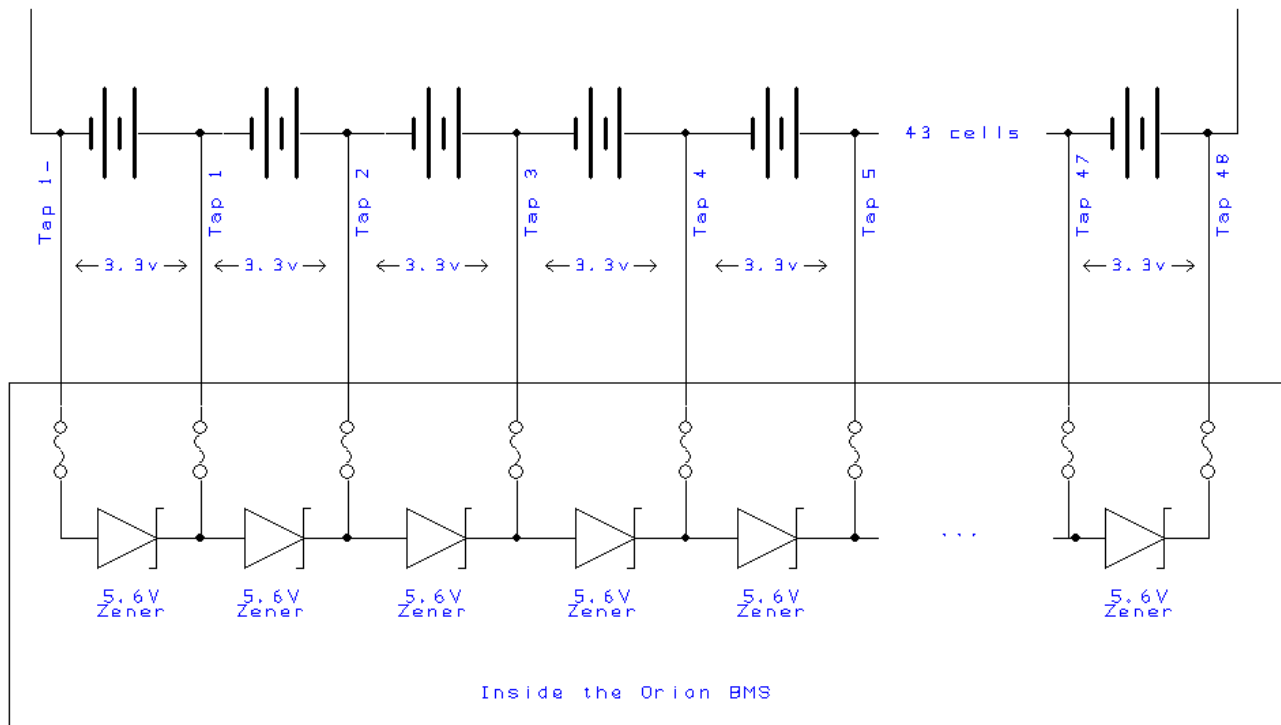


Why Orion BMS Internal Fuses Blow

The Orion BMS has an internal fuse for each of the cell voltage tap wires. These fuses are designed to blow in over-voltage and reverse-voltage conditions. Sufficient current to blow the fuses will only flow through the tap wires during an over-voltage or reverse-voltage condition.

Below is a diagram showing a sample 48 cell battery pack connected to an Orion BMS unit. The internal fuses and protection diodes inside the unit are depicted below. In the diagram, all cell tap voltages are within 0 – 5 volts with respect to the next lower cell. As a result, none of the zener diodes conduct and no significant current is flowing through the BMS. Since no current is flowing, all fuses remain in a closed state.



What causes the fuses to blow?

