Energy Management System

Operation and Installation Manual

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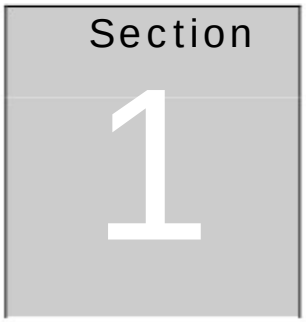
Warning! Read ALL of the instructions before attempting installation. All connections should be made when the system is OFF. No connections of energized wires should be made. Power should not be applied to sense boards until they are attached to the individual cells.

1 Introduction



NOTE: *It is important that you read this manual before installing or operating any of these components.*

Thank you for purchasing Energy Management System (EMS).

The EMS system has everything needed to display the condition of and maintain the health of lithium ion batteries. It consists of two major components, the computer and the cell sense boards. The computer will tell many things about the condition of a battery pack. It will display overview information like the battery state - of - charge, battery current, battery voltage as well as the voltage and temperature of individual cells.. The cell sense boards mount on each individual cell to read voltage and temperature. They also have a battery balancing circuit to equalize the charge of all the cells in a battery pack. There are alarm outputs from the computer for cell over voltage and cell under voltage. These can be used to control other systems in the vehicle such as battery chargers and motor controllers. In addition, there are warnings to let the driver know that error conditions are approaching.

One of the important safety features of the EMS is connection fault detection. When an inadvertent connection is made between the battery pack and the car chassis, it is detected and a warning is shown on the screen.

The EMS is designed so that the battery monitoring is completely isolated from the regular vehicle 12V system. The EMS is powered by a powerful, 8 core 32 - bit

microprocessor that is capable of outputting composite video. A CAN interface option is available to display the EMS information on a CAN display. Many options in the EMS are programmable and can be customized for a specific vehicle.

Section

2

2. Packing List

- **1x – EMS Computer**
- **1 per cell Battery Sense Boards**
- **Cable to go from the computer to the first Cell**
- **1x - Current Shunt**

Note: The number of battery sense boards and the wiring harness vary based on the number of cells in the system.

Section

3

3. Specifications

Items Displayed.....Voltage, Current, Battery Capacity on main screen

Cell number, cell voltage, cell temperature on detail screen

Computer Power…….....8-20V, 120mA or 8 to 85V as an option

Battery Voltage……..….....36-500V

Shunt Input……..…….500A = 50mV

Voltage Resolution……0.1V

Current Resolution ……1A

Temperature Measurement Range -99F to +199F or -146 to +92C

Battery Types Supported…...……Lithium

Video Output……....Composite Video, Color, NTSC

RS-170

Measurement accuracy…….. Better than 1% of Full Scale

Measurement speed …….. Voltage and current 3 times per second main screen

Voltage and Temperature 1 time per second detail screens

Number of cells supported ……128

Cell Voltage……2.5 to 4.5

Balancing Threshold ……..3.7V

Balancing Current ……..0.5A

Digital Output Current……4A surge for 100mS 2A continuous*

Output Delay (default)……30 seconds

Optional Display Interface…….CAN

Connection Fault Detection ……2mA (5000 Ohm/Volt)

*12V input must be able to supply the power used by the alarm outputs

Section

4

4. Installation

ALWAYS USE EXTREME CAUTION WHEN WORKING ON AN ELECTRIC VEHICLE. ALWAYS DISABLE THE CIRCUIT BREAKER WHEN THE ENGINE BAY IS OPEN (THIS WILL HELP MINIMIZE RISK OF SHOCK). ALWAYS TAKE NOTE WHERE THE HIGH VOLTAGE LINES ARE.

