DTC P0A80 - Weak Cell Fault

| Product Family	Fault Supported
Orion BMS [Original] (24 - 180 Cell)	**YES**
Orion BMS 2 (24 - 180 Cell)	**YES**
Orion JR [Original] (16 Cell)	**YES**
Orion JR 2 (16 Cell)	**YES**

FAULT DESCRIPTION

This fault is triggered based on thresholds programmed into the BMS profile that indicate when a cell is "weak". While this error code is designed to indicate a cell is weak, **this error is triggered when certain pre-programmed conditions are met and does not necessarily indicate a dead cell because it can also be triggered by loose busbars, other wiring issues or incorrect error threshold settings in the profile.**

While this error code will not impact the operation of the BMS, this error message likely indicates a problem exists and the actual problem itself (not this error code) may cause the BMS to limit charge or discharge current (as would be the case with a high resistance cell). If the charge and discharge limits are both zero, look for other fault codes, specifically open wire faults or total pack voltage fault codes to begin addressing the issue.

The "weak" cell fault can be triggered as the result of the following 3 conditions:

1. **High measured cell resistance** – The Orion BMS measures each cell's internal resistance and compares the measured resistance against the nominal resistance specified in the profile in the "temperature compensation" section. The current temperature is used to select the nominal resistance value to compare against. If the measured resistance is higher than the nominal resistance by the amount specified in the profile (General Settings -> Maximum Resistance [%]), a fault code will be triggered. For example, if the nominal resistance is 1 mOhm at 20 degrees Celsius and the BMS is programmed with a maximum resistance threshold of 2 mOhm at 20 degrees Celsius, an error code will be triggered if the cell resistance is measured at more than 2
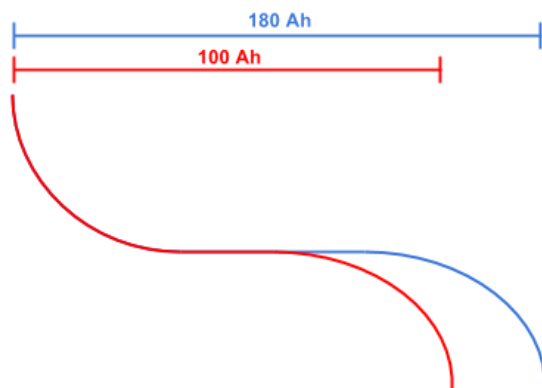
mOhm resistance at 20 degrees Celsius. <u>An increase in the cell resistance will result in an increase in the voltage drop / voltage rise while under load / charge respectively.</u>
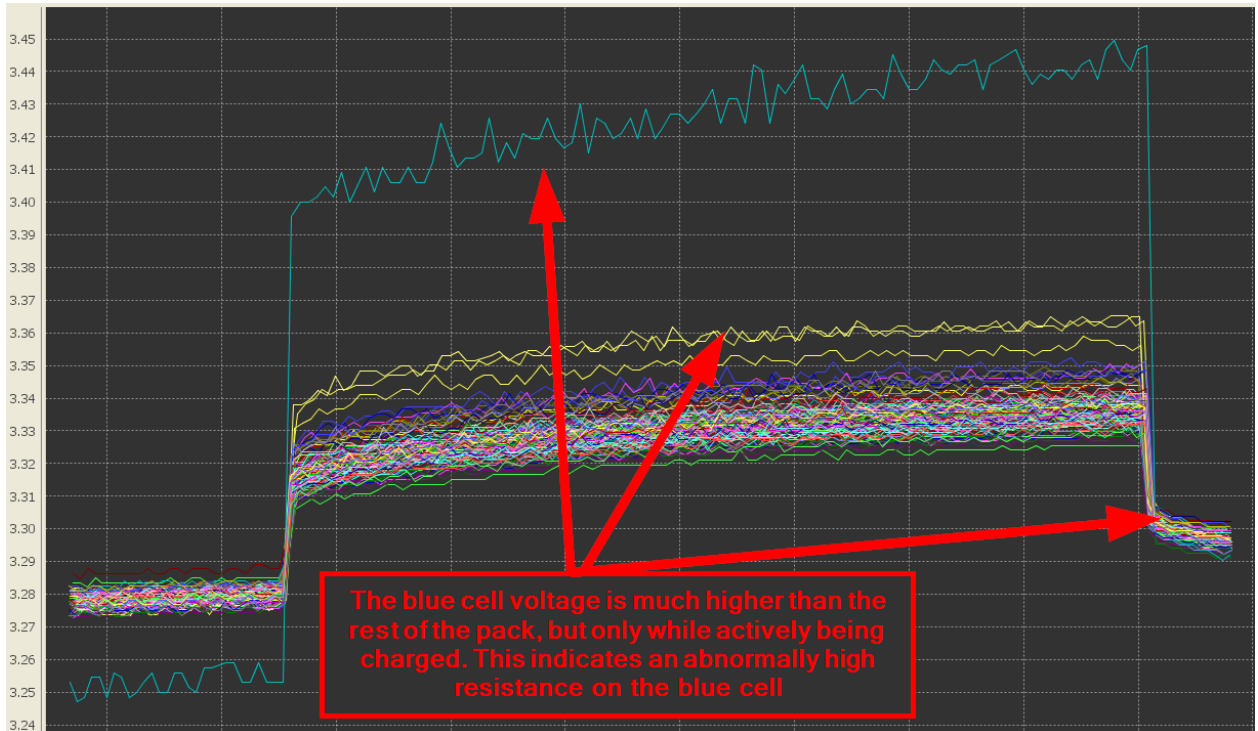
An example of a high resistance cell

