BMS Failure Mode Test Report: DC Charging Interface: Test Procedure, Test Report and Graphs

This excerpt is from the **DRAFT** Test Procedures developed by NHTSA to be shared with GTR

Pages 19 - 117

TABLE OF CONTENTS

DRAFT

DRAFT

DRAFT

BMS Failure Mode Test: DC Charging Interface

Test Procedure

1. PURPOSE

This test procedure is one in a series of BMS failure mode test procedures. This procedure is related to BMS Failure Modes focused on DC Charging System Interface. The purpose of this test procedure is to evaluate the failure modes associated BMS interfaces to the DC charging system for a variety of battery / charging system configurations. The test procedures will simulate real world fault conditions that can occur before, during and after the DC charging and determine the reaction of the BMS to those fault conditions to verify that a transition to a safe system state occurs which will reduce the risk for harm to the operator and the vehicle system. Similar test methodologies will be developed for other BMS interfaces (ex. With Hybrid System controller, etc.).

2. SCOPE

The scope of this test procedure will focus on the BMS interface to the DC charging system. The test procedure will document the steps required to create or simulate the failure modes and how to observe and measure the system response. The test procedure will identify the test limits conditions required (ex. temperatures, battery SOC levels) and boundary conditions. Pass/fail criteria for the system response, system limit conditions, measurement criteria and metrics will be identified as part of the test procedure.

3. REFERENCES

3.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of the publication shall apply.

3.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA) www.sae.org

1. SAE J1113 Electromagnetic Compatibility Measurement Procedures and Limits
2. SAE J1715 Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) Terminology,
3. SAE J1739 Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA)
4. SAE J1766 Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing
5. SAE J1772 Recommended Practice for SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler
6. SAE J1797 Recommended Practice for Packaging of Electric Vehicle Battery Modules
7. SAE J1908 Electrical Grounding Practice
8. SAE J2293 Energy Transfer System for Electric Vehicles—Part 2: Communication Requirements and Network Architecture
9. SAE J2464 Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing

DRAFT

10. SAE J2847 Communication Between Plug-in Vehicles and Off-Board DC Chargers
11. SAE J2929 Electric and Hybrid Vehicle Propulsion Battery System Safety Standard -Lithium-based Rechargeable Cells
12. SAE J2931/3 PLC Communication for Plug-in Electric Vehicles
13. SAE J2950 Recommended Practices (RP) for Transportation and Handling of Automotive-type Rechargeable Energy Storage Systems (RESS).
14. SAE J2953 Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE).

3.1.2 IEC Publications

Available from IEC Central Office; 3, rue de Varembé P.O. Box 131 CH - 1211 Geneva 20 - Switzerland Phone : +41 22 919 02 11 Fax : +41 22 919 03 00 webstore.iec.ch

1. IEC 62660-2 Reliability and abuse testing for lithium-ion cells
2. IEC 61010 Safety requirements for electrical equipment for measurement, control and laboratory use

3.1.3 ISO Publications

Available from ISO Central Secretariat; 1, ch. de la Voie-Creuse CP 56 - CH-1211 Geneva 20 Switzerland; Tel. : +41 22 749 01 11; Fax : +41 22 733 34 30 www.iso.org

1. ISO 6469-1 Electric road vehicles – Safety specifications – Part 1: On-board rechargeable energy storage system (RESS)
2. ISO 6469-3 Electric road vehicles — Safety specifications — Part 3: Protection of persons against electric hazards
3. ISO 12405-1Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 1: High-power applications
4. ISO 12405-2 Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 2: High-energy applications
5. ISO 16750-2 Road vehicles — Environmental conditions and testing for electrical and electronic equipment

3.1.4 UL Publications

Available from UL Corporate Headquarters; 333 Pfingsten Road Northbrook, IL 60062-2096. Telephone: +1.847.272.8800. Customer Service: +1.877.UL.HELPS (1.877.854.3577) www.ul.com

1. UL 2580 Batteries for Use in Electric Vehicles

3.1.5 FMVSS Publications

Available from NHTSA; 1200 New Jersey Avenue, SE West Building Washington, DC 20590 www.nhtsa.gov

1. FMVSS 305 Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection
2. Interim Guidance for Electric and Hybrid-Electric Vehicles Equipped With High Voltage Batteries
3. NHTSA Test Procedure TP-581-01 – Standard regulation on bumper standard

DRAFT

3.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this document.

Electric Vehicle Safety Training Resources – Available from the NFPA
http://www.evsafetytraining.org/resources.aspx

STANDARDIZATION ROADMAP FOR ELECTRIC VEHICLES VERSION 2.0 – Available from the ASNI web site:
http://publicaa.ansi.org/sites/apdl/evsp/ANSI_EVSP_Roadmap_May_2013.pdf

4. DEFINITIONS

Active Protection Device

Safety device that consists of a sensor and actuator and is intended for protection from or mitigation of abusive, out-of range conditions experienced by the DUT.

Ambient Temperature

The ambient temperature for any test defined in this document shall be within the range of 25°C ±10°C.

Safe State of the System

For the purposes of this test procedure, Safe State of the System shall be defined as a condition of the vehicle and charger system that shall contain the high voltage within the system boundaries and protect the operator under any operating condition (faulty or not faulty) from getting harmed.

Breakout Box

A breakout box is a device which allows the test technician to introduce certain conditions between the vehicle charge coupler and the DC charger for the purposes of performing the test procedures in this document. It is further described in section 5.4.

BMS

The BMS is the **B**attery **M**anagement **S**ystem that is typically part of the high voltage battery pack. Its purpose is to monitor both the pack and the individual battery cells, calculate and communicate battery status and state of function to other modules in the vehicle in order for the vehicle system to manage the energy flow into and out of the battery. In the event of a system failure, the BMS can also open contactors, which isolate the battery from the rest of the Hybrid system.

DUT

The DUT is the **D**evice **U**nder **T**est which in the context of this procedure is the high voltage battery system and the BMS in particular.

DRAFT

5. GENERAL TEST REQUIREMENTS

5.1 General Precautions

When working on or around high voltage systems, always follow the appropriate safety precautions. Read and follow the recommended service procedures for high voltage systems and high voltage parts for the vehicle/system under test.

Be sure to wear the appropriate personal protective equipment, which includes Class 0 insulated rubber gloves with leather outer gloves. Always inspect the insulated gloves for any defects that might prevent the insulating properties, and do not wear them if they are damaged.

Always observe high voltage warning labels (see examples below).

Examples of high voltage warning labels (Source: GM First Responder Guide)

5.2 Test-Specific Precautions

While working on a vehicle system always ensure that the emergency parking brake is actuated. Additionally block the drive wheels to prevent unintended vehicle movement.

5.3 Safety Requirements

Portions of this test procedure call for the manipulation of high voltage connections and the introduction of ground faults that can be dangerous to the test technician. Personal protection equipment to isolate the operator of the test from high voltage contact is required at all times when contacting high voltage components. Wear eye protection (face shield) at all times while performing and setting up these tests. Use high voltage insulated tools. Wear high voltage isolation gloves while working on high voltage systems or working with a breakout box.

The work shall be performed in a well-ventilated area to allow the safe removal of any smoke or toxic gases. Fire extinguishing equipment shall be available and easily accessible at all times during the test execution.

5.4 Test Facility/ Equipment Requirements

The following equipment is required to conduct the tests defined in this test procedure. The test equipment shall fulfill the general requirements outlined below

- DC fast charger with a voltage range of 0 VDC to 600 VDC and a power range of ≤ 100kW or a battery test system (e.g. BTS-320)
- DC fast charger breakout box with toggle switches to install faults and internal fuse for protection; NOTE: The test resistance R1 should be easily accessible and changeable during the test setup.

DRAFT

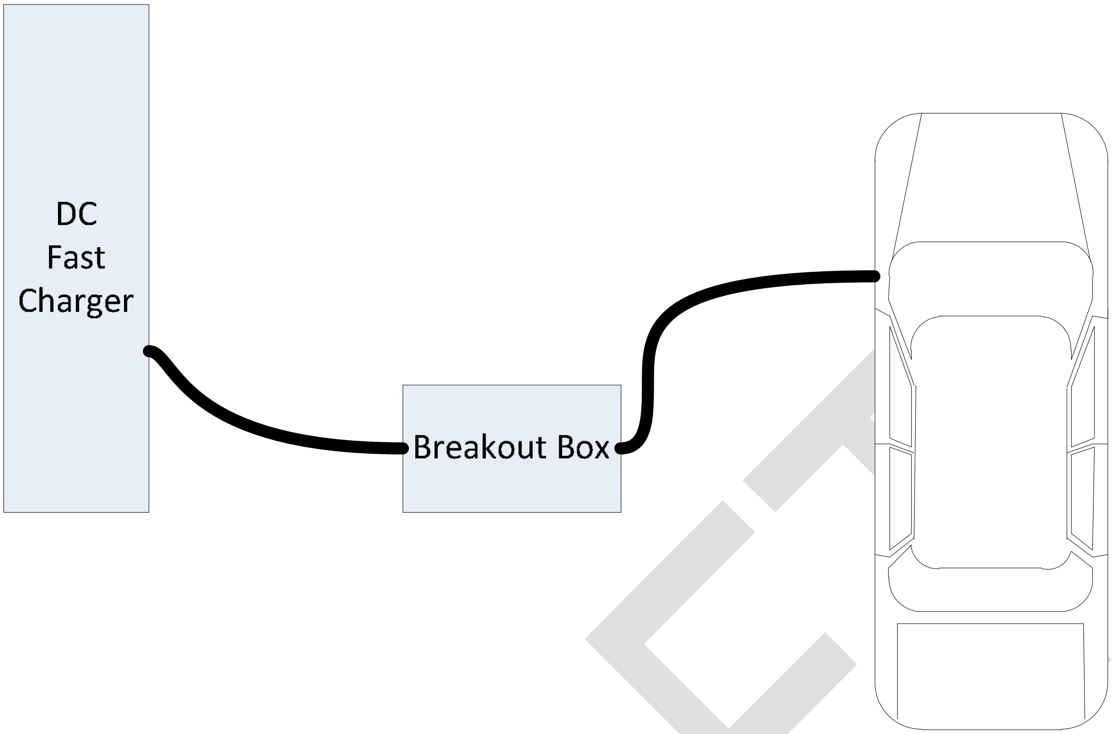


Figure 1 - DC Fast Charge Breakout Box Connection.

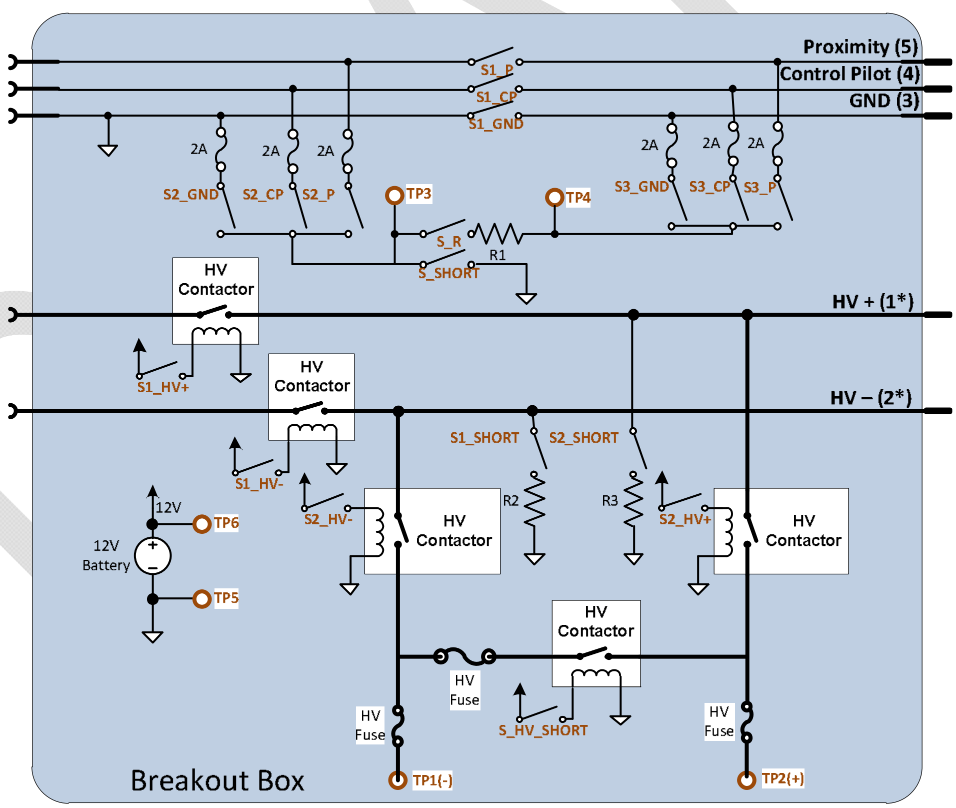


Figure 2 - DC Fast Charge Breakout Box Schematic

- High Voltage Meter to measure DC voltage from 0V to 600V with a minimum safety classification of CAT III according to IEC 61010 (e.g. Fluke 189)
- High Voltage Insulation Tester with a minimum safety classification of CAT III according to IEC 61010, to measure the insulation between high voltage circuits and chassis/earth ground (e.g. Fluke 1503)
- Vehicle specific Scan tool to read & clear diagnostic trouble codes (OEM specific)
- Short circuit protected high voltage power supply (Diode protected against back feeding) (e.g. Magna-Power SL600-2.5)
- Short circuit protected low voltage power supply with voltage regulation from 24V down to 0V with a minimum power of 1200W (e.g. Sorensen XFR 33-85).
- 12V switchable load with a minimum current draw of 20A (@12V), (e.g. automotive fan or pump)
- CAN communication tester/monitor with the ability to generate error frames at a defined rate. (e.g., Vector CANalyzer)

5.5 Test Equipment Calibration

All test equipment shall be maintained and calibrated according to the manufacturer's specific recommendations to ensure valid results conducting the measurements. The calibration certificate shall identify the type of equipment, manufacturer and model number of test equipment along with the measurement range and the accuracy that can be obtained with the test equipment. The test equipment shall clearly identify when the next calibration is due.

5.6 Device Under Test

The device under test for these test procedures is the complete vehicle and DC charger system. A subset of the tests defined in this procedure can also be conducted using a Battery System connected to an external charge station alone or connected to an equivalent battery tester with simulation hardware/software to simulate the charge station operation.

5.7 Test Guidelines

The DUT shall be a representative sample of a number of test objects of identical fit, form and function and similar usage profile. The DUT shall not require any special modifications or alterations in function prior to use for this test procedure. The DUT shall remain installed in the vehicle and all modifications to the vehicle to obtain access for the purpose of parameter measurement shall not alter the overall system configuration (e.g. access to CAN bus shall be with a wire connection as short as possible to prevent the a electrical alteration of the CAN bus configuration).

5.8 Test Parameters

Test temperature	Ambient temperature of 25 ± 10 °C
Beginning SOC	45% to 50% of the maximum normal operating SOC
Ending SOC	[See test procedure details]
Observation period	1 hour at ambient temperature
Relative Humidity	50% ± 25%
Atmospheric Pressure	28 to 32 inches of mercury
System Voltage	12.8V ±0.5V for a 12V vehicle system

DRAFT

5.9 DUT Pre Conditioning

A battery discharge to the system specific minimum SOC level followed by a complete charge operation to the system specific maximum SOC level shall be conducted to verify proper operation of the system prior to testing.

The battery system shall be inspected using the manufacturer recommend service tool to retrieve any fault codes stored. No fault codes shall be present prior to testing.

The DUT shall be soaked at ambient temperature for a sufficient time to ensure internal battery cell temperature has achieved ambient temperature conditions (± 5°C). Depending on the vehicle installation and setup the soak time can be up to 48 hours under constant ambient conditions without exposure to sun load or other heat sources.

6. TEST PROCEDURES

6.1 Ground Fault Test

6.1.1 Purpose

This test will verify that the BMS system reacts appropriately to a loss of or a fault on the ground connection between the vehicle charge port and the charger.

6.1.2 Rationale and Description

A ground fault is a condition where one pole of the DC bus has continuity with ground. This type of fault represents a dangerous condition that can be hazardous to a test technician if not detected and the proper precautions taken.

A ground fault can happen due to contamination (moisture, dust, etc), an internal failure of insulation or breakdown of insulation of cabling due to excess temperature or abrasion.

A loss of the ability to detect a ground isolation fault can be caused by the BMS or charger being in the wrong operating mode, a loss of or impaired connection of the BMS connection to reference ground, or an internal malfunction of the BMS.

This test is designed to determine the effects and the reaction of the BMS to the loss of a ground connection or a fault on the ground connection between the vehicle charge port and the charger and the loss of isolation to ground during a DC charge. The test conditions shall be applied both before a charge session is initiated and during an active charge session to test the effects during different charging modes. The connection to ground will be established through a 30kΩ resistor to prevent harm to the test system in the event that the BMS reaction is not appropriate. The 30kΩ value is chosen so that all possible HV systems (down to 60V) are able to detect the fault (NOTE: The fault threshold for a 60V system would be 500Ω/V * 60V = 30kΩ). Resistor values lower than 30kΩ are not advisable since the heat generation for a high voltage system (e.g. 600V) is too great due to the potential power loss in the event of a dual fault (i.e. The system has already a fault on one HV line to GND prior to testing): P_{loss} = 600V * 600V / 30kΩ = 12W

6.1.3 Sample Preparation

Install the DC charge breakout box between the DC fast charger and the vehicle charging port.

DRAFT

6.1.4 Equipment Setup

Configure the DC charge breakout box to perform the ground fault test with the initial switch setting (Table 1).

Connect the DC charger to the DC charge breakout box (Figure 3).

Connect the DC charge breakout box to the vehicle charge port.

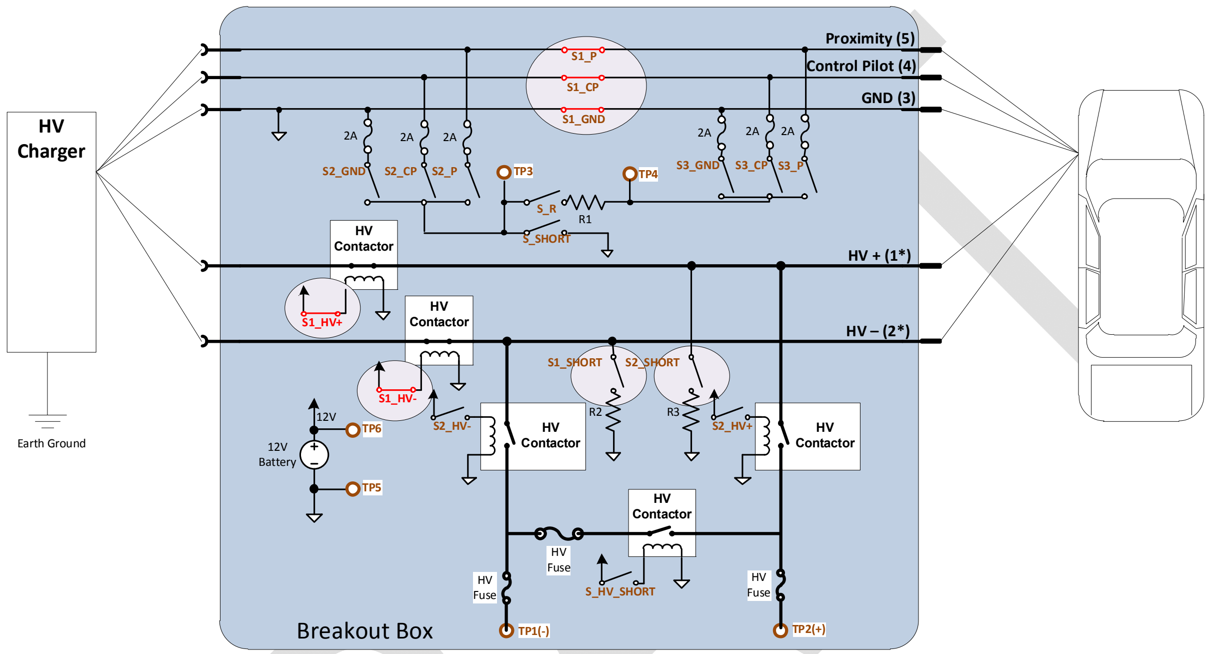


Figure 3 - Initial DC Fast Charge Breakout Box Configuration.

Table 1 - Initial Switch Configuration

CLOSED FOR INITIAL CONFIGURATION AT EQUIPMENT SETUP																	
MANIPULATED DURING TEST																	
S1_P	S1_CP	S1_GND	S2_P	S2_CP	S2_GND	S3_P	S3_CP	S3_GND	S_R	S_SHORT	S1_SHORT	S2_SHORT	S1_HV+	S1_HV-	S2_HV+	S2_HV-	S_HV_SHORT
CLOSED	CLOSED	CLOSED											CLOSED	CLOSED			

6.1.5 Test Method and Procedure

6.1.5.1 Faults Introduced before Charge Session is Initiated:

Fault to ground – DC Positive

1. Introduce a short between the DC positive and the ground connection at the breakout box by **closing** switch **S2_Short**.
2. Attempt to start a charge session.
3. Observe the system behavior. Record any faults on the BMS and the DC fast charge station.
4. Remove the short between the DC positive and the ground connection by **opening** switch **S2_Short**.
5. Clear all faults on the vehicle and key cycle the vehicle.
6. Reset the faults on the charge station as needed.

DRAFT

Fault to ground – DC Negative

1. Introduce a short between the DC negative and the ground connection at the breakout box by **closing** switch **S1_Short**.
2. Plug in the charger and attempt to start a charge session.
3. Observe the system behavior. Record any faults on the BMS and the DC fast charge station.
4. Remove the short between the DC negative and the ground connection by **opening** switch **S1_Short**.
5. Clear all faults on the vehicle and key cycle the vehicle.
6. Reset the faults on the charge station as needed.

Fault – ground connection between station and vehicle removed:

1. Using the breakout box, remove the ground connection between the DC fast charge station and the vehicle by **opening** switch **S1_GND**.
2. Plug in the charger and attempt to start a charge session.
3. Observe the system behavior. Record any faults on the BMS and the DC fast charge station.
4. Replace the previously removed ground connection on the breakout box by **closing** switch **S1_GND** again.
5. Clear all faults on the vehicle and key cycle the vehicle.
6. Reset the faults on the charge station as needed.

6.1.5.2 Faults Introduced During a Fast Charge Session:

Fault to ground – DC Positive

1. Start a charge session.
2. Wait for approximately 1 minute for the charge to initialize and stabilize.
3. Introduce a short between the DC positive and the ground connection at the breakout box by **closing** switch **S2_Short**.
4. Observe the system behavior. Record any faults on the BMS and the DC fast charge station.
5. Stop the charge session.
6. Remove the short between the DC positive and the ground connection by **opening** switch **S2_Short**.
7. Clear all faults on the vehicle and key cycle the vehicle.
8. Reset the faults on the charge station as needed.

Fault to ground – DC Negative

1. Start a charge session.
2. Wait for approximately 1 minute for the charge to initialize and stabilize.
3. Introduce a short between the DC negative and the ground connection at the breakout box by **closing** switch **S1_Short**.
4. Observe the system behavior. Record any faults on the BMS and the DC fast charge station.
5. Stop the charge session.
6. Remove the short between the DC negative and the ground connection by **opening** switch **S1_Short**.
7. Clear all faults on the vehicle and key cycle the vehicle.
8. Reset the faults on the charge station as needed.

DRAFT

Fault – ground connection between station and vehicle removed:

1. Start a charge session.
2. Wait for approximately 1 minute for the charge to initialize and stabilize.
3. Using the breakout box, remove the ground connection between the DC fast charge station and the vehicle by **opening** switch **S1_GND**.
4. Observe the system behavior. Record any faults on the BMS and the DC fast charge station.
5. Stop the charge session.
6. Replace the previously removed ground connection on the breakout box by **closing** switch **S1_GND** again.
7. Clear all faults on the vehicle and key cycle the vehicle.
8. Reset the faults on the charge station as needed.

6.1.6 End of Test Procedure

1. Clear all faults on the vehicle and key cycle the vehicle.
2. Reset the faults on the charge station as needed.
3. Disconnect the vehicle from the DC charge breakout box.
4. Disconnect the charger from the DC charge breakout box.

6.1.7 Documentation and Evaluation

6.1.7.1 Documentation

Fault to ground – DC Positive introduced before charge session is initiated:

Observe the system behavior

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

Fault to ground – DC Negative introduced before charge session is initiated:

Observe the system behavior.

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

Fault – ground connection between station and vehicle removed introduced before fast charge session is initiated:

Observe the system behavior.

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

DRAFT

Fault to ground – DC Positive introduced during a fast charge session:

Observe the system behavior.

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

Fault to ground – DC Negative introduced during a fast charge session:

Observe the system behavior.

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

Fault – ground connection between station and vehicle removed introduced during a fast charge session:

Observe the system behavior.

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

6.1.7.2 Pass Fail Criteria

The pass/fail criteria for the tests above are as follows:
For tests which introduce the fault before the charge has started:
The system shall not start the charge session and the system shall remain in a safe state.
The system shall also set a fault code to identify the problem.

For tests which introduce the fault during the charge:
The system shall stop or abort the charge session and bring the system to a safe state.
The system shall also set a fault code to identify the problem.

6.2 Chassis Ground Offset Test

6.2.1 Purpose

This test will verify that the vehicle and charger system reacts appropriately to an offset on the ground connection between the vehicle charge port and the charger. The test conditions shall be applied both before a charge session is initiated and during an active charge session.

DRAFT

6.2.2 Rationale and Description

The ground between the charge station and the vehicle can become degraded due to increased resistance due to poor connections or failure of a conductor. This condition can result in communication stress (signal offset) causing partial or complete loss of communication. The pilot and proximity signals and/or CAN communication signals can be impaired. This test will introduce a ground offset in the ground connection to determine the reaction of the system.

6.2.3 Sample Preparation

Install the DC charge breakout box between the DC fast charger and the vehicle.

6.2.4 Equipment Setup

Configure the DC charge breakout box to perform the chassis ground offset test with the initial switch setting (Table 2).
Connect the DC charger to the DC charge breakout box (Figure 4).
Connect the DC charge breakout box to the vehicle charge port.

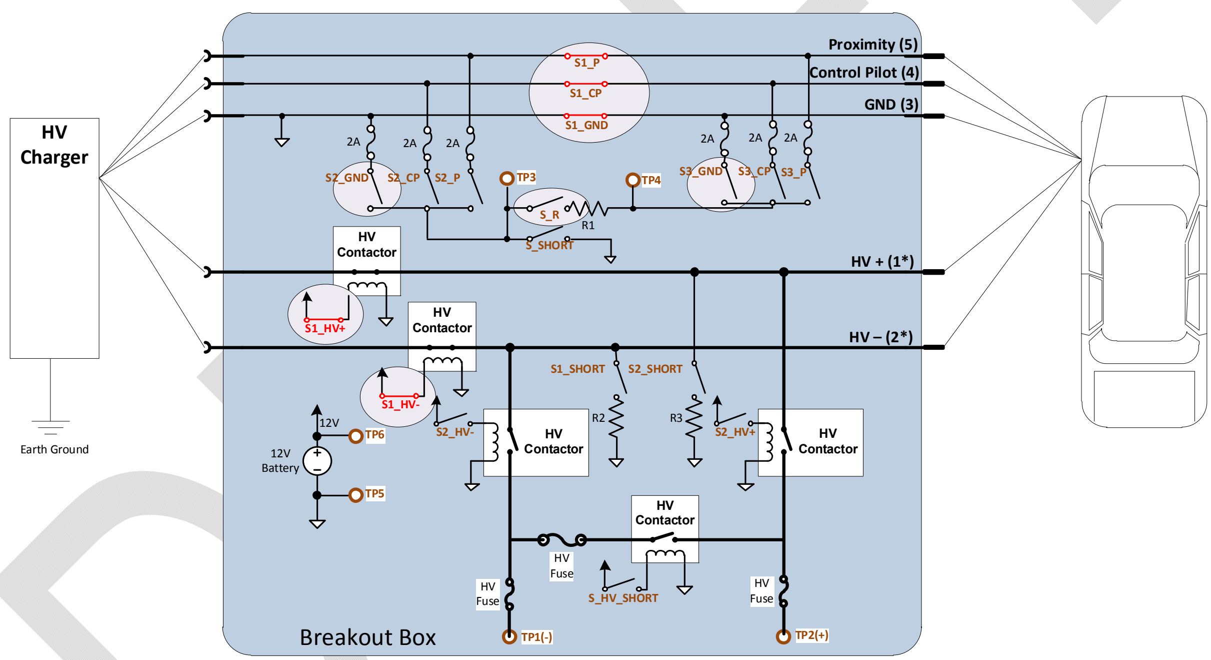


Figure 4 - Initial DC Fast Charge Breakout Box Configuration.

Table 2 - Initial Switch Configuration

CLOSED FOR INITIAL CONFIGURATION AT EQUIPMENT SETUP																	
MANIPULATED DURING TEST																	
S1_P	S1_CP	S1_GND	S2_P	S2_CP	S2_GND	S3_P	S3_CP	S3_GND	S_R	S_SHORT	S1_SHORT	S2_SHORT	S1_HV+	S1_HV-	S2_HV+	S2_HV-	S_HV_SHORT
CLOSED	CLOSED	CLOSED											CLOSED	CLOSED			

Measure the voltage between chassis ground and earth (station) ground (**TP4-TP5**). Record this pre-test value.

DRAFT

6.2.5 Test Method and Procedure

Chassis Ground Offset introduced before a fast charge session

1. Introduce several resistances (1kΩ, 100Ω, 47Ω, 24Ω) between the vehicle and charger ground connections at the breakout box by **closing** switch **S2_GND,S3_GND** and **S_R**.
2. Open the shorting bar connection on the breakout box between the vehicle ground and the charger ground by **opening** switch **S1_GND** leaving only the resistance connected in the above step.
3. Attempt to start a charge session.
4. Observe the system behavior. Record any faults on the BMS and the DC fast charge station.
5. Measure the voltage between chassis ground and earth (station) ground (**TP4-TP5**). Record this value.
6. Remove the resistance installed in step 2 by **opening** switch **S2_GND,S3_GND** and **S_R**.
7. Replace the shorting bar removed in step 3 ground by **closing** switch **S1_GND**.
8. Clear all faults on the vehicle and key cycle the vehicle.
9. Reset the faults on the charge station as needed.
10. Perform test for all resistance values

Chassis Ground Offset introduced during a fast charge session

1. Start a normal charge session.
2. Introduce several resistances (1kΩ, 100Ω, 47Ω, 24Ω) between the vehicle and charger ground connections at the breakout box by **closing** switch **S2_GND,S3_GND** and **S_R**.
3. Open the shorting bar connection on the breakout box between the vehicle ground and the charger ground by **opening** switch **S1_GND** leaving only the resistance connected in the above step.
4. Charge with high power (ramp up current at a rate of **50A/sec,** or the Peak Current Ripple value as defined by the DC charger, to the maximum requested current, followed by a step to zero charge current).
5. Observe the system behavior. Record any faults on the BMS and the DC fast charge station.
6. Measure the voltage between chassis ground and earth (station) ground (**TP4-TP5**). Record this value.
7. Remove the resistance installed in step 2 by **opening** switch **S2_GND,S3_GND** and **S_R**.
8. Replace the shorting bar removed in step 3 ground by **closing** switch **S1_GND**.
9. Clear all faults on the vehicle and key cycle the vehicle.
10. Reset the faults on the charge station as needed.
11. Perform test for all resistance values

6.2.6 End of Test Procedure

1. Using the breakout box, measure the voltage between the vehicle ground and the earth (station) ground (**TP4-TP5**). Record this value.
2. Clear all faults on the vehicle and key cycle the vehicle.
3. Reset the faults on the charge station as needed.