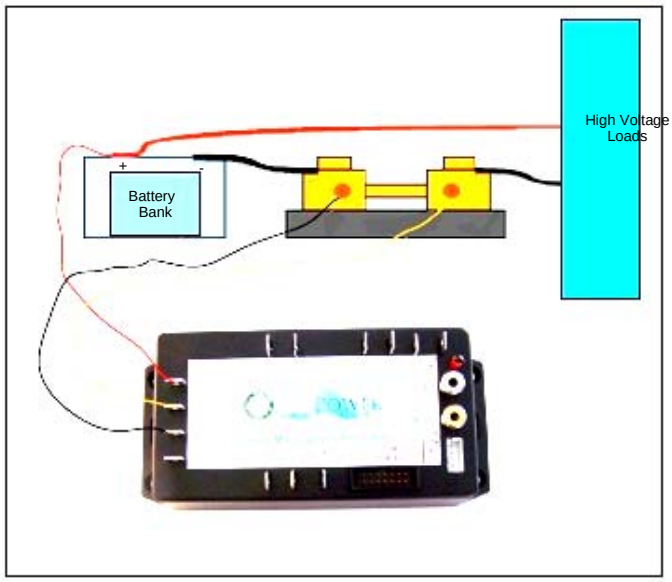
The EMS is designed to make installation easy. All of the connections to it are made with convenient pluggable ¼" quick disconnect terminals. The EMS computer should be installed as close to the shunt as possible. The shunt sense wires should be less than 1' long. Mounting holes for the computer box are shown in **Appendix A.** After the installation is complete, the battery pack must be completely charged before the capacity will read correctly (see **Section 7. Capacity Algorithm** for more details).
For Connection Fault Detection, it is important that the terminal with the chassis wire be attached to the metal chassis of the car. This is required for the Connection Fault Detection to work properly.

Heartbeat LED

When the EMS is correctly connected to 12V, the heartbeat indicator will blink about once per second.

Isolated Battery & Shunt Connections

The Terminals on the left side of the computer are used for making the High - Voltage and shunt connections. Refer to the figure below for these connections. The connections between the battery pack, shunt and high voltage loads are usually large wire (e.g. 2/0). The connections to the EMS from the battery and the shunt can be smaller gauge (e.g. 18 or 20 ga).



High Voltage Connections

12v Vehicle Battery

The 12V supply to the computer is connected on terminals on the top and left of the computer as shown below. This connection should be made through a fused circuit to an always - on point in the 12V system. If the computer looses 12V power then the capacity will reset to 99% (see **Section 7. Capacity Algorithm** for further details). When 12V power is applied, the red “Heartbeat” LED will blink.

12V Connections

Page Select Switch Input

In order to display the voltage and temperature of the individual batteries, a switch to select the appropriate display page is needed. This can be any normally open momentary switch. The switch is connected to the mode (MDE) and ground (GND) pins as shown below. There is no polarity on the switch. These may be small wire (e.g. 18 or 20 ga) for the switch connections.

Page Select Pins

Sense Board Wiring

The sense boards are connected to the computer via a cable which has a 14 pin connector on one end and a 4 pin connector on the other. This cable plugs into the computer as shown below:

The sense board connector has a key to prevent it from being plugged in the wrong way.

The summary screen will show how many sense boards are connected. The sense boards can be connected one at a time while the system is powered up to verify that they are working. This should be done once the sense boards are mounted on the cells. **This will prevent the sense boards from being accidentally shorted to chassis ground.** The sense board that is plugged into the connector closest to the computer is number 1; the cell number follows the series string of sense boards which must also follow the battery pack series connection. As an aid to trouble shooting, it may be useful in a system with many cells to write the ID number on each battery cell. Should the summary screen show less than the full number of cells (an error message of “pack has unmanaged cells” appears), the issue can be located by going to the last cell registering on the screen or the next higher number cell.

As shown in the picture above, the Sense Boards come pre - wired in groups of 4. These should be installed after the bus bars have been installed on the cells. The groups of 4 have an input and output connectors. The input connector plugs into the computer cable. The output connector plugs into the input connector of the next string (visible in the rear of the batteries). The input and output cables have a short length of exposed wires. This is to allow the cable to be fed through the wire combs of the battery. When the installation of the sense boards is complete, the covers can be installed on the cells as shown on the right side of the picture.

Cell number 1 can be either the most negative (as shown above) or the most positive cell. Cell number 1 connects to the computer cable and the cell numbers increment as they go away from the computer cable.