Most often this condition is the result of a loose busbar or a problem with a cell interconnect cable. Because the BMS measures cell voltages by measuring the voltage between each of the cell voltage tap connections, the BMS also "sees" the resistance of the busbar or cable connecting the cell with the adjacent cell. Because of this, the busbar resistance is included in the measured cell resistance. If a busbar, cable or battery terminal is loose, corroded or oxidized, this can cause the measured resistance to rise and trigger the error.
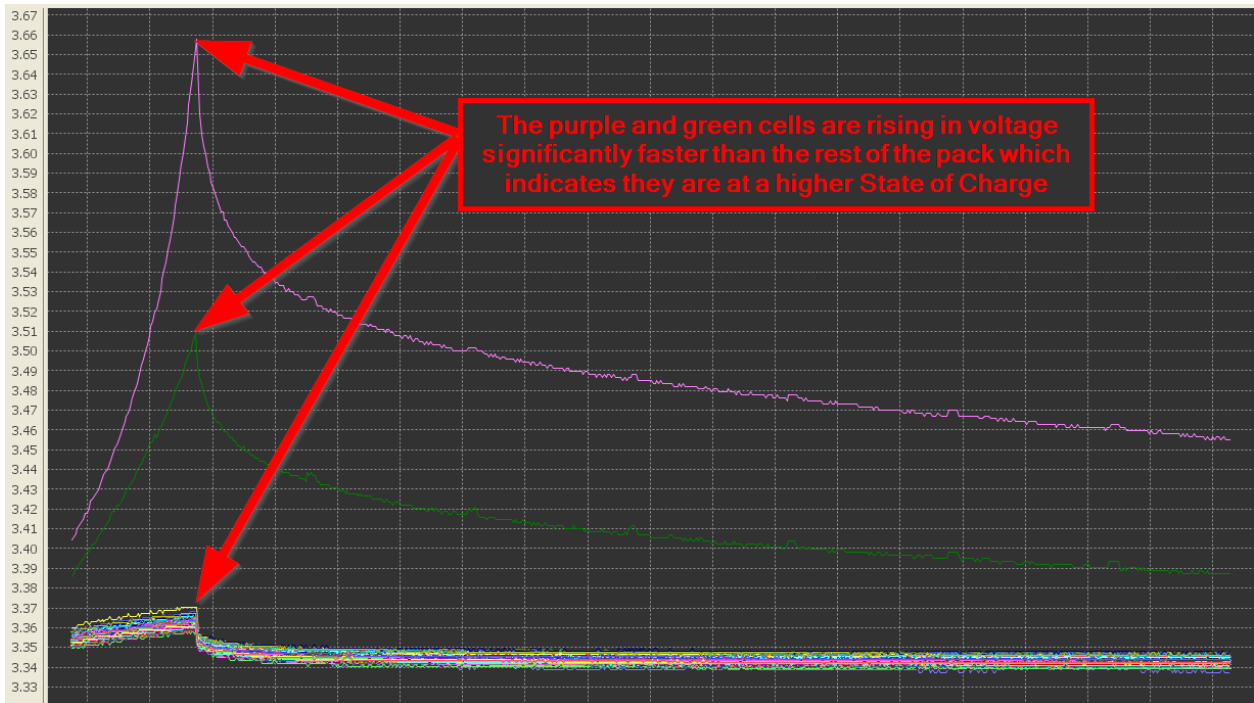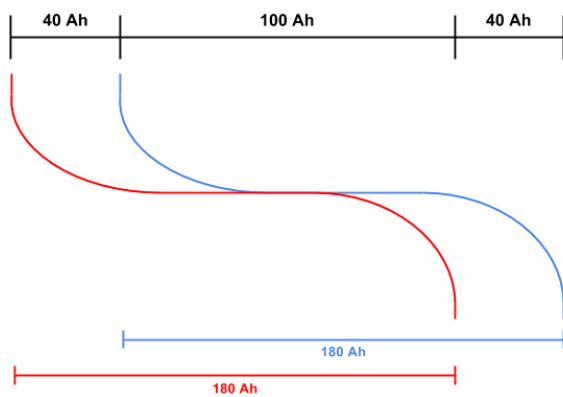
2. **Difference in open (sitting) cell voltage between one cell and the rest of the pack** – In addition to measuring the resistance of the cell, the BMS also looks for significant differences between the open cell voltage of a cell and the rest of the pack. The BMS calculates the open circuit voltage of each cell (this is the voltage as if the cell were setting at rest (no load) even when a load is applied to the cell). The BMS compares each cell's open circuit voltage to the pack average open circuit voltage and if they differ more than the preset value in the profile, a weak cell fault is triggered. The setting is under the "Fault Settings" tab -> "Weak Cell Settings". This can be caused by a cell that has deteriorated disproportionately to the rest of the battery pack or by a cell balance issue.

