Elite Power Solutions
Energy Management System
Operation Manual

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1 – Introduction

Thank you for purchasing an Elite Power Solutions Energy Management System (EMS). This manual covers the operating and installation information for the Elite Power Solutions Energy Management System (EMS). Read the entire manual before attempting to install, service, or operate any of the EMS system components.

The EMS system has everything needed to display the condition of and maintain the health of lithium ion batteries and is specifically designed to work with GBS Lithium Ion batteries. The system consists of two major components, the computer (CPU) and the cell sense boards. The CPU monitors details about the condition of the battery pack, such as current, voltage, state of charge and individual cell details. These details are displayed via video output to an external monitor.

The sense boards form a simple daisy chain by mounting on each cell to read voltage and temperature. They also perform battery balancing during recharging to equalize the charge within the battery pack assembly. Two alarm outputs, one for over voltage, and one for under voltage, provide automatic shut off signals to prevent overcharging or over discharging of the battery pack.

A unique feature of the EMS system built-in ground fault detection. High voltage systems should be floating relative to the chassis for safety. If an inadvertent path to the chassis ground is made, the system will detect it and display a warning for this unsafe condition.

The EMS system is designed such that the battery monitoring is isolated from the 12 volt power. The EMS is powered by a powerful 8 core 32 bit microprocessor which outputs composite video. A CAN (communications area network) interface option is available to output the information from the EMS to other systems.

2 – Specifications

Main Screen Display	Pack Voltage, Pack Current, Battery Capacity, Alarm Message
Individual Cell Screen	Cell number, voltage and temperature
Computer Input Power	9-20V, 120mA
Battery Voltage	12-500V
Shunt Input	500A = 50mV
Pack Voltage Resolution	0.2V
Current Resolution	0.1A
Operating Temperature Range	-4F to +158F or -20 to +70C
Temperature Accuracy	± 5 degrees
Battery Types Supported	Lithium Ion
Video Output	Composite Video, Color, NTSC, RS-170
Measurement accuracy	Better than 1% of Full Scale
Maximum number of cells supported	140
Cell Voltage	2.2V to 4.5V
Balancing Threshold	3.55V
Balancing Current	0.5A
Alarm Output Current	4A surge for 100mS, 2A continuous*
Alarm Output Delay	See Default Alarm Table in section 14
Optional Data Interface	CAN
Ground Fault Detection	2mA (5000 Ohm/Volt)

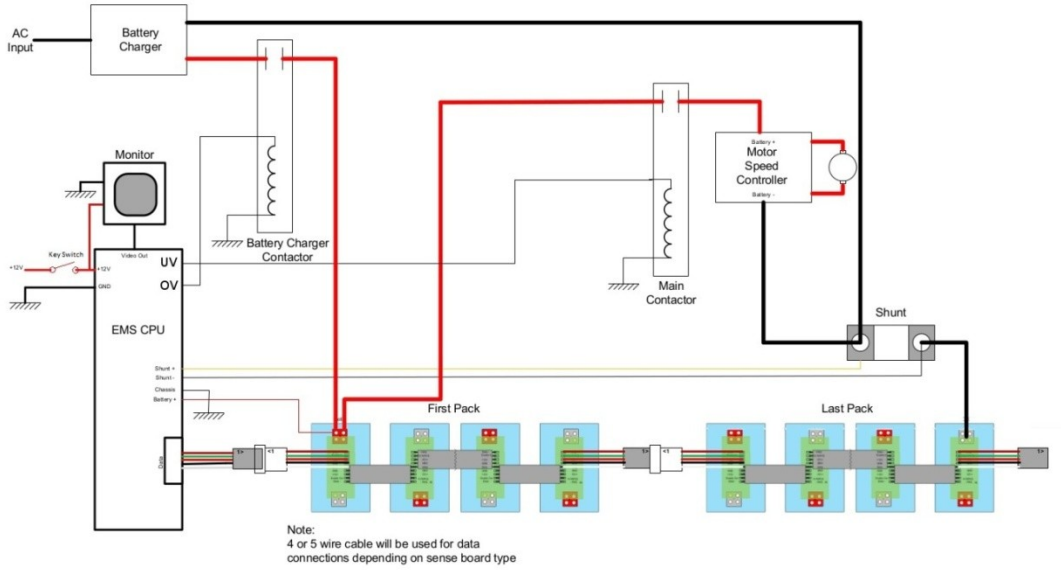
*12V input must be able to supply the power used by the alarm outputs

3 – Installation Overview

ALWAYS USE EXTREME CAUTION WHEN WORKING HIGH VOLTAGE SYSTEMS. ALWAYS DIDCONNECT THE MAIN POWER WHEN WORKING ON ANY HIGH VOLTAGE SYSTEM (THIS WILL HELP MINIMIZE RISK OF SHOCK). ALWAYS TAKE NOTE WHERE THE HIGH VOLTAGE LINES ARE. IF YOU ARE UNCOMFORTABLE PERFORMING ANY OF THESE TASKS, PLEASE STOP AND CONSULT A PROFESSIONAL.

