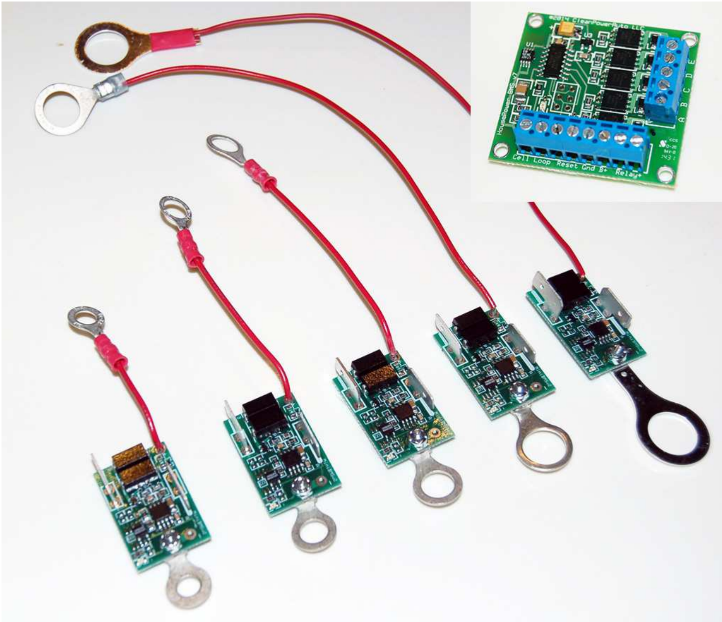


HousePower BMS

CleanPowerAuto LLC

Features:

- Designed for 12V, 24V, 36V, 48V LiFePo4 battery banks, replacing Lead Acid house banks in marine and RV applications, with minimal changes to existing systems and wiring.
- Cell level protection disconnects the bank if any cell is discharged to 2.6V to prevent battery damage.
- Cell level protection disconnects the bank if any cell is overcharged to 3.65V to prevent battery damage.
- Individual cells within the battery bank are actively kept in balance by BMS.
- Separate relay controls for HVC (High Voltage Cutoff) and LVC (Low Voltage Cutoff) allow optional integration with inverters/chargers/solar controllers/etc. to better automate battery management.
- Warning alarm circuit sends audible/visual alerts in advance, allowing you to react on BMS alerts before main contactor is dropped, to prevent unwanted loss of power.
- Warning levels are more conservative than Protection levels, HVC = 3.6V per cell, LVC = 2.9V per cell, allowing time to address the alarms and avoid power loss.
- BMS is Distributed type, i.e. broken into 2 components - cell boards and control board, allowing installation on large banks distributed across multiple boxes/locations.
- Several cell board sizes available to accommodate typical prismatic cells, choose correct board size for your cells. If cells are grouped in parallel, only one board is needed for a P-group.

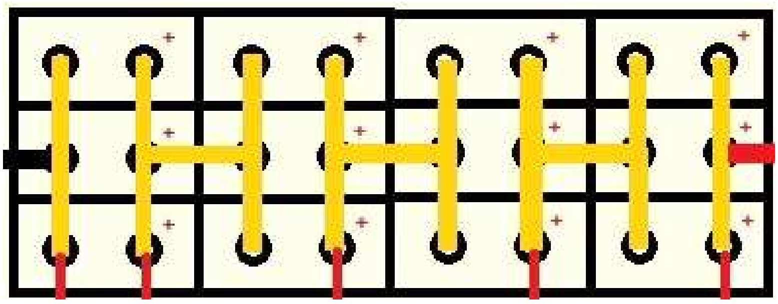
Electrical specifications:

- Operating current – less than 5mA , not counting relay coils
- Relay circuits rating – 15A inrush, 2A continuous
- Relay circuits type – open drain MOSFET switch, pulled to Gnd when active
- Reset button rating – momentary push button, less than 5mA current
- Main relay circuit – normally active (pulled to Gnd) when battery is online, floating (disconnected from Gnd) when battery is offline
- HVC/LVC/Alarm circuits – normally inactive (disconnected from Gnd), activate when HVC/LVC event is triggered by BMS