The sense boards have the plus and minus indicated on them. It will not harm the sense board to connect it backwards, however it will not work. When the board is installed correctly, the green LED will light up. There is also a red LED which indicates that the board is balancing. Normally, this LED will not light. It will come on when the voltage is above 3.7V.

The sense boards, like the cells they attach to, alternate + and – for the series connection. The cabling is designed to go underneath the boards. Should the installation have less than an even multiple of 4 cells, the cable may be cut close to

the last sense board used. Be sure to cut the cable cleanly with no wires left exposed. **Do not cut the cable with 12V power applied to the CPU! The resulting short circuit may damage the EMS computer.**

Battery Balancing

When the cell voltage rises above a predetermined threshold (see specifications for this value), the sense boards draw a small current. This will bring all the batteries in the pack to the same level of charge. When the balancing function is active, the red light will come on.

Video Output

The composite video output of the computer is accessed through the connector shown below, labeled “Video”. This can be connected to the optional LCD screen EPS supplies, or it can be connected to any display which supports a composite video input (e.g. in dash navigation). If the video output needs to be connected a display which does not have the standard RCA type connector then the outer shield wire is connected to the 12V Ground and the center wire is connected to VIDEO.

Section 5

5. Programming

Many parameters in the system can be programmed. Please use this form to tell us how to program your EMS computer.

Contact Name _____Phone _____

Email _____Date _____

Over Voltage Alarm (≤ 3.8V) _____Under Voltage Alarm (≥ 2.5V)_____

Over Current Alarm _____ Over Temp Alarm (≤150°F)_____

Battery Capacity (AH) _____Centigrade/Fahrenheit _____

Ammeter Range_____

Other Parameters _____

_____

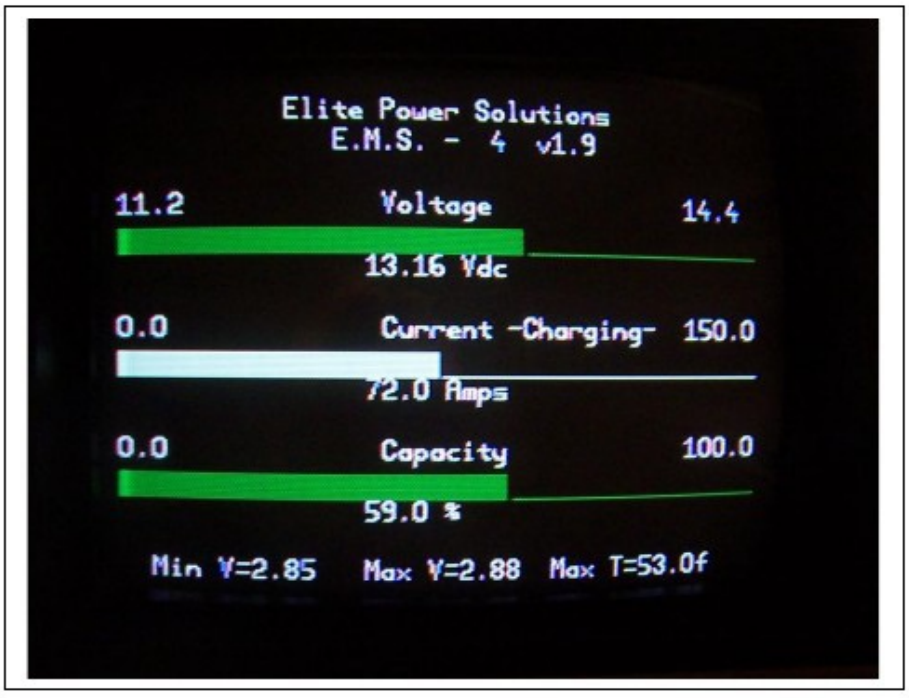
Comments _____

_____

Section 6

6. Usage

When properly installed, the EMS shows the status (Voltage, Current, and Battery capacity) of an Electric Vehicle battery pack. Here is an example of what is displayed on the screen.