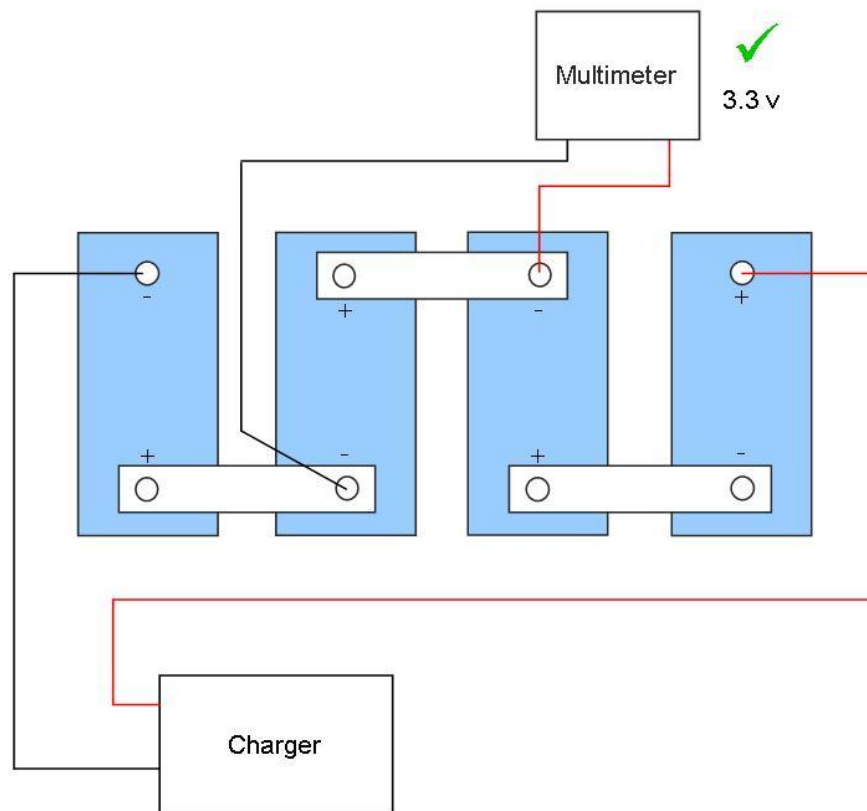
The only time the internal fuses on the tap wires will open is from an over-voltage or reverse-voltage condition. When an over-voltage or reverse-voltage condition occurs, the zener diodes will begin to conduct, causing current to flow through the tap wires and causing the fuses on the taps to blow. This is necessary in order to protect the voltage measurement electronics from damage. Over-voltage and reverse-voltage conditions are both with respect to the adjacent lower cell tap and the adjacent higher cell tap. There are many situations that can lead to over-voltage and reverse-voltage occurring, some of which may be unexpected. While the following few pages are not an exhaustive list, they cover the most common causes.

Reason: Altering wiring with the BMS connected (or loose busbar)