DRAFT

6.2.7 Documentation and Evaluation

6.2.7.1 Documentation

Chassis Ground Offset introduced before a fast charge session

Observe the system behavior.

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

Record the voltage measurement between chassis ground and earth (station) ground, (**TP4-TP5**) ____

Chassis Ground Offset introduced during a fast charge session

Observe the system behavior.

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

Record the voltage measurement between chassis ground and earth (station) ground, (**TP4-TP5**) ____

6.2.7.2 Pass Fail Criteria

The voltage measured between the vehicle ground and the earth ground (**TP4-TP5**) shall be no more than 0.7V per J1772-2012-10 for proper function of the pilot signal.

For tests which introduce the fault before the charge has started:
The system shall not start the charge session and the system shall remain in a safe state.
The system shall also set a fault code to identify the problem.

For tests which introduce the fault during the charge:
The system shall stop or abort the charge and bring the system to a safe state.
The system shall also set a fault code to identify the problem.

6.3 DC Bus Short Test

6.3.1 Purpose

This test procedure will determine if a DC bus short in the vehicle charge coupler can be detected and handled or communicated by the BMS. The test conditions are applied before a charge session is initiated.

DRAFT

6.3.2 Rationale and Description

It is possible for the vehicle coupler to have a short circuit due to tampering with the charge coupler, frayed insulation, etc. This test procedure will introduce a short circuit on the charge coupler prior to a charge session initiation to determine if the BMS can safely detect the short on the coupler before the main charge session is initiated.

6.3.3 Sample Preparation

Install the DC charge breakout box between the DC fast charger and the vehicle.

6.3.4 Equipment Setup

Configure the DC charge breakout box to perform the DC bus short test with the initial switch setting (Table **3**).
Connect the DC charger to the DC charge breakout box (Figure 5).
Connect the DC charge breakout box to the vehicle charge port.
Test the fuse with an ohmmeter before the test to ensure it is not blown (**TP1-TP2**). Replace as necessary.
Record the resistance value of the intact fuse.

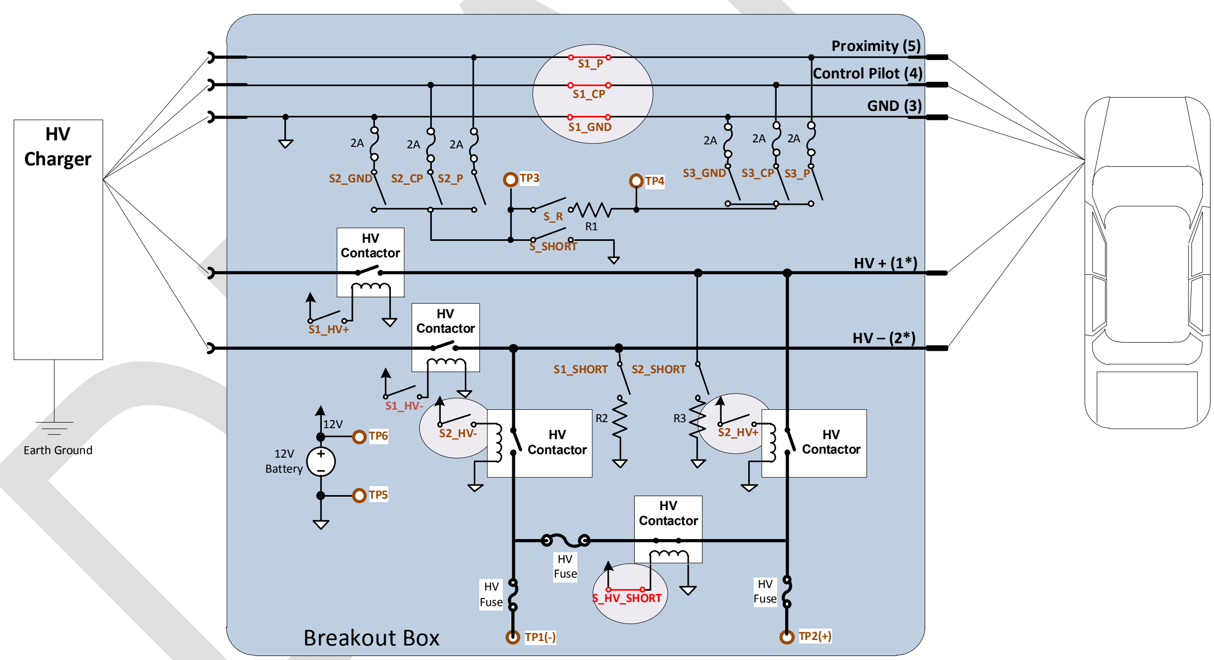


Figure 5 - Initial DC Fast Charge Breakout Box Configuration.

Table 3 - Initial Switch Configuration

CLOSED FOR INITIAL CONFIGURATION AT EQUIPMENT SETUP																	
MANIPULATED DURING TEST																	
S1_P	S1_CP	S1_GND	S2_P	S2_CP	S2_GND	S3_P	S3_CP	S3_GND	S_R	S_SHORT	S1_SHORT	S2_SHORT	S1_HV+	S1_HV-	S2_HV+	S2_HV-	S_HV_SHORT
CLOSED	CLOSED	CLOSED															CLOSED

DRAFT

6.3.5 Test Method and Procedure

DC Bus Short in Charge Coupler

1. Introduce a fused short between the DC positive and DC negative on the Vehicle Side at the breakout box by **closing** switch **S2_HV-** and **S2_HV+**.
2. Attempt to start a normal charge session.
3. Observe the system behavior. Record any faults on the BMS and the DC fast charge station.
4. Remove the short installed in Step 2 box by **opening** switch **S2_HV-** and **S2_HV+**.
5. Measure the fuse with an ohmmeter to determine if it is blown (**TP1-TP2**). Record the resistance value.
6. Clear all faults on the vehicle and key cycle the vehicle.
7. Reset the faults on the charge station as needed.

6.3.6 End of Test Procedure

Disconnect the vehicle and charger from the DC charge breakout box.

Measure the resistance of the fuse after it is removed from the test equipment to determine if the fuse has been blown (**TP1-TP2**). Record the condition of the fuse.

6.3.7 Documentation and Evaluation

6.3.7.1 Documentation

DC Bus Short in Charge Coupler

Observe the system behavior.

Record any faults on the BMS and the DC fast charge station ____.

Measure the fuse (**TP1-TP2**) with an ohmmeter to determine if it is blown. Record the resistance value____.

6.3.7.2 Pass Fail Criteria

The charge session shall not start if the fault is present.
The fuse shall not be damaged.

6.4 DC Bus Held High Test

6.4.1 Purpose

The purpose of this test procedure is to determine the reaction of the vehicle and DC charging system to a vehicle DC bus being held high during disconnect, which means that a potential high voltage is still present at the two charge connector pins.

DRAFT

6.4.2 Rationale and Description

It is possible that the DC bus is held high after disconnect. This can occur if the DC bus discharge that should occur after the charger disconnects from the vehicle is interrupted or the bus voltage measurement does not match the actual bus voltage during the initial connection. DC bus voltage can also be held high if a faulty DC/DC converter is back feeding to the high voltage DC bus. This test will emulate this condition to determine how the system will react to this type of fault.

6.4.3 Sample Preparation

Install the DC charge breakout box between the vehicle and the DC charger.

6.4.4 Equipment Setup

Configure the DC charge breakout box to perform the DC Bus Held High test with the initial switch setting (Table 4).
Connect the DC charger to the DC charge breakout box (Figure 6).
Connect the DC charge breakout box to the vehicle charge port.
Configure a high voltage power supply with diode protection to prevent negative current flow.
Attach the power supply's leads to the breakout box test points: negative connection to TP1(-) and positive connection to TP2(+).
Please refer to the test procedure schematic, below.

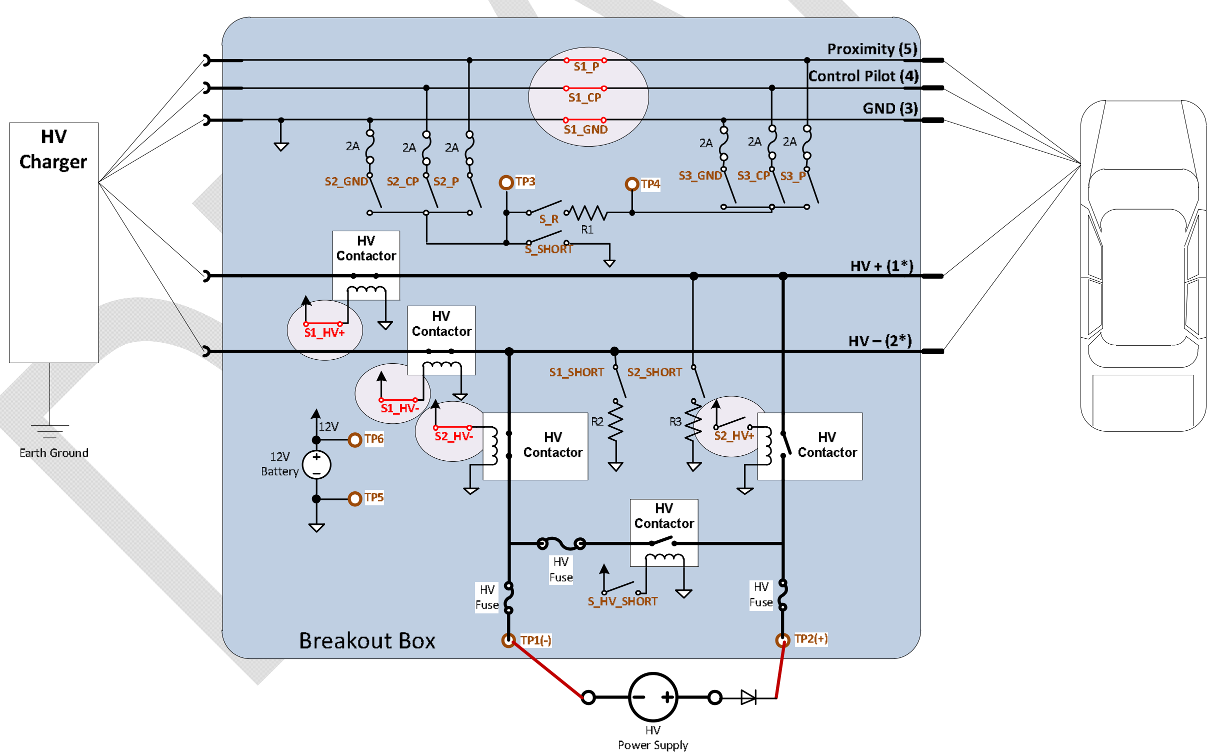


Figure 6 - Initial DC Fast Charge Breakout Box Configuration.

Table 4 - Initial Switch Configuration

CLOSED FOR INITIAL CONFIGURATION AT EQUIPMENT SETUP																	
MANIPULATED DURING TEST																	
S1_P	S1_CP	S1_GND	S2_P	S2_CP	S2_GND	S3_P	S3_CP	S3_GND	S_R	S_SHORT	S1_SHORT	S2_SHORT	S1_HV+	S1_HV-	S2_HV+	S2_HV-	S_HV_SHORT
CLOSED	CLOSED	CLOSED											CLOSED	CLOSED		CLOSED	

DRAFT

6.4.5 Test Method and Procedure

DC bus held high before charging session is started:

1. Using the breakout box, connect the DC bus of the charge coupler to a high voltage power supply (Diode protected to prevent negative current flow) by **closing** the switch **S2_HV+**.
2. Set the power supply to voltage control mode with a current limit.
3. Set the voltage to 60 VDC (+5/-0) and the maximum current to 1A.
4. Start a charge session.
5. Observe the system behavior.
6. Record any faults on the BMS and the DC fast charge station.
7. Remove the connection to the power supply by **opening** the switch **S2_HV+**.

DC bus held high after charging session is ended:

1. Start a normal charge session through the breakout box.
2. Measure the high voltage of the REES (at **TP1-TP2**) and record.
3. Set the power supply to voltage control mode with a current limit.
4. Set the voltage to the RESS voltage measure in step 2. (+5/-0 VDC) and the maximum current to 1A.
5. Using the breakout box, connect the DC bus of the charge coupler to a high voltage power supply (Diode protected to prevent negative current flow) by **closing** the switch **S2_HV+**.
6. End the charge session.
7. Observe the system behavior.
8. Record any faults on the BMS and the DC fast charge station.
9. Remove the connection to the power supply by **opening** the switch **S2_HV+**.

6.4.6 End of Test Procedure

Remove the connection to the power supply by **opening** the switch **S2_HV+**.
Remove the breakout box from the system

6.4.7 Documentation and Evaluation

6.4.7.1 Documentation

DC bus held high before charging session is started:

Observe the system behavior.

Record any faults on the BMS and the DC fast charge station

____.

DC bus held high after charging session is ended:

Observe the system behavior.

Record any faults on the BMS and the DC fast charge station.

____.

Check and record if charge connector can be disconnected from the vehicle

____.

DRAFT

6.4.7.2 Pass Fail Criteria

The charge session shall not start if the fault is present at the beginning of the charge session.

The vehicle and charger system shall not allow the charge connector to be removed from the vehicle coupler if the voltage is held high at the end of a charge session.

6.5 System Overvoltage Test (12V Board Net)

6.5.1 Purpose

The purpose of this test procedure is to simulate an overvoltage on the 12V net during a DC charge session to determine the reaction of the vehicle and charger system to this condition.

6.5.2 Rationale and Description

It is possible for the 12V system on the vehicle to experience an overvoltage due to faulty DC/DC converter or external jump starting or external charging of the 12V battery during a DC fast charge. This test shall introduce this condition to determine how the vehicle and charger system reacts.

6.5.3 Sample Preparation

Install a high power DC power supply in place of the 12V lead acid battery in the vehicle (Figure 7). Ensure that the 12V power to the vehicle is never interrupted during the installation.

6.5.4 Equipment Setup

Configure the DC power supply to provide 12V power to the vehicle to enable a 12V System Overvoltage Test.

Connect the DC charger to the vehicle charge port (without break out box installed).

Refer to the schematic of the test procedure, below. In vehicle systems where there is a DCDC connected to the 12V battery and is activated during charging, it has to be ensured that this DCDC does not interfere with the reduction of the 12V system voltage. It is therefore necessary to either disconnect the DCDC 12V output from the vehicle system (if it is determined that it will not interfere with the charging operation) or alternatively it is possible to install a 150Ohm (100W) resistor at the output of the DCDC inline to the 12V board net. This resistor will limit the current the DCDC can provide to the 12V board net and allow the test to be conducted.

DRAFT

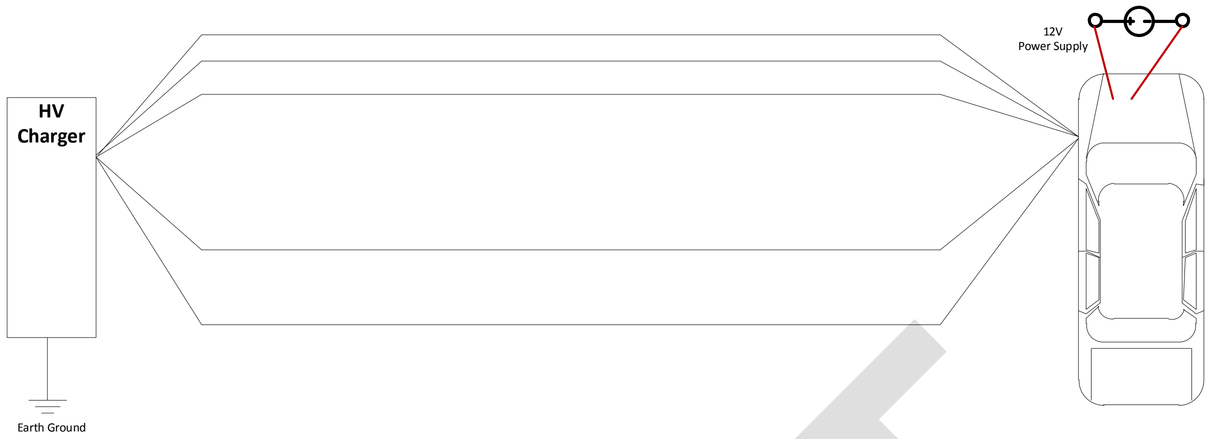


Figure 7 - 12V Power Supply Connection.

6.5.5 Test Method and Procedure

12V system overvoltage

1. Conduct an over voltage test according to ISO 16750-2 for overvoltage conditions.
2. Attempt to start a charge session while applying the conditions outlined in ISO 16750-2 for overvoltage (**18V** for **60 minutes**).
3. Observe the system behavior.
4. Record any faults on the BMS and the DC fast charge station.
5. Return the vehicle 12V system to normal (set DC power supply to 12V).

12V system overvoltage due to jump start condition

1. Conduct an over voltage test according to ISO 16750-2 for jump start overvoltage conditions.
2. Attempt to start a charge session while applying the conditions outlined in ISO 16750-2 for jump start (**24V** for **60 seconds**).
3. Observe the system behavior.
4. Record any faults on the BMS and the DC fast charge station.
5. Return the vehicle 12V system to normal (set DC power supply to 12V).

6.5.6 End of Test Procedure

Return the vehicle 12V system to the original configuration (reinstall 12V lead acid battery).

6.5.7 Documentation and Evaluation

6.5.7.1 Documentation

Document any abnormal behavior from the vehicle or the charger.

____

Document any diagnostic trouble codes in the vehicle after the test.

____

Document any diagnostic trouble codes in the charger after the test.

____

DRAFT

12V system overvoltage
Observe the system behavior.
Record any faults on the BMS and the DC fast charge station.

____

12V system overvoltage due to jump start condition
Observe the system behavior.
Record any faults on the BMS and the DC fast charge station.

____

6.5.7.2 Pass Fail Criteria

The pass criterion for this test shall be a successful charge session or the system shall disconnect and bring the system to a safe state.

6.6 12V System Under voltage Test

6.6.1 Purpose

The purpose of this test is to simulate the gradual discharge of the 12V battery during a fast charge.

6.6.2 Rationale and Description

It is possible for the vehicle's 12V system to experience an under voltage condition during a DC fast charge. This can be due to a faulty DC/DC converter, a loss of connection between the DC/DC and the 12V battery, a faulty 12V battery or the operator leaving on a high current draw accessory during a DC fast charge. This test will introduce this condition to determine how the vehicle and charger system will react to this condition.

6.6.3 Sample Preparation

Install a high power DC power supply in place of the 12V lead acid battery in the vehicle (Figure 8). Ensure that the 12V power to the vehicle is never interrupted during the installation. Alternatively to the DC power supply, a low capacity lead acid battery (4Ah-8Ah) can be used in combination with a low power supply to provide a slowly dropping 12V system voltage.

6.6.4 Equipment Setup

Prepare the power supply according to ISO 16750-2 test “Slow decrease and increase of supply voltage” by setting the starting voltage to 13.2V (or use a fully charged low capacity lead acid battery).
Connect the DC charger to the vehicle charge port (without break out box installed).
Refer to the schematic of the test procedure, below. In vehicle systems where there is a DCDC connected to the 12V battery and is activated during charging, it has to be ensured that this DCDC does not interfere with the reduction of the 12V system voltage. It is therefore necessary to either disconnect the DCDC 12V output from the vehicle system (if it is determined that it will not interfere with the charging operation) or alternatively it is possible to install a 150Ohm (100W) resistor at the output of the DCDC inline to the 12V board net. This resistor will limit the current the DCDC can provide to the 12V board net and allow the test to be conducted.

DRAFT

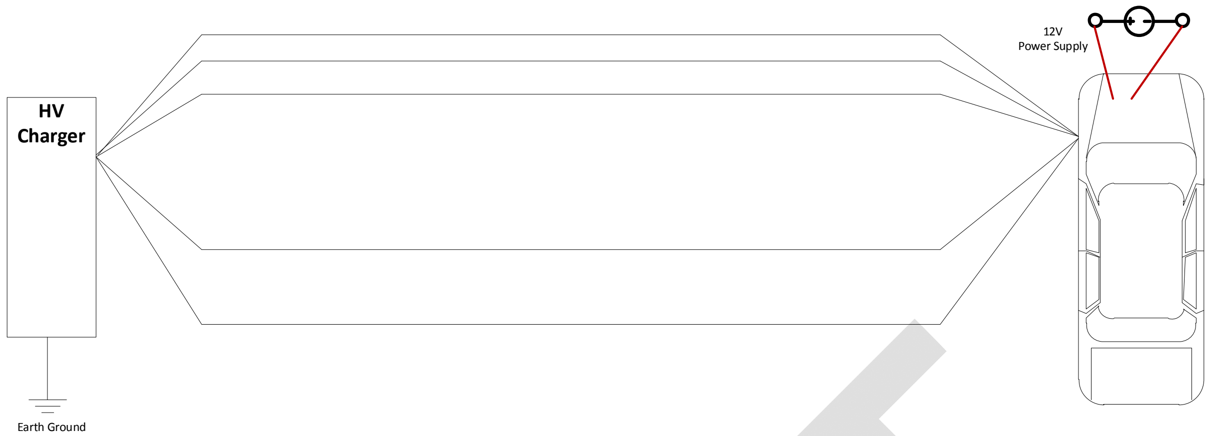


Figure 8 - 12V Power Supply Connection.

6.6.5 Test Method and Procedure

12V system under voltage due to battery discharge

1. Verify that the DC power is set to **13.2V**.
2. Start a charge session.
3. Apply the conditions outlined in ISO 16750-2 for "Slow decrease of supply voltage": Simulate a gradual discharge of the 12V battery with the DC power by supplying the vehicle board with a regulated voltage from a **starting value** of **13.2V** at the beginning of the DC fast charge, **down to** **0V** **at a rate** of **0.5V/min**.
   Note: If possible adjust the DC fast charge rate to be active during the entire duration of the board net voltage slew (26 minutes)
4. Observe the system behavior during the entire charge cycle until the board net voltage of 0V is reached or the charger/vehicle systems enters a permanent fault state.
5. Record any faults on the BMS and the DC fast charge station.
6. Return the vehicle 12V system to normal by reinstalling the 12V battery.

6.6.6 End of Test Procedure

Return the vehicle 12V system to normal by reinstalling the 12V battery.
Clear any codes set in the vehicle or charger.

6.6.7 Documentation and Evaluation

6.6.7.1 Documentation

Document any abnormal observations during the test. This includes any contactors disconnecting, chattering relays, etc.

____

Document when the charge stopped (time and 12V voltage)

____

Document any DTCs from the vehicle.

____

DRAFT

Document any DTCs from the charger.

____

12V system under voltage due to battery discharge

Observe the system behavior during the entire charge cycle until the board net voltage of 0V is reached.

Record any faults on the BMS and the DC fast charge station.

____

6.6.7.2 Pass Fail Criteria

The pass criterion for this test shall be if the charge session stops during the test and the vehicle and charger system is brought to a safe state.

6.7 12V System Disturbance Test

6.7.1 Purpose

The purpose of this test is to simulate a switching 12V load application which can disturb the stability of the12V net.

6.7.2 Rationale and Description

It is possible that a large 12V load turning on and off, such as a pump, fan, aftermarket system, or jump starting a second car, can cause disturbances in the 12V system in the vehicle. These fluctuations, if severe enough, may cause different modules on the vehicle to malfunction during a DC fast charge. This test shall introduce this condition to determine what the reaction of the vehicle and charger system will be.

6.7.3 Sample Preparation

Connect the vehicle to the DC charging system normally, without the breakout box (Figure 9).

6.7.4 Equipment Setup

Prepare the power supply according to ISO 16750-2 test “Slow decrease and increase of supply voltage” by setting the starting voltage to 13.2V.

Connect the DC charger to the vehicle charge port (without break out box installed).

Refer to the schematic of the test procedure, below. In vehicle systems where there is a DCDC connected to the 12V battery and is activated during charging, it has to be ensured that this DCDC does not interfere with the reduction of the 12V system voltage. It is therefore necessary to either disconnect the DCDC 12V output from the vehicle system (if it is determined that it will not interfere with the charging operation) or alternatively it is possible to install a 150Ohm (100W) resistor at the output of the DCDC inline to the 12V board net. This resistor will limit the current the DCDC can provide to the 12V board net and allow the test to be conducted.

DRAFT

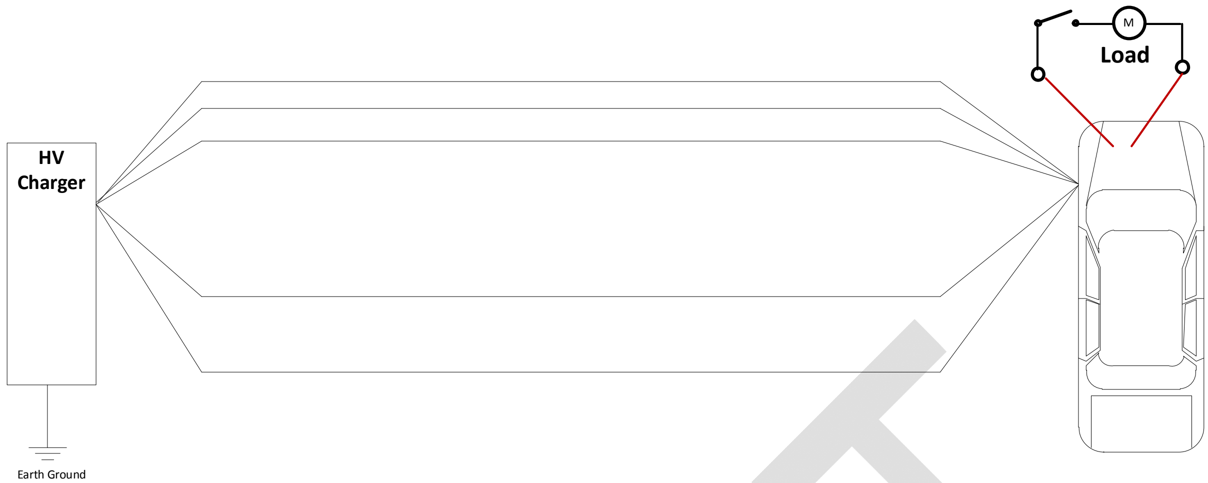


Figure 9 - 12V Load Connection.

6.7.5 Test Method and Procedure

Alternating current pulse applied to LV system while charging:

1. Connect a 20A load to the LV system of the BMS supply. (pump, fan, heater etc)
2. Toggle the load at a **1 Hz** rate on/off.
3. Start a charge session
4. Observe the system behavior
5. Record any faults on the BMS and the DC fast charge station.
6. Remove the load from the vehicle 12V system.

6.7.6 End of Test Procedure

Remove the load from the vehicle 12V system.

6.7.7 Documentation and Evaluation

6.7.7.1 Documentation

Alternating current pulse applied to LV system while charging:

Observe the system behavior

Record any faults on the BMS and the DC fast charge station.

____

6.7.7.2 Pass Fail Criteria

The test shall be considered a PASS if the vehicle or charger does not react to the load switching and the DC charge session is not interrupted.

DRAFT

6.8 12V System EMI/EMC Test

6.8.1 Purpose

The purpose of this test procedure is to determine if electromagnetic disturbances can affect the DC charging system.

6.8.2 Rationale and Description

It is possible that large electromagnetic disturbances during a DC fast charge can affect the low voltage power system and disturb communication between vehicle components. This test shall introduce this type of condition during a DC fast charge and determine the reaction of the vehicle/charger system.

6.8.3 Sample Preparation

Prepare the vehicle and charger system to perform a normal DC fast charge.

6.8.4 Equipment Setup

Prepare the EMI/EMC equipment per SAE test procedures J1113-3, -4, -21, and -24.

6.8.5 Test Method and Procedure

Electromagnetic Disturbance during DC Fast Charge:

1. Conduct the EMI/EMC vehicle level SAE test procedures according to SAE J1113-3,-4,-21,-24 to the extent to which it is feasible.
2. Start a charge session.
3. Observe the behavior of the system.
4. Record any faults on the BMS and the DC fast charge station.

6.8.6 End of Test Procedure

Remove the test equipment.
Record and then clear any codes that may have set in the vehicle or the charger.

6.8.7 Documentation and Evaluation

6.8.7.1 Documentation

Document any vehicle DTCs that occurred during the test.
Document any charger DTCs that occurred during the test.

Observe the behavior of the system.

Record any faults on the BMS and the DC fast charge station.

6.8.7.2 Pass Fail Criteria

The test shall be considered to have passed if no DTCs are set and the DC charge session ends normally and did not stop prematurely.

DRAFT

6.9 Vehicle Movement Test

6.9.1 Purpose

The purpose of this test is to determine if the drive away interlocks of the vehicle system are effective during a DC fast charge.

6.9.2 Rationale and Description

It is possible that the operator of the vehicle will inadvertently try to drive off while the charger is still connected. It is also possible that the vehicle could roll away during a DC fast charge due to faulty park pawl mechanism or park brake mechanism. This test shall introduce this condition during the DC fast charge to determine what the reaction of the vehicle/charger system will be.

6.9.3 Sample Preparation

Position the vehicle so that it can be easily jacked up using a floor jack.
Connect the vehicle to the DC charger.

6.9.4 Equipment Setup

There are no specific equipment setup instructions for this test.

6.9.5 Test Method and Procedure

Vehicle Drive Away Attempt during DC Fast Charge

1. Start a normal charge session.
2. **Release** the parking brake.
3. Observe system behavior.
4. Get inside the vehicle and attempt to **turn on** the vehicle
5. Observe system behavior.
6. **Move the PRND** gear shift lever to the Drive position.
7. Observe system behavior.
8. **Move the PRND** gear shift lever to the Neutral position.
9. **Move the PRND** gear shift lever to the Reverse position.
10. Observe the system behavior.
11. Record any faults on the BMS and the DC fast charge station.
12. Clear all faults on the vehicle and key cycle the vehicle.
13. Reset the faults on the charge station as needed.

Simulated vehicle movement during DC fast charge:

1. Start a normal charge session
2. Elevate one or more wheels on the vehicle.
3. Attempt to **rotate** the wheels at a rate of **1 rev/s** (app 5mph) during the charge.
4. Observe the system behavior.
5. Record any faults on the BMS and the DC fast charge station.
6. Clear all faults on the vehicle and key cycle the vehicle.
7. Reset the faults on the charge station as needed.

DRAFT

6.9.6 End of Test Procedure

Lower the vehicle from the jack

6.9.7 Documentation and Evaluation

6.9.7.1 Documentation

Vehicle Movement during DC Fast Charge

Record system behavior to parking brake release.

____

Record system behavior to attempt to turn on the vehicle.

____

Record system behavior to PRND gear shift lever movement to Drive position.

____

Record system behavior to PRND gear shift lever movement to Neutral position.

____

Record system behavior to PRND gear shift lever movement to Reverse position.

____

Record any faults on the BMS.

____

Record any faults on the DC fast charge station.

____

Simulated vehicle movement during DC fast charge:

Record system behavior to attempt to rotate the wheels during the charge.

____

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

6.9.7.2 Pass Fail Criteria

The test has failed if any unintended vehicle movement is allowed during a fast charge.

Ideally, the BMS should detect the vehicle movement, and stop the charge with a vehicle initiated shutdown.

DRAFT

6.10 Vehicle Crash or Bump Test

6.10.1 Purpose

The purpose of this test is to determine the reaction of the BMS to a low energy collision during a DC fast charge.

6.10.2 Rationale and Description

The typical DC fast charger is located in a public parking lot. It is inevitable that a slow speed collision will occur to an actively charging vehicle during a DC fast charge. This test shall introduce this condition to determine the reaction of the BMS to such an event.

A low speed collision would likely cause vehicle movement which may cover this condition.

