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Section 3

Battery Management System Module (BMS)

This section describes how the BMS monitors and controls the battery pack. The BMS has two harness connectors that are attached to a number of leads in the wiring harness. The leads carry information onto the BMS (Inputs). Concurrently the BMS functions to control various activities in the pack. It does this through additional harness leads attached to the BMS (Outputs). Below is a table of contents outlining the various dialogs explaining the functions of the BMS as well as diagnostic procedures.

•CAUTION

To reduce the chance of personal injury and/or property damage, the following instructions must be carefully observed.

Proper service and repair are important to the safety of the service technician and the safe, reliable operation of all Lithium Ion Battery Packs. If part replacement is necessary, the part must be replaced with one of the same part number or with an equivalent part. Do not use a replacement part of lesser quality.

To gain additional knowledge in the use and handling of Green Cubes Battery Packs, please refer to Green Cubes Publication: USE AND CARE SAFETY GUIDELINES

The service procedures recommended and described in this service manual are effective methods of performing service and repair. Some of these procedures require the use of tools specifically designed for the purpose.

Accordingly, anyone who intends to use a replacement part, service procedure, or tool which is not recommended by the manufacturer, must first determine that neither his safety nor the safe operation of the unit will be jeopardized by the replacement part, service procedure or tool selected.

It is important to note that this manual contains various Cautions and Notices that must be carefully observed in order to reduce the risk of personal injury during service or repair, or the possibility that improper service or repair may damage the unit or render it unsafe. It is also important to understand that these “Cautions” and “Notices” are not exhaustive, because it is impossible to warn of all the possible hazardous consequences that might result from failure to follow these instructions.

All information, illustrations and specifications contained in this manual are based on the latest product information available at the time of publication approval. The right is reserved to make changes at any time without notice.

Documentation
Green Cubes battery packs are made in several voltages. At this time packs are offered from 12V to 80V with some packs able to be set up for variable voltages.
Additionally, upon customer request, custom packs are made.
Due to the large number of offerings and the possibility of custom packs, this manual can only address common or representative builds and is not all inclusive. Therefore, we suggest that one of the first activities a technician engages in, during the visual inspection process, is to document the pack being worked on.
Make notes and take pictures of the system before beginning diagnostics, or any component installations.

BATTERY MANAGEMENT SYSTEM (BMS) CONTROL MODULE

Purpose

The BATTERY MANAGEMENT SYSTEM (BMS) CONTROL MODULE might be considered as the “brains” of the battery pack.

BMS Functions- Partial List

1. Transforms the total pack voltage to output 12 volts on one pin to run the contactor.

2. Transforms total pack voltage of 5 volts to a set of pins to provide feed voltage to the sensors- in our system this is mainly the temperature sensors or thermistors.

3. Performs continuous measurements of all of the cells or cell groups in the pack

4. Operates the MIL (Malfunction Indicator Lamp) if a diagnostic trouble code (DTC) (fault code) is set.

5. Outputs text information that indicates an abbreviated version of the actual fault- If a display screen is available on the vehicle or device.

6. Processes temperature and cell voltage measurements in order to warn the operator of low voltages or low or high temperatures.

7. Activates the contactor to allow battery pack voltage to be transmitted to the device or vehicle.

8. Performs a continuous self diagnosis on certain control functions.

Modes of Operation

Starting Mode- Key-on event

When the toggle switch or key switch is moved to the “ON” position the BMS “wakes up.”
During the wake up event, the BMS quickly monitors cell voltages and temperatures. If cell voltages and temperatures are in a normal state, the BMS activates the contactor.
NOTE: Activation of the contactor may be delayed a few seconds on order to allow the BMS to accumulate its baseline data. If you have the cover for the battery pack removed, you can typically hear an audible “click” when the contactor switching device closes. Once the contactor is activated, the current can flow from the pack to the vehicle or device.

Stopping mode- key-off event

Similarly, upon movement of the key switch or toggle switch to the “OFF” position, the BMS will cause the contactor to switch off after a brief several second delay. An audible click from the contactor may be heard at the completion of this event. When the contactor switches off, battery voltage and current flow to the device or vehicle will stop.