The EMS is designed to make installation as easy as possible. All of the connections 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. A mounting template for the computer is 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).

The EMS system components utilize either a conformal coating or epoxy or silicone coatings on all components to allow them to perform in high humidity environments. However, components are NOT water proof. All components must be installed inside water resistant containers.

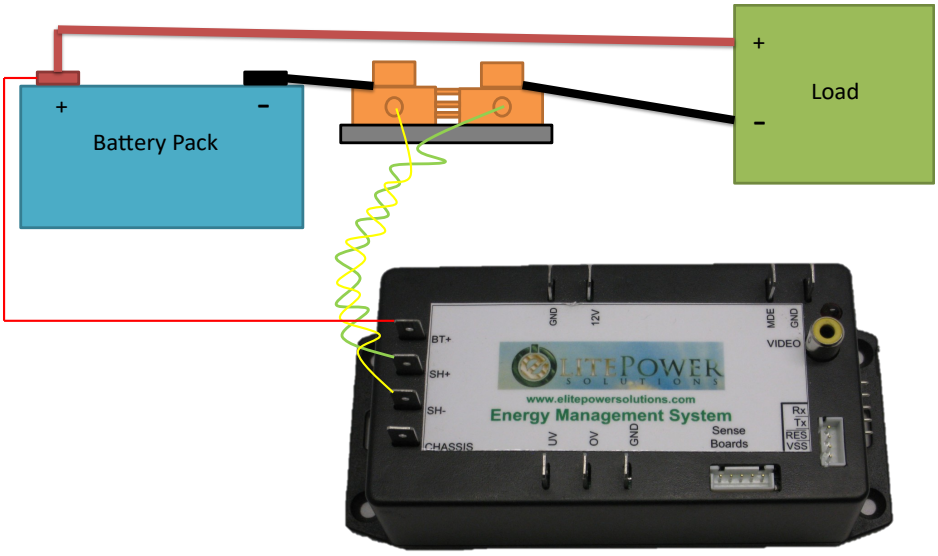


Elite Power Solutions Typical EMS Installation

4 – 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 AWG).



Use extreme caution when making these connections as the full battery pack potential will be present between the shunt and battery pack positive pins. Connecting these wires incorrectly can cause damage to the EMS CPU which will not be covered under warranty.

The wires connecting to the shunt should be a twisted pair or wires with as short of a distance from the CPU as possible to achieve accurate measurements.

5 –12 Volt Power

The CPU is powered by 12 volts, which is connected to the terminals marked “12V” and “GND”. This should be connected to a power source through a 5A fuse. The power can either be always on, or can be switched off to conserve power. 12 volt power must be supplied at any time when the battery pack is being charged or discharged. When 12 volt power is applied the red heartbeat LED will blink.

If the battery pack is more than a 12 volt battery, and the CPU is to be powered off of it, a DC/DC converter must be used so that the battery pack is discharged equally. Under no circumstances canfour cells within the battery pack be tapped for 12 volt power for the CPU as this will cause an imbalance within the battery pack.

Note that there are three pins marked “GND” for ground on the CPU. These three pins are common together. Only one of these pins needs to be connected, the other two are located for convenient connection options.

6 – Heartbeat LED

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

7 – Page Select Switch Input

To change the display on the CPU to the individual cell screen(s) a normally open momentary switch is used to short the pins marked (MDE) to (GND). There is no polarity to the switch and the connection can be small gauge wire (e.g. 18 AWG). In applications where the 12 volt power is grounded to a vehicle chassis only one wire needs to be ran from the MDE pin and can be grounded to the chassis through the momentary switch.

8 – Sense Board Wiring

The sense boards are connected to the CPU via a cable with five pins. Depending on which sense board version the system was supplied with this cable will have either four or five wires connected to it. This connector has a retention mechanism. If removal of this cable is needed never pull in the wires, always pull up on the connector to avoid damage to the wire harness.