A cell with a significantly lower capacity than the rest of the pack will likely cause a large difference in open cell voltages at lower states of charge. Additionally, the internal resistance of cells typically goes up when they are at very low and high states of charge. A lower capacity cell may also trigger a weak pack error code.

3. **Cell being out of balance with the rest of the pack** – A cell that is significantly out of balance with the rest of the pack can trigger this error message for the same reason as above. For balance issues, the issue can easily be resolved by simply balancing the pack.

The purple and green cells are rising in voltage significantly faster than the rest of the pack which indicates they are at a higher State of Charge

An example of two cells being out of balance with the rest of the pack.

Fault Code	Fault Description	Possible Trouble Area
P0A80	Battery cell determined to be abnormally weak, underperforming, out of balance or low in capacity.	• Battery Pack Assembly • Busbar Interconnects

FAULT BEHAVIOR

This fault is **Informational Only** and does not alter the operation of the BMS in any way.

FAULT THRESHOLDS

Fault will trigger when **ANY** of the following conditions are satisfied	(a) **OR** (b) **OR** (c)
(a) High battery cell resistance beyond programmed maximum cell resistance threshold at current battery temperature.	Monitored battery cell is showing abnormally high voltage drop (high cell resistance). This is determined based on the thresholds set on the "Cell Settings" tab -> "Cell Resistance" in the BMS Utility Profile settings. This threshold will change based on the battery pack temperature.
(b) Low battery cell capacity (manifesting in a significantly different sitting voltage than the rest of the battery pack).	Monitored battery cell is demonstrating lower energy capacity than expected (higher voltage than the rest of the pack at full charge and lower voltage than the rest of the pack at low charge).

(c) Battery cell out of balance with the rest of the battery pack.	Monitored battery cell is out of balance with the rest of the battery pack (cell is constantly registering lower voltage than the rest of cells or higher voltage than the rest of cells).

DIAGNOSTIC STEPS

1.	**Determine which cells are flagged as weak by the BMS.**
	
	The BMS will categorize which cells (by cell ID number) are registering this fault code.
	
	Steps to view the list of Open Wiring Fault IDs:
	
	  1) Connect to the BMS using the Orion BMS utility.
	  2) Click the "Diagnostic Trouble Codes" tab at the top.
	  3) View the "Weak Cell" section on the far right hand side of the window.
	
	Please note that these are the tap positions on the BMS itself and do not necessarily correspond to the actual cell numbers. A freeze frame may also be available which will give much more detailed information about the conditions when the fault occurred. Only one freeze frame will be stored, so if multiple cells are "weak", detailed information will only be available for the first cell that was flagged as weak (chronologically).

2.	**Download the freeze frame for the fault code using the BMS Utility.**
	
