Vehicle Mounted Hybrid Battery Charger

1. PURPOSE

The purpose of this document is to define the design specifications and test requirements for the Vehicle Mounted Hybrid Battery Charger, Eaton part number: 4307212

2. SCOPE

This document describes the Charger subsystem design only. The document includes interface specifications and minimum performance specifications the charger system needs to function as specified in the Eaton EPRI\DOE PHEV System Architecture for EVSE Recharging (HBR-09005-2010-0006).

3. RESPONSIBILITY

Standards Engineering shall be responsible for the administration and maintenance of this specification.

The appropriate Chief Engineer/Team Leader of Hybrid Electric Vehicles shall be responsible for the application of this specification and shall approve any proposed revisions and deviations.

4. ACRONYMS, ABBREVIATIONS, AND TERMS; DEFINITION

The following terminology is used in this specification:

Acronym / Abbreviation / Term	Definition
AC	Alternating electrical Current 50/60 Hz
CAN	Controller Area Network
Charger	Charger Module, vehicle mounted
Charge Connector (Vehicle Connector)	Connector on end of EVSE Cord set that mates to the Vehicle Charge Receptacle
Charge Coupler	The EVSE Charge Connector cord set and Vehicle Charge Receptacle.
Charge Enable	A command indicating when charging (output power) is allowed
Charge Receptacle (Vehicle Inlet)	Vehicle mounted receptacle for Charge Coupler
Charger State (evChargerStatus)	Indicates the state of the charger, Not Connected, Connected Standby, Connected Charging, and Not Available
Charge pilot	Primary Control Conductor (SAE J1772)
Command Message	CAN message from the Hybrid system to the Charger.
Control System	Control logic and low voltage I/O circuits for the charger

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Acronym / Abbreviation / Term	**Definition**
Current Limit (evHCMCurrentLimit)	A command indicating the maximum charging current allowed
DC	Direct electrical Current
DCR	DC series resistance
DOD	Depth of Discharge
DOE	Department Of Energy
DTC	Diagnostic Trouble Code
DUT	Device Under Test
EPRI	Electric Power Research Institute
EVSE	Electric Vehicle Supply Equipment
Fault Active/Severity Indicator	Indicates active faults within the Charger and the highest severity level of all currently active faults.
FMI	Failure Mode Indicator (SAE J1939-73 Appendix A)
GFI	Ground Fault Interrupter
HCM	Hybrid Control Module
HEV	Hybrid Electric Vehicle
HV (DC)	High Voltage (DC hybrid system voltage)
Hybrid Battery	High Voltage DC PHEV battery
LV (Low Voltage)	Low voltage (12V or 24V vehicle/battery power or signals)
I/O	Input and Output (typically electrical signals)
Input Current	The current the charger is using from the EVSE
Input Current Limit	Current limit of the EVSE as determined by the Charger
Input Power	The power coming from the EVSE to the Charger
Input Voltage	Voltage applied to the charger from the EVSE
Ignition Status	Vehicle key switch Ignition/Run signal state
Junction Box	Controls the DC contactors to components on HV DC bus
Message Checksum	A message used to monitor the integrity of a node memory
Message Counter	A rolling message counter for checking integrity of a CAN node
Node	A CAN connected control module or microprocessor
OC	Occurrence Count
Output Current	The current the charger is supplying to the HV DC bus
Output Power	The power coming from the Charger HV DC output
PHEV	Plug-in Hybrid Electric Vehicle
PGN	Parameter Group Number
Proximity Detection	Allows Charger to detect presence of Charge Connector (SAE J1772)
SAE	Society of Automotive Engineers
SOC	State Of Charge
SOH	State Of Health
SPN	Suspect Parameter Number
Status Message	CAN message to the Charger from the Hybrid system
Temperature	Temperature of the critical component limiting charger operation.
Vehicle Power	The 12 or 24 volt conventional operating voltage of the vehicle
Voltage Limit	A command indicating the maximum charging voltage allowed

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5. APPLICABLE DOCUMENTS

The following documents and subdocuments shall form a part of this specification to the extent specified or may otherwise serve as reference documents:

ANSI Z535.4	American National Standard for Product Safety Signs and Labels
ASTM B117-97	Standard Practice for Operating Salt Spray (Fog) Apparatus
CISPR 25	Limits and Methods of Measurement of Radio Disturbance Characteristics for the Protection of Receivers used On-Board Vehicles
DCN-119	Eaton J1939 Diagnostics Support Specification for Non-Eaton Products (1.7)
FMVSS 302	Flammability of Interior Materials - Passenger Cars, Multipurpose Passenger Vehicles, Trucks, and Buses (Title 49 Code of Federal Regulations Part 571)
ISO 7637	Road Vehicles – Electrical Disturbance by Conduction and Coupling
ISO 11452	Road Vehicles – Component Test Methods for Electrical Disturbances from Narrowband Radiated Electromagnetic Energy
ISO 12103	Road Vehicles - Test Dust for Filter Evaluation
ISO 16750	Environmental Conditions and Testing for Electrical and Electronic Equipment Third edition.
ISPM 15	International Standards for Phytosanitary Measures Guidelines for Regulating Wood Packaging Material in International Trade
SAE J400	Test for Chip Resistance of Surface Coatings
SAE J514	Hydraulic Tube Fittings
SAE J1113	Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle Components
SAE J1128	Low Tension Primary Cable
SAE J1211	Handbook for Robustness Validation of Automotive Electrical/Electronic Modules.
SAE J1455	Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design
SAE J1673	High Voltage Automotive Wiring Assembly Design
SAE J1742	Connectors for High Voltage On-Board Road Vehicle Electrical Wiring Harnesses, Test methods and general performance requirements
SAE J1772	SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler
SAE J1939	Recommended Practice for a Serial Control and Communications Vehicle Network
TEP-011	Eaton Technical Report
TES-002	Eaton Part Marking
TES-096	Eaton Wire Harnesses Assemblies
TES-124	Eaton Electronic Environment
TES-164	Eaton Charger Control Module Communications Interface Specifications (Revision 0.1)

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2006/28/EC Commission of European Communities, 1994 Electromagnetic Compatibility Directive

6. REQUIREMENTS

6.1. SAMPLE APPROVAL

6.1.1. A request for vendor part approval shall be submitted to the Eaton responsible for this product with a completed "Production Part Approval Process" (PPAP). Level of PPAP to be specified by Eaton purchasing. The supplier shall comply with all requirements set forth in the “Automotive Industry Action Group” (AIAG) PPAP manual.

6.1.2. Layout inspection shall be used to verify the dimensions as specified on the Eaton engineering drawing (or supplier drawing where dimensions are not given on the Eaton drawing).

6.1.3. Functional mechanical checks for free play, mechanical travel, etc., as called out on the Eaton detail drawing, shall be performed on the samples submitted.

6.1.4. All electrical and performance requirements shall be checked per Section 6.3 and detailed drawing.

6.1.5. A report of any discrepancies found shall be submitted to the responsible supply chain manager for evaluation and approval.

6.2. DESIGN APPROVAL

6.2.1. Parts delivered to this specification shall conform to the requirements of all relevant documents and specifications where applicable.

6.2.2. The supplier shall provide a plan for sufficient manufacturing controls, inspections, and tests to assure that the parts comply with the requirements of this specification on a continuing basis. This shall include the development of a sampling program sufficient to assure compliance with this specification.

6.2.3. Historical test data may be used to satisfy PARAMETRIC REQUIREMENTS Section 6.3 and PERFORMANCE Section 7.0 requirements. Actual field performance data and test lab data may be used to satisfy the operating life requirements of PREFORMANCE Section 7.0.

6.2.4. Test results shall be documented per the format described in TEP-011. Data describing the results of this testing shall include a description of the test conditions, and if these conditions differ from those specified herein, Engineering shall undertake an analysis to determine the equivalency.
The supplier shall obtain written confirmation of the acceptability of the test results submitted as adequately fulfilling the requirements of this specification from the Eaton TCO Quality Assurance group prior to the first production shipment.

6.2.5. Eaton reserves the right to perform tests to any or all of the requirements contained herein at any time, and may halt production deliveries in the event of failure to comply with any requirement in section 6.3, 7, 8, and 9. In addition, Eaton may reject any production lot of

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material based upon the requirements of section 6.3, 7, 8, and 9 and an acceptable sampling plan.

6.3. PARAMETRIC REQUIREMENTS

NOTE: Requirements shall be at a free ambient air temperature of 25° ± 5°C [77° ± 9°F], unless otherwise specified.

7. PREFORMANCE

7.1. SYSTEM DEFINITION

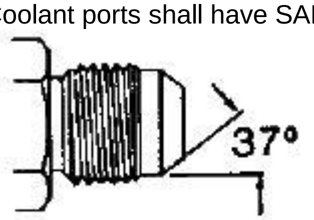
7.1.1. The Vehicle Mounted Hybrid Battery Charger (Charger) converts AC power from an EVSE to DC power for use on the Vehicle VH DC bus. The Charger has internal control system and interact with the HCM and EVSE. It is a self contained contaminant proof enclosure, with liquid cooling ports, mounting holes and integral connectors. The Charger is SAE J1772 compliant.

7.2. TEMPERATURE

7.2.1. Ambient Operating Temperature: -30° to +55° C.
7.2.2. De-rated Operating Temperature -40° to -30° C
7.2.3. Maximum Charger Cold Plate Temperature before output de-rating +60° C.
7.2.4. Maximum Charger Cold Plate Temperature +85° C.
7.2.5. Normal Storage Temperature of -40° to 105° C.
7.2.6. Extreme Storage Temperature of -55° to 125° C for less than 12 hours at a time.

7.3. COOLING

7.3.1. The minimum flow rate of coolant provided to the charger shall be 2.7 gal/min.
7.3.2. The maximum pressure drop across the charger shall be 8 PSI Maximum at 2.7 gal/min
7.3.3. The charger shall handle a maximum coolant flow rate of 5.2 gal/min.
7.3.4. The maximum temperature of the coolant entering the charger shall be 50 degrees C.
7.3.5. Coolant ports shall have SAE 37° (J.I.C.) Hydraulic -10 7/8-14 thread.



7.3.5.1. The pipes shall exit the cold plate on the connector side of the unit, turn 90 Degrees, point away from each other, and be parallel to the long axis of the cold plate.

7.3.6. The Charger cold plate system shall be compatible with a 50/50 mix of water and extended life coolant (ethylene glycol).

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7.4. PACKAGE AND DIMENSION

7.4.1. Charger body Dimensions:
7.4.1.1. See Eaton drawing P/N: 4307212

7.5. MOUNTING

7.5.1. See Eaton drawing P/N: 4307212

7.6. WEIGHT

7.6.1. 24 Kg (+/- 1Kg)

7.7. PACKAGING

7.7.1. Connectors and connection studs shall have protective covers to damage in handling and prevent ingress of contamination.
7.7.2. If using wood packaging, it shall comply with ISPM-15 wood packaging and material for required regions of the world.
7.7.3. Final Packaging shall be approved by Eaton.