Installation and use:

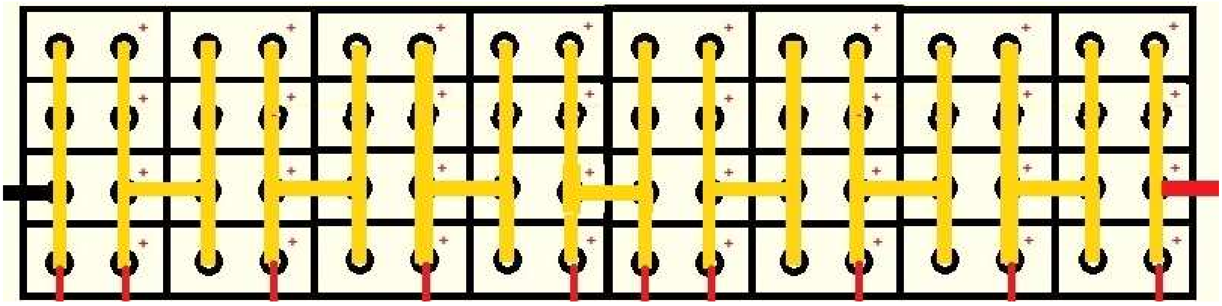
Typical LiFePo4 cells have nominal voltage of 3.2V. To prevent damage and ensure long life cells must be kept within 2.5V-4.0V operating window. LiFePo4 chemistry has flat charge/discharge curve with steep ends on both sides, which means the battery will hold close to nominal voltage until almost full or almost empty. At the end of charge voltage will rise rapidly and at the end of discharge voltage will fall rapidly. BMS is used to automatically protect the battery from reaching those steep ends.

To use LiFePo4 cells in house banks with 12V nominal voltage you must have 4 cells or groups of paralleled cells connected in series to get 12.8V nominal bank voltage. To make larger capacity banks you add more cells in parallel to get larger 4 groups of equally sized cells. For example, to build 600AH 12V bank using 200AH cells, you need 12 cells connected in 3P4S configuration (see below diagram). To make a 800AH bank, you need 16 cells in 4P4S configuration. Each group of paralleled cells makes a "supercell" of larger AH capacity. You always need 4 groups in series (hence 4S) to get proper voltage level. So, valid configurations for 12V bank are 1P4S, 2P4S, 3P4S, 4P4S, 5P4S, etc. You must create parallel groups first, and then connect 4 groups in series. See below picture for example of 3P4S bank layout.



DO NOT create multiple strings of 4 series connected individual cells and put those strings in parallel, this will create unmanageable mess since individual cells in the middle of each string cannot be managed by BMS. BMS must see entire bank as 4 series connected units.

Same rules apply to 24V banks, except there are 8 cells or groups of paralleled cells connected in series, making it a 8S configuration. See below picture for example of 4P8S bank layout.



Install cell boards on your cells. If your cells are grouped in parallel "supercells" you can install the cell board on any one cell in the group since they all share the same voltage at all times. Ring terminal attached to cell board goes onto negative cell terminal and red lead wire terminal goes on positive side of the cell. You MUST install BMS terminals on top of copper links (bus bars or cable lugs), but under the flat washer, to make sure it won't be twisted when you torque the terminal bolt. DO NOT install BMS terminals under copper links to avoid passing high currents thru the BMS terminal. Thread both bolts by hand to secure both sides of BMS module before tightening terminal bolts.

