GM	WORLDWIDE ENGINEERING STANDARDS	General Specification	GMW3172

General Specification for Electrical/Electronic Components – Environmental/Durability

Index

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1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

Note: Requirements stated in any applicable Component Technical Specification (CTS), Subsystem Technical Specification (SSTS), and/or other relevant General Motors requirements document shall take precedence over GMW3172.

1.1 Purpose. This standard applies to Electrical/Electronic (E/E) components for passenger or commercial vehicles and trucks. The standard describes the environmental and durability tests for E/E components based on mounting location.

1.2 Applicability. This standard specifies Environmental/Durability requirements and Analysis/Development/Validation (A/D/V) activities for E/E components that are used in a vehicle environment to ensure reliability over a life time.

This standard includes tests to ensure customer satisfaction of vehicular E/E component performance over a life time of customer usage and exposure to various environmental conditions, such as Vibration, Shock, Temperature, Humidity, Electrical Stresses, and other forces that may occur during manufacturing and shipping.

This standard applies to any component that connects to or is a part of the vehicle electrical system, unless covered by a component-specific test standard, a mechanical horn or incandescent bulb for example.

For example, this applies to a stand-alone component that contains electrical content (such as a Body Control Module). This could also be applied to an electrical/electronic component that resides inside a larger component or assembly (such as a headlamp leveling control motor inside a headlamp assembly).

1.3 Remarks. Not applicable.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ASTM D4728	IEC 60068-2-38	ISO 7637-2 (6/2004) Note 1	ISO 16750-4
IEC 60068-2-1	IEC 60068-2-52	ISO 8820-1	ISO 17025
IEC 60068-2-27	IEC 60068-2-64	ISO 12103-1	ISO 20653
IEC 60068-2-30	IEC 60068-2-78	ISO 16750-2	USCAR-25

Note 1: The version from 6/2004 is required because that is the only version that defines the required waveform.

2.2 GM Standards/Specifications.

GMW3059	GMW8287	GMW14444	GMW16044
GMW3097	GMW8288	GMW14650	GMW16449
GMW3103	GMW14082	GMW15725	GMW16552
GMW3191			

2.3 Additional References.

CG2986 SOR - CTS Electrical and HVAC Brackets

CG3043 Supplement to GMW3172 Component Environmental Test Plan Template

CG3303 Parts Substitution Matrix

CG3814 Electrical Environmental Design Review Checklist

JEDEC JESD 22-A121A

JEDEC JESD 22-A110D

JEDEC JESD 201A

IPC-A-610

IPC-TM-650

IPC-6012

IPC J-STD-001

3 Parametric Definitions

3.1 Temperature and Voltage Definitions.

Table 1: Definitions

Phrase	Symbol	Definition
Minimum Temperature	T_{min}	Minimum limit value of the ambient temperature at which the component is required to operate (as defined by the Temperature Load Code).
Maximum Temperature	T_{max}	Maximum limit value of the ambient temperature at which the component is required to operate (as defined by the Temperature Load Code).
Post Heating Temperature (soak back)	T_{PH}	Maximum limit value of the ambient temperature which may temporarily occur after vehicle cut-off and at which the component may be operated for a brief period, i.e., on the engine and in its environment.
Repaint & Storage Temperature	T_{RPS}	Maximum temperature which can occur during repainting, but at which the component is not operated. Accounts for high temperature storage and paint booth exposure.
Room Temperature	T_{room}	Ambient room temperature.
Minimum Voltage	U_{min}	Minimum limit value of the supply voltage at which the component is required to operate during the test.
Nominal Voltage	U_{nom}	Nominal supply voltage at which the component is operated during the test. Note: U_{nom} includes U_A (for Operating Type 3.2) and U_B (for Operating Type 2.1).
Nominal Voltage, Alternator	U_A	Nominal supply voltage with generator operating (i.e., alternator voltage) at which the component is operated during the test.
Nominal Voltage, Battery	U_B	Nominal supply voltage with generator not operating (i.e., battery voltage) at which the component is operated during the test.
Maximum Voltage	U_{max}	Maximum limit value of the supply voltage at which the component is required to operate during the test.

Note: All voltage levels are defined at the component connector.

3.2 Parameter Tolerances. Unless stated otherwise, the following shall define the test environment parameters and tolerances to be used for all validation testing (see Table 2):

Table 2: Parameters and Tolerances

Parameter	**Tolerance**
Ambient Temperature	Spec. ± 3 °C
Room Temperature (T_{room})	(+23 ± 5) °C
Test Time	Spec. ± 0.5 %
Room Ambient Relative Humidity	(30 to 70) %
Chamber Humidity	Spec. ± 5 %
Voltage	Spec. ± 0.1 V
Current	Spec. ± 1 %
Resistance	Spec. ± 10 %
Random Acceleration (G_{RMS})	Spec. ± 20 % (PSD deviations from applicable tables are not permitted without GM approval)
Acceleration (Mechanical Shock, G)	Spec. ± 10 % (deviations are not permitted without GM approval)
Frequency	Spec. ± 1 %
Force	Spec. ± 10 %
Distance (Excluding Dimensional Check)	Spec. ± 5 %

3.3 Operating Types.

Table 3: Operating Types

<table>
<tr><th colspan="2">Operating Type</th><th>Electrical State</th></tr>
<tr><td>1</td><td colspan="2">No voltage is applied to the component.</td></tr>
<tr><td></td><td>1.1</td><td>Component is not connected to wiring harness.</td></tr>
<tr><td></td><td>1.2</td><td>Component is connected to wiring harness.</td></tr>
<tr><td>2</td><td colspan="2">The component is electrically powered with supply voltage U_B (battery voltage; generator not active/engine shut-off) with all electrical connections made.</td></tr>
<tr><td></td><td>2.1</td><td>Component functions are not activated (i.e., serial data communications are not active or component is OFF).</td></tr>
<tr><td></td><td>2.2</td><td>Component with electric operation and control in typical operating mode.</td></tr>
<tr><td>3</td><td colspan="2">The component is electrically powered with supply voltage U_A (engine/generator active) with all electrical connections made.</td></tr>
<tr><td></td><td>3.1</td><td>Component functions are not activated (i.e., serial data communications are not active or component is OFF).</td></tr>
<tr><td></td><td>3.2</td><td>Component with electric operation and control in typical operating mode.</td></tr>
</table>

3.4 Functional Status Classification (FSC).

Table 4: FSC Definition

Class	Definition of FSC Class
A	All functions of the component perform as designed during and after the test.
B	All functions of the component perform as designed during the test. However, one or more of them may go beyond the specified tolerance. All functions return automatically to within normal limits after the test. Memory functions shall remain FSC A. GM Engineering shall specify which function of the component shall perform as designed during the test and which function can be beyond the specified tolerance. FSC A is also acceptable for components that are classified as FSC B.
C	One or more functions of the component do not perform as designed during the test but return automatically to normal operation after the test. FSC A or B are also acceptable for components that are classified as FSC C.
D	One or more functions of the component do not perform as designed during the test and do not return to normal operation after the test until the component is reset by any “operator/use” action. FSC A, B, or C are also acceptable for components that are classified as FSC D.
E	One or more functions of the component do not perform as designed during and after the test and cannot be returned to proper operation without repairing or replacing the component. FSC A, B, C, or D are also acceptable for components that are classified as FSC E.

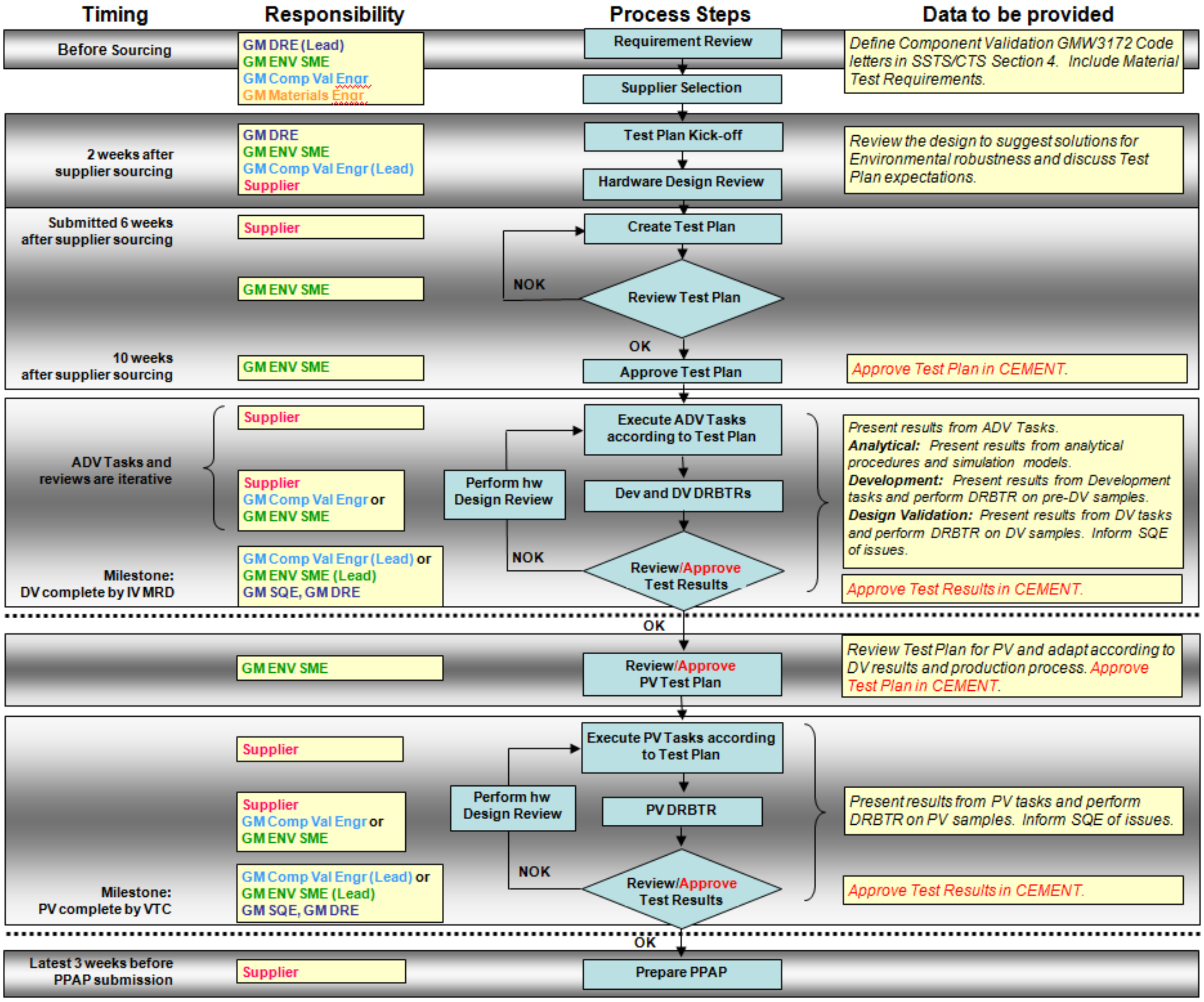
4 Process

4.1 A/D/V Process for Electrical/Electronic Components. The Global Environmental Component Analysis/Development/Validation (A/D/V) Process defined within this document shall be followed for all components with electrical/electronic content. This includes, but is not limited to, Powertrain, Chassis, HVAC, Interior, Body, Closures, Exterior, and Electrical.

For 2013 Model Year and beyond, the Supplier is required to upload all GMW3172 Component Environmental Test Plans (CG3043) and test results to GM’s Component EMc and ENvironmental Test (CEMENT) Database which is accessible through GM Supply Power. CEMENT also requires the Supplier to upload all component EMC test plans and test results (per GMW3097 and GMW3103, as handled by the EMC Department).

4.2 A/D/V Process Flow. The A/D/V Process Flow shall be followed as shown in Figure 1.

Figure 1: A/D/V Process Flow



The A/D/V Process consists of the following major tasks:

- **Requirements Review.** The Requirements Review shall be performed within General Motors (GM) to define the GMW3172 Code letters. This GMW3172 Coding shall be documented in the Component Technical Specification (CTS) Section "Validation". The GM Environmental Subject Matter Expert (ENV SME) shall define this information together with the GM Design Release Engineer (DRE) and GM Component Validation Engineer (CVE). The GM ENV SME shall review the CTS for alignment to GMW3172 prior to sourcing. Also, the GM Materials Engineer needs to provide the Material test requirements. Supplier-proposed exemptions to the GMW3172 must be approved by the GM ENV SME. In case no CTS is available, refer to the Validation section in the SSTS for GMW3172 Coding.

- **Test Plan Kick-off/Environmental Hardware Design Review.** A Test Plan Kick-off/Environmental Hardware Design Review meeting shall be completed jointly by the supplier and GM 2 weeks after supplier sourcing. The purpose of this meeting is to review the design to suggest solutions for Environmental robustness and discuss the Component Environmental Test Plan (CG3043) expectations. In preparation for this meeting, the supplier shall complete the Environmental Hardware Design Review Check List, which can be obtained from GM Supply Power. Refer to the “Environmental Hardware Design Review” section of this document for more detailed instructions. The supplier shall obtain an editable version of the Component Environmental Test Plan (Appendix B in GMW3172) via the reference document CG3043 in the GM Global Document Management (GDM) database or from the GM CVE, the GM ENV SME, or GM Supply Power. It is also available to suppliers through IHS Global.
- **Create and Review Test Plan.** The Component Environmental Test Plan shall be completed by the supplier and submitted in an electronic, editable format to GM 6 weeks after supplier sourcing. Approval in CEMENT shall occur 10 weeks after supplier sourcing, and not to occur less than 10 days prior to the start of testing.
- **Execute A/D/V Tasks.** A/D/V Tasks, including Analytical, Development, and Design Validation (DV), shall be successfully completed by Integration Vehicle Material Required Date (IV MRD) to support vehicle validation.

  Each test result shall be uploaded in CEMENT for approval.

  In case of nonconformance, the GM CVE or GM ENV SME along with the GM Supplier Quality Engineer (SQE) and DRE, shall review the test results and determine if another iteration of DV is required based on design or process changes. The GM CVE or GM ENV SME shall then perform an Environmental Hardware Design Review. Based on the corrective action, the Component Environmental Test Plan shall be modified as required and approved in CEMENT.
- **Execute Product Validation (PV) Tasks.** PV Tasks shall be successfully completed by Validation Test Complete (VTC). The Component Environmental Test Plan shall be reviewed, adapted, and approved in CEMENT to comprehend design changes, production process variations/changes, and DV test results accordingly.

  Each test result shall be uploaded in CEMENT for approval.

  In case of nonconformance, the GM CVE or GM ENV SME, along with the GM SQE and DRE, shall review the test results and determine if another iteration of PV is required based on design or process changes. The GM CVE or GM ENV SME shall then perform an Environmental Hardware Design Review. Based on the corrective action, the Component Environmental Test Plan shall be modified and approved in CEMENT as required.

4.2.1 Test Flows. The Universal Environmental/Durability Test Flows for Platform/Powertrain Development (Figure 2), Platform Design Validation (Figure 3), and Platform Product Validation (Figure 4) are critical elements of the Test Plan.

Some tests in the Platform PV Test Flow may be omitted if DV was successful, there were no part substitutions, design changes, or supplier changes between DV and PV, and the DV samples were manufactured using the production-intent circuit board material, as well as the production-intent manufacturing processes and equipment for the housing and the circuit board. Any omissions from the PV Test Flow shall be agreed upon by the GM ENV SME.

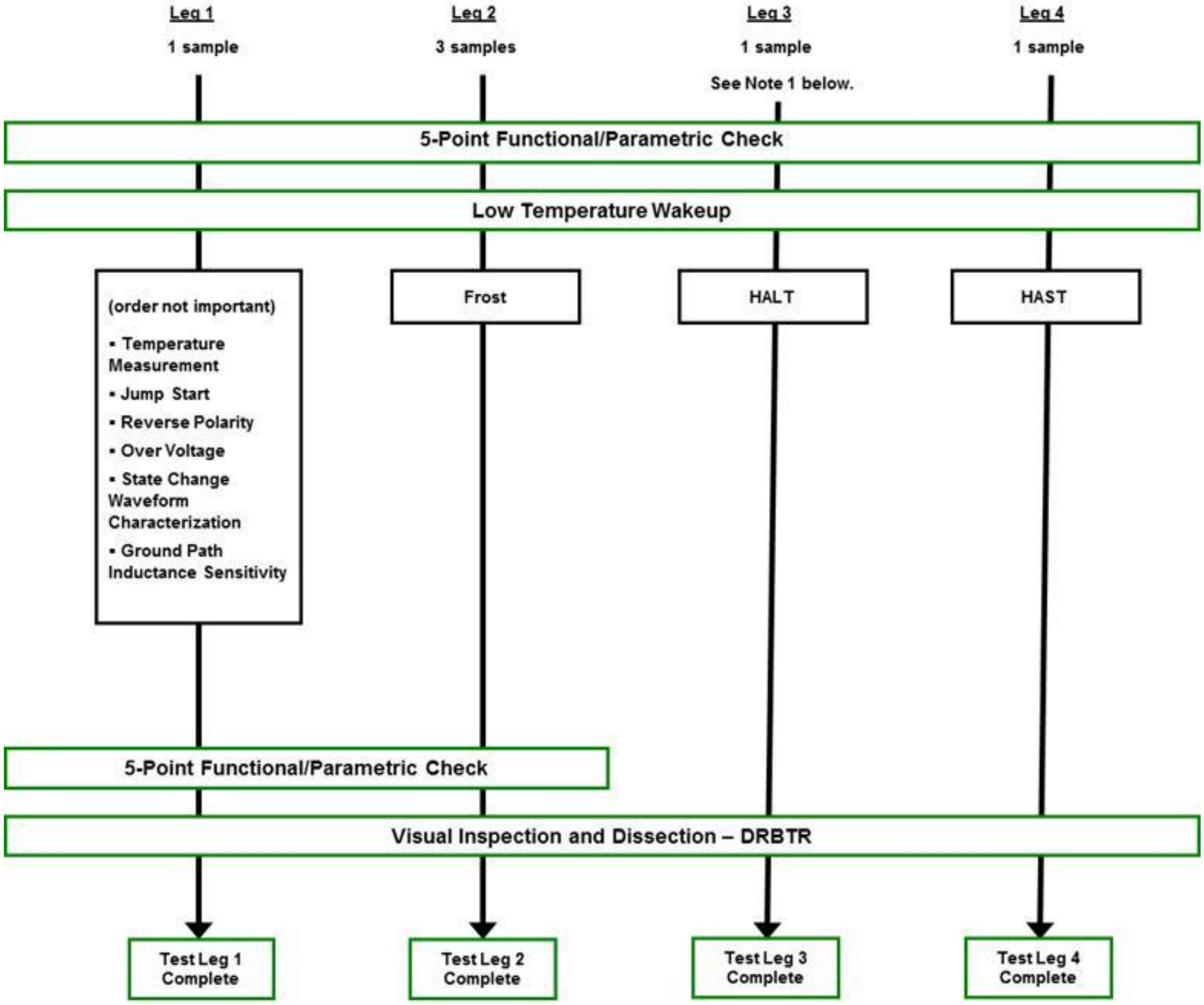
For Powertrain-released components, reference the following Powertrain Test Flows: Development (Figure 2); Electronic Module, In-Transmission (Figure 5); Electronic Module, On-Transmission (Figure 6); Electronic Module, Underhood (Figure 7), and Electronic Module, Passenger Compartment (Figure 8). “Underhood” refers to any electronic control module or sensor near the engine.

The Powertrain PV Test Flow shall be an exact repeat of the DV Test Flow.

The supplier shall include the Test Flows in the Component Environmental Test Plan (CG3043).

The Test Flows as shown in this document effectively evaluate the interactions between fatigue and other failure mechanisms.

Figure 2: Universal Environmental/Durability Test Flow for Development



Note 1: A minimum of one sample is required, but more samples may be required by the specific HALT Test Plan.

Figure 3: Universal Environmental/Durability Test Flow for Platform Design Validation (DV)

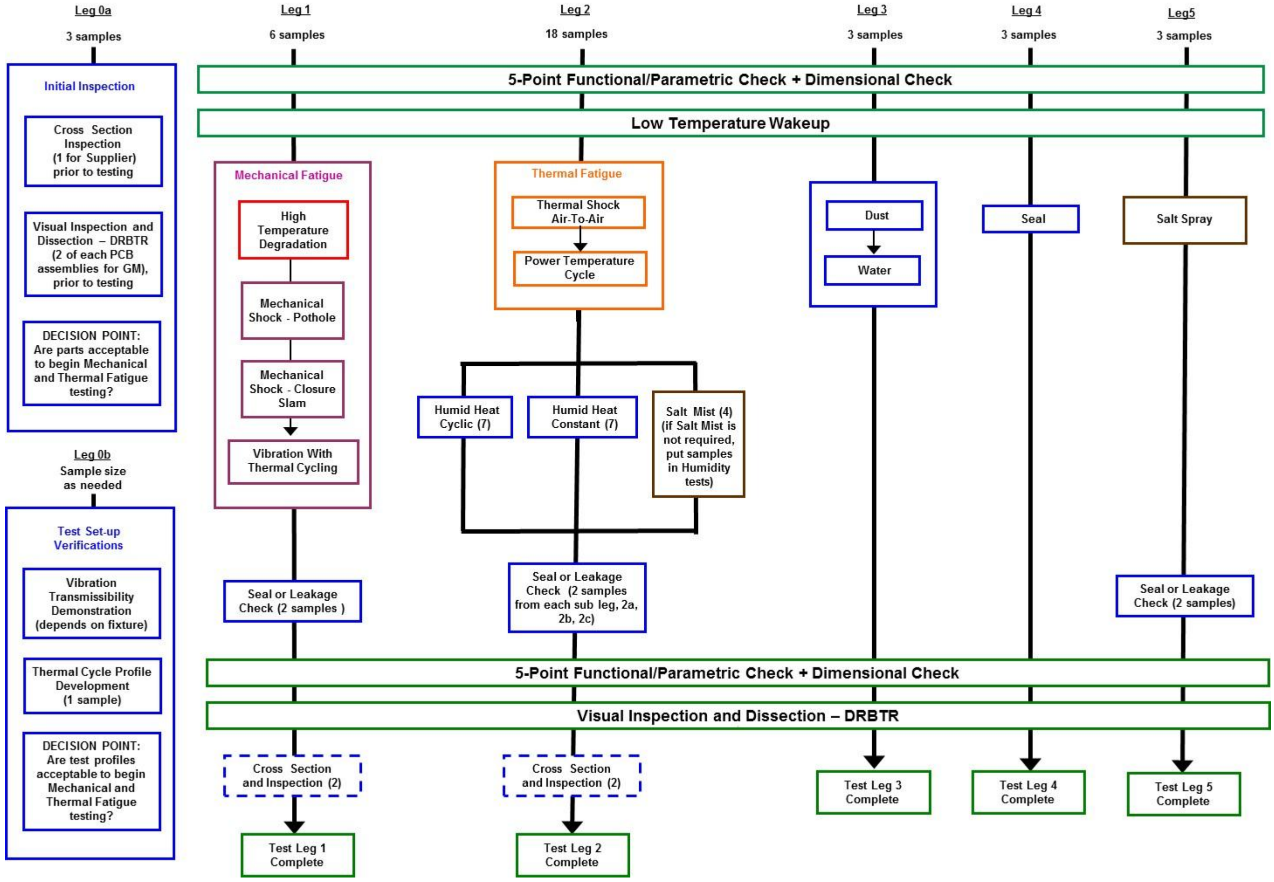


Figure 3: Universal Environmental/Durability Test Flow for Platform Design Validation (continued)

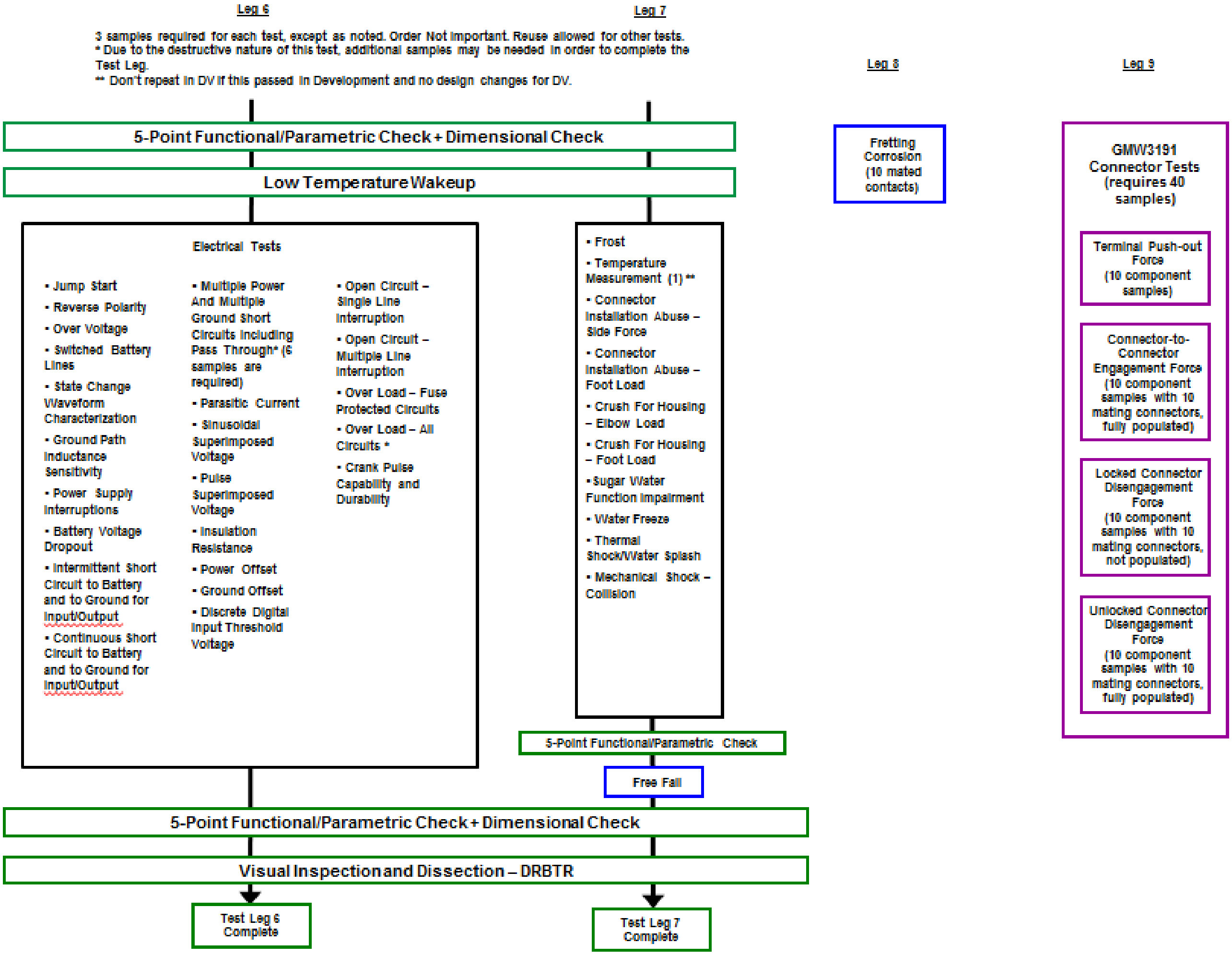


Figure 4: Universal Environmental/Durability Test Flow for Platform Product Validation (PV)

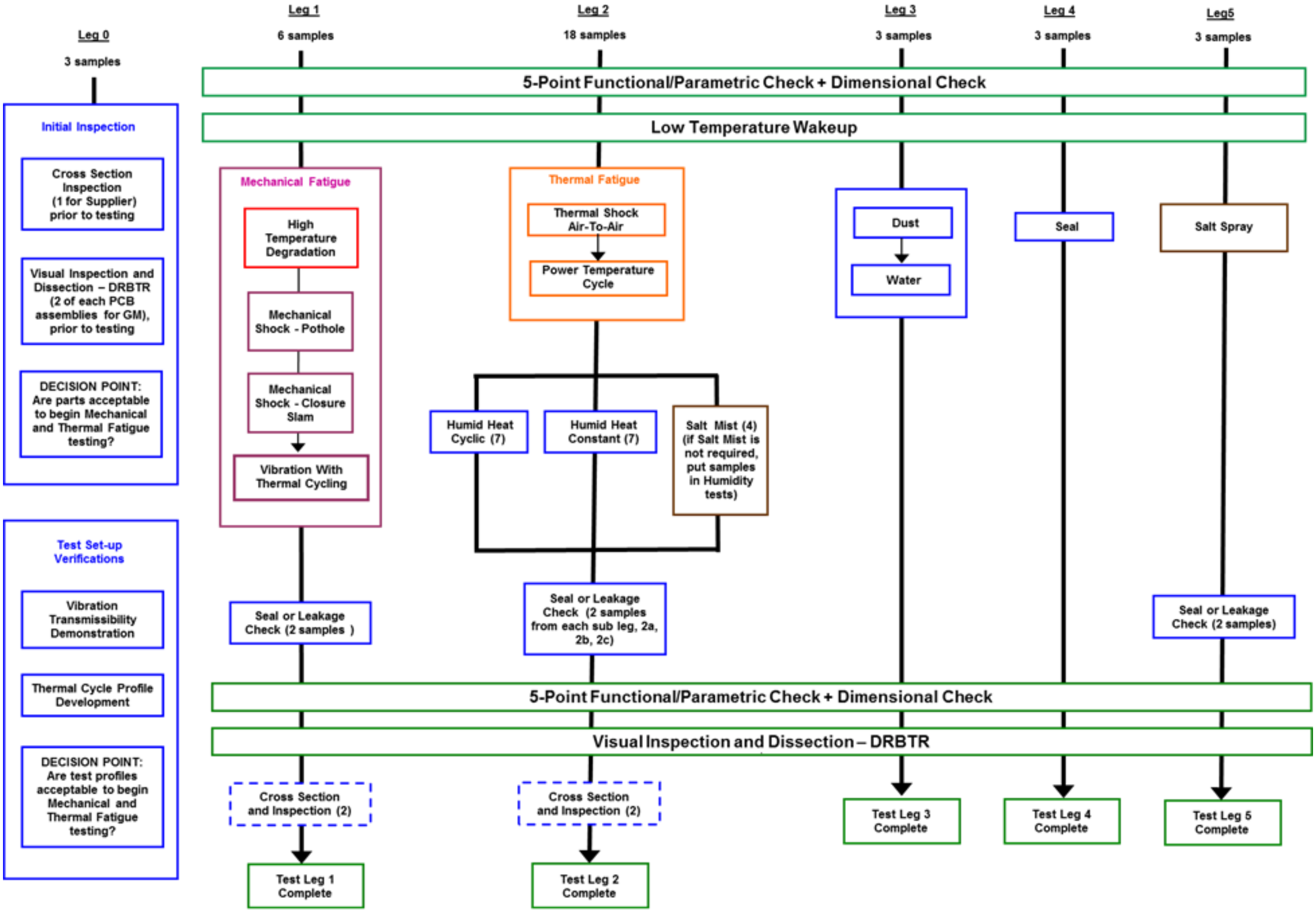


Figure 4: Universal Environmental/Durability Test Flow for Platform Product Validation (continued)

