



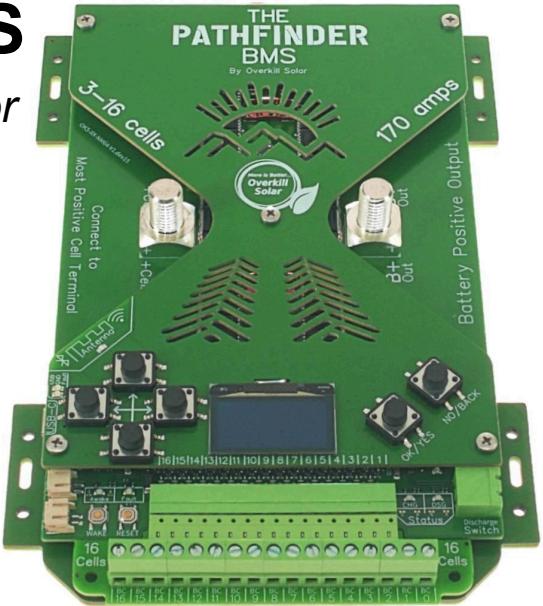
The Pathfinder BMS

Battery Management System for 3 to 16 cell Lithium Batteries

By Overkill Solar LLC

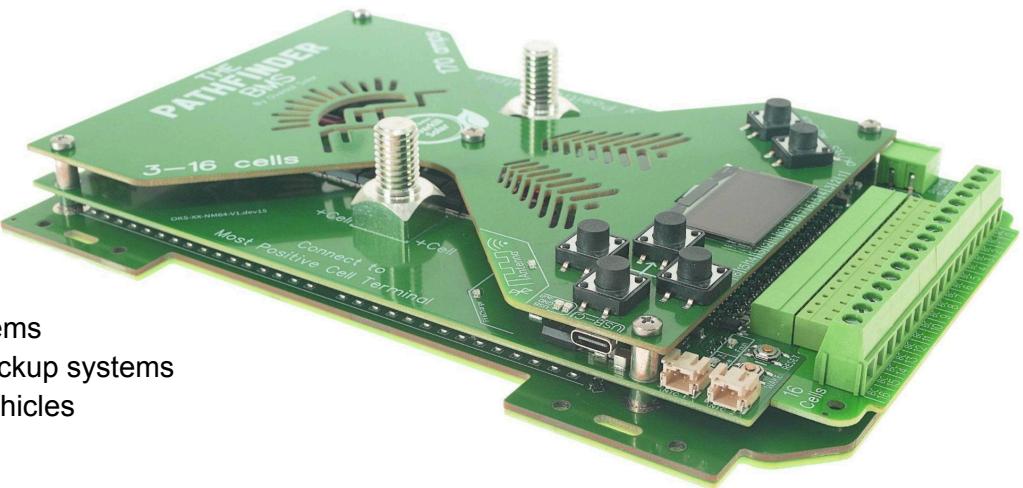
1. Features

- 3 to 16 cells, Min 7V up to Max 64V.
- 170 amps continuous duty current rating.
- Advanced State of Charge tracking.
- Built in OLED user interface.
- DIY focused design with positive side switching.
- Bluetooth, WIFI, & USB interface with free monitoring apps.



2. Applications

- DIY LiFePO4 batteries
- Tesla module conversions
- Recreational Vehicles
- Boats
- Off-Grid Solar power systems
- Grid-connected battery backup systems
- Golf Carts, light electric vehicles



3. Description

The Pathfinder BMS by Overkill Solar is a Battery Management System designed for DIY LiFePO4, NMC, and LTO batteries.

It has been designed and engineered entirely by Overkill Solar, drawing on our years of experience supporting the various JBD BMSs which are now discontinued.

Engineering, Assembly, Testing, and Distribution are done in Naples, FL. Programming is mostly done in Canada, and the components are manufactured in a variety of cheaper countries.

It can operate with battery voltage up to 64V and current up to 170 amps at 100% duty cycle. It features an advanced user interface with a built-in OLED display, user input buttons, Bluetooth and WIFI connectivity, OTA & UF2 firmware updates, MQTT for Home Assistant, and status LEDs.

The cell count is field configurable from 3 to 16 cells for LiFePO4 or LTO, and 3 to 12 cells for NMC.

The Solid state high current switch is on the positive side of the battery for simplified installation and compatibility, and includes Pre-Charge and Pre-Discharge circuits.

The BMS's basic functions are controlled by the Texas Instruments BQ76952 BMS chip, paired with the BQ34Z100 Fuel Gauge chip for advanced State of Charge tracking.

The ESP32-S3 host controller configures and monitors the BMS chips, and provides an advanced user interface.

The BMS is constructed with an efficient and serviceable open frame design. The typical configuration includes:

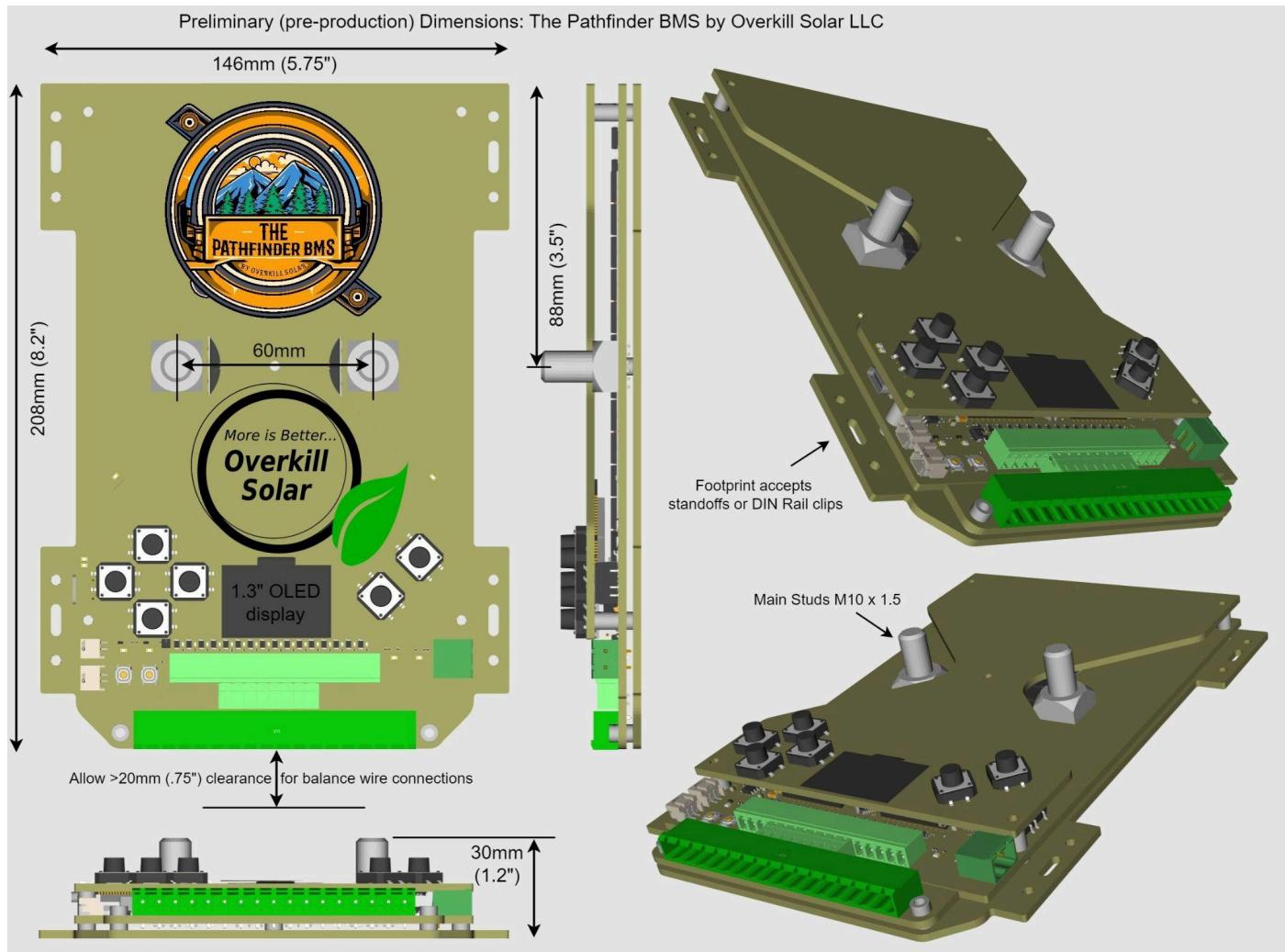
- **Base plate** with a 1 amp passive balancer and several mounting options for surface mounting or DIN rail
- **Main board** with Texas Instruments' BQ76952 BMS chip and BQ34Z100 Fuel Gauge chip, MOSFET solid state switch, Solid brass Main terminals, Pre-Charge and Pre-Discharge circuits, and integrated copper heat sink.
- **User Interface board** with OLED display, input buttons, and ESP32 microcontroller with Bluetooth and WIFI
- **Balance wire terminal board** with a variety of preconfigured options.