There should be 4 cell boards in 12V bank and 8 cell boards in 24V bank. Using 18AWG – 16AWG wire and 0.25" Quick Disconnect crimp terminals fabricate wires to connect all cells in one series string. Leave some slack on each wire to avoid stress if cells shift a little during use. Signal connections are not polarized, so you can connect in any order, as long as wire loop goes thru all cells and both ends meet at the head end control board. Take care not to touch signaling connections to any cell terminals or any other components on the cell boards, as signaling connections must be isolated from the bank voltage.

WARNING: Push on connectors are very tight. With enough force when pushing connector over the blade terminal you can lift the trace off the PCB and damage the connection. We recommend loosening up the connector a little bit with flat screwdriver before pushing it over the terminal.

Cell boards must be kept dry and protected from dirt and other elements, just as well as cell terminals must be protected and kept clean. Install your cells in boxes or enclosed compartments. In corrosive environments you can lightly spray cell terminals and cell boards with battery protection products such as CRC, sold at automotive and marine stores.

Wire the BMS control board according to below diagrams. Reset button can be any suitable momentary push normally open button; its current rating is irrelevant. Power switch must be rated for 3-5 Amps to allow for inrush currents of main relay coil. LVC and HVC relays can be any commonly available relays with coil voltage matching your bank voltage and contact rating appropriate for the control circuits these relays will commutate. HVC and LVC relays are optional and their use may vary depending on the rest of your equipment. Some inverter/chargers, solar controllers, etc. have control inputs, which can be integrated with BMS using HVC/LVC relays to turn those devices on/off based on BMS signals. Or, you can use appropriately rated relays to connect/disconnect charge/load circuits based on BMS signals. If you use alternator to charge your bank it's also possible to wire normally closed contacts of HVC relay into alternator's field control circuit, so the circuit would open when HVC relay is triggered, killing alternator's high current output.

Or you can simply rely on audible/visual alerts from BMS to handle your battery needs. However, in order to protect the battery you must have main contactor wired to completely disconnect the battery from all circuits in case BMS alerts go from warning levels to protection levels. Choose main contactor with coil voltage matching the bank voltage and contacts capable of carrying maximum loads your battery will supply. Commonly used contactor is Tyco EV200, sometimes sold under BlueSea and other brands. It's rated for 500A continuous and 2000A bursts.

Wire Alarm circuit to a device which would bring your attention in case of BMS alerts. This circuit should be limited up to 3 Amp current. Commonly available low power buzzers and/or LED lights can be used. You can wire both audible and visual devices in parallel. BMS alarm is raised for both HVC and LVC events. BMS control board has separate red LEDs for HVC and LVC alerts and you can also tell which alarm is raised based on bank voltage at the time of the alarm.

When BMS detects that bank voltage is at the warning level, it will trigger the alarm signal and HVC or LVC relay, depending on which warning level was detected. BMS warning has a 10 seconds delay designed to filter out false alarms when bank voltage sags briefly under heavy load, such as starting an engine.

If BMS alerts are not acted upon and bank voltage continues to get worse, it will reach protection levels, at which point BMS will drop the main contactor and isolate the bank from all circuits. To engage the main contactor again, press Reset button. If bank voltage is still at protection levels, BMS will allow 60 seconds delay and will drop main contactor again. The delay is designed to give you opportunity to start charging to get the bank voltage above protection levels.

BMS protection also occurs if any one cell or P-group of cells signals abnormal voltage reading, which indicates significant bank imbalance, or may indicate a damaged cell or some other cell level troubles. If this happens, measure voltages across each cell or P-groups of cells and make sure they are all within normal window between 2.5V and 3.65V and are closely balanced.

When building a new bank it's not uncommon to get cells at various state of charge, which requires initial bank balancing to get them all at the same state of charge. Bank balancing is outside of scope of this document. You can find a paper on initial bank balancing at our Web site.

LED Signals description:

HousePower BMS board has a red LED, which provides "heartbeat" signal when BMS is operating normally and battery is within nominal voltage range. This "heartbeat" signal is a brief pulse at one second intervals.

If BMS is in HVC state, this LED will light up solid on, and it will turn off completely if BMS is in LVC state.

