Electric Vehicle Display

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Contents

Overview

The Dilithium Design Electric Vehicle Display displays pack State of Charge, Pack Current and Voltage Measurements, Cell Status, Pack Status, and individual cell voltages.

The Display uses the Dilithium Design Battery Management System. The Display can configure most BMS parameters. Up to four BMS Controllers may be managed by a single Display; cells may be organized in up to four parallel packs.

The Display can optionally be used with the Thunderstruck EVCC (Electric Vehicle Charge Controller). The Display can configure most EVCC parameters, monitors the J1772 plug and charging status, and can show the EVCC charge history.

The Display computes Pack State of Charge in two ways: by "estimation" from BMS Cell Voltage Statistics, and by "charge counting" using an optional Current Sensor.

The Display also supports an optional analog Fuel Gauge.

Figure 1 – EV Display System Diagram
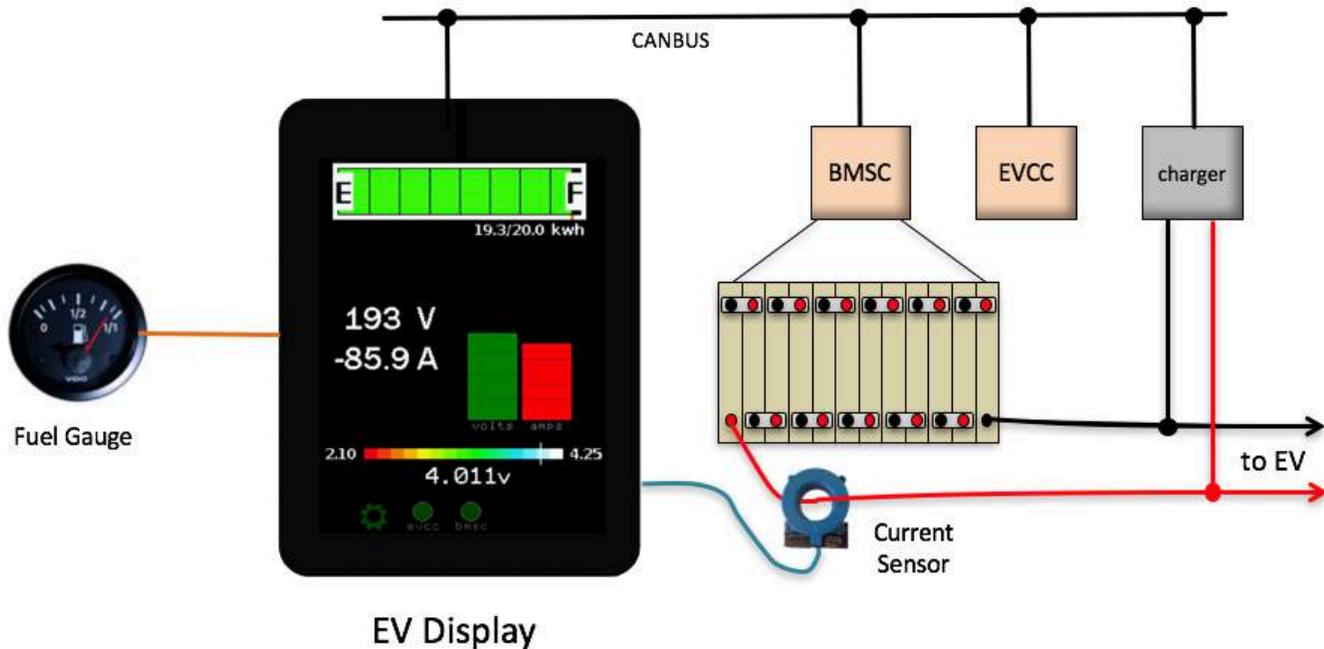
BMS documentation is provided in *Battery Management System v2.0*, http://www.thunderstruck-ev.com/bms/.

EVCC documentation is provided in *EV Charger Controller v2.4*, http://www.thunderstruck-ev.com/evcc-charge-controller.html.

Installation

Mechanical

The Display hardware uses the 4D systems gen4 32-DCT-CLB. This display is a 3.2" 240x320 pixel LCD capacitive touch display with an attached bezel. The datasheet can be found at http://www.4dsystems.com.au/product/gen4_uLCD_32D/.

With bezel, the display measures 98.8mm x 72.6mm. The display is mounted on a flat surface with a rectangular opening (approximately 80mm x 56mm) and affixed to the surface using double-sided tape.