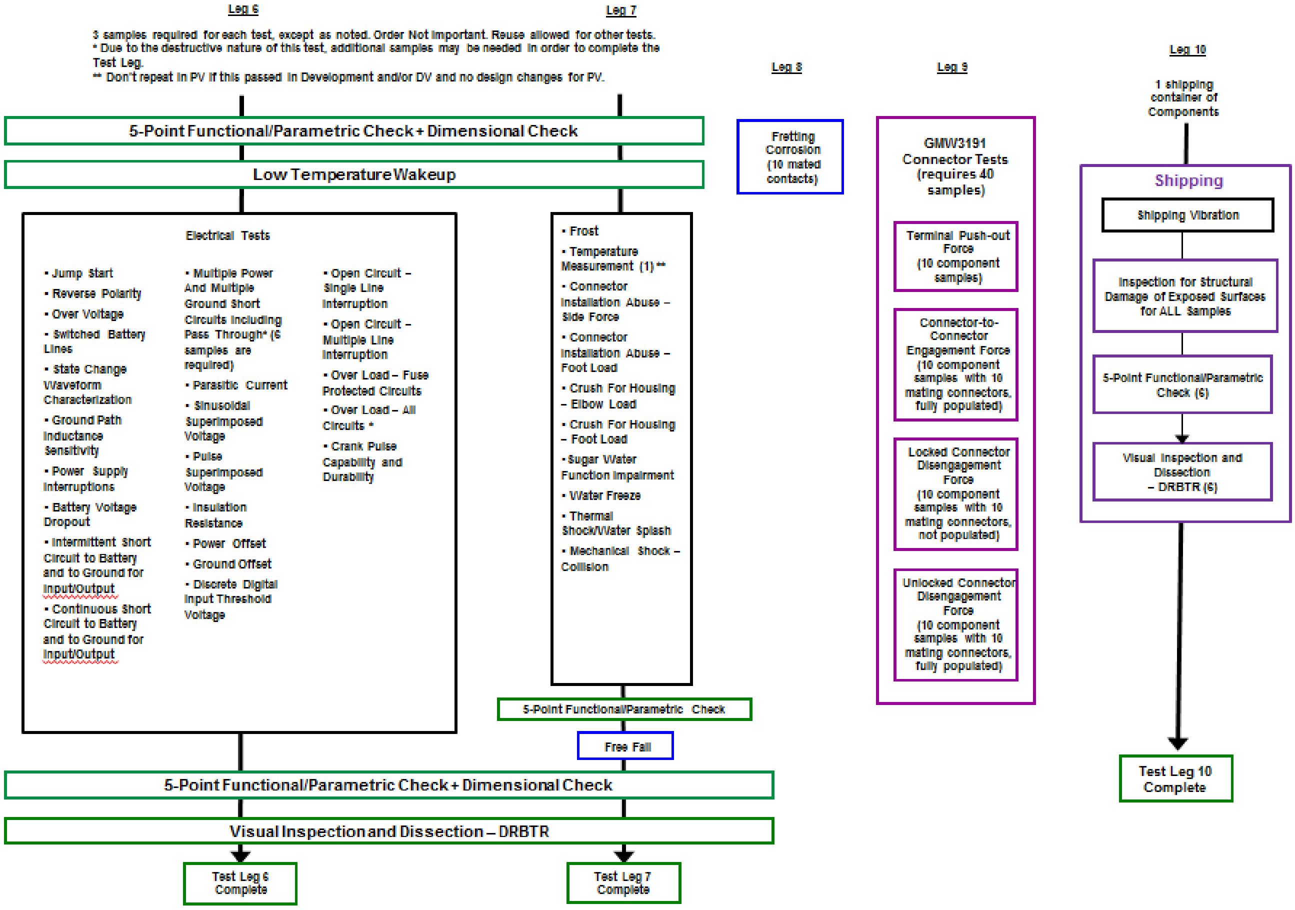


Figure 5: Powertrain Test Flow for Electronic Module, In-Transmission

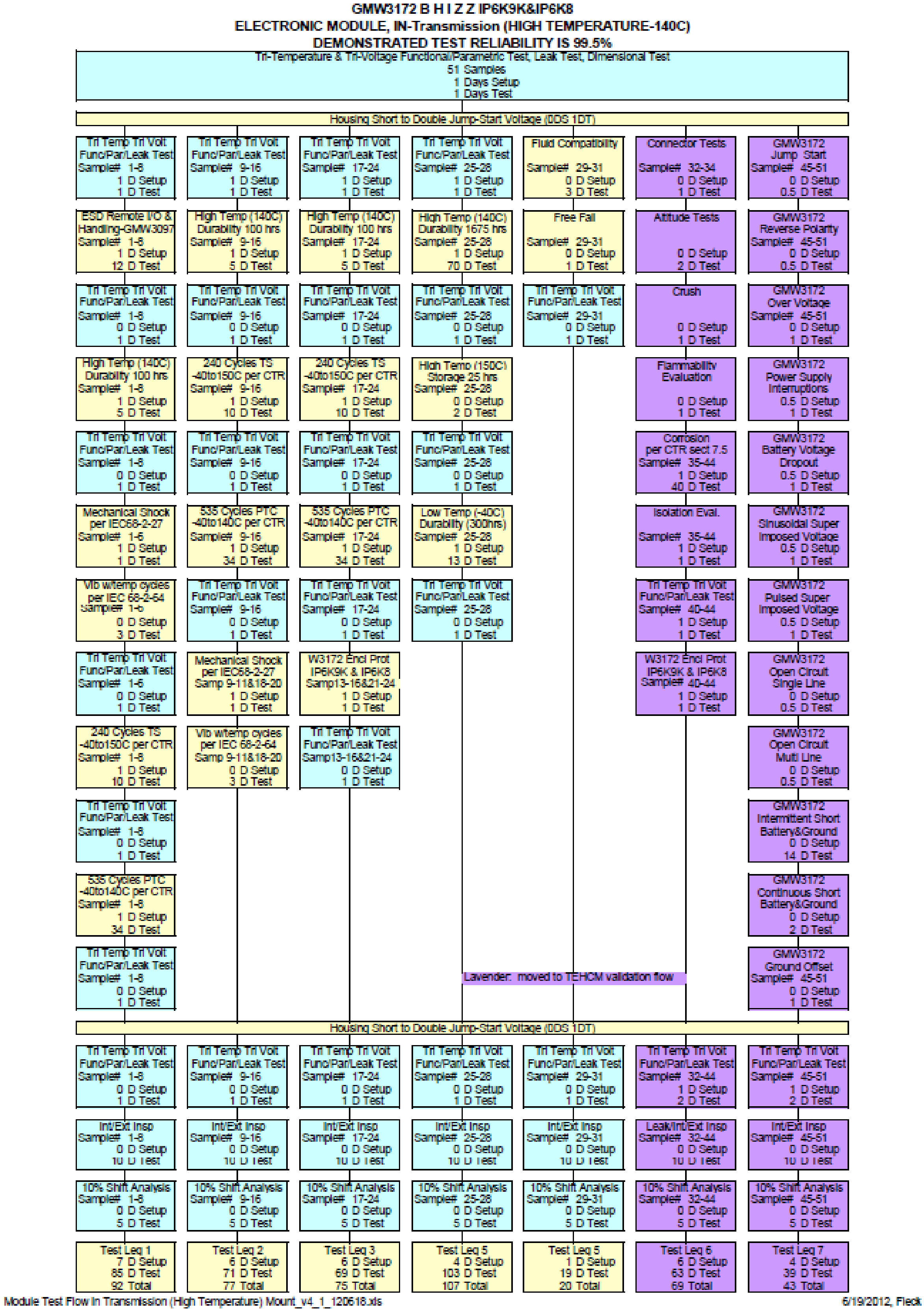


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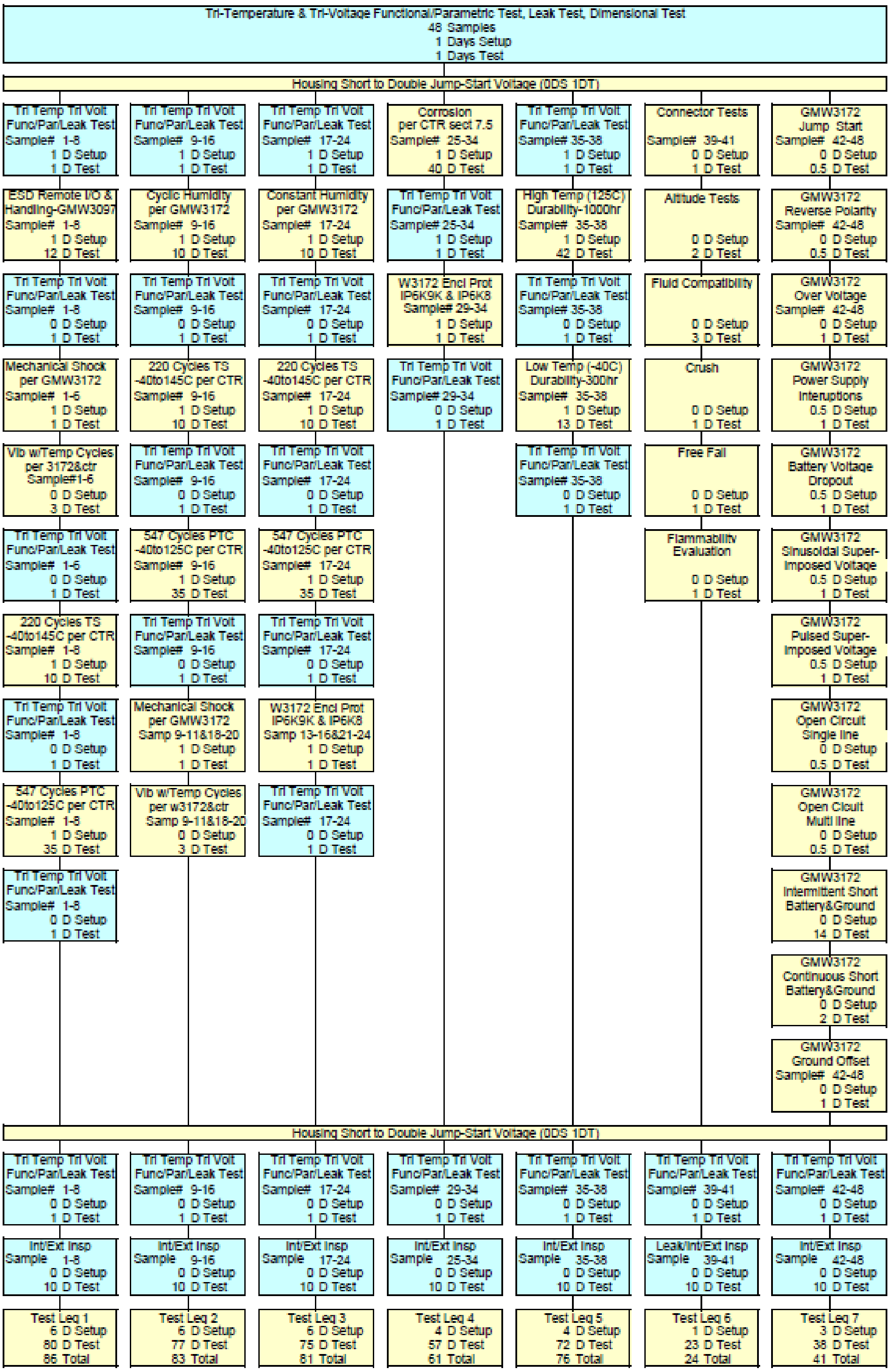
Figure 6: Powertrain Test Flow for Electronic Module, On-Transmission

GMW3172 B H Z Z E IP6K9K&IP6K8
ELECTRONIC MODULE, ON-Transmission (HIGH TEMPERATURE-125C)
DEMONSTRATED TEST RELIABILITY IS 99.5%



Module Test Flow On Transmission (High Temperature) Mount_v5_1_120618.xls 6/19/2012, Fleck

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Figure 7: Powertrain Test Flow for Electronic Module, Underhood

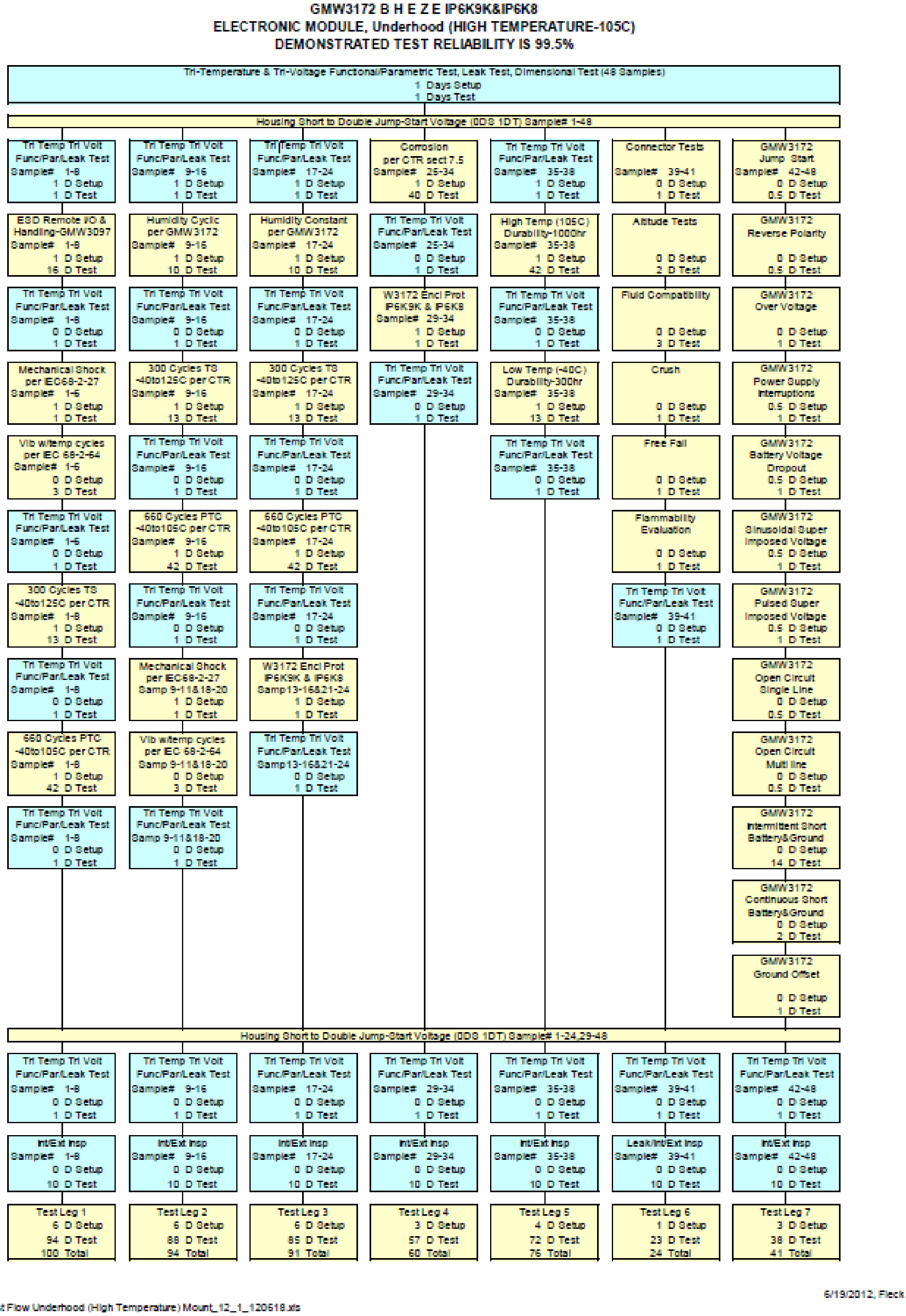
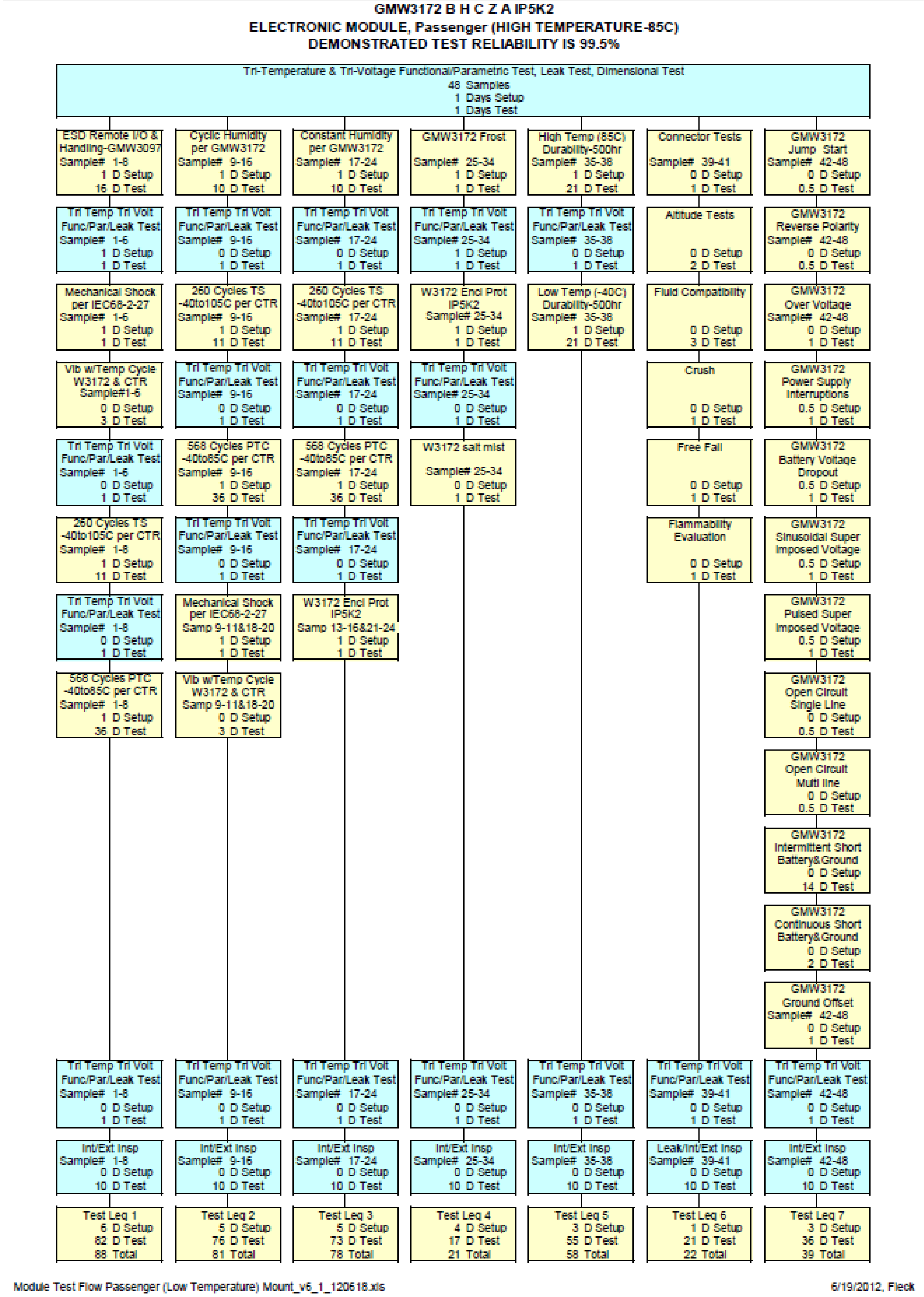


Figure 8: Powertrain Test Flow for Electronic Module, Passenger Compartment



4.2.2 Environmental Hardware Design Review. An Environmental Hardware Design Review, as shown in Figure 1, shall be conducted for all new components, as well as for current production components with modifications, to ensure that the design meets Environmental/Durability compliance.

An Environmental Hardware Design Review is required for any hardware-related modifications (such as internal part swaps or material changes) and manufacturing process changes (such as tooling, solder process, or manufacturing location). Software changes that may affect GMW3172-related requirements shall also be considered. For semiconductor changes, refer to GMW16552.

Environmental Hardware Design Review(s) shall be scheduled by the GM CVE and led by the GM ENV SME.

The objectives of the Environmental Hardware Design Review shall be to:

- Review component schematic design and circuit board layout
- Review component assembly and mechanical construction
- Review technical rationale of Electrical/Electronic design concept, Mechanization design concept, and chosen materials
- Examine any prior relevant analysis, calculations, and test results
- Discuss potential impacts to the product design and manufacturing process using Appendix A (Lead-Free Solder Considerations) as a reference
- Discuss lead-free solder risks and mitigation in the design and in the supply chain
- Evaluate potential changes to the component design
- Propose solutions to problems and appropriate re-validation
- Verify that the proposed circuit board and assembly design satisfies component Environmental/Durability requirements
- Evaluate manufacturing processes and changes
- Evaluate software changes that may affect GMW3172-related requirements
- Perform Thermal Fatigue Analysis
- Establish the part number(s) and family association(s) for CEMENT

Supplier Deliverables:

The Environmental Hardware Design Review Checklist (CG3814) shall be filled out in its entirety by the supplier in preparation for the Environmental Hardware Design Review. If required, the Parts Substitution Matrix (CG3303) shall be filled out in its entirety by the supplier in preparation for the Environmental Hardware Design Review. These forms are available from GM Supply Power or the GM ENV SME.

The following documentation shall be delivered to the GM ENV SME and/or CVE at least 10 working days ahead of the scheduled meeting:

- The Environmental Hardware Design Review Checklist
- The Parts Substitution Matrix, if required
- Functional description
- Vehicle location
- Interface description(s), internal and external to the component
- PCB (Printed Circuit Board) Layout
- Hardware Schematic drawing

- Electrical parts list and associated datasheets
- Material datasheets for all parts (such as materials used for PCB, solder, flux, assembly, connections, etc.) including the Coefficients of Thermal Expansion
- Part placement drawing
- Solder process description (solder alloy, solder temperature profile, cleaning material, process, etc.)
- Assembly Mechanization (assembly drawings, mounting/support locations, openings in housing, cooling concept, etc.)

Note: When available, actual hardware samples or physical mock-ups for visual examination are required.

Attendees:

GM:

- GMW3172 ENV SME
- Component-Responsible Validation Engineer
- DRE
- EMC SME (for CEMENT-related discussion)
- Supplier Quality Engineer (optional)

Supplier:

- Hardware Design Engineer
- Electrical System Engineer
- Environmental/Durability Expert
- Validation/Test Engineer
- Project Manager (optional)

4.2.3 Analytical Activities. The supplier shall conduct Analytical Activities and provide the analytical models and assumptions according to the approved Component Environmental Test Plan (CG3043). Each analytical result shall be reported to the GM CVE, ENV SME, and DRE for evaluation and approval.

4.2.4 Development Activities. The supplier shall conduct Development Activities and provide test samples to GM (may include pre and post test samples) according to the approved Component Environmental Test Plan (CG3043). Each test result shall be reported to the GM CVE, ENV SME, and DRE for evaluation and approval.

Components that have failed during a test shall be analyzed immediately by the supplier. The supplier shall contact the GM CVE (or GM ENV SME) immediately to define further actions. The component shall not be repaired or further used in the Test Flow, unless approved by GM.

4.2.5 Design Validation Activities. The supplier shall conduct Design Validation (DV) and provide test samples (may include pre and post test samples) to GM according to the approved Component Environmental Test Plan (CG3043). Each test result shall be uploaded in CEMENT for approval.

Components that have failed during a test shall be analyzed immediately by the supplier. The supplier shall contact the GM CVE (or GM ENV SME) immediately to define further actions. The component shall not be repaired or further used in the Test Flow, unless approved by GM.

4.2.6 Product Validation Activities. The supplier shall conduct Product Validation (PV) and provide test samples (may include pre and post test samples) to GM according to the approved Component Environmental Test Plan (CG3043). Each test result shall be uploaded in CEMENT for approval.

Components that have failed during a test shall be analyzed immediately by the supplier. The supplier shall contact the GM CVE (or GM ENV SME) immediately to define further actions. The component shall not be repaired or further used in the Test Flow, unless approved by GM.

4.3 Summary of A/D/V Activities. Table 5 is a default summary of A/D/V activities that shall be used for defining tests that will be included in the Component Environmental Test Plan (CG3043) with GM approval. The GM-approved Component Environmental Test Plan (CG3043) defines the required subset of GMW3172 test procedures.

Table 5: Summary of A/D/V Activities

Activity	Phase	FSC	Operating Type	Continuous Monitoring	Functional Cycling
Test Setup and Component Verification					
5-Point Functional/Parametric Check	D, DV, PV[2]	A	2.1, 3.2	Yes	N/A
1-Point Functional/Parametric Check	D, DV, PV[2]	A	2.1, 3.2	Yes	N/A
Continuous Monitoring	D, DV, PV[2]	N/A	As defined in each test	Yes	Yes
Functional Cycling	D, DV, PV[2]	N/A	2.1, 2.2, 3.1, 3.2	Yes	Yes
Visual Inspection and Dissection – DRBTR	D, DV, PV[2]	N/A	1.1	N/A	N/A
Cross Section and Inspection	DV, PV[1]	N/A	1.1	N/A	N/A
Dimensional Check	DV, PV[2]	N/A	1.1	N/A	N/A
Vibration Transmissibility Demonstration	DV, PV[1]	N/A	1.2	N/A	N/A
Thermal Profile Cycle Development	DV, PV[1]	N/A	1.1, 1.2, 3.2	N/A	Yes
Analysis					
Electrical					
Nominal and Worst Case Performance Analysis	A	N/A	N/A	N/A	N/A
Short/Open Circuit Analysis	A	N/A	N/A	N/A	N/A
Mechanical					
Resonant Frequency Analysis	A	N/A	N/A	N/A	N/A
High Altitude Shipping Pressure Effect Analysis	A	N/A	N/A	N/A	N/A
Plastic Snap Fit Fastener Analysis	A	N/A	N/A	N/A	N/A
Crush Analysis	A	N/A	N/A	N/A	N/A
Climatic					
High Altitude Operation Overheating Analysis	A	N/A	N/A	N/A	N/A

Activity	Phase	FSC	Operating Type	Continuous Monitoring	Functional Cycling
Thermal Fatigue Analysis	A	N/A	N/A	N/A	N/A
Lead-Free Solder Analysis	A	N/A	N/A	N/A	N/A
Development					
Electrical					
Jump Start	D, DV, PV[1]	C	3.1, 3.2	Yes	No*
Reverse Polarity	D, DV, PV[1]	C	3.1, 3.2	Yes	No*
Over Voltage	D, DV, PV[1]	C	3.1, 3.2	Yes	No*
State Change Waveform Characterization	D, DV, PV[1]	A	All transitions e.g., 1.2 to 3.2, 3.2 to 1.2	Yes	N/A
Ground Path Inductance Sensitivity	D, DV, PV[1]	A	3.2	Yes	Yes
Mechanical					
Highly Accelerated Life Test (HALT)	D	N/A	3.2	Yes	Yes
Climatic					
Temperature Measurement	D, DV	N/A	3.2	N/A	N/A
Low Temperature Wakeup	D, DV, PV[1]	A	1.2, 3.2	Yes	No*
Frost	D, DV, PV[1]	A	1.2, 3.2	Yes	Yes
Highly Accelerated Stress Test (HAST)	D	A	3.2	Yes	Yes
Design Validation (DV)					
Electrical					
Parasitic Current	DV, PV[1]	N/A	2.1, 2.2	Current only	N/A
Power Supply Interruptions	DV, PV[1]	A, C	3.2	Yes	No*
Battery Voltage Dropout	DV, PV[1]	A, C	2.1, 3.2	Yes	No*
Sinusoidal Superimposed Voltage	DV, PV[1]	A	3.2	Yes	No*
Pulse Superimposed Voltage	DV, PV[1]	A	3.2	Yes	No*

Activity	Phase	FSC	Operating Type	Continuous Monitoring	Functional Cycling
Intermittent Short Circuit to Battery and to Ground for Input/Output	DV, PV[1]	C	2.1, 3.2	Yes	No*
Continuous Short Circuit to Battery and to Ground for Input/Output	DV, PV[1]	C	3.2	Yes	No*
Multiple Power and Multiple Ground Short Circuits Including Pass Through	DV, PV[1]	D, E	3.2	Yes	No*
Open Circuit – Single Line Interruption	DV, PV[1]	C	3.2	Yes	No*
Open Circuit – Multiple Line Interruption	DV, PV[1]	C	3.2	Yes	No*
Ground Offset	DV, PV[1]	A	3.2	Yes	Yes
Power Offset	DV, PV[1]	A	3.2	Yes	Yes
Discrete Digital Input Threshold Voltage	DV, PV[1]	N/A	3.2	Yes	N/A
Over Load – All Circuits	DV, PV[1]	D, E	3.2	Yes	N/A
Over Load – Fuse Protected Circuits	DV, PV[1]	A	3.2	Yes	N/A
Insulation Resistance	DV, PV[1]	C	1.1	N/A	N/A
Crank Pulse Capability and Durability	DV, PV[1]	A, C	2.1, 2.2, 3.2	Yes	No*
Switched Battery Lines	DV, PV[1]	C	2.1, 2.2	Yes	No*
Mechanical					
Vibration With Thermal Cycling	DV, PV[2]	A	3.2	Yes	Yes
Mechanical Shock – Pothole	DV, PV[1]	A	3.2	Yes	Yes
Mechanical Shock – Collision	DV, PV[1]	C	1.2	N/A	N/A
Mechanical Shock – Closure Slam	DV, PV[1]	A	3.2	Yes	Yes
Crush For Housing – Elbow Load	DV, PV[1]	C	1.1	N/A	N/A
Crush For Housing – Foot Load	DV, PV[1]	C	1.1	N/A	N/A
GMW3191 Connector Tests: Terminal Push-out Force	DV, PV[1]	See GMW3191	See GMW3191	N/A	N/A
GMW3191 Connector Tests: Connector-to-Connector Engagement Force	DV, PV[1]	See GMW3191	See GMW3191	N/A	N/A

Activity	Phase	FSC	Operating Type	Continuous Monitoring	Functional Cycling
GMW3191 Connector Tests: Locked Connector Disengagement Force	DV, PV[1]	See GMW3191	See GMW3191	N/A	N/A
GMW3191 Connector Tests: Unlocked Connector Disengagement Force	DV, PV[1]	See GMW3191	See GMW3191	N/A	N/A
Connector Installation Abuse – Side Force	DV, PV[1]	C	1.2	Yes	No*
Connector Installation Abuse – Foot Load	DV, PV[1]	C	1.2	Yes	No*
Free Fall	DV, PV[1]	C, E	1.1	N/A	N/A
Fretting Corrosion Degradation	DV, PV[1]	N/A	N/A	N/A	N/A
Climatic					
High Temperature Degradation	DV, PV[1]	A	2.1, 3.2	Yes	Yes
Thermal Shock Air-To-Air (TS)	DV, PV[1]	C	1.1	N/A	N/A
Power Temperature Cycle (PTC)	DV, PV[1]	A	1.2, 2.1, 3.2	Yes	Yes
Thermal Shock/Water Splash	DV, PV[1]	A	1.2, 3.2	Yes	Yes
Humid Heat Cyclic (HHC)	DV, PV[2]	A	2.1, 3.2	Yes	Yes
Humid Heat Constant (HHCO)	DV, PV[2]	A	2.1, 3.2	Yes	Yes
Salt Mist	DV, PV[1]	A, C	1.2, 2.1, 3.2	Yes	Yes
Salt Spray	DV, PV[1]	A	1.2, 3.2	Yes	Yes
Enclosure					
Dust	DV, PV[1]	C	1.2	N/A	N/A
Water	DV, PV[1]	A	3.2	Yes	Yes
Seal	DV, PV[3]	A	3.2	Yes	Yes
Leakage Check	DV, PV[1]	N/A	1.2	N/A	N/A
Water Freeze	DV, PV[1]	A	2.1, 3.2	Yes	No*
Sugar Water Function Impairment	DV, PV[1]	A	3.2	Yes	N/A
Product Validation (PV)					
Mechanical					
Shipping Vibration	PV[2]	C	1.1	N/A	N/A

Activity	Phase	FSC	Operating Type	Continuous Monitoring	Functional Cycling
Legend for Phase: A = Analysis D = Development DV = Design Validation PV = Product Validation No* = Not required, unless determined necessary by GM. Footnotes: PV[1] = These procedures may be omitted in PV with agreement of the GM ENV SME based on successful DV Test Results and no component design or process changes. PV[2] = These procedures are required in PV in all cases. Exceptions shall be agreed upon by the GM ENV SME. PV[3] = This procedure is required in PV for sealed components. Exceptions shall be agreed upon by the GM ENV SME.					