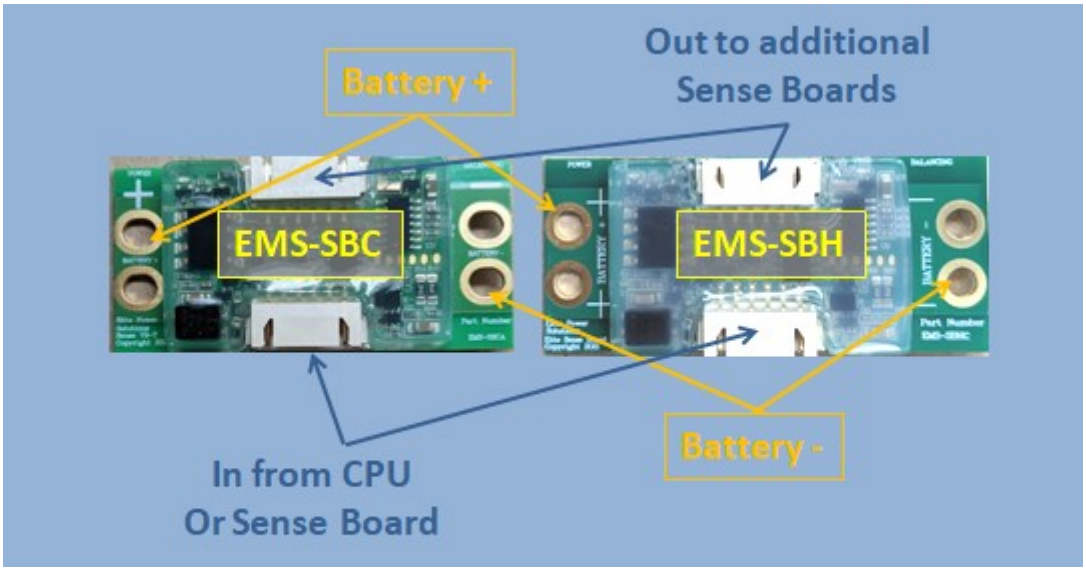
The CPU will automatically index the sense boards based on their position in the daisy chain of boards. The first sense board connected to the CPU will be cell number one and the CPU will count up from there. It is recommended that the negative most cell in the pack be made cell number one and have the daisy chain move toward the most positive cell in the pack. This will aide in troubleshooting if needed; however, the sense boards can be connected in any order.

Before installing sense boards, install all cell jumpers first with the outer two screws tightened. Never install sense boards underneath jumpers as this will cause current to flow through the screws, resulting in a poor connection. Never slide a jumper underneath a sense board while installing as this may cause a short with components which are located on the back of the sense board.

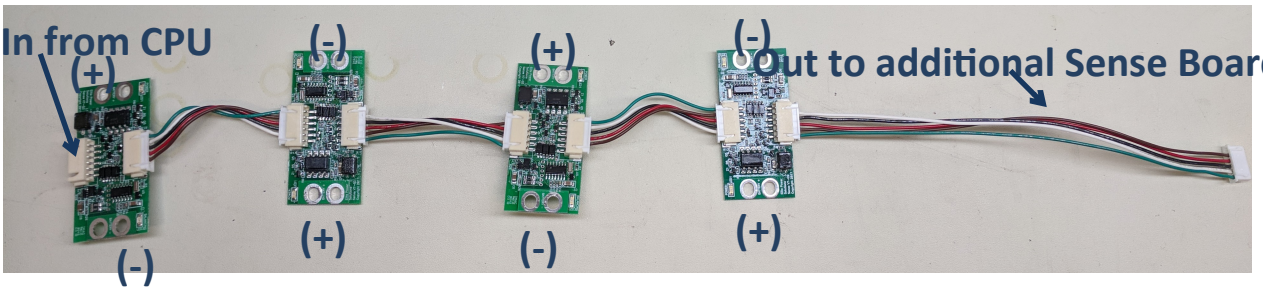
When installing sense boards, keep cell covers installed on all cells except the cell where the sense board is being installed. Do not allow sense boards to lie on battery terminals. This will help prevent accidental damage to sense boards during installation.

The current sense board design is modular, with each connector serving as either an input or an output, depending on the orientation of the signal wires. The sense boards have prominent polarity markings indicating the battery mounting orientation. Ensure that the polarity is correct before installing.