If the vehicle movement test (section 6.9) results in a pass, this test may be omitted.

6.10.3 Sample Preparation

Ensure that the vehicle high voltage system has no isolation fault that will endanger the test personnel. Perform an isolation test according to SAE J1766 at the HV terminals of the charge connector prior to performing this test procedure.

Prepare the vehicle and test fixture for an impact equivalent to FMVSS Test Procedure TP-581, pendulum impact test. It is not necessary to duplicate the full TP-581 instrumentation and data recording. It is only necessary to subject the vehicle to an equivalent impact during the charge session.

In deviation from TP-581, the vehicle shall be parked normally with the parking brake engaged. Do not place the vehicle in neutral as specified in TP-581 as this is not the typical condition during a fast charge session.

6.10.4 Equipment Setup

Set up the pendulum test device according to FMVSS Test Procedure TP-581.

6.10.5 Test Method and Procedure

Simulated vehicle Crash or Bump during DC Fast Charge (front impact)

1. Plug the vehicle in to the DC fast charger
2. Start a charge session
3. Wait for 1 minute for the charger and vehicle to connect and stabilize.
4. Impact the vehicle in the front with the pendulum test device (PTD) at 2.3 +/- 0.1 MPH using the Bumper Impact Block Test Device as defined in TP-581.
5. Observe the state of the charger and vehicle system.
6. Record any faults on the BMS and the DC fast charge station.
7. Record any damage of the charger coupler or cable.
8. Clear all faults on the vehicle and key cycle the vehicle.
9. Reset the faults on the charge station as needed.

DRAFT

Simulated vehicle Crash or Bump during DC Fast Charge (rear impact)

1. Plug the vehicle in to the DC fast charger
2. Start a charge session
3. Wait for 1 minute for the charger and vehicle to connect and stabilize.
4. Impact the vehicle in the rear with the pendulum test device (PTD) at 2.3 +/- 0.1 MPH.
5. Observe the state of the charger and vehicle system.
6. Record any faults on the BMS and the DC fast charge station.
7. Record any damage of the charger coupler or cable.
8. Clear all faults on the vehicle and key cycle the vehicle.
9. Reset the faults on the charge station as needed.

6.10.6 End of Test Procedure

Perform a post test safety inspection to ensure that no high voltage safety violation is present (e.g. disconnected or damaged HV connectors/wires, debris or sharp edges). Inspect all cables and connectors between fast charger and vehicle.

6.10.7 Documentation and Evaluation

6.10.7.1 Documentation

Simulated vehicle Crash or Bump during DC Fast Charge (front impact)

Record system behavior to attempt to charge the vehicle.

____

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

Simulated vehicle Crash or Bump during DC Fast Charge (rear impact)

Record system behavior to attempt to charge the vehicle.

____

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

6.10.7.2 Pass Fail Criteria

The vehicle and charger system shall remain in a safe state with no exposed energized components due to damaged components or subsystems.

DRAFT

6.11 Charge Operation Disturbance Test

6.11.1 Purpose

The purpose of this test is to determine if abnormal actions by the operator can cause an unsafe condition during a DC fast charge.

6.11.2 Rationale and Description

It is possible that unintended conditions for either the vehicle or the charger can be realized by unexpected inputs to either the vehicle or charger during a DC fast charge. This test is designed to test the reaction of the vehicle/charger system to a series of unexpected inputs during a DC fast charge.

6.11.3 Sample Preparation

Connect the vehicle to the DC charging system normally, without the breakout box.

6.11.4 Equipment Setup

There are no specific equipment setup instructions for this test.

6.11.5 Test Method and Procedure

Premature disconnect attempt:
1. Begin a normal charge session
2. After the charge has begun successfully, attempt to disconnect the charge coupler from the vehicle without pressing the stop button on the charger.
3. Record the results

Operator interference at the charger:
1. Begin a normal charge session
2. After the charge has begun successfully, press all the available operator accessible buttons on the DC fast charger
3. Record the results.

Wiggle the connector
1. Begin a normal charge session
2. After the charge has begun successfully, wiggle the charger connector while it is plugged in to the vehicle.
3. Record the results.

Operator interference on the vehicle:
1. Begin a normal charge session
2. After the charge has begun successfully, turn on the vehicle ignition
3. Record the results

DRAFT

Operator interference with the vehicle key fob:

1. Begin a normal charge session
2. After the charge has begun successfully, press all key fob functions on the vehicle transmitter/key
3. Record the result

Operator interference with a remote telematics command:

1. Begin a normal charge session
2. After the charge has begun successfully, exercise all Telematics functions (unlock doors, turn on HVAC remotely during a charge, etc)
3. Record the result

6.11.6 End of Test Procedure

Disconnect the vehicle from the DC charging system.

Record and then clear any codes that may have set in the vehicle or the charger.

6.11.7 Documentation and Evaluation

6.11.7.1 Documentation

Premature disconnect attempt

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

Operator interference at the charger

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

Wiggle the connector

Record System Behavior

____

Record any faults on the BMS

____

DRAFT

Record any faults on the DC Fast Charge Station

____

Operator interference on the vehicle

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

Operator interference with the vehicle key fob

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

Operator interference with a remote telematics command

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

6.11.7.2 Pass Fail Criteria

In all the test instances above, the vehicle and charger shall result in either no reaction, a vehicle initiated shutdown, or a charger initiated shutdown and the vehicle/charger system shall remain in a safe state.

6.12 Charge Connector Control Signal Disturbance Test

6.12.1 Purpose

The purpose of this test procedure is to determine the reaction to control signal disturbances between the vehicle and the fast charger.

DRAFT

6.12.2 Rationale and Description

It is possible that disturbances in the control signals in the charge coupler connector can cause loss of control of the charge session and potentially hazardous situations. These control signals can include field ground, CAN communication, pilot (including PLC over pilot), and proximity signals. PLC signals can degrade due to disturbances induced from the grid (e.g. arc welder, compressor, etc) or incompatible devices on the network. CAN signals can degrade due to increased resistance, too many error frames or a "bus-off" condition on the CAN bus, duplicate messages with the identical charger ID, excess bus loading, etc. The physical connection can degrade or break due to contamination in the charge coupler or connector terminals. The connector can even forcefully "break-away" during a charge session if any vehicle movement or a minor collision is experienced. This test will subject the vehicle/charger system to these types of conditions to determine the reaction of the vehicle/charger system.

6.12.3 Sample Preparation

Install the DC charge breakout box between the vehicle and the DC charger.

6.12.4 Equipment Setup

Configure the DC charge breakout box to perform the Charge Connector Control Signal Disturbance test with the initial switch setting shown in

DRAFT

Table 5.

Connect the DC charger to the DC charge breakout box (Figure 6).

Connect the DC charge breakout box to the vehicle charge port.

Please refer to the test procedure schematic, below.

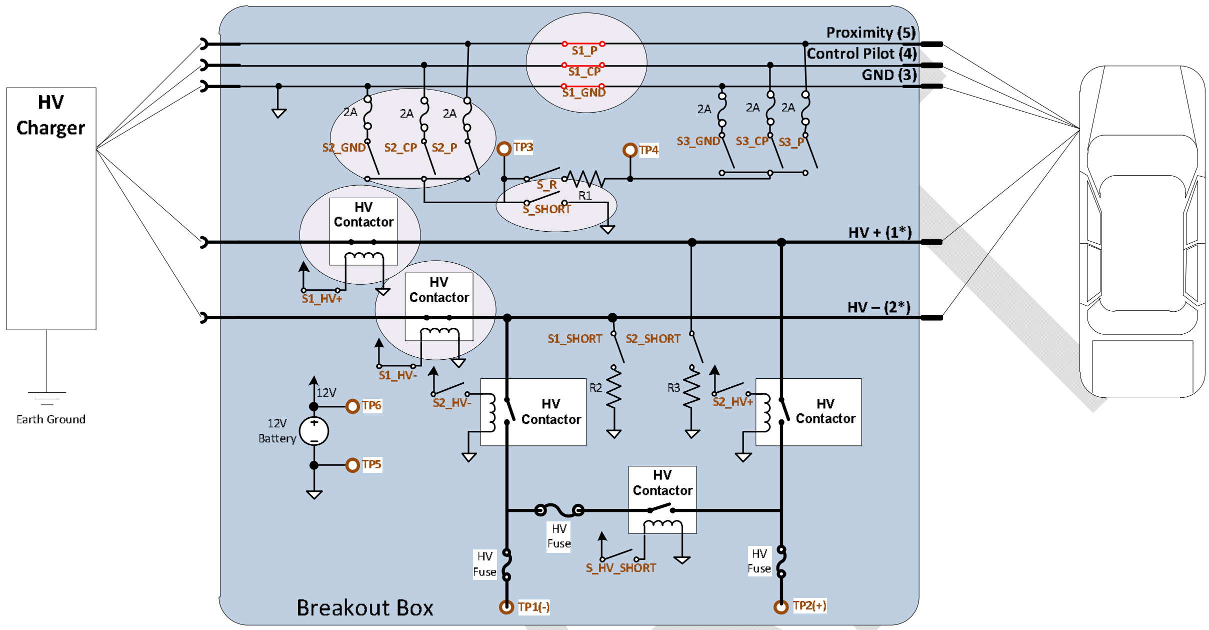


Figure 10 - Initial Breakout Box Configuration for Control Signal Disturbance Test

DRAFT

Table 5 - Initial switch configuration for Control Signal Disturbance Test.

CLOSED FOR INITIAL CONFIGURATION AT EQUIPMENT SETUP																	
MANIPULATED DURING TEST																	
S1_P	S1_CP	S1_GND	S2_P	S2_CP	S2_GND	S3_P	S3_CP	S3_GND	S_R	S_SHORT	S1_SHORT	S2_SHORT	S1_HV+	S1_HV-	S2_HV+	S2_HV-	S_HV_SHORT
CLOSED	CLOSED	CLOSED											CLOSED	CLOSED			

6.12.5 Test Method and Procedure

Communication connection interrupted in breakout box during charge session (Control pilot interruption through breakout box):

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session.
3. Break the control pilot connection in the breakout box by **opening** **S1_CP** switch.
4. Observe the system behavior
5. Record any faults from the BMS and the DC charge station.
6. Return the breakout box switches to the initial state.

Communication connection interrupted in breakout box during charge session (Control pilot short to ground through breakout box):

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session.
3. Short the control pilot connection in the breakout box to ground by **closing** the **S2_CP** and **S_SHORT** switches.
4. Observe the system behavior
5. Record any faults from the BMS and the DC charge station.
6. Return the breakout box switches to the initial state.

Communication connection interrupted in breakout box during charge session (Proximity interruption through breakout box):

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session.
3. Break the proximity signal connection in the breakout box by **opening** the **S1_P** switch.
4. Observe the system behavior
5. Record any faults from the BMS and the DC charge station.
6. Return the breakout box switches to the initial state.

Communication connection interrupted in breakout box during charge session (Proximity short to ground through breakout box):

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session.
3. Short the proximity signal connection in the breakout box to ground by **closing** the **S2_P** and **S_SHORT** switches
4. Observe the system behavior
5. Record any faults from the BMS and the DC charge station.
6. Return the breakout box switches to the initial state.

DRAFT

Introduce high resistance on the control pilot before a charge session

1. Connect the vehicle to the DC charge station through the breakout box
2. Introduce a high resistance on the control pilot in the breakout box by **closing** the **S2_CP**, **S_R**, and **S3_CP** switches and **opening** the **S1_CP** switch.
3. Start a normal charge session.
4. Observe the system behavior
5. Record any faults from the BMS and the DC charge station.
6. Return the breakout box switches to the initial state.

Introduce high resistance on the control pilot during a charge session

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session.
3. Introduce a high resistance on the control pilot in the breakout box by **closing** the **S2_CP**, **S_R**, and **S3_CP** switches and **opening** the **S1_CP** switch.
4. Observe the system behavior
5. Record any faults from the BMS and the DC charge station.
6. Return the breakout box switches to the initial state.

Introduce high resistance on the proximity signal before a charge session

1. Connect the vehicle to the DC charge station through the breakout box
2. Introduce a high resistance on the proximity signal in the breakout box by **closing** the **S2_P**, **S_R**, and **S3_P** switches and **opening** the **S1_P** switch.
3. Start a normal charge session.
4. Observe the system behavior
5. Record any faults from the BMS and the DC charge station.
6. Return the breakout box switches to the initial state.

Introduce high resistance on the proximity signal during a charge session

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session.
3. Introduce a high resistance on the proximity signal in the breakout box by **closing** the **S2_P**, **S_R**, and **S3_P** switches and **opening** the **S1_P** switch.
4. Observe the system behavior
5. Record any faults from the BMS and the DC charge station.
6. Return the breakout box switches to the initial state.

Introduce CAN error frames during a fast charge:

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session
3. Using the CAN tester, introduce CAN error frames at the rate of **1/sec**
4. Increase the CAN error frames to a rate of **500/sec** over a time of **5 minutes**.
5. Observe the system behavior.
6. Record any faults from the BMS or charge station.

DRAFT

CAN bus load increase during a fast charge:

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session
3. Using the CAN tester, introduce non-colliding CAN messages to increase the bus load to **80%** over a period of **5 minutes**. The non-colliding CAN message shall have an ID lower than the lowest observed CAN ID on the network.
4. Observe the system behavior.
5. Record any faults from the BMS or charge station.

CAN bus high shorted to ground

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session.
3. Short the CAN bus high signal to ground connection in the breakout box.
4. Observe the system behavior
5. Record any faults from the BMS and the DC charge station.

CAN bus low shorted to ground

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session.
3. Short the CAN bus low signal to ground connection in the breakout box.
4. Observe the system behavior
5. Record any faults from the BMS and the DC charge station.

6.12.6 End of Test Procedure

Remove the breakout box from the system.

6.12.7 Documentation and Evaluation

6.12.7.1 Documentation

Control pilot interruption through breakout box:

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

Control pilot short to ground through breakout box:

Record System Behavior

____

Record any faults on the BMS

____

DRAFT

Record any faults on the DC Fast Charge Station

____

Proximity interruption through breakout box:

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

Proximity short to ground through breakout box:

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

High resistance on the control pilot before a charge session

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

High resistance on the control pilot during a charge session

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

DRAFT

High resistance on the proximity signal before a charge session

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

High resistance on the proximity signal during a charge session

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

Introduce CAN error frames during a fast charge:

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

CAN bus load increase during a fast charge:

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

CAN bus high shorted to ground

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

DRAFT

CAN bus low shorted to ground

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

6.12.7.2 Pass Fail Criteria

The pass criterion for this test shall be if the charge session stops during the test and the vehicle and charger system is brought to a safe state.

6.13 Charge Connector Field Ground Connection Disturbance

6.13.1 Purpose

The purpose of this test procedure is to determine the reaction to a disturbance between the vehicle field ground and the charger field ground connection.

6.13.2 Rationale and Description

It is possible that the field ground connection between the charger and the vehicle can experience a disturbance during a DC fast charge. This can be due to increased resistance on the connection, mechanical damage such as a broken wire or worn contact. This test shall introduce this condition and determine the reaction of the vehicle/charger system.

6.13.3 Sample Preparation

Install the DC charge breakout box between the vehicle and the DC charger.

6.13.4 Equipment Setup

Configure the DC charge breakout box to perform the Charge Connector Field Ground Connection Disturbance test with the initial switch setting shown in Table 6.

Connect the DC charger to the DC charge breakout box (Figure 11).

Connect the DC charge breakout box to the vehicle charge port.

Please refer to the test procedure schematic, below.

DRAFT

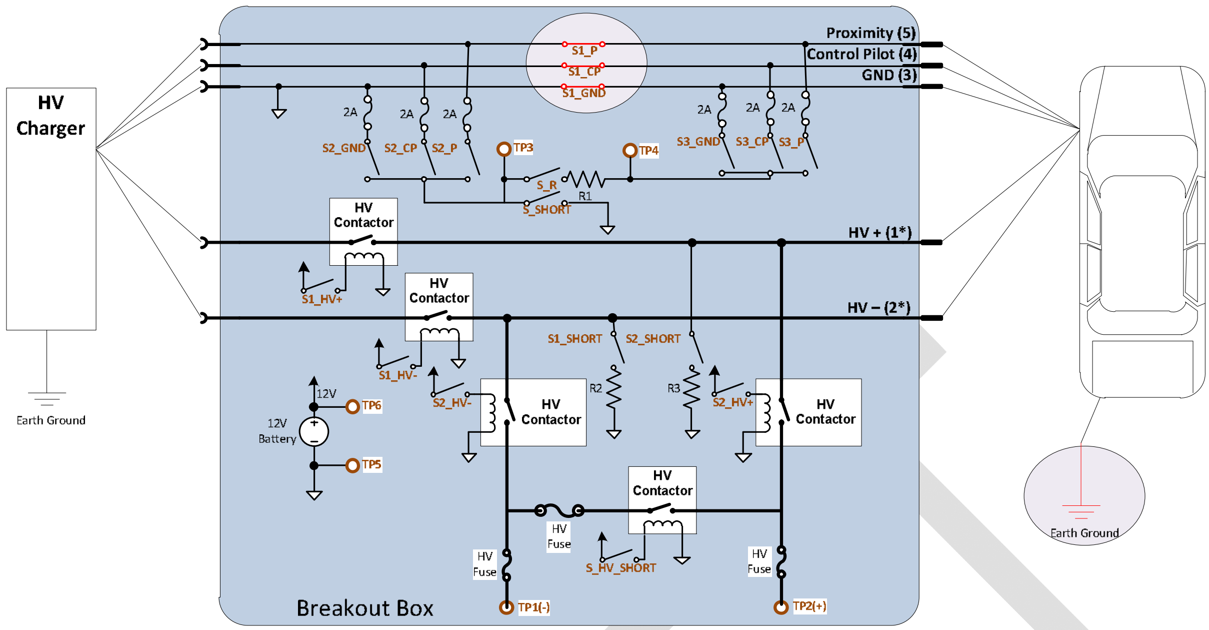


Figure 11 - Initial configuration for Field Ground Connection Disturbance Test.

Table 6 - Initial switch configuration for Field Ground Connection Disturbance Test.

CLOSED FOR INITIAL CONFIGURATION AT EQUIPMENT SETUP																	
MANIPULATED DURING TEST																	
S1_P	S1_CP	S1_GND	S2_P	S2_CP	S2_GND	S3_P	S3_CP	S3_GND	S_R	S_SHORT	S1_SHORT	S2_SHORT	S1_HV+	S1_HV-	S2_HV+	S2_HV-	S_HV_SHORT
CLOSED	CLOSED	CLOSED											CLOSED	CLOSED			

6.13.5 Test Method and Procedure

Remove field ground connection during a fast charge session using the breakout box:

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session.
3. Disconnect the field ground connection in the breakout box.
4. Observe the system behavior
5. Record any faults from the BMS and the DC charge station.

Remove field ground connection, but maintain earth ground using external ground strap during a fast charge session:

1. Connect the vehicle to the DC charge station through the breakout box
2. Install an external ground strap from vehicle chassis to earth ground.
3. Start a normal charge session.
4. Disconnect the field ground connection in the breakout box.
5. Observe the system behavior
6. Record any faults from the BMS and the DC charge station.

6.13.6 End of Test Procedure

Remove the breakout box from the system.

DRAFT

6.13.7 Documentation and Evaluation

6.13.7.1 Documentation

Remove field ground connection during a fast charge session using the breakout box:

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

Remove field ground connection, but maintain earth ground using external ground strap during a fast charge session:

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

6.13.7.2 Pass Fail Criteria

The pass criteria for removing the "remove field ground connection" test shall be the charge session shall stop during the test and the vehicle and charger system shall be brought to a safe state.

The pass criteria for the "removing the field ground connection, but maintain earth ground using external ground straps during a fast charge session" test shall be the charge session may or may not stop during the test and the vehicle and the charger system remain charging in a safe state or shall be brought to a safe state if a shutdown occurs.

6.14 Charge Connector HV Connection Disturbance

6.14.1 Purpose

The purpose of this test is to determine the vehicle/system reaction to poor HV connection between the vehicle and the DC fast charger.

6.14.2 Rationale and Description

It is possible that the HV connection between the vehicle and the charger has become degraded or interrupted during a charge. This can be due to contamination of the terminals resulting in increased resistance of the receptacle/plug interface, worn high voltage contacts, over-temperature of the cable or terminals, or a degraded cable due to inadequate strain relief.

DRAFT

6.14.3 Sample Preparation

Install the DC charge breakout box between the vehicle and the DC charger.

6.14.4 Equipment Setup

Configure the DC charge breakout box to perform the Charge Connector HV Connection Disturbance test with the initial switch setting shown in Table 7.

Connect the DC charger to the DC charge breakout box (Figure 12).

Connect the DC charge breakout box to the vehicle charge port.

Please refer to the test procedure schematic, below.

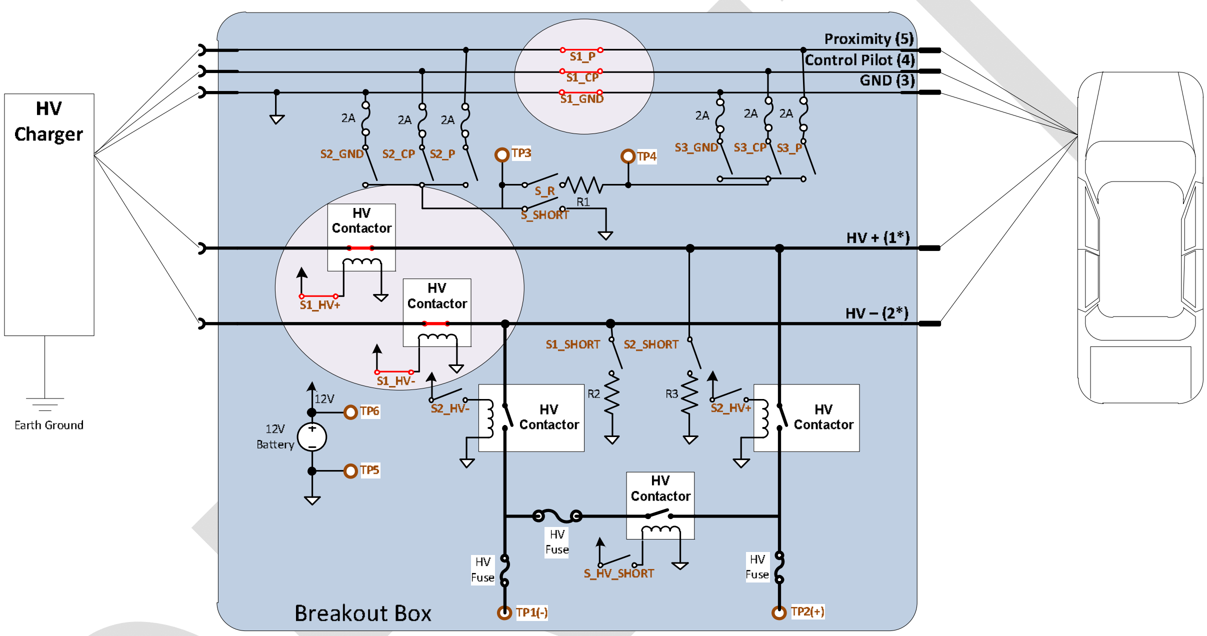


Figure 12 - Initial switch configuration for Charge Connector HV Connection Disturbance Test.

Table 7 - Initial switch configuration for the Charge Connector HV Connection Disturbance Test.

CLOSED FOR INITIAL CONFIGURATION AT EQUIPMENT SETUP																	
MANIPULATED DURING TEST																	
S1_P	S1_CP	S1_GND	S2_P	S2_CP	S2_GND	S3_P	S3_CP	S3_GND	S_R	S_SHORT	S1_SHORT	S2_SHORT	S1_HV+	S1_HV-	S2_HV+	S2_HV-	S_HV_SHORT
CLOSED	CLOSED	CLOSED											CLOSED	CLOSED			

6.14.5 Test Method and Procedure

Interrupt DC connection during fast charge:

1. Connect the vehicle to the DC charge station through the breakout box
2. Start a normal charge session.
3. Allow the charger and vehicle ESS to stabilize for 1 minute.
4. Disconnect one of the DC bus connections (by **opening** either **S1_HV+** or **S1_HV-)** using the breakout box.
5. Observe the system behavior
6. Record any faults from the BMS and the DC charge station.

DRAFT

6.14.6 End of Test Procedure

Remove the breakout box from the system.

6.14.7 Documentation and Evaluation

6.14.7.1 Documentation

Interrupt DC connection during fast charge:

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

6.14.7.2 Pass Fail Criteria

The pass criterion for this test is for the charge session to stop during the test and the vehicle and charger system shall be brought to a safe state.

6.15 Visual Inspection of Charge Port

6.15.1 Purpose

The purpose of this inspection is to detect any incompatibility between the charge plug and the vehicle receptacle.

6.15.2 Rationale and Description

It is possible that low quality adapters or unsupported charging type may cause damage to the connector. This inspection may determine if any damage has occurred due to incompatible or substandard connections.

6.15.3 Sample Preparation

There is no sample preparation required for this test.

6.15.4 Equipment Setup

There is no equipment setup for this test.

DRAFT

6.15.5 Test Method and Procedure

Visual inspection of charge coupler:

1. Look for debris in the connector
2. Look for mechanical damage due to poor fitting connections
3. Look for abrasions which may indicate poor fitting connections
4. Look for distortions or discoloration due to excess heat
5. Look for discoloration on terminals and contacts

6.15.6 End of Test Procedure

There are no end of test procedure requirements for this test.

6.15.7 Documentation and Evaluation

Record any observations of abnormal conditions detected during the visual inspection. It may be necessary to compare the connector and coupler to new and unused parts to determine what is normal and what is abnormal or indicating wear or damage.

6.16 Cooling Heating System

6.16.1 Purpose

The purpose of this test is to determine the reaction of degraded or failed thermal management system in the vehicle/charger system.

6.16.2 Rationale and Description

High powered off-board DC fast charging can charge up to 200A continuous. This would typically require cooling in the energy storage system being charged. It is possible that the vehicle's ESS cooling system is in a degraded state due to loss of refrigerant, failed actuator (pump, fan, etc), or other condition which causes the ESS to overheat during a fast charge. This test is designed to determine the reaction of the vehicle/charger system to this condition.

6.16.3 Sample Preparation

This test requires specific knowledge of the cooling and heating system design details for the ESS on each vehicle tested in order to be able to modify the vehicle system to subject the BMS to the conditions described below.

High Ambient Temperature Test Preparation:

For the high ambient temperature test, the vehicle or ESS must be placed in an environmental chamber capable of increasing the temperature of the sample to 40 DegC (+5/-0). Allow the sample to soak at this temperature for 24 hours prior to the test. Restrict the flow of coolant medium used on vehicles which use active cooling for the ESS (e.g. water cooling loop through battery). The method of restricting the cooling capability of the ESS cooling system may differ significantly from vehicle to vehicle.

DRAFT

Low Ambient Temperature Test Preparation:

For the low ambient temperature test, the vehicle or the ESS must be placed in an environmental chamber capable of decreasing the temperature of the sample to -20 DegC (+0/-5). Allow the sample to soak at this temperature for 24 hours prior to the test. Bypass the battery heater by modifying the coolant hoses coming from the battery heater creating a bypass. Make sure the heater element is still full of glycol even though it is bypassed to prevent damage to the unit. The method of restricting the heating capability of the ESS heating system may differ significantly from vehicle to vehicle.

6.16.4 Equipment Setup

There is not specific equipment setup required for this test procedure.

6.16.5 Test Method and Procedure

Restricted ESS cooling system before and during charging, at high ambient temperature:

1. Place the vehicle or ESS in the environmental chamber for 24 hours at 40 DegC.Connect the vehicle to the DC fast charge station
2. Start a normal charge session.
3. Observe the system behavior during charge
4. Record any faults from the BMS and the DC charge station.

Restricted ESS heating system before and during charging, at low ambient temperature:

1. Place the vehicle or ESS in the environmental chamber for 24 hours at -20 DegC.
2. Connect the vehicle to the DC charge station
3. Start a normal charge session.
4. Observe the system behavior during charge
5. Record any faults from the BMS and the DC charge station.

6.16.6 End of Test Procedure

Remove the restrictions and restore the ESS cooling and heating components back to normal.

6.16.7 Documentation and Evaluation

6.16.7.1 Documentation

Restricted ESS cooling system before and during charging, at high ambient temperature:

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

DRAFT

Restricted ESS heating system before and during charging, at low ambient temperature:

Record System Behavior

____

Record any faults on the BMS

____

Record any faults on the DC Fast Charge Station

____

6.16.7.2 Pass Fail Criteria

The pass fail criteria for these tests are:

The BMS may record an over-temperature or under-temperature fault, limit the charge current, or stop the charge session prematurely.

The charge current limiting behavior of the BMS may vary significantly for each vehicle's ESS.

The BMS shall not allow the ESS to enter into thermal runaway conditions due to excessive charge current at high or low ambient temperatures.

6.17 BMS Internal Fault Detection

6.17.1 Purpose

The purpose of this test is to determine if a BMS is able to detect internal BMS faults which, if not detected and handled adequately, may lead to a hazardous condition.

6.17.2 Rationale and Description

There are a number of internal BMS faults which may cause hazardous conditions. These faults are application specific and require specific knowledge of each OEM BMS architecture and design. Therefore, the following tests shall be described in general terms due to the OEM specific nature of internal BMS designs. The test methods shown are at minimum to be performed and only show a small set of tests that are expected to be completed within a given ESS. It is anticipated that in future revisions of this procedure (or in a separate document) additional test steps are identified.

6.17.3 Sample Preparation

This test requires specific knowledge of the battery system design details for the ESS on each vehicle tested in order to be able to modify the internal subsystems to subject the BMS to the conditions described below. It is therefore required to obtain detailed wiring schematic and wiring layout information to determine appropriate access points to implant the signal modifications required to conduct these tests. It would be desirable to obtain ESS specific break out harnesses from the ESS manufacturer to allow safe access to the BMS signals under test.

DRAFT

6.17.4 Equipment Setup

The equipment requirements for this test is highly ESS design dependent and requires the active support of the ESS manufacturer. It is suggested that sensor signals are modified according to ESS manufacturer recommendations to prevent any damage or unsafe conditions while the test is being conducted.
The equipment for temperature fault simulation could be a variable resistor mounted inline and/or parallel to the actual temperature sensor for a single cell or a number of cells.

The equipment for cell over-/under- voltage test could be a variable resistor divider connecting an upper and lower cell together via the variable resistor combination whereas the midpoint of the resistor divider is connected to the cell sensor signal that is to be manipulated.

6.17.5 Test Method and Procedure

Cell overvoltage fault test:
1. Connect the vehicle to the DC charge station.
2. Set the simulated cell signal to match the actual cell voltage.
3. Start a normal charge session.
4. After 60 seconds alter the simulated cell voltage to reach the ESS specified cell overvoltage threshold (ESS specific) and hold it there.
5. Observe the system behavior
6. Record any faults from the BMS and the DC charge station.

Cell undervoltage fault test:
1. Connect the vehicle to the DC charge station.
2. Set the simulated cell signal to match the actual cell voltage.
3. Start a normal charge session.
4. After 60 seconds alter the simulated cell voltage to reach the ESS specified cell undervoltage threshold (ESS specific) and hold it there.
5. Observe the system behavior
6. Record any faults from the BMS and the DC charge station.

Cell temperature fault test:
1. Connect the vehicle to the DC charge station.
2. Set the simulated cell temperature signal to match the actual cell temperature.
3. Start a normal charge session.
4. After 60 seconds alter the simulated cell temperature to reach the ESS specified cell over temperature threshold (ESS specific) and hold it there.
5. Observe the system behavior
6. Record any faults from the BMS and the DC charge station.