5 Requirements

5.1 Target Life. The life requirement used in this document is 10 years of environmental exposure and 160 900 km (100 000 miles) of customer usage.

When the Vehicle Technical Specification (VTS) defines a different target life in km or miles, adjustments shall be made only for vibration testing. For example, a 150 000 miles requirement shall dictate 1.5 times the number of hours of vibration testing defined in this document.

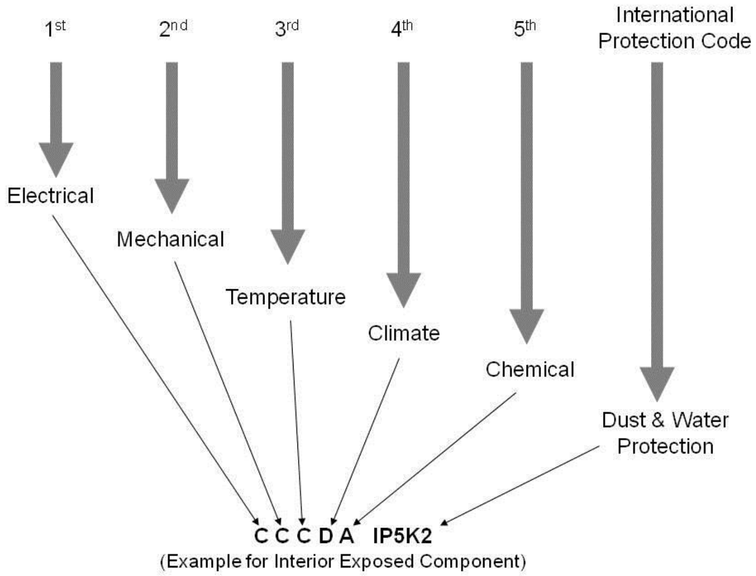
When the VTS defines a different target life in years, no adjustments shall be made.

5.2 Reliability. All reliability values within this document are derived from calculations based on 97 % reliability with a statistical confidence of 50 %. In case of different reliability and confidence requirements, adjustments shall be made accordingly. Component reliability shall be demonstrated in the following tests:

- Vibration with Thermal Cycling, relative to the target life in km or miles for customer usage of 160 900 km (100 000 miles) as a default, or as specified in the VTS.
- Thermal Shock Air-to-Air combined with Power Temperature Cycle, relative to a target life of 10 years of customer usage.

5.3 Quoting Requirements. Environmental requirements shall be assigned in the CTS or SSTS according to Figure 9. In case that the Environmental requirements are missing in the CTS or SSTS, the most appropriate code according to Table 14 shall be used as a default. Multiple International Protection (IP) Codes may be assigned if required. Supplemental Environmental testing for failure mechanisms not covered by this document shall be specified and documented in the Additional Activities section in Appendix B (Component Environmental Test Plan, i.e., CG3043).

Figure 9: Code Letter Sequence Requirement



5.3.1 Code Letter for Electrical Loads. The following table defines the steady state minimum and maximum test voltages to be used as measured at the connector of the component.

The table should also be used in specifying the component criteria requirements unless otherwise specified in the CTS.

Table 6: Code Letter for Electrical Loads

Code Letter	Test Voltage	
	U_{min}	U_{max}
A	4.5 V	16 V
B	6 V	16 V
C (most common)	9 V	16 V
D	9 V	18 V
E	10 V	16 V
F	12 V	16 V
G	4.5 V	5.5 V
Z	As Agreed Upon	

- In the range of the given code letter the Functional Status Classification shall be A.
- In the range of -13.5 V to U_{min} and U_{max} to +26 V, the Functional Status Classification shall be C.

The test voltages for Electrical Code Letters A - F depend on the Operating Types as shown in Table 7.

Table 7: Test Voltages

Test Voltage	U_{min} (from Table 6)	U_{nom}	U_{max} (from Table 6)	Operating Types
U_A	Applies	14 V	Applies	3.1/3.2 (Generator operating)
U_B	Applies	12 V	N/A	2.1/2.2 (Generator not operating)

For Electrical Code Letter G, U_{nom} = 5.0 V.

5.3.2 Code Letter for Mechanical Loads. See Table 8.

Table 8: Code Letter for Mechanical Loads

Code Letter	Requirements				
	Crush For Housing	Random Vibration	Mechanical Shock – Pothole and Collision	Mechanical Shock – Closure Slam	Free Fall
A Note 1	Elbow Load	Engine or Transmission (without special balancing feature)	Yes	No	Yes
B Note 1	Elbow Load	Engine or Transmission (with special balancing feature)	Yes	No	Yes
C	Elbow Load	Car Sprung Masses	Yes	No	Yes
D	Elbow Load and Foot Load	Car Sprung Masses	Yes	No	Yes
E	Elbow Load	Car Sprung Masses	Yes	Yes	Yes
F	Elbow Load	Car Unsprung Masses	Yes	No	Yes
G	Elbow Load	Truck Sprung Masses	Yes	No	Yes
H	Elbow Load and Foot Load	Truck Sprung Masses	Yes	No	Yes
I	Elbow Load	Truck Sprung Masses	Yes	Yes	Yes
J	Elbow Load	Truck Unsprung Masses	Yes	No	Yes
Z	as agreed upon				

Note 1: The random vibration profiles for these code letters are identical. GMW3172 no longer has a distinction between with or without special balancing feature. The duplicate lines cannot be deleted in order to support past published test standards.

Note: The CTS or the PDT (Product Development Team) shall define the vehicle type (i.e., car or truck) and the mileage requirement (e.g., 100 000 miles, 150 000 miles, etc.).

Note: Distinction between Car/Truck and Sprung/Unsprung Masses:

- Trucks are defined as pickup trucks or commercial vehicles (body on frame vehicles (BOF), includes SUVs based on a truck platform).

- Cars are defined as passenger cars, SUVs, or crossover vehicles (body frame integral (BFI) vehicles, unibody; includes SUVs based on a car platform).
- Sprung Masses are defined as components attached to the body, frame, or sub-frame of a vehicle (i.e., mounted above the springs of a vehicle).
- Unsprung Masses are defined as components attached to the wheels, tires, or moving suspension elements of a vehicle.

Note: Brackets not integral to the component are not covered by this specification.

5.3.3 Code Letter for Temperature Loads. See Table 9.

Table 9: Code Letter for Temperature Loads

Code Letter	T_{min}	T_{max}	T_{PH} Use for 5 % of the total High Temperature Degradation test. Component is powered.	T_{RPS} Use for one hour of the High Temperature Degradation test. Component is <u>not</u> powered.
A	-40 °C	+70 °C	N/A	+95 °C
B	-40 °C	+80 °C	N/A	+95 °C
C	-40 °C	+85 °C	N/A	+95 °C
D	-40 °C	+90 °C	N/A	+95 °C
E	-40 °C	+105 °C	N/A	N/A
F	-40 °C	+105 °C	+120 °C	N/A
G	-40 °C	+120 °C	N/A	N/A
H	-40 °C	+125 °C	+140 °C	N/A
I	-40 °C	+140 °C	N/A	N/A
J	-40 °C	+95 °C	N/A	N/A
Z	as agreed upon			

5.3.4 Code Letter for Climatic Loads. See Table 10.

Table 10: Code Letter for Climatic Loads

Code Letter	High Temperature Degradation	Thermal Shock/Water Splash	Seal Note 1	Salt Mist or Salt Spray	Cyclic Humidity	Constant Humidity	Frost Note 3
A	2000 h	NO	NO	YES	YES	YES	YES
B	2000 h	NO	YES	YES	YES	YES	YES
C	2000 h	YES	NO	YES	YES	YES	YES
D	500 h	NO	NO	YES	YES	YES	YES
E Note 2	500 h	NO	NO	YES	YES	YES	YES
F	500 h	NO	YES	YES	YES	YES	YES
G Note 2	500 h	NO	NO	YES	YES	YES	YES
H Note 2	500 h	NO	NO	YES	YES	YES	YES
I Note 2	500 h	NO	YES	YES	YES	YES	YES
J	500 h	YES	YES	YES	YES	YES	YES
K Note 2	2000 h	YES	NO	YES	YES	YES	YES
L Note 2	2000 h	NO	YES	YES	YES	YES	YES
M	500 h	YES	NO	YES	YES	YES	YES
N Note 2	500 h	NO	YES	YES	YES	YES	YES
O	2000 h	YES	YES	YES	YES	YES	YES
Z	as agreed upon						

Note 1: If the above table specifies the Seal test and/or the IP Water Code is 8, then the Seal test shall be performed as specified in this document.
Note 2: Some rows are identical due to the deletion of the column for Xenon Arc and references to various test parameters from previous versions of this document. The duplicate lines cannot be deleted in order to support past requirements. As a best practice, choose the first occurrence of a duplicate line as the Climatic Code.
Note 3: The Frost test is not applicable for non-sealed components with vent openings.

5.3.5 Code Letter for Chemical Loads. The Coding defines the requirements related to the position of the component in the vehicle which will dictate the required fluid compatibility requirements (see Table 11). For the specific list of fluids to test refer to GMW16449. This test is not included in GMW3172. It is the responsibility of the GM Materials Engineer and Validation Engineer.

Note: Consult with the GM Materials Engineer to determine if any additional material-related testing is required.

Table 11: Code Letter for Chemical Loads

Code Letter	Mounting Location for Chemical Loads
A	Cabin Exposed
B	Cabin Unexposed
C	Interior Door Mounted (Unexposed)
D	Trunk
E	Under Hood
F	Exterior Area
G	Chassis
Z	as agreed upon

5.3.6 Code Letter for International Protection by Enclosures. GM uses a subset of the International Protection (IP) Codes (see Table 12 and Table 13).

The coding behind IP definitions is similar to ISO 20653, Protection of electrical equipment against foreign objects, water and access.

Table 12: Code Letter for International Protection by Enclosures – Dust

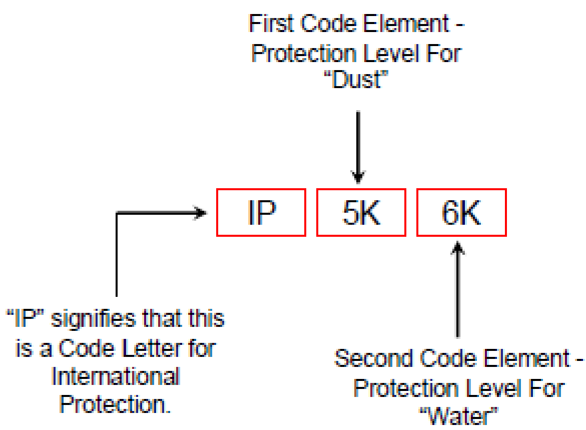
First code element	Brief description	Requirements
X	Not required	None – Shall only be used in conjunction with Water IP codes 6K, 8K, or 9K
5K	Dust-protected	Dust shall only penetrate in quantities which do not impair performance and safety
6K	Dust-tight	Dust shall not penetrate

Table 13: Code Letter for International Protection by Enclosures – Water

Second code element	Brief description	Requirements
0	Not Protected	None
2	Water drips with enclosure inclined by 15°	Vertical drips shall not have any harmful effects, when the enclosure is tilted at any angle up to 15º on either side of the vertical
3	Water spray	Water spray which sprays against the enclosure from any direction at a 60º angle shall not have any harmful effects
4K	Splash water with increased pressure	Water which splashes against the enclosure from any direction with increased pressure shall not have any harmful effects
6K	Strong high-velocity water with increased pressure	Water which is directed against the enclosure from any direction as a strong jet with increased pressure shall not have any harmful effects
8	Seal – Continuous immersion in water	Water shall not penetrate in a quantity causing harmful effects if the enclosure is continuously immersed in water under conditions which shall be agreed between supplier and GM
9K	Water during high pressure/ steam-jet cleaning	Water which is directed against the enclosure from any direction shall not have any detrimental effect

The example in Figure 10 explains the use of letters in the IP-Code. For details see ISO 20653, Protection of electrical equipment against foreign objects, water and access.

Figure 10: IP-Code Example



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5.3.7 Code Designation by Location in the Vehicle. This document distinguishes between the following mounting locations and defines the minimum recommended Electrical, Mechanical, Temperature, Climatic, Chemical, Dust and Water Protection requirements. Other mounting locations are possible and can be addressed using a custom combination of Z code letters (see Table 14).

Table 14: Code Letters Based on Location in the Vehicle

Mounting Location	Electrical Loads	Mechanical Loads	Temperature Loads	Climatic Loads	Chemical Loads	Dust and Water Protection
	Code letter per Table 6	Code letter per Table 8	Code letter per Table 9	Code letter per Table 10	Code letter per Table 11	Code letter per Table 12 and Table 13
Engine Compartment						
High location, remote from engine and heat sources or mounted on intake manifold	A – F, S Typically C	C	F	A	E	IP6K9K
High location, close to engine or heat sources	A – F, S Typically C	C	H	A	E	IP6K9K
At/in engine	A – F, S Typically C	A or B	H or I	B	E	IP6K9K
At/in transmission	A – F, S Typically C	A or B	I	B	E	IP6K9K
Low	A – F, S Typically C	C or G	F or H	A, B, C, or O	E	IP6K6K and IP6K8 or IP6K9K and IP6K8
Passenger Compartment						
Low temperature load (Under dashboard)	A – F, S Typically C	C	A, B or C	D	A or B	IP5K2
Normal temperature load (Dashboard display or switch)	A – F, S Typically C	C	D	E	A	IP5K2
High temperature load (Top of dashboard with sun load)	A – F, S Typically C	C	E or J	E	A	IP5K2

Mounting Location	Electrical Loads	Mechanical Loads	Temperature Loads	Climatic Loads	Chemical Loads	Dust and Water Protection
	Code letter per Table 6	**Code letter per Table 8**	**Code letter per Table 9**	**Code letter per Table 10**	**Code letter per Table 11**	**Code letter per Table 12 and Table 13**
High Temperature load (on or behind rear view mirror)	A – F, S Typically C	C	D, E, or J	E	A	IP5K2
Low mount/under seat	A – F, S Typically C	D	A	D or F	B	IP5K2 or IP5K8
Other Locations						
Trunk low mount	A – F, S Typically C	C or D	A, B, or C	F	D	IP5K8
Trunk high mount	A – F, S Typically C	C or D	A, B, or C	D	D	IP5K2
Doors and hatches (wet area)	A – F, S Typically C	E	B or C	H	B	IP5K3 or IP5K6K
Doors and hatches (dry area)	A – F, S Typically C	E	B or C	E or D	A	IP5K3
Exterior splash area	A – F, S Typically C	C	A, B, or C	J	F	IP6K9K
Chassis and underbody	A – F, S Typically C	C	A, B or C	I, J or N	F	IP6K8 and/or IP6K9K
Unsprung masses	A – F, S Typically C	F	A, B or C	J or N	F	IP6K8 or IP6K9K
Sealed body cavities	A – F, S Typically C	C	A, B or C	D	B	IP5K2
Unsealed body cavities	A – F, S Typically C	C	A, B or C	H or I	F	IP5K4K

Mounting Location	Electrical Loads	Mechanical Loads	Temperature Loads	Climatic Loads	Chemical Loads	Dust and Water Protection
	Code letter per Table 6	Code letter per Table 8	Code letter per Table 9	Code letter per Table 10	Code letter per Table 11	Code letter per Table 12 and Table 13
Exterior at the base of the windshield inside the Plenum or inside the engine compartment	A – F, S Typically C	C	D, E, F or G	I	E	IP6K6K and IP6K8
Roof mounted inside the vehicle cabin	A – F, S Typically C	C	D	D	B	IP6K2 or IP5K2

6 Test Setup and Component Verification

6.1 5-Point Functional/Parametric Check.

Purpose: This check shall verify full functionality of the component as defined in the CTS while exposed to 3 temperatures and 3 voltages.

Applicability: This check shall be performed at the beginning and at the end of all test legs.

Operating Type: 2.1 (to confirm functionality in Sleep Mode/OFF mode) / 3.2

Monitoring: As defined in the following procedure.

Procedure: The 5-Point Functional/Parametric Check shall be performed at the following five points:

1. (T_{min}, U_{min})
2. (T_{min}, U_{max})
3. (T_{room}, U_{nom}), where U_{nom} is U_B for Operating Type 2.1, and U_A for Operating Type 3.2
4. (T_{max}, U_{min})
5. (T_{max}, U_{max})

The temperature of the component shall be stabilized at the target temperature (± 3 °C), for ≥ 0.5 h prior to the 5-Point Functional/Parametric Check.

The 5-Point Functional/Parametric Check shall be conducted with actual vehicle loads or equivalent. All loads shall be documented in the Component Environmental Test Plan (CG3043).

The power supply shall be capable of supplying sufficient current to avoid current limiting under high in-rush conditions.

The 5-Point Functional/Parametric Check shall:

1. Validate functionality by monitoring and recording that all outputs (both hardwired and on-vehicle data bus communications) are in the correct state for a given set of inputs and timing conditions.
2. Measure parametric values by monitoring and recording the specific voltage, current, and timing levels for all inputs and outputs in order to verify that these levels meet the CTS/SSTS requirements, including tolerances.
3. Measure non-electrical parameters such as motor torque, LED brightness, color and intensity of backlighting, contrast ratio of a display, etc. by monitoring and recording the appropriate specific values in order to verify that these levels meet the CTS/SSTS requirements, including tolerances. These parameters shall be defined in the Component Environmental Test Plan.

4 Perform the Dimensional Check according to paragraph 6.7. This procedure shall be performed on the following samples as a baseline during the Initial 5-Point Functional/Parametric Check, at T_{room} only: 2 samples from High Temperature Degradation, 2 from HHCO, 2 from HHC, 2 from Seal, and 2 from Thermal Shock/Water Splash.

This procedure shall be performed again on the same samples during the Final 5-Point Functional/Parametric Check, at T_{room} only.

5 Compare selected parametric measurements taken on the component before and after testing. Comparisons to the original measurements, individually and as a group statistically, shall be made to identify and quantify any performance degradation. If degradation limits are not specified in the CTS, the supplier, the GM ENV SME or CVE, and the GM DRE shall collaborate to define the degradation acceptance/failure criteria.

Criteria: Functional Status Classification shall be A.

6.2 1-Point Functional/Parametric Check.

Purpose: This check shall verify full functionality of the component as defined in the CTS while exposed to a single temperature and single voltage.

Applicability: This check shall be performed during or after tests as defined in the Component Environmental Test Plan (CG3043).

Operating Type: 2.1 (to confirm functionality in Sleep Mode/OFF mode) / 3.2

Monitoring: As defined in the following procedure.

Procedure: The 1-Point Functional/Parametric Check shall be performed at (T_{room}, U_B for Operating Type 2.1, and U_A for Operating Type 3.2), unless otherwise specified in the Component Environmental Test Plan.

The temperature shall be stabilized for at least 0.5 h prior to the 1-Point Functional/Parametric Check.

The 1-Point Functional/Parametric Check shall be conducted with actual vehicle loads or equivalent. All loads shall be documented in the Component Environmental Test Plan.

The power supply shall be capable of supplying sufficient current to avoid current limiting under high in-rush conditions.

The 1-Point Functional/Parametric Check shall:

1 Validate functionality by monitoring and recording that all outputs (both hardwired and on-vehicle data bus communications), or a subset thereof, as defined in the Component Environmental Test Plan, are in the correct state for a given set of inputs and timing conditions.

2 Measure parametric values by monitoring and recording the specific voltage, current, and timing levels for all inputs and outputs, or a subset thereof, as defined in the Component Environmental Test Plan, in order to verify that these levels meet the CTS/SSTS requirements, including tolerances.

3 Measure non-electrical parameters such as motor torque, LED brightness, color and intensity of backlighting, contrast ratio of a display, etc. by monitoring and recording the appropriate specific values in order to verify that these levels meet the CTS/SSTS requirements, including tolerances. These parameters shall be defined in the Component Environmental Test Plan.

Criteria: Functional Status Classification shall be A.

6.3 Continuous Monitoring.

Purpose: Continuous Monitoring shall detect the functional status of the component during and after exposure to the test environment. Continuous Monitoring shall detect false actuation signals, erroneous serial data messages, fault codes, or other erroneous Input/Output (I/O) commands or states. This shall be documented in detail in the Component Environmental Test Plan (CG3043).

Applicability: This check shall be performed during the tests as defined in the Component Environmental Test Plan.

Operating Type: As defined in each individual test.

Monitoring: Not applicable

Procedure: Continuous Monitoring shall:

1 Detect functionality by monitoring and recording that all outputs (both hardwired and on-vehicle data bus communications), or a subset thereof as defined in the Component Environmental Test Plan, are in the correct state for a given set of inputs and timing conditions. The sampling rate shall be fast enough to detect intermittent functionality and errors shall be flagged automatically. The monitoring sampling rate shall be defined in the Component Environmental Test Plan.

2 Monitor and record internal diagnostic codes, if available.

3 Include periodic observation of specific component functionality, such as optical monitoring of test patterns or stability of LEDs or bulbs.

6.4 Functional Cycling.

Purpose: Functional Cycling shall simulate customer usage during and after exposure to the test environment. This shall be documented in detail in the Component Environmental Test Plan (CG3043).

Applicability: Functional Cycling shall be performed during the tests as defined in the Component Environmental Test Plan.

Operating Type: 2.1/2.2/3.1/3.2

Monitoring: As defined in the following procedure.

Procedure: While the component is exposed to the test environment, all component inputs/outputs, displays, human-interfaces, and mechanical actuations shall be cycled and monitored for proper functional operation. This may include power moding if applicable. The functional cycling rate shall be defined in the Component Environmental Test Plan.

Functional Cycling shall occur during any test that includes Operating Type 3.2. Exceptions shall be included in the Component Environmental Test Plan. The functional cycling scheme shall exercise the component and allow for detection of degradation or failure. The electrical/mechanical loading shall reflect the normal usage in the vehicle application.

The input/output cycling and monitoring shall be automatic.

6.5 Visual Inspection and Dissection – DRBTR.

Purpose: This activity shall identify any structural faults, material/component degradations or residues, and near-to-failure conditions caused by environmental testing. This activity supports the Design Review Based on Test Results (DRBTR) process as defined in GMW16044. The Visual Inspection and Dissection – DRBTR is a visual review down to the microscopic level of the component's housing, internal parts, and electrical connections at the completion of testing as specified in the Universal Environmental/Durability Test Flows. Examinations are also made before testing to inspect the build quality and use as a baseline for comparison purposes.

Applicability: All components.

Operating Type: 1.1

Monitoring: Not applicable

Procedure:

Prior to DV/PV testing: Two pre-test samples shall be provided to the GM ENV SME or CVE upon request. This shall occur as soon as possible after the DV/PV build in order to discover build issues (such as solder quality, conformal coating quality, etc.) quickly and begin the resolution process as soon as possible. These samples shall not be used for DV/PV testing. The GM ENV SME and CVE shall perform the inspection, along with the GM DRE, Resident DRE, GM SQE, and Supplier if needed. All parties shall be informed of observations and areas of concern.

Alternatively, inspection of pre-test samples can occur at the test facility by the GM ENV SME and CVE, along with the GM DRE, Resident DRE, GM SQE, and Supplier if needed. These samples could be used for testing if the integrity is not compromised due to the inspection.

After DV/PV testing: The supplier shall perform the DRBTR activity on all samples, or as agreed upon. The DRBTR shall be performed with the GM ENV SME and/or CVE present, or as agreed upon. These agreements shall be made with the GM ENV SME and the CVE. The GM DRE, Resident DRE, GM SQE, and Supplier should be present as well. All parties shall be informed of observations and areas of concern as defined in GMW16044.

A subset of the samples shall be cross-sectioned, as described in paragraph 6.6 of GMW3172.

All samples shall be available for GM review upon request.

The following samples shall be kept assembled and reserved for inspection and/or dissection by the GM ENV SME or CVE upon request: one sample from the Mechanical Fatigue leg, two samples from the Thermal Fatigue leg (one from Humid Heat Constant and one from Humid Heat Cyclic), and one sample from the Corrosion test leg. The GM ENV SME and CVE shall perform the inspection, along with the GM DRE, Resident DRE, GM SQE, and Supplier if needed. All parties shall be informed of observations and areas of concern.

The DRBTR inspection/dissection process is described as follows. Perform an external inspection of the component housing. Then disassemble the component for an internal inspection. The inspection shall use visual aids (e.g., magnifiers, microscopes, dyes, etc.) as necessary.

The following are examples of inspection items:

1 **Degraded Mechanical and Structural Integrity:** Signs of degradation, cracks, melting, wear, fastener failures, etc.

2 **Solder/Part Lead Fatigue Cracks or Creep or Pad-Lift:** Emphasis on large integrated circuits, large massive parts or connector terminations (especially at the end or corner lead pins). Also, parts in high flexure areas of the circuit board.

3 **Damaged Surface Mount Parts:** Emphasis on surface mounted parts near circuit board edges, supports or carrier tabs. Also, surface mounted parts located in high flexure areas of the circuit board and near connector terminations.

4 **Degraded Large Part Integrity and Attachment:** Leaky electrolytic capacitors, contaminated relays, heat sink/rail attachments, etc.

5 **Material Degradation, Growth, or Residues of Corrosion:** Melted plastic parts; degraded conformal coatings, solder masks or seals; circuit board delaminations, lifted circuit board traces, corrosion such as black silver sulfide spots, organic growths, or environmental residues due to dust, salt, moisture, etc. All foreign residues shall be analyzed for material composition and conductivity.

6 **Other Abnormal or Unexpected Conditions:** Changes in appearance or smell. Indicators of poor manufacturing processes. Objectionable squeak and rattles, especially after vibration fatigue.

7 **The Formation of Whiskers When Tin, Zinc, or Silver is Used:** The Component Environmental Test Plan (CG3043) provided in this document will effectively precipitate the formation of whiskers. A close examination of the circuit boards with a magnifying device shall occur on all components, particularly on the components that experienced PTC. The appearance of whiskers during environmental testing will indicate the probability of similar whisker formations occurring in the field. The formation of whiskers poses a risk to close-pitched parts, and may result in a short-circuit situation of parts or components that are stored for service.

   If whiskers are present, they shall be measured for total axial whisker length and whisker density range, as defined in JEDEC JESD 22-A121A, Test Method for Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes.

8 **Electromigration and Dendritic Growth:** The circuit board and all parts must be free of signs of electromigration and dendritic growth.

9 **Viscous material runoff and leaks:** Grease runoff and grease footprint. Internal leaks of viscous materials (including liquids, coolants, grease, oils, etc.).

