NOTE: The terminals are connected directly to pack voltage and so there can be up to 90V connected on the harness. Be Careful!**

Once the cell harness is verified, it is safe to plug into the Master or Satellite. Cell Harness connectors may be plugged in or unplugged in any order. It is not necessary to remove 12V power from the BMS in order to plug or unplug Cell Harness connectors.



## Temperature Sensors

Each Unsealed Satellite BMS module supports 3 external thermistors and these should be mounted to measure battery cell temperatures. It is important that these are used since the VCU adjusts the max allowable current (both discharge and charge) based on the cell temperatures as well as alerts the user of a critical over-temp event is occurring. The thermistors supplied with each BMS module is the Vishay NTCLE413E2103F102L 10k sensor. You can substitute your own sensors as long as you know the temperature versus resistance calibration values and understand that the maximum resistance readable by the BMS is 131kOhms and enter the values in the calibration table in the VCU software. All thermistors used in the BMS must have the same calibration.

The thermistors are wired to pins A1 & B1 for thermistor 1, pins A2 & B2 for thermistor 2 and pins A3 & B3 for thermistor 3. Polarity is unimportant.

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