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5. Layout and Dimensions



6. Ratings

Parameter	Value
Max current at 22c ambient, 100% duty cycle	170 amps
Max current at 30c ambient, 100% duty cycle	TBD
Max current at 35c ambient, 100% duty cycle	TBD
Max current at 40c ambient, 100% duty cycle	TBD
Max current surge, 10 seconds	400 amps
Max short circuit detection setpoint	1000 amps
Max main board operating temperature	80c
Min main board operating temperature	-30c
Passive balancer high temperature shutdown	100c
Max system voltage	64v
Min system voltage	7v
Max cell count	16 cells
Min cell count	3 cells
Max Battery Capacity	640 amp-hours
Current measurement resolution	20mA
Voltage measurement resolution	1mV

7. Compliance info

ROHS:

Not ROHS compliant. The BMS assembly contains leaded solder. To avoid unnecessary exposure to lead, do not eat the BMS. May cause cancer in California. Do not dispose of it in a landfill in Europe.

FCC part 15:

The User Interface board contains an ESP32-S3-WROOM-1U wireless controller.

FCC IDENTIFIER: 2AC7Z-ESPS3WROOM1U

This component has an integrated antenna and is tested and certified for FCC part 15 compliance.

UL listing:

This product has not been evaluated by a Nationally Recognized Testing Laboratory, ie. UL. It is up to you to determine whether they are fit for your particular project, and what regulations apply to that use.

Data Privacy:

Neither the Overkill Solar mobile app nor the BMS itself gathers any personal information. They do not transmit anything via the internet to Overkill Solar or anyone else, except for operational data via MQTT, if configured by the user.

8. Cell Protections

The pathfinder BMS monitors the health of the connected battery cells and takes action to protect them by disconnecting from the rest of your electrical system. It's important to understand that the BMS can not control charge or discharge rates or voltage, it can only disconnect the cells to prevent damage under abnormal conditions.

All of the protection parameters are initialized during startup when selecting the cell count and chemistry, and all parameters can be customized via the mobile app or the on screen display.

Most of the protection parameters have a setpoint, trigger delay and reset delay.

Overcurrent protections:

- Overcurrent in discharge level 1 (multi-second delay)
- Overcurrent in discharge level 2 (millisecond delay)
- Overcurrent in discharge level 3 (microsecond delay)
- Overcurrent in charge level 1 (multi-second delay)

Voltage Protections:

- Cell Over Voltage
- Cell Under Voltage

Temperature Protections:

- Charge Over Temp
- Charge Under Temp
- Discharge Over Temp
- Discharge Under Temp

Permanent Fail Protections:

These parameters do not automatically reset. Once triggered, the BMS must be rebooted.

- Charge Overcurrent PF
- Discharge Overcurrent PF
- Cell Over Voltage PF
- Cell Under Voltage PF

9. Cell Balancing

The Pathfinder bms has a low current balancer built into the main board which controls an optional passive or active balancer built into the base plate.

Balancing parameters can be customized via the mobile app or the on screen display.

Standard Passive Balancer

The main board has a low current passive balancer which operates at about 50 millamps.

When any cell voltage rises above the *balancer start voltage*, and is greater than *delta to balance* relative to the lowest cell voltage, the balancer connects a resistive load to the high cell in order to bleed off excess energy as waste heat. This circuit also activates the high current balancer board, if equipped.

High Current Passive Balancer

The high current passive balancer board operates at about 1 amp. Waste heat is absorbed by the mounting base, and it includes over temperature shutoff circuitry. The BMS has a “*max cells to balance*” parameter, which sets the most cells to balance simultaneously. If the balancer gets too hot, consider reducing the number of cells to balance. The default is 4.

High Current Active Balancer

A high current active balancer option is planned but is not yet available.

10. Cell Count Setup & Balance wire connections

Possible configurations:

LiFePO4: 3 to 16 cells

LTO: 4 to 16 cells

NMC: 3 to 12 cells

The Pathfinder BMS can be configured in the field for any cell count from 3-16, as long as the system voltage is in range. More than 12 cells of Lithium-ion would exceed the 64v maximum.

Automatic cell count detection

The BMS auto-detects the cell count and type at startup. If any of the balance wire connections are missing or out of order, the cell count detection will fail. In that case, the BMS can still display the cell voltage measurements on the screen for troubleshooting. Once the faults are corrected, reset the BMS to retry automatic cell count detection.

The balance wire terminal boards simplify the configuration for cell counts less than 16. Boards with screw terminals accept up to 14ga wire. 20ga or 18ga wire is recommended. Tesla kits feature a pre-wired plug-and-play connector.

Warning: connecting balance wires out of order can damage the cell voltage inputs.

Before plugging in the balance wire connector, measure the voltage between each adjacent terminal to be sure that none of them exceed a single cell voltage. A higher voltage between 2 adjacent terminals indicates connections are out of order.

Balance Terminal Boards

Each Pathfinder BMS comes with 1 terminal board for the balance wire connections. The 16s board is universal and can be used for any battery from 3-16 cells.

For simplified wiring, a variety of other terminal boards are available. These boards make all of the required jumper connections and only expose the terminals that are needed for the indicated battery setup.

The prewired Tesla boards combine with 1 or 2 of our Tesla module retrofit boards for 24 or 48v Tesla battery assemblies.