7.8. SHIPPING

7.8.1. Plant specifications: TBD

7.9. MAINTENANCE

7.9.1. No maintenance shall be required.

7.10. SERVICEABILITY

7.10.1. The Charger is a line replaceable unit and is not field serviceable.

7.11. WARRANTY

7.11.1. The Charger shall operate for 3 years or 250,000 miles vehicle miles which ever comes first.

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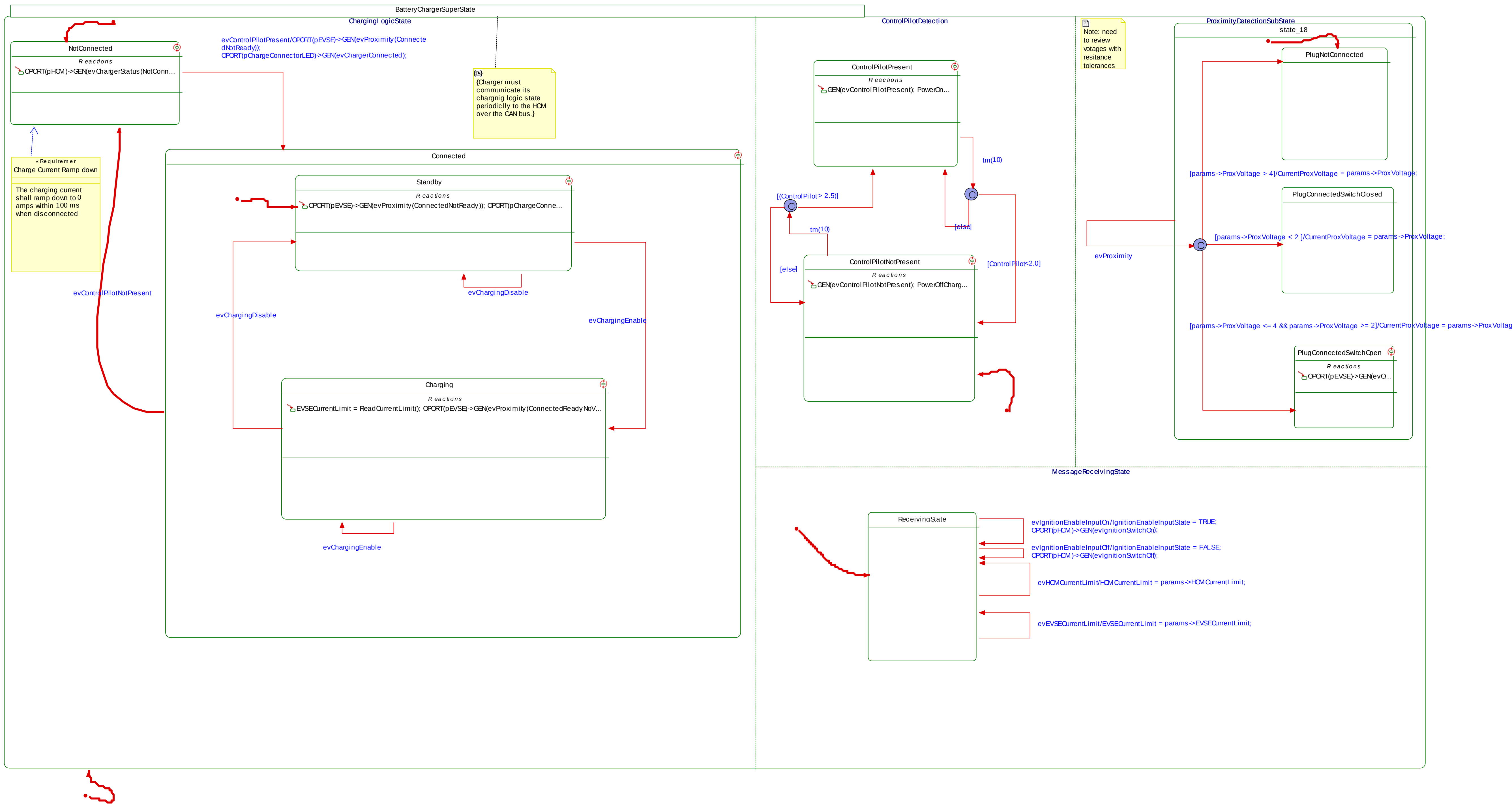
7.12. REFERENCE STATE CHART FOR CHARGER.



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7.12.1. The “BatteryChargerSuperState” is a collection of concurrent state machines comprising the logic of the Charger.

7.12.1.1. The “ChargerLogicState” shows the initialization state of “NotConnected” and the state of “Connected”.

7.12.1.2. The “Connected” state shows the initialization state of “Standby” and the state of “Charging”.

7.12.1.3. The “ControlPilotDetection” state shows the initialization state of “ControlPilotNotPresent” and the state “ControlPilotPresent”

7.12.1.4. The “ProxmityDetectionSubState” state shows the initialization state of “PlugNotConnected”, the state “PlugConnectedSwitchClosed”, and the state “PlugConnectedSwitchOpen”.

7.12.1.5. The “MessageRecievedState” state shows the “Command Message” continuously being received by the Charger.

7.12.1.6. The “MessageSender” state shows the “Status Message” continuously being sent by the charger.

7.13. INPUT POWER INTERFACE

7.13.1. Shall comply with the SAE J1772 Standard

7.13.1.1. Shall be capable of handling a 120 nominal (114 to 126) VAC at 50/60 Hz input (SAE J1772 AC Level 1 requirement).

7.13.1.2. Shall be capable of handling a 240 nominal (208 to 250) VAC at 50/60 Hz input (SAE J1772 AC Level 2 requirement).

7.13.1.3. Shall not exceed the electrical current capability of the EVSE that it is connected to (SAE J1772 requirement).

7.13.1.4. Shall have a factory set input maximum current limit of 30 amps to prevent overheating of Charge Coupler connection and Vehicle wiring.

7.13.1.5. Shall not include an integral SAE J1772 Charge Receptacle Connector.

7.13.2. Shall have a connector that conforms to Mil C 5015 arrangement 22-22 and service rating A, except that it shall be a bayonet type.

7.13.2.1. Pin “A” shall be AC Power (L1)

7.13.2.2. Pin “B” shall be Control Pilot

7.13.2.3. Pin “C” shall be Proximity Detection

7.13.2.4. Pin “D” shall be AC Power (L2, N)

7.13.2.5. M6 stud shall be provided as a Charger Chassis ground for SAE J1772.

7.13.3. Shall have an AC input power factor greater than 0.98.

7.13.4. Shall have an AC input total harmonic distortion less than 15%.

7.13.5. Shall have an AC isolation requirement of 1500 volts to the LV DC circuits.

7.13.6. Shall have an AC isolation requirement of 1500 volts to the HV DC circuits.

7.13.7. Shall have a minimum resistance of 10M Ohm between the AC input and the Vehicle chassis.

7.13.8. The Control Pilot input circuit shall be designed that at short to AC Mains will not allow AC mains voltage on the LV DC circuits.

7.13.9. The Proximity Detection input circuit shall be designed that at short to AC Mains will not allow AC mains voltage on the LV DC circuits.

7.13.10. An active AC Mains short to the Control Pilot or Proximity Detection circuit shall provide enough ground current to trip the GFI circuit in the EVSE.

7.14. OUTPUT POWER INTERFACE

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7.14.1. Shall be capable of 5.0 kW DC output power at a SAE J1772 AC Level 2 nominal input voltage and 40 amp service (30 amps constant current into the charger).
7.14.2. Shall be capable of a DC output charging voltage range of 298 volts to 428 volts.
7.14.3. Shall have a factory set Output Voltage limit of 428 volts that can not be exceeded in operation.
7.14.4. Shall be capable of a controllable DC charging current from 0 to 16 amps, with sufficient AC input power.
7.14.5. Shall never sink current from or load other devices on the HV DC output.
7.14.6. Shall have a minimum resistance of 10M Ohm between the High Voltage DC output and the Vehicle Chassis.
7.14.7. Shall have an isolation requirement of 1500 volts to LV DC circuits.
7.14.8. Shall have a Charger High Voltage Interlock Loop (HVIL) in the High Voltage DC Output connector with two pins that must be closed to enable the high Voltage DC output.
7.14.9. Shall have a Vehicle High Voltage Interlock Loop (HVIL) in the High Voltage DC Output connector with two pins shorted together. The conductor between the two pins should match the current rating of the pins.
7.14.10. Shall have a connector that conforms to Mil C 5015 arrangement 24-11 and service rating A, except that it shall be a bayonet type.
7.14.10.1. Pin “A” shall be Charger High Voltage Interlock Loop (connected to Charger Pin “C” by harness to enable High Voltage DC Output).
7.14.10.2. Pin “B” shall have no connection
7.14.10.3. Pin “C” shall be Charger High Voltage Interlock loop (connected to Charger Pin “A” by harness to enable High Voltage DC Output).
7.14.10.4. Pin “D” shall be Positive High Voltage DC Output
7.14.10.5. Pin “E” shall have no connection
7.14.10.6. Pin “F” shall be Negative High Voltage DC Output
7.14.10.7. Pin “G” shall be Vehicle High Voltage Interlock Loop (connected to Pin “I” inside Charger).
7.14.10.8. Pin “H” shall have no connection
7.14.10.9. Pin “I” shall be Vehicle High Voltage Interlock Loop (connected to Pin “G” inside Charger.

7.15. CONTROL I/O INTERFACE

7.15.1. The charger shall be able to detect as faults, shorts to Vehicle Power Positive, shorts to Chassis ground, and open connections on all signals in this connector.
7.15.2. Shall have a connector that conforms to Mil C 5015 arrangement 20A48 and service rating C, except that it shall be a bayonet type.
7.15.2.1. Pin “A” shall have no connection
7.15.2.2. Pin “B” shall be “Spare Vehicle Power Return” (connected to Charger Chassis ground stud inside the Charger).
7.15.2.3. Pin “C” shall be “Ignition/Run” Input (Charger Enable)
7.15.2.4. Pin “D” shall be “Charger Connected” Output
7.15.2.5. Pin “E” shall be “Charger Status Indicator Red” Output
7.15.2.6. Pin “F” shall be “Charger Status Indicator Green” Output
7.15.2.7. Pin “G” shall be “Charger Status Indicator Return” (connected to Charger Chassis ground stud inside the Charger)
7.15.2.8. Pin “H” shall be “Block Heater Enabled” Output
7.15.2.9. Pin “J” shall be “Control High Voltage Interlock Loop (connected to Charger Pin “T” by harness to enable High Voltage DC Output)

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7.15.2.10. Pin “K’ shall have no connection.
7.15.2.11. Pin “L” shall have no connection.
7.15.2.12. Pin “M” shall be “Vehicle Power” Positive
7.15.2.13. Pin “N” shall be “CAN Low”
7.15.2.14. Pin “P” shall have no connection
7.15.2.15. Pin “R” shall be “Vehicle Power” Negative (connected to Charger Chassis ground stud inside the Charger)
7.15.2.16. Pin “S” shall be “Block Heater Enable Return” (connected to Charger Chassis ground stud inside the Charger)
7.15.2.17. Pin “T” shall be “Control High Voltage Interlock Loop (connected to Charger Pin “J” by harness to enable High Voltage DC Output)
7.15.2.18. Pin “U” shall be “CAN High”
7.15.2.19. Pin “V” shall be “CAN Shield”

7.16. CONTROL I/O POWER FUNCTION

7.16.1. Shall operate off of fused conventional 12/24 volt Vehicle power.
7.16.1.1. Shall operate fully during 10ms dropout of Vehicle power.
7.16.1.2. The Charger shall not exceed 5/2.5 amp current draw when operating on 12/24 volts.
7.16.1.3. Shall have a direct power ground pin that connects to the Vehicle Power negative.
7.16.1.4. Shall have a low power sleep/hibernation mode.
7.16.1.4.1. Shall draw no more than 2 milliamps when in this mode.
7.16.1.4.2. Shall enter this mode when no SAE J1772 signals are present and the vehicle ignition/run signal is not detected after a period of 1 minute. (The Time period shall be calibratable).
7.16.1.4.3. Shall wake from sleep/hibernation when a SAE J1772 Charge Connector is detected.
7.16.1.4.4. Shall wake from sleep/hibernation when the vehicle ignition/run signal is detected.
7.16.2. Shall have a Vehicle Power level output “Charger Connected” active high signal that indicates when a Charge Connector is detected.
7.16.2.1. Shall be an active high signal that is intended to drive an automotive relay solenoid of at least 500 milliamps minimum.
7.16.3. Shall have a Vehicle Power level output “Block Heater Enable” active high signal that indicates when the Charger is getting A.C. Mains Power.
7.16.3.1. Shall be an active high signal that is intended to drive an automotive relay solenoid of at least 500 milliamps minimum.
7.16.4. Shall shut off the Output Power and turn off all active signals when the 12/24 volt Vehicle power is removed.