10 **Fretting Corrosion:** All internal unsoldered contacts/connections (e.g., fuse holders, press fit connections, PCB-to-PCB connections, ribbon cables, etc.) and external connections shall be microscopically inspected for evidence of fretting corrosion (i.e., presence of oxidized debris or evidence of heating).

11 **Sealant Integrity**: Prior to disassembly, visually inspect the seal for signs of degradation. During disassembly, focus on the manner of sealant separation and sealant residues on both sealing surfaces (e.g., cohesive or adhesive detachment).

12 **Specific Test Inspection Items:** Additionally, as described below in the Criteria section, test samples shall be inspected according to the specific tests that are listed.

Criteria: A summary of each component's condition shall be documented and reported to the GM ENV SME or CVE, as defined in GMW16044. The supplier may be required to perform further investigation (including cross-sectioning) to determine the degree or type of degradation. GM Engineering will decide as to the necessity of corrective action. The pre-test and post-test samples shall comply with the acceptance criteria according to the latest version of IPC-A-610, Acceptability of Electronic Assemblies. Class 3 shall be applied, unless the CTS states otherwise.

The total axial whisker length shall not exceed the acceptance criteria as stated in JEDEC JESD 201A, Environmental Acceptance Requirements for Tin Whisker Susceptibility of Tin and Tin Alloy Surface Finishes, for Class 2. The total whisker density range shall not exceed 45 whiskers per lead or termination at which it was measured.

Sealant Integrity: Seal separation can be either "cohesive" or "adhesive" by design.

Separation of components that are sealed using liquid or paste type sealant (e.g., RTV, wet-dispensed, etc.) must show 100 % "cohesive separation" of the sealant on all seal surfaces. Cohesive separation is characterized as a splitting of the sealant such that a film of sealant remains on both of the substrate surfaces. Lack of cohesive separation indicates an incompatibility between the sealant and substrate. In other words, when the component housing is pulled apart, the sealant shall be capable of a 100 % cohesive separation (i.e., sealant should be on both sides of the surface, for example 50 % on one side, 50 % on other side).

The other type of seal separation is "adhesive separation", which is typical of a gasket application. An adhesive sealant is characterized by a lack of residue on the contacting substrate surface. In other words, for adhesive separation, the seal shall remain entirely on one of the substrate surfaces that comprise the sealing interface.

Additionally, the following are procedure-specific inspection criteria as defined by each of the following specific tests:

Vibration With Thermal Cycling, Mechanical Shock – Pothole, Mechanical Shock – Collision, Mechanical Shock – Closure Slam:

There shall be no evidence of structural damage.

Connector Installation Abuse – Side Force, Connector Installation Abuse – Foot Load:

There shall be no damage to the connector(s), housing, and circuit board to which the connector is attached.

Crush for Housing – Elbow Load, Crush for Housing – Foot Load:

No contact between the case, PCB assembly, and other electrical parts shall be allowed. No damage to the housing, connector, PCB assembly, other electrical parts, and mechanical parts shall be allowed.

Open Circuit – Single Line Interruption, Open Circuit – Multiple Line Interruption, Intermittent Short Circuit to Battery and to Ground for Input/Output, Continuous Short Circuit to Battery and to Ground for Input/Output:

There shall be no evidence of overheating.

Over Load – All Circuits:

If an output is not over-current protected, then minor amounts of carbon are allowed near the open circuit; however, amounts beyond this on the circuit board are not permitted.

Over Load – Fuse Protected Circuits:

There shall be no evidence of discoloration from overheating.

Multiple Power and Multiple Ground Short Circuits Including Pass Through:

For the Low Resistive Short test, there shall be no evidence of overheating.

For the High Resistive Short test, minor amounts of carbon may appear near the open circuit; however, amounts beyond this on the circuit board are not permitted.

Frost, Humid Heat Cyclic (HHC), Humid Heat Constant (HHCO):

There shall be no evidence of electromigration or dendritic growth.

Thermal Shock/Water Splash:

Inspection shall be performed using a UV light.

There shall be no evidence of water ingress inside the component and the connector.

Water:

Inspection shall be performed using a UV light.

For non-sealed components, water shall never reach electric/electronic parts or connector terminals. There shall be no drops of water on the circuit board. Additionally, water shall not accumulate within the component housing and reach the electric/electronic parts or connector terminals.

For sealed components, no water shall pass any seal.

Salt Mist and Salt Spray:

There shall be no liquid ingress and/or internal dendrites. Also, based on the level of corrosion, GM Engineering will decide as to the necessity of corrective action.

Dust:

For dust rating of 6K, no dust ingress is allowed. For a dust rating of 5K, the quantity and location of dust shall be evaluated for potential risk.

Seal:

Inspection shall be performed using a UV light.

There shall be no evidence of water ingress inside the component and the connector.

6.6 Cross Section and Inspection.

Purpose: Cross sectioning shall inspect the quality of the solder joints and intermetallic bonds of the parts to the circuit board, and identifies solder joint concerns such as cracks and voids that may result in issues over a lifetime of component usage. Also, this will inspect for the quality of via and through-hole plating and drilling.

Applicability: All components that have PCB(s).

Operating Type: 1.1

Monitoring: N/A.

Procedure: The supplier shall perform this activity on one sample prior to testing, 2 samples from Thermal Fatigue, and 2 samples from Vibration with Thermal Cycling as shown in the Test Flow. All cross-sectional pictures shall be made available to GM.

The cross section points shall be identified in the GMW3172 Component Test Plan, as negotiated between the supplier and GM. Different items to be cross sectioned can be selected on each PCB. If possible try to plan section cuts to include as many feature of interested as possible, for example:

- A row of solder balls.
- A row of PTH (plated through hole) vias.
- A row of through-hole connector pins.

Solder joints to target shall be those of large mass parts, through-hole parts, Ball Grid Arrays (BGAs) parts, and surface mount device (SMD) parts having the largest relative footprints on the circuit board. Additionally, electrical vias and thermal vias shall be targeted.

Note: Perform cross sectioning on at least one of every type of solder joint, electrical connection, and via that exist on the PCB in both Leg 1 and Leg 2. This shall include a solder joint from each type of solder process that applies (i.e., reflow, wave, selective, and reworked, etc.). Solder joints most at risk include interfaces with large CTE differentials or corner pins of surface mounted parts with large diagonal lengths. Vias most at risk are those with the smallest diameter.

The Test Plan shall include a pictorial of the PCB board with the intended cross-sections identified, numbered, and described.

Applicable cross section standards are IPC-TM-650, IPC-6012, and IPC J-STD-001.

Sample selection shall be as follows:

- One sample that is not subjected to testing shall be cross-sectioned by the supplier. This shall occur as soon as possible after the DV/PV build in order to find production issues quickly and begin the resolution process as soon as possible. This will serve as an early indicator of production issues, as well as a control sample to judge degradation as compared to end-of-test samples.

Attention: GM review and approval of the report is required before Mechanical and Thermal Fatigue testing can begin.

- At the end of testing, at least four samples from the Test Flow shall be selected, two from Thermal Fatigue and two from Vibration with Thermal Cycling.
- If testing is done to ensure production line moves or updates, one control sample shall be taken from the existing production line and two samples shall be selected from the new production line. The samples from the new production line shall be taken from different production shifts and different days.

The following cross section procedure shall be used:

1 The component circuit board shall be removed from its housing. Potting material shall be removed if applicable.
2 Prior to cross sectioning, perform a surface examination according to IPC-TM-650, 2.1.5. Note any pinholes, scratches, wrinkles, inclusions, or other abnormalities, or pits and dents exceeding the point count. Provide pictures of the observations.
3 Perform cross sectioning of test samples according to IPC-TM-650, 2.1.1 and 2.1.1.2. Use IPC-TM-650, 2.1.1.1 for ceramic parts.
4 Evaluate the test section points as negotiated between GM and the supplier to provide detailed information as described below. Record minimum and average plating thicknesses, including pictures, as well as the quality of the plating, irregular plating, nodules, voids, and cracks. Measure the average thicknesses of the intermetallic bonds and provide detailed pictures of the intermetallic boundaries. Also record and include pictures of circuit board solder material fillets, hole fillings, etc.
5 A summary of each component's cross section results shall be documented and reported to GM.
6 The supplier may be required to perform further investigation to determine the degree or type of degradation.
7 If required, perform measurements of suspect areas according to IPC-TM-650, 2.2.2 and/or 2.2.5.

Criteria: A summary of each component's condition shall be documented and reported to the GM ENV SME or CVE. GM Engineering will evaluate the reports and decide as to the necessity of corrective action.

All samples shall comply with the acceptance criteria according to the latest versions of IPC-A-610, IPC-6012, and IPC J-STD-001, for Class 3, unless the CTS states otherwise.

Before test, no solder cracks are allowed.

After test, no solder cracks measuring greater than 25 % of the cross-sectional length across an area are allowed.

Solder voids shall not exceed 25 % by volume in the solder joint.

The intermetallic boundary shall be acceptable in terms of grain structure growth, thickness, regularity, and uniformity of the intermetallic layer.

Acceptability of the solder bonding strength shall be based on an average combined thickness of Copper-Tin intermetallic bonds of Cu3Sn and Cu6Sn5 that shall be ≥ 1 µm and not greater than 6 µm maximum (5 µm preferred) after all soldering procedures are completed. When Nickel-Tin systems are used, the Ni3Sn4 intermetallic thickness after all soldering processes are completed shall be (0.25 to 0.75) µm.

6.7 Dimensional Check.

Purpose: This check shall verify that the component's external dimensions, that are critical to the vehicle interface, meet the requirements as defined in the drawing or CTS after exposure to temperature and humidity conditions.

Applicability: All components.

Operating Type: 1.1

Monitoring: N/A

Procedure: This procedure shall be performed on the following samples as a baseline during the Initial 5-Point Functional/Parametric Check, at T_{room} only: 2 samples from High Temperature Degradation, 2 from HHCO, 2 from HHC, 2 from Seal, and 2 from Thermal Shock/Water Splash.

This procedure shall be performed again on the same samples during the Final 5-Point Functional/Parametric Check, at T_{room} only.

If this is performed as a stand-alone activity only, then the Dimensional Stability tests as defined in the applicable following GM standards from the Material Engineering group shall be used: GMW14444 for interior components, GMW14650 for exterior components, or GMW15725 for underhood components. Three samples shall be tested.

All dimensions affecting the vehicle interface shall be included, e.g., mounting points, header connectors, external dimensions, etc.

Criteria: Functional Status Classification is not applicable to this check. Any Dimensional measurements that do not meet the part drawing requirements shall be considered a nonconformance.

6.8 Vibration Transmissibility Demonstration.

Purpose: This method shall verify the component mounting details of the component to the test fixture and the vibration input profile to the test samples prior to executing the Highly Accelerated Life Test, the Vibration with Thermal Cycling, and the Mechanical Shock tests.

Applicability: All Components.

Operating Type: 1.2

Monitoring: Accelerometer-based monitoring as described in the procedure below.

Procedure:

Component Mounting Considerations: Components under test shall be mechanically connected to the mounting surface of the test fixture to represent vehicle mounting orientation and attachment methods. The component's actual integral mounting provisions (e.g., mounting tabs, snap fits, clips, etc.) that interface to the vehicle structure (e.g., vehicle frame, bracket, etc.) shall be utilized in the test mounting. The proper size, type of mounting devices, attachment interfaces, mounting torque, and associated tolerance of fixing bolts or other attachment devices shall be used.

Harness connection fixture points shall be representative of the production-intent vehicle harness routing from the component connector up to the location of the first design-representative tie down point. As a default, the first tie down point on the harness shall be 100 mm away from the component connector. After that point, the harnesses shall be tied down securely so that they do not influence the vibration input to the test samples.

Any interfacing connections to the component other than harnesses shall be in a vehicle-representative orientation. Examples are coolant hoses, linkage cables, etc.

The component mounting orientation, the fixing points, and the attachment methods of the component and other mechanical interfaces shall be reviewed and approved by the GMW3172 ENV SME prior to starting the test. This information shall be included in the GMW3172 Component Environmental Test Plan (CG3043).

Test Fixture Analysis: If requested by the GMW3172 ENV SME, the supplier shall provide the math-model data, FEA analysis results, and engineering drawing of the test fixture to GM in order to **review and approve** prior to the building of the test fixture.

Test Fixture Transmissibility: The test fixture, when loaded with the test samples, shall be shown to provide a vibration level that is representative of the test input at the mounting locations as measured on the test fixture. The integrity of the mechanical stress energy level shall be verified through a mechanical stress transmissibility demonstration. Also, the natural resonant frequency of the loaded fixture shall be measured and shall not fall within the frequency range of the test profile. This information shall be documented in the test report.

A mechanical stress transmissibility demonstration shall be performed to assure that the true value of the vibration, as measured in each intended axis at the checkpoint for **each** sample, is within the tolerance required for the test. The following test parameters shall be chosen to achieve this goal: control method, location of the checkpoint(s), and location of the reference point.

A single checkpoint (i.e., which is called the "reference point") (as defined in IEC 60068-2-64) shall be selected for the derivation of the control signal (as defined in IEC 60068-2-64). The checkpoint shall be located on the test fixture as close as possible to one of the fixing points of one of the specimens.

Cross-axis acceleration shall be measured at the checkpoint for **each** sample, close to the fixing points, to ensure that the cross-axis acceleration does not contain high, narrow peaks that are beyond tolerance levels. The cross-axis motion is specified as the motion of the two axes that are orthogonal to the direction of the drive axis.

The test parameters listed above (i.e., chosen control method, location of the checkpoint(s), and the location of the reference point) and the data collected from the vibration transmissibility demonstration shall be **reviewed and approved** by the GMW3172 ENV SME prior to starting the test. This information shall be documented in the test report.

A picture of the loaded test fixture shall be included in the GMW3172 Component Environmental Test Plan (CG3043).

Criteria:

1 The natural resonance frequency of the loaded test fixture shall be above the upper frequency of the test profile.

2 The true value of the Mechanical Shock input as measured at the checkpoint for each sample, shall be within 10 % of the intended value in the drive axis.

3 The true value of the Vibration, as measured in each intended axis at the checkpoint for each sample, shall be within 20 % of the random vibration requirement (effective acceleration) in GMW3172 as represented by the tolerance bands. The tolerance bands are calculated by adjusting the PSD breakpoints by 64 % (0.64 x breakpoint) for lower tolerance and 144 % (1.44 x breakpoint) for the upper tolerance. An example of how this applies to the Random Vibration for Sprung Masses is shown below in Figure 11 and Tables 15 thru 17.

Figure 11: Example for Acceleration Tolerance Bands for Random Vibration - Sprung Mass Profile

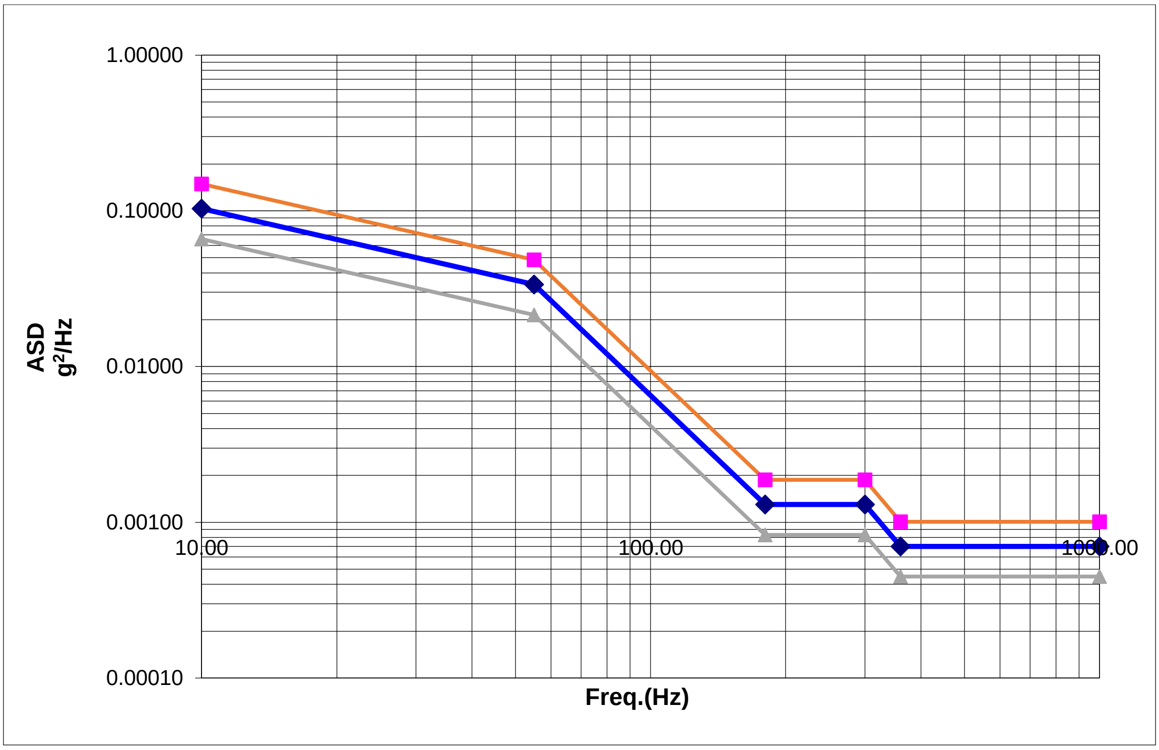


Table 15: Random Vibration Profile Lower Tolerance Band for Sprung Mass Profile

FREQ in Hz	PSD in $(m/s^2)^2/Hz$	PSD in g^2/Hz
10	6.3519	0.0660
55	2.0680	0.0215
180	0.0800	0.0008
300	0.0800	0.0008
360	0.0431	0.0004
1000	0.0431	0.0004

Effective Acceleration = 15.7 m/s^2 = 1.6 G_{RMS}

Note: Each break point is 64 % of the original.

Table 16: Random Vibration Profile Upper Tolerance Band for Sprung Mass Profile

FREQ in Hz	PSD in $(m/s^2)^2/Hz$	PSD in g^2/Hz
10	14.2917	0.1486
55	4.6531	0.0484
180	0.1800	0.0019
300	0.1800	0.0019
360	0.0969	0.0010
1000	0.0969	0.0010

Effective Acceleration = 23.5 m/s^2 = 2.4 G_{RMS}

Note: Each break point is 144% of the original.

Table 17: GMW3172 Requirement for Random Vibration Profile for Sprung Mass Profile

FREQ in Hz	PSD in $(m/s^2)^2/Hz$	PSD in g^2/Hz
10	9.9248	0.1032
55	3.2313	0.0336
180	0.1250	0.0013
300	0.1250	0.0013
360	0.0673	0.0007
1000	0.0673	0.0007

Effective Acceleration = 19.6 m/s^2 = 2.0 G_{RMS}

4 For Vibration, the cross-axis acceleration for each sample in the two axes that are orthogonal to the direction of the drive axis shall be less than or equal to 0.45 times the acceleration G_{RMS} of the drive axis at any frequency. The cross-axis acceleration upper limit is calculated by adjusting the PSD breakpoints by 20.25 % (0.2025 x breakpoint). An example of how this applies to the Random Vibration for Sprung Masses is shown below in Figure 12 and Table 18.

Figure 12: Example for Cross-Axis Acceleration Upper Limit for Random Vibration - Sprung Mass

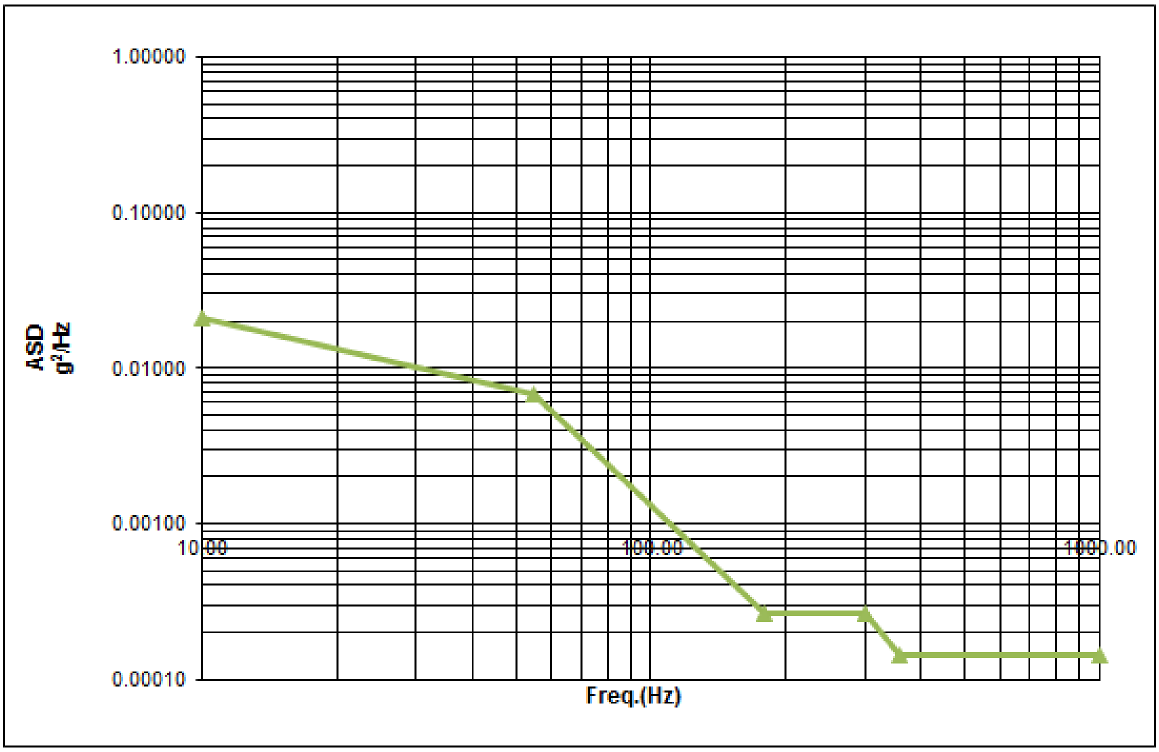


Table 18: Random Vibration Cross-Axis Acceleration Upper Limit for Sprung Mass

FREQ in Hz	PSD in $(m/s^2)^2/Hz$	PSD in g^2/Hz
10	2.0098	0.0209
55	0.6543	0.0068
180	0.0253	0.0003
300	0.0253	0.0003
360	0.0136	0.0001
1000	0.0136	0.0001

Effective Acceleration = 8.8 m/s^2 = 0.9 G_{RMS}

Note: Each break point is 20.25 % of the original.

5 For Mechanical Shock, the positive or negative peak acceleration for each sample, perpendicular to the intended shock direction, shall not exceed 30 % of the value of the peak acceleration of the nominal pulse in the intended direction.

6.9 Thermal Cycle Profile Development.

Purpose: This activity shall establish the thermal cycle profiles to be used in Thermal Shock Air-To-Air (TS) and Power Temperature Cycle (PTC) testing.

Applicability: All components.

Operating Type: 1.1 (TS), 1.2/3.1/3.2 (PTC)

Monitoring: Temperature logging.

Procedure:

1 Attach an internal thermocouple to a sample and position it in the center of the TS / PTC chamber. As a default, locate the thermocouple on the PCB.

2 Program the PTC chamber to cycle between T_{min} and T_{max} at the ramp rate that will be used during the PTC test. The agreed upon functional cycling and Operating Types in the PTC test shall be used.

Once the component temperature reaches T_{min} +3 °C / T_{max} -3 °C, dwell for 15 minutes.

Document the PCB temperature at the end of the 15 minutes. This is the temperature to be used as the T_{max} in the TS test and shall be referred to as $T_{max\ TS}$. (Example: If a component shall be tested from (-40 to +85) °C, and generates an additional self-heating of 10 °C, then the TS test shall be performed from (-40 to +95) °C.).

3 Program the TS chamber to cycle between T_{min} and $T_{max\ TS}$. The transfer time shall be ≤ 30 s, according to ISO 16750-4.

Once the component temperature reaches T_{min} +3 °C / $T_{max\ TS}$ -3 °C, dwell for 15 minutes.

4 The following information shall be provided separately for TS and PTC, with items a and b on the same graph:
- **a** Chamber temperature profile,
- **b** Component internal thermocouple (PCB temperature) profile,
- **c** Component location in chamber,
- **d** Component internal thermocouple location.

Criteria: The provided thermocouple data shall demonstrate that the component dwells for 15 minutes once it reaches T_{min} +3 °C and T_{max} -3 °C, for at least 2 cycles of PTC, and dwells for 15 minutes once it reaches T_{min} +3 °C and $T_{max\ TS}$ -3 °C, for at least 2 cycles of TS.

7 Analysis

7.1 Analysis Mission. The Analysis shall be used to aid in designing reliability and robustness into the component during the time when physical components are not yet available. Analysis should be the earliest activity in the A/D/V process and provides the earliest component design learning and improvement opportunity. All Analytical activities shall be documented in the Component Environmental Test Plan (CG3043).

Analytical activities shall be completed prior to the design freeze for building development level hardware.

7.2 Electrical.

7.2.1 Nominal and Worst Case Performance Analysis.

Purpose: This analysis shall identify that the design of the circuit is capable of producing the required functions.

Applicability: All components.

Operating Type: Not applicable

Monitoring: Not applicable

Procedure: Use a circuit analysis program to determine voltage, current, and power dissipation for each part across the ranges of operation temperature, voltage supply, and I/O voltage/current. The circuit analysis shall be modeled taking into account the worst-case tolerance combinations of the parts.

Criteria: Verify that the design of the circuit is capable of producing the required functions under all conditions. The component shall meet the requirements according to CTS/SSTS and GMW14082.

7.2.2 Short/Open Circuit Analysis.

Purpose: This analysis shall identify that the component withstands intermittent and continuous shorts to battery/supply voltages and to ground, as well as open circuit conditions. Additionally, this analysis can be used to verify the ability of the hardware to support setting and resetting of Diagnostic Trouble Code (DTC).

Applicability: All components.

Operating Type: Not applicable

Monitoring: Not applicable

Procedure: Use a circuit analysis program to perform intermittent (default: (1 to 100) Hz square wave) and continuous conditions for short and open circuits to determine voltage, current, and power dissipation for each part across the ranges of operation temperature, supply voltage, and I/O voltage/current. The circuit analysis shall be modeled taking into account the worst-case tolerance combinations of the parts.

Criteria: Verify ability of parts to withstand intermittent and continuous short/open circuit conditions. The analysis shall verify that the part's operating parameters as defined by the part's data sheet (e.g., temperature, voltage, current, power dissipation, etc.) shall not be exceeded. Additionally, verify that the voltage and current levels allow setting and resetting of DTC.

7.3 Mechanical.

7.3.1 Resonant Frequency Analysis.

Purpose: This analysis shall identify the resonant frequency of the circuit board to detect structural weaknesses that may lead to mechanical fatigue.

Applicability: All components with a circuit board.

Operating Type: Not applicable

Monitoring: Not applicable

Procedure: Considering the circuit board mounting configuration, calculate the resonant frequency of the circuit board by using appropriate software such as Finite Element Analysis. Alternatively, if a physical sample is available prior to DV, and the proper mounting configuration is assured, then a physical test can be used to determine the resonant frequency (e.g., impulse hammer or sine sweep evaluation).

Criteria: The resonant frequency of the circuit board shall be > 150 Hz. The supplier must provide evidence of appropriate corrective action when the resonant frequency is < 150 Hz. The corrective action shall be reviewed with the GM Component Validation Engineer.

7.3.2 High Altitude Shipping Pressure Effect Analysis.

Purpose: This analysis shall identify mechanical destruction that may occur during shipping in an un-pressurized aircraft up to an altitude of 15 240 m above sea level.

Applicability: All sealed components or components containing parts that are sealed.

Operating Type: Not applicable

Monitoring: Not applicable

Procedure: The following series of steps shall be taken to ensure adequate robustness of the structure under pressure to the effects of the low pressure stress resulting from air shipment.

1 Quantify the burst pressure (P_{burst}) of the component (or part) under internal pressure using finite element analysis or a comparable method. Use a worst case analysis process considering the variation of material parameters (such as the minimum wall thickness) and the effects of material weakening relative to temperature effects (glass transition temperatures). The glass transition temperature (T_g) is the temperature whereupon the material properties, such as stiffness, changes its characteristics.

2 Use the following equation for the analysis:

$P_{burst} \geq (P_{assembly} - P_{altitude}) \times DM$

where:

- P_{burst}: Component (or part) burst pressure
- $P_{assembly}$: Internal pressure of component (or part) during assembly (this should be either the ambient air pressure at the assembly location, or it may be a different pressure if modified by the manufacturing process)
- $P_{altitude}$: Pressure in the freight section of the airplane at 15 240 m, use 11 kPa.
- Design Margin (DM): 4

Criteria: The component (or part) burst pressure must exceed the resulting internal pressure during air shipment by a factor of 4.

7.3.3 Plastic Snap Fit Fastener Analysis.

Purpose: This analysis shall ensure that the plastic snap fit of the component is adequately designed. This analysis shall also identify structural robustness of plastic snap fit fastener design fundaments, including:

- Adequate retention force during complete vehicle life.
- Acceptable ergonomic forces during vehicle assembly and disassembly for serviceability.
- Presence of compliance mechanisms to prevent rattles.
- Adequate design margin to ensure that flexing during vehicle installation does not exceed the elastic limit of the plastic.

Applicability: All components that incorporate plastic snap fits.

Operating Type: Not applicable

Monitoring: Not applicable

Procedure: Perform a Finite Element Analysis, or equivalent, of the plastic snap fit to prove the capability of the design elements including:

1 Adequate retention force during complete vehicle life.

2 Acceptable ergonomic forces during vehicle assembly and disassembly for serviceability.

3 Presence of compliance mechanisms to prevent rattles.

4 Adequate design margin to ensure that flexing during vehicle installation does not exceed the elastic limit of the plastic.

Criteria: Evidence that the design meets the four design elements stated in the procedure.

7.3.4 Crush Analysis.

Purpose: This analysis shall identify structural weaknesses of the housing that could either lead to excessive stress to parts inside the component or to the housing itself.

Applicability: All components where forces from elbow or foot loads from assembly or servicing are possible. This may include use as a supporting surface for other assembly operations.