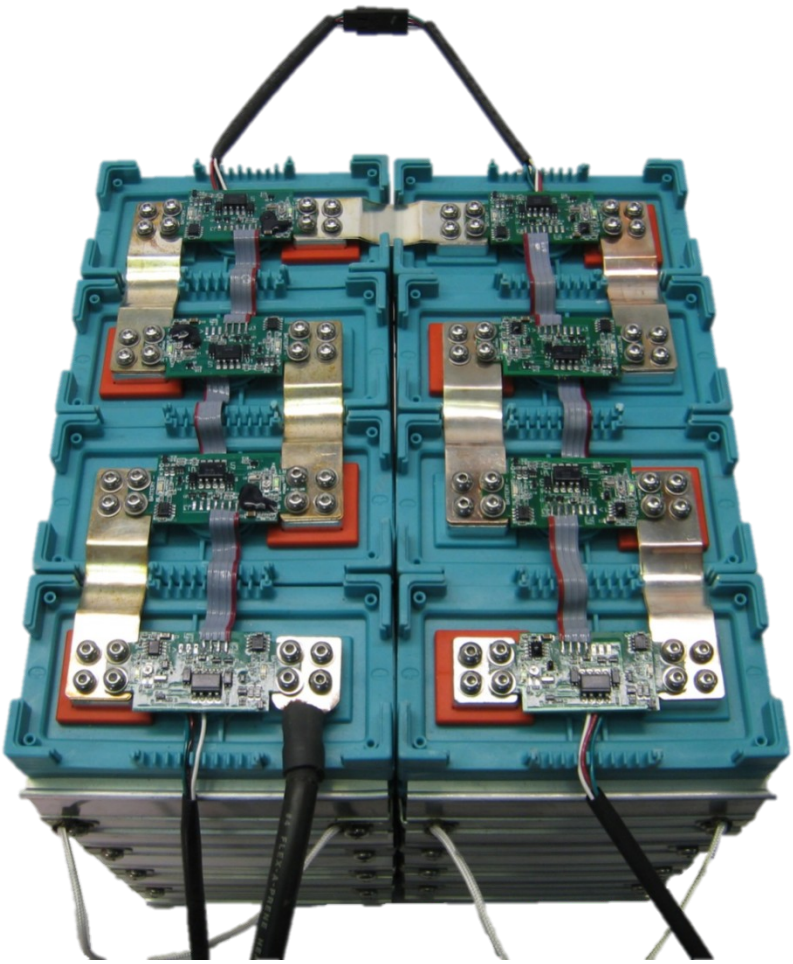
The boards should not be damaged by a reverse polarity; however, they will not function. When a sense board is installed correctly the green led will light up. There is also a red LED on the sense board, which indicates cell balancing is occurring. This led will light up any time the cell voltage is 3.55V or higher.



When connecting boards, the green wire will swap orientation every board.



Older sense boards had an input and an output connector and were hard wired together in 4 cell strings. The male connector is the input; the female connector is the output. An example is shown below for reference. This style of board string is no longer supported for new manufacture.



9 – Battery Balancing

When the battery voltage rises during charging to 3.55V or above, the red balancing LED will illuminate on the sense board to indicate the cell is balancing. The sense boards will draw 0.5A until the voltage has dropped below 3.55V. It is normal for some cells to balance more than others and some cells to rarely balance.

10 – Video Output

The EMS CPU outputs composite video output through a common RCA type jack. This can be connected to the optional LCD screen EPS provides or any other display which will accept this type of input (e.g. in dash DVD). The video cable is not provided as length requirements vary. A shielded cable is recommended if there is snow or static in the video signal.

11 – CAN Bus Output (Optional)

If ordered with the optional CAN bus interface, this connector will be on the side of the CPU.

A pig tail connector is provided. The connections are as follows from left to right as pictured:

NC	No Connection
GND	CAN Ground
CANL	CAN Low Data
CANH	CAN High Data
12V	Optional 12V input, not typically used

When making a connection to an EPS charger, only the GND, CANL and CANH pins are used. Two LED's will light when there is nothing connected to the CAN output, but indicate