7.17. CHARGER STATE DEFINITION

7.17.1. The Charger shall have the following states.
7.17.1.1. Not Connected
7.17.1.1.1. Shall be no connection from the EVSE to Charge Coupler detected.
7.17.1.1.1.1. Shall be no Proximity Detection signal indicating connection.
7.17.1.1.1.2. Shall be no Control Pilot signal indicating connection
7.17.1.1.1.3. Shall be no AC power on the Vehicle Inlet connector.
7.17.1.2. Connected Standby

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7.17.1.2.1. Shall be EVSE connection detected by the Proximity Detection signal or the Control Pilot signal or by AC power on the Vehicle Inlet connector.

7.17.1.3. Connected Charging

7.17.1.3.1. Shall be the Charger providing HV DC output current.

7.17.1.4. Not Available

7.17.1.4.1. Shall indicate the Charger State is indeterminate

7.18. CONTROL FUNCTIONS

7.18.1. Shall terminate HV DC output if CAN Command Messages are not received for 1 second.

7.18.2. Shall not allow HV DC output until SAE J1772 conditions are satisfied.

7.18.3. Shall not allow HV DC output until a active Charge Enable is received by CAN.

7.18.4. Shall not allow HV DC output current to exceed

7.18.4.1. Factory programmed limits.

7.18.4.2. Levels that would exceed the current limit of the EVSE.

7.18.4.3. The “Current Limit” from the CAN Command message.

7.18.5. Shall not allow HV DC output voltage to exceed

7.18.5.1. Factory programmed limits.

7.18.5.2. Levels that would exceed the current limit of the EVSE.

7.18.5.3. The “Voltage Limit DC” from the CAN Command message.

7.18.6. Shall not allow HV DC output until it determines that it is connected to the HV Hybrid battery.

7.18.6.1. Shall determine it is connected to the HV Hybrid battery by detecting a voltage of 260 Volts to 428 Volts on the HV DC bus.

7.18.7. Shall comply with TES-164 Eaton Charger Control Module Communications Interface Specifications.

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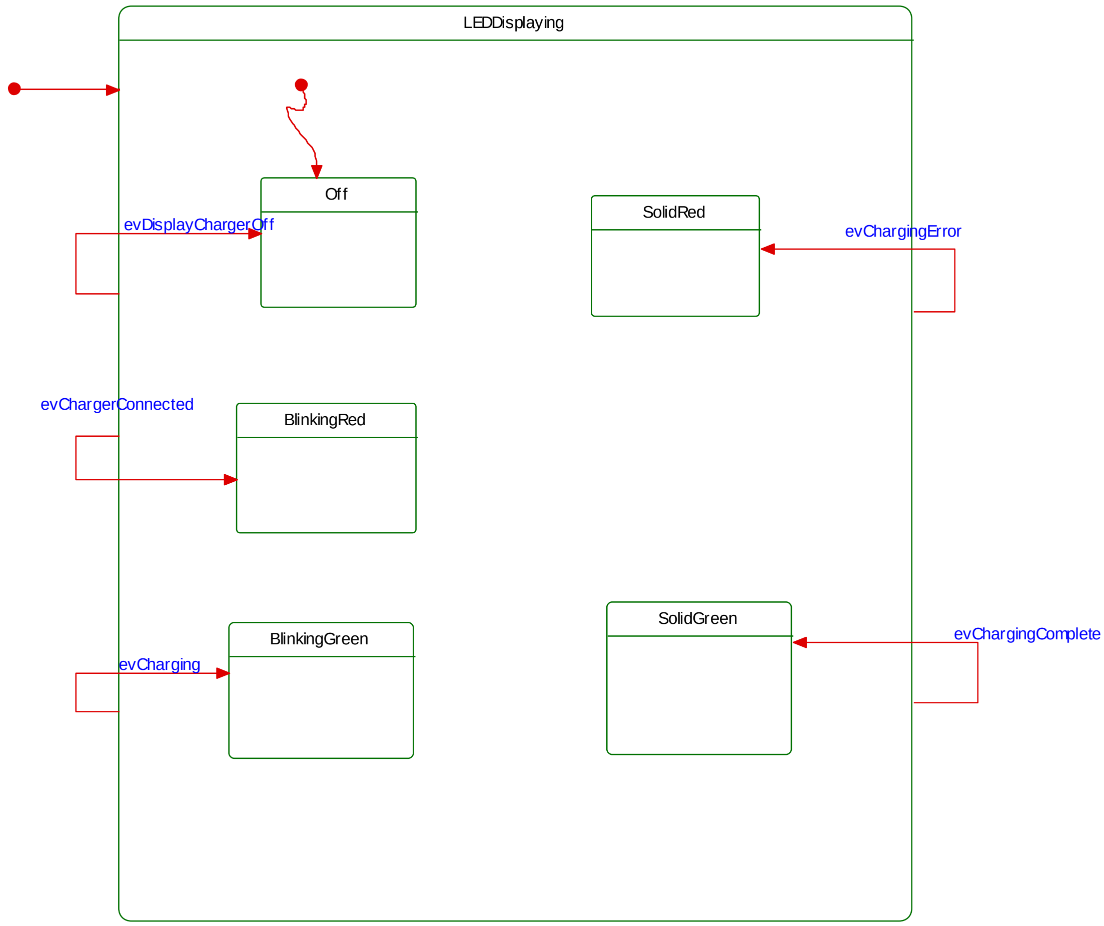
7.19. REFERENCE STATECHART FOR CHARGER DISPLAY STATE INDICATOR



7.19.1. The “LEDDisplaying” state shows the initialization state of “Off”, the state “BlinkingRed”, the state “BlinkingGreen”, the state “SolidGreen, and the state “SolidRed”.

7.20. CONTROL I/O CHARGER DISPLAY STATE INDICATOR

7.20.1. Shall have two Charge Status indicator signals for driving LED’s or indicator lights communicating charging status to the vehicle operator at the Vehicle Inlet.

7.20.1.1. Shall be on/off Vehicle Power level outputs of at least 50 milliamps that can be switched at a 5Hz or slower rate.

7.20.1.2. Shall be protected from automotive transients that could damage a load of a LED in series with a resistor.

7.20.1.3. Shall be protected from shorts to LV DC signals.

7.20.1.4. Shall have a connector pin as a common dedicated return to the Charger Vehicle Power negative battery connection.

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7.20.1.5. One shall be named Red Status Indicator signal.
7.20.1.6. One shall be named Green Status Indicator signal.
7.20.2. The Charger Display State: “Off”
7.20.2.1. Shall indicate the no Charge Connector is present or the Charger is in the sleep/hibernation mode.
7.20.2.2. Red Status Indicator is off.
7.20.2.3. Green Status indicator is off.
7.20.3. The Charger Display State: “BlinkingRed”
7.20.3.1. Shall indicate Charge Connector detected.
7.20.3.2. Red Status Indicator is blinking at 1 Hz.
7.20.3.3. Green Status indicator is off.
7.20.4. The Charger Display State: “BlinkingGreen”
7.20.4.1. Shall indicate HV DC is providing charging current.
7.20.4.2. Red Status Indicator is off.
7.20.4.3. Green Status indicator is Blinking at 1 Hz
7.20.5. The Charger Display State: “SolidGreen”.
7.20.5.1. Shall indicate Charge Complete “Complete” is being received from the Hybrid system.
7.20.5.2. Red Status Indicator is off.
7.20.5.3. Green Status indicator is on.
7.20.6. The Charger Display State: “SolidRed”.
7.20.6.1. Shall indicate Charge System Fault “Fault Active” is being received from the hybrid system and/or the Charger Control System detects an active “Soft Failure” or “Failure”.
7.20.6.2. Red Status Indicator is on.
7.20.6.3. Green Status indicator is off.

7.21. FAULT RESPONSE

7.21.1. The Charger shall determine and take the appropriate action as to protect the Charger from damage or hazardous conditions and report a Fault Severity Level per TES-164.
7.21.2. The Charger shall detect when the Charger or critical components are operated in extreme or harsh conditions and report a Fault Severity Level per TES-164
7.21.3. The Charger shall detect when a critical component or function has drifted out of normal operating ranges or fails and report a Fault Severity Level per TES-164.
7.21.4. For more Fault response information see TES-164 Charger Control Module Communications Interface specification and Appendix “A” in this document for preliminary fault information.

8. LABELING

8.1. All applicable Safety and Hazard labels shall be visible from the top and side of the unit. High voltage safety labels shall comply with ANSI-Z535.4.
8.2. Final labeling shall be reviewed and approved by Eaton.
8.3. The nameplate shall have the following markings stamped into it following TES-002:
8.3.1. Eaton Corporation
8.3.2. Part Number
8.3.3. Model Name
8.3.4. Serial Number
8.3.5. Date Code
8.3.6. Bar Code

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9. ENVIROMENTAL REQUIREMENT

9.1. ALTITUDE

9.1.1. Environmental Condition

9.1.1.1. Components exposed to high altitudes may have reduced efficiency of the cooling system or may be subjected to the stress of trapped pressure.

9.1.1.1.1. Conduct test per SAE J1455 June 2006 at the following test conditions:

9.1.1.1.1.1. Condition 1: Normal product operation at 12,000 feet altitude: Unit operating with full load 62.0 kPa (similar to 12,000 ft) maximum product temperature.

9.1.1.1.1.2. Condition 2: Hot and Cold: Unit operating with full load, 62.0 kPa (similar to 12,000 ft) minimum product temperature.

9.1.1.1.1.3. Condition 3: Air shipment of parts in an unpressurized, unheated cargo compartment at 40,000 feet. Unit not operating, 18.6 kPa (40,000 ft) with temperature of -50 ^{o}C.

9.1.2. Test duration:

9.1.2.1. Two hours or 5 times the thermal time constant of the device under test, whichever is longer.

9.1.3. Acceptance Criteria:

9.1.3.1. Unless stated otherwise in the performance specification, for conditions 1 and 2, the unit shall operate normally and meet all specifications; for condition 3, no damage or deterioration shall be allowed.

9.2. CONDUCTED IMMUNITY

9.2.1. Vehicle Power Operating Voltage

9.2.1.1. Environmental Condition

9.2.1.1.1. Based on industry standards, the necessary operating voltage range for an electronic module is 8 to 16 volts for 12-volt systems and 16 to 32 volts for 24-volt systems.

9.2.1.1.2. Testing

9.2.1.1.2.1. Functional tests and performance tests conducted to demonstrate suitability for use in the environment described herein, as well as tests that demonstrate compliance with the product specification shall be conducted over the extremes of the operating range.

9.2.1.1.3. Acceptance Criteria:

9.2.1.1.3.1. The modules shall operate normally and meet all the appropriate product specifications when the supply voltage is within the range described as operating voltage.

9.2.2. Vehicle Power Over Voltage

9.2.2.1. Environmental Condition

9.2.2.1.1. Various conditions in the vehicle can cause higher than normal voltage such as regulator failure and double battery jump start. The over voltage range shall be for 24 V nominal voltage system: 36 volts.

9.2.2.2. Testing:

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9.2.2.2.1. Conduct testing per ISO 16750-2 Third edition, Paragraph 4.3.

9.2.2.3. Acceptance Criteria:

9.2.2.3.1. Unless stated otherwise in the performance specification, the Charger may work normally, may shut off, or may otherwise protect itself when the supply voltage is in the over voltage range. It is anticipated that the Charger can stop operation and the processor may reset. If the Charger shuts down, it must do so in normal manner as possible without causing any hazards. No damage shall occur to the Charger. When the voltage returns to the operating voltage range, the Charger shall resume normal operation. This operation is described as Class A preferred or Class B in the ISO 16750 standard.

9.2.3. Vehicle Power Supply Inconsistent Voltage

9.2.3.1. Environmental Condition

9.2.3.1.1. During maintenance and during some failure conditions, the Charger may be exposed to a supply voltage that is not consistent throughout the vehicle or various pins and circuits on the module(s). For example, the nominal Vehicle battery voltage may be 24 volts but an I/O pin may be exposed to 36 volts from a vehicle connection during jump start, conventional battery charging, servicing, or a miss wire condition.