Operating Type: Not applicable

Monitoring: Not applicable

Procedure: Perform a Finite Element Analysis, or equivalent, to insure that the requirements for the Crush For Housing test(s) are met. The intended load must be identified as being produced by a person's elbow or foot as described in the Crush For Housing – Elbow Load or Crush For Housing – Food Load, as applicable for the component.

Criteria: Sufficient clearance between parts of the component and housing shall be demonstrated when the necessary forces are applied. The deflection of the component cover must not generate forces on parts within the component or on the circuit board.

7.4 Climatic.

7.4.1 High Altitude Operation Overheating Analysis.

Purpose: This analysis shall identify cooling weaknesses that may lead to overheating on parts as a result of low air density at high altitude.

The reduced air density at high altitude will reduce convective heat transfer and may cause marginal designs to overheat while operating within the vehicle.

Applicability: All components where heat dissipation may be reduced due to low air density caused by high altitudes.

High altitude analysis shall be performed on all components that contain significant heat generating elements on their circuit board and are cooled by air flow (i.e., convection).

Operating Type: Not applicable

Monitoring: Not applicable

Procedure: Use the following equation to determine the maximum component operating temperature at high altitude:

$T_{max\_part} \geq T_{altitude} = \Delta T_{part\_oper} \times Multiplier_{altitude} + T_{ambient} + 10\ °C$

where:

- T_{max_part}: Maximum allowable temperature from part data sheet.
- $T_{altitude}$: Calculated operating temperature of part at altitude.
- $T_{ambient}$: Ambient temperature at altitude (4572 m). Use +35 °C as the default value.
- ΔT_{part_oper}: Temperature increase of part due to operation (this is the temperature difference of the component when the part is at sea level). This can be obtained either by Thermal Analysis of the part or by a physical measurement of the part in the component.
- $Multiplier_{altitude}$: The Multiplier value is based on altitude and air flow. The multipliers as noted in Table 18 are used to adjust the temperature rise for high altitude effects in the equation.
- +10 °C: This is the safety margin.

Table 18: Parameters for Overheating Analysis

Altitude	Multiplier		
	Fan Cooled (Low Power Fan)	**Fan Cooled (High Power Fan)**	**Naturally Cooled Convection (No Fan)**
0 m	1	1	1
4572 m	1.77	1.58	1.33

Note: The bolded value of (1.33) will be the most frequently used value in GM calculations.

Criteria: $T_{max\_part} \geq T_{altitude}$. T_{max_part} is based on the operating specifications for the part generating heat and other affected parts nearby.

7.4.2 Thermal Fatigue Analysis.

Purpose: This analysis shall identify thermal fatigue weaknesses caused by cyclic temperature change when materials with different Coefficients of Thermal Expansion (CTE) are attached to each other. For example, the different CTEs of circuit board parts result in fatigue stress to the junctions used to attach those parts to the circuit board (e.g., solder and lead wires). The expansion rates of different materials added to a circuit board assembly (e.g., potting materials) may also result in the unacceptable deformation of the junctions and/or the structure of the component resulting in electrical or mechanical problems.

Applicability: All components.

Operating Type: Not applicable

Monitoring: Not applicable

Procedure:

1 Identify the package types of all the parts of the component.

2 Identify the CTE of each package type, and all variants within the package type, of the parts of the component.

3 Identify the differences of the CTEs for each package type of the parts and for the part to which they are attached.

4 Perform the analysis to quantify fatigue life of the part junctions from the expansion and contraction during temperature cycling of the component by using an appropriate method such as Finite Element Analysis.

Criteria: The calculated fatigue life shall be three times greater than the required life of the component.

7.5 Enclosure. None.

7.6 Material.

7.6.1 Lead-Free Solder Analysis.

Purpose: This analysis shall identify solder joint weaknesses, part/material degradation, or contamination that may occur due to the use of lead-free solder. This analysis supports the Environmental Hardware Design Review to evaluate the soldering process.

Applicability: All components manufactured with lead-free solder.

Operating Type: Not applicable

Monitoring: Not applicable

Procedure: Use the Appendix A (Lead-Free Solder Considerations) as a reference to discuss potential impacts to the product design and manufacturing process.

Provide full disclosure throughout the supply chain regarding risks when lead-free solder is used. All risks are to be addressed and mitigated through the Environmental Hardware Design Review.

Criteria: The analysis shall show evidence that the lead-free solder effects are reviewed and adjustments made to the test plans, design, and process. The part's data sheets shall support all lead-free solder processes.

8 Development

8.1 Development Mission. Development activities are designed to detect weaknesses or design oversights that were not comprehended, or could not be evaluated, during Analysis activities. The Development activities shall be performed on first samples to provide the earliest opportunity to qualitatively evaluate and improve physical components. HALT is a typical example of this type of activity.

Weaknesses detected during Development activities shall be corrected prior to validation. All Development activities shall be documented in the Component Environmental Test Plan (CG3043).

8.2 Electrical.

8.2.1 Jump Start.

Purpose: This test shall verify the component's immunity to positive over-voltage. This condition can be caused by a double-battery start assist.

Applicability: All components that have power supplied by the vehicle battery 12 V wiring system, either directly or through an external component.

Operating Type: 3.1/3.2 (with voltage as defined in procedure).

Monitoring: Continuous Monitoring.

Procedure:

1 Soak the component un-powered until its temperature has stabilized to T_{room}.
2 Apply 26.0 V (unless otherwise stated, e.g., PPEI requires 26.5 V) for 1 minute to all I/O connected to vehicle battery voltage, either directly or through an external component, while in Operating Type 3.1.
3 With the voltage level unchanged, transition to Operating Type 3.2.
4 Remain in Operating Type 3.2 for 1 minute.
5 Remain in Operating Type 3.2 and transition voltage from 26.0 V to U_A.

Criteria: Functional Status Classification shall be C. All functions needed to start the engine must meet Class A during the test, if not stated differently in the CTS.

8.2.2 Reverse Polarity.

Purpose: This test shall verify the component's immunity to reverse polarity voltage on the power inputs. This condition can be caused by an accidental reversal of the charging device.

Applicability: All components that have power supplied by the vehicle battery 12 V wiring system. This test is not applicable to generators, inductive loads with clamping diodes but without reverse polarity protection, or components that have an exemption stated in the CTS.

Operating Type: 3.1/3.2 (with voltage as defined in procedure).

Monitoring: Continuous Monitoring.

Procedure:

1 Connect the component to a power supply.

2 Apply -13.5 V for 2 minutes to all I/O connected to vehicle battery voltage, either directly or through an external component, while in Operating Type 3.1.

3 With the voltage level unchanged, transition to Operating Type 3.2.

4 Remain in Operating Type 3.2 for 2 minutes.

5 Remain in Operating Type 3.2 and transition voltage from -13.5 V to U_A.

Note: This test shall be performed with all of the battery voltage supplied loads.

Criteria: Functional Status Classification shall be C.

8.2.3 Over Voltage.

Purpose: This test shall verify the component's immunity to over voltage conditions. These conditions can be caused by generator regulator failures or battery charging events.

A battery charging event can be for example a connection to a "quick charge battery charger" where the voltage exceeds +16 V.

Special focus of this test is on the correct functioning of the over voltage protection circuit.

Applicability: All components in the vehicle that have power supplied by the vehicle battery 12 V wiring system.

Operating Type: 3.1/3.2 (with voltage as defined in Table 19).

Monitoring: Continuous Monitoring.

Procedure:

1 Connect the power supply to the battery inputs of the component and to all loads that have battery inputs.

2 Raise ambient temperature to T_{max} – 20 °C and stabilize the component at this temperature.

3 Turn on the power supply and subject the component to the required test voltage for the required test time as noted in Table 16 with Operating Type 3.1.

4 Repeat steps (2) and (3) with Operating Type 3.2.

Table 19: Over Voltage Requirements

Component Type	Test Voltage	Test Time
Components which contain over voltage protection circuits that switch off power consumption in the range of (+16 to +18) V.	Continuously sweep between +16 V and +18 V at 1 V/minute [Note 1].	60 minutes
Components which do not contain over voltage protection circuits that switch off power consumption.	Provide a constant +18 V.	60 minutes

Note 1: Over voltage protected components will experience worst case power consumption during sweeping the supply voltage. This simulates voltage variation caused by the generator (due to changes of engine speed) or caused by the battery charging device (especially with high current pulses).

Criteria: Functional Status Classification shall be C.

8.2.4 State Change Waveform Characterization.

Purpose: This test shall verify that the component behaves adequately during state changes (e.g., component initialization, shutdown, etc.).

Applicability: All components.

Operating Type: All transitions between possible operating types (e.g., 1.2 to 3.2 and 3.2 to 1.2), including internal state changes (e.g., shutdown phase, wakeup phase).

Monitoring: Continuous Monitoring. Especially, the voltage and current levels of signal lines are reviewed in graphical form with an oscilloscope or other equivalent measurement tool.

Procedure:

1 Change operation state.

2 Record all waveforms of signal lines during the entire transition phase (before, during, and after state changes). Evaluate integrity of monitored signal lines for proper performance.

3 Repeat steps (1) and (2) for all other possible state changes.

Criteria: Functional Status Classification shall be A. Transients that occur as a result of state change transitions shall not produce disruptive levels of disturbance to downstream components. One consideration in analyzing the waveform is to detect inadvertent actuation of outputs and floating inputs.

8.2.5 Ground Path Inductance Sensitivity.

Purpose: This test shall verify that the component is immune to ground path inductance that may interfere with fast signal changes.

Applicability: All components with fast signal changes or rapid current changes (e.g., PWM, single line serial data communication, switching loads, etc.).

Operating Type: 3.2

Monitoring: Continuous Monitoring. Additionally, recording of ground path and input/output signals with an oscilloscope or other equivalent measurement tool.

Procedure:

1 Place a 5 µH inductor in the ground path of a bench test setup.

2 Operate the component to create the maximum current change rate at the highest frequency possible in the ground path. This may be achieved by simultaneously activating all inputs to the component that will generate switching events at the maximum rate of change. PWM duty cycle shall be chosen worst case to produce maximum current change rate.

Criteria: Functional Status Classification shall be A. Additionally, evaluate input/output signals and ground path integrity for proper performance.

8.3 Mechanical.

8.3.1 Highly Accelerated Life Test (HALT).

Purpose: HALT shall identify structural and functional weaknesses due to vibration and temperature effects by increasing stresses to the component beyond the required test limits until it fails.

HALT is a test procedure to identify possible component robustness issues early and quickly during development in order to address solutions prior to Design Validation testing. HALT cannot be a substitute for validation testing because HALT cannot demonstrate reliability.

Applicability: This test applies to new technology, lack of experience with this technology, lack of experience with the supplier, new manufacturing processes, or based on other lessons learned from previous history. This test can also be used to evaluate product improvements.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to GMW8287.

HALT is a form of Stepped Stress testing consisting of the following tests:

1 Cold Step

2 Hot Step

3 Rapid Thermal Transitions

4 Vibration Step

5 Combined Rapid Thermal Transitions with Vibration Step

Note: Refer to Section 6.8 Vibration Transmissibility Demonstration for component mounting instructions.

After weaknesses are identified during HALT, root-cause analysis is then performed to establish the failure mechanism and understand the physics of the failure. Based on this knowledge, a design change can be made to remove the failure mechanism. A subsequent HALT test should be performed to verify that the design change removed the failure mechanism and that no new failure modes were injected.

Criteria: Test anomalies and failure analysis shall be reviewed by GM Engineering and the supplier to determine if corrective actions are required.

Note: Stress temperatures used in this test may be above the effective glass transition temperature of certain plastic materials and may lead to unrealistic failure mechanisms, which may not be relevant to the application of the component.

8.4 Climatic.

8.4.1 Temperature Measurement.

Purpose: This method shall identify overheat areas in the component that may lead to part degradation.

Note: If this activity was not performed in the Development phase or if a design change from Development to DV could affect the temperature measurement, then this shall be performed in DV. Furthermore, if the component will be damaged due to the setup for this test because of thermocouple placement, then this activity shall be performed on a dedicated component.

Applicability: All components where heat may be produced.

Operating Type: 3.2

Monitoring: The operating stabilization temperatures are to be monitored during the measurement.

Procedure: Perform the measurement in the highest power consumption scenario possible. This shall be done using infrared imaging or thermocouple measurements according to the procedure in GMW8288.

Quantify temperatures and evaluate design margin using the following equation:

$$T_{part\_max\_spec} \geq T_{part} + (T_{max} - T_{air\_ambient}) + DM$$

where:

- $T_{part\_max\_spec}$: Maximum allowable temperature from part/material data sheet.
- T_{part}: Temperature of part measured at maximum load.
- T_{max}: Maximum temperature from Temperature Code rating in this document.
- $T_{air\_ambient}$: Temperature of ambient air in test chamber according to GMW8288.
- DM: Design Margin, +10 °C minimum (or as agreed upon by GM and supplier).

Criteria: Functional Status Classification is not applicable to this test. The part shall meet the maximum allowable temperature with the Design Margin.

8.4.2 Low Temperature Wakeup.

Purpose: This test shall verify the component's ability to function after prolonged exposure to low temperature extremes.

Applicability: All components equipped with electronics that contain internal or external communication (e.g., microprocessors, transceivers, RAM, displays, etc.) or that provide repetitive electronic signals (e.g., clocks, oscillators, inverters, etc.).

Operating Type: 1.2/3.2 as shown in Figure 13.

Monitoring: Continuous Monitoring during Operating Type 3.2 phases.

Procedure: Use the test methods according to IEC 60068-2-1, Test Ab, Cold. T_{min} of the operating temperature range is the low temperature that shall be used.

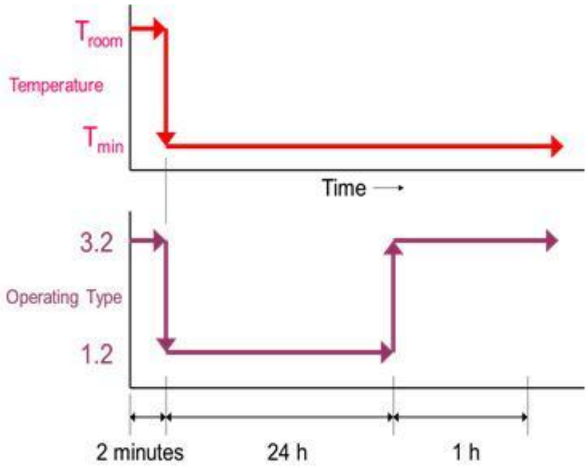
1 Prior to the start of a 24 h cycle, the component shall be energized at T_{room} for 2 minutes and evaluated for proper function at U_{nom}.

2 The component shall then be soaked at T_{min} for 24 h at Operating Type 1.2.

Note: The time at T_{min} may be reduced, per the GM ENV SME, for components with low thermal mass. The component shall be stabilized at T_{min} for 1 h minimum.

3 At the end of the cold soak, and while still at T_{min}, the component shall be turned ON and evaluated for proper function for 1 h at Operating Type 3.2.

Figure 13: Low Temperature Wakeup Profile



Criteria: Functional Status Classification shall be A.

8.4.3 Frost.

Purpose: This test shall evaluate that the component is robust against moisture formation caused by rapid temperature change in a high humidity environment.

Applicability: All sealed or non-vented (i.e., closed) components.

Operating Type: 1.2 during cold phase; 3.2 during exposure to high humidity.

Monitoring: Continuous Monitoring during the time the component is energized.

Procedure: Use the test methods according to IEC 60068-2-30, Test Db, Damp heat, cyclic, with the temperature and humidity profile defined in Figure 14.

1. Soak the component in a cold chamber (-20 °C) for a 2 h minimum, while in Operating Type 1.2.
2. Transfer the component to a hot chamber maintained at +45 °C and 95 % relative humidity within 3 minutes. Configure for Operating Type 3.2.
3. Perform Continuous Monitoring while the component is in the hot chamber for 4 h. Steps 1 through 3 constitutes one cycle.
4. Repeat steps 1 through 3 for the remaining cycles as required by Table 20.

Figure 14: Frost Profile

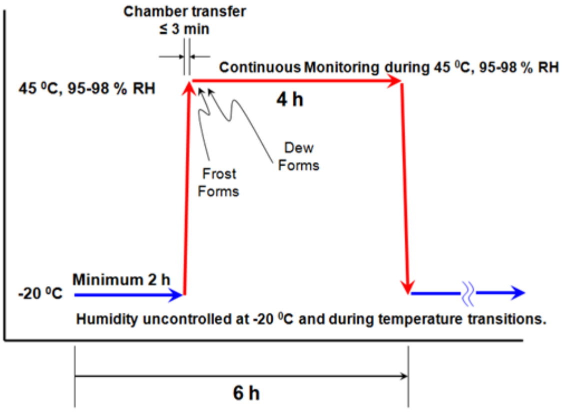


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Table 20: Frost Test Requirements

Component Type	Number of cycles performed
Sealed components with or without a pressure exchange membrane	10
Non-Sealed components without vent openings	1
Non-Sealed components with vent openings	0

Criteria: Functional Status Classification shall be A. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of electromigration or dendritic growth.

8.4.4 Highly Accelerated Stress Test (HAST).

Purpose: The HAST test shall identify structural and functional weaknesses due to the effects of high levels of humidity and temperature.

Applicability: This test is applicable to non-hermetically sealed components capable of withstanding temperatures of at ≥ +110 °C. This test applies to new technology, lack of experience with this technology, lack of experience with the supplier, new manufacturing processes, or based on other lessons learned from previous history. This test can also be used to evaluate product improvements.

Operating Type: 3.2, with the component at U_{max}, operated in such a manner to minimize power dissipation.

Monitoring: Continuous Monitoring during intermediate and final 1-Point Functional/Parametric Checks at T_{room}/U_{max} (i.e., readouts, per JEDEC JESD22-A110D). Intermediate readouts shall be performed at 50 % and 75 % of test duration.

Procedure: Use the test methods according to JEDEC JESD 22-A110D, Highly-Accelerated Temperature and Humidity Stress Test (HAST).

Criteria: Functional Status Classification shall be A. Test anomalies and failure analysis shall be reviewed by GM Engineering and the supplier to determine if corrective actions are required.

Note: Stress temperatures used in this test may be above the effective glass transition temperature of certain plastic materials and may lead to unrealistic failure mechanisms, which may not be relevant to the application of the component.

8.5 Enclosure. Not applicable.

8.6 Material. Not applicable.

9 Design Validation (DV)

9.1 DV Mission. The Design Validation (DV) shall be a quantitative and qualitative verification that the component design meets the requirements for Environmental, Durability, and Reliability. The DV activities shall be executed on production design-intent components with production-intent parts, materials, and processes (including solder and fluxes). All DV activities shall be documented in the Component Environmental Test Plan (CG3043).

9.2 Electrical. This section defines additional Electrical procedures for DV. See Table 5 Summary of A/D/V Activities for applicable procedures for DV.

9.2.1 Parasitic Current.

Purpose: This test shall verify that the component's power consumption complies with the specification for Ignition OFF state. This is to support power management and engine start ability following long term storage/parking conditions.

Applicability: All components directly connected to the vehicle battery.

Operating Type: 2.1/2.2

Monitoring: The current is measured in the various states of OFF Asleep (Operating Type 2.1) and OFF Awake (Operating Type 2.2). The current value shall be stored graphically.

Procedure: Measure the current in all of the component supply lines. The current measuring device must have a sampling rate that is ten times higher than the shortest current peak duration that the component creates. All inputs and outputs shall be electrically connected to their original load (or equivalent).

1 Connect the component to a variable power supply and adjust the input voltage to U_B. The component shall be at T_{room}.

2 Place the component into OFF Asleep mode.

3 Use a measurement device that is capable of integrating measured current over time. Measure a minimum of five internal wakeup events for components that wake up (i.e., transition from OFF Asleep to OFF Awake, without external triggers). For components that do not wake up, wait in OFF Asleep mode for 10 minutes. While waiting, watch the current value for random fluctuations, then if stable, measure current for 10 s. Calculate the average current over the measured period. In case of random current fluctuations this behavior shall be documented.

4 Decrease the supply voltage at a linear slope until 11.5 V. Measure the current according to step (3).

5 Decrease the supply voltage at a linear slope until 11.0 V. Measure the current according to step (3).

6 Decrease the supply voltage at a linear slope until 10.5 V. Measure the current according to step (3).

7 Decrease the supply voltage at a linear slope until 10.0 V. Measure the current according to step (3).

This ramp down shall include at least 2 internal wakeup events, with a maximum slope of 0.5 V/minute.

Criteria: Functional Status Classification is not applicable to this test. The maximum allowable average parasitic current shall be 0.125 mA if not provided in the CTS. Analyze the stored current waveforms for any random fluctuations. Unintentional wakeups are not allowed.

9.2.2 Power Supply Interruptions.

Purpose: This test shall verify the proper reset behavior of the component. It is intended primarily for components with a regulated power supply or a voltage regulator. This test shall also be used for microprocessor-based components to quantify the robustness of the design to sustain short duration low voltage dwells.

Applicability: All components that may be affected by a momentary drop in voltage. This includes components supplied by regulated voltage provided by other components. This test is particularly important for components that have microprocessors, clocks, or ASICs.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to ISO 16750-2, Reset behaviour at voltage drop.

Figure 15: Power Supply Interruptions Profile

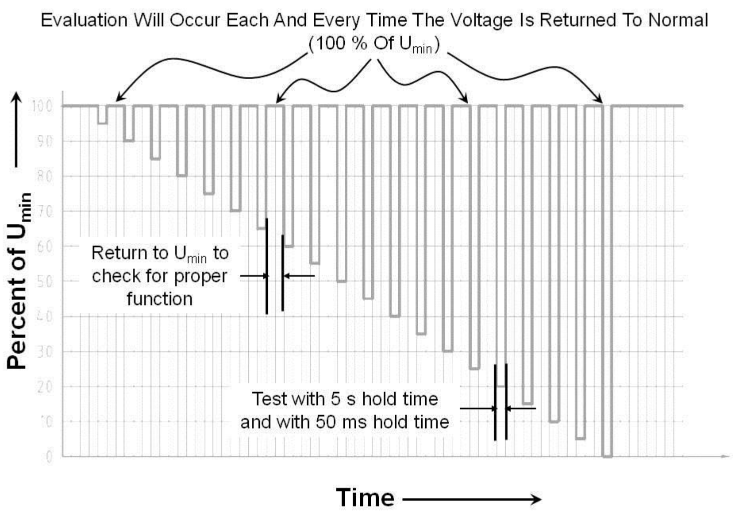

Figure 15 shows the execution of the procedure.

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1 Stabilize the component at T_{min}. Apply U_{min} to the component.

2 Apply the test pulse to all supply voltage inputs simultaneously. Decrease the voltage by 5 % and hold this decreased voltage for 5 s.

3 After each test pulse return to 100 % U_{min} and verify proper functionality.

4 Repeat steps (2) and (3) with a further decrease of 5 % U_{min}. Repeat this until 0 % U_{min} is reached.

5 Repeat steps (2) to (4) with a test pulse hold time of 50 ms at each decreased voltage.

6 Repeat steps (2) to (5) for each supply voltage input separately in case of multiple supply voltage inputs, while maintaining the untested inputs at U_{min}.

7 Repeat steps (2) to (6) with the component at T_{max}.

Criteria: Functional Status Classification shall be A after returning to Umin following each voltage drop and C elsewhere.

9.2.3 Battery Voltage Dropout.

Purpose: This test shall verify the component's immunity to voltage decrease and increase that occurs during discharge and charging of the vehicle battery.

Applicability: All components that have power supplied by the vehicle battery 12 V wiring system. This test is particularly important for components that have microprocessors, clocks, or ASICs.

Operating Type: 2.1 from T2 through T3 for FSC C periods. 3.2 for FSC A periods.

Monitoring: Continuous Monitoring.

Procedure:

1 Set up the battery voltage dropout profile as shown in Figure 16.

2 Soak the component un-powered until its temperature has stabilized to T_{min}.

3 Power up the component and inject the battery voltage dropout test profile with the following parameters from variation "A" in Table 21.

4 Repeat step (3) three additional times with the variations "B", "C", and "D".

5 Repeat steps (2) through (4) at T_{max}.

Figure 16: Battery Voltage Dropout Profile

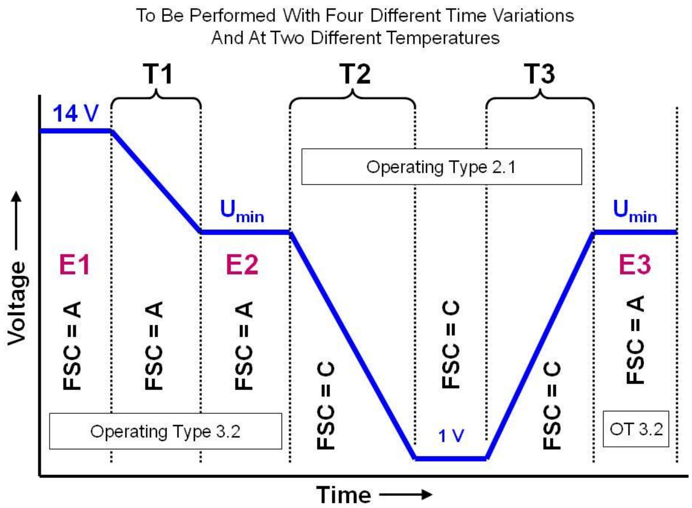


Table 21: Battery Voltage Dropout Values

Variations	Time		
	T1	T2	T3
A	0.01 s	10 s	1 s
B	0.1 s	600 s	10 s
C	0.5 s	3 600 s	120 s
D	1 s	28 800 s	7 200 s

Notes:

- Stabilize at the voltage levels defined in regions E1, E2, and E3 for enough time to perform Functional Evaluations (i.e., to allow Continuous Monitoring to verify correct functionality).
- The duration at 1.0 V shall be for a minimum of 1.0 minute in order to force the component to reset during following voltage increase.

Criteria: Functional Status Classification shall be as shown depending on the zone per Figure 16. There shall be no inadvertent behavior during the transitions.

9.2.4 Sinusoidal Superimposed Voltage.

Purpose: This test shall verify the component's immunity to generator output ripple voltage due to rectified sinusoidal generator voltage.

Applicability: All components that have power supplied by the vehicle battery 12 V wiring system.

Operating Type: 3.2, with voltage levels as defined in ISO 16750-2, superimposed alternating voltage, Severity Level 2.

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to ISO 16750-2, superimposed alternating voltage, Severity Level 2 (4 V_{p-p}).

Criteria: Functional Status Classification shall be A.

9.2.5 Pulse Superimposed Voltage.

Purpose: This test shall verify the component's immunity to supply voltage pulses that occur on battery supply in the normal operating voltage range. These voltage pulses will simulate a sudden high current load change to the battery supply line, causing a voltage drop or voltage rise at switch on or off. This test simulates loads with inrush current behavior such as motors, incandescent bulbs, or long wire harness resistive voltage drops modulated by PWM controlled high loads.

Applicability: All components that have power supplied by the vehicle battery 12 V wiring system.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Refer to Figure 17.

1 Connect the component to the U_o output.

2 Stabilize component at temperature T_{room}.

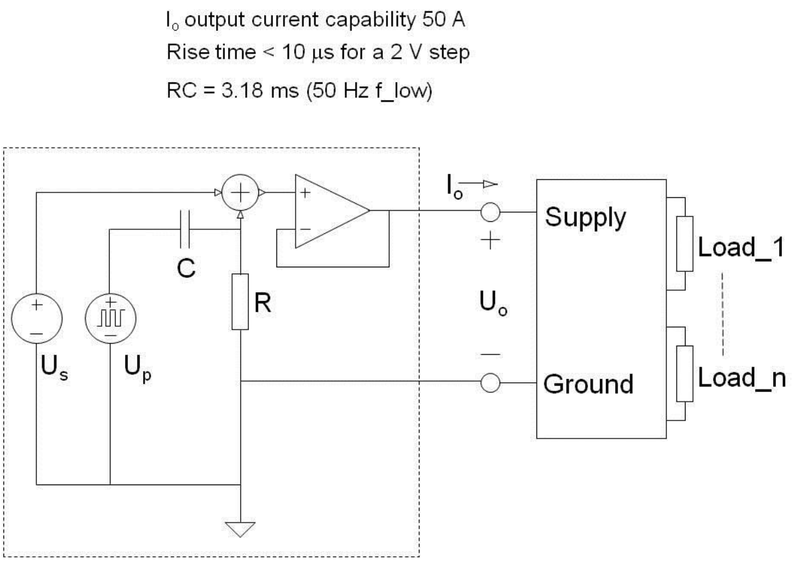
3 Set $U_s = U_{max}$ - 2 V.