Mechanical drawings can be found at http://www.4dsystems.com.au/productpages/gen4-uLCD-32D-CLB/downloads/gen4-uLCD-32D-CLB_drawing_R_1_0.PDF

A PCB is mounted directly on the back of the display and connects to the display using a 30pin flat cable. The PCB has two connectors: a 5-pin Systems connector and a 4-pin Hall connector. When mounting the display, the 5-pin Systems connector is towards the bottom.
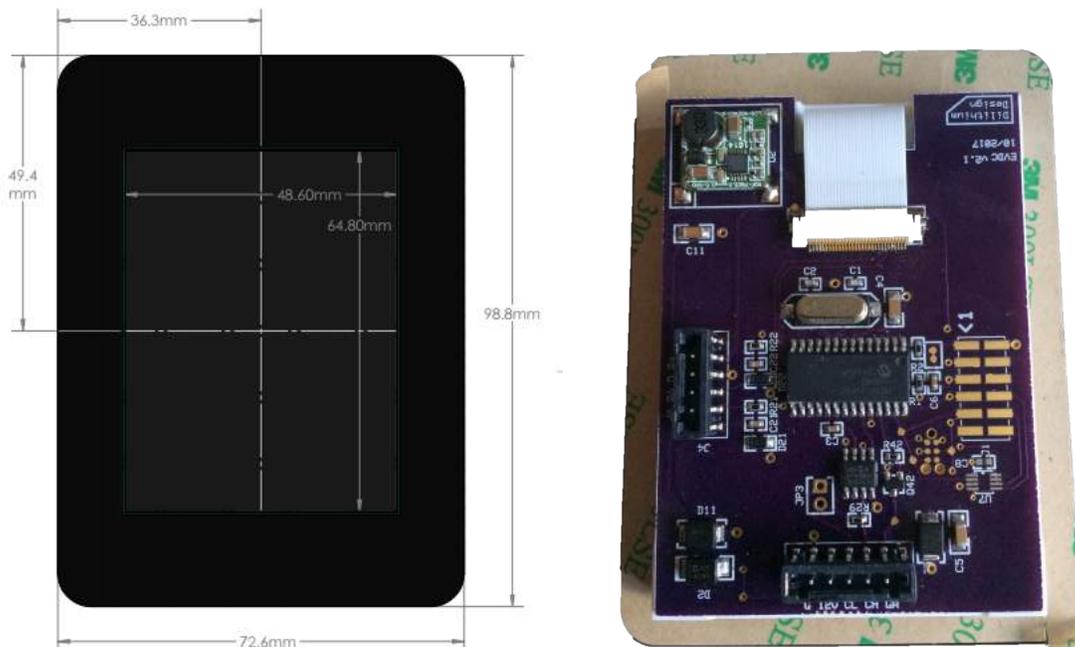

Figure 2 – Display Hardware

The System and Hall connectors use "push-in" connectors. These connectors accept 20-24 gauge stranded or solid wire; stranded 20 gauge wire is recommended. To make a connection, strip the wire back 1/4". Twist the wire end and insert. Be sure that all strands of wire get correctly inserted to prevent shorting between adjacent wires.
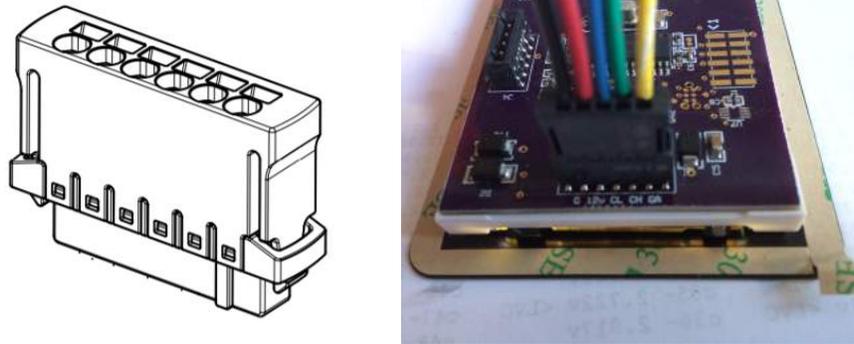
Figure 3 – Push-in Connector

Removing the wire from the connector requires a removal tool: insert the tool into the associated slot above the wire and wiggle it in. This will collapse the spring holding the wire and the wire can be removed.

The wire header part numbers are

- 5p Systems Connector   Harting 14310513101000
- 4p Hall Connector   Harting 14310413101000

The removal tool is Harting 14990000001. Alternately, the Molex KK terminal removal tool, part number W-HT-1884, is widely available and has been found to work well.

Systems Connector

The System Connector provides 12V power, CAN, and the analog gauge "sender" connection.

gnd	+12V	CANL	CANH	gauge

Figure 4 – Systems Connector Pinout

The **gnd** and **+12V** inputs on the System Connector provide Display power. Power should be enabled when the EV is being driven or being charged. Maximum 12V power consumption is approximately 100ma.

If the Thunderstruck EVCC is being used, display power may be provided directly from the EVCC 12V_SW output.