A: 16s with screw terminals

B: 12s with screw terminals

C: 8s with screw terminals

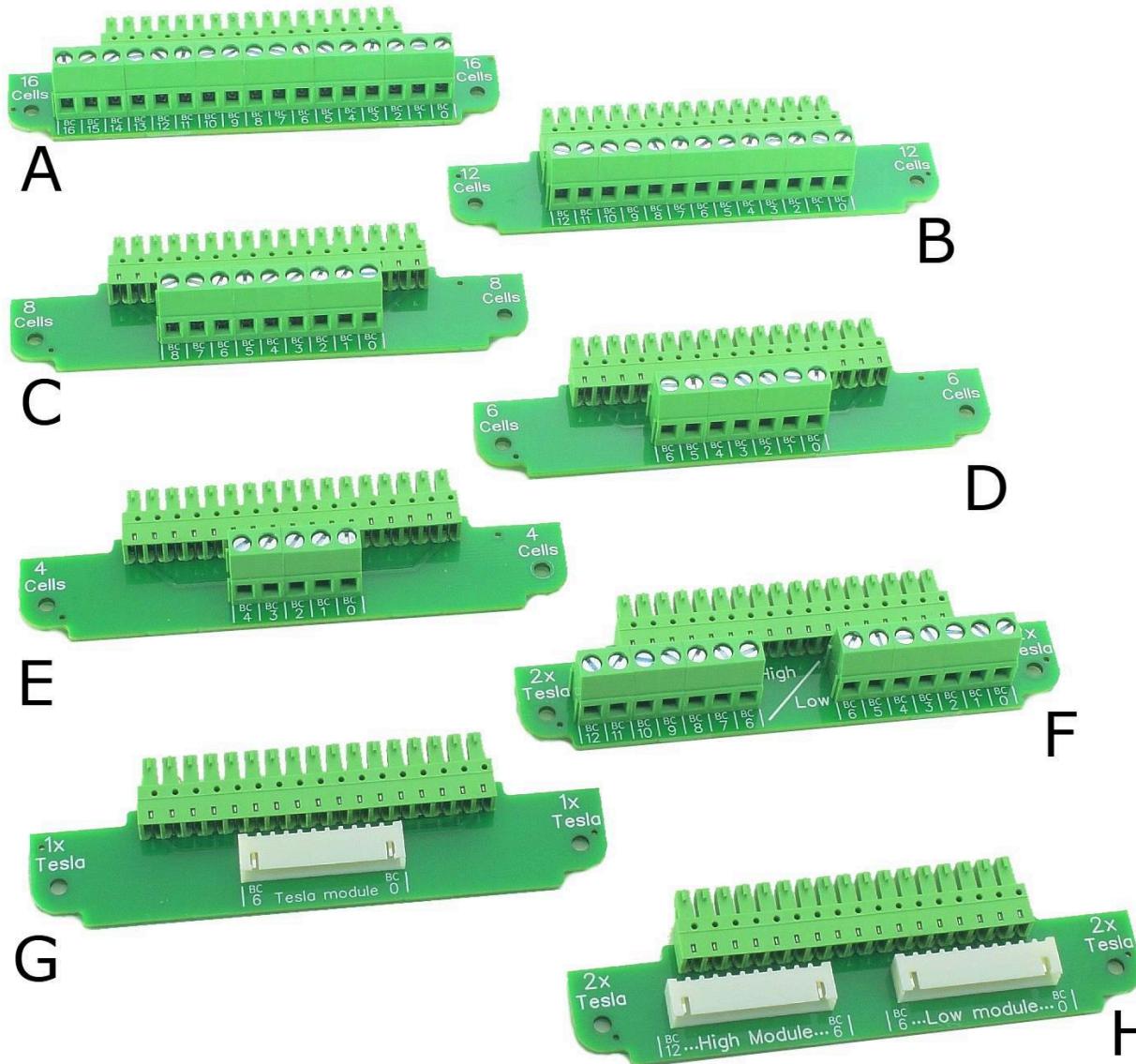
D: 6s with screw terminals

E: 4s with screw terminals

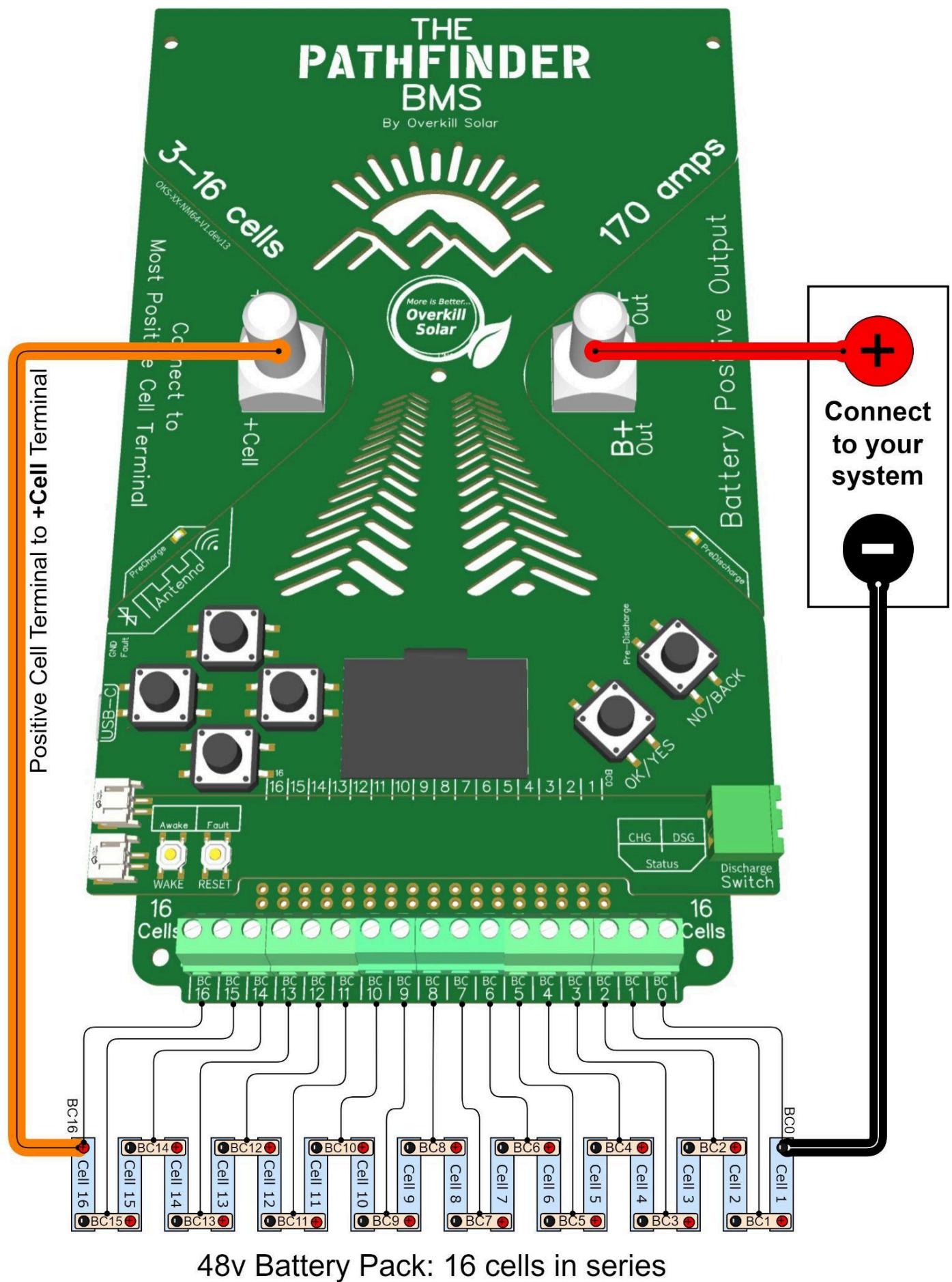
F: 12s Tesla modules with screw terminals (2 series modules)

G: 6s Tesla module, prewired

H: 12s Tesla modules, prewired (2 series modules)



16 Cell Connection drawing



This drawing shows the general layout of a 16 cell battery. Note that the most positive terminal (BC16) on the group of cells is connected only to BC16 and the “+Cell” terminal of the BMS.

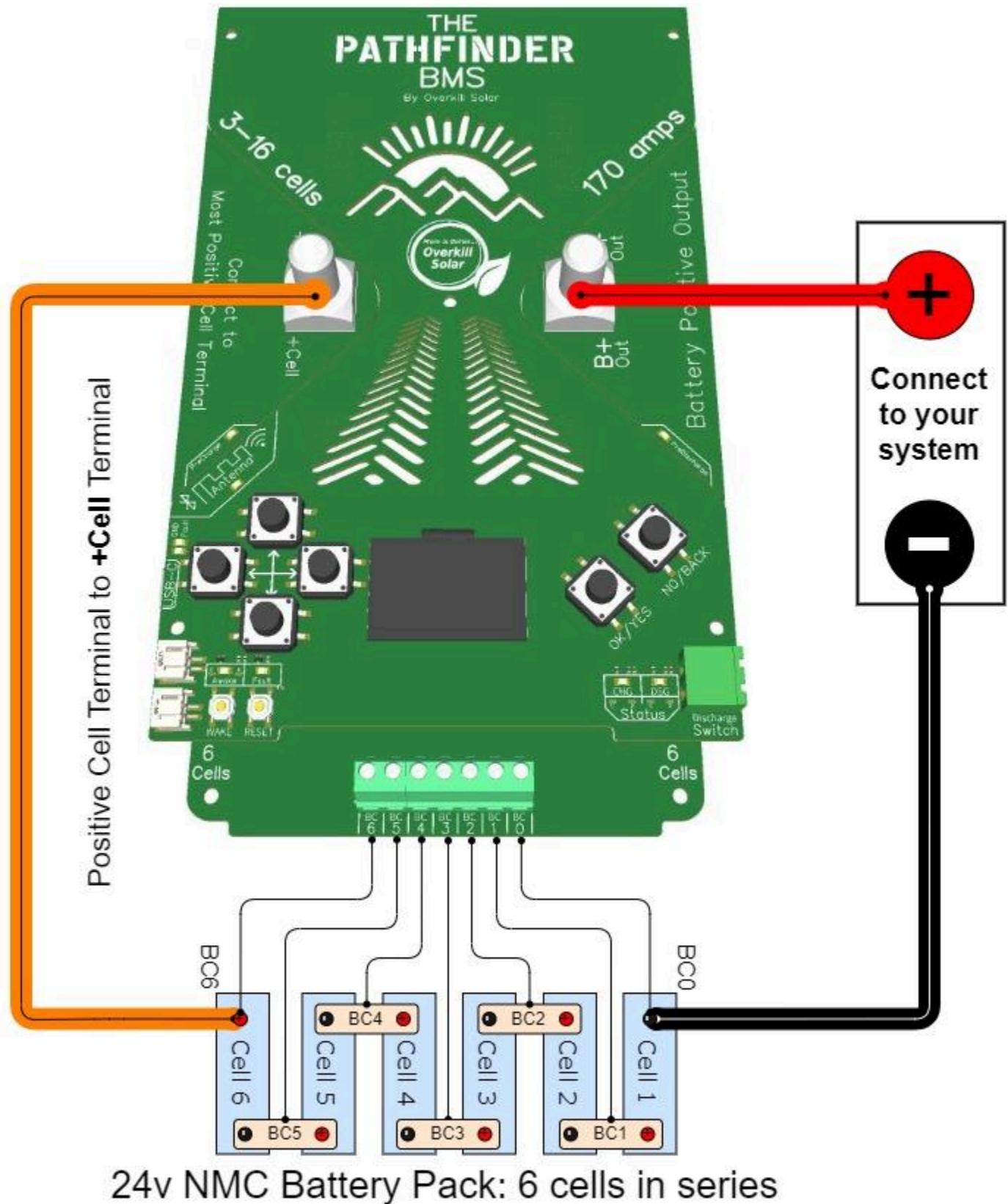
The “B+” terminal connects to the positive side of your electrical system. Do not connect anything else to the cells. Doing so would bypass the BMS protection.

The most negative terminal on the group of cells is connected to the negative (or ground) side of your electrical system. It is OK to connect this wire to a chassis ground, if applicable.

All 17 balance wires (AKA voltage sensing wires) must be connected as shown for a 16 cell battery. See note 1 for tips on connecting balance wires.

The Pathfinder BMS must switch the positive side of the system. If you are retrofitting a battery that has a BMS on the negative side, you must re-wire the battery for positive side switching.