4 Perform 5 continuous frequency sweep cycles while continuously monitoring for intermittent faults.

5 Decrease U_s by 1 V.

6 Repeat steps (4) and (5) until ($U_s = U_{min}$ + 2 V).

Figure 17: Pulse Superimposed Voltage Setup



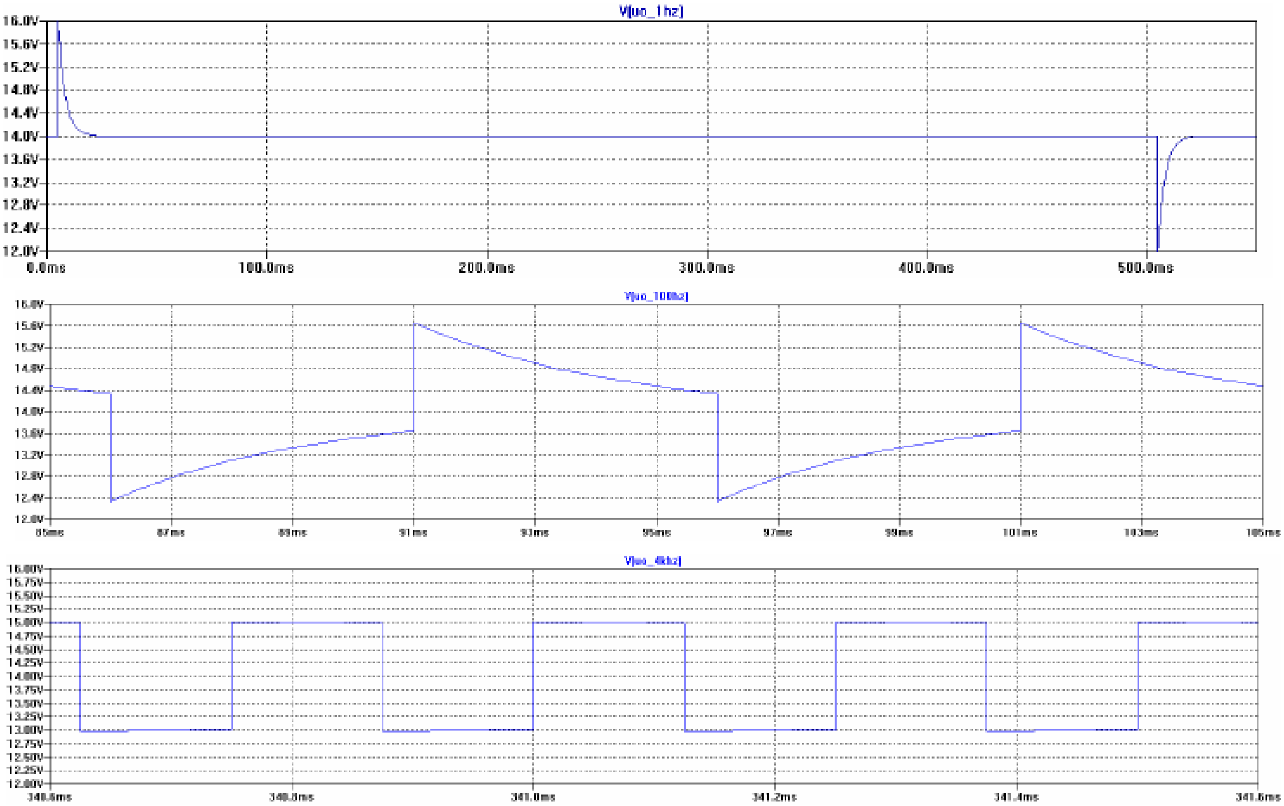
Test Setup Definitions/Parameters:

- $U_0 = U_s + U_p$
- $U_s = (U_{min} + 2\text{ V})$ to $(U_{max} - 2\text{ V})$ DC voltage
- U_p = Square wave -1 V to +1 V 50 % duty cycle (2 V_{p-p})
- U_p frequency sweep range: 1 Hz to 4 kHz
- Frequency sweep type: Logarithmic
- Frequency sweep duration for one cycle: 120 s for 1 Hz to 4 kHz to 1 Hz

Notes:

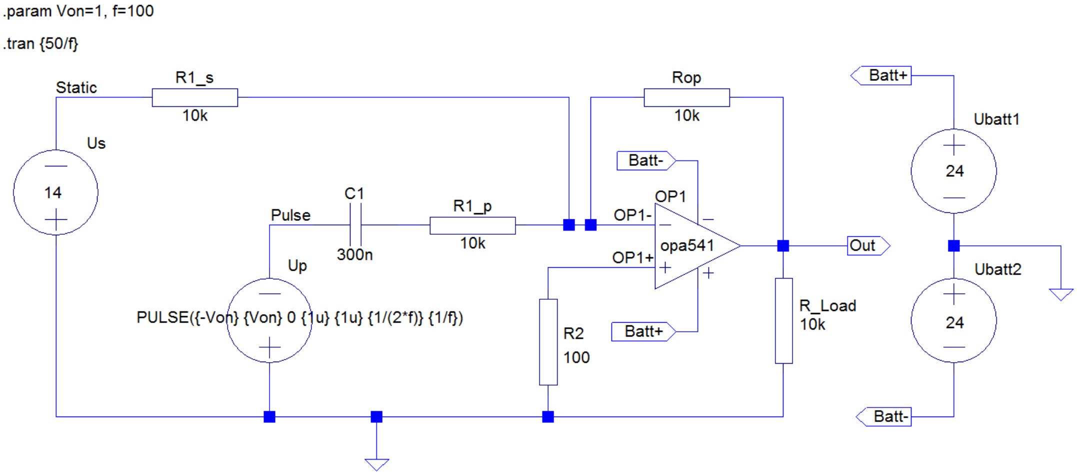
- The test shall be performed with real or equivalent loads connected (Load_1 to Load_n) and the output currents driven in the full range from I_load_min to I_load_max for each U_s step.
- The U0 waveform will depend on the frequency. Figure 17 shows examples of the following frequencies: 1 Hz, 100 Hz and 4 kHz (U_s = +14 V, U_p = +1 V / -1 V).

Figure 18: Examples for Pulse Waveforms



As an example, the Pulse Superimposed Voltage test setup can be realized as shown in the electrical schematic of Figure 19, verified with SPICE simulation.

Figure 19: Example for Pulse Superimposed Voltage Test Setup



Criteria: Functional Status Classification shall be A.

9.2.6 Intermittent Short Circuit to Battery and to Ground for Input/Output.

Purpose: This test shall verify the component's immunity to intermittent short circuit events on Input/Output (I/O) lines as well as the component's ability to recover automatically from these events. Vehicle battery power and ground lines will be treated separately in paragraph 9.2.8 "Multiple Power and Multiple Ground Short Circuits Including Pass Through".

Applicability: All components equipped with I/O lines.

Operating Type: 2.1/3.1/2.2/3.2 (with steady-state loads continuously on, PWM loads at minimum duty cycle for 5 cycles, 50 % duty cycle for 5 cycles and maximum duty cycle for 5 cycles).

Monitoring: Continuous Monitoring.

Procedure:

1 Lower and stabilize the chamber temperature to T_{min}.

2 Apply U_{max} to the component.

3 At t = 0 s, switch the Operating Type from 2.1/3.1 (OFF) to 2.2/3.2 (ON). The inputs and outputs under test shall be in an electrical steady state condition no later than t = 5 s.

4 At t = 15 s, apply a short circuit to battery to each applicable I/O for a duration of 1 minute and then remove the short circuit for a duration of 45 s (the combination of steps (3) and (4) shall equal 2 minutes). See Notes below for further explanations.

5 Switch the Operating Type from 2.2/3.2 (ON) to 2.1/3.1 (OFF).

6 Repeat steps (3) through (5) until 15 cycles are complete.

7 Confirm the correct operation of the outputs with normal loads.

8 Adjust the battery voltage to U_{min} and repeat steps (3) through (7).

9 Repeat steps (2) to (8) for short circuit to ground.

10 Stabilize the chamber temperature to T_{max} and repeat steps (1) through (9).

Notes:

- In step (4), multiple shorts may be applied simultaneously (e.g., to reduce test time), but the supplier shall make sure that the test is valid for single shorts as well (by design or analysis).
- In step (4), the durations for short circuit condition and normal condition shall be modified in order to ensure activation/deactivation of short circuit protection.
- Care has to be taken that the power supply has a current limitation (set to 50 A, if not otherwise specified) and that test setup withstands the maximum current.

Criteria: Functional Status Classification shall be C. Fuse replacements are not permitted. During the short circuit event, a short on one or several I/O lines shall not lead to an undefined behavior of the component. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of overheating.

9.2.7 Continuous Short Circuit to Battery and to Ground for Input/Output.

Purpose: This test shall verify the component's immunity to continuous short circuit events on Input/Output (I/O) lines. Vehicle battery power and ground lines will be treated separately in paragraph "9.2.8 Multiple Power and Multiple Ground Short Circuits Including Pass Through".

Applicability: All components equipped with I/O lines.

Operating Type: 3.2 (with steady-state loads continuously on, PWM loads at minimum duty cycle for 5 minutes, 50 % duty cycle for 5 minutes and maximum duty cycle for 5 minutes).

Monitoring: Continuous Monitoring.

Procedure:

1 Lower and stabilize the chamber temperature to T_{min}.

2 Apply U_{max} to the component.

3 Apply a continuous short circuit to battery voltage to each applicable I/O. The short circuit duration is defaulted to 15 minutes, but may be shorter or longer depending on the protection design.

4 Remove the short circuit condition for battery voltage.

5 Confirm the correct operation of the outputs with normal loads.

6 Repeat steps (2) through (5) for U_{min}.

7 Repeat steps (2) through (6) for short to ground.

8 Raise and stabilize the chamber temperature to T_{max} and repeat steps (2) through (7).

Note:

- In step (3), multiple shorts may be applied simultaneously (e.g., to reduce test time), but the supplier shall make sure that the test is valid for single shorts as well (by design or analysis).
- Care shall be taken that the power supply has a current limitation (set to 50 A if not otherwise specified) and that test setup withstands the maximum current.

Criteria: Functional Status Classification shall be C. During the short circuit event, a short on one or several I/O lines shall not lead to an undefined behavior of the component. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of overheating.

9.2.8 Multiple Power and Multiple Ground Short Circuits Including Pass Through.

Purpose: This test shall verify the component's immunity to low resistive shorts and benign failure for high resistive shorts in response to short circuit fault currents being drawn through the component. Because the response of the component may vary based upon fault current level and fuse opening time, each pass through circuit should be tested at two different fault current levels.

Applicability: This test applies to all components with multiple supply lines and/or multiple ground lines including pass through. A "pass through" is a configuration where more than one connector pin is connected within the component without any internal current limiting devices. If a "pass through" circuit is connected on one side to a battery or switched power circuit (e.g., Run/Crank), then it is a power pass through. If a "pass through" circuit is connected on one side to ground, then it is a ground pass through. In either case, the opportunity exists for a short circuit fault on one side of the pass through to cause fault current to flow through the component. This test does not apply to components with a single power line and a single ground line and with no pass through.

Operating Type: 3.2 (with steady-state loads continuously on)

Monitoring: Continuous Monitoring.

Procedure:

Procedure - Low Resistive Short:

1 Raise and stabilize the chamber temperature to T_{max}.

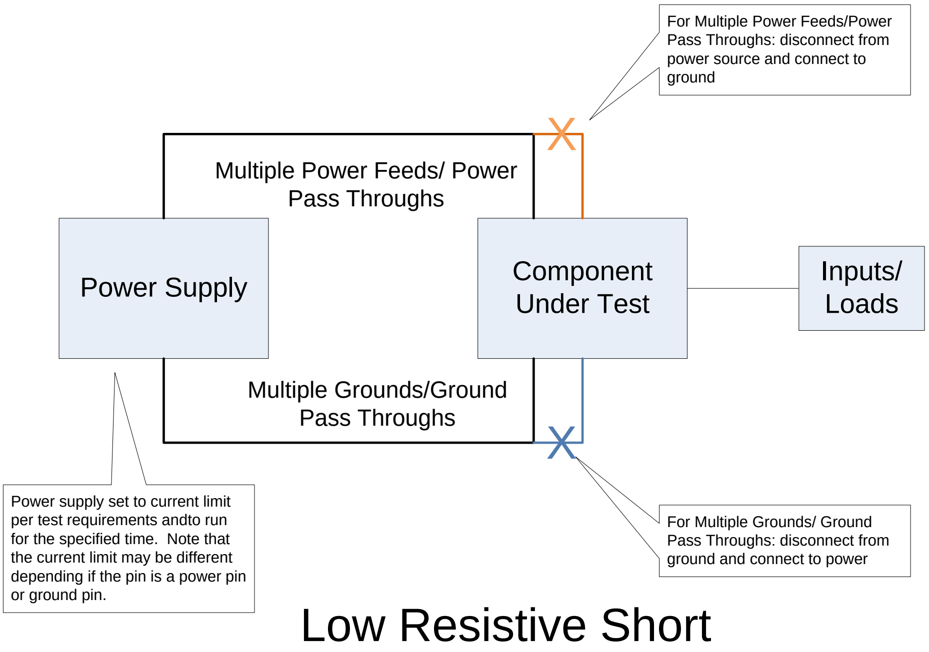
2 Apply U_{max} to one side of each pass through circuit in the component. Multiple pass throughs shall be tested separately.

3 Set up a power supply to current limit at 250 % of the anticipated fuse rating representing a low resistive short circuit and for a duration of 300 ms. For multiple power / power pass through circuits, use the largest fuse rating that is anticipated to be used in vehicle applications (default value: 15 A for input ratings ≤ 10 A, 30 A for input ratings > 10 A). For multiple ground / ground pass through circuits, assume a 30 A fuse rating.

4 At t = 0 s, turn on unit under test and run for 300 s.

5 At t = 300 s: For multiple power pins / power pass throughs disconnect the pin under test from power and connect to ground for 300 ms. For multiple ground pins / ground pass throughs disconnect the pin under test from ground and connect to power for 300 ms. The wire used shall be < 35 mΩ and capable of handling the rated current.

Figure 20: Low Resistive Short Setup



Note: The tested samples are not allowed to perform the High Resistive Short test. New samples shall be used for the High Resistive Short test.

Procedure - High Resistive Short:

1 Raise and stabilize the chamber temperature to T_{max}.

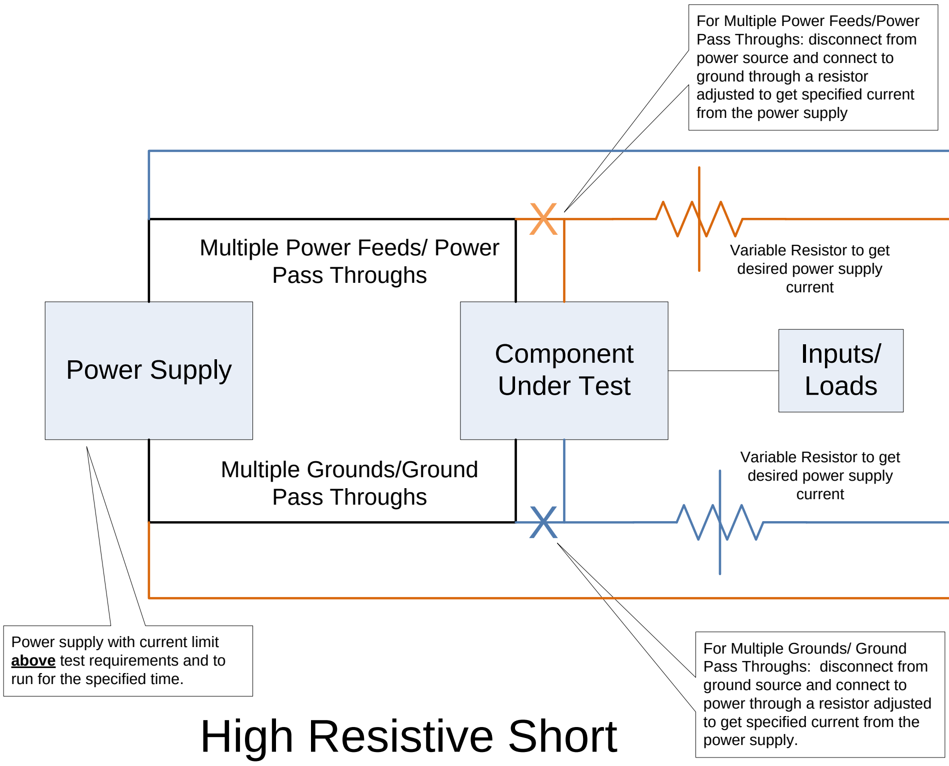
2 Apply U_{max} to one side of each pass through circuit in the component. Multiple pass throughs shall be tested separately.

3 At t = 0 s, turn on unit under test and run for 300 s.

4 At t = 300 s: For multiple power pins / power pass throughs disconnect the pin under test from power and connect to ground through a power resistor. For multiple ground pins / ground pass throughs disconnect the pin under test from ground and connect to power through a power resistor. In either case adjust the power resistor to obtain a current of 130 % of fuse rating at the power supply.

5 Run step 4 for a duration of 10 minutes.

Figure 21: High Resistive Short Setup



Criteria: For the Low Resistive Short test, Functional Status Classification shall be D. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of overheating.

For the High Resistive Short test, Functional Status Classification shall be E. One module may be used repeatedly for High Resistive Short testing provided damage does not invalidate the test on different pass through circuit. Additionally, during the Visual Inspection and Dissection – DRBTR, minor amounts of carbon may appear near the open circuit; however, amounts beyond this on the circuit board are not permitted.

9.2.9 Open Circuit – Single Line Interruption.

Purpose: This test shall verify that the component is immune to single line open circuit conditions.

Applicability: All components.

Operating Type: 3.2 (outputs have to be operated at maximum specified load).

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to ISO 16750-2, Single line interruption. Apply this procedure for all I/O circuits, one circuit at a time.

For supply power and ground lines, the interruption duration shall be 15 minutes, for all other I/O circuits the interruption duration shall be 10 s.

Note:

- In the case of multiple supply power lines, they need to be treated both as a single line (interrupted simultaneously) and as separate lines.
- In the case of multiple ground lines, they shall be treated both as a single line (interrupted simultaneously) and as separate lines.

Criteria: Functional Status Classification shall be C. Additionally, during the Visual Inspection and Dissection – DRBTR, evidence of overheating is not allowed.

9.2.10 Open Circuit – Multiple Line Interruption.

Purpose: This test shall verify that the component is immune to multiple line open circuit conditions. This will occur when a vehicle harness connector becomes disconnected.

Applicability: All components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to ISO 16750-2, Multiple line interruption. Disconnect and reconnect the connector of the component. In the case of multiple connectors, they shall be disconnected and reconnected separately.

Criteria: Functional Status Classification shall be C. Additionally, during the Visual Inspection and Dissection – DRBTR**,** evidence of overheating is not allowed.

9.2.11 Ground Offset.

Purpose: This test shall verify the component's ability to function properly when subjected to ground offsets.

Applicability: All I/Os on the component without signal return line. This means all I/Os on the component where voltage offsets occur in the ground line(s). Ground offsets will occur between different components within a vehicle due to voltage losses in the ground lines. The resistive nature of the wire harness (e.g., wire resistance, wire length, connector material, etc.) will result in different ground offsets at each I/O on the component. For further information, refer to GMW14082 (voltage supply model).

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: As shown in the test setup in 22, the offset shall be applied to each ground line of the I/O simulation device separately and simultaneously. The simulation device shall be constructed according to the CTS interface documentation of the component. If this information is not available, refer to GMW14082 for defining I/O circuits of the simulation device.

1 Apply U_{min} to the component.

2 Subject the applicable ground line of one representative I/O simulation device to a +1.0 V offset relative to the component ground.

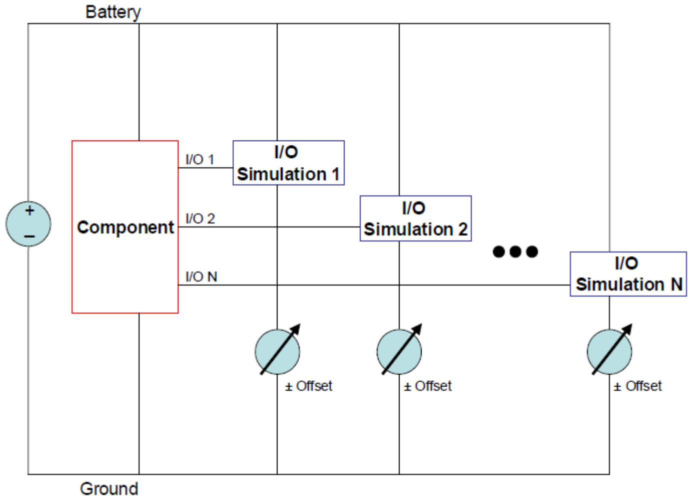
3 Repeat step (2) for the next applicable I/O simulation device.

4 Repeat step (2) for all I/O simulation devices simultaneously.

5 Repeat steps (2) through (4) for a -1.0 V offset relative to the component ground.

6 Repeat steps (2) through (5) with U_{max} instead of U_{min}.

Figure 22: Ground Offset Setup



Criteria: Functional Status Classification shall be A.

9.2.12 Power Offset.

Purpose: This test shall verify the component's ability to function properly when subjected to power offsets.

Applicability: All components with I/O that is referenced to a power supply (permanent or switched) from another component as well as components with multiple battery inputs. Power offsets will occur between different components or between different battery inputs of a component within a vehicle due to voltage losses in the power lines. The resistive nature of the wire harness (e.g., wire resistance, wire length, connector material, etc.) will result in different power offsets at each I/O on the component. For further information, refer to GMW14082 (voltage supply model).

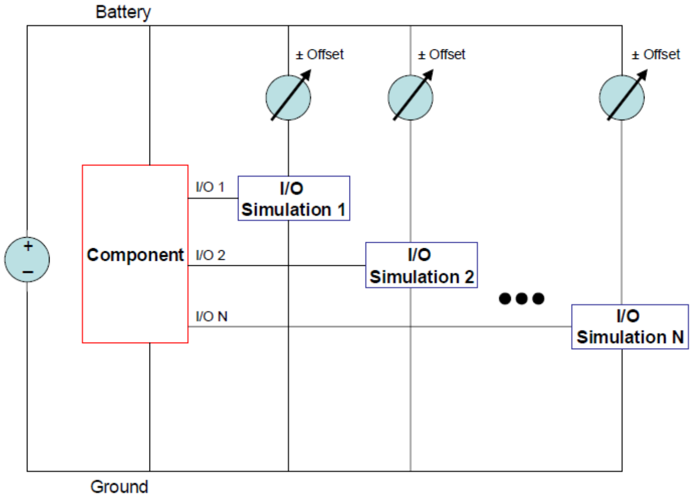
Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: As shown in the test setup in Figure 23, the offset shall be applied to each power line of the I/O simulation device separately and simultaneously. The simulation device shall be constructed according to the CTS interface documentation of the component. If this information is not available, refer to GMW14082 for defining I/O circuits of the simulation device.

1. Apply U_{min} to the component.
2. Subject the applicable power line of one representative I/O simulation device to a +1.0 V offset relative to the component power.
3. Repeat step (2) for the next applicable I/O simulation device.
4. Repeat step (2) for all I/O simulation devices simultaneously.
5. Repeat steps (2) through (4) for each applicable power line individually if the component has more than one battery input.
6. Repeat steps (2) through (5) for a -1.0 V offset relative to the component power.
7. Repeat steps (2) through (6) with U_{max} instead of U_{min}.

Figure 23: Power Offset Setup



Criteria: Functional Status Classification shall be A.

9.2.13 Discrete Digital Input Threshold Voltage.

Purpose: This test shall verify the capability of discrete digital input circuits (including switch interfaces) to withstand minor voltage fluctuations without causing a change of active/inactive state.

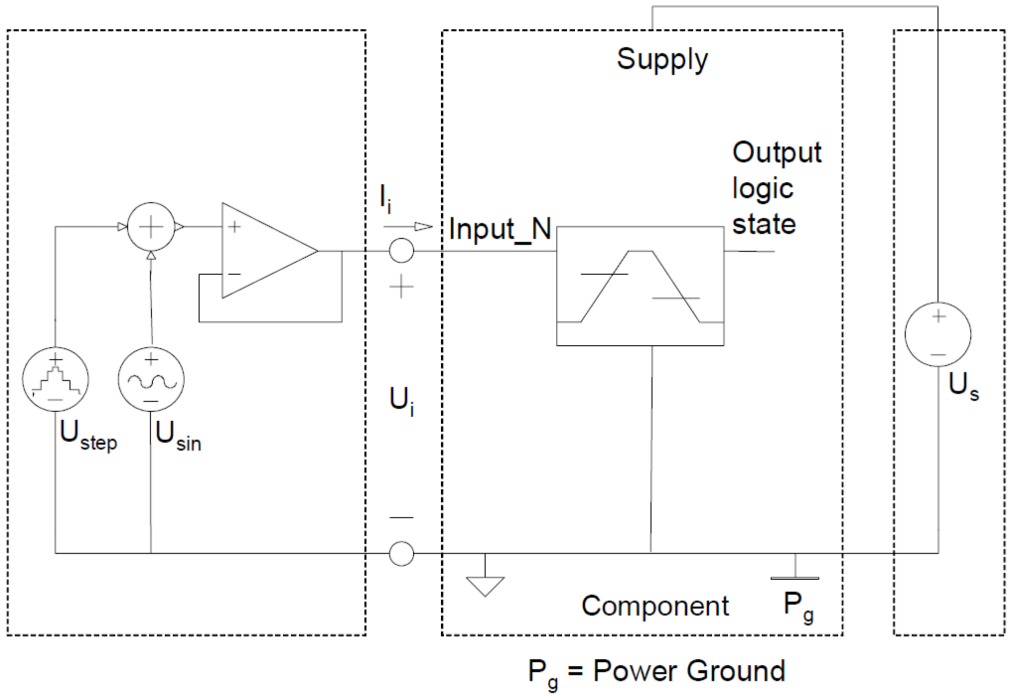
Applicability: Discrete digital input and switch input interfaces with transmitters grounded locally without signal return to receiver. It can be replaced by Analysis at Environmental Hardware Design Review.

Operating Type: 3.2

Monitoring: Continuous Monitoring. Additionally, readout of logic state and current.

Procedure: Connect the component to the U_s supply and power ground. Refer to Figure 24, and follow the given sequence.

Figure 24: Threshold Voltage Setup



1 At T_{room} perform the following sequence (see Figure 25).

2 Adjust U_s to U_{min} for the component.

3 Adjust U_{step} to 0 V.

4 Adjust U_{sin} to 50 Hz sinusoidal with an amplitude of 200 mV peak-peak.

5 Read logic output state and store.

6 Step U_{step} by 250 mV increments from 0 to U_{min} while recording the output logic state. Keep each step for 5 s and sample output with a 100 ms repetition rate until all 50 recorded logic states in a row have changed to the new value.

7 Store input value of U_{step} when this occurs to the name U_{ih_rise}. Continue until U_{min} is reached.

8 While at U_{min} start to decrease U_{step} by 250 mV steps from U_{min} down to 0 V. Use the same procedure as in step (6) to detect a logic state change.

9 Store input value of U_{step} when this occurs to the name U_{il_fall}. Continue until 0 V is reached.

10 Rise voltage U_{step} to $(U_{ih\_rise}+U_{il\_fall})/2$ and record the number of state changes during a 5 s time period as Nth_U_{min} (see Figure 25).

11 Repeat steps (2) to (10) by replacing U_{min} with U_{max} and store the new U_{ih_rise} and U_{il_fall}.

12 Repeat steps (2) to (11) at T_{max} and T_{min} for the component.

13 Write a report including:

- At T_{room} and U_{min}: U_{ih_rise}, U_{il_fall} and Nth_U_{min}
- At T_{room} and U_{max}: U_{ih_rise}, U_{il_fall} and Nth_U_{min}
- At T_{max} and U_{min}: U_{ih_rise}, U_{il_fall}
- At T_{max} and U_{max}: U_{ih_rise}, U_{il_fall}
- At T_{min} and U_{min}: U_{ih_rise}, U_{il_fall}
- At T_{min} and U_{max}: U_{ih_rise}, U_{il_fall}

Figure 25: Threshold Voltage Waveform – All Steps

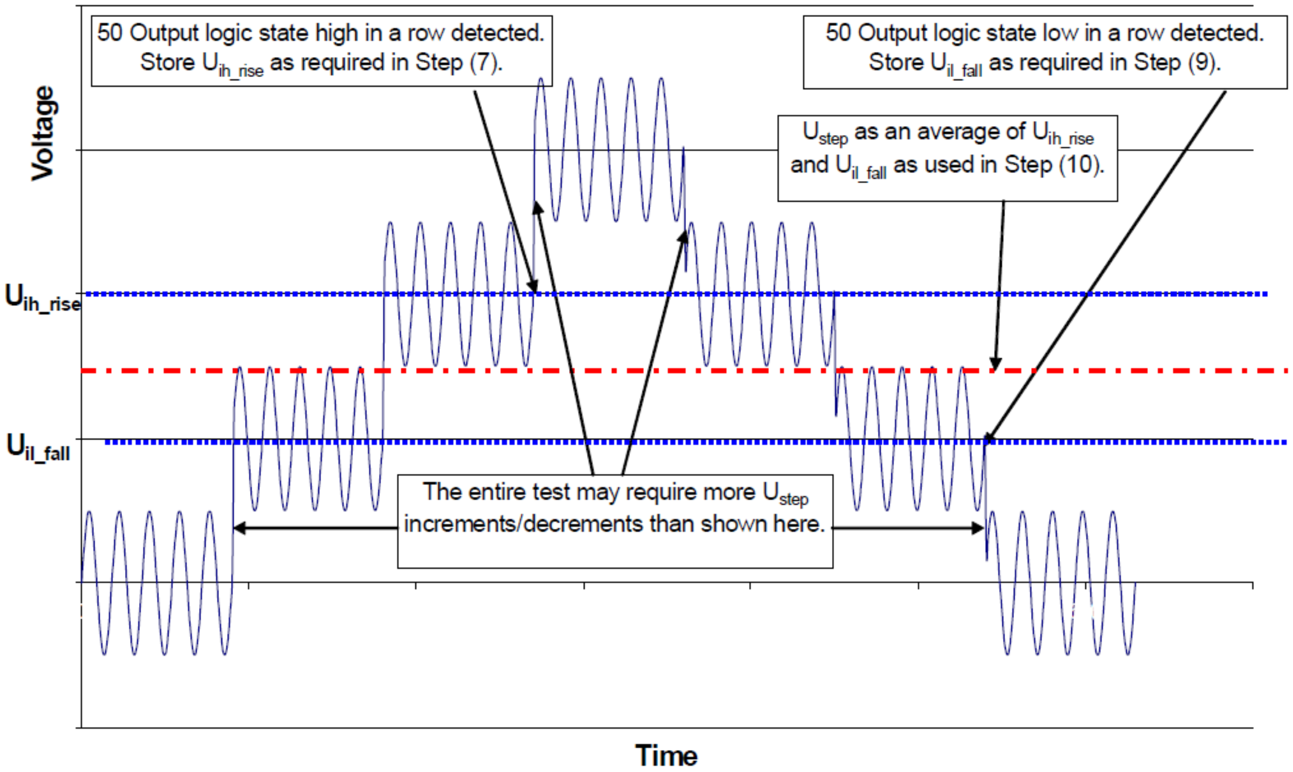
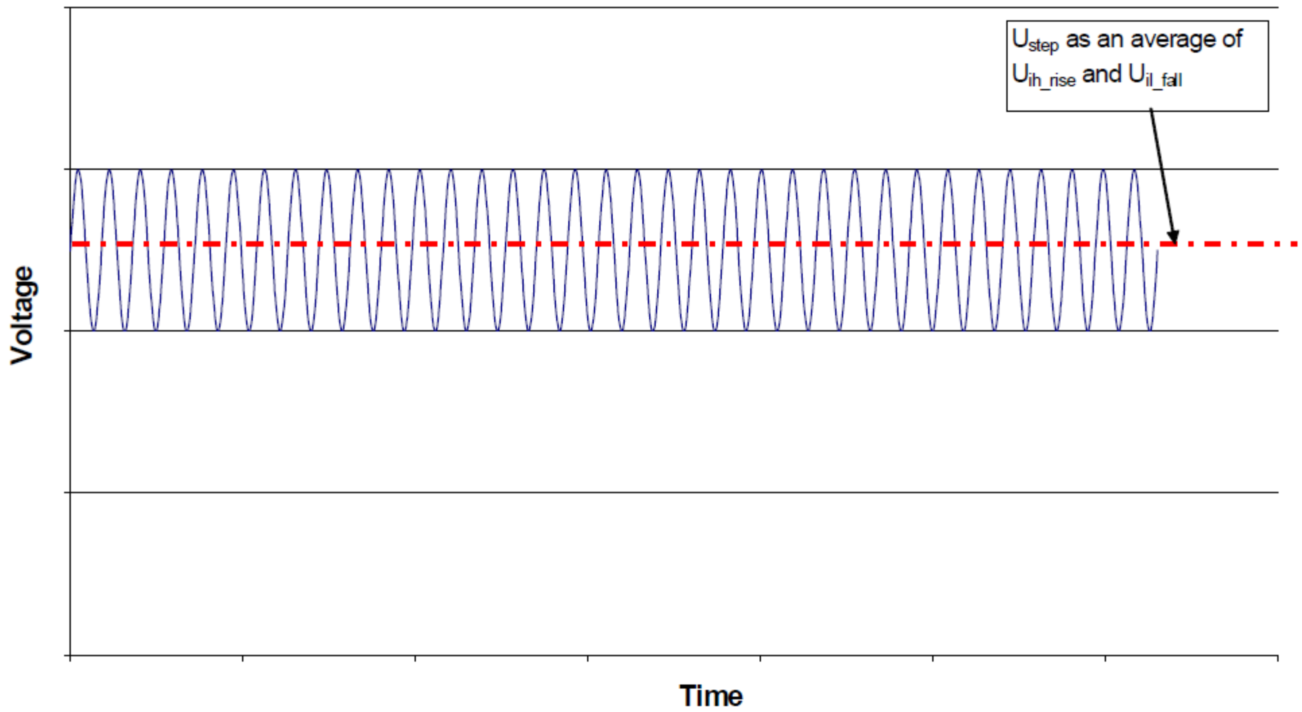


Figure 26: Threshold Voltage Waveform – Step (10)



Criteria: Functional Status Classification is not applicable to this test. All discrete digital input interfaces shall be able to correctly detect the logic levels stated by GMW14082:

Logic Low: -1 V < U_{il} < 2 V

Logic High: 4.5 V < U_{ih} < U_{max} + 1 V

This then requires that the U_{ih_rise} and U_{il_fall} both fall into the range (2.0 to 4.5) V over the full operating temperature and voltage range. The interface hysteresis is included in this requirement. The current shall not increase significantly (> 5 mA) during the (U_{ih_rise}+U_{il_fall})/2 range.