Operating Mode

During normal operation the BMS will acquire input data consisting of cell voltages, temperatures, and pack activities such as charging and discharging rates. It will control charge rates and send alerts and activate the MIL (Malfunction Indicator Lamp). It will also log fault codes and accumulate fault histories.

Primary and Secondary BMS (2 controller-module battery packs)

Some battery packs will contain two BMS units. Packs with two BMS units are typically larger packs with a large number of cells. The secondary BMS will piggy-back with the primary unit to allow monitoring for additional cells. The two battery packs can communicate with each other through a small 4 wire harness that interconnects the two BMS units.
Diagnostics for the primary-secondary configuration is controlled by the primary BMS only.

Out-of-parameter (low voltage) alert mode

If, during normal operation, the battery voltage falls below a pre-determined threshold, the BMS will send an alert to the operator. The actual alert signal style may vary from device to

device or vehicle to vehicle depending on the vehicle manufacturers preference. Once the alert has been sent, the operator has a defined amount of time until the vehicle will shut down. The defined time should allow the operator ample time to return to the charging station. Although the time-to-shutdown will vary, a table of approximate specified voltage values and alert-to-shutdown times appears at the end of this section.

Overheated operations mode

The battery pack has at least one (possibly two or more) cell temperature sensors (thermistors) that constantly measure temperature of two adjacent cells in one or more locations of the pack. If for some reason the cells overheat, the BMS will instantly shut down the pack. Congruently, if the temperature sensor leads become detached at the connector or if the circuit between the sensors and the BMS become open the BMS will be unable to read a measurement and will shut down the pack.

Excessively Cold Operation Mode

Some battery packs have a heating device that is used to maintain an acceptable temperature during charging and in some cases, during operation.

The heating devices are not designed to warm an overly chilled battery.

The heating devices are only active under two conditions. (1) During operation the temperature falls below 0 degrees C/32 degrees F for an extended period of time and (2) During the charging event when the battery is connected to a charger (w/ charge detect loop). If the battery reaches temperatures above or below the “Battery Temperature specs” the BMS will open the main contactor until the battery temperature specification window is restored.

Shut-down mode

There are several conditions that will cause the BMS to shut down the pack.

1. Pack at higher than specified voltage
2, Pack at lower than specified voltage
3. Cell at higher than specified voltage
4. Notable difference between cell voltages
5. Higher than specified charge rate
6. Higher than specified temperature
7. Lower than specified temperature

When the BMS instigates the shut down mode, it opens the circuit to the contactor primary leads. The contactor opens and voltage will no longer pass from the pack to the vehicle or device.

NOTE: In some instances, if the BMS instigates the shut down mode and the vehicle key or toggle switch is on- the operator may need to cycle the key-off in order to re-initiate pack operation.

Emergency Override mode

During normal operation of the vehicle or device, the battery charge will slowly diminish from a full charge cell voltage of 3.6V per cell-group or 93V pack voltage.

When the battery falls below a pre-set limit of 2.8V per cell group or 72.8V pack voltage, the BMS will provide a warning signal to the operator. After the warning signal the operator has a set amount of time to finish work and return the vehicle to the charging area. If for some reason the operator is unable to return to the charging area during the time allotted, the BMS will shut down the device in an effort to protect the battery.

When this occurs, an emergency override process is available on a one-time basis.

Emergency Override Procedure

To instigate the emergency override procedure, the operator may rapidly energize the key switch or device switch in rapid succession. The prescribed switching sequence needs to occur within a 10 second interval and is follows:

on/off- on/off- on.

at this juncture the BMS will close the contactor and the vehicle or device will operate for a timed period of 300 seconds (5 minutes) which should allow the operator to return the vehicle/device to the charging station and be connected to the charger.

Fault Notification Mode
Malfunction Indicator Lamp (MIL)
The Malfunction Indicator Lamp (MIL) found on most vehicles, is designed to alert the operator that a problem has occurred and that the equipment should be taken for service as soon as reasonably possible. If the problem goes away, the light will go out in most cases after 10 seconds, but a DTC will remain stored in the BMS fault history graph. When the light remains "ON" with the pack switched "ON" or when a malfunction is suspected due to an operational problem, the "On-Board Diagnostic (OBD) System Check" must be performed as the first step. These checks will expose malfunctions which may not be detected if other diagnostics are performed prematurely.