9.2.3.2. Testing

9.2.3.2.1. Demonstrate that all LV I/O pins and power supply pins will withstand connection to the highest operating voltage described in the operating voltage range with the battery at 13.8 Volts.

9.2.3.2.2. Demonstrate that all LV I/O pins and power supply pins will withstand connection to the highest operating voltage described in the operating voltage range with the battery at 0 Volts.

9.2.3.3. Acceptance Criteria

9.2.3.3.1. The Charger shall not activate any actuator or otherwise change the status of any part under it's control, unless specifically required in the performance specification. No degradation or damage to the components shall occur.

9.2.4. Vehicle Power Reversed Voltage

9.2.4.1. Environmental Condition

9.2.4.1.1. In the course of maintaining a vehicle, the positive and negative battery cables may be connected with reversed polarity. Also, it can occur that the main power to the Charger is reversed while the remainder of the wiring remains in its intended state and the battery is connected normally.

9.2.4.2. Testing

9.2.4.2.1. Conduct testing per ISO/CD 16750-2 Third edition, Paragraph 4.7, Case 2 for the Nominal voltages of 12 and 24 at room temperature.

9.2.4.2.1.1. Conduct testing on a system that includes all of the sensors, loads and peripheral devices. Particular attention shall be given to sensors and loads that have a ground or power connection elsewhere in the vehicle, (i.e., separate from the system wiring), to assure a realistic load. Reverse the main power wires (do not swap ignition or I/O connections with remote power sources) to the module or group of modules (not the whole vehicle) in a manner consistent with accidental miswiring of the module(s). Maintain the reversal for 1 minute duration at room temperature.

9.2.4.3. Acceptance Criteria:

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9.2.4.3.1. Unless stated otherwise in the performance specification, the unit(s) shall not operate during this test. The Charger shall not activate any actuator or otherwise change the status of any part unless specifically required in the performance specification. No degradation or damage to the components shall occur. For the ISO/CD 16750 test, it is acceptable for a vehicle fuse or circuit breaker to trip to protect the Charger. The unit shall operate normally when the correct polarity is restored and the fuse/breaker is replaced/reset.

NOTE: The ISO requirement of -28 volts exceeds the former requirement of -27 volts and the J1455 requirement of -24 volts. Consistent with past practice at Eaton, twelve-volt systems shall also pass the -28 volt requirement since double battery hook-ups with 2 twelve-volt batteries are sometimes used and can be accidentally reversed. Only the ISO document specifies a time duration.

9.2.5. Vehicle Power Momentary Drop in Supply

9.2.5.1. Environmental Condition

9.2.5.1.1. Due to various non ideal conditions in the electrical system, brief interruptions of the electrical supply may occur. During the disruption, the voltage on the battery line may drop to a level that is less than the normal battery voltage.

9.2.5.2. Testing:

9.2.5.2.1. Conduct testing per ISO 16750-2 Paragraph 4.6.1. Third edition

9.2.5.2.2. Values for Table 1 and 2 are: Usmin = 9 Usmax = 32

9.2.5.3. Acceptance Criteria:

9.2.5.3.1. Unless stated otherwise in the performance specification, the module(s) shall operate class A or B as described in the standard. Remote devices powered by the module must also operate class A or B as described in the standard. Unless specifically stated otherwise in the product specification, reset shall not be allowed.

9.2.6. Vehicle Power High Source Impedance

9.2.6.1. Environmental Condition

9.2.6.1.1. During the life of a vehicle, the source resistance of the vehicle battery may become high. Ultimately, it may become high enough to prevent proper operation of the module(s). The high resistance may be due to a partially discharged vehicle battery, the aging of the Vehicle battery, or deterioration of the low voltage wiring and connectors. The condition of high source impedance has been seen in field experience with high impedance batteries and battery chargers that can cause a current to flow that might not blow the fuse and thus might damage the unit.

9.2.6.2. Testing:

9.2.6.2.1. Test the module(s) during a power up situation with a normal battery or a low impedance power supply. At the output of the battery or power supply connect an adjustable series resistance. Adjust the series resistance to a variety of values so that voltage at the module terminals drops to a variety of low values during power up. Choose enough set points of the series resistor so that the low voltage occurs in 0.2 volt increments throughout the power up region of the module. Unless stated otherwise in the performance specification the power up region is the range of battery voltage between the lowest voltage at which the module(s) will remain on and the highest voltage at which the module(s) will remain off.

9.2.6.3. Acceptance Criteria:

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9.2.6.3.1. The Charger shall be able to either operate normally when the series resistance is low or not operate at all when the impedance is high. Improper operation or brown out operation is not acceptable. Unexpected behavior such as actuator activity, lights, sounds or current draw is not acceptable. Circuit shall have sufficient hysteresis to prevent oscillations during power up and voltage dip due to in-rush current. Hysteresis shall be at least 1.2 volts.

9.2.6.4. Test Setup

9.2.6.4.1. Monitor the reset behavior of the Charger. Also monitor the behavior of the various actuators and other Charger activities. Operate the module in the idle mode or non-charging mode as is typical after power up.

9.2.6.4.2. Use a power rheostat in series with a low impedance battery or power supply to power the system. The rheostat may need to be capable of resistance values in the range of .02 to 100 ohms depending on the low voltage current draw of the Charger.

9.2.6.4.3. Set the battery/power supply for the highest voltage in the power up transition range of the Charger. This is the range of voltages where the Charger shall transition from “off” to “on” with an increasing vehicle supply voltage. It is not the maximum operating voltage of the Charger.

9.2.6.5. Test procedure

9.2.6.5.1. With the Charger operating at the upper limit of the transition range, increase the resistance of the rheostat from zero so that the module terminal voltage is 0.2 volts less than the battery/power supply voltage.

9.2.6.5.2. Remove and restore the power connection to cause a power up reset.

9.2.6.5.3. Observe the behavior at reset and record:

9.2.6.5.3.1. Unexpected behavior such as actuator activity, lights, sounds or current draw

9.2.6.5.3.2. Repeated resets or chatter

9.2.6.5.3.3. Brown out conditions where the unit is in a state of partial power up.

9.2.6.5.4. Remove and restore the power connection to cause a power up reset.

9.2.6.5.5. Provide the ignition (run) signal to Charger.

9.2.6.5.6. Observe the behavior and record:

9.2.6.5.6.1. Unexpected behavior such as actuator activity, lights, sounds or current draw

9.2.6.5.6.2. Repeated resets or chatter

9.2.6.5.6.3. Brown out conditions where the unit is in a state of partial power up.

9.2.6.5.7. Remove and restore the power connection to cause a power up reset.

9.2.6.5.8. Simulate the connection of an EVSE to the charger.

9.2.6.5.9. Observe the behavior and record:

9.2.6.5.9.1. Unexpected behavior such as actuator activity, lights, sounds or current draw

9.2.6.5.9.2. Repeated resets or chatter

9.2.6.5.9.3. Brown out conditions where the unit is in a state of partial power up.

9.2.6.6. Repeat the Test procedure above, decreasing the voltage by 0.2 volts each time until the Charger will no longer power up for each test case.

9.2.7. Vehicle Power Superimposed Alternating Voltage

9.2.7.1. Environmental Condition

9.2.7.1.1. The nominal DC voltage supply in a vehicle may be affected by various equipment such that the voltage varies rapidly above and below the nominal value. Starting vehicles that have dead batteries is a common occurrence. Battery chargers are often used to temporarily supply current capacity to start the engine. The typical battery charger supplies an unregulated, unfiltered, pulsating, and DC voltage. This

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pulsating supply may cause the electronic module to repeatedly start and reset at the rate of 120 Hz (100 Hz in Europe).

9.2.7.2. Testing:

9.2.7.2.1. The EVSE is not to be connected for this test, since HCM will not allow the engine to start with the EVSE plugged in.

9.2.7.2.2. Conduct testing per ISO 16750-2 Third edition, Paragraph 4.4, superimposed alternating voltage. This test simulates a residual AC on the DC supply. The peak to peak voltage is 4 volts (severity 2) and the frequency ranges from 50 Hz to 20 kHz.

9.2.7.2.3. In addition to the ISO/CD 16750 test, use either an actual battery charger of suitable capacity or use a full wave rectified sine wave supply with a peak voltage of 18 volts with low source impedance to simulate a battery charger. A completely discharged 12 volt truck battery is used in the typical vehicle configuration. Monitor the operation of the module while starting the vehicle. (This test is intended to be preformed on the actual vehicle by Eaton as part of the acceptance criteria.)

9.2.7.3. Acceptance Criteria:

9.2.7.3.1. Unless stated otherwise in the performance specification, no disruption of operation shall occur during the superimposed alternating voltage test. This is Class A operation in the ISO standard. For the battery charger starting test, the Hybrid Charger may or may not operate. Also, the Charger shall not exhibit any unexpected operation (e.g., unintended outputs or prevent starting of the engine).

9.2.8. Vehicle Power Battery Discharge and Recovery

9.2.8.1. Environmental Condition

9.2.8.1.1. During the life of a vehicle, the operating voltage may not remain near the nominal value but may remain at some other value for an extended period of time.

9.2.8.2. Testing:

9.2.8.2.1. Test per ISO 16750-2, Paragraph 4.5, Third edition.

9.2.8.2.2. Slow decrease of supply voltage. This test simulates a gradual discharge and recharge of the battery. Decrease the supply voltage from V max to 0 volts and increase it from 0 volts to V max at a rate of 0.5 V per minute. The progression of voltage change shall be smooth, continuous and without steps.

9.2.8.3. Acceptance Criteria:

9.2.8.3.1. The Charger shall operate normally without disruption in the range of voltage described as the operating range in the performance specification. The change from operating to not operating or vice versa shall be "clean" and without chatter, partial power up (or down) of circuitry, latch-up in undesirable states, or excessive resets. Operation shall be ISO 16750 class A when the voltage is within the operating voltage range. The operation shall be ISO 16750 class C or better outside the operating voltage range.

9.2.9. Reset Behavior at Vehicle Power Voltage Drop

9.2.9.1. Environmental Condition

9.2.9.1.1. The conditions that cause a reset may be irregular. In particular, the power source may drop to a low voltage and return to normal. It is necessary to verify the reset behavior of the device under test at different voltage drops.

9.2.9.2. Testing:

9.2.9.2.1. Test per ISO 16750-2 Third edition Paragraph 4.6.2, Reset behavior at voltage drop.

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9.2.9.2.2. Usmin = 9 volts

9.2.9.3. Acceptance Criteria:

9.2.9.3.1. The Charger shall operate normally when the voltage is within the operating range or stop operating during the low voltage portions of the test and return to normal operation when the voltage returns to the Usmin level as defined in the ISO standard. The change from operating to not operating or vice versa shall be "clean" and without chatter, partial power up (or down) of circuitry, latch-up in undesirable states, excessive resets or partial reset.

9.2.10. Vehicle Power Pulses

9.2.10.1. Environmental Condition

9.2.10.1.1. The battery supply lines to electronic module(s) and other devices have transient voltages that may disrupt the operation of a device. A variety of pulses are superimposed on the D.C. supply lines. The sequence of pulses provides a varied assortment of voltages, rise times and pulse duration common in vehicles.

9.2.10.2. Testing:

9.2.10.2.1. Conduct testing per ISO 7637–2 Second edition as corrected 2004-09-15, SAE J1455 June 2006, Paragraph 4.11.2.2.1, SAE J1113 Mar 2000, GMW 3097 Feb 2004, and ISO 16750-2 Third edition.

9.2.10.2.2. Conduct the test once with no EVSE connected and the ignition (run) signal connected to Vehicle Power positive.

9.2.10.2.3. Repeat the test once with the EVSE connected, ignition (run) signal open and the Charger providing HV DC Output.