	The BMS will normally produce a freeze frame on the "Diagnostic Trouble Codes" screen in the BMS Utility when this fault code occurs that contains a comprehensive list of BMS data parameters at the time the fault occurred. **It is strongly recommended that the freeze frame be downloaded from the BMS and saved to disk before the fault is cleared again** as this data may assist in the future if further diagnostics are required. <u>Additionally this freeze frame data may be requested by Technical Support if further assistance is required.</u>
	
	NOTE: Only Fault Codes with a (F) next to them have freeze frame data available for download. If there is no (F) next to the fault, there is no stored freeze frame available and this step can be skipped.
	
	Steps to download the Freeze Frame:
	
	  1) Connect to the BMS using the Orion BMS utility.
	  2) Click the "Diagnostic Trouble Codes" tab at the top.

	3) Select the correct fault code by clicking on the ID on the left side of the screen to initiate the Freeze Frame retrieval. 4) Once the retrieval process is complete, click the "Export (CSV)" button to save the freeze frame data to the computer disk.
3.	### Determine if fault was set due to high resistance or open voltage. This can be determined by looking at the freeze frame data and looking at the cell resistances and the open cell voltages and comparing them to the values programmed into the BMS profile. For example, if the affected cell's open circuit voltage is 0.5V lower than most of the other cells and the trigger threshold is 0.5V, that is likely the cause. Likewise, if the cell resistance is greater than 4.0 mOhm and the maximum resistance threshold is also 4.0 mOhm with the nominal resistance of 1 mOhm for this specific temperature, that is likely the cause. Go to the next step based on whether the issue is high resistance or open cell voltage difference.
4.	### High Resistance: **Step 1. Check if there is additional resistance from long cables, busbars, fuses, and particularly loose terminals.** This can be done by inspecting the battery pack. If a longer cable or longer busbar is used to connect the cell in question to the next cell, "busbar compensation" or re-wiring may be required to compensate for the additional resistance. Please see the wiring manual for more information on high resistance cables. Special rules apply to the placement of fuses and if a fuse is directly adjacent to a "weak cell", please review the wiring manual to ensure proper placement. **Step 2. Check to see if the high resistance can be explained by difference in temperature.** Low temperatures can cause dramatic increases in resistance for some cells. If the cell is a significantly lower temperature than the rest of the pack such as when a pack is split into multiple locations, it may be necessary to add (or move) a thermistor to this cell so the BMS can monitor the temperature better or ideally, alter the thermal management to keep all cells roughly the same temperature. **Step 3. Determine if the high resistance can be explained by the state of charge.** The internal resistance of most Lithium-ion cells will spike significantly at very high and low states of charge such as the top 2% and bottom 2%. Look at the actual cell voltage under no load (open cell voltage) for clues if the cell is fully charged or fully discharged. **Step 4. Check the nominal resistance in the BMS profile to ensure it is proper for the type of cell selected at the temperature where the error code was triggered.** The nominal resistance table can be found in the BMS utility under thermal compensation. The Orion BMS may incorrectly set an error if the nominal resistances in this table are wrong.