NOTE: See the Diagnostic Trouble Codes Section in Section 4 for additional information

Using the PC to read DTC's
Accessing the BMS Using the BMS Tool

Installing the BMS Tool onto your PC
You may access the BMS tool on-line by locating the Green Cubes Technology web site.

Connect the USB cable to your PC. Turn on your PC and select the BMS tool from your menu.
Next Connect your PC to the USB diagnostic link connector (DLC) located on the device.
You may need to remove the cap from this connector to access the connector.

NOTE/Caution: It is highly recommended that you purchase a PC Isolation device to install in series with your USB cable. Since the BMS is a powered device, stray voltages and signals are frequently encountered. A USB isolator must be used to protect your PC.

Non-Scan Diagnosis of operating concerns (No DTC's Set)
If Operating concerns still exist after following the OBD system check and reviewing the Symptoms tables, an out of range sensor may be suspected. Because of the unique design of the BMS, the BMS will occasionally replace sensed values with calibrated default values in the case of a sensor or circuit malfunction. By allowing this to occur, limited system performance is restored until the system is repaired. A basic understanding of sensor operation is necessary to be able to diagnose an out of range sensor.
If the sensor is out of range, but still within the operating "window" of the BCS, the problem may go undetected by the BCS and may result in an operation concern.

To identify a sensor that is out of range,
you could unplug the sensor electrical connector while the system is functional. After a short period of time, the DTC for that sensor will set, illuminate the MIL, and replace the sensed value with a calibrated default value. If at that point, a noticeable performance variation may be observed, the DTC table for that particular sensor should be followed to correct the problem.
NOTICE: Be sure to clear each DTC after disconnecting and reconnecting each sensor. Failure to do so may result in a misdiagnosis of the operation concern.

Battery Disconnect Caution

•Caution: Before servicing any electrical component, the system operating switch-key must be in the OFF or LOCK position and all electrical loads must be OFF, unless instructed otherwise in the procedures. As a further precaution, you may want to disconnect the battery cables from the battery fork truck or device. This will help ensure that there will not be any accidental short-to-ground connections. Failure to follow these precautions may cause personal injury and/or damage to the equipment or its components.

Documentation

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Make notes and take pictures

of the system before beginning diagnostics, or any component installations.

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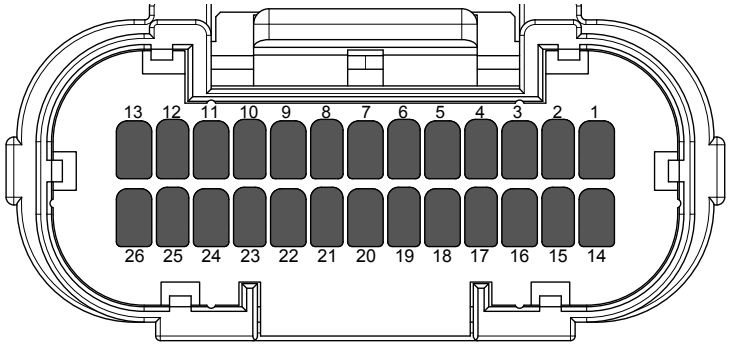
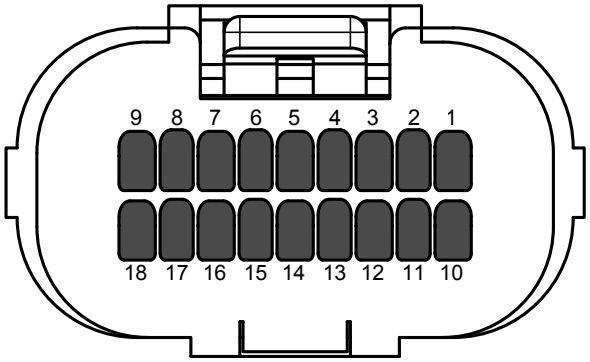
BMS Connector Identification (1 of 2)