Perform any additional test to cover all BMS related internal fault detections (e.g. High Voltage Interlock Circuit, Cooling System Actuator Disconnection, Cooling System Sensor Disconnection,…).

DRAFT

6.17.6 End of Test Procedure

Remove all implanted BMS system faults and restore the ESS harness and components back to normal.

6.17.7 Documentation and Evaluation

6.17.7.1 Documentation

Observe the system behavior

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

6.17.7.2 Pass Fail Criteria

The BMS shall detect all implanted faults within a time frame that prevents an unsafe ESS condition.

6.18 Overcharge Test

6.18.1 Purpose

This purpose of this test is to determine the reaction of the system to an overcharge condition.

6.18.2 Rationale and Description

It is possible that the DC charger applies more current than is requested by the vehicle BMS. This can be due to a failure in communication between the vehicle and the charger or a defective DC power supply in the charger.

This test should be conducted by connecting to an equivalent battery tester with simulation hardware/software to simulate the charge station operation. Alternately, if engineering access to the charge station software debugging interface is available, the test conditions can be achieved by modifying the signals using overrides which may be available in the charger software debugging interface.

6.18.3 Sample Preparation

There are no specific sample preparation requirements for this test.

6.18.4 Equipment Setup

Configure the battery tester with simulation hardware/software to allow the override of the current request signal coming from the vehicle.

DRAFT

6.18.5 Test Method and Procedure

Override of current request using DC charger control overrides.

1. Start a charge session.
2. Wait for approximately 1 minute for the charge to initialize and stabilize.
3. Continue to charge to approximately 90% SOC and the charge current requested by the vehicle is observed to reduce at least 10% from the maximum charge current observed during the start of the test.
4. Substitute a current request signal to the DC charger that is 10% higher than the current actually requested by the vehicle.
5. Observe the system behavior. Record any faults on the BMS and the DC fast charge station.

6.18.6 End of Test Procedure

Store the vehicle in an open space area and monitor any heat generation (using thermal imaging camera) for a duration of at least 72 hours. Then reduce the battery charge to 50% SOC and continue monitoring the thermal signature for 48 hours. Perform a battery system check according to the manufacturer recommended practice to ensure that no long term failure are present.

6.18.7 Documentation and Evaluation

6.18.7.1 Documentation

Observe the system behavior

Record any faults on the BMS

____

Record any faults on the DC fast charge station

____

6.18.7.2 Pass Fail Criteria

The pass criteria are as follows:

The system shall stop or abort the charge session and bring the system to a safe state.

The system shall also set a fault code to identify the problem.

END OF DOCUMENT

DRAFT

DRAFT

BMS Failure Mode Test Report: DC Charging Interface

Test Report

1. PURPOSE

This test report details the findings of a series of BMS failure mode tests according to the test procedure *"BMS Failure Mode Test Procedure: DC Charging Interface"*.

2. SCOPE

The scope of this test report will focus on the BMS interface to the DC charging system test results. The test was conducted using a 2014 Chevrolet Spark Electric Vehicle with a SAE DC fast charge port. The following tests were not within the scope of this project and were therefore omitted from testing:

- System Overvoltage Test (12V Board Net) [6.5]
- 12V System Disturbance Test [6.7]
- 12V System EMI/EMC Test [6.8]
- BMS Internal Fault Detection [6.17]

3. GENERAL TEST INFORMATION

3.1 Test Property Information

The following test property and test equipment was used to conduct the tests.

Figure 13 - GM Spark Test vehicle.

Model:Chevy Spark EV
Year:2014
VIN:KL8CL6S07EC509683

3.2 Test Facility/ Equipment Used

The following equipment was used to conduct the tests.

- Public charging station with SAE fast charge port in Irvine, CA. The maximum available charge current for this station was 50A.
- Engineering fast charging station with SAE fast charge port in Santa Ana, CA with a maximum available charge current of 70A. This engineering station allowed the software modification to simulate some of the test conditions.
- Proto type break out box.
- Fluke DVM 289
- Fluke Scopemeter 199C
- Tektronix current probe A622
- Lead Acid battery "Everstart ES5LBS": 12V, 4Ah
- CANalyzer V8.0
- Vehicle Scan Tool "Global Diagnostic System 2"

Figure 14 - Public charging station in Irvine, CA.

DRAFT

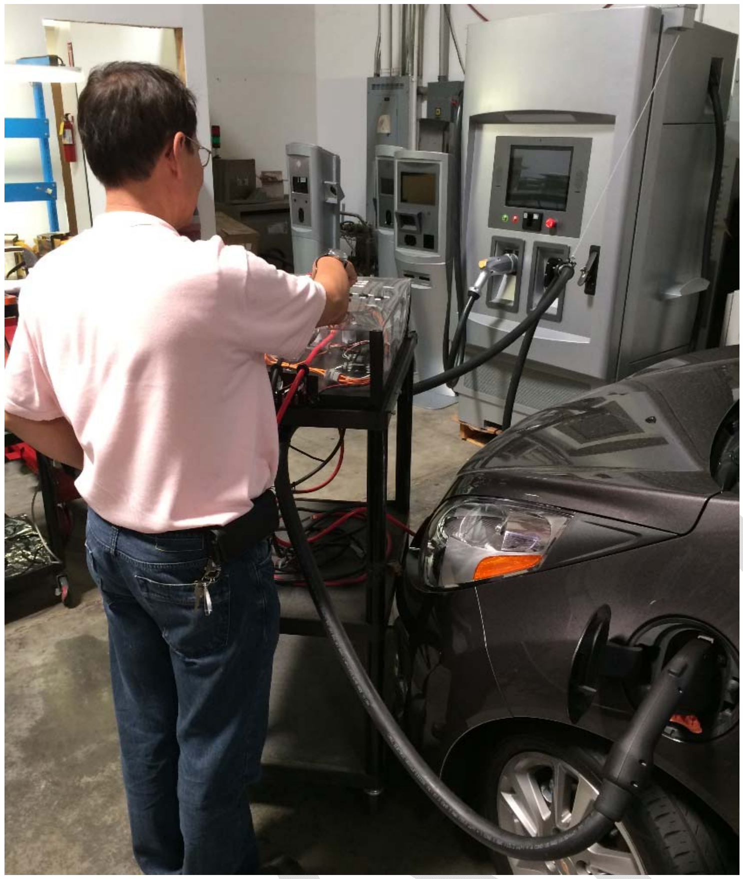


Figure 15 - Engineering charging station with break out box installed.

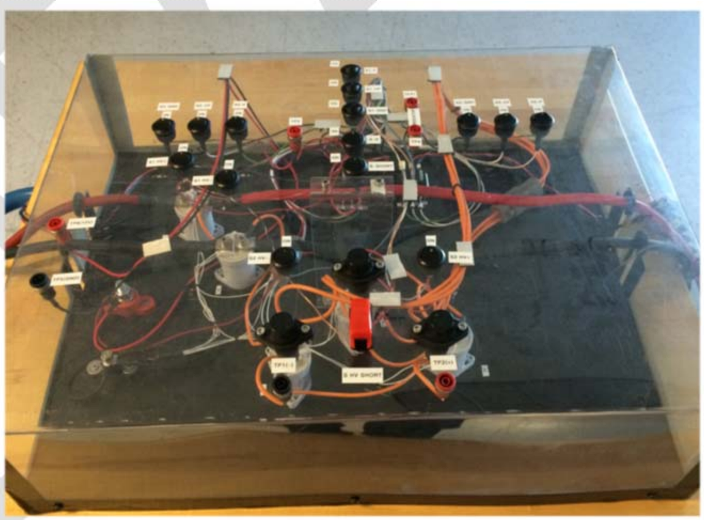


Figure 16 - Prototype break out box.

DRAFT

Figure 17 - Fluke DVM and Fluke hand held Scope

Figure 18 - Tektronix Current Probe

Figure 19 - 12V lead acid battery

DRAFT

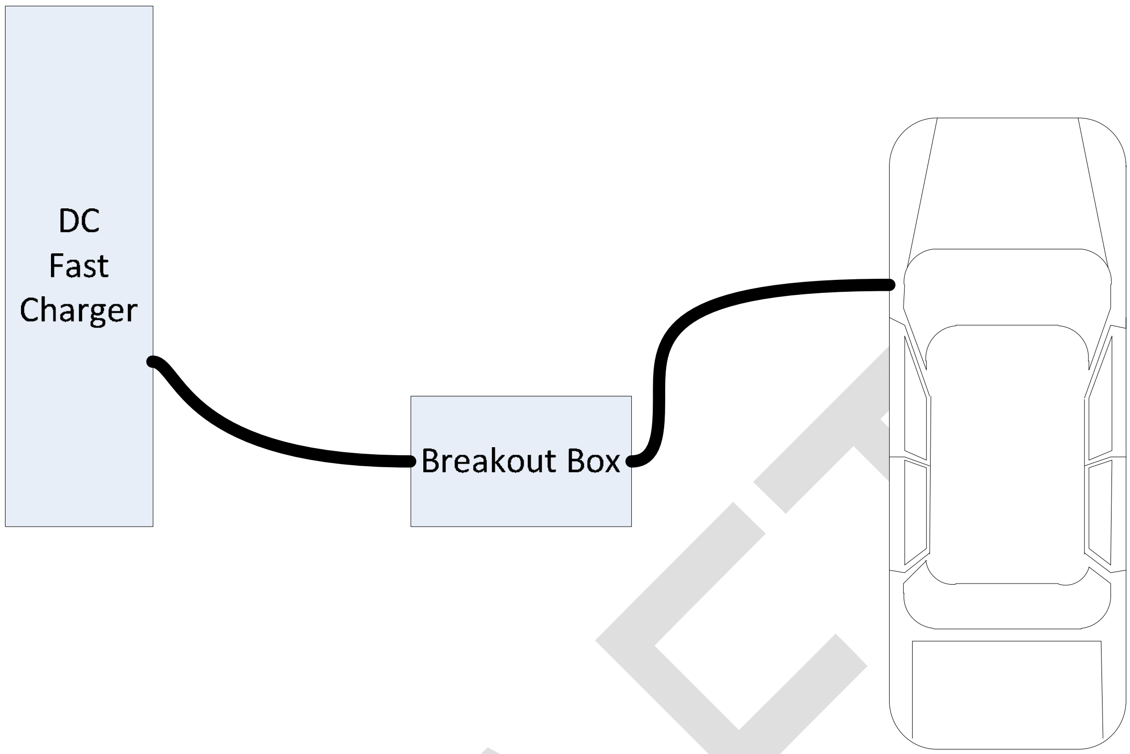


Figure 20 - DC Fast Charge Breakout Box Connection.

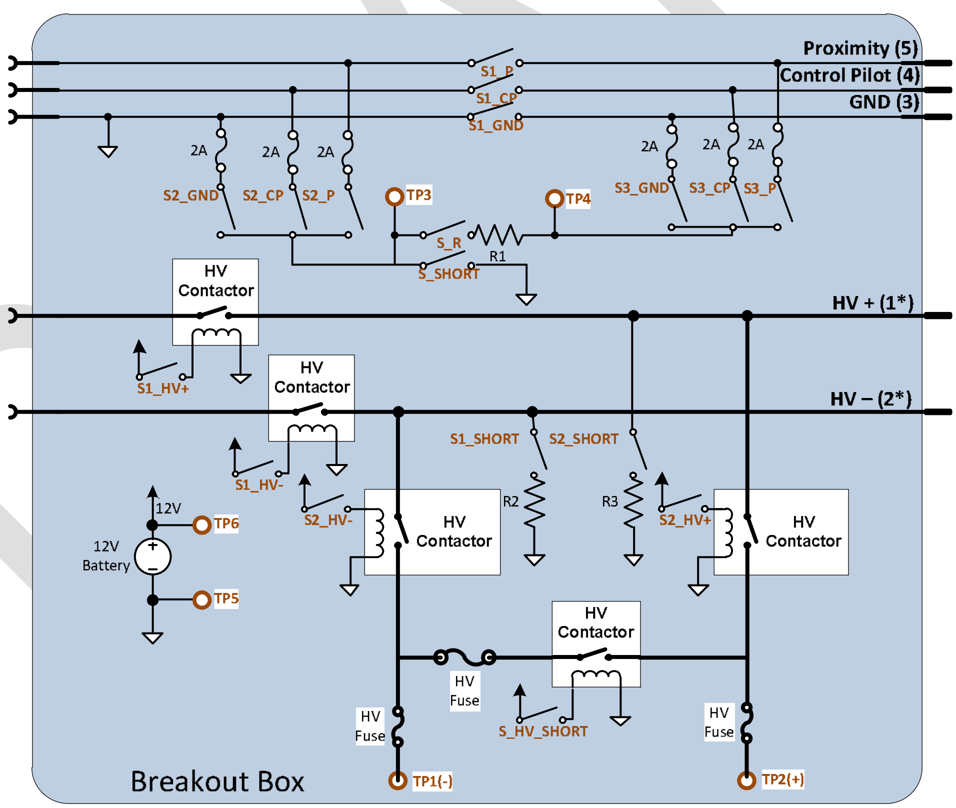


Figure 21 - DC Fast Charge Breakout Box Schematic.

4. TEST RESULTS

4.1 Ground Fault Test – P6.1.5

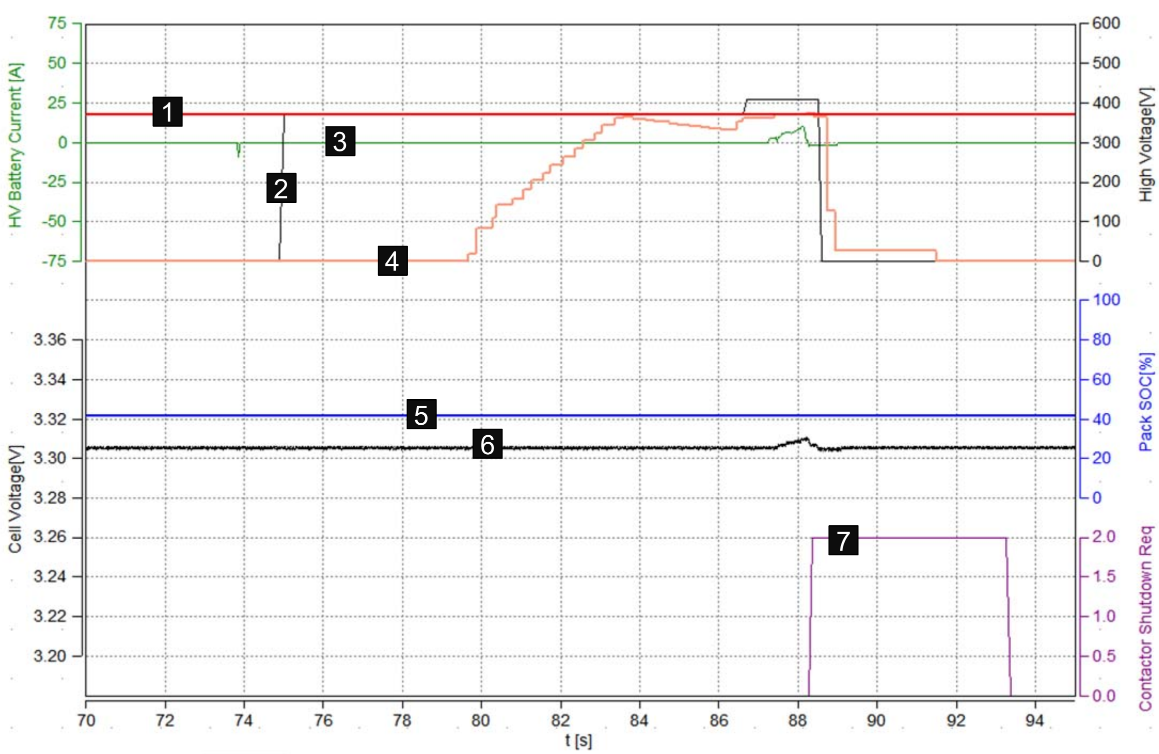
Fault to GND – DC Positive introduced before charge session initiated:
Data File: Spark_2014-07-22__008.MDF

Connected 24kΩ resistor between HV positive and chassis GND on break out box; Started charging session; Charging stopped after app 2 seconds with fault. Vehicle display shows "Not able to Fast Charge" & "Use Standard Cord". Vehicle control opened contactors to interrupt charging. Retrieved DTCs from vehicle (see "20140722_1427_Isolation_HVPlus.pdf"). The following DTCs were set:

P1E00 – Hybrid PowertrainControl Module 2 Request MIL illumination
P300B – Hybrid/EV Battery DC Charging Output Current Performance
P302F – Hybrid/EV Battery DC Charging System Isolation Lost

The charging station reported a fault and also shut down due to vehicle request for shutdown.
The following graph shows the charging cycle and the shutdown at time 88s:

Graph 1 - Charging Cycle and Shutdown at 88s



Legend:
1. High Voltage Battery Voltage [V] sensed by BMS
2. Off Board High Voltage Charging Station Target Voltage [V]
3. High Voltage Battery Current [A] sensed by BMS
4. Off Board High Voltage Charging Station Voltage Output [V]
5. Customer Usable State of Charge [%]
6. High Voltage Battery Cell Voltage (single) [V]
7. High Voltage Contactor Shutdown Request (1=Emergency; 2=Controlled; 3=Emergency Crash)

✔☐Test passed, vehicle remains in safe condition

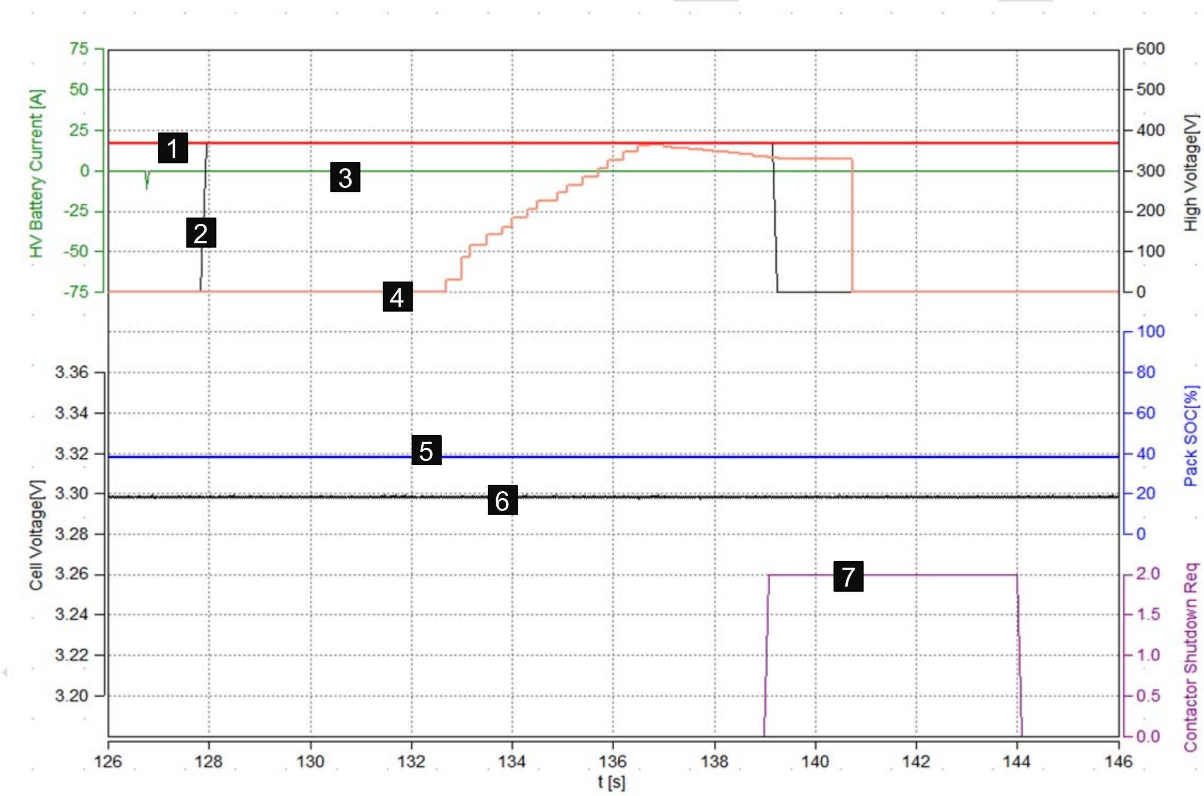
Fault to GND – DC Negative introduced before charge session initiated:
Data File: Spark_2014-07-22__009.MDF

Connected 24kΩ resistor between HV negative and chassis GND on break out box; Started charging session; Charging stopped after app 2 seconds with fault. Vehicle display shows "Not able to Fast Charge" & "Use Standard Cord". Vehicle control opened contactors to interrupt charging. Retrieved DTCs from vehicle (see "20140722_1505_Isolation_HVNeg.pdf"). The following DTCs were set:

P302F – Hybrid/EV Battery DC Charging System Isolation Lost

The charging station reported a fault and also shut down.
The following graph shows the charging cycle and the shutdown at time 139s:

Graph 2 - Charging Cycle and Shutdown at 139s



Legend:
1 High Voltage Battery Voltage [V] sensed by BMS
2 Off Board High Voltage Charging Station Target Voltage [V]
3 High Voltage Battery Current [A] sensed by BMS
4 Off Board High Voltage Charging Station Voltage Output [V]
5 Customer Usable State of Charge [%]
6 High Voltage Battery Cell Voltage (single) [V]
7 High Voltage Contactor Shutdown Request (1=Emergency; 2=Controlled; 3=Emergency Crash)

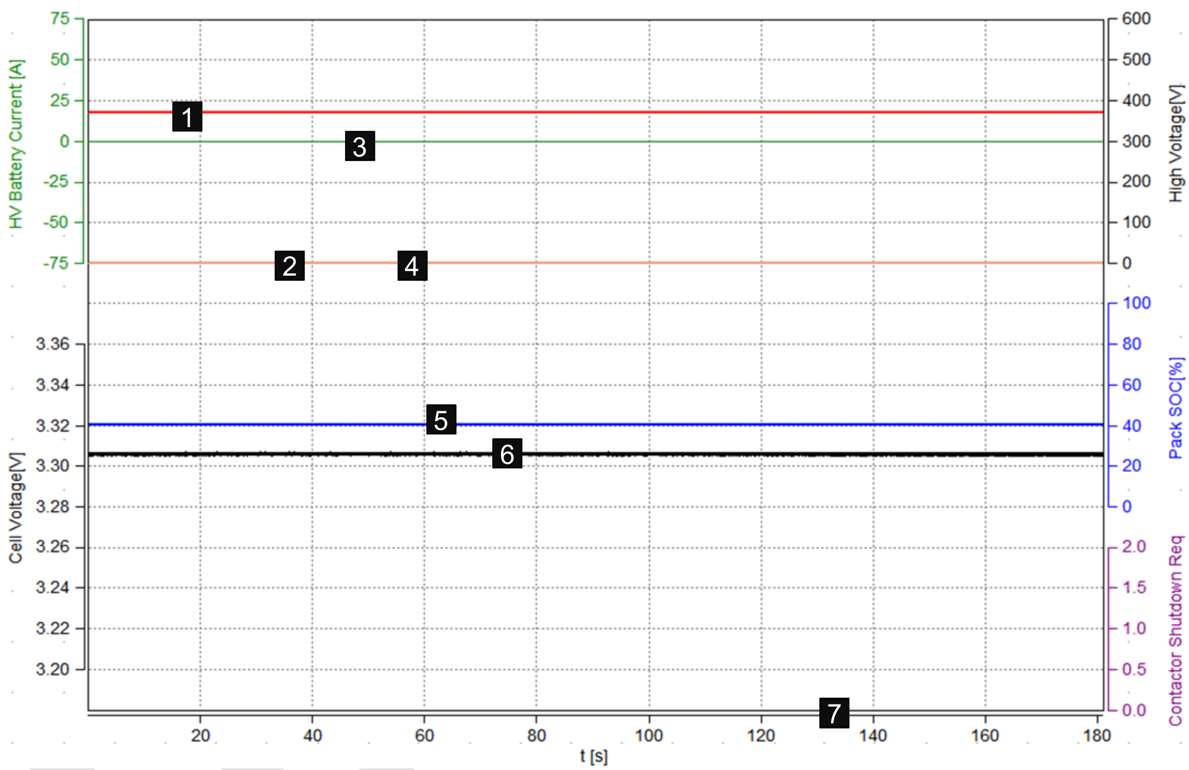
✔☐Test passed, vehicle remains in safe condition

Fault – Ground connection between station and vehicle removed before charge session initiated:
Data File: Spark_2014-07-22__0012.MDF

Removed the chassis GND connection between charging station and vehicle on the break out box before charging was initiated; Started charging session on charger; No reaction on vehicle side. Charge Station timed out after several communication attempts. No DTCs were set.

The charging station timed out and shut down.
The following graph shows the attempted charging cycle:

Graph 3 - Attempted Charging Cycle



Legend:
1 High Voltage Battery Voltage [V] sensed by BMS
2 Off Board High Voltage Charging Station Target Voltage [V]
3 High Voltage Battery Current [A] sensed by BMS
4 Off Board High Voltage Charging Station Voltage Output [V]
5 Customer Usable State of Charge [%]
6 High Voltage Battery Cell Voltage (single) [V]
7 High Voltage Contactor Shutdown Request (1=Emergency; 2=Controlled; 3=Emergency Crash)

✔☐Test passed, vehicle remains in safe condition

Fault to GND – DC Positive introduced during charge session:

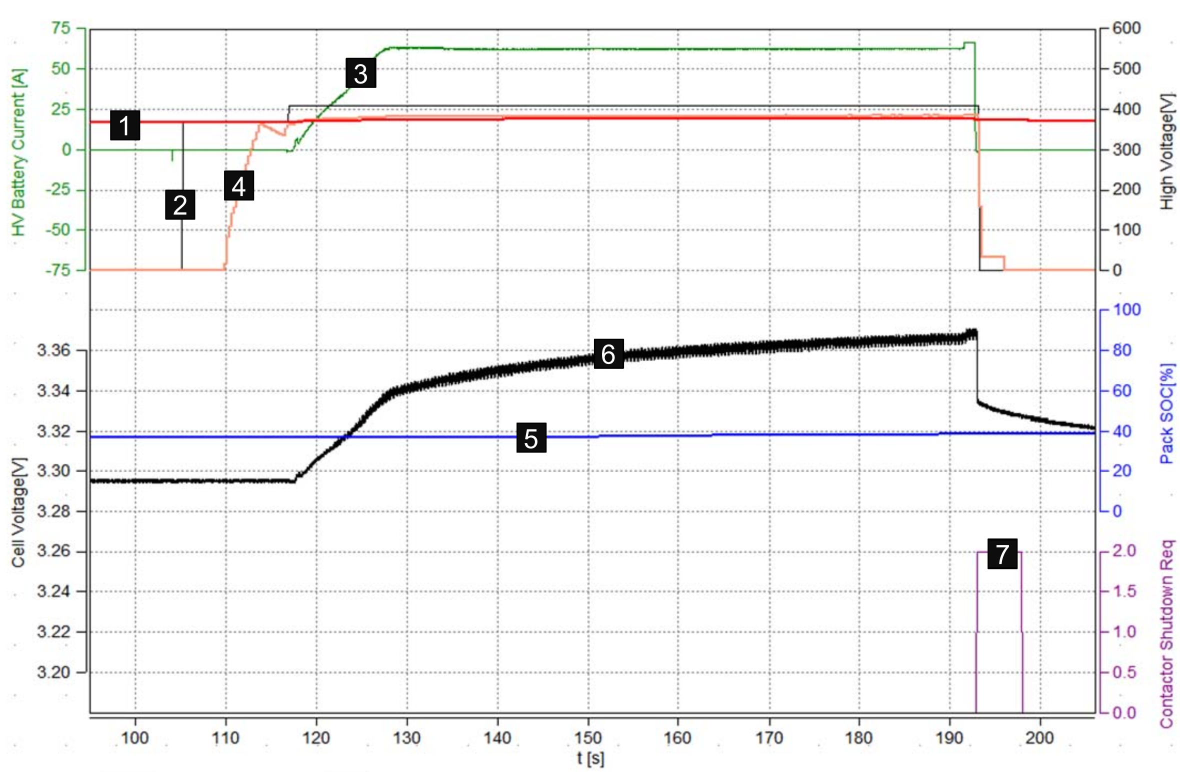
Data File: Spark_2014-07-22__0010.MDF

Started charging session; After app 60s connected 24kΩ resistor between HV positive and chassis GND on break out box; Charging stopped after app 30 seconds with fault inserted. Vehicle display shows "Not able to Fast Charge" & "Use Standard Cord". Vehicle control opened contactors to interrupt charging. Retrieved DTCs from vehicle (see "20140722_1523_Isolation_HVPlus during charge.pdf"). The following DTCs were set:

P302F – Hybrid/EV Battery DC Charging System Isolation Lost

The charging station reported a fault and also shut down.
The following graph shows the charging cycle and the shutdown at time 193s:

Graph 4 - Charging Cycle and Shutdown at 193s



Legend:

1 High Voltage Battery Voltage [V] sensed by BMS
2 Off Board High Voltage Charging Station Target Voltage [V]
3 High Voltage Battery Current [A] sensed by BMS
4 Off Board High Voltage Charging Station Voltage Output [V]
5 Customer Usable State of Charge [%]
6 High Voltage Battery Cell Voltage (single) [V]
7 High Voltage Contactor Shutdown Request (1=Emergency; 2=Controlled; 3=Emergency Crash)

✔ Test passed, vehicle remains in safe condition

Fault to GND – DC Negative introduced during charge session:
Data File: Spark_2014-07-22__0011.MDF

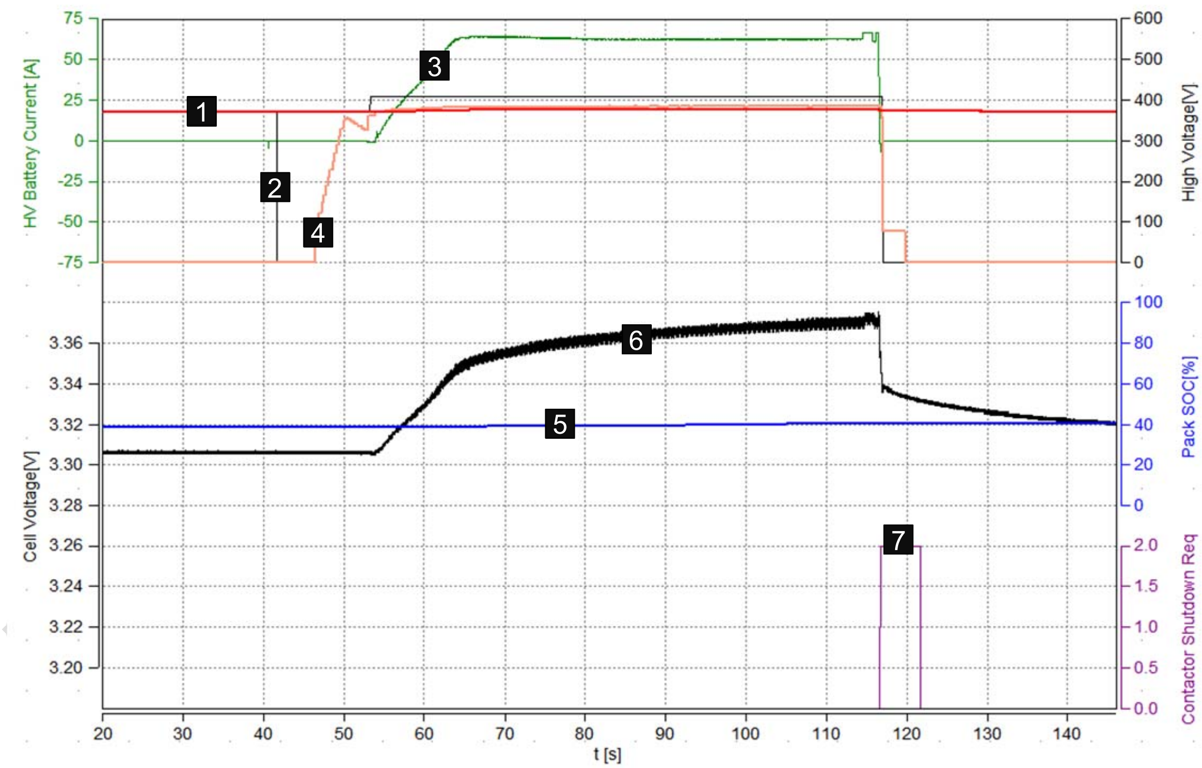
Started charging session; After app 60s connected 24kΩ resistor between HV negative and chassis GND on break out box; Charging stopped after app 3 seconds with fault inserted. Vehicle display shows "Not able to Fast Charge" & "Use Standard Cord". Vehicle control opened contactors to interrupt charging. Retrieved DTCs from vehicle (see "20140722_1529_Isolation_HVNeg during charge.pdf"). The following DTCs were set:

P302F – Hybrid/EV Battery DC Charging System Isolation Lost

The charging station reported a fault and also shut down.