The **CANL** and **CANH** inputs connect to the EV CAN network. A CAN termination resistor in the Display may be enabled by installing the bridge between the right two pins of jumper JP3. This jumper is adjacent the 5p Systems Connector.
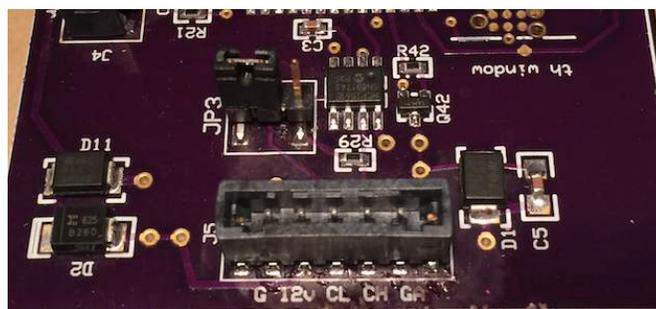

Figure 4 – CAN Termination Jumper

See BMS documentation for CAN wiring guidelines.

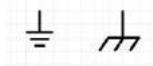The **gauge** output connects directly to the "sender" input on an analog fuel gauge.

Analog Fuel Gauge

Analog Fuel gauges typically have three connections: +12V, Ground, and "sender".

Figure 5 - Analog Fuel Gauge Connections

Note that the "Ground" connection on the meter might be indicated by "-", or by a symbol:

Connect EV +12V and Ground to the gauge, and connect the gauge "sender" connection to the Display "gauge" output on the Systems Connector.

Conventionally, the Fuel Gauge is connected to a gas tank float "sender": a variable resistor which changes resistance based on the level of the float. Usually this connection only uses one wire as the return connection is made directly to chassis ground.

The Display has been tested with a variety of fuel gauges, including VDO and Bosch. The fuel gauge and the sender are a matched set, there are common values, there are no standard ones. The Display uses Pulse Width Modulation (PWM) to drive the meter. In order to accommodate the different fuel gauges, the PWM settings must be configured in the Display for the gauge to work properly. See *SOC Configuration*, below.

Hall Connector

The Display supports LEM HTFS Hall sensors. These sensors are single range, bidirectional sensors that come in several models: HTFS-200, -400, -600, and -800, and current ranges: +/- 300A, +/- 600A, +/- 900A, and +/- 1200A.

| Vref | Vout | gnd | +5 |

Figure 6 - Hall Sensor

The LEM HFTS reference voltage connection, Vref, can be overdriven to shift the working range. The HTFS-200, for example, can have its range shifted from -300A to +300A to -100A to +500A.

The Display supports all HTFS models and automatically adjusts for reference voltage adjustments.

The LEM HTFS datasheet can be found at: http://www.lem.com/docs/products/htfs_200_800-p.pdf

A small PCB board has been developed to make the installation simpler; the PCB has a 4p connector (identical to the connector on the DisplayPCB). The sensor and PCB may be installed directly on a traction cable as the hole is large enough for a 2/0 lug. The "bottom" (e.g., PCB side) of the sensor should be installed in the + terminal towards the pack.

The four connections from the Hall Sensor connect directly to the 4p Display connector.

State of Charge Calculation

Voltage SoC

The Display can estimate pack SoC by using individual cell voltage statistics. The Display maintains a running average of the voltage of the lowest cell in the pack. It then determines a "Voltage" SoC by scaling this average between the BMS configured High Voltage Cutoff (HVC) and Low Voltage Cutoff (LVC) values.

The Voltage SoC approximates actual pack SoC but it has limitations. Lithium Cell chemistries generally do not have a flat discharge curve and it is overall more difficult to measure SoC based on a voltage estimate. And, even though the Voltage SoC calculation uses a running average of cell voltages, the pack, and hence, the Voltage SoC may "sag" under extended load and then recover later.

The Voltage SoC is the most accurate at the "high" and "low" ends of the scale. If all cells are near HVC, the pack is considered "full". When any cell is at LVC or below, the pack is considered "empty". Since the lowest cell voltage is used to determine SoC, a failing cell will affect the SoC results.

Charge SoC

The Display supports SoC calculation by Charge Counting. This technique requires an initial "starting" SoC value and the configured capacity of the Pack in Kilowatt-Hours. WattHours removed from or added to the pack are measured and the SoC value is adjusted up or down. There must also be a method for sychronizing the starting SoC value as well as resynchronizing this value later to make sure that errors do not accumulate.

In order to enable the Charge SoC feature, it is necessary to use a Current Sensor, configure the Current Sensor type and to configure the pack capacity.

Pack Current measurement is provided by the Hall Sensor, however, for better accuracy when charging, the Display will preferentially use the EVCC reported current readings if this information is available.

When Charge SoC is configured, the Charge Counting approach is used to drive the display. The SoC value is stored in nonvolatile memory periodically so that when the EV is driven, stopped, and then restarted, then the SoC will resume with the last stored value. The Display uses the Voltage SoC to periodically adjust the Charge SoC, and so there is no manual synchronization needed.

It is necessary to estimate and configure Pack Capacity. If the pack capacity is not known, it may be determined by experimentation. If the configured capacity is too low, then the SoC will empty faster than it should; likewise, if the configured capacity is too high, the SoC will empty slower than it should. Periodic synchronization with the Voltage SoC will keep the displayed SoC to within reasonable limits. However, some experimentation and adjustment may be needed to determine actual pack capacity.