9.2.14 Over Load – All Circuits.

Purpose: This test shall verify the component's ability to withstand overload situations or open circuit in a safe manner.

Applicability: All components with or without built-in internal overload-protected output circuits. This also applies to components containing fuses, such as Bused Electrical Centers, for power outputs that are equipped with built-in internal overload protection.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1 Raise and stabilize the test chamber temperature to T_{max}.

2 Apply U_{nom} to the component.

3 With variable resistor, load each output to draw a maximum operating load current (I_{max}) for 10 minutes.

4 Using a variable power supply, increase the current in increments of 10 % of I_{max} by changing the variable resistor load. Hold each current increase for a 10 minutes dwell period.

5 Continue to increase the current in 10 % increments until an open circuit conditions exists or a component with built-in protection begins to limit current. For all other cases, increase current until 3 x I_{max}, but ≤ 50 A, is reached.

6 Identify the current level in Amperes when the open circuit condition exists. Pay special attention for the generation of smoke or thermal activity near the time of failure. Document observations in the test report.

7 Return the component to full function by performing all required re-initializations conditions and confirm the correct operation with normal loads.

Note: Output circuits without current protection may not return to correct operation for the output under test.

8 Repeat steps (1) to (7) at T_{min}.

Criteria: If an output is over-current protected, then Functional Status Classification shall be D for the associated function(s).

If an output is not over-current protected, then Functional Status Classification shall be E for the associated function(s). Additionally, during the Visual Inspection and Dissection – DRBTR, minor amounts of carbon are allowed near the open circuit; however, amounts beyond this on the circuit board are not permitted.

For critical functions, the Functional Status Classification shall be A.

9.2.15 Over Load – Fuse Protected Circuits.

Purpose: This test shall verify the ability of a component containing circuit protection features such as a fuse or circuit breaker, used for power distribution to the vehicle (such as a Bused Electrical Center) to withstand maximum current allowable by the internal circuit protection feature.

Applicability: All components containing internal circuit protection features, such as a fuse or circuit breaker. Power outputs equipped with built-in internal (electronic) overload protection are exempt from this test.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Test all circuits that are protected with the approved application circuit protection feature as detailed on the component drawing or specification (fuse, circuit breaker, etc.) according to the following procedure:

1 Raise and stabilize the chamber temperature to T_{max}.

2 Apply U_{nom} to the component.

3 Put a shunt (i.e., short circuit) in place of the circuit protection feature.

4 Apply an overload circuit condition to the circuit so that the load current is 1.35 x I_{rp} (nominal current of the circuit protection feature) for the required test duration. Use the test duration as defined in ISO 8820-1, Operating time rating, considering the upper tolerance + 10 %

5 Repeat step (4) with an overload circuit condition so that the load current is 2 x I_{rp}. Adjust the test duration accordingly as defined in ISO 8820-1, Operating time rating.

6 Repeat step (4) with an overload circuit condition so that the load current is 3.5 x I_{rp}. Adjust the test duration accordingly as defined in ISO 8820-1, Operating time rating.

Criteria: Functional Status Classification shall be A. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of discoloration from overheating.

9.2.16 Insulation Resistance.

Purpose: This test shall verify the component's immunity to loss of insulation. This could result in electrical performance degradation and signal interference.

Applicability: All components that are subjected, internally or externally, to voltages (positive or negative, transient or steady state) > 30 V. See Note listed below in the procedure.

Operating Type: 1.1

Monitoring: Measure insulation resistance in procedure, step (2).

Procedure:

1 Use the test methods according to ISO 16750-2, "Insulation resistance". For situations where the standard test voltage of 500 V does not fit the part's rating voltage, a modified voltage will be necessary as noted below.

2 After the test, perform a 1-Point Functional/Parametric Check.

Note:

- Circuit boards with inductive loads: Less voltage (< 100 V) can be used with electronic components to prevent damage to susceptible parts such as capacitors.
- Inductive components: A test voltage > 300 V is suitable for components such as motors.
- Power Converter: Legal insulation requirements exceed 500 V.
- Optionally, the humidity preconditioning of the ISO-test shall be replaced by the HHC test in Leg 2 of the Test Flow (use a minimum of 3 samples).

Criteria: Functional Status Classification shall be C. The insulation resistance shall be > 10 x 106 Ω.

9.2.17 Crank Pulse Capability and Durability.

Purpose: This test shall verify the functional capability and durability of components subjected to crank pulses that are generated by conventional starters and by the stop/start system.

Applicability: All components that will be subjected to crank pulses (initial start and/or stop/start) on the power line supplied by the vehicle battery 12 V wiring system (both battery and/or ignition inputs). The initial fall rate for all waveforms shall be adjusted to15 V/ms for components that are not allowed to reset during any one of the crank pulse waveforms.

Operating Type: 2.2 (during stop) / 3.2 (after start) for waveform #1 and #2 (stop/start scenario)

2.1 (off mode) / 3.2 (after start) for waveform #3 and ISO 7637-2 (6/2004) Pulse 4 waveforms (initial start scenario)

Monitoring: Continuous Monitoring throughout the entire waveform.

Procedure: Subject the component to the waveforms defined in Table 22 and Table 23.

Table 22: Stop/Start Crank Waveforms

Waveform 1		Waveform 2		Waveform 3	
t (ms)	U (V)	t (ms)	U (V)	t (ms)	U (V)
0.00	12.00	0.00	12.00	0.00	12.00
100.00	12.00	100.00	12.00	100.00	12.00
100.30	6.00	101.00	6.00	140.00	4.00
150.00	6.00	102.00	6.00	155.00	4.00
280.00	9.25	202.00	9.00	175.00	9.25
410.00	8.50	702.00	10.00	305.00	7.65
480.00	9.50	703.00	12.00	375.00	8.55
600.00	8.75	1.000.00	12.00	495.00	7.88
670.00	9.55			565.00	8.60
780.00	8.75			675.00	7.88
840.00	9.76			735.00	8.78
930.00	9.00			825.00	8.10
1010.00	10.00			905.00	9.00
1030.00	9.50			925.00	8.55
1110.00	11.00			1005.00	9.90
1530.00	12.00			1425.00	12.00
1930.00	12.00			1825.00	12.00

Table 23: Requirements Levels for the Immunity to ISO 7637-2 (6/2004) Pulse 4: Crank Pulse

Pulse Severity	U_S Note 1	U_a Note 1	t_9 Note 1	t_{11} Note 1
I	4 V	2.5 V	1 s	40 ms
II	5 V	3 V, 2.5 V	2 s	60 ms
III	6 V	4 V, 3 V, 2.5 V	5 s	80 ms
IV	7 V	5 V, 4 V, 3 V, 2.5 V	10 s	100 ms

t_{10}, t_8 and t_7 as defined in ISO 7637-2 (6/2004). Default value for t_7 shall be 15 ms. Default value for t_8 shall be 50 ms. All severity levels shall be tested.
Note 1: As defined in ISO 7637-2 (6/2004).

Table 24 provides the default number of cycles. The required number of cycles may be modified in agreement with the GM ENV SME.

The Crank Waveform Functional Test cycles are required for all components.

The Crank Waveform Durability Test cycles are required only where there is a durability concern (i.e., electromechanical movement due to crank) and when it is not covered by another component specific test procedure.

10 % of the Durability Test cycles shall be performed at T_{min} and 10 % of the Durability Test cycles shall be performed at T_{max}.

The cycle time between pulses shall be adequate to verify function after each functional cycle and adequate to not create any failures due to an unrealistic pulse frequency.

Table 24: Crank Waveform Cycles

Crank Waveform Note 1	**Crank Waveform Functional Test cycles**	**Crank Waveform Durability Test cycles**
Waveform 1	10	20 000
Waveform 2	10	20 000
Waveform 3	10	20 000
ISO 7637-2 (6/2004) pulse 4 severity I Ua = 2.5 V	10	4000
ISO 7637-2 (6/2004) pulse 4 severity II Ua = 3 V	10	4000
ISO 7637-2 (6/2004) pulse 4 severity II Ua = 2.5 V	10	4000
ISO 7637-2 (6/2004) pulse 4 severity III Ua = 4 V	10	4000
ISO 7637-2 (6/2004) pulse 4 severity III Ua = 3 V	10	4000
ISO 7637-2 (6/2004) pulse 4 severity III Ua = 2.5 V	10	4000
ISO 7637-2 (6/2004) pulse 4 severity IV Ua = 5 V	10	4000
ISO 7637-2 (6/2004) pulse 4 severity IV Ua = 4 V	10	4000
ISO 7637-2 (6/2004) pulse 4 severity IV Ua = 3 V	10	4000
ISO 7637-2 (6/2004) pulse 4 severity IV Ua = 2.5 V	10	4000
Total	130	100 000
Note 1: The initial fall rate for all waveforms shall be adjusted to 15 V/ms for components that are not allowed to reset during any one of the crank pulse waveforms.		

1. Perform all the Durability Test Cycles first, if applicable.
2. Perform a 1-Point Functional/Parametric Check after the completion of all Durability Test Cycles for each waveform (total of 13 Functional Checks).
3. Perform the Functional Test Cycles.
4. After each individual Functional Test Cycle for each waveform, an abbreviated Functional Check shall be performed (total of 130 Functional Checks)

Note: The time between durability test cycles shall be such that the internal voltages in the component shall have had time to stabilize.

Note: While the waveform voltage is at 12 V, the component shall be in Operating Type 3.2. When at 12 V after the pulse, a functional test shall be performed.

Criteria: Functional Status Classification shall be A. Temporary functional deviations are only accepted if defined by the CTS.

9.2.18 Switched Battery Lines.

Purpose: This test shall verify the robustness of the component to switched battery lines contact bouncing. It is intended for components with electronic circuits powered through switched battery lines switched with a contact. This test shall also be used for microprocessor-based components to quantify the robustness of the design to contact bouncing.

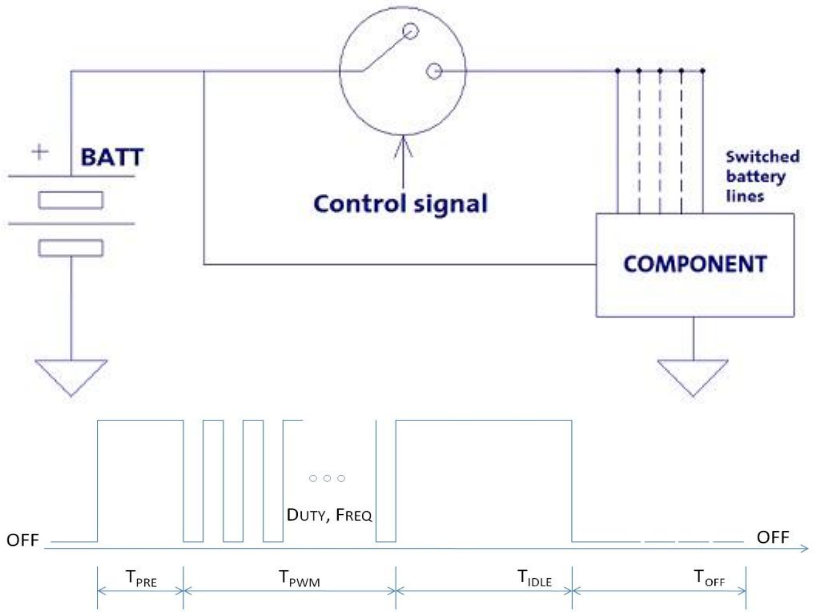
Applicability: All components that have switched power supplied by the vehicle battery 12 V wiring system.

Operating Type: Transition between 2.1 and 2.2.

Monitoring: Continuous Monitoring. Special attention shall be given to the behavior of outputs, including regulated output voltages

Procedure: Power supply shall be provided by an automotive battery representing as well as possible the production configuration ($U_B \geq 12.0$ V). Connect the component to the power supply through a controllable switch with a switching time ≤ 200 ns. Control the switch with a signal as shown in Figure 27.

Figure 27: Switched Battery Lines Setup



Parameter values:

- T_{PRE} = pre-energizing period = 25 µs, 50 µs, 125 µs, 500 µs, 1 ms
- T_{PWM} = relay emulated bouncing period = 50 µs, 100 µs, 250 µs, 500 µs, 1 ms
- PWM frequency = 5 kHz, 10 kHz, 20 kHz, 50 kHz, 100 kHz
- PWM duty cycle = 20 %, 50 %, 80 %
- T_{IDLE} = 100 ms: transient completed
- $T_{OFF} \geq 5$ s: off state time
- Number of PWM cycles ≥ 5

The switch shall conduct only unidirectional current and shall be high impedence when off.

1 Stabilize the component at T_{min}.

2 Apply test pulse waveform sweeping timing and frequency parameters using listed values.

Test has to be performed in each parameter combination that leads to a minimum of 5 PWM cycles which is defined by $T_{PWM} \geq 5*(1/\text{PWM frequency})$. This results in 15 pairs of the T_{PWM} and PWM frequency values. These pairs are combined with the 15 permutations of the T_{PRE} and PWM Duty Cycle. This results in a total of 225 different required parameter combinations, as shown in Table 25.

Each parameter combination shall be repeated 180 times.

An abbreviated functional check (which verifies the component completed power up initialization) shall be performed during T_{IDLE} after each parameter combination.

3 Repeat step (2) at T_{room} and T_{max}.

Table 25: Switched Battery Lines Parameter Combinations

T_{PRE}	T_{PWM} / PWM Frequency	Duty Cycle	Combinations
25 µs	50 µs / 100 kHz	20 %, 50 %, 80 %	3
25 µs	100 µs / 100, 50 kHz	20 %, 50 %, 80 %	6
25 µs	250 µs / 100, 50, 20 kHz	20 %, 50 %, 80 %	9
25 µs	500 µs / 100, 50, 20, 10 kHz	20 %, 50 %, 80 %	12
25 µs	1 ms / 100, 50, 20, 10, 5 kHz	20 %, 50 %, 80 %	15
50 µs	50 µs / 100 kHz	20 %, 50 %, 80 %	3
50 µs	100 µs / 100, 50 kHz	20 %, 50 %, 80 %	6
50 µs	250 µs / 100, 50, 20 kHz	20 %, 50 %, 80 %	9
50 µs	500 µs / 100, 50, 20, 10 kHz	20 %, 50 %, 80 %	12
50 µs	1ms / 100, 50, 20, 10, 5 kHz	20 %, 50 %, 80 %	15
125 µs	50 µs / 100 kHz	20 %, 50 %, 80 %	3
125 µs	100 µs / 100, 50 kHz	20 %, 50 %, 80 %	6
125 µs	250 µs / 100, 50, 20 kHz	20 %, 50 %, 80 %	9
125 µs	500 µs / 100, 50, 20, 10 kHz	20 %, 50 %, 80 %	12
125 µs	1 ms / 100, 50, 20, 10, 5 kHz	20 %, 50 %, 80 %	15
500 µs	50 µs / 100 kHz	20 %, 50 %, 80 %	3
500 µs	100 µs / 100, 50 kHz	20 %, 50 %, 80 %	6
500 µs	250 µs / 100, 50, 20 kHz	20 %, 50 %, 80 %	9
500 µs	500 µs / 100, 50, 20, 10 kHz	20 %, 50 %, 80 %	12
500 µs	1 ms / 100, 50, 20, 10, 5 kHz	20 %, 50 %, 80 %	15
1 ms	50 µs / 100 kHz	20 %, 50 %, 80 %	3
1 ms	100 µs / 100, 50 kHz	20 %, 50 %, 80 %	6
1 ms	250 µs / 100, 50, 20 kHz	20 %, 50 %, 80 %	9
1 ms	500 µs / 100, 50, 20, 10 kHz	20 %, 50 %, 80 %	12
1 ms	1 ms / 100, 50, 20, 10, 5 kHz	20 %, 50 %, 80 %	15
			225

Criteria: Functional Status Classification shall be C.

9.3 Mechanical.

9.3.1 Vibration with Thermal Cycling. This test shall verify that the component is immune to vibration that occurs in the vehicle. The following vibration tests reference different test conditions for mounting locations as well as for cars and trucks.

Note: The profiles in GMW3172 are derived from a collection of actual vehicle measurements. This test addresses two sources of vibration that a vehicle can experience:

- In all cases, vibration in a vehicle is mostly due to rough road surfaces over which the vehicle travels. This represents worst case roads, such as driving over Belgian blocks.

- Also, engine vibration is an input to engine- or transmission-mounted components. This represents worst case engine conditions, such as an engine operating with a wide open throttle.

The vibration portion of this test demonstrates 97 % reliability, with a statistical confidence of 50 % for vibration fatigue (R97/C50), relative to a target life requirement (in miles) for customer usages as shown in Table 26.

Note: To achieve a certain reliability level, a specific number of samples are required. In the case of R97/C50, a sample size of 23 shall be tested for 1 life. When a reduced sample size is used, an increase in the number of lives is required. For example, as shown in Table 26, when 6 samples are used, this requires an increase in test duration equal to 2 lives. Other reliability levels or sample sizes require different adjustments. Consult the GM ENV SME or CVE for more explanations if needed.

All vibration tests shall have a superimposed thermal cycle as defined in paragraph 9.3.2.4 "Thermal Cycle Profile Used During All Vibration Tests".

Note: Refer to paragraph 6.8 "Vibration Transmissibility Demonstration" for component mounting instructions.

All vibration tests shall use the durations defined in Table 26.

Table 26: Duration for Vibration Test for a Sample Size of 6 (for 97 % reliability and 50 % confidence)

Location	Body Style	Duration for each axis (x, y, and z), based on mileage requirement in CTS		
		100 000 miles (160 900 km)	150 000 miles (241 350 km)	200 000 miles (321 800 km)
Engine or Transmission	Car or Truck	44 h	66 h	88 h
Sprung Masses	Car	16 h	24 h	32 h
Sprung Masses	Truck	36 h	54 h	72 h
Unsprung Masses	Car	16 h	24 h	32 h
Unsprung Masses	Truck	36 h	54 h	72 h

Note: This procedure is intended to test the mounting features that are integral to the component case or housing. Stand-alone brackets are not covered by this specification and shall not be used in the test. Stand-alone brackets can be specific to certain applications and may not apply to global common components. To test stand-alone brackets, refer to the bracket test procedures in CG2986, CTS for Electrical and HVAC Brackets.

9.3.1.1 Random Vibration – Mounting Location Engine or Transmission.

Purpose: This test shall verify that the component is immune from the effects of vibration when it is located on the engine or transmission. Random vibration is used to capture all vibration effects from piston/valve train higher frequencies) and road-induced vibration (lower frequencies).

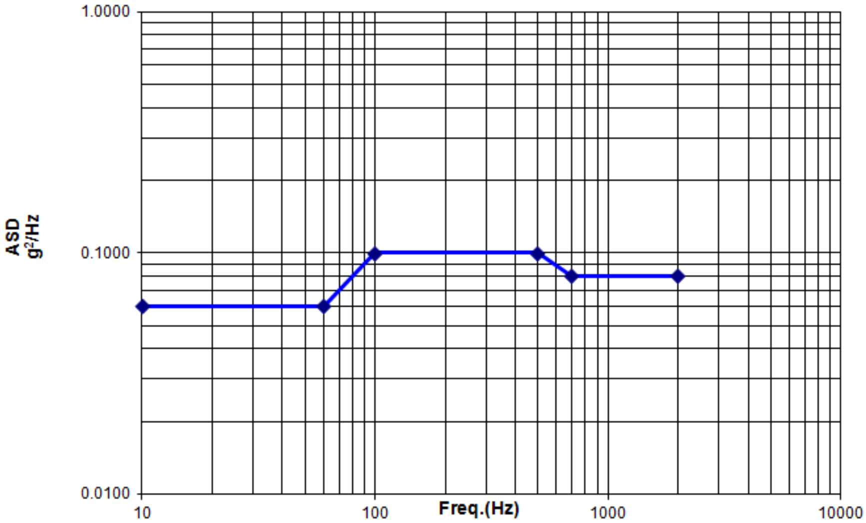
Applicability: All components attached to the engine or transmission.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to IEC 60068-2-64, Test Fh, Vibration, broad-band random (digital control) and guidance.

Figure 28: Random Vibration Profile for Engine or Transmission



Effective Acceleration = 127 m/s^2 = 12.96 G_{RMS}

Table 27: Random Vibration Profile for Engine or Transmission

Frequency	Power Spectral Density
10 Hz	5.7702 $(m/s^2)^2/Hz$ = 0.0600 g^2/Hz
60 Hz	5.7702 (m/s2)2/Hz = 0.0600 g^2/Hz
100 Hz	9.6170 $(m/s^2)^2/Hz$ = 0.1000 g^2/Hz
500 Hz	9.6170 $(m/s^2)^2/Hz$ = 0.1000 g^2/Hz
700 Hz	7.6936 $(m/s^2)^2/Hz$ = 0.0800 g^2/Hz
2000 Hz	7.6936 $(m/s^2)^2/Hz$ = 0.0800 g^2/Hz

Criteria: Functional Status Classification shall be A. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of structural damage to the component.

9.3.1.2 Random Vibration – Mounting Location Sprung Masses.

Purpose: This test shall verify that the component is immune from the effects of vibration when it is located on a sprung mass.

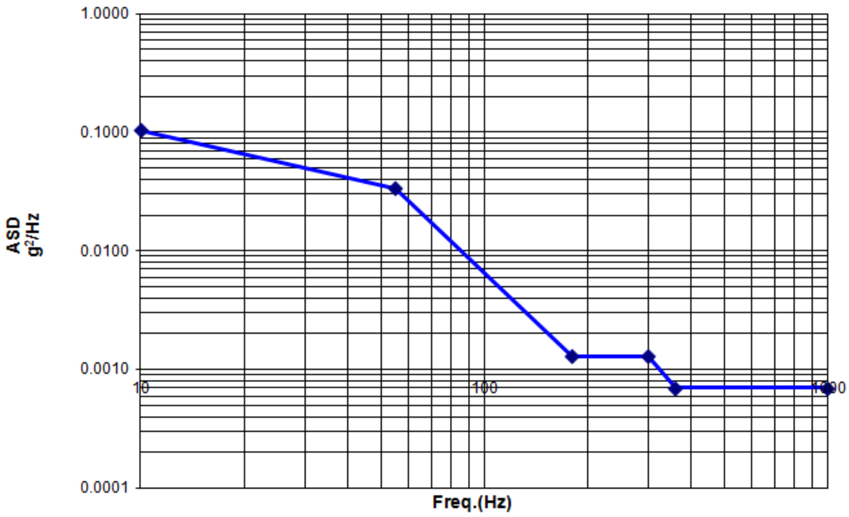
Applicability: All components attached to the body, frame, or sub-frame of a car or truck.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to IEC 60068-2-64, Test Fh, Vibration, broad-band random (digital control) and guidance.

Figure 29: Random Vibration Profile for Sprung Masses



Effective Acceleration = 19.6 m/s² = 2.0 G_{RMS}

Table 28: Random Vibration Profile for Sprung Masses

Frequency	Power Spectral Density
10 Hz	9.9248 $(m/s^2)^2$/Hz = 0.1032 g^2/Hz
55 Hz	3.2313 $(m/s^2)^2$/Hz = 0.0336 g^2/Hz
180 Hz	0.1250 $(m/s^2)^2$/Hz = 0.0013 g^2/Hz
300 Hz	0.1250 $(m/s^2)^2$/Hz = 0.0013 g^2/Hz
360 Hz	0.0673 $(m/s^2)^2$/Hz = 0.0007 g^2/Hz
1000 Hz	0.0673 $(m/s^2)^2$/Hz = 0.0007 g^2/Hz

Criteria: Functional Status Classification shall be A. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of structural damage to the component.

9.3.1.3 Random Vibration – Mounting Location Unsprung Masses.

Purpose: This test shall verify that the component is immune from the effects of vibration when it is located on an unsprung mass.

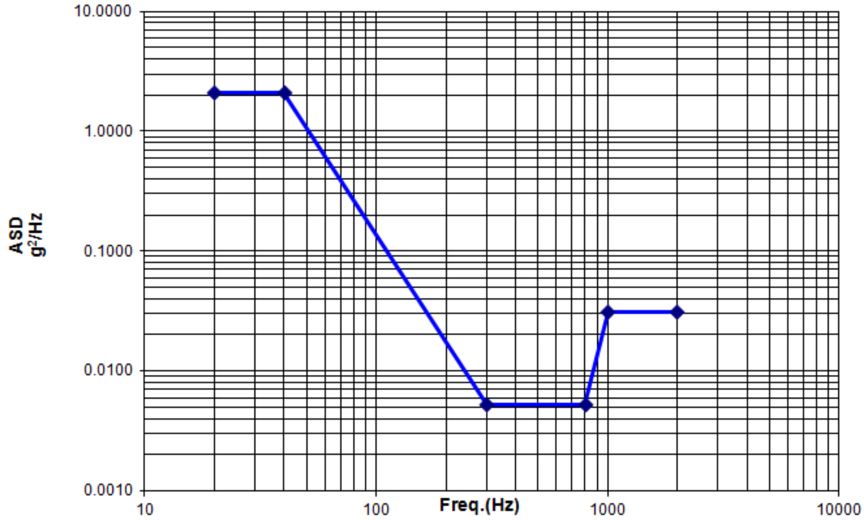
Applicability: All components attached to the wheels, tires, or moving suspension elements of a car or truck.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to IEC 60068-2-64, Test Fh, Vibration, broad-band random (digital control) and guidance.

Figure 30: Random Vibration Profile for Unsprung Masses



Effective Acceleration = 107.3 m/s² = 10.95 G_{RMS}

Table 29: Random Vibration Profile for Unsprung Masses

Frequency	Power Spectral Density
20 Hz	200.2748 $(m/s^2)^2/Hz$ = 2.0825 g^2/Hz
40Hz	200.2748 $(m/s^2)^2/Hz$ = 2.0825 g^2/Hz
300 Hz	0.5001 $(m/s^2)^2/Hz$ = 0.0052 g^2/Hz
800 Hz	0.5001 $(m/s^2)^2/Hz$ = 0.0052 g^2/Hz
1000 Hz	3.0005 $(m/s^2)^2/Hz$ = 0.0312 g^2/Hz
2000 Hz	3.0005 $(m/s^2)^2/Hz$ = 0.0312 g^2/Hz

Criteria: Functional Status Classification shall be A. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of structural damage to the component.

9.3.1.4 Thermal Cycle Profile Used During All Vibration Tests. Vehicle vibration stress can occur together with extremely low or high temperatures; therefore, a simultaneous temperature cycle profile as shown below shall be applied repetitively during the vibration tests.