9.2.10.2.4. When the standards provide a choice of test parameters, the worst case parameters apply.

9.2.10.2.5. The highest voltage suggested in the ISO 7637 document for the test pulse shall be used as the worst case requirements.

9.2.10.2.6. Test details not described in ISO 7637 shall be taken from the GMW3097 document.

9.2.10.2.7. Note 1: The SAE J1113-11 -600 volt 20 ohms pulse shall be applied to LV Vehicle power and Ignition (run/Vign) separately. Also, it shall be applied to all inputs and outputs that may be connected to an inductive load.

9.2.10.2.8. Note 2: The waveform shall be modified to drop to 4 volts during the low voltage period, T7, and the duration of the low voltage, T7, shall be extended to 200 milliseconds. An additional Acceptance Criteria for this test is that the Charger Connected signal does not change state.

9.2.10.2.9. Note 3: The criteria of code A for 12 volt systems and the criteria of code E for 24 volt systems shall apply. An additional Acceptance Criteria for this test is that the Charger Connected signal does not change state.

SOURCE	WORST CASE	COMMENT
ISO 7637-2, pulse 1	-200 volts, 10 ohms	
SAE J1113-11 Heavy-Duty Trucks pulse 1	-600 volts, 20 ohms	See: Note 1 of Test Pulse 1 in standard

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ISO 7637-2, pulse 2a	50 volts, 2ohms t1= .2 second 500 pulses	
SAE J1113-11 pulse 2b	20V, 0.0 ohm	
ISO 7637-2, pulse 3a	-150V 50Ω /-200V 50Ω	12V / 24V systems
ISO 7637-2, pulse 3b	150V 50Ω / 200V 50Ω	12V / 24V systems
ISO 7637-2, pulse 4	Drop by 7 volts	Starting 12 V Note 2
ISO 7637-2, pulse 4	Drop by 16 volts	Starting 24 V
ISO 16750-2: 4.6.3	Per Standard	See: Starting Note 3 in standard
ISO 7637-2 pulse 5a	87 volt / 174 volt 8 ohm	Load Dump 12V / 24V systems

9.2.10.3. Acceptance Criteria:

9.2.10.3.1. The operation may be disrupted during the negative pulses or Load Dump, but shall return to normal operation after the pulse(s) are completed (Class C operation in the ISO 16750 standard). The operation may not be disrupted during the positive pulses except for load dump (Class A operation in the ISO 16750 standard).

9.2.11. Vehicle Power Load Dump Special

9.2.11.1. Environmental Condition

9.2.11.1.1. The load dump condition represents any type of short term, high voltage exposure and can be caused by a variety of situations. The commonly cited scenario occurs under the conditions of a faulty battery cable, which makes an intermittent connection with the battery terminal. If the alternator is producing current at full capacity to charge a dead battery when the battery cable becomes disconnected from the battery terminal, the alternator will produce a high voltage output for a short period of time while the alternator regulator adjusts the operating conditions.

9.2.11.1.2. This load dump test is similar to the SAE J1455 load dump test with the exception that this test measures the 70 joules of energy in a substituted 1 ohm load rather than stored in the capacitor.

9.2.11.2. Testing

9.2.11.2.1. Configure the load dump tester with:21000 µf
Rws =19 ohms
Rs = 0.4 ohms
Capacitor voltage = 100 V
Where Rws (resistance, wave shaping) is connected across the capacitor at the start of the pulse and Rs (resistance, series) is connected between the capacitor & Rws combination and the DUT.

9.2.11.2.2. Verify that the waveform has a 400 ms time constant without the module(s) connected. At the point where the voltage has dropped from 100 volts to 45.6 volts, the waveform should be 400 ms wide.

9.2.11.2.3. Connect a temporary 1 ohm load to the tester

9.2.11.2.4. Connect a digital oscilloscope to the 1 ohm load

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9.2.11.2.5. Operate the tester and capture the waveform for the report. With the 1 ohm load connected, when the voltage has dropped from 100 volts to 45.6 volts, the waveform should be approximately 27 milliseconds wide.
9.2.11.2.6. Replace the 1 ohm load with the module(s) under test
9.2.11.2.7. Operate the tester and capture the five pulse waveforms at 10 second intervals, as described in SAE J1455, for the report.
NOTE: It may not be possible to capture all 5 pulses.
9.2.11.2.8. Conduct the test once with the ignition (run) signal connected to Vehicle Power positive.
9.2.11.2.9. Repeat the test once with the EVSE connected and the Charger providing HV DC Output and the ignition (run) signal open.
9.2.11.2.10. Note 1: For the load dump pulse, both the pulses in ISO 7637, as well as the load dump pulse from ASE J1455 apply. The load dump pulse must be applied to the LV Vehicle power (Vbatt) and Ignition (run/Vign) lines simultaneously.

SOURCE	WORST CASE	COMMENT
SAE J1455 Load Dump - special	Special	Load Dump, Note 1 Special (See Section 9.3.11)

9.2.11.3. Acceptance Criteria:
9.2.11.3.1. The operation may be disrupted during the negative pulses and the load dump pulse but shall return to normal operation after the pulse(s) is completed. This is class C operation in the ISO 16750 standard.

9.3. WITHSTAND VOLTAGE
9.3.1. Environmental Condition
9.3.1.1. Electrical systems that operate on high voltage use insulation to isolate the voltage and protect other devices and personnel from the high voltage. As a precaution, it is necessary that the insulation withstand voltage is higher than the nominal system voltage.
9.3.2. Testing:
9.3.2.1. Test per ISO 16750-2 Second Edition 2006-08-01, Paragraph 4.11. Apply 500 volts A.C. to various connector pins and housing pieces that are normally insulated from each other. In addition to systems that contain relays, motors and coils, any system that has a nominal operating voltage higher than Vehicle Power shall be tested.
NOTE: The insulation requirement applies to all insulation that separates the high voltage from other parts of the system.
9.3.2.2. Acceptance Criteria:
9.3.2.3. Unless stated otherwise in the performance specification, there shall be no damage to the module or other system parts. Functional status shall be Class C in the ISO 16750 standard.

9.4. SHORT AND OPEN CIRCUIT PROTECTION ON LOW VOLTAGE CIRCUITS
9.4.1. Environmental Condition

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9.4.1.1. Short circuit to ground can occur on any Low Voltage harness wire in a vehicle. Also, open circuits and shorts can occur between any wire in the same Low Voltage harness or Low Voltage connector.

9.4.2. Testing:

9.4.2.1. Test per ISO 16750-2 Third edition, Paragraph 4.9 and 4.10.

9.4.2.2. Connect all input and output lines to typical loads or devices. Monitor the module(s) during the exposure to verify the performance.

9.4.2.3. Shorts to Vehicle battery positive shall be done to with a line fused with the recommended Low Voltage fuse to power the Charger.

9.4.3. Acceptance Criteria:

9.4.3.1. Unless stated otherwise in the performance specification, it is necessary to confirm that the module and system perform in a predictable manner consistent with the performance specification. Also, verify that the module and system return to normal operation after the short or open is removed and the fuse on Vehicle battery positive is replaced. Also, verify that no damage to the module has occurred: ISO 16750 Class C operation.

9.4.4. Test Setup Consideration:

9.4.4.1. It is anticipated that this test will be repeated several times throughout the product life and that a test apparatus (break out box or vehicle simulator) will be constructed to facilitate the test. As a practical matter, the welfare of the test apparatus shall be considered. If shorting particular lines will cause extensive damage (e.g., short ground to Vehicle Battery Positive) to the test setup, these lines may be exempted from actual test provided that another means of demonstrating compliance is available.

9.5. INSULATION RESISTANCE

9.5.1. Environmental Condition

9.5.1.1. High voltage can cause deterioration of electrical insulation leading to early failure.

9.5.2. Testing:

9.5.2.1. Conduct testing per ISO 16750-2 Third edition, Paragraph 4.12.

9.5.2.2. Apply 100 V.D.C or 500 V.D.C. to terminals and other parts insulated from each other as described in the standard. Electronic components are not tested above working voltage of the component.

9.5.3. Acceptance Criteria:

9.5.3.1. The insulation resistance shall be greater than 10 MΩ.

9.6. GROUND REFERENCE AND SUPPLY OFFSET

9.6.1. Environmental Condition

9.6.1.1. The chassis and other metal parts of a vehicle may be used for electrical purposes or chassis ground. The uncontrolled electrical properties (e.g. corrosion resistance between parts) and uncertain current flow may cause voltage differences between various points throughout the vehicle.

9.6.2. Testing:

9.6.2.1. The Charger Direct Connection to Vehicle Power and the SAE J1772 ground stud connection on the Charger body are intended to mitigate the Ground Reference and Supply offset issues. This testing shall be preformed only on Charger I/O signals that use the vehicle Chassis as a return path (Ignition/Run, Charger Connected, and Block Heater Enabled).

9.6.2.2. Test per ISO 16750-2 Third edition, Paragraph 4.8. An electronic system shall withstand an offset of +/- 1 V anywhere the electronic system is grounded to the vehicle. Each ground point shall be considered and tested.

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9.6.3. Acceptance Criteria

9.6.3.1. The Charger shall operate normally and without disruption. No defects or deterioration shall be allowed.

9.6.4. Test Procedure information:

9.6.4.1. The purpose of this procedure is to test for the effects of heavy currents from all over the vehicle which may use the module ground system to return to the battery. These currents can be quite large and the resistance of the vehicle frame and body parts can be poor. Rust, paint, and anodizing can give undesirable vehicle ground resistance.

9.6.4.2. Design a method of monitoring the system for proper operation. Typical methods of monitoring include fault codes set by the software, visual observation of continuous actuator movement, and system responses to stimuli from a test box or simulator.

9.6.4.3. Identify all the Charger I/O signals are dependent on Vehicle Power Negative, the Charger vehicle chassis ground stud, or other metal part of the vehicle that is used as a specific Charger I/O reference. Create a list of ground point pairs such that each point is paired with every other point, e.g., 6 points gives 15 pairs.

9.6.4.4. Set up a system that includes or simulates the module(s) and all of the various devices such as motors, relays, solenoids, sensors, and modules that communicate with the Charger. The lengths and diameter of the wiring should represent a typical vehicle installation. Where necessary for system operation, the vehicle conduction (chassis ground) path may be simulated by connecting a 1 ohm resistor between ground points.
Note: The resistor is not required but is allowed if the system depends on the connection to operate.

9.6.4.5. Monitor the System under test and verify that no disruption of operation occurs or record the nature of the disruption in the test log. Repeat the application of offsets for all of the ground pairs identified above.

9.7. DELIBERATE DESTRUCTION

9.7.1. Environmental Condition

9.7.1.1. Circumstances may occur where the Vehicle Power (Low Voltage electrical system) is connected to a very high voltage. It is important to understand how the unit fails and to know the destruction of the unit does not cause a hazardous condition.

9.7.2. Testing

9.7.2.1. The Charger shall is operated in a simple mode that is easily monitored. The EVSE shall be connected and the HV DC output shall be active. The Vehicle Power shall be increased in steps. When the Charger no longer functions or does not function properly the voltage and behavior will be noted. Each change in behavior and/or failure mode will be noted.

9.7.3. Failure Behavior

9.7.3.1. The increase in voltage is continued beyond any voltage limits in the specification and until changes no longer occur and it is clear that the Charger has been destroyed.

9.7.4. Acceptance Criteria

9.7.4.1. The Charger shall not start a fire or otherwise create a hazard to nearby personnel. The Charger shall not produce excessive smoke. Unexpected behavior is not allowed (unintended outputs). The Charger shall command the EVSE to discontinue AC power to the charger. The list of behavior changes and voltage will be included in the test report.

9.8. DROP TEST

9.8.1. Environmental Condition

9.8.1.1. In the manufacturing process, during shipping, and in service, electronic modules may be accidentally dropped.

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9.8.2. Testing:

9.8.2.1. Transit Drop Test: Conduct testing per SAE J1455 June 2006. The module in the shipping carton shall be dropped 6 inches onto a hard surface several times in various orientations. The service part shipping carton shall be used rather than the production bulk package.