Cell boards also have red LEDs, which indicate the status of each cell as described in below table:

LED mode	Description
Long Pulse	All OK, but HVC or LVC happened in last 30 min
Short Pulse	all OK – voltage above LVC and below HVC, no shunting
Slow Flash	Shunting/balancing in progress, voltage still below HVC
Rapid Flash	HVC condition
No light	LVC condition or bad board or wrong install polarity

Balancing function:

At the end of charge, when cell voltage starts climbing rapidly and reaches 3.55V, BMS turns on shunting/balancing function, which bypasses portion of charge current thru shunting resistors, hence slowing down charge rate of the cell, while other cells are catching up. This allows all cells to get closer in their final voltages at the end of charge, a process called Top Balancing. Since BMS can only shunt a small amount - 0.7A, this is enough to maintain a balanced pack, but may not be enough for initial balance if cells came from the factory at various states of charge levels. Manual initial balance may be required for newly assembled packs or packs where some cells have been replaced. You can read more about initial balancing in our document called "**How to perform initial LiFePo4 battery pack balancing using MiniBMS**", which is available at our Web site's Product Support page.

Warning and Protection levels and Recovery levels:

This is often misunderstood part of BMS logic, so it requires more detailed explanation.

BMS monitors both *pack level* and *cell level* voltages simultaneously. Pack level alarms are more conservative, so they only trip Warning circuits (HVC/LVC/Alarm), but do not trip Protection circuit (Main contactor). On the other hand, cell level alarms are less conservative and trip Protection circuit as well as Warning circuits. When cell level alarm is detected, it will first trip Warning circuits, then after 1 minute it will trip Protection circuit. This additional delay gives you a chance to react (i.e. start charging the pack) before Main contactor is dropped.

Warning alarms recover automatically when voltage recovers, but Protection alarm is persistent until Reset button is pressed, to bring more attention to potential cell level issues.

If pack is healthy and well balanced, then all cell voltages will be the same or very close most of the time. Since Warning levels are more conservative than Protection levels, they are reached first and HVC/LVC/Alarm circuits are activated. If you have those circuits wired such that voltage deterioration stops when HVC/LVC activate, then battery will never reach Protection levels. If you don't wire optional HVC/LVC circuits, your battery is still protected by Main contactor; but this protection causes battery disconnect, which is unwanted in some applications (boat, RV) but can be tolerated in other applications. It's up to you to decide if you want to wire HVC/LVC circuits, but you must have Main contactor wired as minimal protection for your battery pack.

If pack is not well balanced or there is a weak or damaged (i.e. reduced capacity) cell, then cell level Protection alert could come before pack level Warning alert. You could try to improve the balance or in case of a weak cell you can just live with this sequence of BMS alerts until you have a chance to replace a weak cell. In many cases weak or slightly damaged cells can still perform well for a long time, even though overall pack capacity is reduced to the diminished capacity of the weakest cell.

To prevent oscillations of BMS signals when voltage is hovering at HVC/LVC thresholds, HousePower BMS has built-in hysteresis for HVC/LVC voltages as follows:

HVC turn on – 3.6V per cell
HVC turn off – 3.45V per cell
LVC turn on – 2.9V per cell
LVC turn off – 3.1V per cell

In addition to voltage hysteresis there is also 10 seconds time hysteresis for each threshold, to filter out brief voltage sags/spikes, which could be caused by engine starting or other brief heavy loads.