Step 5. Manually measure the resistance of the cell at the actual cell terminals.

At this step, it is now likely that either the cell or the busbars connecting the cell to the next cell actually has a high resistance. Cell resistance can be measured by applying a known load (or source) to the battery pack and measuring the voltage drop at the cell. Care must be taken to ensure that the known load or source will not over-charge or over-discharge any cell in the pack as this can cause damage and a serious safety hazard. This can be done by using a multimeter with the leads on *the actual cell terminals* (not the screws, ring terminals, etc). With the leads on the terminals, note the cell voltage with no load (or source). Then apply the known source and measure the cell's voltage again at the terminal after the load has been on 10 seconds. Calculate the cell's DC resistance with the following calculation: DC resistance = (Voltage_before_load – Voltage_after_load) / known_amperage. If the cell is high resistance, replace the cell.

Step 6. If cell resistance is good, look specifically for loose terminals, oxidized terminals, or bad crimps.

The resistance of the busbars and connections will increase dangerously if terminals are loose, oxidized, etc. Busbars and terminals can oxidize or corrode in ways that are not visible or obvious. If there is a question, remove, clean and reseat the busbar or terminal (always disconnect all cell voltage tap and pack voltage connectors from the BMS first!) The resistance of the busbars can be measured by applying a known load (or source) to the battery pack and measuring the voltage drop on the busbar and therefore calculating the resistance. Care must be taken to ensure that the known load or source will not over-charge or over-discharge any cell in the pack as this can cause damage and a serious safety hazard. Using a multimeter capable of measuring voltages in millivolts, measure the voltage between the actual cell terminal of the suspect cell and the actual cell terminal of the next adjacent cell connected to the same busbar. The measurement should read 0.000v (or almost that) with no load. When a known load is applied, make note of the voltage. Typically the voltage drop should only be a few millivolts, but the actual value will vary depending on the amperage used to test and based on the thickness of the busbars and terminals. Because of this, it may be useful to measure the resistance of surrounding busbars for comparison. The resistance of the busbar can be calculated with the following formula: busbar_resistance (in ohms) = Voltage_measured / amperage.

| 5. | **Difference in Open Circuit Voltage:** |

Step 1. Check the cell voltages when the battery pack is fully charged.
Carefully monitoring the battery for unsafe conditions such as high temperature and over-voltage, charge the battery pack up to full charge (use the BMS to control the charger ensuring that no cells get over-charged). When at a full state of charge, compare all cell voltages using the Orion BMS utility or a multimeter. For iron-phosphate cells, the voltage should be compared immediately after the charge termination since the voltages will quickly fall back into the 3.35 volt range and will mask the difference in balance. If the cell in question has a noticeably different voltage than the rest of the pack, the difference in open circuit voltage is likely due to a difference in balance. If the open circuit voltage is identical to the rest of the pack at full state of charge, the issue is likely that the cell has a deteriorated capacity. To confirm deteriorated capacity, cell voltages can be graphed using the data logging and graphing capabilities in the Orion BMS utility and the shape of the discharge curves can be analyzed.

6.	**If the problem persists, contact technical support.** If all above steps fail to determine the cause of the fault then additional support is needed. **Please contact the company or reseller that the BMS was originally purchased from for additional questions, warranty claims, repair requests and technical support.**