9.8.3. Acceptance Criteria:

9.8.3.1. No defects or deterioration of performance of the Charger shall be allowed.

9.9. ELECTROSTATIC DISCHARGE

9.9.1. Environmental Condition

9.9.1.1. Parts, equipment and people can acquire an electrostatic charge. This charge might find a discharge path through the electronic module(s). The rapid discharge might damage components or couple into a circuits disrupting operation.

9.9.2. Testing:

9.9.2.1. Test per ISO-10605 Use a simulator or ESD gun to produce high voltage charges or pulses that are delivered to each exposed connector pin and any place where ESD pulses might occur during the use of the product.

9.9.3. Acceptance Criteria:

9.9.3.1. The Charger shall exhibit region I performance (no disruption of operation) for air discharges up to ±15 kV and region I performance for contact discharges up to 8 kV.

9.10. FLAMMABILITY

9.10.1. Environmental Condition

9.10.1.1. A fire can occur in or around a vehicle. While other parts of the vehicle may or may not contribute to the flame, the electronic module shall be substantially non-combustible.

9.10.2. Testing:

9.10.2.1. Conduct testing per UL94B.

9.10.3. Acceptance Criteria:

9.10.3.1. External materials shall not burn, nor transmit a flame front across its surface at a rate of more than 102 mm per minute. Internal materials shall not contribute to the flame. Surrogate material is acceptable.

9.11. FUNGUS

9.11.1. Environmental Condition

9.11.1.1. Many materials can support fungal growth. Organic materials are often used in electronic modules in the form of plastics and coatings. Fungal growth can disrupt operation and/or detract from appearance.

9.11.2. Testing:

9.11.2.1. Test per SAE J1455 June 2006. Modules are tested for immunity to the effects of fungus growth by inoculating the module with a fungal spore solution in a manner that permits fungal growth. A typical fungal spore mixture consists of Aspergillus flavus, A. versicolor and Penicillium funiculosum. A 30 day growth period is allowed.

NOTE: If documented evidence is available that shows that the materials used in the construction of the module do not support fungal growth, this evidence may be adequate to demonstrate conformance to this requirement. Such a substitution shall be done with a consensus of all concerned parties.

9.11.3. Acceptance Criteria:

9.11.3.1. Any fungal growth that does occur shall be examined and a determination made as to the long-term effects. If a clear and certain determination is made that no degradation of performance shall occur over the life of the product (degrade the high voltage

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insulation, etc…) and that the fungal growth does not obscure product labels the fungal growth shall be allowed. Otherwise, it shall not be allowed.

9.12. DUST

9.12.1. Environmental Condition

9.12.1.1. Dust can create a harsh environment for electronic module(s) mounted on the exterior of a truck and can even lead to long-term problems when mounted in interior locations.

9.12.2. Testing:

9.12.2.1. Test per SAE J1455 June 2006, ISO 12103 (dust). Modules intended for use on the chassis and thereby exposed to high levels of dust, shall be tested for resistance to the related deterioration. The module does not need to be operational during the test but does need to have all mating connectors and protective shields in place.

9.12.2.2. The dust may meet the SAE J726 standard as described in SAE J1455; however, this standard has been cancelled. Similar dust that meets the ISO 12103 standard may also be used.

9.12.2.3. The DUT should be placed in a dust chamber with sufficient dry air movement to maintain the concentration of dust specified for the full duration of the test. An alternate method involves placing the DUT in a cubical box containing dust that is agitated at intervals of 15 minutes by compressed air or a fan blower, after which time the dust is allowed to settle.

9.12.3. Acceptance Criteria:

9.12.3.1. No degradation in performance shall be allowed. Minor changes in appearance are allowed provided such changes do not indicate that continued exposure would lead to a premature failure or early end of life.

9.13. HIGH AND LOW TEMPERATURE

9.13.1. Environmental Condition

9.13.1.1. Trucks operate in a range of temperatures throughout the world that include the cold temperatures of the northern latitudes and the hot temperatures produced by vehicle self heating combined with summer heat. Electronic components shall operate throughout the world.

9.13.2. Testing:

9.13.2.1. Conduct testing per SAE J1455 June 2006. In the course of truck operation, modules shall be exposed to temperature extremes for a prolonged period of time. Operate the Charger for 336 hours at each temperature extreme with the Charger powered during the test, but not charging. Repeat the test for 8 hours at each temperature extreme with the Charger providing full output during the test. Check the module periodically to verify operation. The temperature extremes shall be as follows: -30 °C cold plate inlet temperature with ambient air temperature of -40 °C and 55 °C cold plate inlet temperature with ambient air temperature of 85 °C.

9.13.3. Acceptance Criteria:

9.13.3.1. The Charger shall operate normally and meet all performance requirements. No damage or deterioration shall be allowed.

9.14. HIGHLY ACCELERATED LIFE TEST

9.14.1. Environmental Condition

9.14.1.1. Electronic modules are exposed to continuous vibration and sudden temperature changes on a vehicle. It is the nature of electronic modules, the components within the modules, and associated components (e.g. wire harness) to be quite resistant to the

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effects of vibration and thermal shock since they have no moving parts and have no heavy load bearing parts. Devices and designs that are not resistant to this combined stress often have manufacturing defects or design defects.

9.14.2. Testing

9.14.2.1. Using the HALT (highly accelerated life test) chamber, expose electronic modules and other devices to continuous random vibration of 50 Gs rms with frequency content up to 10 kHz and simultaneous rapid thermal transitions.

9.14.2.2. Test Chamber

9.14.2.2.1. Before the HALT exposure, maintenance shall be conducted on the chamber to clean the hammers. Verification of the hammer performance will show the impact capacity of each hammer individually and demonstrate that each hammer is capable of delivering full acceleration. Hammer performance data shall be included in the test report.

9.14.2.2.2. The hammers shall provide impact excitation in 3 orthogonal axis. The hammer arrangement shall also be such that combinations of hammers shall provide rotational vibration in each of the three orientations.

9.14.2.2.3. Rapid thermal transitions shall change the air temperature in the chamber at a rate or 70° C/minute or faster.

9.14.2.3. Test cycle

9.14.2.3.1. The test temperatures shall be maximum and minimum product temperatures. Between thermal transitions, the holding time at the maximum and minimum temperatures shall be 3 times the thermal time constant of the device under test. The thermal time constant is the time that it takes for the inner most part or most thermally remote part of the module to change in temperature by 63 % of a step change in the ambient air temperature.

9.14.2.3.2. The transition between the maximum and minimum product temperatures shall be as fast as the chamber will allow.

9.14.2.3.3. The module will be continuously exposed to random vibration of 50 G rms.

9.14.2.4. Mounting

9.14.2.4.1. With the aid of a mounting fixture when needed, the test samples shall be bolted directly to the surface of the test bed. It is common practice to bypass the vibration isolators to increase the stress level and to test circuit boards without the protection of the enclosure. However, vibration isolators and enclosures also need to be tested. Thus, more than 1 test may be needed to evaluate the unprotected circuit board and also evaluate the vibration isolators and enclosures. When multiple tests are needed to demonstrate the performance of the module(s), the tests shall be considered separately in regard to sample size.

9.14.2.5. Monitoring

9.14.2.5.1. When possible, the device under test shall be powered and operating during the test so as allow monitoring of the operation and give an accurate indication of the time of failure. Alternatively, the test may be stopped periodically and the parts checked for proper operation at intervals when the total accumulated exposure time is 0, 1, 2, 5, 10, 20, 50, and 100 hours. The test is usually suspended after 100 hours. Parts that have not failed at the time of suspension will use 100 hours as their time to failure value.

9.14.2.6. Sample Size

9.14.2.6.1. A sample size of 10 to 18 pieces may be burdensome during the early development of a product where prototypes are scarce and costly. With agreement from Eaton, the sample may include units from various stages of development such as DV

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(design validation) and PV (process validation) testing as well as RQR (restricted quantity release) and LQR (limited quantity release) units. In this way, the confidence can increase in a series of HALT tests over a period of time.

9.14.2.7. False Failures

9.14.2.7.1. Failures can occur that are strictly a result of the high degree of acceleration and will not occur at lower levels of acceleration. After the root cause has been determined, and a failure is clearly determined to be due only to the high level of acceleration, the test can be modified to use a lower level of acceleration for either thermal shock or vibration. The test will run for a corresponding longer test period as determined by Miner's rule.

9.14.3. Acceptance Criteria

9.14.3.1. Failed components shall be examined and the root cause of the failure determined. Repeat the test as many times as is necessary to demonstrate the durability of the product. Design changes shall be made to prevent the reoccurrence of relevant failures. There are no definite pass/fail criteria; however, 50 rapid thermal cycles with 50 G RMS continuous random vibration is often enough to build confidence.

9.15. HUMIDITY

9.15.1. Environmental Condition

9.15.1.1. Electronic modules are exposed to humid and dry conditions.

9.15.2. Testing

9.15.2.1. Test per SAE J1455 June 2006. Expose modules to 90 % relative humidity for 30 cycles, 8 hours per cycle. A cycle shall consist of a series of temperature variations as described in the table below. The operation of the module shall be continuously monitored throughout the test.

HUMIDITY CYCLE	
TEMPERATURE	**DURATION (minutes)**
Max Product Operating temp	**120**
Transition	**90**
-30 °C	**120**
Transition	**60**
+38 °C	**60**
Transition	**30**

9.15.3. Acceptance Criteria

9.15.3.1. No defects or deterioration of performance is allowed. Minor changes in appearance of modules that are not visible in the normal operation of the truck will be allowed (e.g., slight dulling of the surface finish).

9.16. LIQUID CONTAMINANTS

9.16.1. Environmental Condition

9.16.1.1. Chemicals used in and around a vehicle may come in contact with an electronic module. The module may be painted as part of the assembly process

9.16.2. Testing

9.16.2.1. Conduct testing per SAE J1455 June 2006. Expose modules to approximately 30 chemicals and liquids commonly found in the truck environment. In addition to the chemicals listed in the standard, include urea used in exhaust after treatment.

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9.16.3. Acceptance Criteria

9.16.3.1. No failure or deterioration is allowed.

9.17. RADIATED EMISSIONS

9.17.1. Environmental Condition

9.17.1.1. Electrical and electronic device can produce radio frequency waves that interfere with radio operation or other equipment operation.

9.17.2. Testing

9.17.2.1. Conduct Testing per:

9.17.2.1.1. CISPR 25 Second Edition 2002-08

9.17.2.1.2. Unless stated otherwise in the product specification, conduct testing with loads operating; this includes the intermittent use of motors, solenoids and other devices. Two tests are needed to demonstrate compliance:

TEST	FREQUENCY RANGE
CISPR 25	**150 kHz to 2 GHz.**
95/54/EC	**30 MHz TO 1 GHz**

9.17.2.1.3. Additional test plots of various configurations (with and without loads) of the system may be made to isolate the source of radiation from the system. The system as a whole, with functioning loads and peripheral devices, must meet the criteria above.

9.17.3. Acceptance Criteria:

9.17.3.1. Emissions shall not exceed the limits in the table below (similar to CISPR 25 limit but with extended frequency ranges).

Limits for broadband and narrowband radiated disturbances from components.

Frequency Range (MHz)	Broadband Limit (dBuV/m)			Narrowband level (dBuV/m)	
	Peak Detector	Quasi Peak Detector	Bandwidth (kHz)	Peak Detector	Bandwidth (kHz)
0.15 – 0.30	56	43	9	41	9
0.30 – 0.53	56	43	9	41	9
0.53 – 2.0	51	38	9	34	9
2.0 – 5.9	36	23	9	22	9
5.9 – 6.2	36	23	9	22	9
6.2 – 30	36	23	9	22	9
30 –54	36	23	120	22	9
54 – 70	36	23	120	22	9
70 – 87	25	12	120	12	9
87 – 108	25	12	120	12	9
108 –144	25	12	120	12	9
144 – 172	25	12	120	12	9
172 – 420	25	12	120	12	9
420 – 512	32	19	120	19	9
512 – 820	32	19	120	19	9
820 – 960	38	25	120	25	9

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960 – 2000	38	25	120	25	9

9.18. CONDUCTED EMISSIONS

9.18.1. Environmental condition

9.18.1.1. Electrical and electronic equipment can produce voltage transients and noise voltage on the power wires and signal wires. The transients and noise voltage can disrupt the operation of other devices.