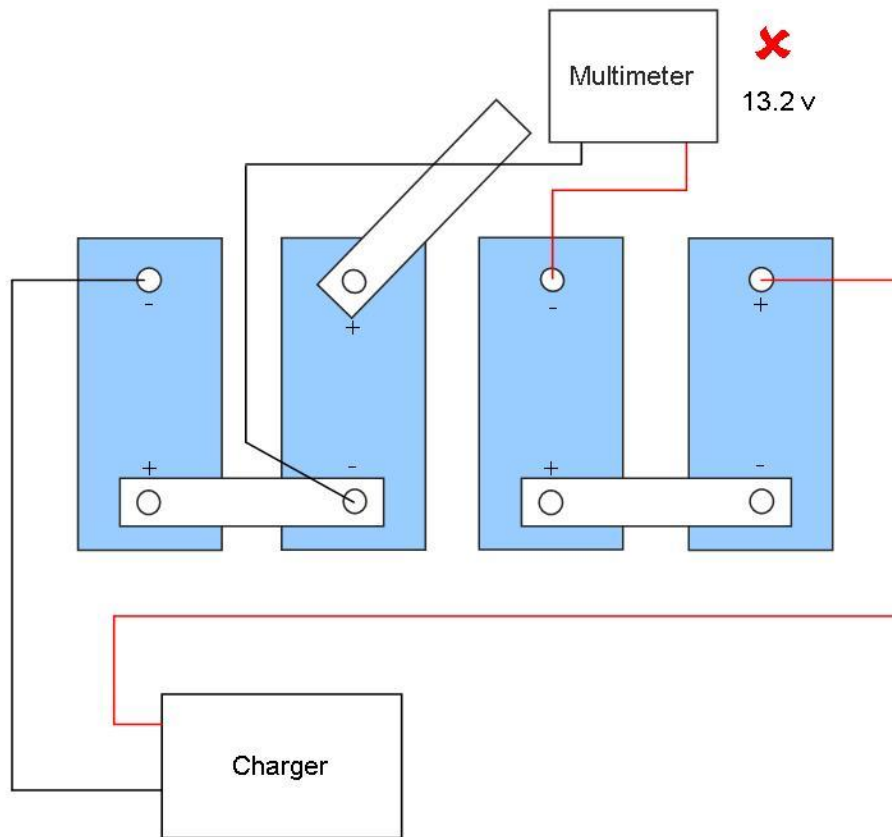
By far, the most common cause of blown fuses and/or more serious damage to the Orion BMS is when battery pack wiring is altered with the Orion BMS still connected. While it may seem counter-intuitive, removing a busbar with the BMS cell tap wires connected can result in the voltage of the entire battery pack across two adjacent cell tap wires due to capacitors in a battery charger, resistance from a connected load (motor controller, DC:DC converter, lighting, etc.), stray capacitance, a breakdown in isolation within the battery pack, or other such causes. Since these voltages are well beyond the maximum rated voltage between two cell taps, damage to the unit is likely to occur.

It is very important, both for safety and for the health of the BMS, that all cell tap wires are always disconnected before any modifications are made to the wiring of the battery pack. We recommend designing the battery box enclosure to require the cell taps to be disconnected before the battery wiring can be modified or applying warning stickers throughout the battery pack indicating that the BMS must be disconnected before the battery pack is serviced.

The below example shows a 13.2 volt battery pack. A volt meter is measuring 3.3v from cell tap #1 to #2 in the example.



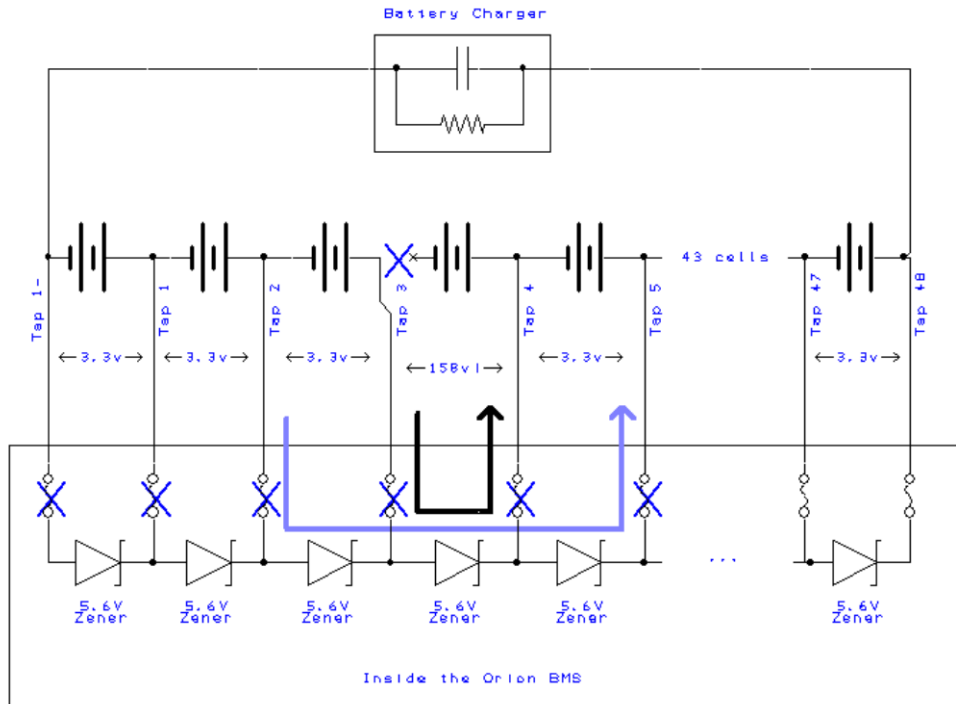
The next diagram shows what happens when the busbar is disconnected. As the busbar is now open, battery voltage is no longer present at the battery charger, but the internal capacitors in the charger are still charged at the pack voltage (13.2 volts) and have no place to discharge. Because of this, the full battery voltage is present across cell tap #1 and #2 (the multimeter leads in the diagram). Because the voltage is now the full battery voltage, the zeners inside the BMS break down and conduct, causing the fuses inside the BMS to blow.