The following graph shows the charging cycle and the shutdown at time 117s:

Graph 5 - Charging Cycle and Shutdown at 117s



Legend:
1 High Voltage Battery Voltage [V] sensed by BMS
2 Off Board High Voltage Charging Station Target Voltage [V]
3 High Voltage Battery Current [A] sensed by BMS
4 Off Board High Voltage Charging Station Voltage Output [V]
5 Customer Usable State of Charge [%]
6 High Voltage Battery Cell Voltage (single) [V]
7 High Voltage Contactor Shutdown Request (1=Emergency; 2=Controlled; 3=Emergency Crash)

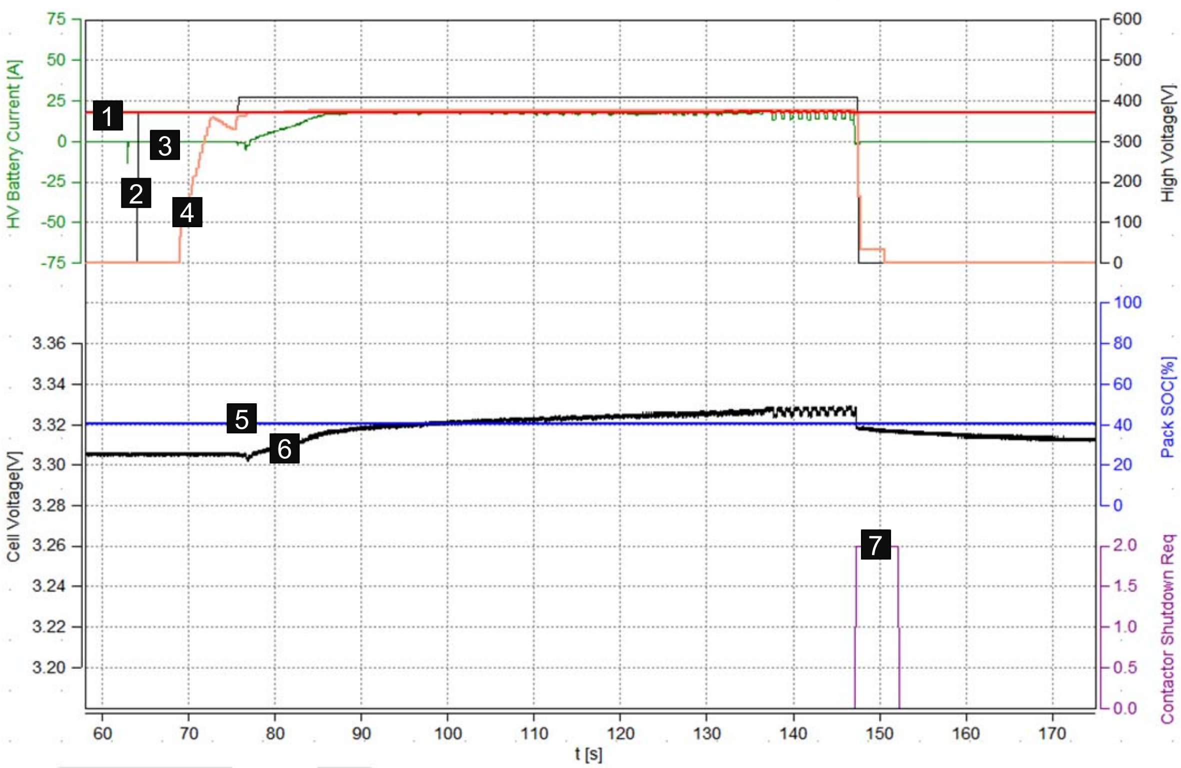
✔☐ Test passed, vehicle remains in safe condition

Fault – Ground connection between station and vehicle removed during charge session:
<u>Data File</u>: Spark_2014-07-22__0013.MDF

Started charging session on charger; Removed the chassis GND connection between charging station and vehicle on the break out box app 79s after charging was initiated; Charging interrupted. Charge Station shut down. Vehicle sounded horn after app 30s. No DTCs were set.

The following graph shows the attempted charging cycle:

Graph 6 - Attempted Charging Cycle



<u>Legend</u>:
1 High Voltage Battery Voltage [V] sensed by BMS
2 Off Board High Voltage Charging Station Target Voltage [V]
3 High Voltage Battery Current [A] sensed by BMS
4 Off Board High Voltage Charging Station Voltage Output [V]
5 Customer Usable State of Charge [%]
6 High Voltage Battery Cell Voltage (single) [V]
7 High Voltage Contactor Shutdown Request (1=Emergency; 2=Controlled; 3=Emergency Crash)

✔□Test passed, vehicle remains in safe condition

4.2 Chassis Ground Offset Test – P6.2.5

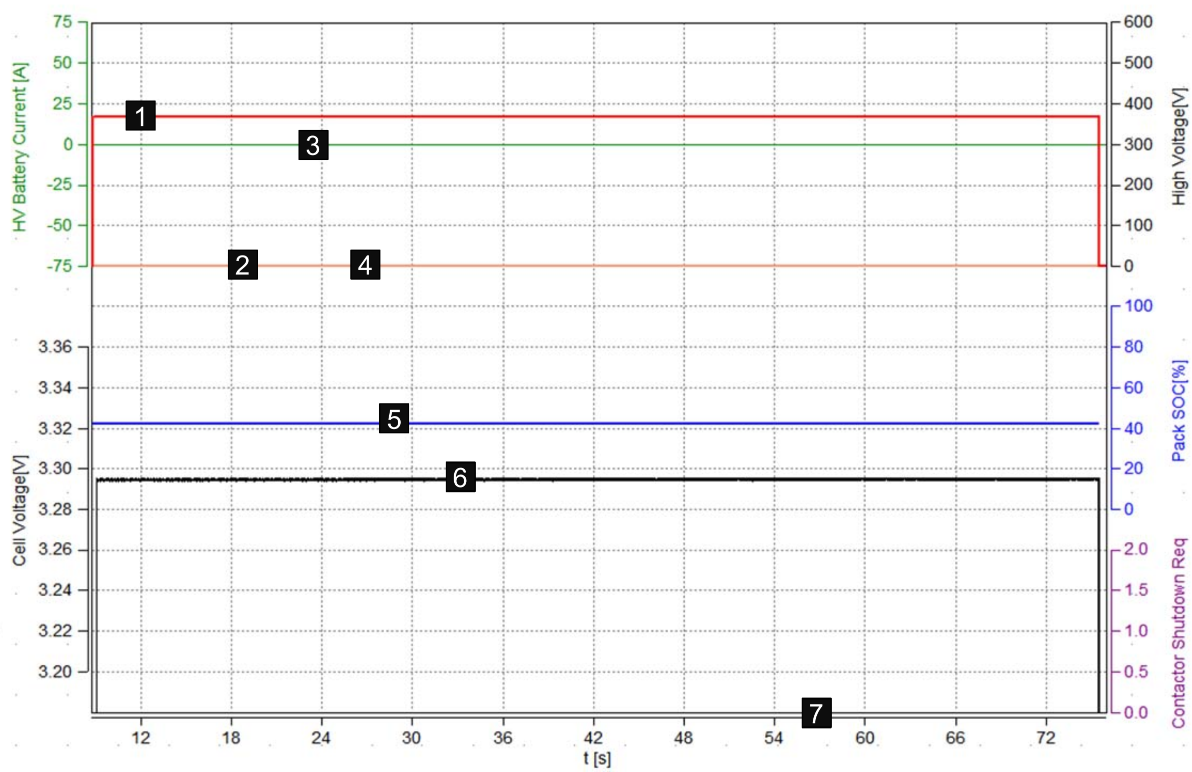
Chassis Ground Offset introduced before a fast charge session:
Data File: Spark_2014-07-23__004.MDF

Switched in 100Ω resistor between charge station earth GND and vehicle GND at the break out box, before charging operation started; Started charging session on charger; Charge Station was unable to establish communication. Charge Station shut down with fault of "Unexpected Proximity Signal Fault". No DTCs were set.

Measured toggling 0V / 0.3V between charge station earth ground and vehicle ground (TP4 - TP5); across 100Ω resistor).

The following graph shows the charging cycle:

Graph 7 - Chassis Ground Offset Before Fast Charge 100 Ω Resistor



Legend:
1 High Voltage Battery Voltage [V] sensed by BMS
2 Off Board High Voltage Charging Station Target Voltage [V]
3 High Voltage Battery Current [A] sensed by BMS
4 Off Board High Voltage Charging Station Voltage Output [V]
5 Customer Usable State of Charge [%]
6 High Voltage Battery Cell Voltage (single) [V]
7 High Voltage Contactor Shutdown Request (1=Emergency; 2=Controlled; 3=Emergency Crash)

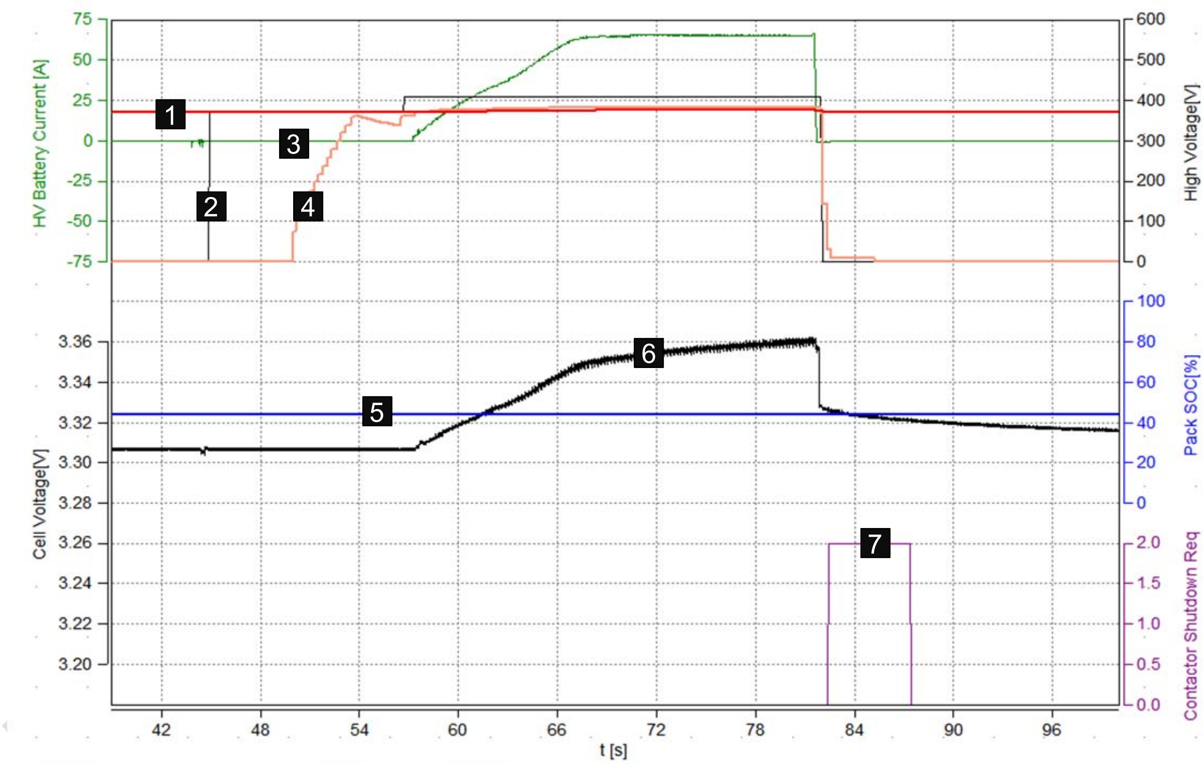
✔☐Test passed, vehicle remains in safe condition

Chassis Ground Offset introduced before a fast charge session:
Data File: Spark_2014-07-23__006.MDF

Switched in 47Ω resistor between charge station earth GND and vehicle GND at the break out box, before charging operation started; Started charging session on charger; Measured 0.138V between charge station earth ground and vehicle ground before charging started (TP4 - TP5); across 47Ω resistor). Once charging communication was established measured 0.012V between charge station earth ground and vehicle ground (TP4 - TP5); across 47Ω resistor). Charging current ramped up to 65A and after app 20s charging interrupted. Charging station shut down. No vehicle DTCs were set.

The following graph shows the charging cycle:

Graph 8 - Chassis Ground Offset Before Fast Charge 47Ω Resistor



Legend:
1 High Voltage Battery Voltage [V] sensed by BMS
2 Off Board High Voltage Charging Station Target Voltage [V]
3 High Voltage Battery Current [A] sensed by BMS
4 Off Board High Voltage Charging Station Voltage Output [V]
5 Customer Usable State of Charge [%]
6 High Voltage Battery Cell Voltage (single) [V]
7 High Voltage Contactor Shutdown Request (1=Emergency; 2=Controlled; 3=Emergency Crash)

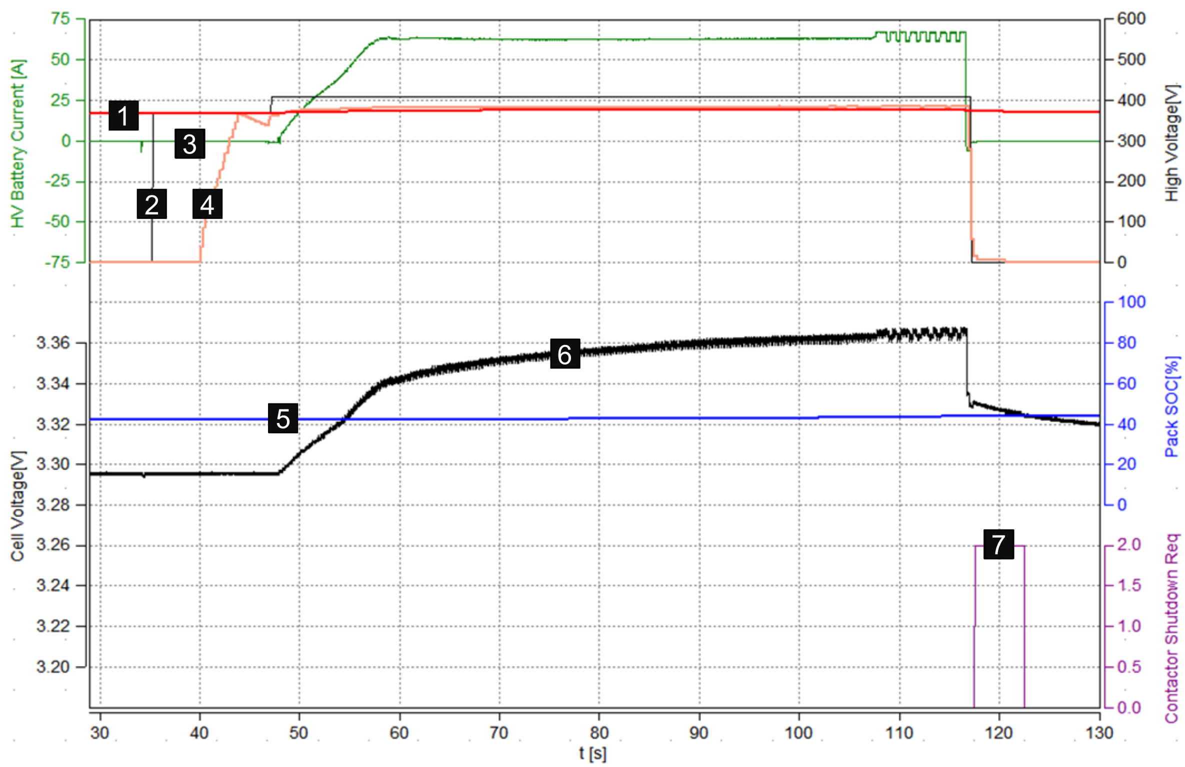
✔ Test passed, vehicle remains in safe condition

Chassis Ground Offset introduced before a fast charge session:
Data File: Spark_2014-07-23__005.MDF

Switched in 24Ω resistor between charge station earth GND and vehicle GND at the break out box, before charging operation started; Started charging session on charger; Once charging communication was established measured 0.07V between charge station earth ground and vehicle ground (TP4 - TP5); across 24Ω resistor). Charging current ramped up to 65A continued without interruption until charging was stopped via operator. No issues on charging station observed. No vehicle DTCs were set.

The following graph shows the charging cycle:

Graph 9 - Chassis Ground Offset Before Fast Charge 24Ω Resistor



Legend:
1 High Voltage Battery Voltage [V] sensed by BMS
2 Off Board High Voltage Charging Station Target Voltage [V]
3 High Voltage Battery Current [A] sensed by BMS
4 Off Board High Voltage Charging Station Voltage Output [V]
5 Customer Usable State of Charge [%]
6 High Voltage Battery Cell Voltage (single) [V]
7 High Voltage Contactor Shutdown Request (1=Emergency; 2=Controlled; 3=Emergency Crash)

✔ Test passed, vehicle remains in safe condition

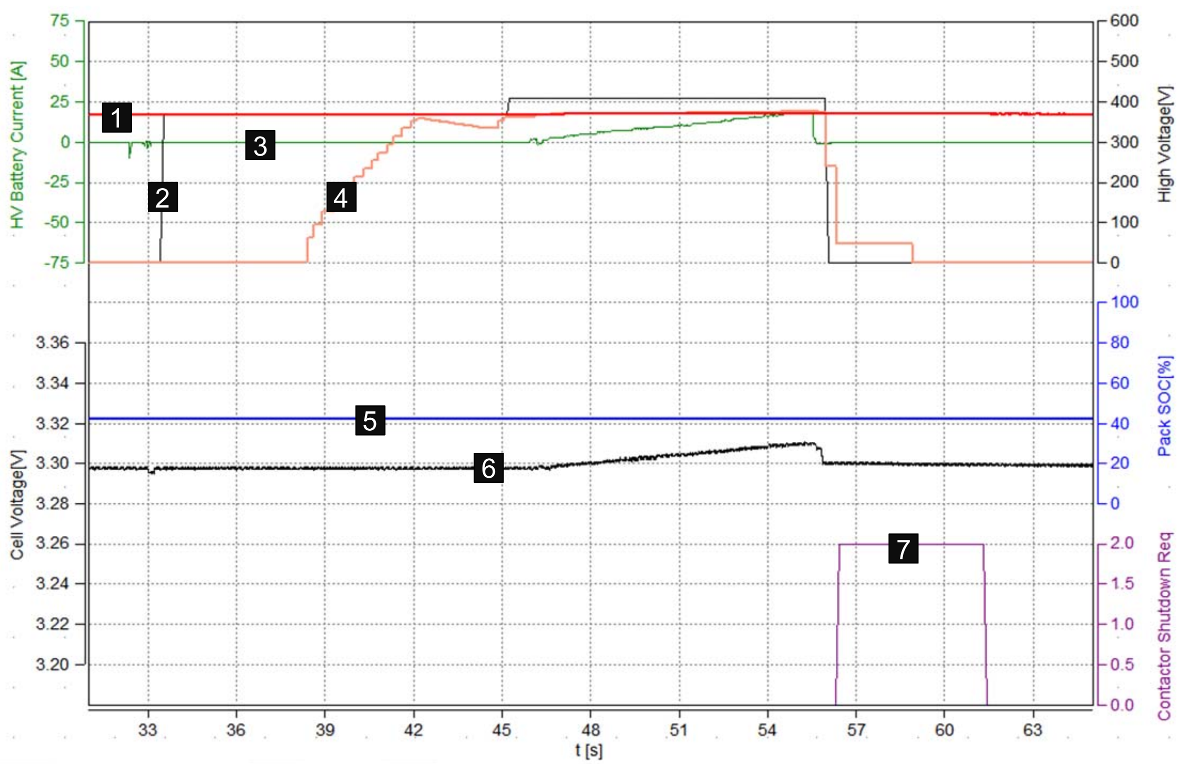
Chassis Ground Offset introduced during a fast charge session:
Data File: Spark_2014-07-23__003.MDF

Started charging session on charger; Switched in 1kΩ resistor between charge station earth GND and vehicle GND at the break out box, some time after charging operation started; Upon the insertion of the resistance the charging interrupted. Charge Station shut down. No DTCs were set.

Measured 2.9V between earth ground and vehicle ground (TP4 - TP5); across 1kΩ resistor).

The following graph shows the charging cycle:

Graph 10 - Chassis Ground Offset During Fast Session 1KΩ Resistor



Legend:
1 High Voltage Battery Voltage [V] sensed by BMS
2 Off Board High Voltage Charging Station Target Voltage [V]
3 High Voltage Battery Current [A] sensed by BMS
4 Off Board High Voltage Charging Station Voltage Output [V]
5 Customer Usable State of Charge [%]
6 High Voltage Battery Cell Voltage (single) [V]
7 High Voltage Contactor Shutdown Request (1=Emergency; 2=Controlled; 3=Emergency Crash)

✔ Test passed, vehicle remains in safe condition

4.3 DC Bus Short Test – P6.3.5

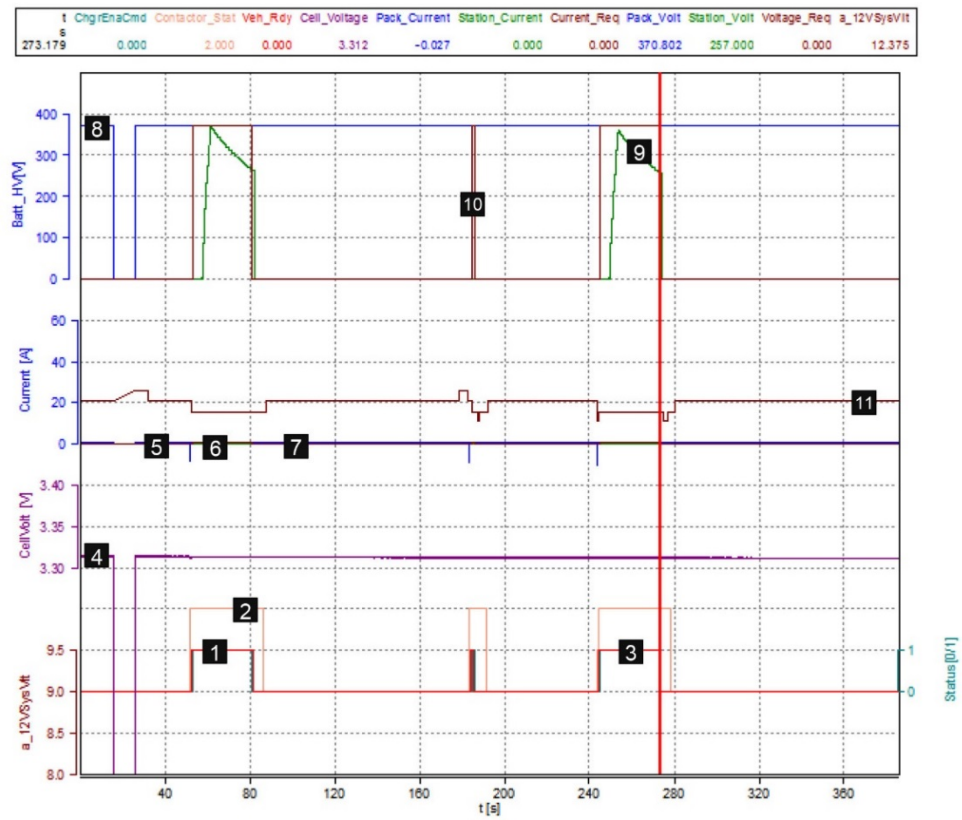
DC Bus Short in Charge Coupler:
Data File: Spark_2014-08-04__004.MDF

Installed short on charge coupler side by activating the switches S1 HV- and S1 HV+ and S1 HV short at the break out box. Attempted to start charge operation. Charge operation start did not succeed, station timed out after several attempts.

Vehicle did never attempt to activate contactors due to 0V at input.

The following graph shows the charging cycle:

Graph 11 - DC Bus Short in Charge Coupler



Legend:

1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3 Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4 High Voltage Battery Cell Voltage (single) [V] {purple}
5 High Voltage Battery Current [A] sensed by BMS {blue}
6 Off Board High Voltage Charging Station Current Output [A] {green}
7 Off Board High Voltage Charging Station Current Request [A] {brown}
8 High Voltage Battery Voltage [V] sensed by BMS {blue}
9 Off Board High Voltage Charging Station Voltage Output [V] {green}
10 Off Board High Voltage Charging Station Target Voltage [V] {brown}
11 12V System Voltage [V] {brown}

✔ Test passed, vehicle remains in safe condition

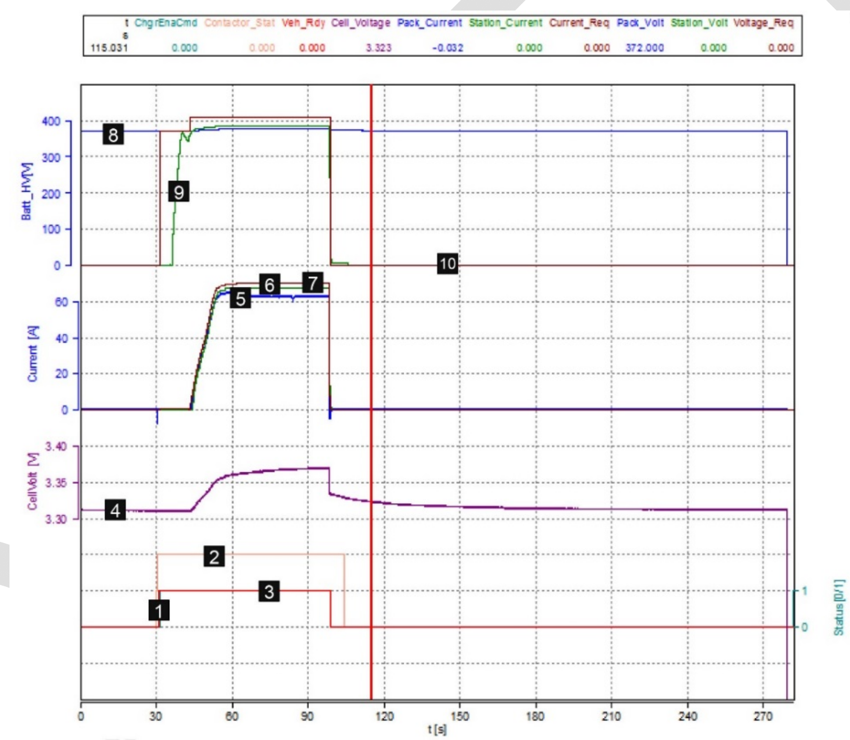
4.4 DC Bus Held High Test – P6.4.5

DC Bus held high before charging session started:
Data File: Spark_2014-07-25__005.MDF

Using a power supply and the break out box, applied 62V at the high voltage lines prior to starting the charge operation. Charging operation started without issues, no fault indication; After stopping the charging operation manually, the system shut down normally. No DTCs were set at the vehicle or station. The 62V were still present at the HV lines. The mechanical lock was released by the vehicle and the charge coupler could be removed without any issues. No indication from the charge station that 62V were still at the coupler!

The following graph shows the charging cycle:

Graph 12 - DC Bus Held High Before Charge Session



Legend:

1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3 Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4 High Voltage Battery Cell Voltage (single) [V] {purple}
5 High Voltage Battery Current [A] sensed by BMS {blue}
6 Off Board High Voltage Charging Station Current Output [A] {green}
7 Off Board High Voltage Charging Station Current Request [A] {brown}
8 High Voltage Battery Voltage [V] sensed by BMS {blue}
9 Off Board High Voltage Charging Station Voltage Output [V] {green}
10 Off Board High Voltage Charging Station Target Voltage [V] {brown}

Test did not pass, high voltage (62V) was still present at the contacts when a release of the coupler was possible. The vehicle system did not indicate any faults.

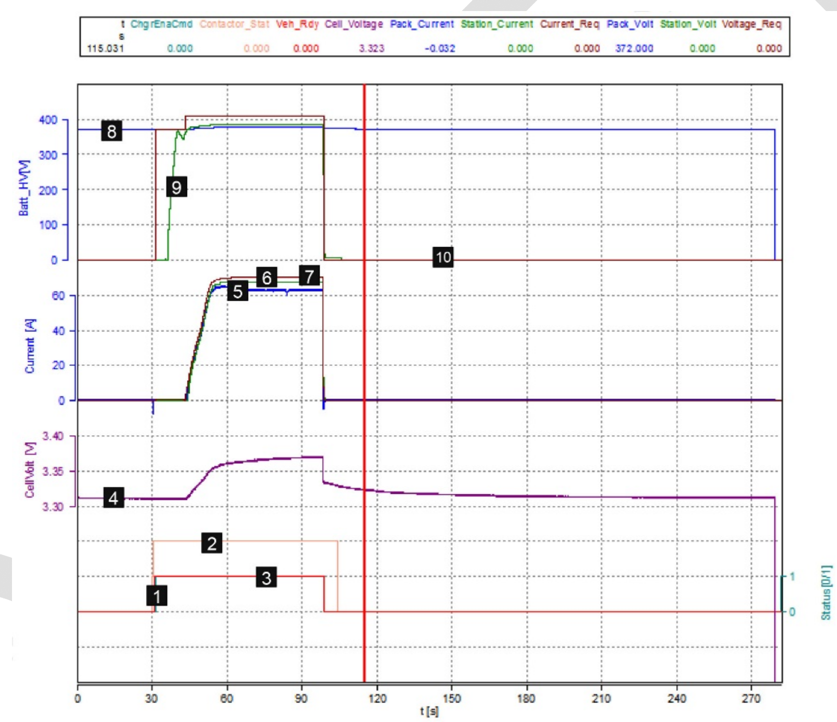
NOTE: The charger station did not indicate the presence of high voltage at the charge coupling contacts.

DC Bus held high after charging session ended:
Data File: Spark_2014-07-25__009.MDF
Using a 3300uF capacitor (with a 5kΩ parallel bleed down resistor), the high voltage at the charge coupler was kept high after charging was stopped. The voltage started bleeding down and at app. 240V the vehicle release the mechanical lock of the charge coupler. At this point it was possible to disconnect the charge coupler (with 240V still on the contacts). Indication on vehicle display alerted of the charging problem: “"Problem Detected with charging station". No indication at the charge station. DTC was set.”. Retrieved DTCs from vehicle (see “20140725_1330_HVHeldHighAfterCharge.pdf”):

> *U18A4 – Lost Communication with Hybrid/EV Battery DC Charging Communication Gateway*

The following graph shows the charging cycle:

Graph 13 - DC Bus Held High After Charge Session Ended



Legend:
1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3 Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4 High Voltage Battery Cell Voltage (single) [V] {purple}
5 High Voltage Battery Current [A] sensed by BMS {blue}
6 Off Board High Voltage Charging Station Current Output [A] {green}
7 Off Board High Voltage Charging Station Current Request [A] {brown}
8 High Voltage Battery Voltage [V] sensed by BMS {blue}
9 Off Board High Voltage Charging Station Voltage Output [V] {green}
10 Off Board High Voltage Charging Station Target Voltage [V] {brown}

Test did not pass, vehicle allowed the release of the charge coupler at around 240V. No fault codes or DTCs were set!