9.18.2. Testing:

9.18.2.1. Conduct testing per CISPR 25 Second Edition 2002-08 and GMW3097 February 2004. Pulse emissions, broadband emissions and narrow band emissions conducted on the Control I/O Interface wires and Output Power Interface Interlock wires shall be measured. The system or module shall be operating in the normal mode. Both sets of limits apply. The tests can be combined into one test if the more stringent limits are used.

9.18.3. Acceptance Criteria:

9.18.3.1. The emissions levels shall be below CISPR 25 class 5 limit and also blow the GMW3097 levels for both Europe and Global frequency ranges. Emitted pulses shall be below the GMW3097 specified level.

9.19. RADIATED IMMUNITY

9.19.1. Environmental condition

9.19.1.1. Strong electromagnetic fields can disrupt the operation of electronic devices. These fields may emanate from within the vehicle or from external sources.

9.19.2. Testing:

9.19.2.1. To demonstrate the ability to function in these fields, an electromagnetic field shall be generated and the electronic module(s) shall be exposed to the field while the performance of the module(s) is monitored.

9.19.2.2. Three tests below are needed to demonstrate immunity:

Immunity Tests	Test Standard
BCI	ISO 11452-4 Third Edition 2005-04-01 and GMW3097 February 2004 Paragraph 3.4.1
Anechoic Chamber	ISO 11452-2 Second Edition 2004-11-01 and GMW 3097 February 2004 Paragraph 3.4.2
European Directive	2006/28/EC

9.19.2.3. Methods and limits are contained in the 2006/28/EC document. Testing for the GMW3097 requirements demonstrates compliance with the ISO 11452 requirements. Thus a separate test for ISO 11452 is not needed. For convenience, the limit table for the Anechoic Chamber test is repeated below.

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Frequency (MHz)	Level 1 (V/m)	Level 2 (V/m)	Modulation
400…1000	50	100	CW, AM 80 %
800…2000	50	70	CW PM PRR=217 Hz, PD=0.57 ms
1200…1400		600	Radar pulse packets PRR=300 Hz, PD=3us with only 50 pulses output every 1s

9.19.2.4. Monitoring

9.19.2.4.1. With all test methods, all of the various circuits and actions of the module(s) shall be active to verify that the activity is not disrupted by the electromagnetic field.

9.19.2.4.2. The test plan shall describe the circuitry that is active and describe the various activities of the module(s). The plan shall demonstrate that at least 85 % of the circuitry is used in some fashion in the test such that disrupted or unintended operation will be detected. In addition, communication lines shall be in use except for communication lines used exclusively for service purposes. The communications lines shall be in use in such a way that disrupted communications will be detected. A fully populated vehicle wire harness with devices typical of operation on trucks such as relays, motors, lights, solenoids and other modules shall be used.

9.19.2.5. Threshold

9.19.2.5.1. In addition to the conformance test listed in the table above, the ISO 11452-2 GMW 3097 anechoic test shall be conducted at 200 V/m. If a change in parameters or disruption in operation or unintended operation occurs, the frequency range will be noted and the test will be stopped. The field strength will be reduced to a level where normal operation occurs and then gradually increased until the threshold of the disruption or unintended operation is reached. The threshold will be measured throughout the range of disrupted or unintended operation.

9.19.2.5.2. A graph of the thresholds shall be supplied as part of the development effort and shall be included in the test report.

9.19.2.6. Acceptance Criteria:

9.19.2.6.1. The Charger shall meet or exceed the performance described in the GMW 3097 documents listed above. The Charger shall operate as designed during and after exposure the radiated field in 2006/28/EC (SAE region I) No deviation in performance is allowed. A graph of the thresholds shall be supplied as part of the development effort and shall be included in the test report.

9.20. MAGNETIC FIELD IMMUNITY

9.20.1. Environmental Condition

9.20.1.1. Strong magnetic fields are often produced by electrical devices. Modules can be exposed to strong 60 Hz magnetic fields from the utility power systems.

9.20.2. Testing:

9.20.2.1. Test per GMW3097 February 2004. To demonstrate immunity to 60 Hz magnetic fields, modules shall be operated in a field created by Helmholtz coils.

9.20.3. Acceptance Criteria:

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9.20.3.1. The Charger is expected to operate normally. No deviation in performance is allowed (SAE region I).

9.21. SALT FOG (Tested at PEC Level)

9.21.1. Environmental Condition

9.21.1.1. Exposure to salt occurs during winter conditions where road salt and water are splashed on the exterior of a vehicle. Common road salts are NaCl, MgCl2, and CaCl2. The atmosphere near the ocean contains a significant amount of salt. Vehicles operated within several miles of the ocean are exposed to salty air.

9.21.2. Testing:

9.21.2.1. Test per ASTM B 117-97 April 1997. The Charger shall be exposed to a salt fog atmosphere at 35C. The Charger shall be powered and operating under normal Charging conditions. The duration of the exposure shall be 200 hours.

9.21.3. Acceptance Criteria:

9.21.3.1. There shall be no changes that could impair normal performance or reduced life expectancy including changes to the sealing function. Marking and labeling shall remain visible and legible. The Charger may show deterioration of appearance.

9.22. SHOCK

9.22.1. Environmental Condition

9.22.1.1. Electronic modules can be exposed to a mechanical impulse or shock.

9.22.2. Testing:

9.22.2.1. Test per SAE J2464. An impulse acceleration pulse of ±25 G (60ms half sine) shall be applied to the module in each of 3 directions, X, Y, and Z (6 pulses total).

9.22.3. Acceptance Criteria:

9.22.3.1. No damage or degradation of performance shall be allowed.

9.23. STORAGE

9.23.1. Environmental Condition

9.23.1.1. Parts for vehicles are sometimes stored in locations without heat or air conditioning. The temperature extremes may exceed those encountered in normal use. The packaging for parts is also exposed to these temperatures.

9.23.2. Testing

9.23.2.1. Subject modules to a high temperature of 125 °C and a low temperature of -55 °C for 3 12 hour periods (36 hours total) at each temperature allow the modules to return to room temperature between each cycle. The modules are not powered.

9.23.3. Acceptance Criteria

9.23.3.1. Any damage or degradation shall be examined and a judgment made as to the degree of deterioration and the importance of such deterioration. Conditions that cause a deterioration of performance and that are not obvious visually shall not be allowed (i.e. hidden damage). Damage or degradation of packaging or shipping containers shall not be allowed.

9.24. IMMERSION

9.24.1. Environmental Condition

9.24.1.1. Electrical system on the exterior of a vehicle often becomes thoroughly wet. The conditions are similar to complete immersion. Elastic seals, intended to prevent water

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ingress, often become hardened or “dried out” with exposure thermal cycles and thus do not prevent leakage in the later life of the product.

9.24.2. Testing:

9.24.2.1. Test per SAE J2464. Submerge module completely in a solution of water with 5% NaCl for a minimum of 2 hours with sealed mating connectors with only vehicle power applied. The temperature of the case and the air concentrations of hazardous substances should be monitored throughout the test. The potential and resistance of the case before and after testing should be documented. Any visible leaks from the module should be analyzed for toxicity. The entire test should be videotaped and photographs should be taken of the test setup and the module both before and after testing.

9.24.3. Measurements for evaluation purposes only:

9.24.3.1. Voltage potentials shall be measured at five discreet locations around the module to determine if there are any shock hazards in the water. Voltages will be measured between two probes separated by 10 inches. Two measurements will be made at the module end with electrical connection, one at six inches and one at 12 inches from the module. The other three voltages will be measured at the side mid points and the opposite end of the module and should be taken approximately four inches from the module.

9.24.4. Acceptance Criteria:

9.24.4.1. Upon immersion, the unit cannot have a sudden, violent venting event. No catastrophic damage shall occur that could result in injury or danger to an individual near the Charger. The unit does not need to be operational after testing.

9.25. THERMAL CYCLE

9.25.1. Environmental Conditions

9.25.1.1. With various weather conditions, vehicles are exposed to extreme thermal cycles.

9.25.2. Testing:

9.25.2.1. Test per SAE J1455 June 2006 using the thermal profile in Figure 14 for 100 cycles (23°C to 85°C to -40°C to 23°C). The inlet temperature of the cold plate can be used to speed up the cycle time, but the inlet flow should not exceed the temperature extremes or the thermal profile. The soak time at each temperature shall be dependent on the module mass as indicated in the table below unless the thermal time constant of the module is known. To reduce test time the soak time can be reduced to 3 thermal time constants for the thermal time constant of the module. The thermal time constant is the time that it takes for the inner most part of the module to change in temperature by 63 % of a step change in the ambient air temperature.

DEVICE MASS (kg)	SOAK TIME (hours)
Up to 0.2	1
0.3 - 0.8	2
0.9 - 1.5	3
1.5-4	4
Over 4	5

9.25.2.2. The Charger shall be operating during the test, but not always charging. The communications and fault conditions shall be checked continuously,.

9.25.2.3. After the Charger has soaked at the stable temperatures (23°C, 85°C, to -40°C) temperate the cold plate temperature will be adjusted to 23°C at room temperature,

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50°C at the hot extreme, and -30 °C at the cold extreme, the Charger will commanded to start charging at full power. After it is determined the Charger is operating properly for 15 minutes the charging will stop and the temperature cycling will continue to the next stable temperature.

9.25.3. Acceptance Criteria:

9.25.3.1. The Charger shall operate normally throughout the entire temperature range. No damage or permanent degradation shall occur during the exposure.

9.26. VIBRATION

9.26.1. Environmental Condition

9.26.1.1. Trucks are a continuous source of vibration. Electronic modules shall withstand this vibration. On transmissions, the frequency spectrum extends up to 10 kHz. The intensity of the vibration varies significantly at different points in the vehicle. The intensity of the vibration in the cab and on the bumper is much lower than on the transmission.

9.26.2. Testing

9.26.2.1. Design and testing for frequencies up to 10 kHz can be divided into two ranges: 1) up to 2.0 kHz and 2) 2.0 kHz to 10 kHz.

9.26.2.2. For frequencies up to 2.0 kHz, conduct testing per SAE J1455 June 2006; modules shall be exposed to vibration levels similar to those encountered in the truck. The vibration shall be applied in each of 3 orthogonal axes in 3 separate applications, 1 axis each. All normal hardware shall be used including mounting brackets and vibration isolators. The unit shall be powered during the test. The vibration profile is described by a line that connects the following table of points on the G2/Hz VS Frequency graph. This graph represents typical worst case vibration where the vibration level has been increased (accelerated) to reduce the test time. With each test profile, 50 hours in each of the 3 axies (150 hours total exposure) represents 30,000 hours of vehicle operation (approx 2 times life)

9.26.2.3. The acceleration of the test level was derived using the following formula.

Gtest = Gfield X (Tfield /Ttest)1/m

Where:
Gtest is the accelerated level of vibration
Gfield is the vibration level measured on vehicles
Ttest is the time of exposure in the test
Tfield is the life of the product
m is the acceleration constant for solder (9.3)

9.26.2.4. The following Profile for Chassis Mounted Modules is to be used for the Charger

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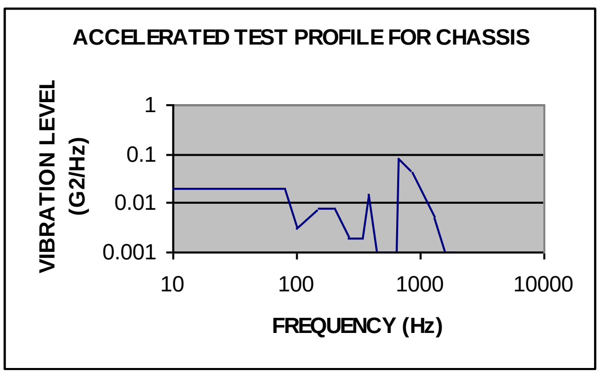
VIBRATION TABLE PROFILE Chassis Mounted DUT	
Frequency (Hz)	**Power (G^2/Hz)**
10	0.019
80	0.019
100	0.003
150	0.008
200	0.008
260	0.002
345	0.002
375	0.015
445	0.001
630	0.001
667	0.077
860	0.043
1310	0.005
1560	0.001
2000	0.001



9.26.2.5. Frequencies from 2 kHz to 10 kHz shall be considered and a test plan shall be developed. Electrodynamic shakers in this range are not available as of this writing. Thus, another method shall be used to verify that the electronic wire harnesses, connectors and module(s) will withstand this stimulation. A possible test method includes the use of impulse stimulus, which contains significant high frequencies.