In the above example, the total pack voltage is only 13.2 volts, which would blow fuses in a revision C or D unit, but likely would not damage a revision E unit. If this same scenario were to occur on a higher voltage battery pack, internal fuses on any revision of the Orion BMS will blow as the voltage would exceed 24 volts. The below electrical diagram shows the same situation, only with a larger 158v battery pack. When the voltage between the cell taps rises rapidly, the zener diodes inside the BMS begin to conduct, discharging the battery charger's capacitors, resulting in blown fuses. In this case, it is possible to blow all fuses within a particular cell group. Typically current will first flow through the two closest cell taps as it is the path of least resistance (black line in the following diagram) and then seek alternative paths as fuses blow (light purple line.)

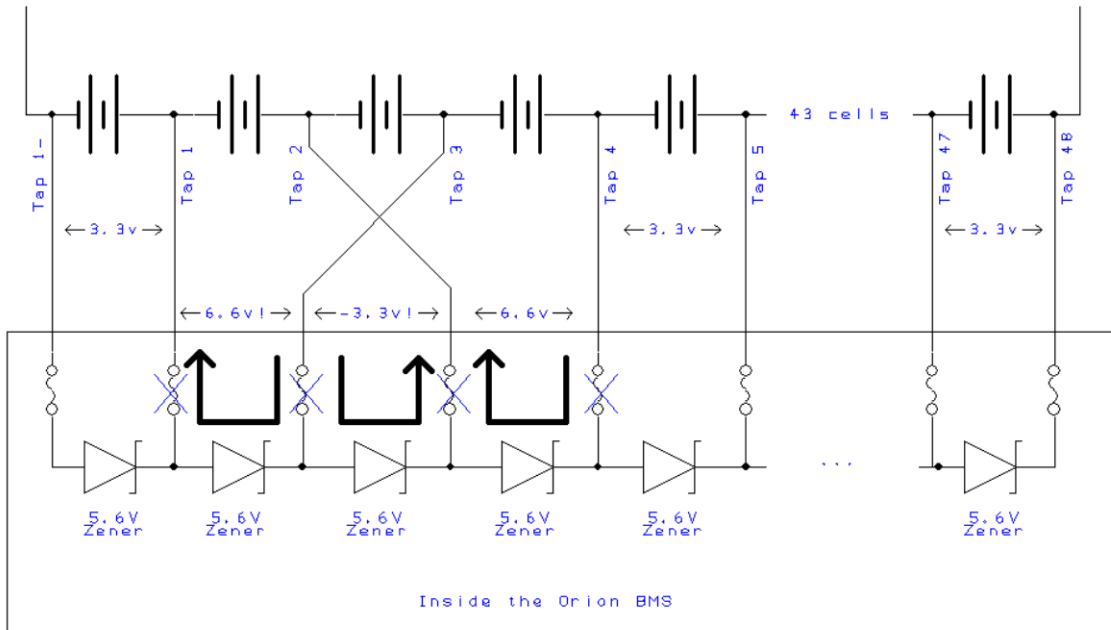
When voltages between 2 cell taps to the BMS exceed 60V, more substantial damage to the BMS than blown fuses may occur.