Screens

Startup Screen

When the Display is first powered up, it shows a Startup screen for a few seconds. During this time, the Display attempts to discover if there is an EVCC or BMSCs present on the CANBUS. The Display will then show the firmware version numbers of all discovered devices.

Version Numbers for the Display, EVCC, and BMSC(s)

While the Startup screen is being displayed, it is possible to "freeze" it by touching the screen before it transitions to the next screen. This gives time to make note of the firmware version numbers if needed. Touching the screen again will unfreeze the display.

Toobar

At the bottom of most screens is the Toolbar. This region of the screen has the several icons arranged from left to right. Icons display status and are used for Navigation.

Two toolbar examples are given below:

Back Icon

The "back Icon" looks like a "left arrow". It is only used for navigation and is not present on all screens. If touched, it will navigate to the previous screen; most often the Status Screen.

Setup Icon

The "setup Icon" looks like a "gear". It is only used for navigation and will navigate to the Configuration Screen. When in a Configuration screen, this icon will be white.

EVCC Status

The EVCC icon displays as an **empty circle** if the EVCC is not detected.

If the EVCC is detected, the charge plug is not inserted, and the EVCC is operating normally, the icon will appear as a **green circle**.

If the EVCC is detected, the charge plug is not inserted and the EVCC is in cell loop failure or BMS timeout the icon will appear as a **red circle**.

If the EVCC is detected, the charge plug is inserted and the EVCC is charging, this icon will appear as a **red charge cord**.

If the EVCC is detected, the charge plug is inserted and the EVCC is not charging, then the icon will appear as a **blue charge cord**.

If the EVCC is not detected, touching the EVCC Icon has not effect. If the EVCC is detected, then touching the EVCC Icon will navigate to Charge History.

BMSC Status

The BMSC icon displays as an **empty circle** if the BMSC is not detected.

If the BMSC2, BMSC3, or BMSC4 are not detected, then no icon is displayed.

If a BMSC (any of BMSC, BMSC2, BMSC3, BMSC4) is detected and is operating normally, the icon will appear a **green circle**.

If any BMSC is detected and it has a minor alert (such as configuration not locked), the icon will appear a **yellow circle**.

If any BMSC is detected and it has a major alert (such as cell over High Voltage Cutoff), the icon will appear a **red circle**.

If a BMSC is not detected, touching the associated Icon has not effect. If the BMSC is detected, then touching the BMSC Icon will navigate to BMSC Status.

Status Screen

The **Status** Screen is the main screen. The Status screen is divided into four regions: State of Charge, Voltmeter and Ammeter, Cell Voltage Summary, and Toolbar.

State of Charge

Voltmeter / Ammeter

Cell Voltage Summary

Toolbar
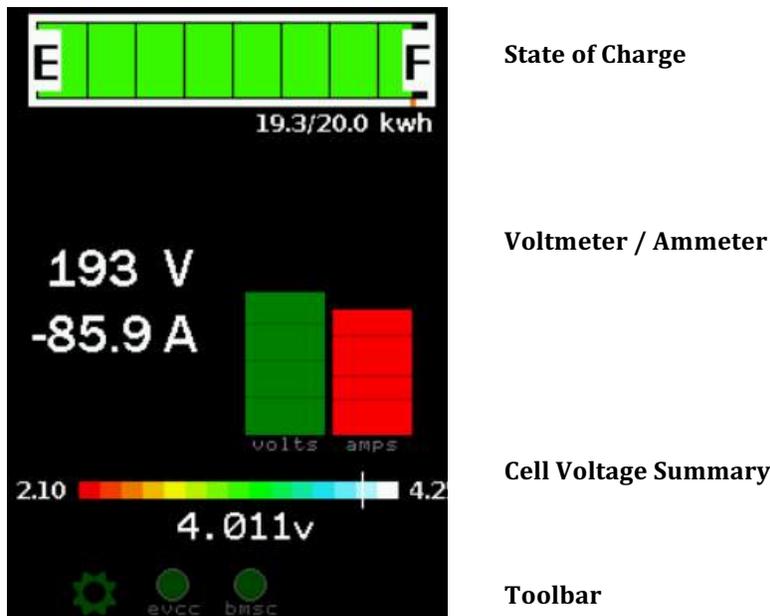
The **State of Charge** is a digital fuel gauge. If a current sensor is being used, this gauge also shows the estimated Kilowatt Hours of pack capacity remaining.

The **Voltmeter** shows the Pack Voltage measurement. The Display calculates pack voltage by adding the cell voltages of all cells in Pack 1.

The **Ammeter** shows Pack Current. This gauge is displayed if a current sensor is being used. Pack current is negative when the pack is being discharged and positive when the pack is being charged.

The graphical displays of the Voltmeter and Ammeter are auto-ranging. The Voltmeter display is linear. The Ammeter display is logarithmic

If the EVCC is available, when charging, the charger reported pack current is used instead of the current as reported from the current sensor. The charger measurement is likely more accurate at the relatively lower currents used in charging.