Wiring diagrams for various bank sizes:

HousePower BMS wiring diagram for 12V bank

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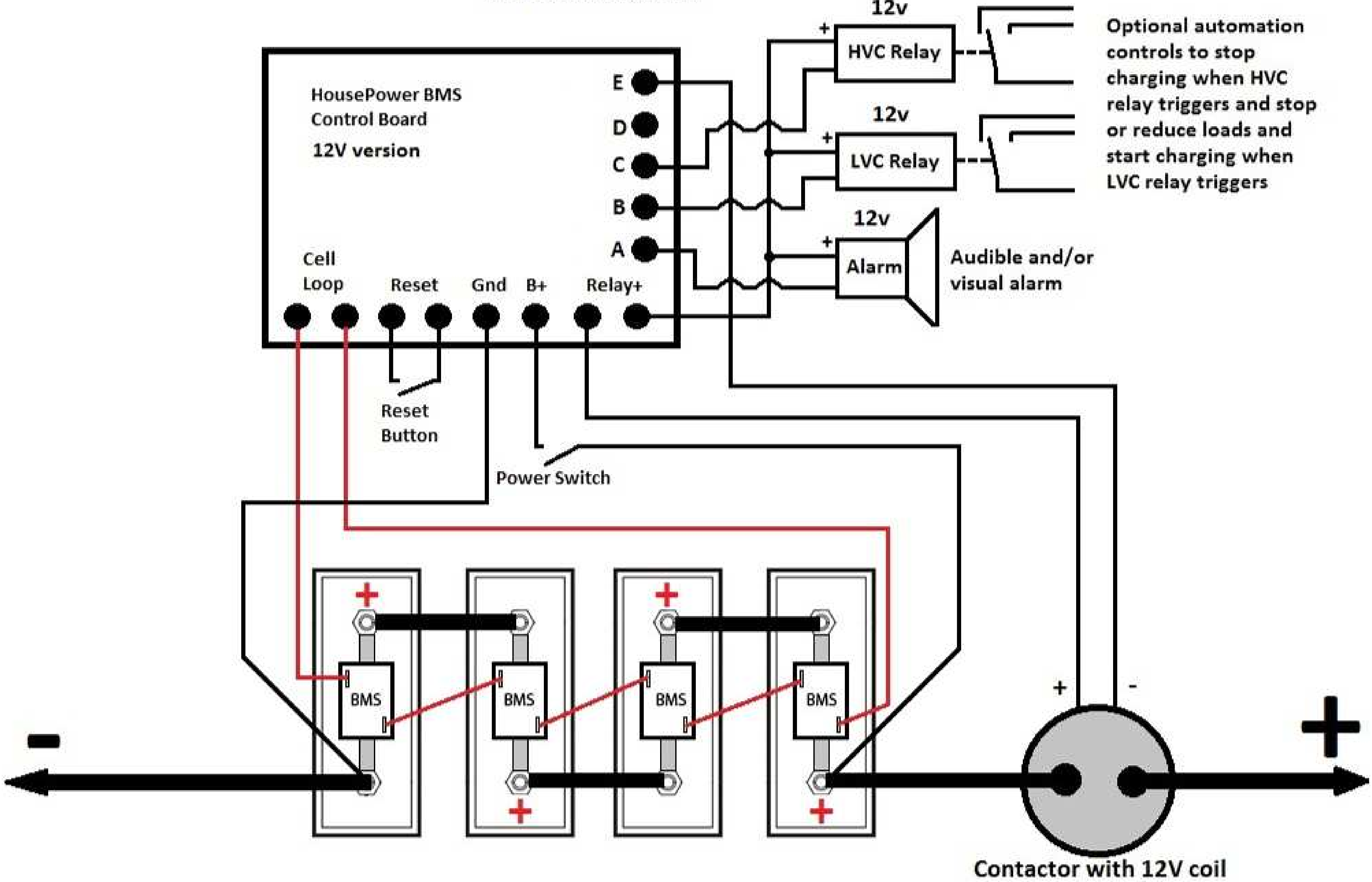