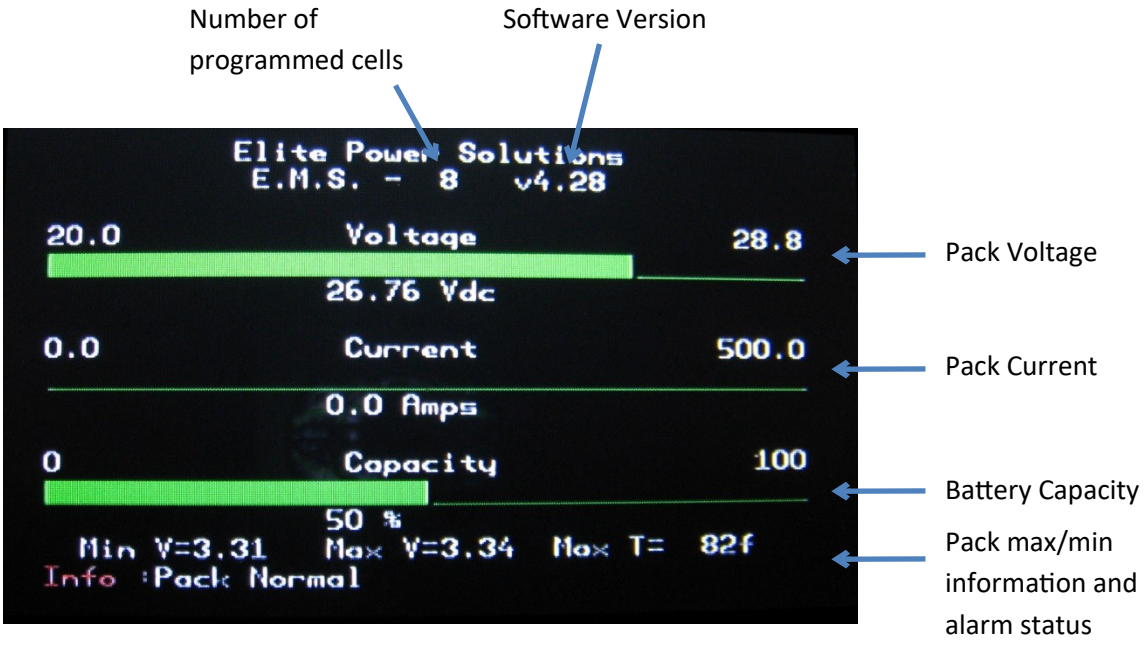
that the CAN portion of the CPU is working. When a CAN device is connected these lights will dim significantly, but will flash rapidly indicating data is being transmitted.

If a CAN device is not connected during initial power up the COM may go idle. If this happens cycle the power to the CPU to reset it.

For a more complete specification for the CAN data transmitted please contact EPS.

12 – Main Screen

When properly installed, the EMS system will display the voltage, current, capacity and alarm status of a Lithium Ion battery pack. This is an example of what the main screen displays:



Number of Cells is indicated at the top of the screen as “E.M.S – x” where x is the number of sense boards the CPU has been programmed to manage. If the system detects a value other than the programmed value, it will trigger an unmanaged cell alarm.

Software Version is displayed to the right of the number of cells. This is the version of the software programmed in to the CPU. EPS is constantly updating the software which can add new features. For information on receiving a software update please contact EPS or the vendor that the system was purchased from.

Battery Pack Voltage is the total battery pack voltage. This updates in real time and the numerical value is displayed below the bar. This bar will be green whenever voltage is

between 3.0V × N (the number of cells in the pack) and 3.4V × N. When the voltage drops below 3.0V × N the bar will turn red to indicate low voltage. The bar will also turn red when the voltage rises over 3.4V x N to indicate that the target charging voltage range has been attained. If the voltage goes outside of the range of the bar, an off scale message will appear.

Battery Pack Current is the current either being drawn from the battery or being charged in to it. Like the voltage bar, this is indicated in real time and the numerical value is displayed below the bar. This bar will be green and will turn red when current is above 200A. When current is negative and the battery is being charged this bar will turn white and “Charging” will be displayed.

Battery Pack Capacity is the battery state of charge. It works by tracking the amount of charge that goes in and out of the battery pack. It will reset to 100% during charging when the current is within a normal charging range for a battery charger and the total battery pack voltage reaches 3.52 × N (the number of cells). When the system is powered up for the first time this value will read 50%. The battery will have to be charged to full in order to reset the capacity reading correctly to 100% the first time.