The **Cell Voltage Summary** shows the range of cell voltages present within the pack as well as the average cell voltage. The scale is calculated from the configured High Voltage Cutoff and Low Voltage Cutoff values in the BMS. In the example above:

- 2.10 is the BMS programmed Low Voltage Cutoff Voltage
- 4.25 is the BMS programmed High Voltage Cutoff Voltage
- 4.011v is the average cell voltage of all cells in all packs

The "white" indicator bar indicates the cell voltages. The left border of the white indicator is the lowest cell voltage in the pack, the right border is the highest cell voltage in the pack and the width of the indicator gives an overall indication of pack balance.

In the example above, the pack is very well balanced and the white "indicator" appears as a fairly thin line. The example below shows a less well-balanced pack. Note the wider "indicator" line.


The **Toolbar** is used to indicate status and for navigation. In the example above, the Toolbar shows three icons: a Setup icon, an EVCC icon and a BMSC icon. Both the EVCC and BMSC icons are green, indicating that these devices have been detected on the CANBUS, are communicating properly with the Display, and that there are no alerts present.

To Navigate from this screen:

- Go to the **Cell Map** by touching the Voltmeter / Ammeter
- Go to the **Cell Voltages** by touching the the Cell Voltage Summary
- Go to **Setup** by touching the Toobar Setup Icon
- Go to **Charge History** by touching the Toobar EVCC Icon
- Go to **BMSC Status** by touching the Toolbar BMSC icon

Cell Map

The **Cell Map** shows a graphical representation of all cells. Cells are arranged in packs; each row of 12 cells is a cell group. A color is assigned to every cell based on its voltage. The example below left shows a single pack of 48 cells. The example on the right shows three parallel packs each with 42 cells. (Note that in this case there are two BMSCs [see the extra Toolbar icon]).
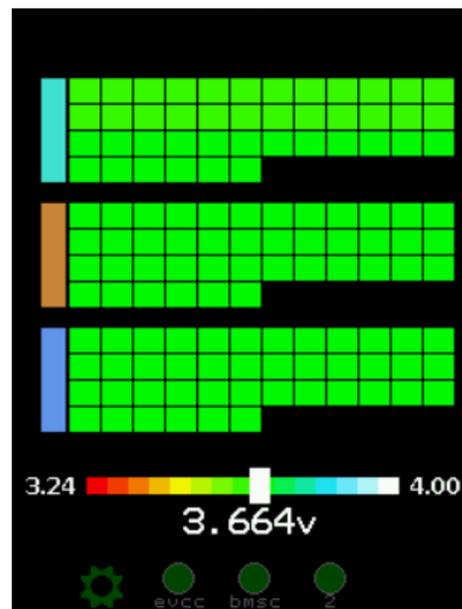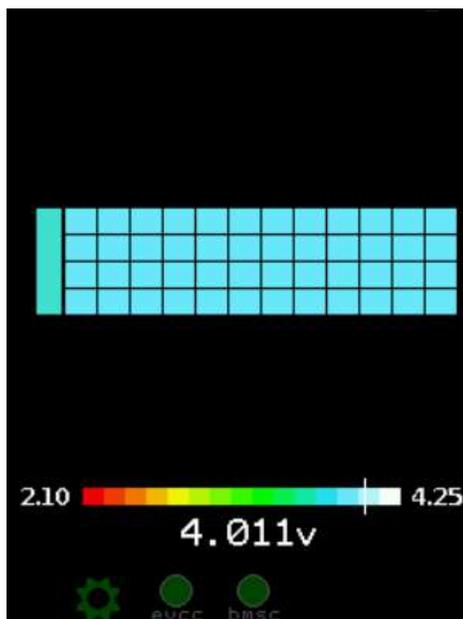
By default, the BMS assume a single Pack and that cells are ordered in physical order. In order to define multiple BMSCs, multiple packs, or change the default cell ordering requires using the BMS serial interface. See the BMS manual for more details.

Each pack is represented by a different color. Pack 1 is turquoise, Pack 2 is brown, and Pack 3 is cornflower blue, pack 4 is gold. This is shown by the colored bar to the left of each group of cells.

The color of the rectangle for each cell is assigned according to the legend at the bottom.

The **Cell Map** screen also shows the Cell Voltage Summary. See Status Screen for a description.