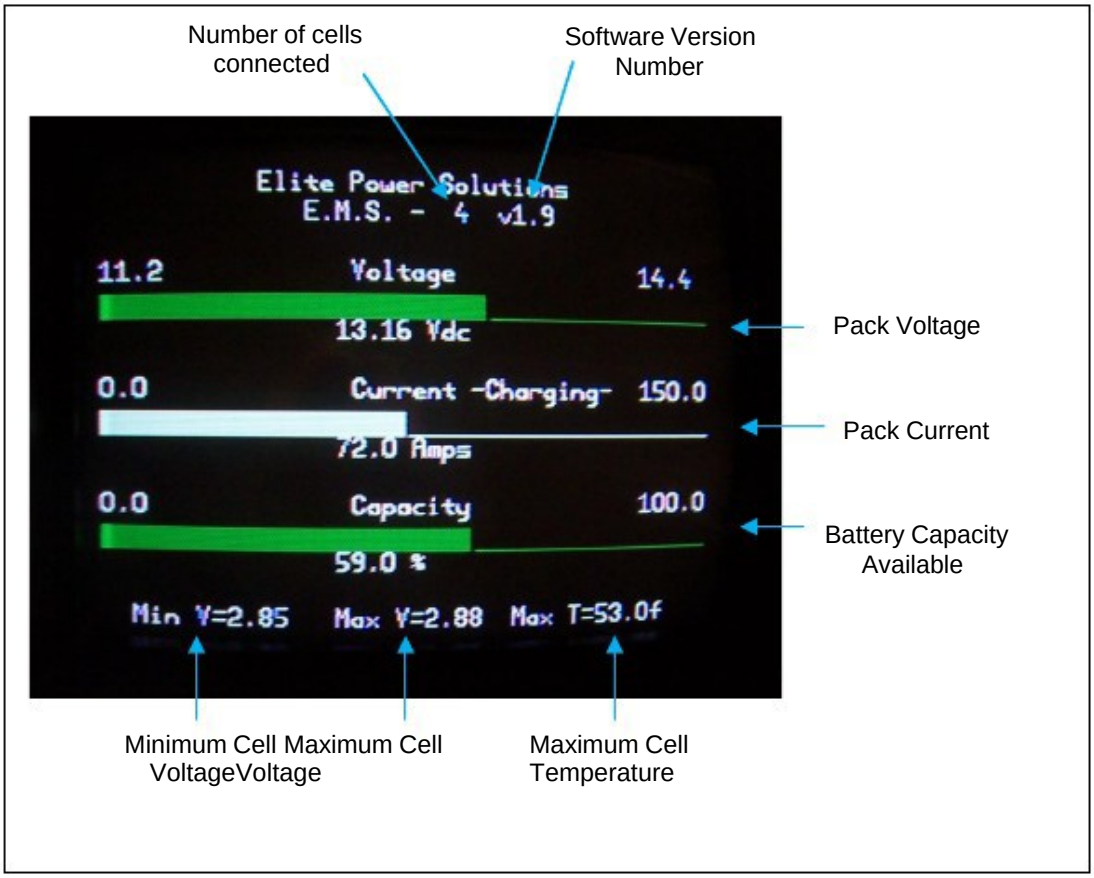


Main Screen

Video Display

The EMS has at least two pages of information it can display. The first is a summary page which has information for the entire system. The second consists of one or more detail pages which show voltage and temperature for each cell. The number of detail pages is determined by the number of cells. Twenty cells are displayed per page.

Home Page



Battery Voltage is the total voltage of the battery system. This value is updated in real time. When something happens that changes the battery voltage, such as accelerating the vehicle, this value changes immediately. The voltage is displayed as a bar graph from 2.8V x the number of cells to 3.6V x the number of cells. The voltage is also displayed as a number which gives a precise reading. The graph is green when the voltage is above 3.0V per of maximum, and it changes to red when it is below. If the voltage goes outside the range of the graph, a warning (off scale high or off scale low) will show instead of a bar.

Battery Current is the total current being drawn from or put into the battery system. It is updated in real time, just like the battery voltage. The voltage is displayed as a bar graph from 0 to the maximum expected value and a number which gives a precise reading. The graph is green when the current is below 40% of maximum, and it changes to red when it is above. When the battery is being charged, the graph changes to white and the notation “(charging)” appears.