It is important to note that a battery charger or load does not need to be connected to the battery pack to cause high voltages between cell taps when a busbar is removed. Isolation faults, built up charge against the chassis (stray capacitance), or capacitors on snubber circuits can all be enough to cause damage. Damage from this can be prevented by ensuring that the cell tap harnesses are fully disconnected from the BMS before any wiring is altered on the battery pack. Additionally, this can be caused by intentional re-wiring of the battery pack or by loose busbars (which also pose a fire risk from arcing.)



Reason: Cell tap wires reversed

For revision C & D units, reversed cell tap wires will lead to a blown fuse. While revision E units are designed to survive a single tap wire reversed for short periods of time, the unit may not survive for longer times or if multiple wires are crossed. Never leave a BMS unit connected with reversed tap wires. Even though the BMS may survive, this condition will drain attached cells.



In the above schematic, cell taps 2 and 3 are reversed. This leads to 6.6v between cell taps 1 and 2 and 3 and 4 with a reverse voltage between taps 2 and 3. In this case, 4 of the zener diodes will conduct and current will flow through the tap wires. This condition leads to up to 4 fuses blown (but may be as few as 2 fuses depending on the order that they blow.) For revision E units, fuses will generally reset to their normal state once the above fault is fixed.

Reason: Accidental contact to cell tap

If a cell tap wire accidentally comes into contact with a different voltage cell while the harness is plugged into the BMS unit, significant voltage may be present. This can also happen if a tap wire is cut or abrades and shorts to another wire or another terminal. Cell tap wiring must not be altered with the BMS connected both for safety reasons and to prevent damage to the BMS. Care must also be taken to route the cabling in such a way that it cannot abrade or be cut by objects.

Reason: Transients (and shorts within the high voltage battery pack)

Transients may also cause fuses to blow inside the BMS. Transients are very rapid voltage spikes that can occur as a result of switching loads, rapid changes in current or other causes. Small transients occur regularly due to loads switching on and off, and the BMS is designed to withstand these common transients. Very large transients, typically caused by shorts within a battery pack or by hard switching very large loads, can be very high voltage and can cause damage, not only to the BMS, but also to lithium-ion cells.

Reason: Extremely weak cell, internal cell failure (fairly rare)

When current is flowing through the battery pack, high resistance connections within the battery pack can cause “voltage drop” that will cause higher or lower voltages at certain cell taps. This most commonly occurs with extremely weak cells or faulty cells which have become internally open. This failure is fairly rare. If cells have become over-discharged or over-charged, the cell impedance will become very high. The BMS will not allow charge or discharge if it detects a seriously under-charged or over-charged cell. However, if the user ignores the BMS and continues to charge or discharge, the cell can cause significant voltage drop (or in some cases reverse voltages) that can cause fuses to blow.

Differences between Revision E and previous revisions

Revisions C & D of the Orion BMS contain standard fuses. Once these fuses blow in these units, the unit must be serviced and the fuses replaced. Fuses in these units will blow if voltages exceed 5.5v or if there is reverse voltage below 0v.

Revision E of the Orion BMS also contain standard fuses, but these units also contain additional resettable fuses which protect against certain kinds of temporary lower voltage wiring faults. In **most** cases where the over voltage or reverse voltage conditions are less than 24 volts for less than 10 minutes, the resettable fuses will reset to normal after the fault is cleared. In situations where faults result in higher voltages across two cell taps, the standard fuses are designed to blow. If this occurs, the BMS must be returned for service.