HousePower BMS wiring diagram for 24V banks

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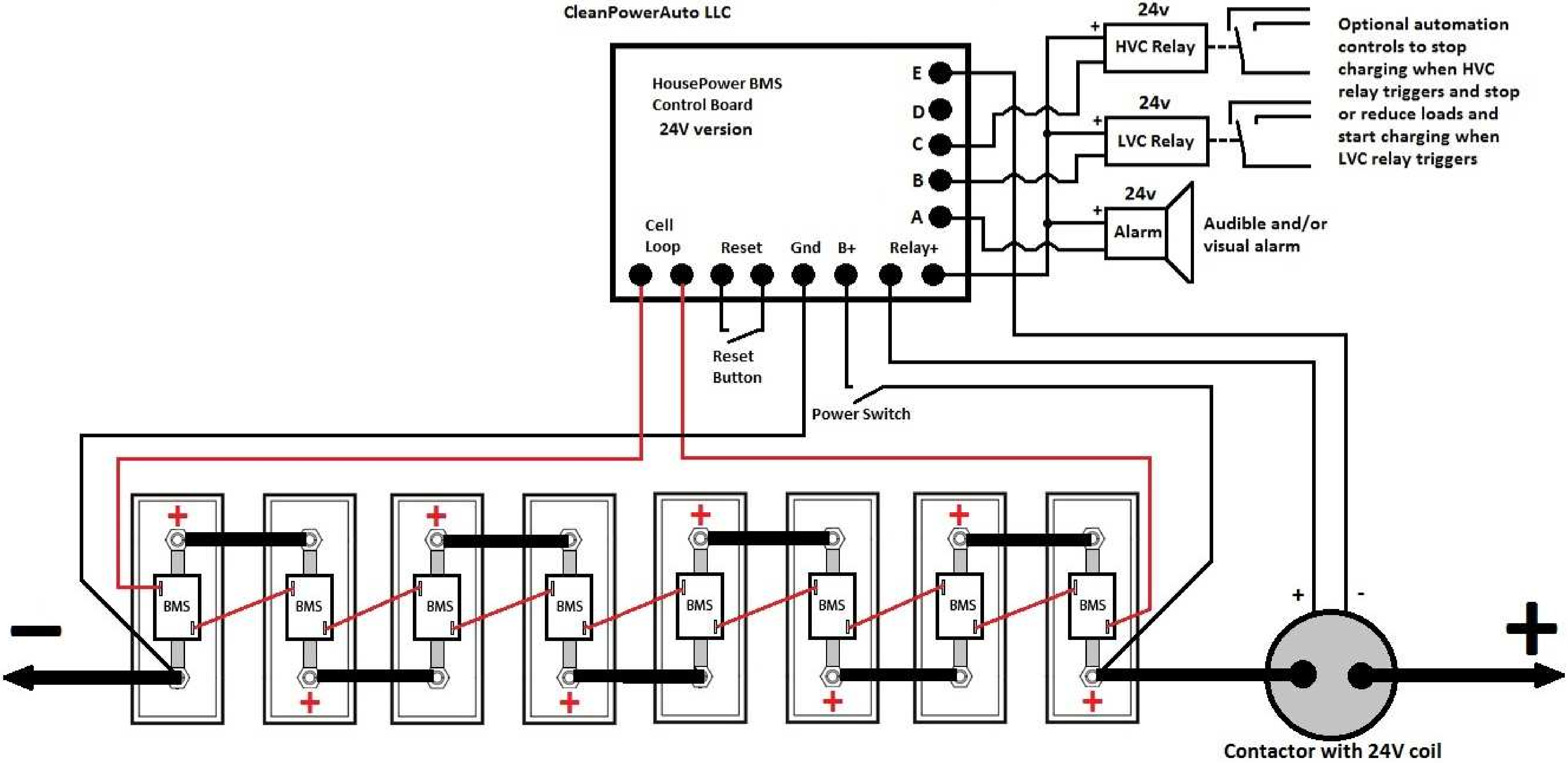