9.26.3. Acceptance Criteria:

9.26.3.1. Unless stated otherwise in the performance specification, no damage or deterioration of the module shall be allowed.

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10. APPENDIX "A" (to be superseded by Eaton TES-164)

10.1. Preliminary fault response and actions:

10.1.1. In cases where more than one sensor or component exists to measure a characteristic, the fault for that characteristic should be determined by the worst case condition of all conditions measured. For example: The fault "Thermal sensor defective" would be set if any thermal sensor is determined to be defective.

10.1.2. When detecting out of range sensor failure the Charger shall, in addition to signal range, determine sensor drift due to temperature and set the appropriate fault if drift is excessive. If the sensor drifts high, then the out of range high fault shall be set. Likewise if the sensor drifts low, the out of range low fault shall be set.

10.1.3. Faults Severity levels shall start at the lowest severity possible; and then if conditions remain or continue to deteriorate, the severity level shall be increased to the next higher level until the highest level is reached.

10.1.3.1. "Warning" is the lowest severity level of 1.

10.1.3.1.1. The Charger is operating and does not require the main contactors to be opened.

10.1.3.1.2. If necessary to protect the Charger hardware, the Charger shall operate in a degraded condition that results in a reduction in available output power.

10.1.3.1.3. The charger shall communicate this status to the HCM.

10.1.3.2. "Soft Failure" is the middle severity level of 5.

10.1.3.2.1. The charger is operating in a condition that it can not safely maintain and is ramping down the Output Current to zero in 2.0 seconds. The charger shall monitor the "Soft Failure" condition and resume operation if the "Soft Failure" condition clears.

10.1.3.3. "Failure" shall be the highest severity level of 6.

10.1.3.3.1. The charger is operating outside its safe operating limits.

10.1.3.3.1.1. The charger shall attempt to ramp the Output Current to zero within 2.0 seconds.

10.1.3.3.1.2. The charger shall command the EVSE to open the contactors when the Output Current reaches zero or after 2.0 seconds.

10.1.3.3.1.3. The HCM will open the Charger HV DC bus contactor, when zero Output Current achieved or within 2.0 seconds whichever is first.

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10.2. Fault Action Table per SAE J1939-73:

Signal	Description	Fault	Condition to Set Fault Active (Trigger Condition)	Condition to Set Fault Inactive (Exit Condition)	FMI	Fault Severity Indicator	Charger Action	SPN
Bulk 1 Voltage	Internal Charger voltage supply 1	Bulk 1 Error- Most Severe	Bulk1 voltage below **???** volt operating level for 100 ms or greater.	Internal Bulk1 voltage above **???** for 100ms or EVSE disconnection and reconnection.	31	5	Soft Failure	520422
Bulk 2 Voltage	Internal Charger voltage supply 2	Bulk 2 Error- Most Severe	Bulk2 voltage below **???** volt operating level for 100 ms or greater.	Internal Bulk2 voltage above **???** for 100ms or EVSE disconnection and reconnection.	31	5	Soft Failure	520422
Bulk Voltage	Internal Charger voltage supply 1 and 2	Bulk Voltage Error- Most Severe	Bulk1 or Bulk2 voltage below **???** for over 1 minute.	EVSE disconnection and reconnection.	31	6	Failure	520422
CAN	Controller area Network	High Message Error Rate	Charger counter of nonsequential message errors reaching 64, with every good message causing the same counter to decrement until it saturates at zero.	Charger nonsequential message count returns to zero.	19	1	Warning	520422
CAN	Controller area Network	Command Timeout Error	Valid CAN Command not received for 300 ms or greater.	Valid CAN Command received.	19	5	Soft Failure	520422
Check Sum	Memory integrity algorithm	Bad Intelligent Device Or Component	Trigger condition shall be a Checksum interrupt.	EVSE disconnection and reconnection	12	6	Failure	520422
Cold Plate Temperature	Main indicator of Charger temperature	Data Valid But Below Normal Operating Range - Least Severe	Charger cold plate temperature is less than -30 degC for 1 second or greater.	Charger cold plate temperature is above -25 degC for 1 second.	17	1	Warning	520424
Cold Plate Temperature	Main indicator of Charger temperature	Data Valid But Above Normal Operating Range - Least Severe	Charger cold plate temperature is Higher than +65 degC for 1 second or greater and/or the Charger is derating the Output current to keep the temperature below +85 degC.	Charger cold plate temperature is below +60 degC for 1 second and the Charger is not derating the output to control temperature.	15	1	Warning	520424
Cold Plate Temperature	Main indicator of Charger temperature	Data Valid But Above Normal Operating Range - Moderately Severe	Charger cold plate temperature is Higher than +85 degC for 1 second or greater.	Charger cold plate temperature is below +80 degC for 1 second.	16	5	Soft Failure	520424
Cold Plate Temperature	Main indicator of Charger temperature	Data Valid But Above Normal Operating Range - Most Severe	Charger cold plate temperature is Higher than +85 degC for 30 seconds or greater.	EVSE disconnection and reconnection.	0	6	Failure	520424
IGBT Temperature	Main Power Transistor temperature	Data Valid But Above Normal Operating Range - Least Severe	Not implemented	NA	15	1	Warning	520425
IGBT Temperature	Main Power Transistor temperature	Data Valid But Above Normal Operating Range - Moderately Severe	Not Implemented	NA	16	5	Soft Failure	520425
Input Current	Alternating Current from the Electric Vehicle Service Equipment	Current Above Normal - Moderately Severe	Charger AC input Current exceeds 32 amps and/or the Current Limit set by the EVSE per SAE J1772 for 300 ms.	Charger AC input current is below 30amps and EVSE current limit for 300ms.	6	5	Soft Failure	520426
Input Current	Alternating Current from the Electric Vehicle Service Equipment	Current Above Normal - Most Severe	Charger AC Input Current exceeds 32 amps and/or the Current Limit set by the EVSE per SAE J1772 for 600 ms.	EVSE disconnection and reconnection.	6	6	Failure	520426
Input Voltage	Alternating Voltage from the Electric Vehicle Service Equipment	Voltage Below Normal - Moderately Severe	Charger AC input voltage below than 100 VAC for 300 ms with SAE J1772 switch “S2” closed for more than 3 seconds.	Charger AC input voltage above 114Vac for 300ms.	4	5	Soft Failure	520427
Input Voltage	Alternating Voltage from the Electric Vehicle Service Equipment	Voltage Above Normal - Moderately Severe	Charger AC input voltage higher than 250 VAC for 300 ms or greater.	Charger AC input voltage below 245Vac for 300ms.	3	5	Soft Failure	520427
Input Voltage	Alternating Voltage from the Electric Vehicle Service Equipment	Voltage Above Normal - Most Severe	Charger AC input voltage that exceeds the safe input voltage of the charger 265 Volts for 300 ms or greater.	EVSE disconnection and reconnection.	3	6	Failure	520427
Interlock Loop	High Voltage Interlock Loop signal	Open Circuit	When the any connector interlock is open.	EVSE disconnection and reconnection.	5	6	Failure	520428
Logic supply Voltage	Internal Charger Logic voltage supply	Voltage Below Normal - Most Severe	Internal logic supply below 9 volts for 300 ms or greater.	EVSE disconnection and reconnection.	4	6	Failure	520429
Logic Temperature	Logic Circuit Temperature	Data Valid But Above Normal Operating Range - Most Severe	Logic temperature exceeds +85 degC for 1 second or greater.	EVSE disconnection and reconnection.	0	6	Failure	520430

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Magnetics Temperature	Magnetic component Temperature	Data Valid But Above Normal Operating Range - Most Severe	Magnetics temperature exceeds +105 degC for 1 second or greater.	EVSE disconnection and reconnection.	0	6	Failure	520431
Output Current	Charger Output Current to the High Voltage DC bus	Current Below Normal - Least Severe	Charger unable to produce the output current to meet the minimum voltage limit of 298 volts for 1 second or greater.	Charger able to produce an output current to meet an output voltage of more than 298 volts for 1 second the Warning is reset.	5	1	Warning	520432
Output Current	Charger Output Current to the High Voltage DC bus	Current Above Normal - Most Severe	Charger Output Current exceeds 16.5 amps for and/or the Current Limit set by the HCM for 300 ms.	EVSE disconnection and reconnection.	6	6	Failure	520432
Output Voltage	Charger Output Voltage to the High Voltage DC bus	Voltage Below Normal – Least Severe	Not implemented	NA	4	1	Warning	520433
Output Voltage	Charger Output Voltage to the High Voltage DC bus	Voltage Above Normal – Most Severe	Charger Output voltage exceeds 448V or the voltage limit sent in the Command Message for 300 ms.	EVSE disconnection and reconnection.	3	6	Failure	520433
Pilot Signal	SAE J1772 Pilot signal from the Electric Vehicle Service Equipment	Abnormal Frequency Or Pulse Width Or Period	EVSE Pilot frequency exceeds 1020 Hz or less than 980 Hz for 300 ms and is not sitting at a valid DC level.	EVSE disconnection and reconnection.	9	6	Failure	520434
Pilot Signal	SAE J1772 Pilot signal from the Electric Vehicle Service Equipment	Condition Exists	Charger detects a SAE J1772 PILOT signal error.	EVSE disconnection and reconnection.	31	6	Failure	520434
Proximity Signal	SAE J1772 Proximity signal from the Electric Vehicle Service Equipment	Condition Exists	Charger detects a SAE J1772 PROXIMITY signal error	EVSE disconnection and reconnection.	31	6	Failure	520435
Self Test	Charger internal fault diagnostics	Bad Intelligent Device Or Component	Failure detected by internal Charger Diagnostics	EVSE disconnection and reconnection.	12	6	Failure	520436
Vehicle Power Voltage	Vehicle power voltage to the Charger	Voltage Below Normal - Moderately Severe	When 12 Volt vehicle power falls below 8 volts for 1 second or 24 Volt vehicle power falls below 16 volts for 1 second. (The voltage and time shall be calibratable).	12 Volt vehicle power is above 8 volts for 300 milliseconds or 24 Volt vehicle power is above 16 volts for 300 milliseconds.	4	5	Soft Failure	520437
Vehicle Power Voltage	Vehicle power voltage to the Charger	Voltage Above Normal - Least Severe	When 12 Volt vehicle power is above 16 volts for 300 milliseconds or 24 Volt vehicle power is above 32 volts for 300 milliseconds.	12 Volts vehicle power is below 16V for 300 milliseconds or 24 Volts vehicle power is below 32V for 300 milliseconds.	3	1	Warning	520437
Vehicle Power Voltage	Vehicle power voltage to the Charger	Voltage Above Normal - Moderately Severe	When 12 Volt vehicle is above 16 volts for 5 seconds or 24 Volt vehicle power is above 32 volts for 5 seconds.	12 Volt vehicle power is below 16 volts for 5 seconds or 24 Volt vehicle power is below 32 volts for 5 seconds.	3	5	Soft Failure	520437

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11. APPROVED SUPPLIERS

Supplier	Comments	Approval Report

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