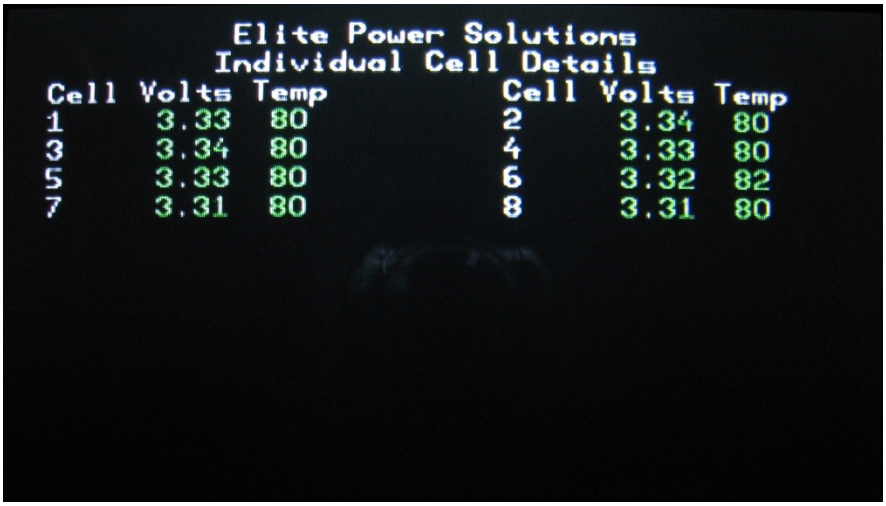
Min/Max Cell Voltage provides a quick overview of the maximum and minimum cell voltages within the battery pack. Depending on the number of cells within the battery pack, these values update every 1 -2 seconds.

Alarms and Warnings are displayed at the bottom of the screen after the word “Pack:”. There are seven alarms:

- Over voltage (highest cell is over 3.8V after a 3 second delay)
- Under voltage (lowest cell is below 2.8V after a 30 second delay)
- Over current (current exceeds 10C for 10 seconds)
- Over temperature (highest cell exceeds 150°F or 65°C)
- Under temperature (lowest cell is below 32°F or 0°C, charging is not allowed)
- Ground fault (There is a high voltage leakage greater than 2mA to the chassis pin)
- Unmanaged cells (The programmed number of cells does not equal the number of cells read)

13 – Individual Cell Page

To access the individual cell detail page(s) refer to section 7, Page Select Switch Input. When momentary switch is pressed and released it will change the display to show the first 20 cells in the pack with details of voltage and temperature of each cell as shown below:



If there are more than 20 cells in the pack, pressing the button again will advance to the next 20 cells until the last cell page is reached, then pressing the button again will return to the main screen.

Cell (number) is the location of the sense board relative to the daisy chain of sense boards. The cell connected to the CPU first is number one.

Volts is the actual cell voltage. This updates every 1-2 seconds, depending on the number of cells in the pack.

Temp is the temperature reading. This updates every 1-2 seconds, depending on the number of cells in the pack. The number will turn red if the cell exceeds the upper temperature limit. Readings are in °F by default; upon request, this can be set to read in °C.

The cell temperature is measured at the positive terminal of each sense board. If a single cell has noticeably higher temperature during use than other cells, but the temperature goes back down quickly this may be an indication of a poor connection where there is high contact impedance. Also, during balancing the temperature will temporarily rise due to electrical energy being converted to heat.

Note that this screen will not automatically update if cells are connected or disconnected. To update the screen the Page Select button must be pressed until it has cycled back through the main screen, then back to the individual cell detail screens in order to update the view. Cell voltage and temperatures are updated in real time on these screens.

14 – Alarms

In order to protect the battery pack, there are a number of alarms, which are based on cell voltage, temperature, pack current, and fault conditions. The CPU contains two alarm output pins, UV for under voltage and OV for over voltage. When any of the alarm conditions are met for a specified duration of time they will activate the respective action listed in the table below.

Default Alarm Table:

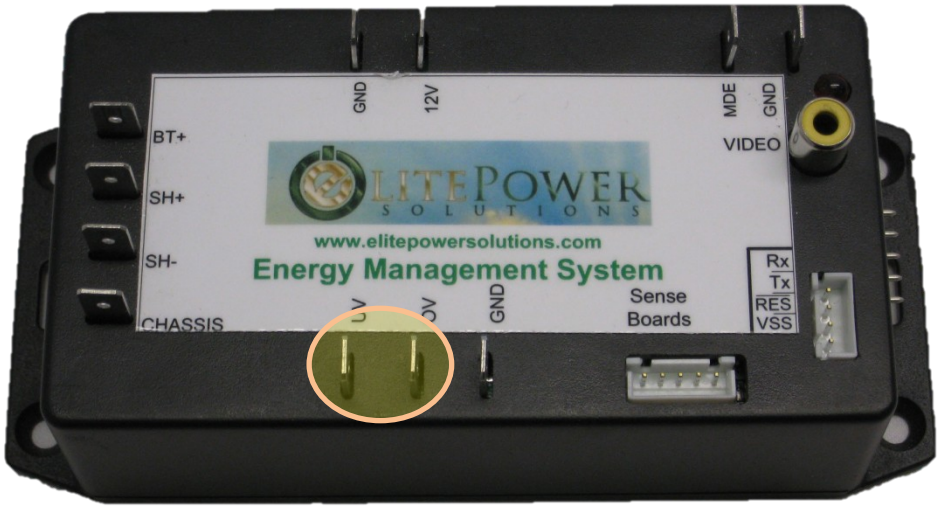
Alarm	Condition(s)	Delay Time	Actions
Under Voltage	Minimum cell voltage is below 2.8V	30 seconds	UV = 0V OV = 12V
Over Voltage	Maximum cell voltage is above 3.8V	3 seconds	UV= 12V OV = 0V
Over Current	Pack current exceeds 10C	10 seconds	UV = 0V OV = 0V
Under Temperature	Minimum cell temperature is less than 32°F (0°C)	30 seconds	UV = 12V OV = 0V
Over Temperature	Maximum cell temperature is greater than 150°F (65°C)	30 seconds	UV = 0V OV = 0V
Unmanaged Cells	The number of sense boards detected does not equal the programmed value	30 seconds	UV = 0V OV = 0V
Pack to chassis fault	Pack voltage exceeds 2mA to the chassis pin on the CPU	30 seconds	UV = 12V OV = 12V

The alarm limit values may vary with custom configurations.
The same delay time must elapse once an alarm condition is cleared to deactivate the alarm.

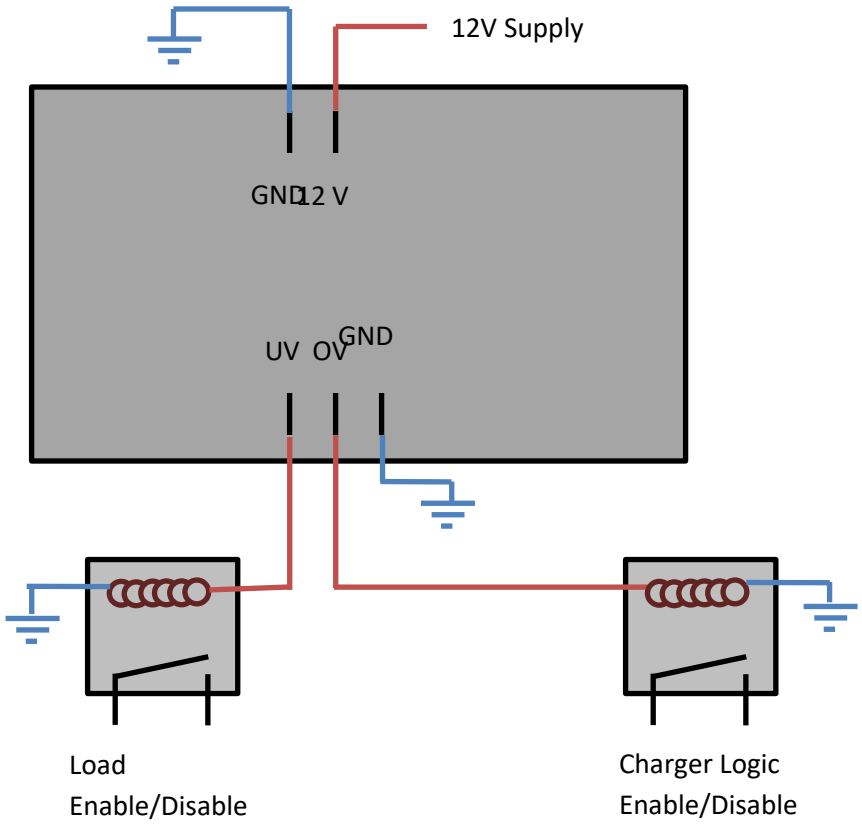
15 – Controlling Devices with Alarm Outputs

The alarm outputs on the CPU output 12 volts and can drive continuously 2A with up to a 4A surge. Exceeding these limits or short circuiting these pins may cause damage to the CPU. The alarms act according to the above table. It is very important that these alarm outputs be able to disconnect the battery pack from loads and charging sources when they activate.

To fully protect the battery there must be a no parasitic load condition. Ensure that items such as controller pre-charge resistors, DC/DC converters, lights, etc. are all disconnected in the event that the low voltage alarm triggers. **Failure to properly implement these alarm interlocks may void the warranty on the battery**.