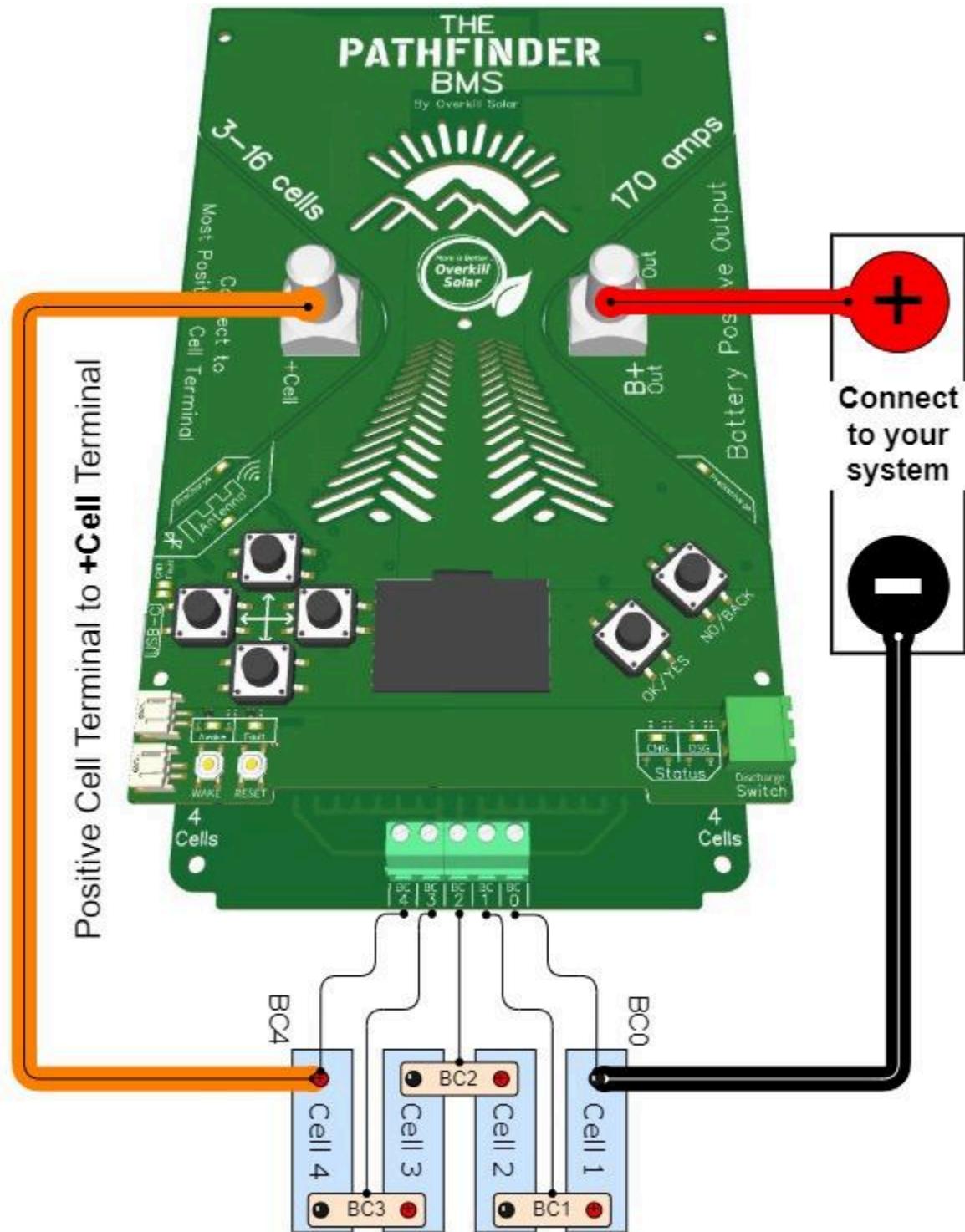
6 cell connection drawing



This drawing shows a 6 cell terminal board used to connect a 6 cell pack (such as a Tesla model S module).

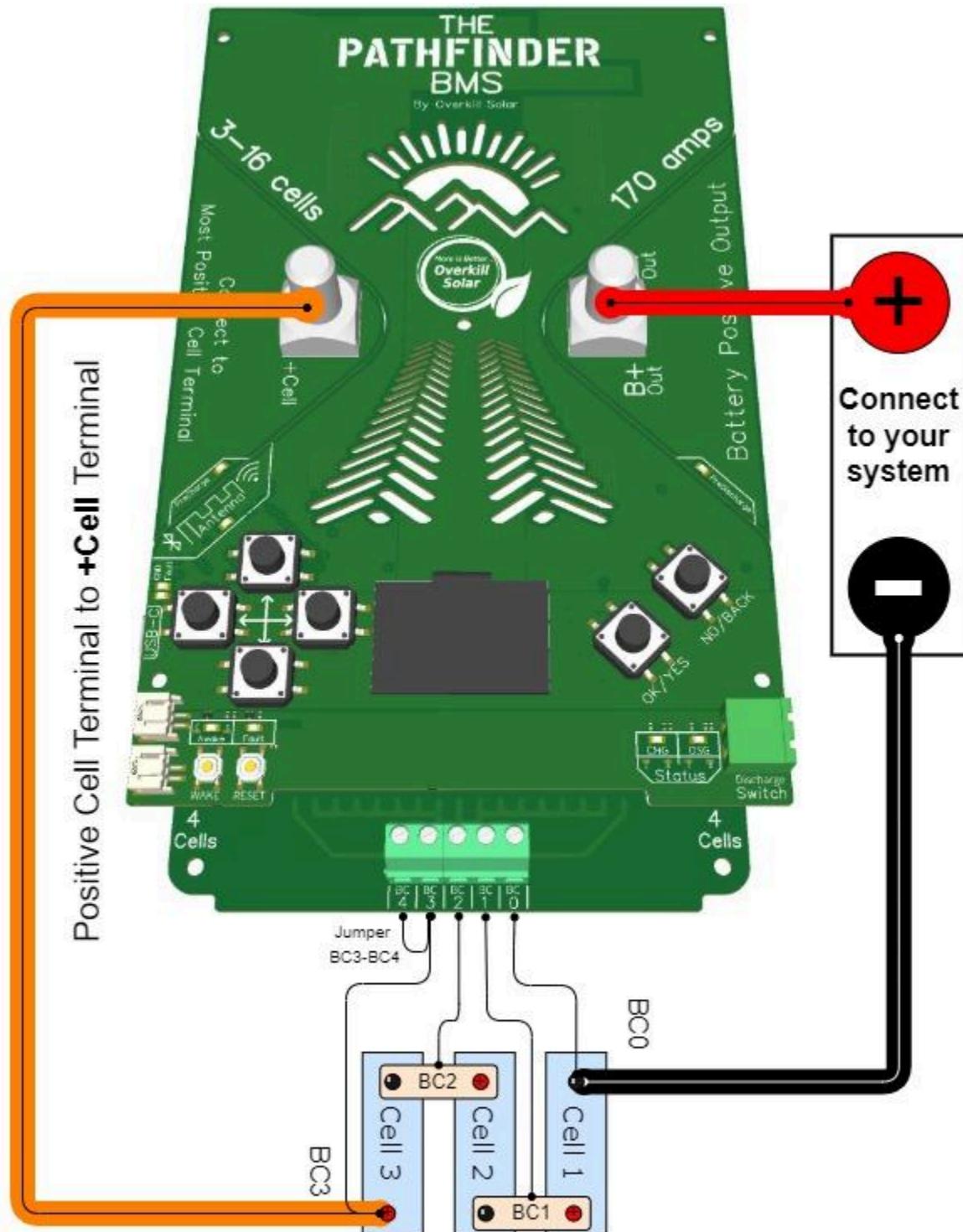
Note that the terminal board labels the balance connections BC0-BC6. All appropriate jumper connections are made by the terminal board, leaving only the connections needed for the 6 cell battery.

4 cell Connection Diagram



This diagram shows 4 LiFePO4 cells connected for a 12v battery, using a 4 cell terminal board.

3 Cell Connection Diagram



This drawing shows 3 cells connected using a 4 cell terminal board. BC3 is jumpered to BC4.

Arbitrary Configuration

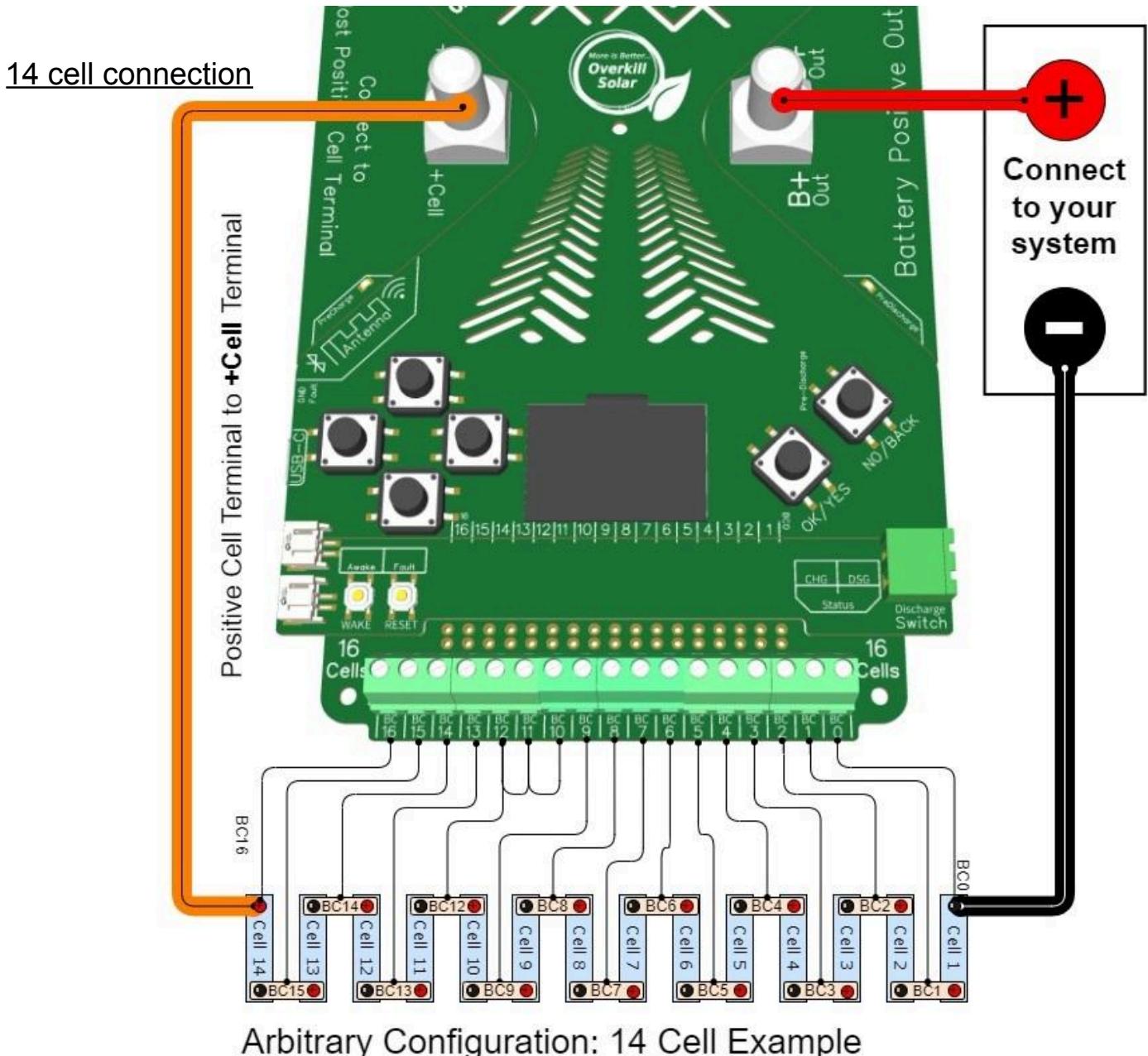
With a 16s terminal board, the Pathfinder BMS can be configured for any cell count from 3 to 16 cells.