NOTE: The charger station did not indicate the presence of high voltage at the charge coupling contacts either.

4.5 12V System Under voltage Test – P6.6.5

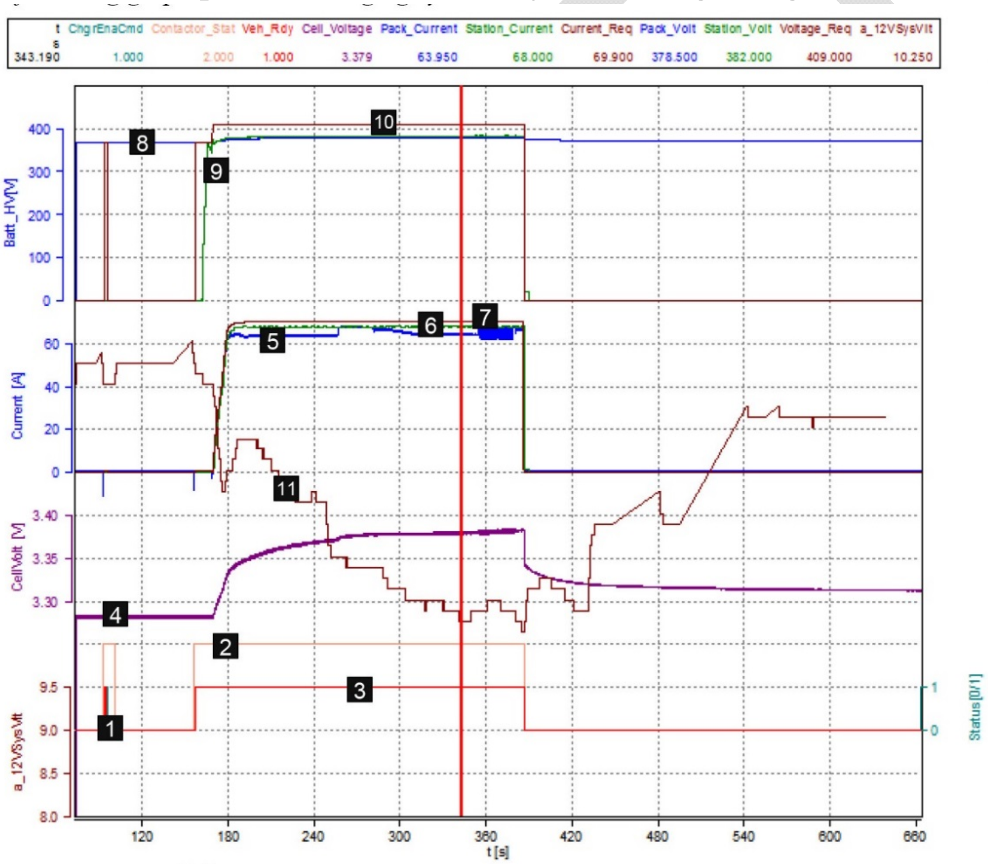
Slow reduction of 12V system voltage during charge:
Data File: Spark_2014-08-04__001.MDF

Installed small (4Ah) 12V battery and power supply to slowly (0.5V/min) drop battery voltage during charge;. Vehicle aborted charging at around 10V. Retrieved DTCs from vehicle (see "20140804_1320_12VBattDrain.PDF"). The following DTCs were set:

P0562 – System Voltage Low Voltage

The following graph shows the charging cycle:

Graph 14 - Slow Reduction of 12V During Charge



Legend:

1. High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2. High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3. Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4. High Voltage Battery Cell Voltage (single) [V] {purple}
5. High Voltage Battery Current [A] sensed by BMS {blue}
6. Off Board High Voltage Charging Station Current Output [A] {green}
7. Off Board High Voltage Charging Station Current Request [A] {brown}
8. High Voltage Battery Voltage [V] sensed by BMS {blue}
9. Off Board High Voltage Charging Station Voltage Output [V] {green}
10. Off Board High Voltage Charging Station Target Voltage [V] {brown}

⓫ 12V System Voltage [V] {brown}

✔ Test passed, vehicle remains in safe condition

4.6 Vehicle Movement Test Result – P6.9.5

Vehicle Movement during DC Fast Charge

Data File: Spark_3.MDF

Record system behavior to parking brake release.

Pressing the electronic parking brake release did NOT release the parking brake. The parking brake is electronically controlled and actuated at the time the charger establishes communication with the vehicle and the bus pre charge is performed; station and vehicle do not report any faults.

✔ Test passed, vehicle remains in safe condition

Record system behavior to attempt to turn on the vehicle.

Vehicle ignition can be turned on during fast charge operation, AC operational, all comfort functions are operational; Dash Indicator shows "Charge Cord Connected"; Power steering is operational; no impact on charging behavior; station and vehicle do not report any faults.

✔ Test passed, vehicle remains in safe condition

Record system behavior to PRND gear shift lever movement to Drive position.

Shift lever is locked; unable to move out of park; could not interrupt charging; no impact on charging behavior; station and vehicle do not report any faults.

✔ Test passed, vehicle remains in safe condition

Record system behavior to PRND gear shift lever movement to Neutral position.

Shift lever is locked; unable to move out of park; could not interrupt charging; no impact on charging behavior; station and vehicle do not report any faults.

✔ Test passed, vehicle remains in safe condition

Record system behavior to PRND gear shift lever movement to Reverse position.

Shift lever is locked; unable to move out of park; could not interrupt charging; no impact on charging behavior; station and vehicle do not report any faults.

✔ Test passed, vehicle remains in safe condition

Record system behavior to attempt to rotate the wheels during the charge.

The parking brake is electronically controlled and actuated at the time the charger establishes communication with the vehicle and the bus pre charge is performed; rotating of the wheels is not possible; station and vehicle do not report any faults.

✔ Test passed, vehicle remains in safe condition

DRAFT

4.7 Charge Operation Disturbance Test Result – P6.11.5 N/A

Data File: Spark_4.MDF

DRAFT

Premature disconnect attempt.

After the charge has begun successfully, attempt to disconnect the charge coupler from the vehicle without pressing the stop button on the charger; Pushing Charge Coupler Release Button stopped charging; Charger handle could be released after several seconds. Vehicle switched to normal operation mode (parking brake on).Vehicle fully operational without requirement to key cycle; Station and vehicle do not report any faults.
✔ Test passed, vehicle remains in safe condition

Operator interference at the charger.

Pressed all touch screen buttons; None (but Stop) button did change charging behavior; Stop button stops charging and vehicle switches out of charging mode; Several Stop button presses after charging got stopped caused charger to throw a fault "No CAN communication, Terminal out of service"; After removing and reinserting charge coupler into vehicle and followed by activating charge the vehicle resulted in "Fast Charging Stopped" mode on operator display and station is stuck in "Preparing to charge; Communicating to vehicle" mode; Station and vehicle do not report any faults.
✔ Test passed, vehicle remains in safe condition

Wiggle the connector.

Unable to disturb the charge operation; no impact on charging behavior; station and vehicle do not report any faults.
✔ Test passed, vehicle remains in safe condition

Operator inference on the vehicle.

Vehicle ignition can be turned on during fast charge operation, AC operational, all comfort functions are operational; Dash Indicator shows "Charge Cord Connected"; Power steering is operational; no impact on charging behavior; station and vehicle do not report any faults.
✔ Test passed, vehicle remains in safe condition

Operator interference with the vehicle key fob.

After charging started actuated all key fob functions by pressing buttons (unlock doors, turn on HVAC remotely during a charge, etc). None of key fob functions disturbed charge operation; no impact on charging behavior; station and vehicle do not report any faults.
✔ Test passed, vehicle remains in safe condition

Operator inference with a remote telematics command.

N/A Telematics functions not available

DRAFT

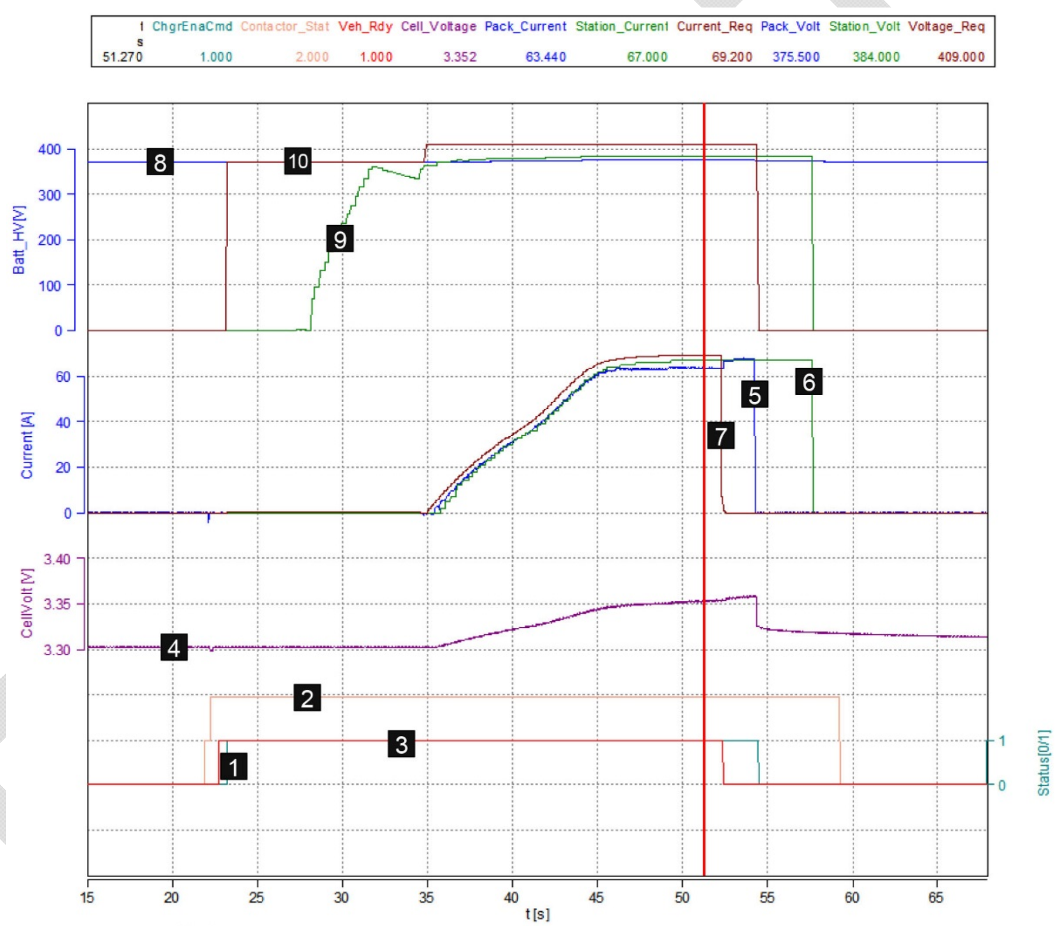
4.8 Charge Connector Control Signal Disturbance Test – P6.12.5

Control Pilot interruption through breakout box:
Data File: Spark_2014-07-23__009.MDF

Started charging and subsequently interrupted Pilot signal at break out box after 20s of full current (at time 53s in graph below). Charging current continued for app 3s and then interrupted. Charger returns to initial state before charging. No vehicle DTCs were set.

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 15 - Control Pilot Interruption



Legend:

- 1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
- 2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
- 3 Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
- 4 High Voltage Battery Cell Voltage (single) [V] {purple}
- 5 High Voltage Battery Current [A] sensed by BMS {blue}
- 6 Off Board High Voltage Charging Station Current Output [A] {green}
- 7 Off Board High Voltage Charging Station Current Request [A] {brown}
- 8 High Voltage Battery Voltage [V] sensed by BMS {blue}
- 9 Off Board High Voltage Charging Station Voltage Output [V] {green}
- 10 Off Board High Voltage Charging Station Target Voltage [V] {brown}

SAE International

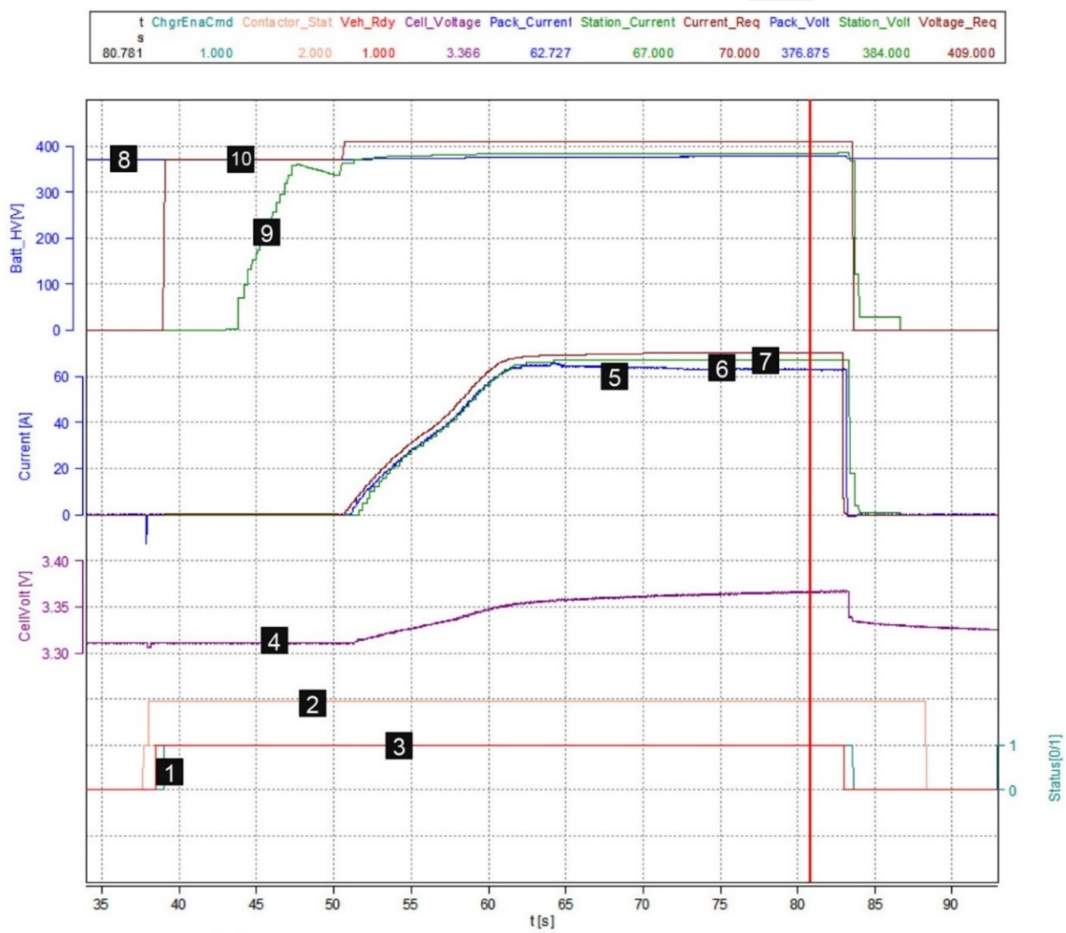
✔ Test passed, vehicle remains in safe condition

Control Pilot short to ground through breakout box:
<u>Data File</u>: Spark_2014-07-23__0016.MDF

Started charging and subsequently generated short to GND at Pilot signal at break out box after 20s of full current (at time 83s in graph below). Charging interrupted immediately. Charger returns to initial state before charging. No vehicle DTCs were set.

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 16 - Control Pilot Short to Ground



<u>Legend</u>:

- 1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
- 2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
- 3 Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
- 4 High Voltage Battery Cell Voltage (single) [V] {purple}
- 5 High Voltage Battery Current [A] sensed by BMS {blue}
- 6 Off Board High Voltage Charging Station Current Output [A] {green}
- 7 Off Board High Voltage Charging Station Current Request [A] {brown}
- 8 High Voltage Battery Voltage [V] sensed by BMS {blue}
- 9 Off Board High Voltage Charging Station Voltage Output [V] {green}
- 10 Off Board High Voltage Charging Station Target Voltage [V] {brown}

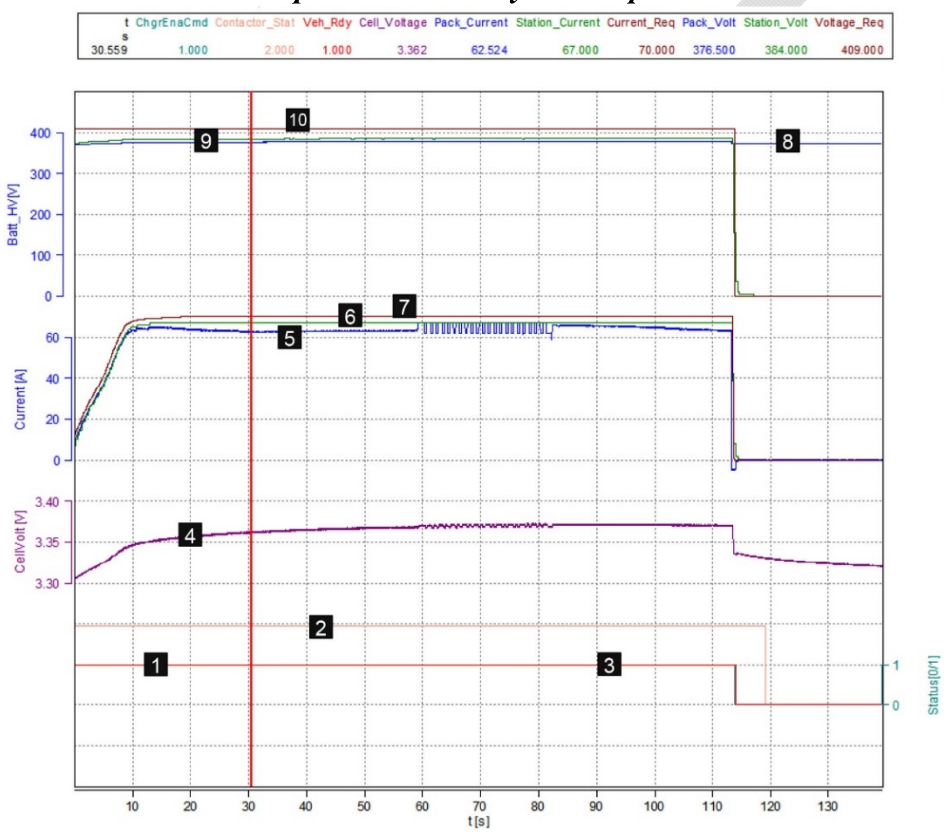
✔ Test passed, vehicle remains in safe condition

Proximity interruption through breakout box:
Data File: Spark_2014-07-23__0015.MDF

Started charging and subsequently interrupted Proximity signal at break out box after 20s of full current (at time 31s in graph below). Charging current continued without any interruption until manually stopped by operator. No vehicle DTCs were set.

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 17 - Proximity Interruption



Legend:

1. High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2. High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3. Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4. High Voltage Battery Cell Voltage (single) [V] {purple}
5. High Voltage Battery Current [A] sensed by BMS {blue}
6. Off Board High Voltage Charging Station Current Output [A] {green}
7. Off Board High Voltage Charging Station Current Request [A] {brown}
8. High Voltage Battery Voltage [V] sensed by BMS {blue}
9. Off Board High Voltage Charging Station Voltage Output [V] {green}
10. Off Board High Voltage Charging Station Target Voltage [V] {brown}

✔ Test passed, vehicle remains in safe condition

NOTE: The physical interruption of the Proximity signal was between the station and the charger handle. This means that the vehicle still had a valid Proximity signal available. We noticed that the station did not monitor the proximity signal and therefore did not perform any action or provide any feedback.

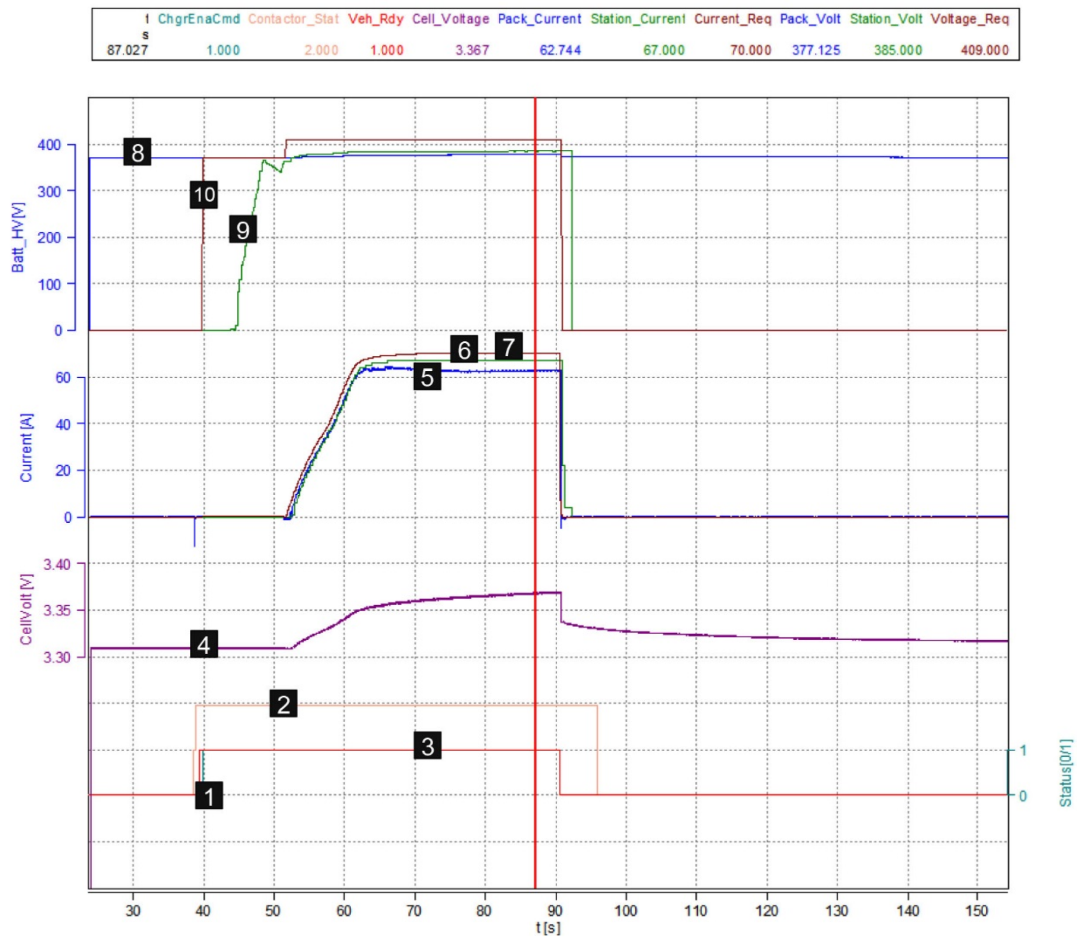
DRAFT

Proximity short to ground through breakout box:
Data File: Spark_2014-07-23__0017.MDF

Started charging and subsequently generated short to GND at Proximity signal at break out box at full current (at time 90s in graph below). Charging interrupted immediately. Charger detected overvoltage at its output. Vehicle forced contactors open. No vehicle DTCs were set.

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 18 - Proximity Short to Ground



Legend:
1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3 Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4 High Voltage Battery Cell Voltage (single) [V] {purple}
5 High Voltage Battery Current [A] sensed by BMS {blue}
6 Off Board High Voltage Charging Station Current Output [A] {green}
7 Off Board High Voltage Charging Station Current Request [A] {brown}
8 High Voltage Battery Voltage [V] sensed by BMS {blue}
9 Off Board High Voltage Charging Station Voltage Output [V] {green}
10 Off Board High Voltage Charging Station Target Voltage [V] {brown}

✔□Test passed, vehicle remains in safe condition

NOTE: We noticed that the station did not monitor the proximity signal and therefore did not perform any action at the time the signal was shorted. This led to the overvoltage condition and subsequent shutdown on the station side. It also meant that the vehicle interrupted the charging cycle by opening the charge contactors during full current operation which can lead to major degradation of the contactors and potentially welding of the contactors.

It would therefore be a good practice on the station side to monitor the Proximity signal during high current charge operation and drastically reduce the charge current immediately upon detection of a Proximity signal short to GND condition.

High resistance inline Control Pilot signal before a charge session:
Data File: Spark_2014-07-24__001.MDF

*Installed **24Ω** resistance inline the control pilot signal using the break out box before the charge session was started. Started charging and measured voltage across the Control Pilot signal **(TP3 – TP4: -0.007V)**. Charging started and continued without any impact. Stopped charging manually. No vehicle DTCs were set.*

Data recording for this session not available; Recorder was not started.

✔ Test passed, vehicle remains in safe condition

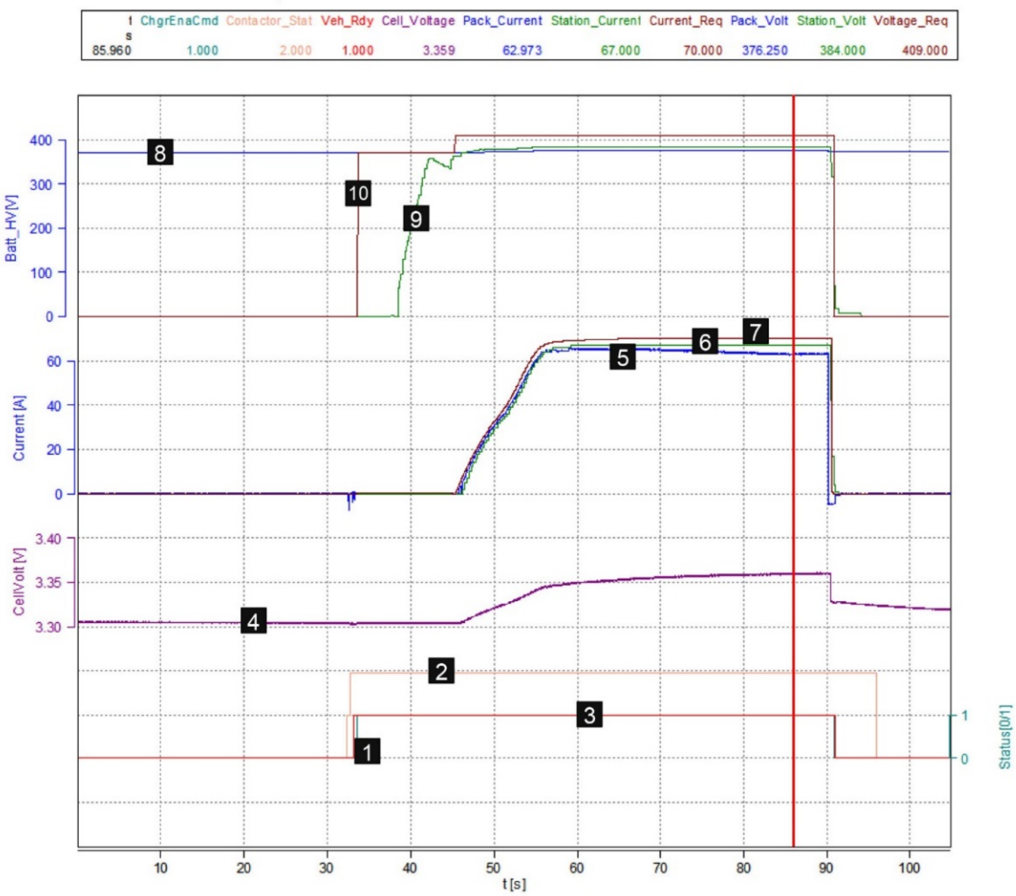
DRAFT

High resistance inline Control Pilot signal before a charge session:
Data File: Spark_2014-07-24__002.MDF

*Installed **47Ω** resistance inline the control pilot signal using the break out box before the charge session was started. Started charging and measured voltage across the Control Pilot signal **(TP3 – TP4: -0.012V)**. Charging started and continued without any impact. Stopped charging manually. No vehicle DTCs were set.*

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 19 - High Resistance Inline Control Pilot Before Charge Session, 47Ω Resistor



Legend:

- 1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
- 2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
- 3 Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
- 4 High Voltage Battery Cell Voltage (single) [V] {purple}
- 5 High Voltage Battery Current [A] sensed by BMS {blue}
- 6 Off Board High Voltage Charging Station Current Output [A] {green}
- 7 Off Board High Voltage Charging Station Current Request [A] {brown}
- 8 High Voltage Battery Voltage [V] sensed by BMS {blue}
- 9 Off Board High Voltage Charging Station Voltage Output [V] {green}
- 10 Off Board High Voltage Charging Station Target Voltage [V] {brown}

SAE International

✔ Test passed, vehicle remains in safe condition

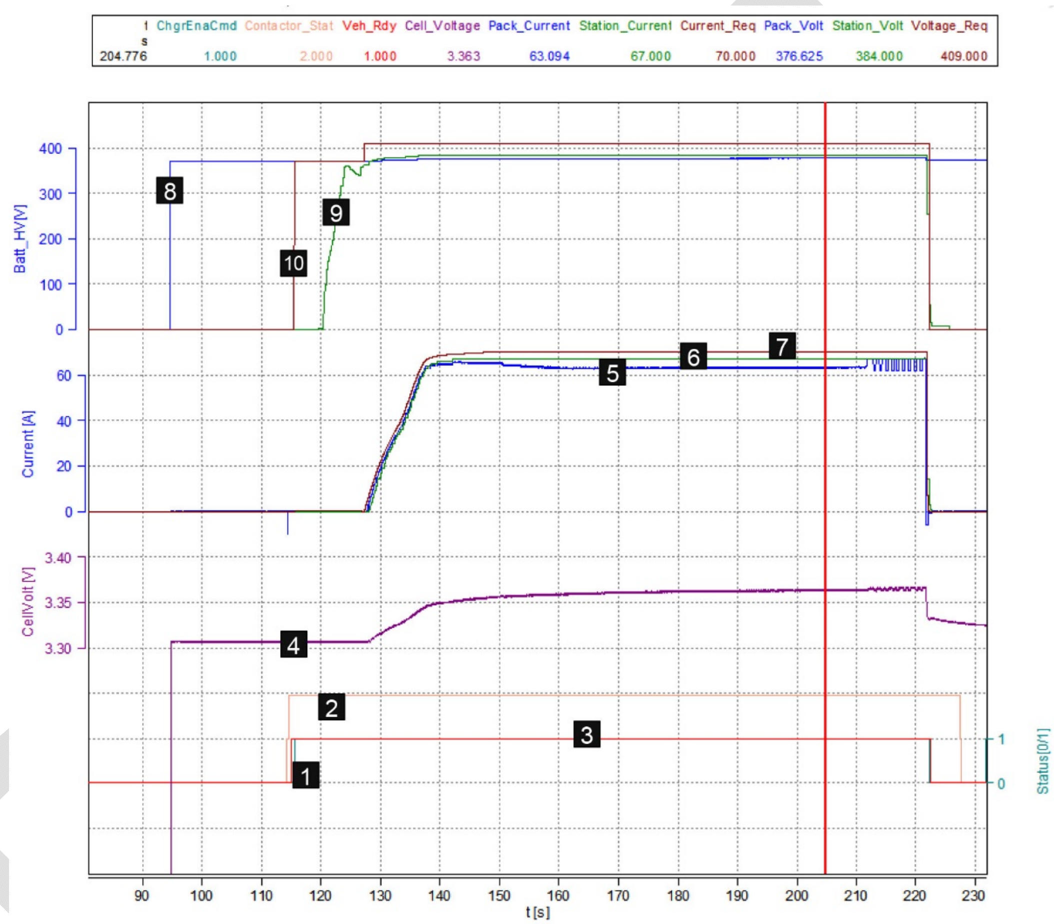
DRAFT

High resistance inline Control Pilot signal before a charge session:
Data File: Spark_2014-07-24__003.MDF