To Navigate from this screen:

- Return to **Status** by touching the Cell Map display
- Go to the **Cell Voltages** by touching the the Cell Voltage Summary
- Go to **Setup, Charge History, BMSC Status** by touching the appropriate Toobar Icon

Cell Voltages

The **Cell Voltages** shows detailed cell voltage values. Up to two Cell Groups are displayed on one screen.
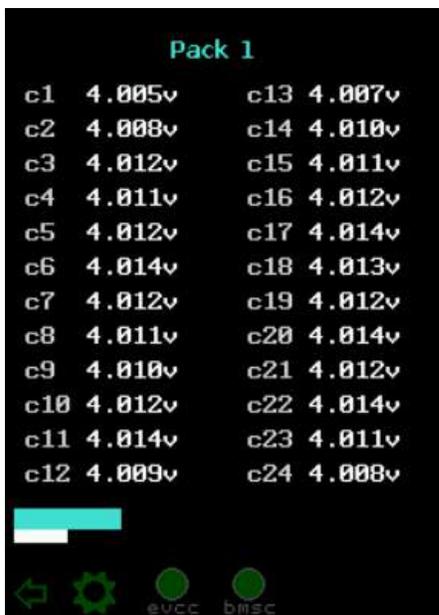
Cell Voltages

Pack / Group Navigation

Toolbar

The Pack/Group Navigation bars show the packs, color coded by pack. The "white bar" below shows which Cell Groups are being displayed. To navigate to different cell groups, touch to the left or right in the Pack/Group Navigation area.

Touch anywhere in the Cell Voltages area to return to **Status**.

BMSC Status

The **BMSC Status** shows the BMS Controllers, BMS Satellites and LTCs. This screen shows which devices are configured (e.g., "supposed to be there") as well as discovered (e.g., "are actually there"). It shows the physical to logical mapping of LTCs to Cell Groups as well as any active BMS alerts. It also shows the cells managed by the BMSC.

In the example on the left, there is one BMSC that manages 48 cells in four cell groups. The BMSC has one satellite. All cells are in Pack 1.

The example in the middle shows BMSC2 which is managing 84 cells in eight cell groups. The cells are in two different packs with a non-default cell ordering.

The example on the right shows a BMSC with alerts. In this case, the satellite is not present. This shows up as an "ltc census" alert, and the second satellite shows LTCs that are configured but not discovered shown in "red outline".
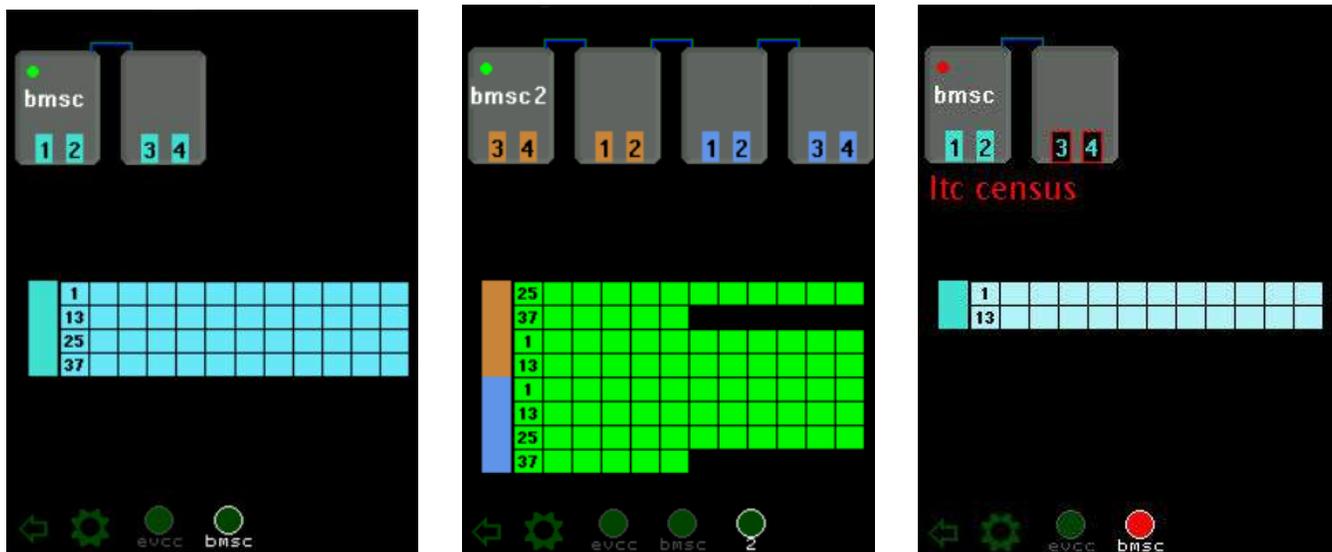

Configuration

The Configuration Screen can be reached by touching the "Configuration" Icon on the Toobar. There are three main areas of configuration: SOC Configuration, EVCC Configuration, and BMSC Configuration. This is navigated using the top line of the configuration display.

Parameter editing is performed by touch. By convention, parameter names and non-editable fields are in dim characters and editable fields are in bright characters. To edit, touch an editable field. Edits are performed using "up-" and "down-" "arrows". Tap to increment by 1; for numeric entry, hold the touch to go faster. To finish editing, touch anywhere on the screen to remove the "arrows". Edits happen right away and configuration (to the BMSCs, EVCC, or display) are immediately sent.