BC0 must be connected to the most negative cell terminal, and BC16 must be connected to the most positive cell terminal. The minimum number of cells is 3. Cell 1 must be connected to BC0-BC1, cell 2 must be connected to BC1-BC2, and the top cell must be connected to BC15-BC16. All other unused cell connections must be shorted together. See the example drawings below.

In other words, **Cells 1,2, and 16 must be connected** at a minimum, and all open balance wire connections will be jumpered to the active cell connections on both sides. Every balance wire connection must be connected to a cell terminal, **there can not be any open or floating cell inputs**.

All other cells can be connected to any of the inputs, as long as they are in ascending order.

For example, for a 14 cell pack, the 2 skipped cells can be in any position excluding 1,2, or 16.



In this 14 cell drawing, BC10, BC11, and BC12 are jumpered together for the 2 missing cells.

11. Main Terminal Studs

Specifications:

Main lug thread size: M10 x 1.5

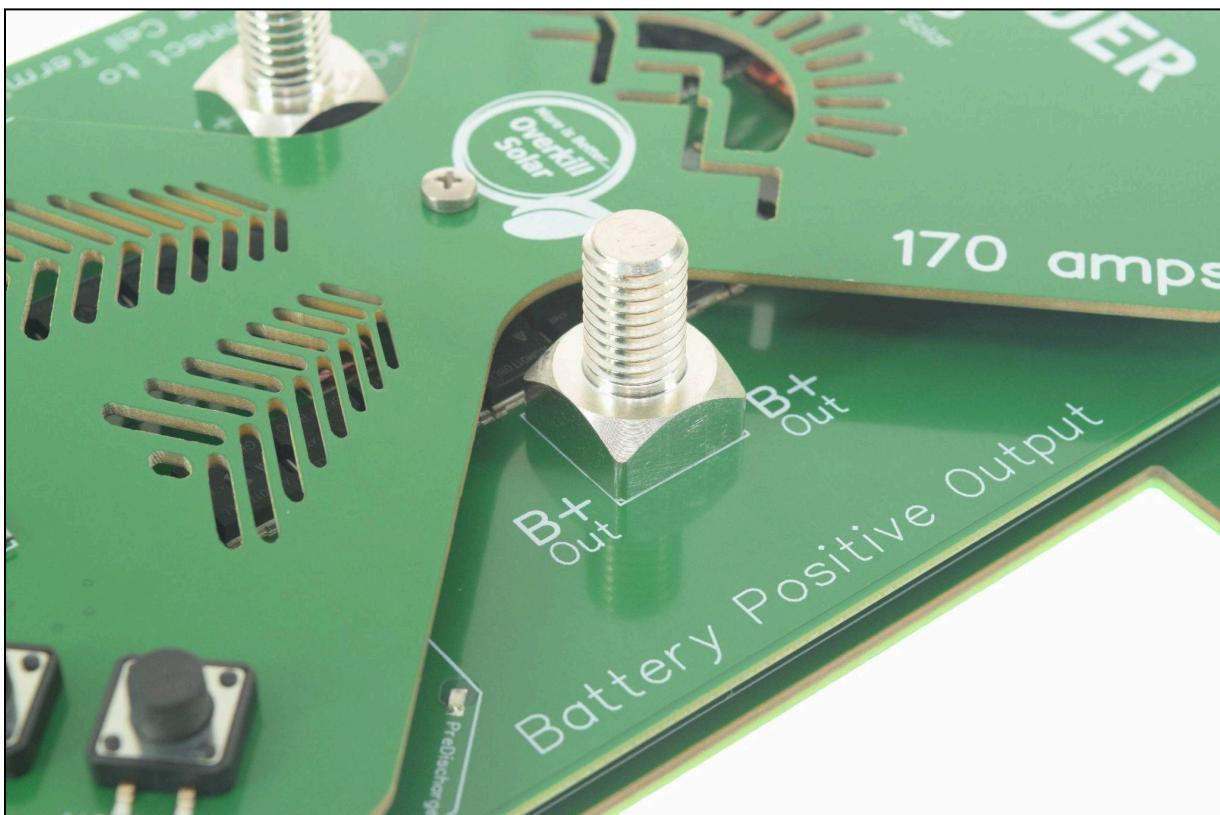
Main lug threaded length: 15mm

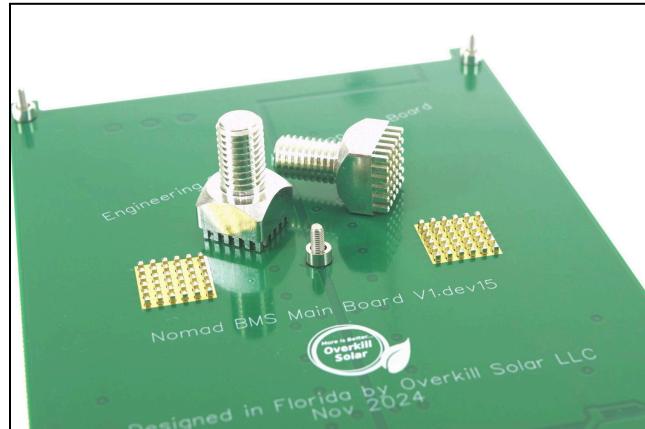
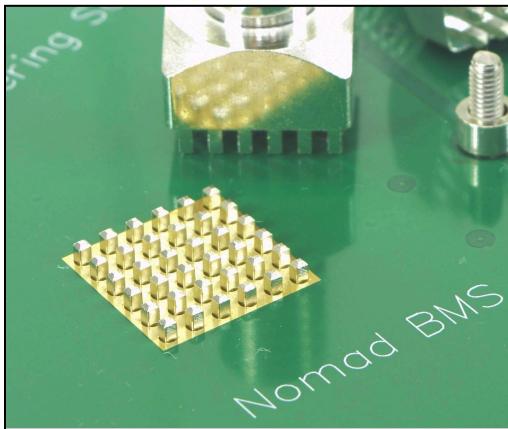
Main lug Material: Tin plated Brass

Tightening torque: 150in-lb (17Nm) with backup wrench

The main terminals use solderless press-fit technology. Pressing the terminals into the main board causes the terminal pins to permanently cold-weld to the copper board plating. The force to remove these terminals far exceeds the force needed to destroy the board substrate-they will never come out.

In testing, we found that the resistance of this connection is much lower than a soldered terminal.





The studs are milled from solid brass and tin plated. The included nuts and washers are 304 stainless steel.

Use a thin 17mm open end wrench to hold the bottom of the main terminals when tightening the nuts. Ensure that the wrench does not get pinched when the nut is tightened! This can crack the circuit board. **The wrench needs to be less than 8mm thick.**

Do not use an impact wrench or impact driver to tighten the main terminals, as this puts unacceptable vibration stress on the main circuit board.

These terminals are available in other shapes and sizes, such as threaded holes instead of studs. Contact Overkill Solar if the standard threaded stud is unacceptable for your application.

12. SOC Measurement and Learning Cycle

The Pathfinder BMS has a dedicated chip whose only job is to track the battery's state of charge. (BQ34Z100 by Texas Instruments)

This chip has a detailed setup and calibration procedure. We have performed this setup on a sample of LiFePO₄ and NMC batteries, and the resulting config files are saved in the firmware.

During the first boot up or after a full reset, one of the stored configurations will be loaded, based on the detected chemistry type. The user can choose a different chemistry type if it was not correctly detected. (The voltage range of LiFePO₄ and NMC overlaps significantly)

After a config file has been loaded, the BQ34Z100 is set up for the chemistry type but not the specific battery pack. The design capacity needs to be set to match the size of the cells.