*Installed **100Ω** resistance inline the control pilot signal using the break out box before the charge session was started **(TP3 – TP4: -0.293V)**. Started charging and measured voltage across the Control Pilot signal drop down **(TP3 – TP4: -0.024V)**; charging continued without any impact. Stopped charging manually. No vehicle DTCs were set.*

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 20 - High Resistance Inline Control Pilot Before Charge Session, 100Ω Resistor



Legend:

1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3 Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4 High Voltage Battery Cell Voltage (single) [V] {purple}
5 High Voltage Battery Current [A] sensed by BMS {blue}
6 Off Board High Voltage Charging Station Current Output [A] {green}
7 Off Board High Voltage Charging Station Current Request [A] {brown}
8 High Voltage Battery Voltage [V] sensed by BMS {blue}
9 Off Board High Voltage Charging Station Voltage Output [V] {green}
10 Off Board High Voltage Charging Station Target Voltage [V] {brown}

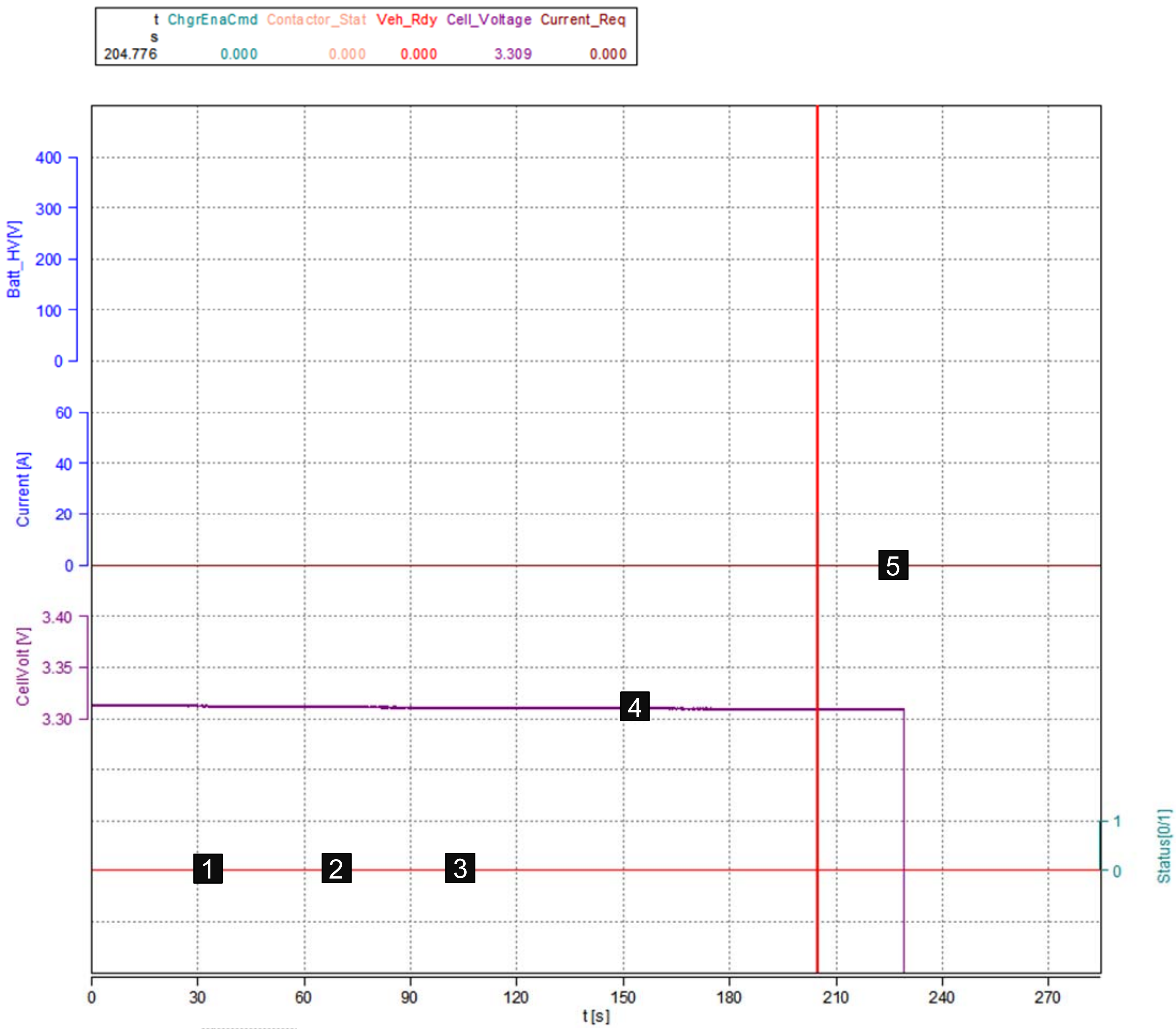
✔□Test passed, vehicle remains in safe condition

High resistance inline Control Pilot signal before a charge session:
Data File: Spark_2014-07-24__004.MDF

*Installed **1kΩ** resistance inline the control pilot signal using the break out box before the charge session was started **(TP3 – TP4: -2.344V)**. Charger could not start charging. Charger fault occurred. Vehicle set internal fault on CANalyzer data "Failed_ChargerSystemIncompatibility". Vehicle shut down automatically after 2 minutes. No DTCs set at vehicle.*

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 21 - High Resistance Inline Control Pilot Before Charge Session, 1KΩ Resistor



Legend:
1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3 Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4 High Voltage Battery Cell Voltage (single) [V] {purple}
5 Off Board High Voltage Charging Station Current Request [A] {brown}

✔ Test passed, vehicle remains in safe condition

NOTE: The above diagram shows no charging activity.

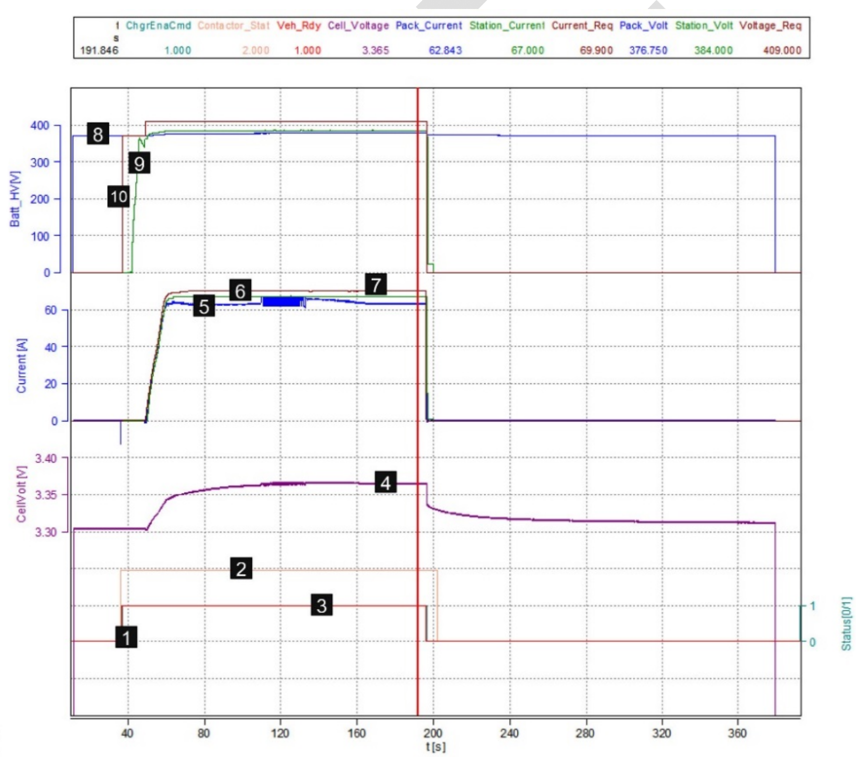
High resistance inline Control Pilot signal during a charge session:
Data File: Spark_2014-07-24__005.MDF

Started charging session without modification to Control Pilot signal. After charging started installed following resistors inline with control pilot signal using break out box and measured associated voltage drop:
***24Ω** at 60s: -0.006Vno impact*
***47Ω** at 105s: -0.012Vno impact*
***100kΩ** at 150s: -0.024Vno impact*
***1kΩ** at 195s: -0.090Vcharging stopped; voltage switched to -2.344V*

After charging shut down, the vehicle display shows the message "Fast Charging Stopped"; Vehicle set an internal fault which showed up on CANalyzer data as "Failed_ChargerSystemIncompatibility". Vehicle shut down automatically after 3 minutes. No DTCs set at vehicle.

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 22 - High Resistance Inline Control Pilot During Charge Session



Legend:
1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3 Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4 High Voltage Battery Cell Voltage (single) [V] {purple}
5 High Voltage Battery Current [A] sensed by BMS {blue}
6 Off Board High Voltage Charging Station Current Output [A] {green}
7 Off Board High Voltage Charging Station Current Request [A] {brown}
8 High Voltage Battery Voltage [V] sensed by BMS {blue}
9 Off Board High Voltage Charging Station Voltage Output [V] {green}
10 Off Board High Voltage Charging Station Target Voltage [V] {brown}

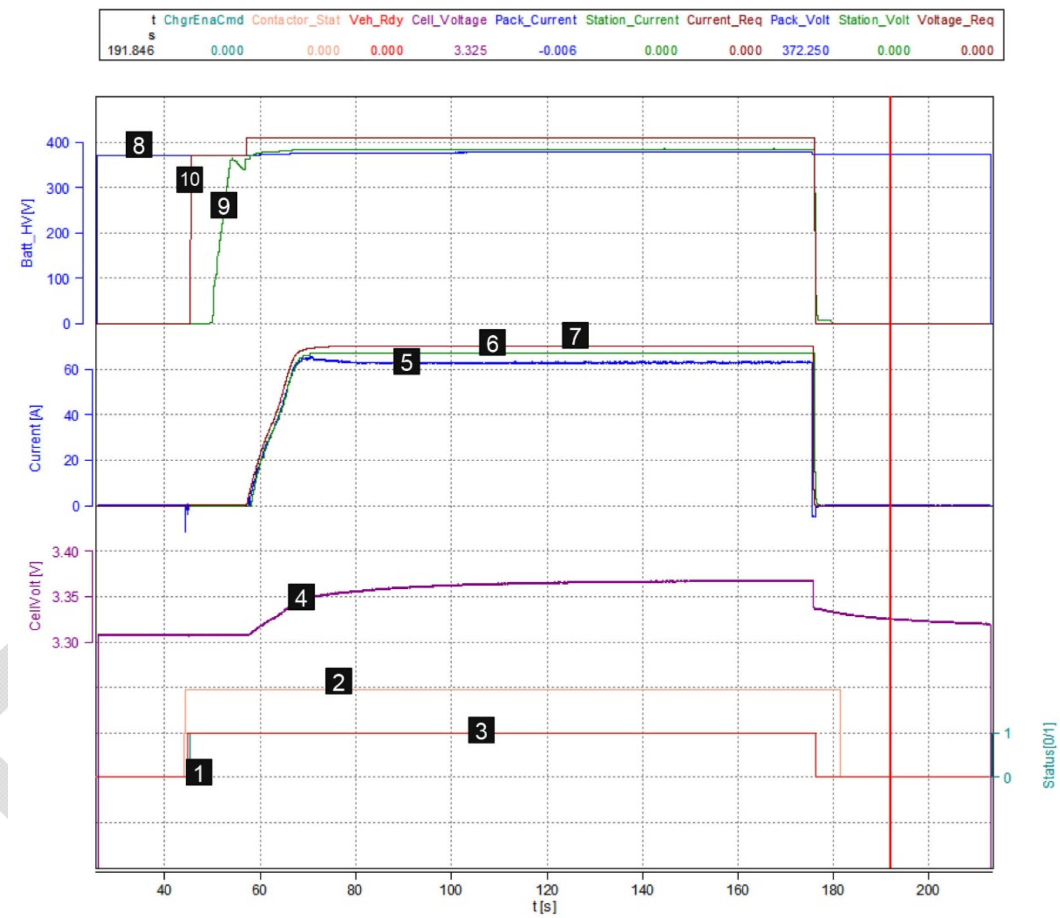
✔☐Test passed, vehicle remains in safe condition

High resistance inline Proximity signal before a charge session:
Data File: Spark_2014-07-24__006.MDF

Installed ***24Ω*** *resistance inline the Proximity signal using the break out box before the charge session was started. Started charging and measured voltage across the Proximity signal* ***(TP3 – TP4: 0V)****. Charging started and continued without any impact. Stopped charging manually. No vehicle DTCs were set.*

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 23 - High Resistance Inline Proximity Signal Before Charge Session, 24Ω Resistor



Legend:

1. High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2. High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3. Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4. High Voltage Battery Cell Voltage (single) [V] {purple}
5. High Voltage Battery Current [A] sensed by BMS {blue}
6. Off Board High Voltage Charging Station Current Output [A] {green}
7. Off Board High Voltage Charging Station Current Request [A] {brown}
8. High Voltage Battery Voltage [V] sensed by BMS {blue}
9. Off Board High Voltage Charging Station Voltage Output [V] {green}

10 Off Board High Voltage Charging Station Target Voltage [V] {brown}

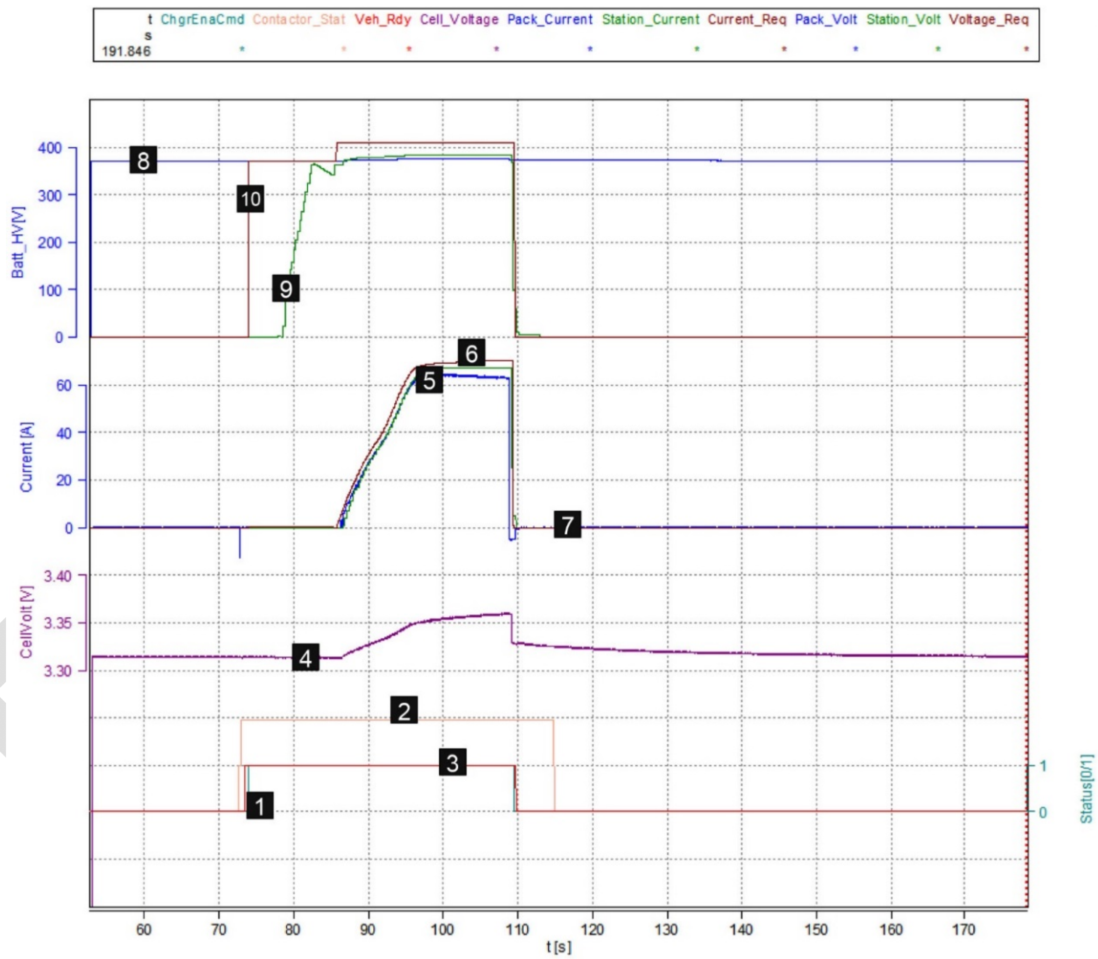
✔ Test passed, vehicle remains in safe condition

High resistance inline Proximity signal before a charge session:
Data File: Spark_2014-07-24__007.MDF

*Installed **47Ω** resistance inline the Proximity signal using the break out box before the charge session was started. Started charging and measured voltage across the Proximity signal **(TP3 – TP4: 0V)**. Charging started and continued without any impact. Stopped charging manually. No vehicle DTCs were set.*

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 24 - High Resistance Inline Proximity Signal Before Charge Session, 47Ω Resistor



Legend:

1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3 Vehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4 High Voltage Battery Cell Voltage (single) [V] {purple}
5 High Voltage Battery Current [A] sensed by BMS {blue}
6 Off Board High Voltage Charging Station Current Output [A] {green}
7 Off Board High Voltage Charging Station Current Request [A] {brown}

❽ High Voltage Battery Voltage [V] sensed by BMS {blue}
❾ Off Board High Voltage Charging Station Voltage Output [V] {green}
❿ Off Board High Voltage Charging Station Target Voltage [V] {brown}

✔ Test passed, vehicle remains in safe condition

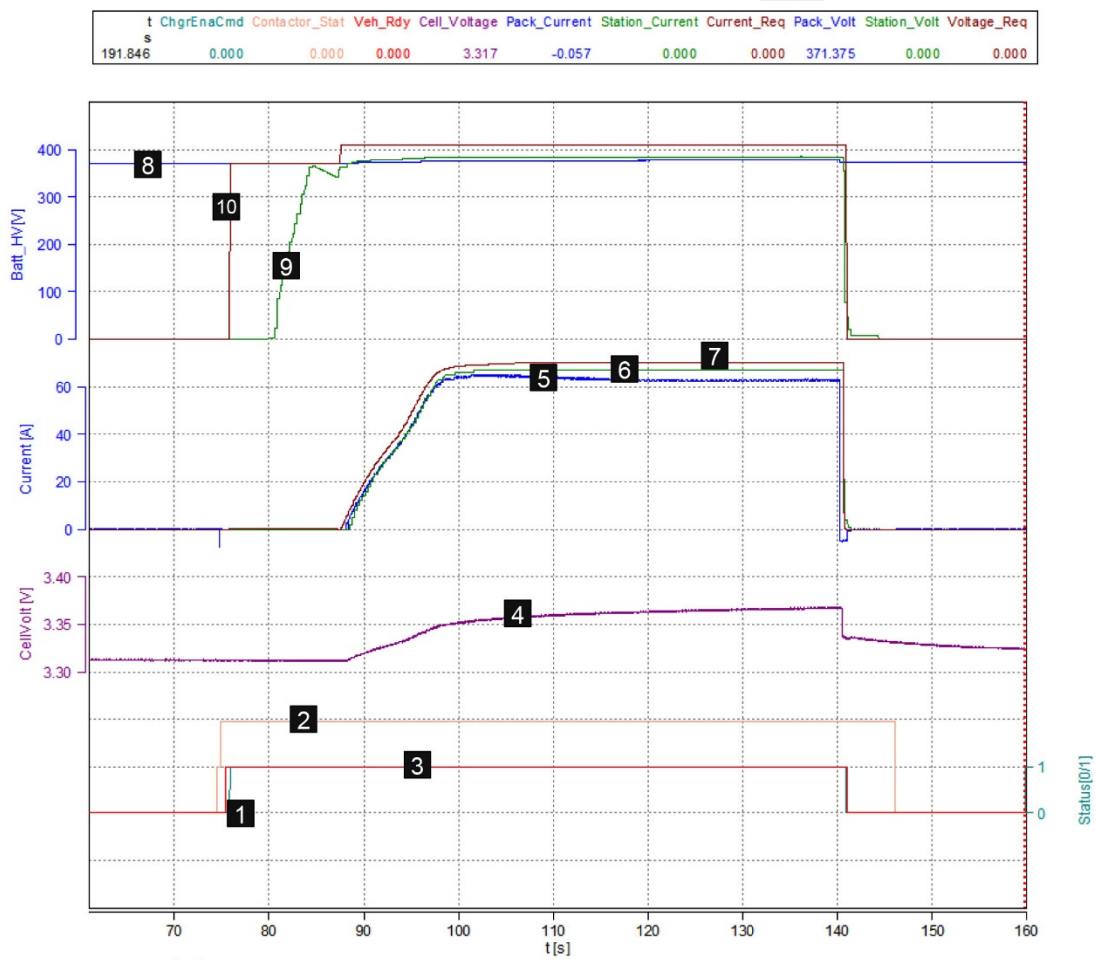
DRAFT

High resistance inline Proximity signal before a charge session:
<u>Data File</u>: Spark_2014-07-24__008.MDF

*Installed **100Ω** resistance inline the Proximity signal using the break out box before the charge session was started. Started charging and measured voltage across the Proximity signal **(TP3 – TP4: 0V)**. Charging started and continued without any impact. Stopped charging manually. No vehicle DTCs were set.*

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 25 - High Resistance Inline Proximity Signal Before Charge Session, 100Ω Resistor



<u>Legend</u>:

1	High Voltage Charger High Voltage Power Supply Enable [0/1]	{light green}
2	High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close)	{tan}
3	*V*ehicle Ready for Charging [0/1] (0=False; 1=True)	{red}
4	High Voltage Battery Cell Voltage (single) [V]	{purple}
5	High Voltage Battery Current [A] sensed by BMS	{blue}
6	Off Board High Voltage Charging Station Current Output [A]	{green}
7	Off Board High Voltage Charging Station Current Request [A]	{brown}
8	High Voltage Battery Voltage [V] sensed by BMS	{blue}
9	Off Board High Voltage Charging Station Voltage Output [V]	{green}
10	Off Board High Voltage Charging Station Target Voltage [V]	{brown}

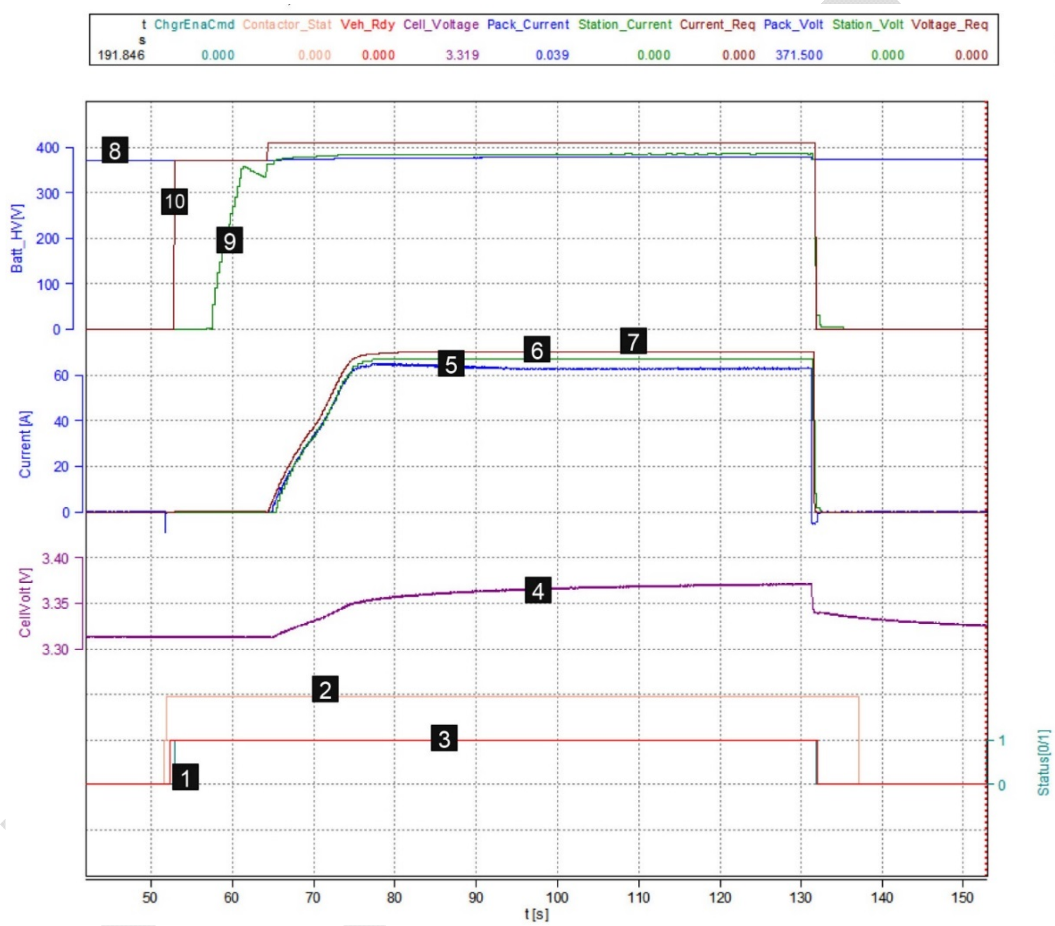
✔ Test passed, vehicle remains in safe condition

High resistance inline Proximity signal before a charge session:
Data File: Spark_2014-07-24__009.MDF

*Installed **1000Ω** resistance inline the Proximity signal using the break out box before the charge session was started. Started charging and measured voltage across the Proximity signal **(TP3 – TP4: 0V)**. Charging started and continued without any impact. Stopped charging manually. No vehicle DTCs were set.*

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 26 - High Resistance Inline Proximity Signal Before Charge Session, 1KΩ Resistor



Legend:
1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3 *V*ehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4 High Voltage Battery Cell Voltage (single) [V] {purple}
5 High Voltage Battery Current [A] sensed by BMS {blue}
6 Off Board High Voltage Charging Station Current Output [A] {green}
7 Off Board High Voltage Charging Station Current Request [A] {brown}
8 High Voltage Battery Voltage [V] sensed by BMS {blue}
9 Off Board High Voltage Charging Station Voltage Output [V] {green}
10 Off Board High Voltage Charging Station Target Voltage [V] {brown}

✔ Test passed, vehicle remains in safe condition

High resistance inline Proximity signal during a charge session:
Data File: Spark_2014-07-24__0010.MDF

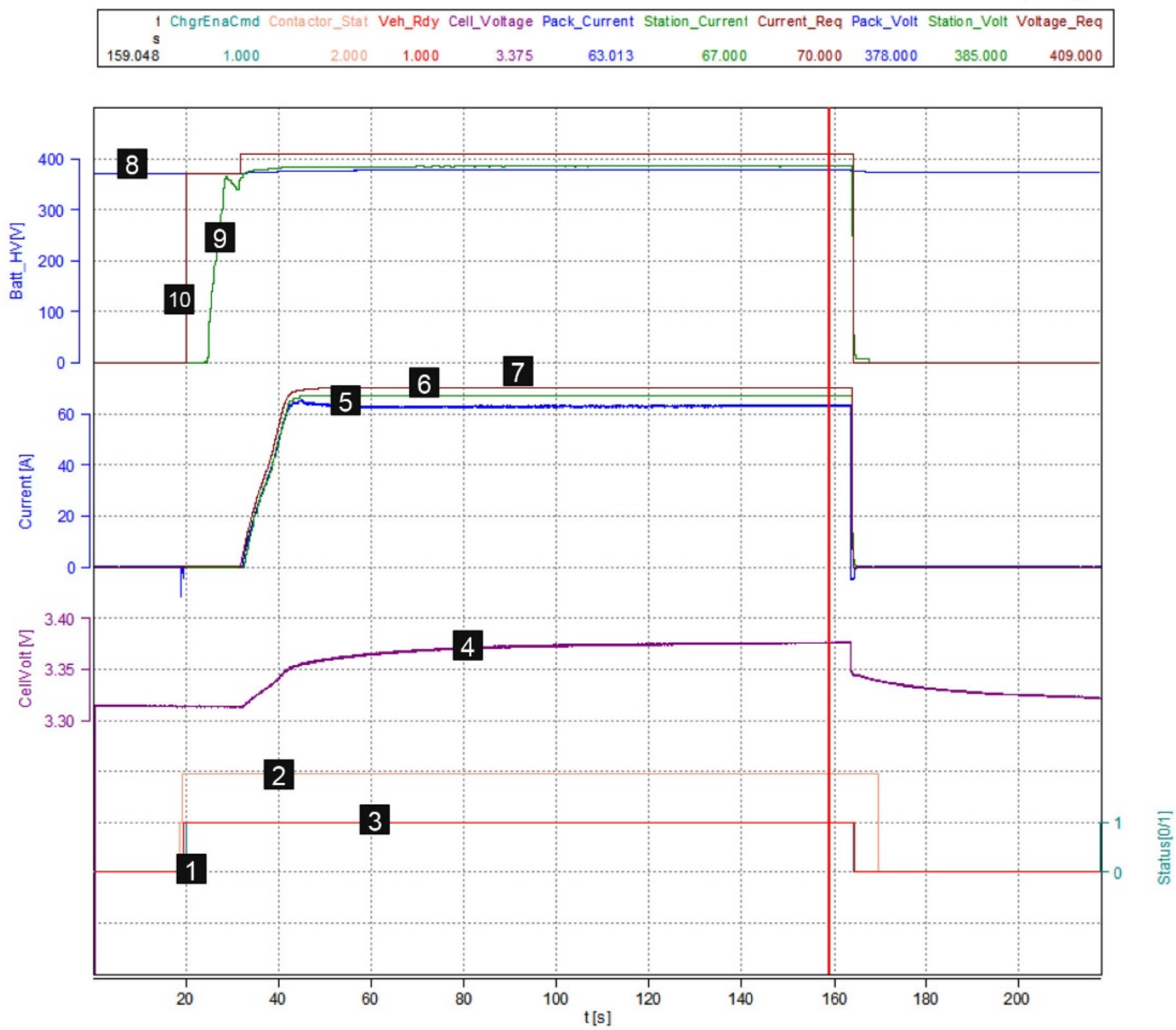
Started charging session without modification to Proximity signal. After charging started installed following resistors inline with Proximity signal using break out box and measured associated voltage drop:

24Ω *at 60s: 0Vno impact*
47Ω *at 75s: 0Vno impact*
100kΩ *at 95s: 0Vno impact*
1kΩ *at 135s: 0Vno impact*

The inline resistance did not affect the charging operation in any way. No vehicle DTCs were set.

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 27 - High Resistance Inline Proximity Signal During Charge Session



Legend:

1	High Voltage Charger High Voltage Power Supply Enable [0/1]	{light green}
2	High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close)	{tan}
3	*V*ehicle Ready for Charging [0/1] (0=False; 1=True)	{red}
4	High Voltage Battery Cell Voltage (single) [V]	{purple}
5	High Voltage Battery Current [A] sensed by BMS	{blue}
6	Off Board High Voltage Charging Station Current Output [A]	{green}
7	Off Board High Voltage Charging Station Current Request [A]	{brown}
8	High Voltage Battery Voltage [V] sensed by BMS	{blue}
9	Off Board High Voltage Charging Station Voltage Output [V]	{green}
10	Off Board High Voltage Charging Station Target Voltage [V]	{brown}

✔□Test passed, vehicle remains in safe condition

NOTE: The physical interruption of the Proximity signal was between the station and the charger handle. This means that the vehicle still had a valid Proximity signal available. The station did not monitor the proximity signal and therefore there was no voltage drop across inline resistance.