BMS Pin Number J1 (J100)	Circuit type	Wire Color	Circuit Description
J1-1	C1+	WHT	Cell 1 Monitor input
J1-2	C2+	WHT	Cell 2 Monitor input
J1-3	C3+	WHT	Cell 3 Monitor input
J1-4	C4+	WHT	Cell 4 Monitor input
J1-5	C5+	WHT	Cell 5 Monitor input
J1-6	C6+	WHT	Cell 6 Monitor input
J1-7	C7+	WHT	Cell 7 Monitor input
J1-8	C8+	WHT	Cell 8 Monitor input
J1-9	C9+	WHT	Cell 9 Monitor input
J1-10	C10+	WHT	Cell 10 Monitor input
J1-11	C11+	WHT	Cell 11 Monitor input
J1-12	C12+	WHT	Cell 12 Monitor input
J1-13	C13+	WHT	Cell 13 Monitor input
J1-14	PWR-IN	WHT	Power Input
J1-15	PWR-GND	WHT	Power Ground
J1-16	BTS 1-RTN	WHT	Battery Temperature Sensor Return (Ground)
J1-17	BTS 1- FEED	WHT	Battery Temperature Sensor 1 (BTS1) Signal
J1-18			Battery Temperature Sensor 2 (BTS 2) Signal
J1-19			Battery Temperature Sensor 4 (BTS 4) Signal
J1-20			Battery Temperature Sensor 5 (BTS 5) Signal
J1-21			Battery Temperature Sensor 6 (BTS 6) Signal
J1-22	BTS 3 (2)-FEED	WHT	Battery Temperature Sensor 3 (BTS 3) Signal
J1-23	BTS 3 (2) RTN	WHT	Battery Temperature Sensor Return (Ground)
J1-24	C16+	WHT	Cell 16 Monitor input
J1-25	C15+	WHT	Cell 15 Monitor input
J1-26	C14+	WHT	Cell 14 Monitor input

BMS Connector Identification (2 of 2)



BMS Pin Number J2-(J101)	Circuit type	Wire Color	Circuit Description
J2-1	GO 1	WHT	Contactor 1 enable
J2-2	GO 2	WHT	Contactor 2 enable
J2-3	GO 3		
J2-4	GO 4		
J2-5	CAN 1 LO	WHT	CAN 1 Low
J2-6	CAN 1 HI	WHT	CAN 1 High
J2-7	EXT-RESET	WHT	External Reset
J2-8	PACK NEG (-)	WHT	Battery Pack Ground (NEG) (-)
J2-9	+12V AUX	WHT	+ 12 Volt Auxiliary
J2-10	GO 5		
J2-11	GO 6		
J2-12	KEY IN	WHT	Key Switch Voltage In (Wake Up)
J2-13	CHGR DET	WHT	Charger Detect Input
J2-14	SPARE IN	WHT	Cooling Feed +
J2-15	CAN 2 HI	WHT	CAN 2 High
J2-16	CAN 2 LO	WHT	CAN 2 Low
J2-17	SRN	WHT	Shunt Return
J2-18	SRP	WHT	Shunt Feed

During normal operation the BMS continually monitors all the battery pack functions. Three of the main parameters monitored are temperature, cell voltage and pack voltage. When the pack voltage or the cell voltage gets too high, the BMS shuts down the pack. Then the pack voltage gets too low, the BMS sends a low voltage warning. About ~10 minutes after sending the low voltage warning the BMS will shut down the pack. Below you will find a chart with the thresholds used to integrate or remove alert and shut down actions. Keep in mind that we make dozens of different packs and that the figures shown here are for comparative purposes only. Your particular battery pack may have slightly different thresholds or actions.
In order for the BMS to be absolutely certain about a voltage or temperature event, we delay each action for a few seconds to allow the BMS to insure that the measurement causing a particular action was a verified measurement.

Alert/Shut down Chart

Cause	ACTION Alert or Shutdown	Instigate Action	Remove Action
Charge over-temp	Alert	57 C / 134.6 F	55 C / 131 F
Charge under-temp	Alert	-7C / 19.4 F	-5C / 23 F
Discharge over-temp	Alert	57C /134.6 F	55C
Discharge under-temp	Alert	-22 C / -7.6 F	-20 C / -4 F
Pack Over voltage	Alert	94.9 V	89.7 V
Pack under voltage	Alert	72.8 V	75.4 V
Cell over voltage	Alert	3650 mV	3450mV
Cell under voltage	Alert	2800 mV	2900 mV
Pack over-temp	Shutdown	65 C / 149 F	
Cell under-voltage	Shutdown	2550 mV	
Cell over voltage	Shutdown	3700 Mv	