Battery Capacity is the state of charge of the battery (0 to 100%). It works by counting the amount of energy drawn from and put into the battery. It also uses voltage as a “sanity” check. If the battery is being charged, and the voltage goes above 3.6V x the number of cells, the display will automatically show 100%. Similarly, if the battery voltage falls to 2.5V x the number of cells then the display will show 0%. When the system is powered up for the first time it will show 50%. The graph bar is green when there is more than 50% of battery capacity available, and red when it is below 50%.

Number of Cells is the number of sense boards the computer finds. It is updated once every few seconds. This is useful for when connecting the sense boards during installation. As they are connected, the number will increase.

Minimum Cell Voltage is the minimum of the readings of the individual cell voltages. This value is updated after each scan of the individual cells, every 1 - 2 seconds.

Maximum Cell Voltage is the maximum of the readings of the individual cell voltages. This value is updated after each scan of the individual cells, every 1 - 2 seconds.

Maximum Cell Temperature is the maximum of the readings of the individual cell temperatures. This value is updated after each scan of the individual cells, every 1 - 2 seconds. The Letter F or C indicates whether the temperature is in Fahrenheit or centigrade.

Version Number is the software release number. This number is changed whenever there is a change in the software release.

Alarms and Warnings are displayed below the cell voltages and temperature when an alarm or warning condition occurs. There are 5 alarms and warnings: over voltage, under voltage, over current, over temperature and connection fault. They are described in more detail below.

Detail Page

The data for up to 20 cells is displayed on each page as two columns of up to 10.

Cell number is the ID number of the cells. The ID numbers start with the cell connected closest to the computer.

Cell Voltage is the actual voltage on each cell. This value is updated every 1 - 2 seconds. The number is shown in green if it is above 3.0V and below 3.7V. If it is outside this range, it changes to red.

Cell Temperature is the actual temperature of each cell. If it is less than a set point value, it is shown in green otherwise it is shown in red. The temperatures are normally shown in Fahrenheit, but it may be set to Centigrade. The temperatures are in the same units as on the summary page. The set point for the numbers to change from green to red is normally 150F.

Alarms and Warnings

To protect the battery pack, there are a number of alarms and warnings. These are based on Voltage, Current, Temperature and connection fault. As one or more of these parameters go out of range, a warning will first appear on the screen. If the parameter goes further out of range, an alarm indication will appear on the screen and an output will be activated.

The set points can be programmed at the factory. The defaults for those set points are as follows:

OC Over Current 800A

OT Over Temperature 150F

OV Over Voltage 3.8

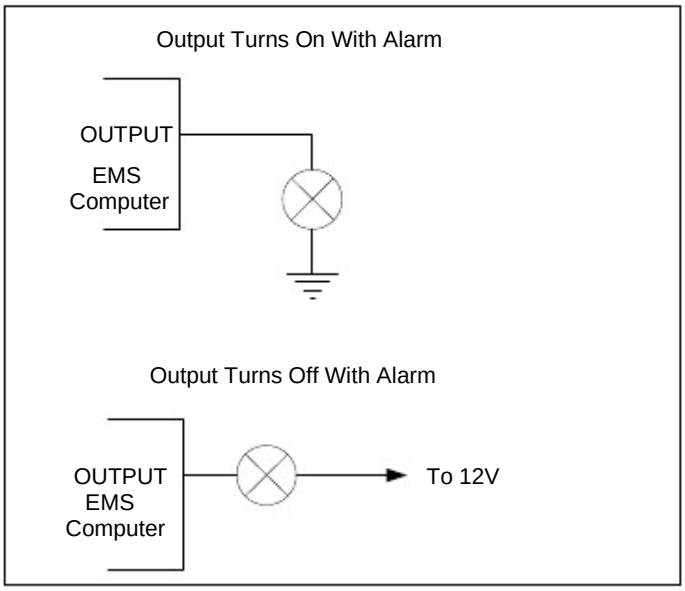
UV Under Voltage 2.5

The connection fault alarm is activated when a connection between the battery pack and the chassis is detected.

If the number of sense boards is different than a pre - programmed value, an unmanaged cell error will be generated. Both the under voltage and the over voltage alarm outputs will become 0 volts if this occurs.