HousePower BMS wiring diagram for 36V banks

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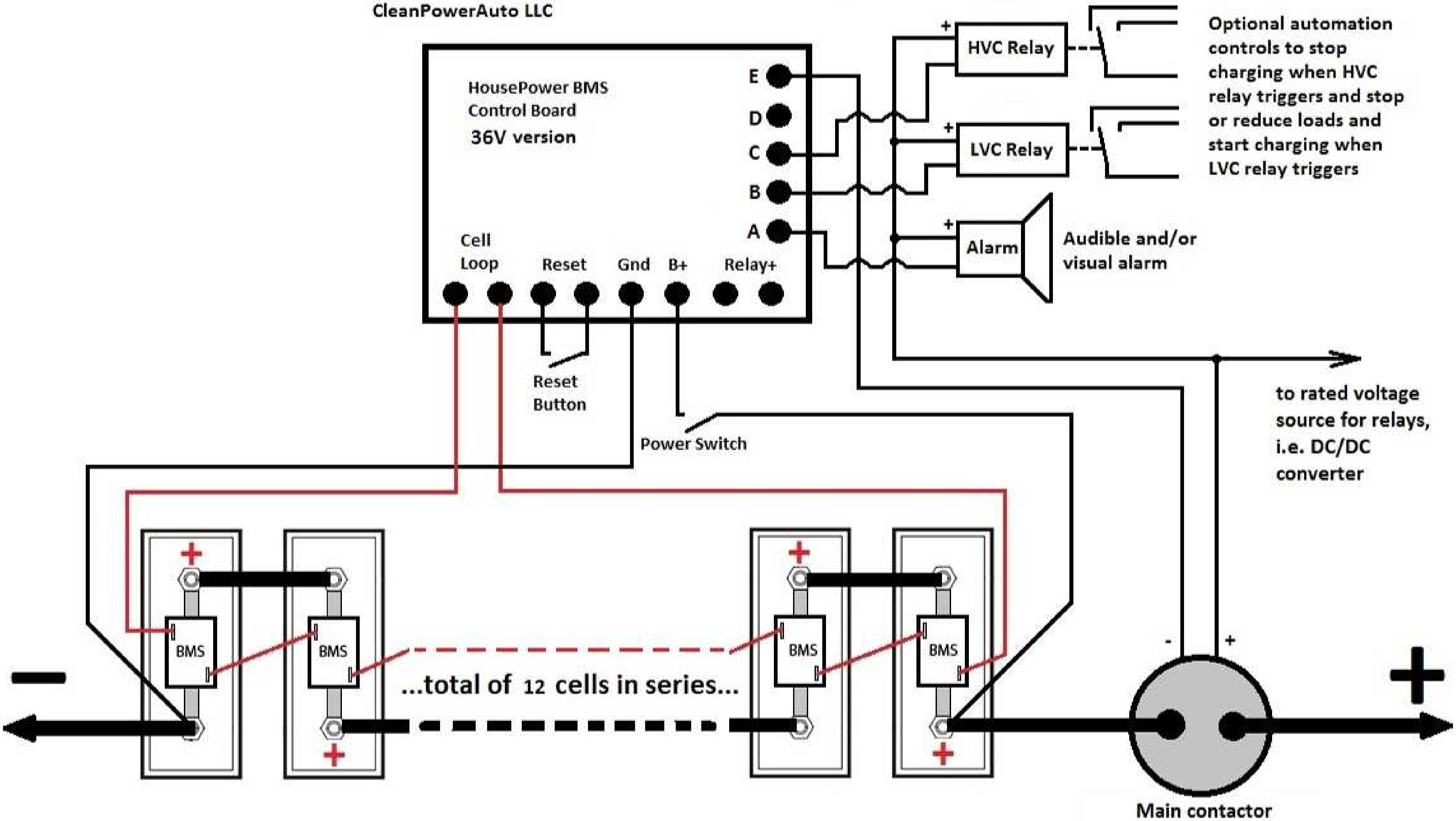

HousePower BMS wiring diagram for 48V banks

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