Once the capacity parameters are set, the chip will be waiting for a learning cycle to complete. Until the learning cycle is finished, the SOC confidence level may be low, and it will increase as the chip gathers data.

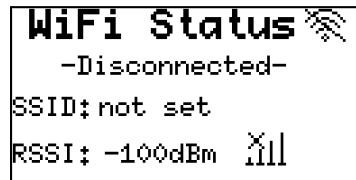
This chip also calculates Time to empty/full based on the average current, and the state of health (SOH), which is defined as the ratio of design capacity to measured capacity.

SOC: 100 %
SOC Confidence: 100 %
10.00 55.00 55.00

SOH: 100 %
(State of Health)

13. Wifi

The Pathfinder can connect to a 2.4Ghz WiFi network. Credentials are entered via the built in screen. The wifi connection is used to check Overkill Solar's github for OTA updates (if enabled), and for sending MQTT messages to HomeAssistant (if enabled).



14. Bluetooth (BLE)

The free Overkill Solar mobile app can monitor all BMS data and change all settings except for WiFi and MQTT setup. The mobile device must be in range of the antenna to use bluetooth.

The BLE status screen shows the MAC address of the connected device (client) and the signal strength.



15. Password

A password is required to connect using bluetooth. When a new bluetooth device tries to connect, the BMS will show a confirmation message, and the user must press a button to allow the connection. This ensures that only someone with physical access to the BMS hardware can connect to it wirelessly with the mobile app.

Once the same password is set in the BMS and mobile device, it will be remembered on the next connection.

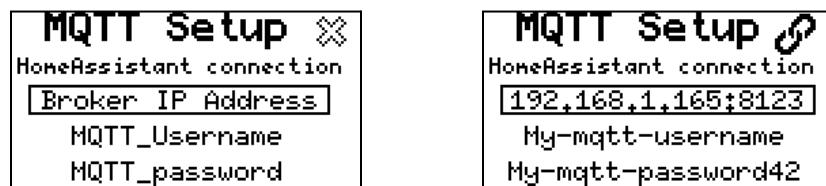
The password must be reentered by default when writing any parameters. This prevents accidental changes when unauthorized people have access to the mobile device, for example if children are playing with a tablet used to monitor the BMS.

16. MQTT (HomeAssistant)

MQTT is a messaging format used to send data to HomeAssistant or other custom applications. To use MQTT, enter your MQTT broker credentials via the built in screen. We have tested it using Mosquito Broker in HomeAssistant.

When the BMS successfully connects to your MQTT broker, it will publish a discovery message that allows HomeAssistant to automatically discover all of the available BMS data. The HomeAssistant app can then be used for monitoring multiple BMSs remotely over the internet.

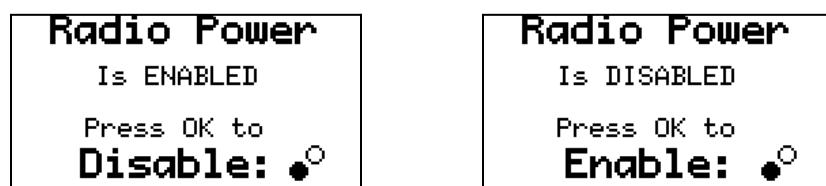
In the future we plan to use MQTT for remote monitoring directly to the Overkill Solar Mobile app via the internet.



17. Radio Power

All wireless radio power can be disabled via the built in screen. Once Radio power is turned off, WiFi, Bluetooth, OTA updates, and MQTT will be unavailable, and the BMS will not do any wireless communication. It must be reenabled via the built in screen to use any of the wireless functions.

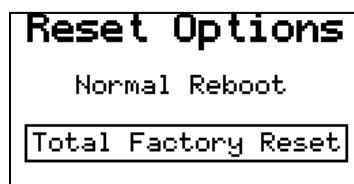
A normal reset will not override this setting, but a full factory reset will reenable radio power.



18. Reset Options

The BMS can be reset 3 ways.

- **Physical reset button:** Press to immediately reboot the BMS and user interface. Settings will be reloaded. This button can also be used to enter “storage mode” (deep sleep)
- **Normal Reboot** via the built in screen: Reboot the BMS and user interface. Settings will be saved and reloaded.
- **Total Factory Reset** via the built in screen: All settings, configs, passwords, and calibrations will be erased and reloaded from factory defaults.



19. Firmware Updates

OTA: Over-the-air

Over-the-air firmware updates can be enabled if a WIFI connection has been set up.

The BMS checks a folder on Overkill Solar's Github to find new updates. If a new update is found, it will either install the update or prompt you via the OLED screen, depending on the settings. It will load only stable updates by default, but it can be configured to load Beta updates if you want to help test new features.

During the update process the BMS will reboot, and the outputs will turn off for a short time. Before allowing an update to proceed, make sure your system is in a safe state for this battery to be switched off.

If you have updates set to automatically install, it is possible for multiple Pathfinder BMSs to update at the same time. They are not intentionally synchronized, but it could happen.

OTA can only load the latest update, so if you want to roll back an update, use the UF2 update method.



UF2: USB Flashing Format

UF2 (USB Flashing Format) enables the BMS to appear as a mass storage device when connected to a PC via USB-C.

To update the BMS, activate UF2 mode via the button interface, then drag and drop a **.uf2** update file into the drive. If the file is compatible, the BMS will update itself automatically—no WiFi or internet connection required.

Check for new UF2 updates on the Overkill Solar website. All firmware updates will be archived and available to download. Beta and Stable updates will be available in separate folders.

Do not copy other file types into the BMS while in UF2 mode. It is not a general purpose flash drive or storage device.



20. Ambient Temperature De-rating

The BMS's current rating is primarily based on the temperature of the MOSFET high current switch. For a short time, the MOSFET switch array can handle many times the base current rating without damage, up to the maximum short circuit detection setpoint. This allows the BMS to handle large startup/inrush currents.

The BMS main board has an integrated copper heat sink with a temperature sensor that will protect the BMS from overtemperature damage. The 100% duty cycle current rating is defined by the continuous current that will cause a temperature rise to 50c starting from 22c ambient temperature in still air. (Standard room temperature)

Higher ambient temperatures or restricted airflow will result in higher temperatures on the main board, and lower ambient temperatures or increased airflow will result in lower temperature on the main board.

The following charts indicate the current rating in different ambient conditions:

TODO: add derating charts

21. Pre-Charge/Pre-Discharge function

The Pathfinder BMS has a pre-charge and pre-discharge circuit in addition to the main solid state switch. The purpose of these circuits is to eliminate problems caused by inrush currents.

The pre-discharge circuit will engage when the main discharge FETs have been commanded on, if the system voltage is low. It connects the battery to the output via a low value resistor, and monitors the system voltage until it rises to a sufficient level to prevent a damaging inrush current, at which point the main FET array will switch on.

The pre-charge circuit is used when the battery is in low-voltage shutdown and a charging source is connected to the system. It connects the battery to the output via a low value resistor, and waits for the battery voltage to rise to a safe level before allowing the main FET array to switch on. This prevents large charging currents from damaging cells that are deeply discharged.

22. Discharge Switch

The Pathfinder BMS has a 2 pin connector for a remote discharge shutoff switch. This circuit can optionally be connected to a dry contact switch or relay and used to switch off the battery output. (“Dry Contact” means a simple isolated switch or relay, not connected to any external voltage sources)

When this circuit is disconnected or open, the BMS will operate normally. When the circuit is connected or closed, the BMS will disable the discharge FETs, blocking all discharge current. Charge current will still be allowed. This function can not be disabled by the controls or apps. Simply unplug it to disable the discharge switch function.

23. Functional Modes

Active mode

Full power operation: When the battery is at high SOC or actively charging or discharging. Screen is on, Bluetooth/WIFI active, FETs active.

Idle Mode

Power saving operation: When the battery is at low SOC, no charge current, low discharge current. Screen off, Bluetooth/Wifi status depends on settings. Reduced update rates are available. FETs are active. You may have to press a button to wake the user interface from idle mode at low SOC.

Storage Mode

Storage mode is the lowest power mode and can be used for shipping and long term storage. In this mode, the BMS consumes 1 μ A on average. (0.000,001 amps)

Alternatively, the balance wire terminal board can be unplugged to reduce power consumption to zero, and prevent the battery from waking automatically.

When the BMS is connected to a battery, with nothing connected to the B+ output, it can be put into storage mode. Press and hold the “Reset” button on the main board for more than 1 second to put the BMS to sleep.

The BMS will periodically check for voltage on the B+ terminal, which will wake it up. Pressing the “Wake” button will also wake the BMS. If the B+ terminal has any voltage from connected equipment, it is not possible to enter storage mode.

Recovery mode

If the battery has discharged far enough to trigger a low voltage cutoff, it is difficult to recharge the battery using “smart” chargers or solar charge controllers.

This is because they must detect the presence of the battery before they will begin charging, but the BMS has disconnected to protect the cells. The BMS prevents all discharging current but allows charging current. In this state, the system voltage may be zero, which stops smart chargers from beginning to charge.