DRAFT

CAN error frames during a fast charge:
Data File: Spark_2014-07-08__002.MDF

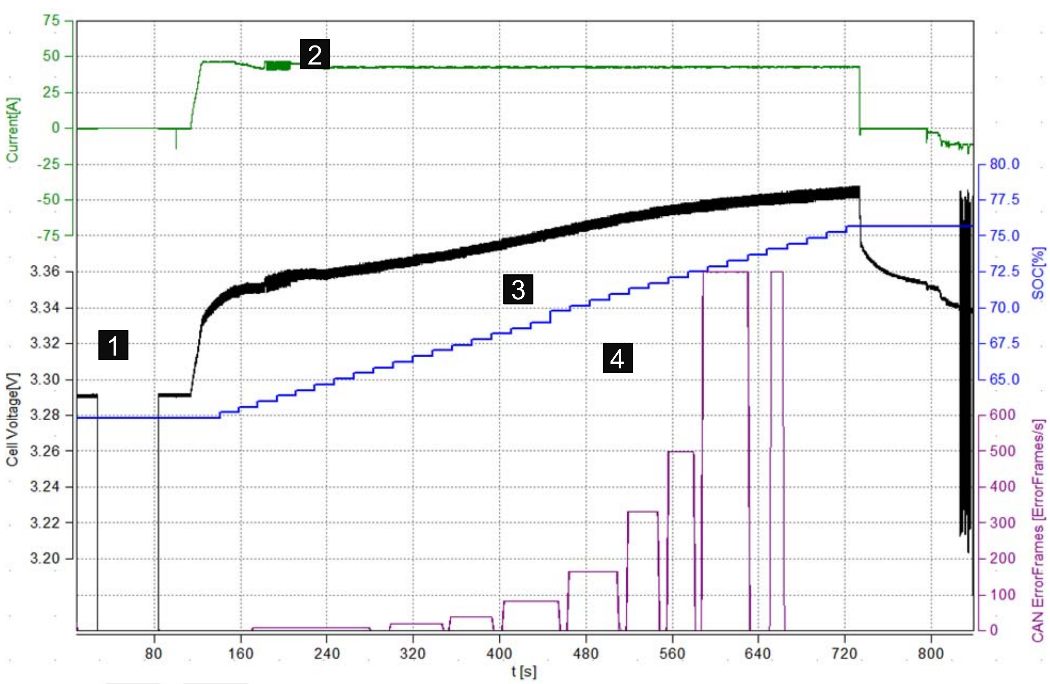
Started CANalyzer recording of both vehicle main CAN network and High Voltage battery/charger CAN network; Introduced CAN error frames at the following different rates:

Error frames every 100ms=> no problem
Error frames every 50ms=> no problem
Error frames every 25ms => no problem
Error frames every 12ms=> no problem
Error frames every 6ms => no problem
Error frames every 3ms => no problem
Error frames every 2ms => no problem
Error frames every 1ms => no problem

There was no degradation in the CAN data rate noticeable. All communication between battery BMS and charging hardware performed without issues. There were no vehicle DTCs set. The charging station did not report any errors.

The following graph shows the charging and the induced error frames:

Graph 28 - Charging Cycle and Induced CAN Error Frames During Fast Charge



Legend:
1 High Voltage Battery Cell Voltages (all) [V] {black}
2 High Voltage Battery Current [A] sensed by BMS {green}
3 Customer Usable State of Charge [%] {blue}
4 CAN error frames [#/s] {purple}

✔ Test passed, vehicle remains in safe condition

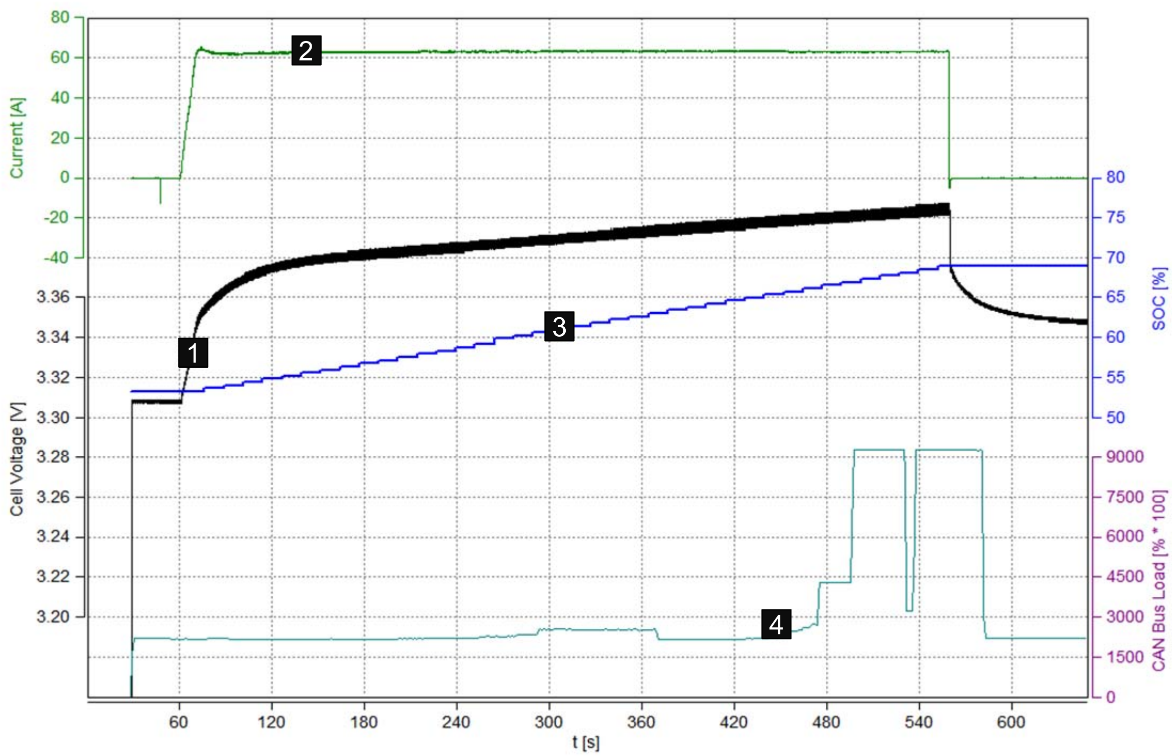
CAN bus load increase during a fast charge:
Data File: Spark_2014-07-08__002.MDF

Started CANalyzer recording of both vehicle main CAN network and High Voltage battery/charger CAN network; Introduced dummy CAN message frame so increase bus load up to >80%.

There was no degradation in the CAN data rate noticeable. All communication between battery BMS and charging hardware performed without issues. There were no vehicle DTCs set. The charging station did not report any errors. The charge operation was manually stopped by the operator.

The following graph shows the charging and the induced bus load:

Graph 29 - Charging Cycle and CAN Bus Load Increase During Fast Charge



Legend:
1 High Voltage Battery Cell Voltages (some) [V] {black}
2 High Voltage Battery Current [A] sensed by BMS {green}
3 Customer Usable State of Charge [%] {blue}
4 CAN Bus Load [%] {light blue}

✔ Test passed, vehicle remains in safe condition

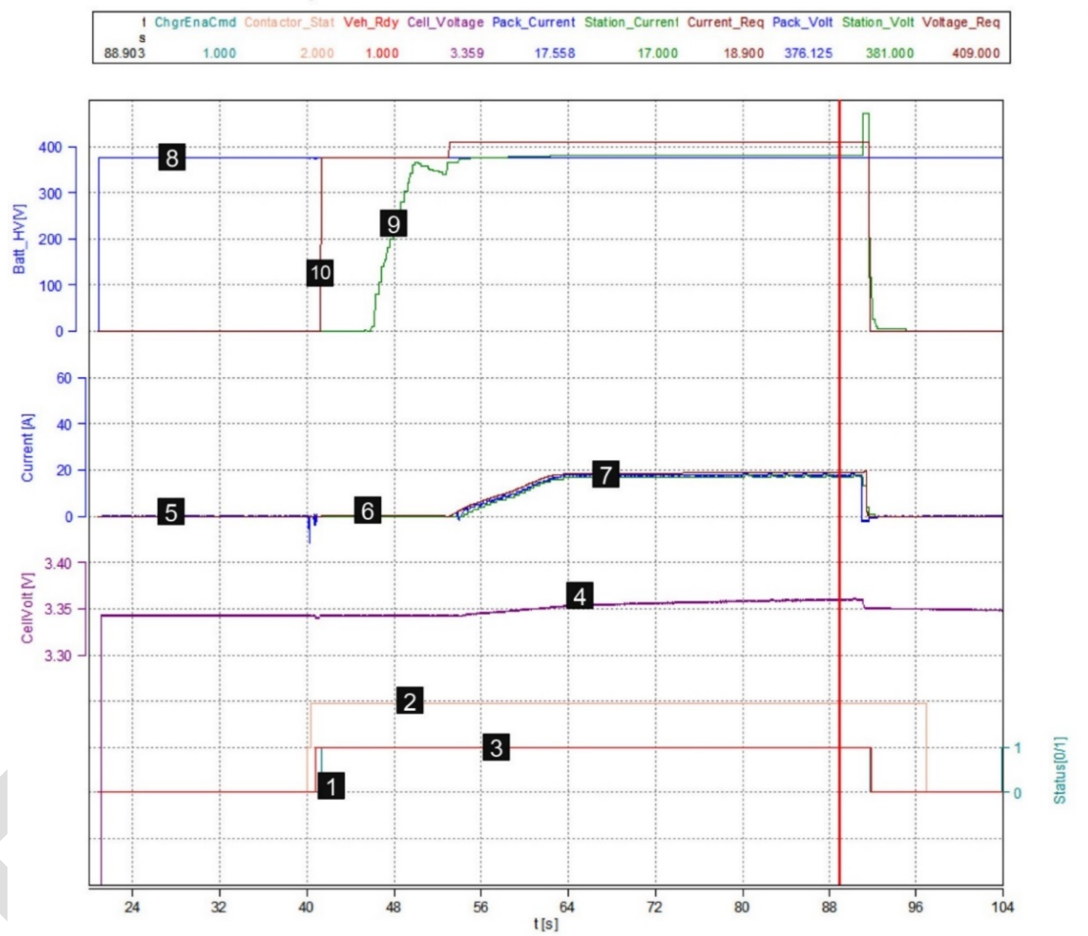
4.9 Charge Connector HV Connection Disturbance – P6.14.5

Interrupt DC High Voltage Positive connection during fast charge:
Data File: Spark_2014-07-24__0013.MDF

Started vehicle charging operation. Interrupted High Voltage positive connection using break out box. Charger Station detected loss of current and shut down immediately. No vehicle DTCs were set.

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 30 - Interrupt DC High Voltage Positive During Fast Charge



Legend:

1. High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2. High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3. *V*ehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4. High Voltage Battery Cell Voltage (single) [V] {purple}
5. High Voltage Battery Current [A] sensed by BMS {blue}
6. Off Board High Voltage Charging Station Current Output [A] {green}
7. Off Board High Voltage Charging Station Current Request [A] {brown}
8. High Voltage Battery Voltage [V] sensed by BMS {blue}
9. Off Board High Voltage Charging Station Voltage Output [V] {green}
10. Off Board High Voltage Charging Station Target Voltage [V] {brown}

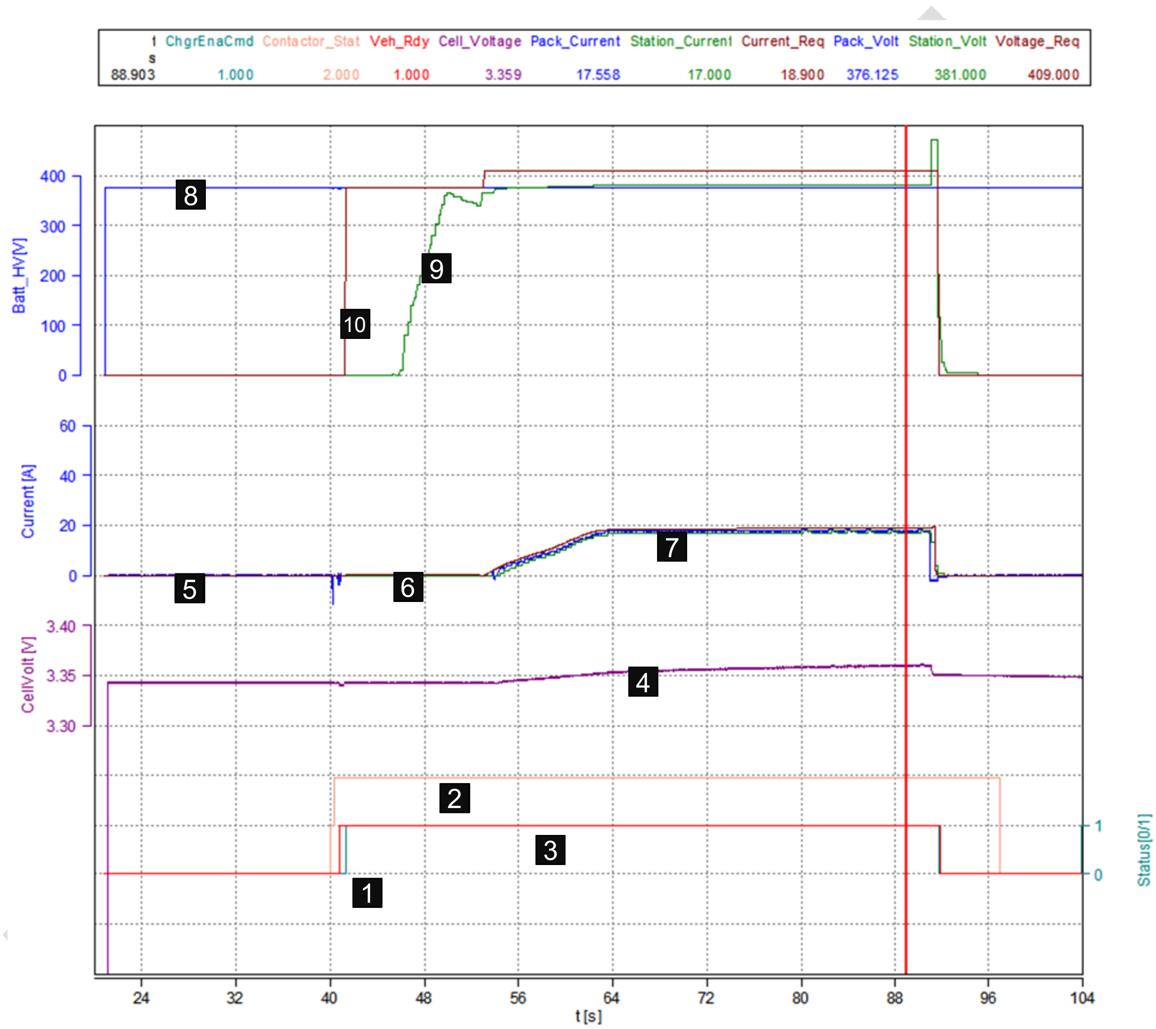
✔□Test passed, vehicle remains in safe condition

SAE International

Interrupt DC High Voltage Negative connection during fast charge:
Data File: Spark_2014-07-24__0014.MDF

Started vehicle charging operation. Interrupted High Voltage negative connection using break out box. Charger Station detected loss of current and shut down immediately. No vehicle DTCs were set.
The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 31 - Interrupt DC High Voltage Negative During Fast Charge



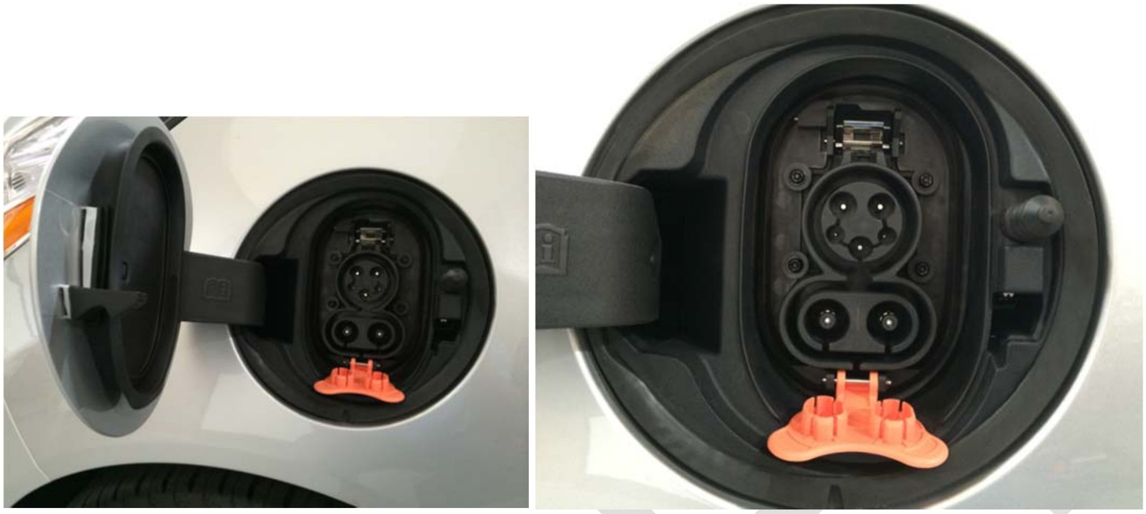
Legend:

1 High Voltage Charger High Voltage Power Supply Enable [0/1] {light green}
2 High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close) {tan}
3 *V*ehicle Ready for Charging [0/1] (0=False; 1=True) {red}
4 High Voltage Battery Cell Voltage (single) [V] {purple}
5 High Voltage Battery Current [A] sensed by BMS {blue}
6 Off Board High Voltage Charging Station Current Output [A] {green}
7 Off Board High Voltage Charging Station Current Request [A] {brown}
8 High Voltage Battery Voltage [V] sensed by BMS {blue}
9 Off Board High Voltage Charging Station Voltage Output [V] {green}
10 Off Board High Voltage Charging Station Target Voltage [V] {brown}

✔☐Test passed, vehicle remains in safe condition

4.10 Visual Inspection of Charge Port – P6.15.5

Inspected Charge Coupler and vehicle receptacle for any damage or debris.



No problems detected on vehicle side of charge receptacle.

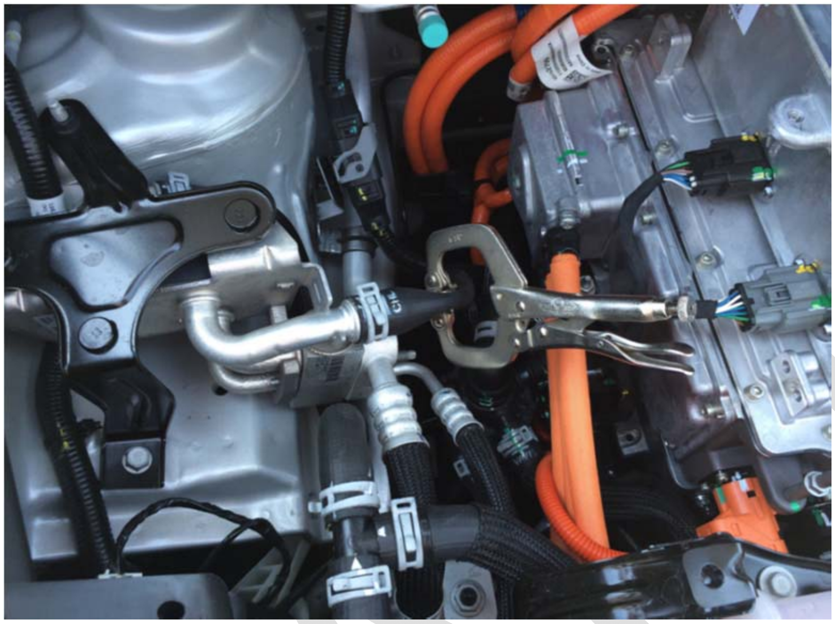
No problems detected on the charger coupler side.
Note: During extensive testing at the engineering charger location, an insufficient mechanical switch connection after charge coupler connection was detected. This led to repeated random charge start failures, that requires wiggling of the charge coupler. The mechanical interlock connection for this coupler is not optimal.

DRAFT

4.11 Cooling Heating System – P6.16.5

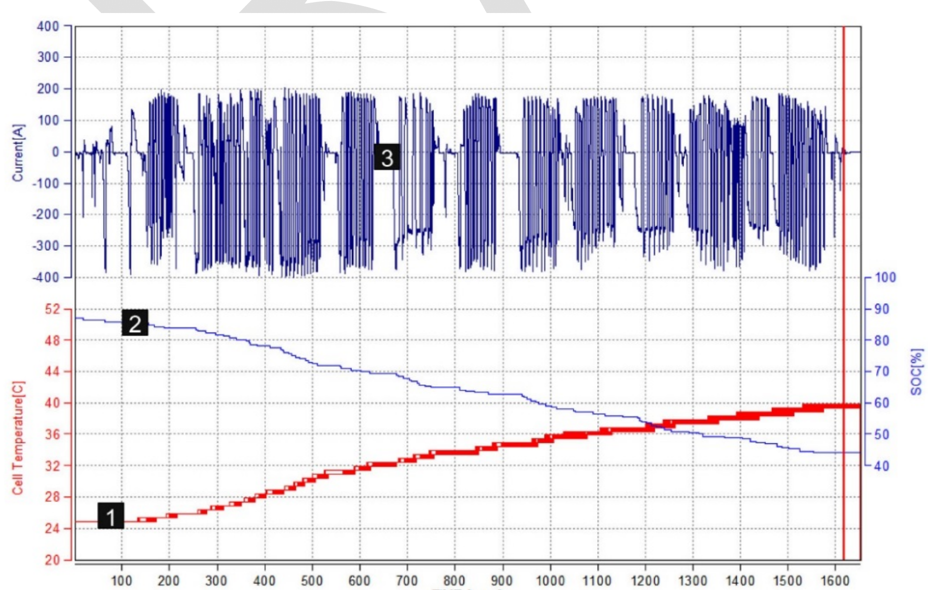
Restricted ESS cooling system before and during charging, at high ambient temperatures.

1. *Installed restriction in battery cooling circuit, to drastically reduce battery cooling performance*



2. *Performed constant accel/decel driving maneuvers to deplete high voltage battery SOC and increase internal temperature from 25°C to 40°C.*
   Data File: Spark_2014-07-09__0031.MAT
   The following graph shows the driving cycle:

Graph 32 - Driving Cycle, Restricted Cooling System

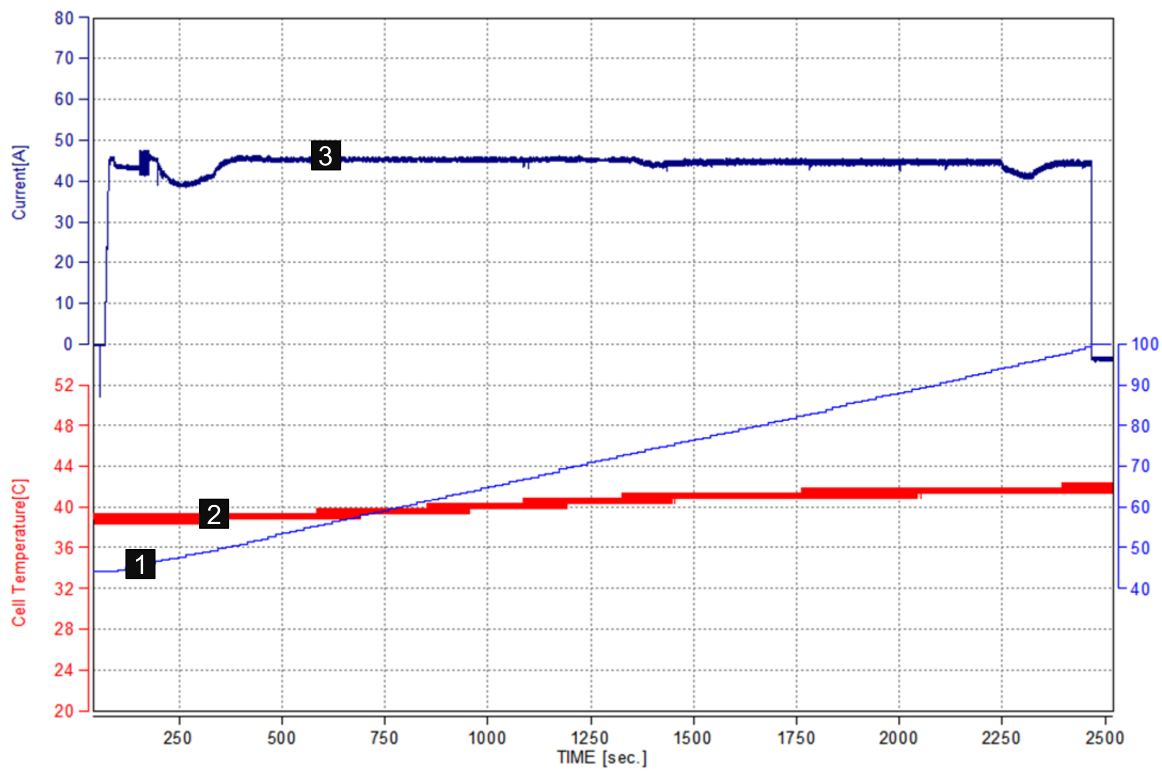


DRAFT

3. Performed fast charging at charging station (cooling restriction still installed)with 45A up to 80% SOC; Internal temperature from changed from 39.5°C to 42.5°C
   The charging rate is not high enough to cause any over temperature issues for the vehicle system

   The following graph shows the charging cycle:
   Data File: Spark_2014-07-09__0032.MAT

Graph 33 - Charging Cycle, Restricted Cooling System



Legend:
1 Customer Usable State of Charge [%] {blue}
2 Cell Temperatures [°C] sensed by BMS {red}
3 High Voltage Battery Current [A] sensed by BMS {blue}

✔ Test passed, vehicle remains in safe condition

DRAFT

4.12 Overcharge Test – P6.18.5

Increase charge current 10% above allowed requested charge current:
Data File: Spark_2014-07-24__0018.MDF

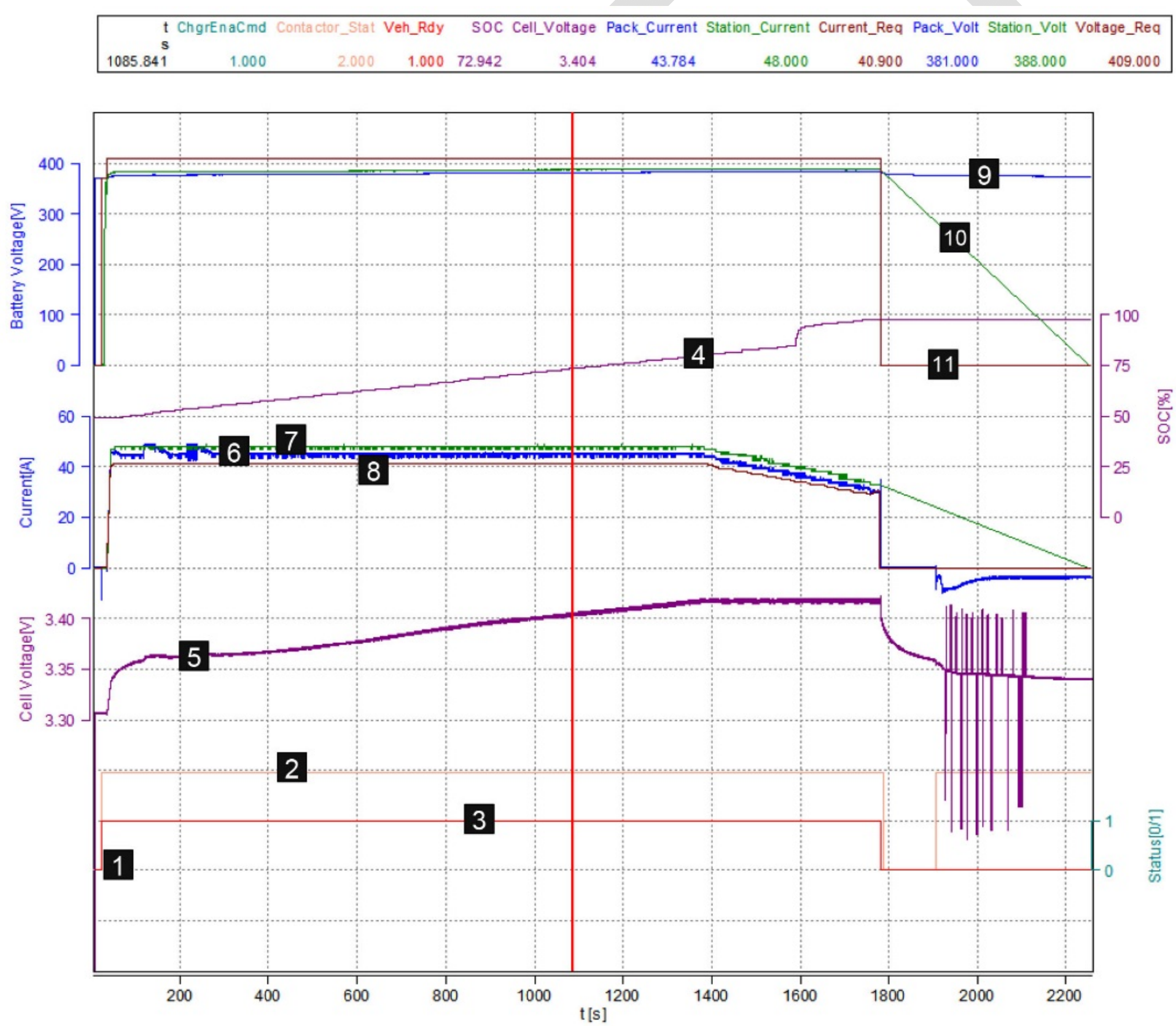
Changed charger software controls of the engineering charge station to deliver 55A charge current and report only 45A to the vehicle. Started charging the vehicle from 50% SOC. Vehicle allowed charging until it reached 97.3% SOC and forced a shut down at that point. Vehicle set an internal fault which showed up on CANalyzer data as "FAILED_PEVRESSMalfunction". Retrieved DTCs from vehicle (see "20140725_1508_OverCharge.pdf").

The following DTCs were set:

U18A4 – Lost Communication with Hybrid/EV Battery DC Charging Communication Gateway

The following graph shows the charging cycle (red vertical line is cursor; values shown are values measured at cursor):

Graph 34 - Overcharge Test, Increase Charge Current 10% Above Requested Charge Current



Legend:

1	High Voltage Charger High Voltage Power Supply Enable [0/1]	{light green}
2	High Voltage Contactor Status [0/1] (0=Open; 1=Precharge; 2=Close)	{tan}
3	Vehicle Ready for Charging [0/1] (0=False; 1=True)	{red}
4	Customer Usable State of Charge [%]	{purple}
5	High Voltage Battery Cell Voltage (single) [V]	{purple}
6	High Voltage Battery Current [A] sensed by BMS	{blue}
7	Off Board High Voltage Charging Station Current Output [A]	{green}
8	Off Board High Voltage Charging Station Current Request [A]	{brown}
9	High Voltage Battery Voltage [V] sensed by BMS	{blue}
10	Off Board High Voltage Charging Station Voltage Output [V]	{green}
11	Off Board High Voltage Charging Station Target Voltage [V]	{brown}

✔ Test passed, vehicle remains in safe condition

All test data is available on a USB jump drive labeled “SAE-3697 BMS Failure Mode”.

END OF DOCUMENT

DRAFT