Controlling Other Devices with Alarm Outputs

There are 2 outputs available on the EMS for controlling other devices. These outputs will supply up to 4A surge and 2A continuous. These outputs can signal an alarm when there is an error condition and serve as interlocks to the vehicles components. When power is removed from the EMS computer, the outputs will not supply current.



Please note that the outputs are reverse logic: the output will supply current when there is NO error.

These outputs can directly drive relays without a suppression diode.

There are two error outputs: Over Voltage and Under Voltage. These outputs have a time delay so that the condition causing the error must be present for 30 seconds for the output to activate, and absent for 30 seconds for the output to de - activate.

Over Voltage is active (i.e. 0 Volts) when any cell voltage is too high. It is typically used to turn off a charger when the battery is charged.

Under voltage is active (i.e. 0 Volts) when any cell voltage is too low. It is typically used to turn off a motor controller when the battery is discharged.

The other error conditions of Unmanaged Cells, Over Current and Over Temperature will cause both the Over Voltage and Under Voltage outputs to become active after the 30 second delay.

The alarm outputs are located as shown below:

Section 7

7. Capacity Algorithm

The EMS keeps track of the capacity of the battery bank by tracking the current in and out of the battery (integrating the current over time). However, there are corrections to the calculation to allow for a more accurate reading over time. Because the EMS is keeping track of all current in or out of the battery, it must be powered at all times. When the EMS first powers up, it sets the capacity to 50% so it will not read correctly until after the first complete charge. Subsequent charges must reach a total pack voltage of 3.6V X the number of cells in order to reset the EMS Display to full charge. If the battery voltage falls below the low voltage alarm, it is reset to zero. These values can be changed (see chapter 5 Programming).

The cell capacity (Amp Hours) must be programmed to the right value for the capacity algorithm to work properly.

Section

8

8. CAN Interface

A CAN BUS interface is available as an option for the EMS computer. The CAN BUS Interface transmits all the summary information on the main page, alarm status, and the information on the detail page about the sense boards continuously over the BUS, so that a display device can present the data in graphical form. The video output is also operational, so that the data can be verified.

The CAN BUS is electrically isolated from 12V to reduce interference in the data transfer from chargers and motor controllers.

The CAN option can be identified by the presence of the CAN BUS connector on the side of the computer:

The green terminal block can be unplugged for easy wiring. Simply insert wires into the terminal block and tighten the screws.

The signals available on the interface are as follows:

12V the 12V input

CAN H the normally high CAN signal in the differential pair

CAN L the normally low CAN signal in the differential pair

GND isolated ground

NC make no connection to this pin

The typical connection to another CAN device, or to the CAN bus will be only CAN H, CAN L and GND. This connection is best made with a shielded 2 conductor cable. The shield is connected to GND. This cable is typically 22ga.

There are two status indicators to indicate traffic on the BUS, RX (received data), on the right and TX (transmitted data), on the left. The blinking lights indicate that data traffic is present. If they are always on or always off, there is a fault on the bus.

The CAN interface uses a simple, proprietary, protocol. Full details of the data transfer are available on request from us. Other protocols are planned to be supported, please contact us for more information.

Section 9

9. Trouble Shooting

The red light does not blink	Check 12V connection
No Video	Check that the video output is present with another monitor Check video cable is fully plugged in
Sense Boards not detected	Check wiring Check first board and verify green light on, if not, check board is oriented on battery correctly or board is defective
Incorrect number of boards detected	Check wiring Check first non - working board and verify green light on, if not, check board oriented on battery correctly, the connection is good or board is defective
board showing - 225 degrees	Temperature sensor on bottom of board broken
Not reading pack voltage	Check battery + and – wiring Check Bat+ is fully plugged in

Not reading pack current	Check battery + and – wiring Check wiring to shunt, may be reversed Check shunt + is fully plugged in
Current display wrong polarity	Shunt wires reversed
“Snow” on video display	Check grounding on monitor Move video cable away from noise sources
No CAN data received	Check CAN H and CAN L are not reversed Check receiving device is set for 500K BAUD Check software revision on EMS

Appendix A. Enclosure Mounting