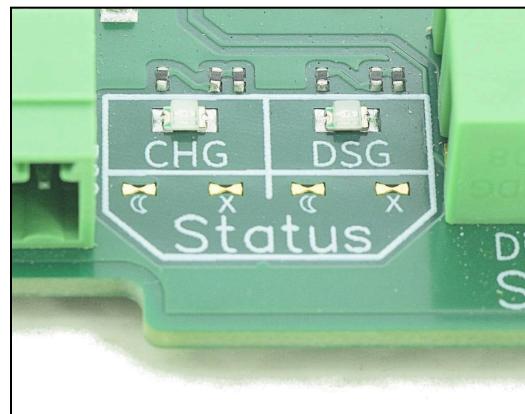
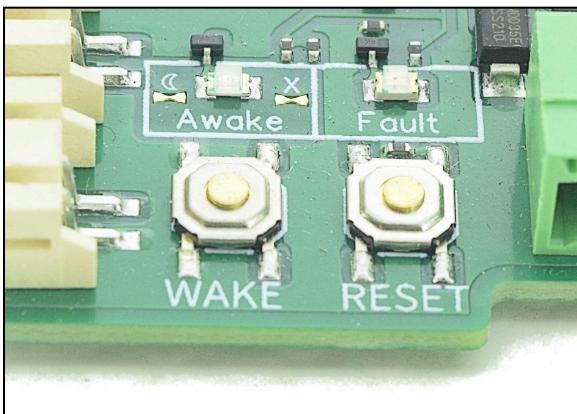
The pathfinder BMS has a recovery mode which will enable the pre-discharge circuit at a programmable interval. This “bumps” the voltage in the rest of the system so that the chargers will start up. If the system still has loads connected, the voltage may not rise enough for the chargers to start charging. In this situation, manual intervention will be needed, such as disconnecting all loads, and/or “jump starting” the system with another battery or with a “dumb” charging source like a shore power converter or a raw solar panel.

24. LED indicators

The pathfinder has several LED indicators, including antenna activity, Awake, Fault, DSG & CHG FET status, and balancer status.

Because they are always on, the Awake and DSG & CHG FET status LEDs are each provided with cuttable traces to reduce the brightness or disable them entirely. In the photos below, the Moon icon indicates the brightness trace- cutting this trace will reduce the LED brightness by about 90%. The X indicates the cut trace to disable the LED. This can be reversed by soldering the cut trace pad, or possibly by covering the cut with conductive ink.

Each green LED with a cut trace consumes $350\mu\text{A}$ (microamp) at normal brightness, and with the brightness trace cut each consumes only $60\mu\text{A}$.



25. Cell Temperature Probes

The Pathfinder has 2 external cell temperature probes.

The standard probes are 50cm long and are replaceable.

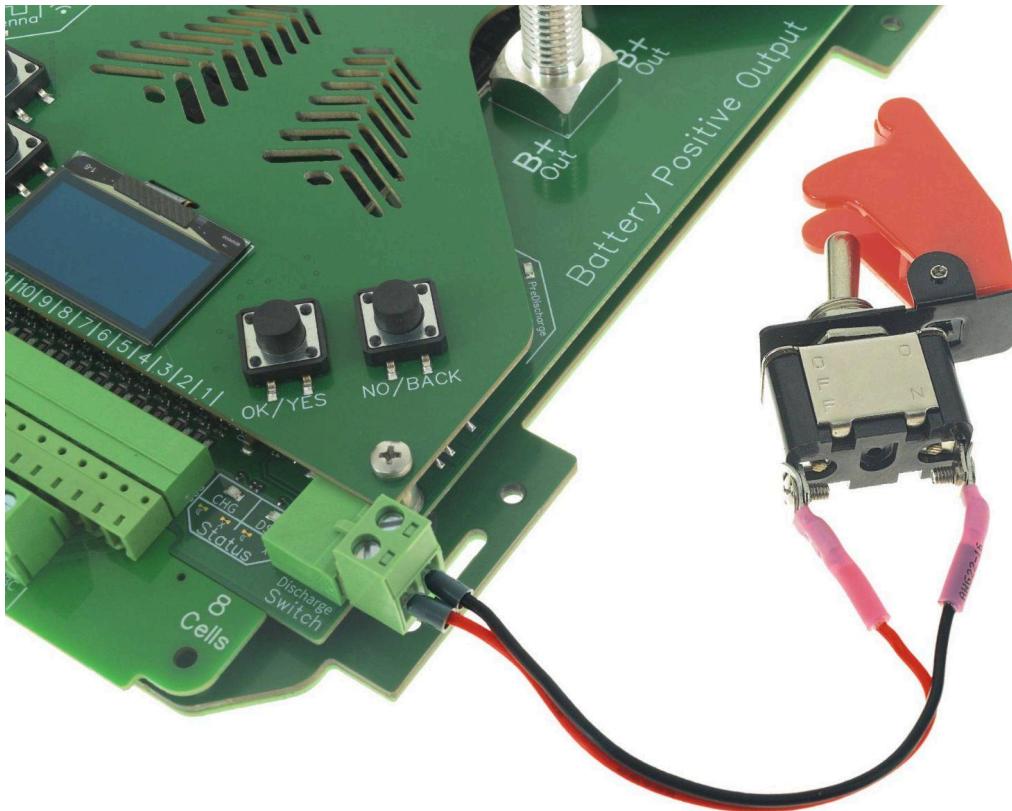
Any $10\text{k}\Omega$ 3950K NTC with a PH2.0 connector can be used.



26. Discharge Switch

The Pathfinder has a 2 pin connection for an external discharge switch. This functions like a remote battery shutoff. The circuit is normally open ON. When the circuit is closed, the discharge FETs will turn OFF, preventing the battery from discharging. The BMS will still allow the battery to charge.

This input should be connected to a dry contact- either a switch or relay. "dry contact" means that it is not connected to any other power sources or circuitry. It must remain isolated from other parts of the electrical system. The connector can be simply unplugged to disable this function.



Discharge Switch dry contact example.

27. Manual Output Controls

The main outputs (FETs) can be manually switched off in either direction (charge or discharge) via controls on the mobile app or the built in screen.

This screen Allows the user to command the FETs off, and shows the actual status of the FETS and the discharge switch input.

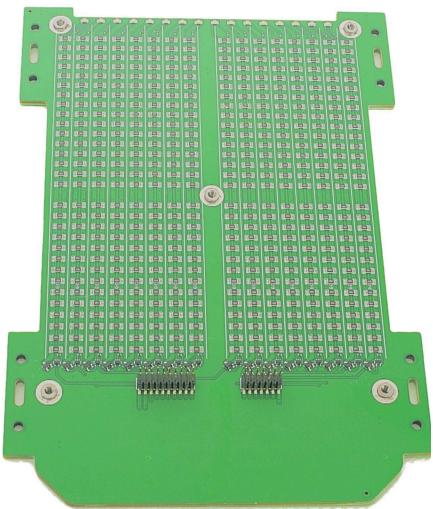
The DSG and CHG Status LEDs also show The actual state of the output FETs.

MOSFET CONTROL		
Set:	Command	Status
Charge:	ON <input type="checkbox"/>	ON
Dischg:	OFF <input type="checkbox"/>	OFF
DSG SW:	ON (open)	

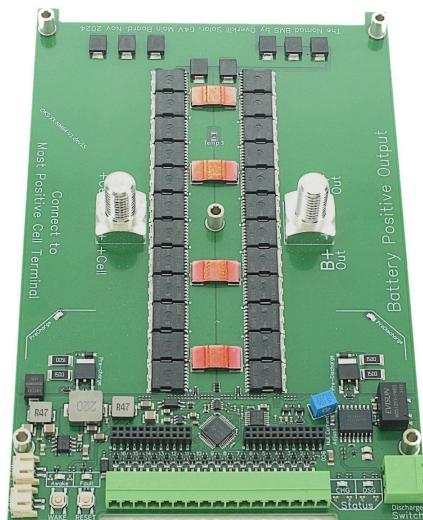
28. Interchangeable Parts

A Pathfinder BMS is an assembly of 4 printed circuit boards that are normally packaged and sold together as an assembly. Each component board has a descriptive part number and version number. All component boards with the same major version number (V1.x) are compatible and interchangeable.

These boards will be available as spare parts, and the assembly is user serviceable to the extent of swapping boards. Always unplug the balance wire assembly before separating the other boards. See the Pathfinder user manual for more info.



Base with Balancer

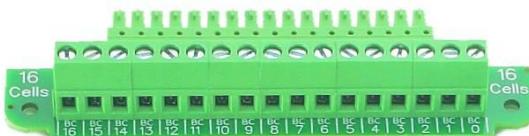


Main Board



User Interface Board

Balance connection board (multiple options)



29. Notes & FAQ

Note 1: Which stud to use? Where is BCx?