When all parameters are within normal ranges, these alarm outputs will be 12 volts. They will drop to 0 volts during an alarm condition. When power to the CPU is removed, these outputs will not supply power. Systems should be designed such that they require power from the alarm outputs from the CPU in order to function.



16 – Capacity Algorithm

The EMS CPU keeps track of the capacity of the battery pack by tracking current in and out of the battery (coulomb counting). There are several corrections built in to the software to ensure that the capacity stays accurate over time.

The capacity will reset to 100% if the following conditions are met:

- Total pack voltage measures 3.52V × N (N being the number of cells) when being charged by a battery charger.

or:

- The over voltage alarm is triggered when being charged by a battery charger, see default alarm table for set points.

The capacity will reset to 0% if the following conditions are met:

- The under voltage alarm is triggered and discharging current is not excessive, see default alarm table for set points.

When the EMS is powered up the first time the capacity will read 50%, which is approximately the state of charge that the batteries ship at when new. To sync the capacity, the battery pack must be charged full, which will trigger a reset to 100%.

The capacity measurement is done based on the programming in the CPU. CPU's cannot be interchanged if they have been programmed for a different battery pack configuration.

Upon special request, the CPU can be programmed to extend battery life by limiting the depth of discharge to 80%. This will scale the capacity bar such that 100% of the scale is 80% of the battery capacity. Once the capacity reaches 0%, which is 20% of the actual capacity remaining, the under voltage (UV) output will automatically shut off.

17 – Ground Fault Detection

The pin marked “Chassis” is used for the ground fault detection circuitry integrated in to the EMS CPU. This should be connected to its own dedicated chassis ground point. When this is done, and the shunt and battery positive wires are connected properly, the system will be able to detect a ground fault anywhere within the battery pack. This feature will display an alarm message on the screen if there is a fault condition, but will not cause any alarm actions to be taken. If this message appears there is a potentially dangerous ground fault condition which should be corrected.

The alarm will be triggered any time a current of 2mA or greater is detected from the battery pack to the chassis pin.

If the EMS system is being used on a lower voltage system (<50 volts) where the battery pack is grounded to the chassis, this wire should not be installed to disable this feature. EPS does not recommend grounding battery packs in excess of 12 cells in series for safety.

When performing work on a high voltage battery pack, the Chassis pin should temporarily be disconnected as it will induce a very small, non-dangerous, electrical current to the chassis which could cause small electrical shocks.

18 – Troubleshooting

Symptom	Possible Causes
No heartbeat LED on CPU	• Check 12 volt input power
No Video	• Check video cable • Check power to screen
Sense Boards not detected	• Check for green LED on sense boards • Check wiring for breaks • Check Sense Board polarity • Check 12 volt input to CPU • Cycle through individual cell screen(s) to update information
Data jumps around rapidly	• Check 12 volt input to CPU, low voltage will cause data to be bad • EMI noise, route data cabling away from high voltage cabling • Noise on 12 volt input, test with isolated 12 volt power source
No pack voltage reading	• Check wiring at BT+ and SH-, pack voltage should be present here
No pack current reading	• Check SH+ and SH- connections to the shunt • All current must pass through the shunt
Current shows “charging” during discharging	• SH+ and SH- wires are reversed
No CAN data	• CAN device must be connected during initial power up. • CANH and CANL are reversed • BAUD rate not correct (500K default)
Pack has “Unmanaged Cells” alarm message appears	• Check individual cell screen for number of cells detected. • If the number of cells is deficient to the number expected, check the last sense board which shows up and the first that does not. • Check cell voltages with a multimeter. V2 sense boards will lose communication if voltage drops below 2.2V
Cell voltage too low alarm appears	• Pack is discharged and needs to be recharged • Bad battery cell
Cell voltage is too high alarm appears	• Pack is charged and has shut off the charging source to protect itself • Bad battery cell
Cell temperature is too high	• A sense board is reporting a temperature above the spec limit and is shutting down the system to protect the battery

	• Check for loose connections
Cell temperature is too low	• A sense board is reporting a temperature below the spec limit for charging and has shut off charging equipment to protect the battery pack
Pack to chassis fault alarm appears	• A potentially dangerous leakage current to the chassis has occurred. Find the source of this leakage and remove it. • For low voltage systems where the battery pack is grounded to the chassis disconnect this pin to eliminate this feature.

Appendix A: Enclosure Mounting