The example below shows the "maxv" EVCC parameter being edited.
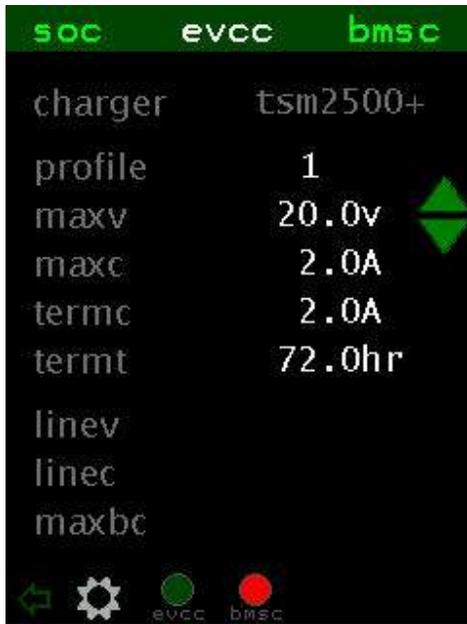
Some parameters, like **linev**, are optional. In order to create and edit linev, tap the linev parameter name and the default value of linev will appear where it may be edited normally. To delete an optional parameter, tap the parameter name again.

SOC Configuration

The SOC configuration sets the Current Sensor Type, the Pack Capacity and sets the PWM settings for the Analog Display.
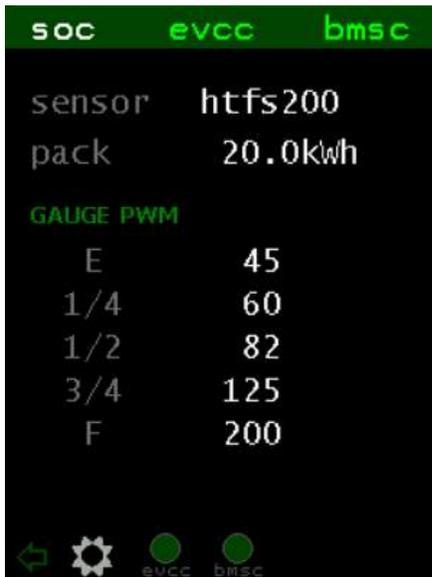

Navigation

Configuration

Toolbar

To set the Gauge PWM parameters, connect the analog meter. When editing these parameters, the SoC display is disabled so the user can immediately see the effect of each setting. Set each field one at a time and adjust the value from 0-255 to get the desired reading on the gauge. The SoC display will resume 30 seconds or so after editing.

Touch the "Back" Icon in the Toolbar to return to **Status**.

EVCC Configuration

The EVCC configuration screens sets the most important EVCC parameters.   For details on the purpose and operation of these parameters, see the EVCC documentation.
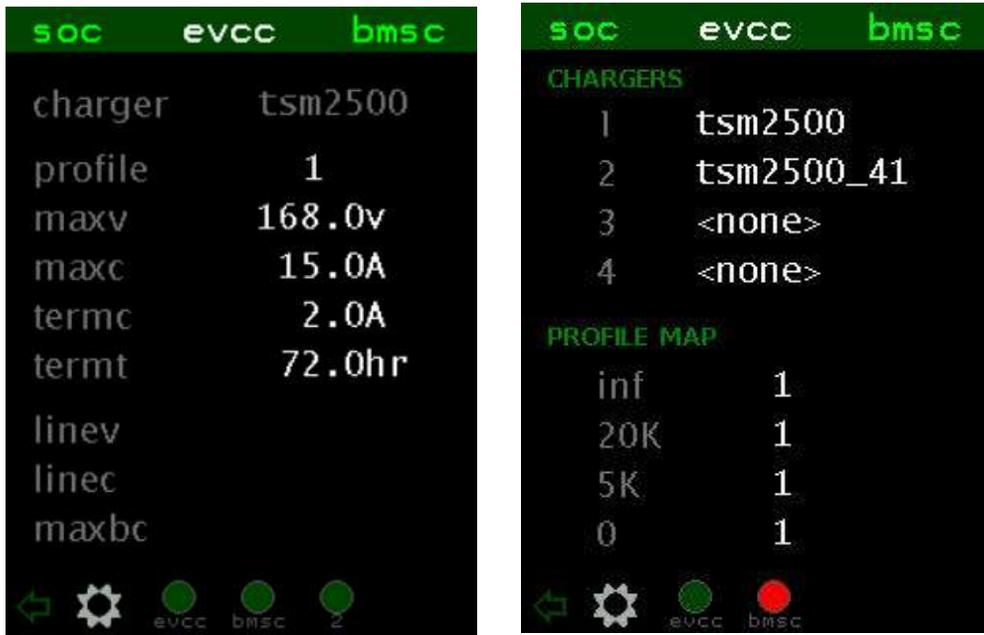

Note that in this screen, the charger type is dim and noneditable. In order to define multiple chargers and to set charge profiles touching the "charger" row, this will go to a second screen (shown on the right) where chargers and profiles may be edited.

Touch the "Back" Icon in the Toolbar to return to **Status**.