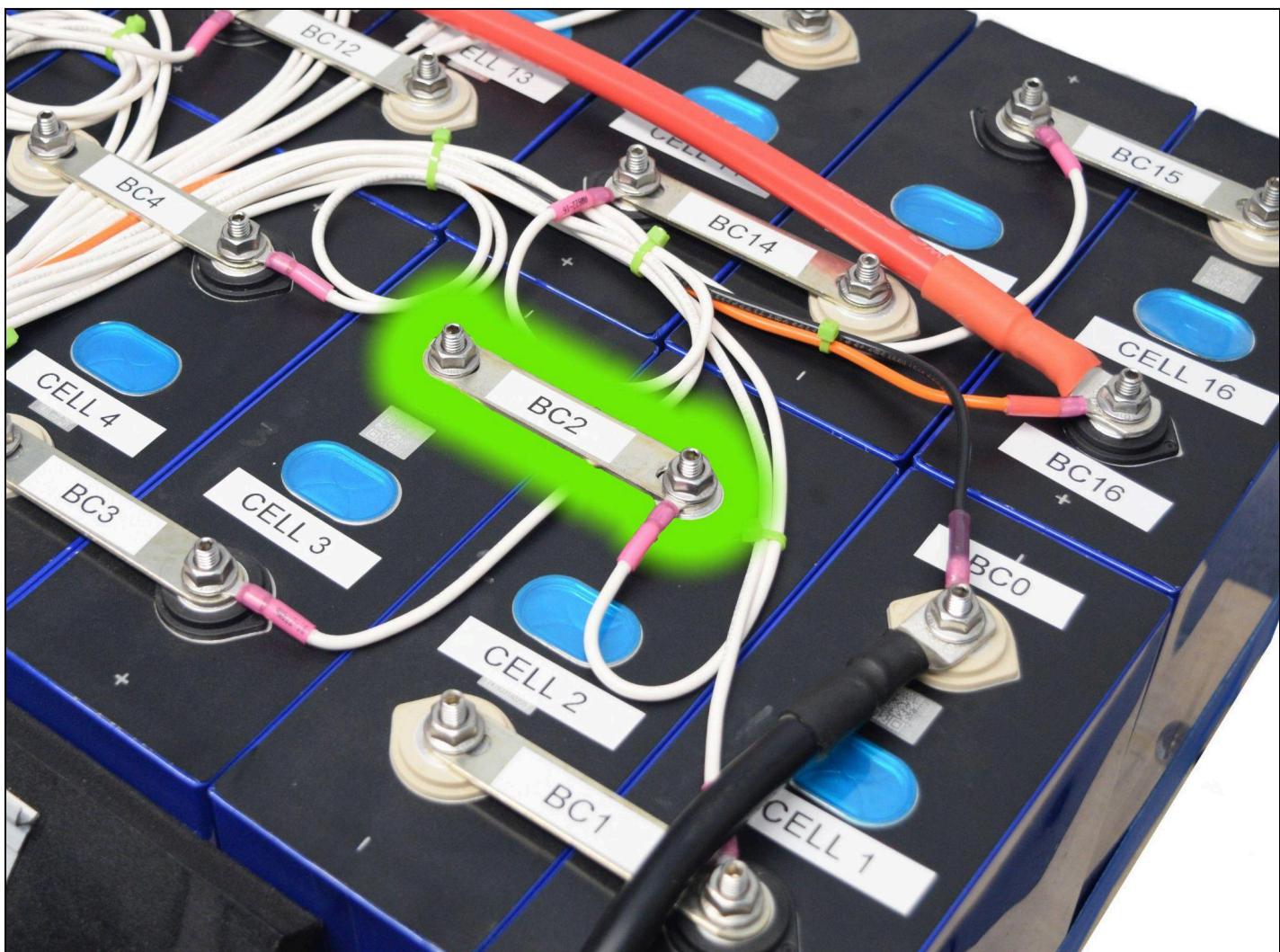
We usually specify that each balance wire should be attached to the positive terminal of the corresponding cell.

For example, "connect wire BC2 to the positive terminal of Cell 2."

This is only for consistency in the instructions, because anywhere on the node between 2 cells is the same as far as electricity is concerned.

For example, wire BC2 can be connected to the positive terminal of cell 2, or to the negative terminal of cell 3, or it can be bolted or soldered to the center of the bus bar connecting these cell terminals. In fact, attaching the wire to the center of the bus bar may be technically superior, but we don't think it's worth the extra effort in practice.

In this photo, all of the highlighted parts are "BC2"



30. Definitions

LiFePO4 Lithium-Iron-Phosphate, our favorite lithium cell chemistry.

NMC Nickel Manganese Cobalt, classic lithium ion cell chemistry.

LTO Lithium Titanate, lower cell voltage cell chemistry, very long cycle life, less common.

BMS Battery Management System, the circuit board that protects lithium cells.

OTA Over-the-Air Update, uses an internet connection to fetch updates.

UF2 USB Flashing Format, a file format designed by Microsoft for offline updates.

DIY Do-it-yourself, it's what we do.

OLED Organic Light Emitting Diode, a dot matrix display in which each pixel emits its own light.

MOSFET metal-oxide-semiconductor field-effect transistor, the component used for switching high current.

FETs shorthand for MOSFETs- The solid state high current switching component.

31. Units and Conversions

“s” The lowercase s is used as an abbreviation for X number of cells. As in 4s, 8s, 16s.

Also used for seconds in this document, depending on context.

“c” Temperatures are in units of celsius.

To convert to Fahrenheit, use the formula $(c * 5/9) + 25$

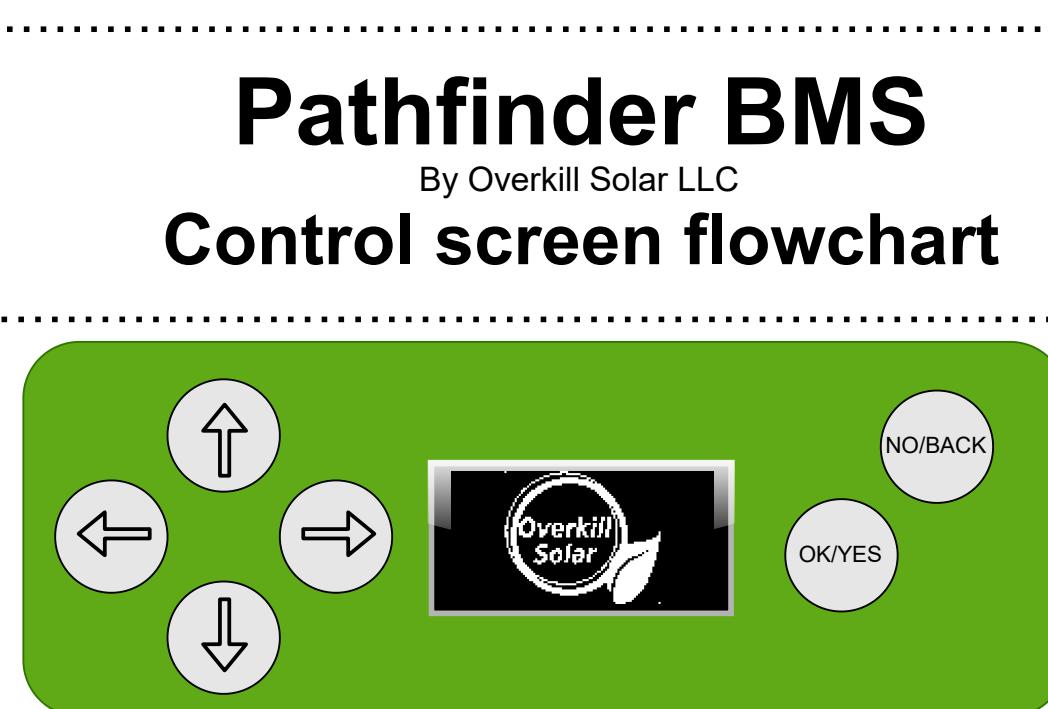
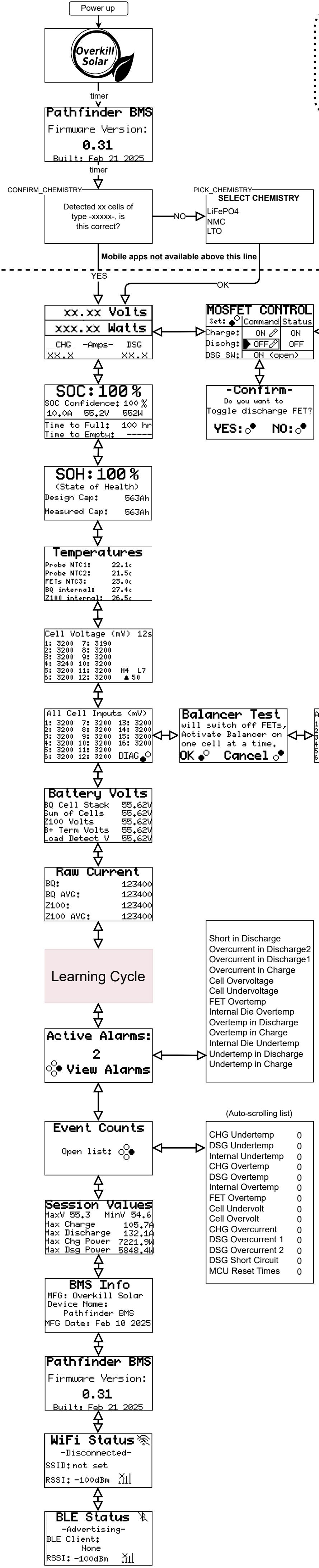
To convert to Kelvin, use the formula $c + 273.15$

32. Revision History

March 2025: First edition

33. Screen Flowchart

A PDF flowchart of the built in screen navigation:



The Pathfinder BMS user manual contains a description of each screen and their functions. Highlighted screens are unfinished at the moment.