BMSC Configuration

The BMSC configuration screen sets BMS parameters. BMSC configuration is "broadcast" and setting the a parameter will set it in all connected BMSC(s). For details on the purpose and operation of these parameters, see the EVCC documentation.
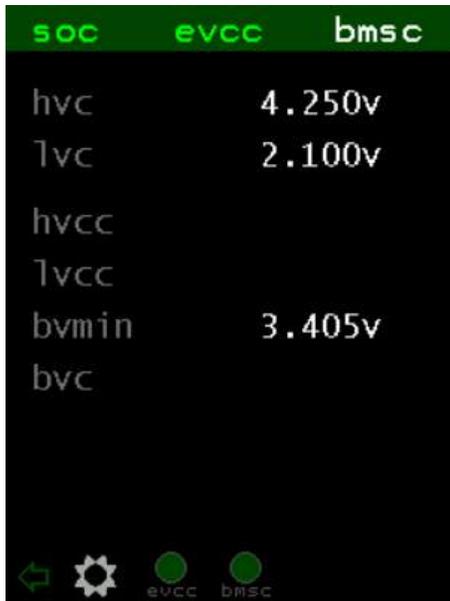
Touch the "Back" Icon in the Toolbar to return to **Status**.

Charging

Charge Progress

When charging, the Display reverts to a charge progress screen, that shows voltage, amps, and Watt Hours. This screen is purposely dim as it may be on for several hours while charging. Touching the charge progress screen will return to the Status Screen where all operations are available.
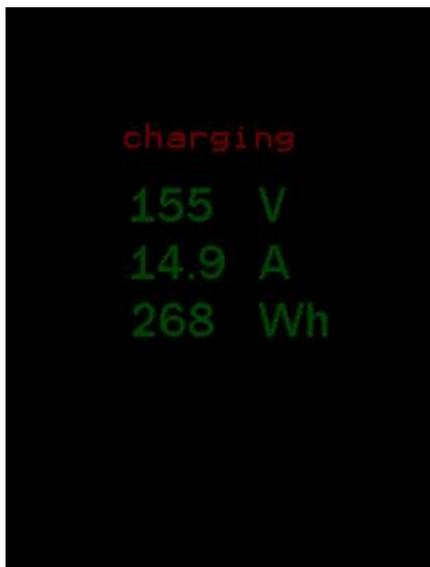
Charge History

Touching the EVCC Icon will show the charge history. Historical information the charge cycles is kept here. Navigation is with the arrows in the title bar.

Display Quick Start

BMSC Configuration

Step 1. Verify the firmware version(s) of each BMSC(s).

    The BMSC version should be 2.0.9 or greater.

Step 2. Configure BMS Ids if multiple BMSCs are being used

Step 3. Configure cell mapping if non-default cell mapping is used

Step 4. Execute the "lock" command the set the configuration.

EVCC Firmware (if the EVCC is being used)

Step 5. Verify the EVCC firmware version number by using the serial port.

    The EVCC version must be 2.4.18 or greater. If not, the firmware should be upgraded.

Installation

Step 6. Mount the Display.

Step 7. Connect power. Power up the Display to verify the Startup Screen and touch operation.

Step 8. Connect CANH and CANL to the BMS (and EVCC) CAN network. Install the CAN jumper on JP3 if a CAN termination is required at the Display. Power up the BMS, EVCC and Display.

    Verify that all devices, satellites, and cells can be detected.

Step 9. Connect the analog gauge if used. Program the Gauge PWM configuration points.

Step 10. Connect the Hall Sensor if used. Configure the .Sensor Type and Pack Capacity

System Testing

Step 11. Spin the motor to verify that the polarity of the Hall Sensor. When drawing current from the pack, the Ammeter should read a negative number. If not, the Hall sensor needs to be "turned around".

Step 12. If using the EVCC, connect the J1772 charge plug and verify that the Display detects the charge plug, that charging starts

Step 13. Verify that the Display can be used to configure EVCC and BMSC parameters

Done.

Warrantee and Support

The Thunderstruck return policy is available at http://www.thunderstruck-ev.com/return-policy.html.

The Display is warranted to be free from defects in components and workmanship under normal use and service for a period of 1 year.

When failing to perform as specified during the warranty period we will undertake to repair, or at our option, replace this product at no charge to its owner, provided the unit is returned undamaged and shipping prepaid, to Thunderstruck motors.

The product is intended for non-commercial use by hobbyists. The warranty does not apply to defects arising from miswiring, abuse or negligence, accidents, opening the enclosure, or reverse engineering. Dilithium Design, LLC shall not be responsible for any incidental or consequential damages.

Dilithium Design, LLC reserve the right to make changes or improvements in design or manufacturing without assuming any obligation to change or improve products previously manufactured and / or sold.

For general support and warrantee issues, contact the dealer.

For errors in this document, or comments about the product, contact
djmdilithium@gmail.com

Document History

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Rev 1.0.1	Oct 2018	Minor Updates