Figure 31: Thermal Cycle Profile Used During All Vibration Tests

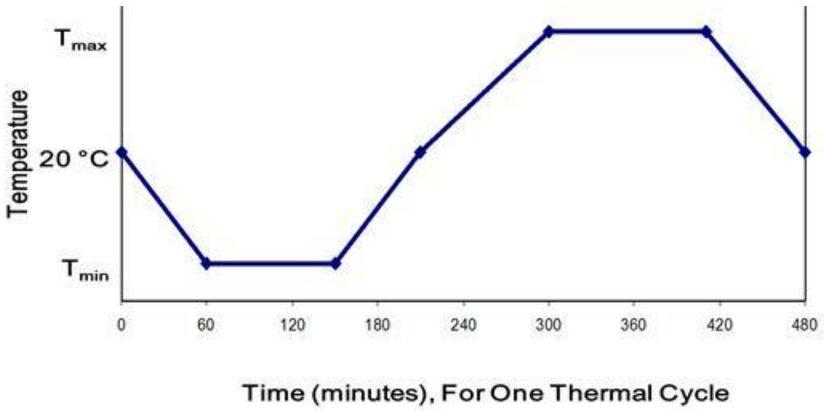


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Table 30: Thermal Cycle Profile Used During All Vibration Tests

Time	Temperature
0 minutes	+20 °C
60 minutes	T_{min}
150 minutes	T_{min}
210 minutes	+20 °C
300 minutes	T_{max}
410 minutes	T_{max}
480 minutes	+20 °C

9.3.2 Mechanical Shock – Pothole.

Purpose: This test shall verify the component's immunity to mechanical shock events produced by potholes.

Applicability: All components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to IEC 60068-2-27, Test Ea, Shock. Refer to Table 31 for details. Use a half sine shock pulse.

Table 31: Mechanical Shock – Pothole

Component Location	Peak	Duration	Number of Impacts
Unsprung Masses	100 G	11 ms	20 x 6 = 120
Sprung Masses	25 G	10 ms	400 x 6 = 2400
Sprung Masses (Passenger Compartment, if agreed upon by GM Engineering)	12 G	20 ms	400 x 6 = 2400

Note: The multiplier of 6 as noted in Table 31 refers to the six Cartesian directions of possible motion.

Note: Refer to paragraph 6.8 "Vibration Transmissibility Demonstration" for component mounting instructions.

Criteria: Functional Status Classification shall be A. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of structural damage to the component.

9.3.3 Mechanical Shock – Collision.

Purpose: This test shall verify the component's immunity to mechanical shock events produced by minor collisions (< 25.7 km/h or 16 miles/h).

Applicability: All components.

Operating Type: 1.2

Monitoring: Not applicable

Procedure: Use the test methods according to IEC 60068-2-27, Test Ea, Shock. Refer to Table 32 for details.

Perform a 1-Point Functional/Parametric Check.

Table 32: Mechanical Shock - Collision

Description	Value
Acceleration	50 G
Nominal shock duration	11 ms
Nominal shock shape	half sine
Total Number of shocks	6 x 6 directions (±X, ±Y, ±Z) = 36

Note: Refer to paragraph 6.8 “Vibration Transmissibility Demonstration” for component mounting instructions.

Criteria: Functional Status Classification shall be C. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of structural damage to the component.

9.3.4 Mechanical Shock – Closure Slam.

Purpose: This test shall verify the component’s immunity to slam events (door, decklid, liftgate, endgate, and hood).

Applicability: Required only for components located in closure areas.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to IEC 60068-2-27, Test Ea, Shock. Refer to Tables 33 thru 34 for details.

Table 33: Slam Based Mechanical Shock Loads

Description	Value
Side Door or Liftgate < 1 m in length	40 G
Side Door or Liftgate ≥ 1 m in length, or Rear back door	90 G
Decklid, Endgate, or Hood Latch Ajar Switch	40 G
Touch pads or side door latches	90 G
Nominal shock duration	6 ms
Nominal shock shape	half sine

Table 34: Total Quantity of Mechanical Shocks for Closures

Closure	Number of shocks
Driver and Passenger Front Door and Rear Back Door	200 000
Decklid	51 600
Rear Side Door	100 000
Liftgate	50 000
Endgate	30 000
Hood	3 000

Table 35: Shock Direction and Temperature for Closure Slam Cycles

Shock Direction	Percent of Total Cycles	Environment
+ Z	10%	Ambient
- Z	10%	Ambient
+ Z	5%	Cold (-30 °C)
- Z	5%	Cold (-30 °C)
+ Z	5%	Hot (+80 °C)
- Z	5%	Hot (+80 °C)
+ X	5%	Ambient
- X	5%	Ambient
+ X	5%	Cold (-30 °C)
- X	5%	Cold (-30 °C)
+ X	5%	Hot (+80 °C)
- X	5%	Hot (+80 °C)
+ Y	5%	Ambient
- Y	5%	Ambient
+ Y	5%	Cold (-30 °C)
- Y	5%	Cold (-30 °C)
+ Y	5%	Hot (+80 °C)
- Y	5%	Hot (+80 °C)

Note: The test must be conducted in all six Cartesian directions, where the Z direction is perpendicular to the plane of the closure when the slam occurs.

Notes:

1. The acceleration values for 40G and 90G are based on measured acceleration data on vehicles with the same or similar closure panel architecture. This test was developed from actual measured vehicle data of slam events. This level represents the worst case shock, as measured from a collection of different vehicles and mounting locations.
2. The cycle counts are based on the requirements in the GM Closures SSTS specifications.
3. Refer to paragraph 6.8 “Vibration Transmissibility Demonstration” for component mounting instructions.

Criteria: Functional Status Classification shall be A. No structural damage to the component is permitted. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of structural damage to the component.

9.3.5 Crush For Housing – Elbow Load.

Purpose: This test shall verify that the housing of the component and the parts inside of the housing are not affected by resting on the component with elbow loads.

Applicability: All components

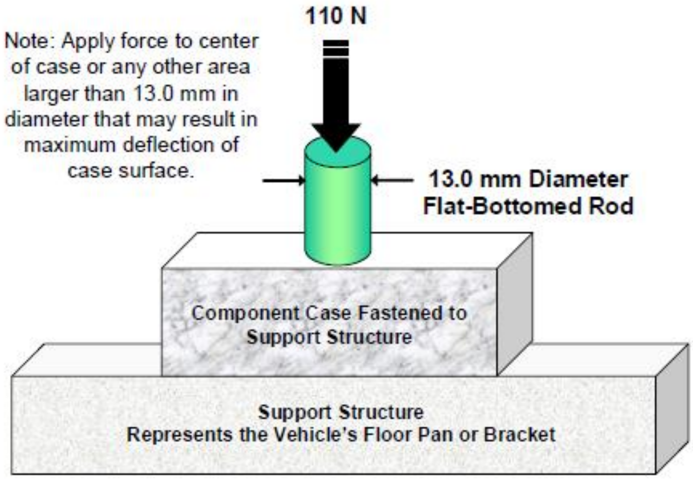
Operating Type: 1.1

Monitoring: Observe physical case deflection during loading.

Procedure: The component shall be set up to allow testing on all external surfaces with a 13.0 mm or larger diameter area. Subject the component to an evenly distributed 110 N force about any 13.0 mm diameter area for 1.0 s as shown in Figure 32 (this represents the force applied by a person's elbow).

Perform a 1-Point Functional/Parametric Check after all surfaces have been tested.

Figure 32: Elbow Load Applied to Component Housing.



Criteria:

1 Functional Status Classification shall be C.

2 The component shall be opened and inspected for any evidence of contact and signs of damage, including the housing, connector, and PCB assembly, as part of the Visual Inspection and Dissection – DRBTR. No contact between the case, PCB assembly, and other electrical parts shall be allowed. No damage to the housing, connector, PCB assembly, other electrical parts, and mechanical parts shall be allowed.

3 The deflection forces must not cause the cover to detach or "open up".

9.3.6 Crush For Housing – Foot Load.

Purpose: This test shall verify that the housing of the component and the parts inside of the housing are not affected by resting on the component by foot loads.

Applicability: All components that may experience foot loads during vehicle assembly or servicing.

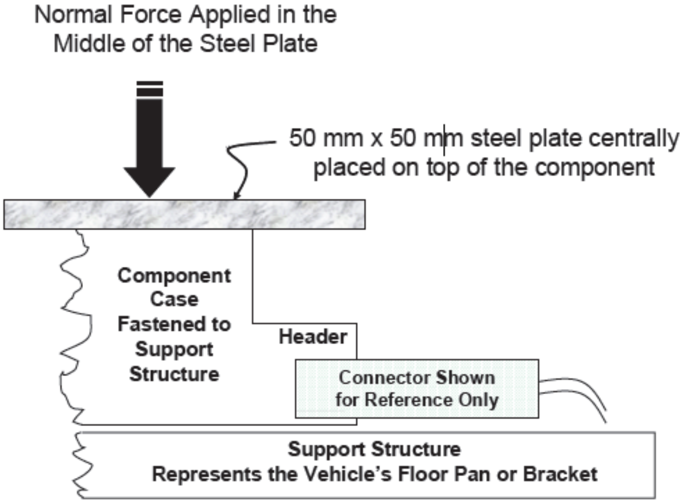
Operating Type: 1.1

Monitoring: Observe physical case deflection during loading.

Procedure: Locate a 50 mm x 50 mm (or appropriately sized) rigid steel plate on all applicable surface(s) of the component. Subject the component to an evenly distributed 890 N force applied normally to the applicable surface(s) of the component through the steel plate for 1 minute as shown in Figure 33.

Perform a 1-Point Functional/Parametric Check after the test.

Figure 33: Foot Load Applied to Applicable Surface of Component Housing



Criteria:

1 Functional Status Classification shall be C.

2 The component shall be opened and inspected for any evidence of contact and signs of damage, including the housing, connector, and PCB assembly, as part of the Visual Inspection and Dissection – DRBTR. No contact between the case, PCB assembly, and other electrical parts shall be allowed. No damage to the housing, connector, PCB assembly, other electrical parts, and mechanical parts shall be allowed.

3 The deflection forces must not cause the cover to detach or "open up".

9.3.7 GMW3191 Connector Tests.

Purpose: These tests shall verify the functionality and durability of the connector according to GMW3191.

Applicability: All connectors of the component that interface to the vehicle harness. This includes connectors that are permanently attached to a wiring harness (pigtail).

Note: Typically, for the first development of a new connector system (used in a new component), the validation is performed as part of the entire GMW3191 execution, and those results may be used as surrogate data to demonstrate these GMW3172 requirements.

When a component introduces a change to a component's connector system or uses a connector that has never been tested by GMW3191 on this application, these are the minimum tests from GMW3191, which are identified here in GMW3172, that need to be executed.

Other tests from GMW3191 and/or GMW3172 may also apply to ensure appropriate connector functionality, such as the Seal test. However, if a new connector supplier is implemented, the connector system needs to be re-tested according to the entire GMW3191.

Operating Type: See GMW3191.

Monitoring: See GMW3191.

Procedure: The following GMW3191 (Connector Test and Validation Specification) tests shall be executed on the component assembly:

Note: The test names and procedures are according to GMW3191, issue date June 2012. The tests shall be performed according to the latest version of GMW3191.

- Terminal Push-out Force

This test measures the minimum force needed to displace a terminal a small distance in the component. This assures that normal mating and un-mating operations do not cause a displacement that degrades the electrical performance of the connector system.

Note: This test will damage the component.

Note: This test requires 10 component samples. Each pin on each component shall be tested.

- Connector-to-Connector Engagement Force

The connection system to mate a component's connector(s) to the vehicle's wiring harness should not require excessive force for a person to perform manually. Therefore, forces needed to engage fully populated female and male connectors to each other cannot exceed specified levels. Otherwise, the connection will be too difficult for people to manually perform.

This test verifies that the mating force of a connector system is not excessive (reference USCAR-25 for the ergonomic requirements) during the vehicle assembly process and service operations.

Note: This test should not damage the component.

Note: This test requires 10 component samples with connectors that are fully populated with terminals and wires in order to test 10 mating connector pairs for each connector of the component.

- Locked Connector Disengagement Force

Connectors use locking mechanisms to lock the connection system together as an added assurance against disengagement due to vibration events or external forces applied to the harness.

This test verifies that a connector system (with a primary locking feature) will not become unmated when a minimum force is applied. This will ensure that a connector system remains mated in a vehicle application.

Note: This test will damage the connector housing.

Note: This test requires 10 component samples with connectors that are not populated with terminals and wires in order to test 10 mating connector pairs for each connector of the component.

- Unlocked Connector Disengagement Force

Connectors may need to be disengaged during vehicle service, i.e., to replace a failed component or make repairs to a component.

If the locking features are properly disengaged, the connection system should not require excessive manual force to disconnect. Likewise, the lock feature itself should not require excessive manual force to disengage. Otherwise, these tasks will be too difficult for people to perform manually.

This test verifies that the un-mating force of a connector system (with all locks disengaged) is not excessive during service operations. Also, this test verifies that the force to disengage the primary locking feature(s) is not excessive during service operations.

Note: This test will damage the connector housing.

Note: This tests requires 10 component samples with connectors that are fully populated with all terminals, wires, TPA's, and seals. 5 of these test samples will have the connector lock physically removed or otherwise disabled.

Criteria: See GMW3191.

9.3.8 Connector Installation Abuse – Side Force.

Purpose: This test shall verify that the connector(s) of the component are not affected by resting on the connector by hand or elbow loads as a result of side forces during connector attachment or other assembly operations.

Applicability: All components that have connectors with at least a 13.0 mm diameter area.

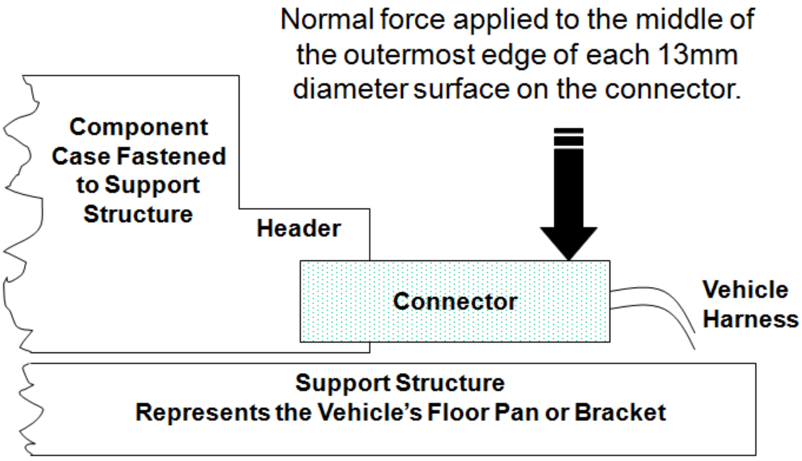
Operating Type: 1.2

Monitoring: Not applicable

Procedure: The component shall be set up to allow testing on the connector surface with a 13.0 mm or larger diameter area. Subject the connector to an evenly distributed 110 N force about each 13.0 mm diameter area for 1.0 s, as shown in Figure 34. Repeat this test for all applicable surfaces and connectors.

Perform a 1-Point Functional/Parametric Check after all surfaces have been tested.

Figure 34: Side Force Connector Setup



Criteria: Functional Status Classification shall be C. Additionally, during the Visual Inspection and Dissection – DRBTR, the connector(s), housing, and circuit board to which the connector is attached shall not show any damage.

9.3.9 Connector Installation Abuse – Foot Load.

Purpose: This test shall verify that the connector(s) of the component are not affected by foot loads on the connector.

Applicability: All components that may experience foot loads during vehicle assembly or servicing.

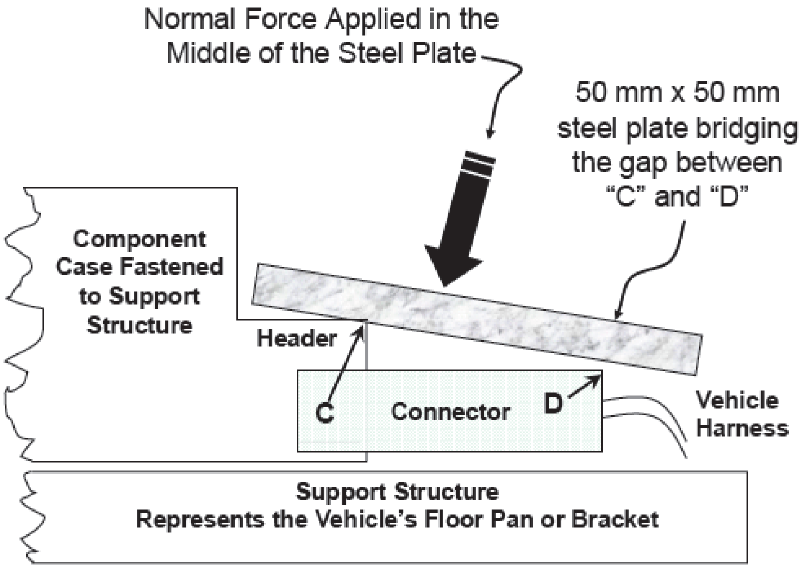
Operating Type: 1.2

Monitoring: Not applicable

Procedure: A simulated foot load of 890 N of a distributed force shall be applied normally through a (50 x 50) mm (or appropriately sized) rigid steel plate for 1 minute to the connector and connector header as shown in Figure 35. This plate represents the sole of a person's shoe. Repeat this test for all applicable directions and connectors.

Perform a 1-Point Functional/Parametric Check after all surfaces have been tested.

Figure 35: Foot Load Connector Setup



Criteria: Functional Status Classification shall be C. Additionally, during the Visual Inspection and Dissection – DRBTR, the connector(s), housing, and circuit board to which the connector is attached shall not show any damage.

9.3.10 Free Fall.

Purpose: This test shall verify that the component will not suffer functional degradation after a falling event if no visible damage is observed. Damage may occur if the component is dropped on the floor during handling, assembly, or service.

Applicability: All components

Operating Type: 1.1

Monitoring: Not applicable

Procedure:

1 Perform the test using the following parameters:

- Number of test samples: 3
- Drops per test sample: 2
- T_{room}
- Drop Height: 1 m
- Drop Surface: Concrete

2 Choose the X-axis for the first drop. Following the drop, perform a 1-Point Functional/Parametric Check.

3 Repeat the drop with the same axis, but in the opposite direction. Following the drop, perform a 1-Point Functional/Parametric Check.

4 Repeat steps (2) and (3) with the second sample in the Y-axis.

5 Repeat steps (2) and (3) with the third sample in the Z-axis.

6 Document all visual damage by pictures and add them to the test report.

Note: If significant damage occurs in the first of a drop in a given axis, then a new sample needs to be used for the drop in the opposite direction of that axis

Criteria: Minor visible external damage to the component is permitted as long as it does not affect the performance, the attachment interface to the vehicle, or the surfaces visible to the customer. The component shall pass the 5-Point Functional/Parametric Check at the end of the test. Functional Status Classification shall be C.

If there is significant visible external damage to the component as judged by the GM Component Validation Engineer, then the component does not have to meet the performance and functional requirements. The 1-Point Functional/Parametric Check shall still be executed for engineering judgment. Functional Status Classification shall be E.

9.3.11 Fretting Corrosion Degradation.

Purpose: This test shall verify that the contacts inside the component are immune to wear out due to a combination of relative motion, temperature, and humidity.

Applicability: All components that have internal contacts that are not soldered or welded such as fuse holders, press fit connections, PCB-to-PCB connections, ribbon cables, etc.

Operating Type: Not applicable

Monitoring: Not applicable

Procedure:

Note: All Dry Circuit Resistance measurements shall be taken with the samples stabilized at T_{room} for 2 h minimum.

1 Prepare a minimum of 10 mated contacts. The contacts shall be isolated from the internal circuitry to allow the measurement of the contact resistance without any influence from the internal circuitry.

2 Measure the contact resistance per the *Dry Circuit Resistance* measurement test procedure as specified in GMW3191.

3 Subject the components to 4 h of random vibration using the Random Vibration Test according to the mounting location of this component. The default axis of vibration is parallel to the direction of the contact.

4 Measure the contact resistance per the *Dry Circuit Resistance* measurement test procedure as specified in GMW3191.

5 Subject the components to the environmental conditions stated in the Humid Heat Constant test (HHCO) for a duration of 1 day.

6 Measure the contact resistance per the *Dry Circuit Resistance* measurement test procedure as specified in GMW3191.

7 Subject the components to 4 h of random vibration using the Random Vibration Test according to the mounting location of this component. The default axis of vibration is parallel to the direction of the contact.

8 Measure the contact resistance per the *Dry Circuit Resistance* measurement test procedure as specified in GMW3191.

Criteria:

- Functional Status Classification is not applicable to this test.
- The resistance measured shall always meet the value as required by GMW3191 Dry Circuit Resistance Acceptance Criteria.
- The resistance measured in steps (4), (6), and (8) shall not increase more than 2 times the original resistive value measured in step (2).

9.4 Climatic. This section defines additional Climatic procedures for DV. See Table 5 Summary of A/D/V Activities for applicable procedures for DV.

9.4.1 High Temperature Degradation.

Purpose: This test shall verify the component's immunity to degradation resulting from the effects of high temperature.

The 1 h temperature, repaint, and storage portion of the test (T_{RPS}) is designed to evaluate structural warpage effects.

The temperature post heat portion of the test (T_{PH}), which is 5 % of the total test time, adds to the thermal degradation resulting from elevated post heat temperatures. This occurs on underhood components following engine shutoff due to lack of air flow or engine coolant flow through the engine. This results in increased temperature to underhood components.

Applicability: All components.

Operating Type: 2.1 during testing at T_{RPS}; 2.1/3.2 during all remaining portions of the test.

Monitoring: Continuous Monitoring.

Procedure: The test duration of components that are Climatic coded as A, B, C, K, or L shall be 2000 h. All others shall be tested to 500 h.

Note: Components required to be exposed to 2000 h of high temperature reflects the longer operational time at high temperature as opposed to other areas of the vehicle.

Note: For components that contain internal fluids, grease, oil, coolant, etc., the component shall be mounted in vehicle orientation during the test.

Use the test methods according to ISO 16750-4, High-temperature tests, Operation, with the following exceptions:

1 Components that are Temperature coded as A, B, C, or D shall be tested to an elevated temperature level of 95 °C (T_{RPS}) for one additional hour at the beginning of the test, in Operating Type 2.1.

2 The duration of the test, as indicated in the Climatic Load Code (i.e., 500 h or 2000 h), shall be performed with the operating voltages in the following order: U_{max} for 10 %, U_{min} for 10 %, and U_{nom} for 80 % of the total time.

- Components that are Temperature coded as F or H shall be tested to an elevated post heating temperature level (T_{PH}) for 5 % of the entire test duration, applied during the beginning of the U_{nom} portion of the test.
- The component shall be exercised for as many Functional Cycles, as defined in the Component Environmental Test Plan (CG3043), as possible during the test. Functional Cycling shall be applied during all voltage levels.
- The component shall be transitioned to Sleep/OFF mode (Operating Type 2.1) long enough to ensure Sleep/OFF mode, then return back to Operating Type 3.2. As a default, this shall occur once every 4 h.

Criteria: Functional Status Classification shall be A.

9.4.2 Thermal Shock Air-To-Air (TS).

Purpose: This test, in combination with Power Temperature Cycle (PTC), shall verify that the component is immune to thermal fatigue and degradation that is caused by temperature changes and possible miss-matching of the CTE of materials.

The combination of TS and PTC is used to demonstrate the required level of reliability for thermal fatigue.

Applicability: All components.

Operating Type: 1.1

Monitoring: Not applicable.

Procedure: Use the test methods according to ISO 16750-4, Temperature cycling – Rapid change of temperature with specified transition duration, with the following requirements:

- Manual transfer methods between chambers shall not be used.
- The thermal test profiles shall be determined according to the Thermal Cycle Profile Development section in GMW3172. This information shall be approved by GM prior to starting the test.

1 Perform the required number of Thermal Shock cycles per Table 36. The sample size and distribution of cycles between TS and PTC are the recommended default values.

Note: Optionally, since Thermal Shock Air-to-Air is not monitored, it is acceptable to periodically stop the test to verify functionality.

Note: To check for specific failure mechanisms of a material other than Lead-Free solder (e.g., copper windings, aluminum wire bonds, etc.) that has a higher accelerated fatigue rate (i.e., higher S-N slope) it is acceptable to perform a 5-Point Functional/Parametric Check at the point when the required reliability has been demonstrated for that material.

Note: If a component needs to be permanently removed during the test, it should be replaced with a dummy component in order to maintain the same thermal characteristics in the chamber.

2 Perform a 1-Point Functional/Parametric Check at the conclusion of the Thermal Shock Air-to-Air cycles.

Table 36: Number of Thermal Cycles for a Sample Size of 18

Code Letter for Temperature	Vehicle Field ΔT	Combined Number of TS + PTC Cycles	Number of TS Cycles	Number of PTC Cycles
A (-40 °C to +70 °C)	+33 °C	418	318	100
B (-40 °C to +80 °C)	+43 °C	670	512	158
C (-40 °C to +85 °C)	+48 °C	805	615	190
D (-40 °C to +90 °C)	+53 °C	943	720	223
J (-40 °C to +95 °C)	+58 °C	1084	828	256
E, F (-40 °C to +105 °C)	+67 °C	1314	1004	310

Code Letter for Temperature	Vehicle Field ΔT	Combined Number of TS + PTC Cycles	Number of TS Cycles	Number of PTC Cycles
G (-40 °C to +120 °C)	+72 °C	1225	936	289
H (-40 °C to +125 °C)	+77 °C	1348	1030	318
I (-40 °C to +140 °C)	+89 °C	1572	1201	371

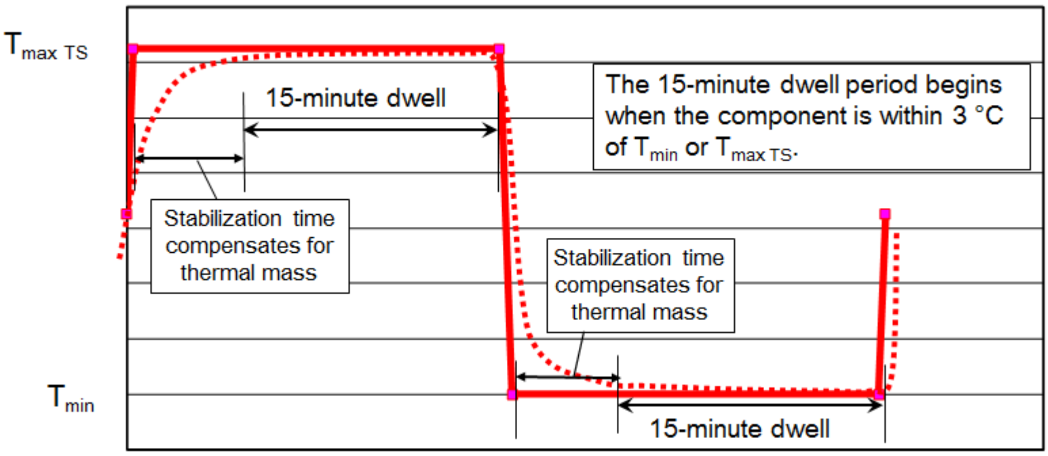
Note: For GM Powertrain-released components, refer to the Powertrain DV/PV Test Flows and the GM Powertrain ENV SME for the number of Thermal Shock Air-to-Air and PTC cycles.

The number of thermal cycles, as shown in Table 36, is based on the following:

- Test Reliability of 97 %, with a Confidence of 50 %. For other levels of Reliability/Confidence, the required number of thermal cycles on test shall be determined by the GM ENV SME.
- Sample size of 18. For other sample sizes, the required number of thermal cycles on test shall be determined by the GM ENV SME.
- An acceleration factor of lead-free solder material, using an S-N slope of 2.65. For other materials, the required number of thermal cycles on test shall be determined by the GM ENV SME.
- Temperature Change Rates of 19 K/minute for Thermal Shock and 7 K/minute for PTC. For other change rates, the required number of thermal cycles on test shall be determined by the GM ENV SME.
- Two thermal cycles per day of customer usage, based on two drive cycles per day. For components that experience multiple thermal cycles per drive cycle (e.g., wheel speed sensors, high current power electronics, etc.) the required number of thermal cycles on test shall be determined by the GM ENV SME and the GM DRE.

Figure 36: Thermal Shock Profile

Note: The solid line is the temperature of the chamber. The dashed line is the internal temperature of the component at material interfaces (e.g., solder joints). Stabilization time (as developed in *Thermal Cycle Profile Development*) is added to compensate for component thermal mass, ensuring that the component soaks at T_{min} and $T_{max\ TS}$ for a 15-minute dwell period. Tmax TS is the temperature due to self-heating, while at Tmax, and is determined in the *Thermal Cycle Profile Development.* Since the component is not powered in this test, Tmax TS compensates for the lack of self-heating.



Criteria: Functional Status Classification shall be C.

9.4.3 Power Temperature Cycle (PTC).

Purpose: This test, in combination with Thermal Shock (TS), shall verify that the component is immune to thermal fatigue and degradation that is caused by temperature changes and possible miss-matching of the CTE of materials.

This test is continuously monitored; therefore, PTC may detect intermittent operation due to open circuit conditions caused by thermal fatigue.

The combination of PTC and TS is used to demonstrate the required level of 97 % reliability and 50 % confidence.

Applicability: All components.

Operating Type: 1.2/3.1/3.2 (refer to Table 37, Power Moding)

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to ISO 16750-4, Temperature cycling – Temperature cycle with specified change rate, according to the parameters from Table 37, along with the following requirements:

- For components that contain internal fluids, grease, oil, coolant, etc. the component shall be mounted in vehicle orientation during the PTC test.
- The thermal test profiles shall be determined according to the Thermal Cycle Profile Development section in GMW3172. This information shall be approved by GM prior to starting the test.
- The electrical/mechanical loading shall reflect the normal usage in the vehicle application.

Perform the required number of PTC cycles per Table 36. The sample size and distribution of cycles between TS and PTC are the recommended default values.

Note: If a component needs to be permanently removed during the test, it should be replaced with a dummy component in order to maintain the same thermal characteristics in the chamber.

Figure 37: Power Temperature Cycle Profile

Note: The solid line is the temperature of the chamber. The dashed line is the internal temperature of the component at material interfaces (e.g., solder joints). Stabilization time (as developed in *Thermal Cycle Profile Development*) is added to compensate for component thermal mass, ensuring that the component soaks at T_{min} and T_{max} for a 15-minute dwell period.

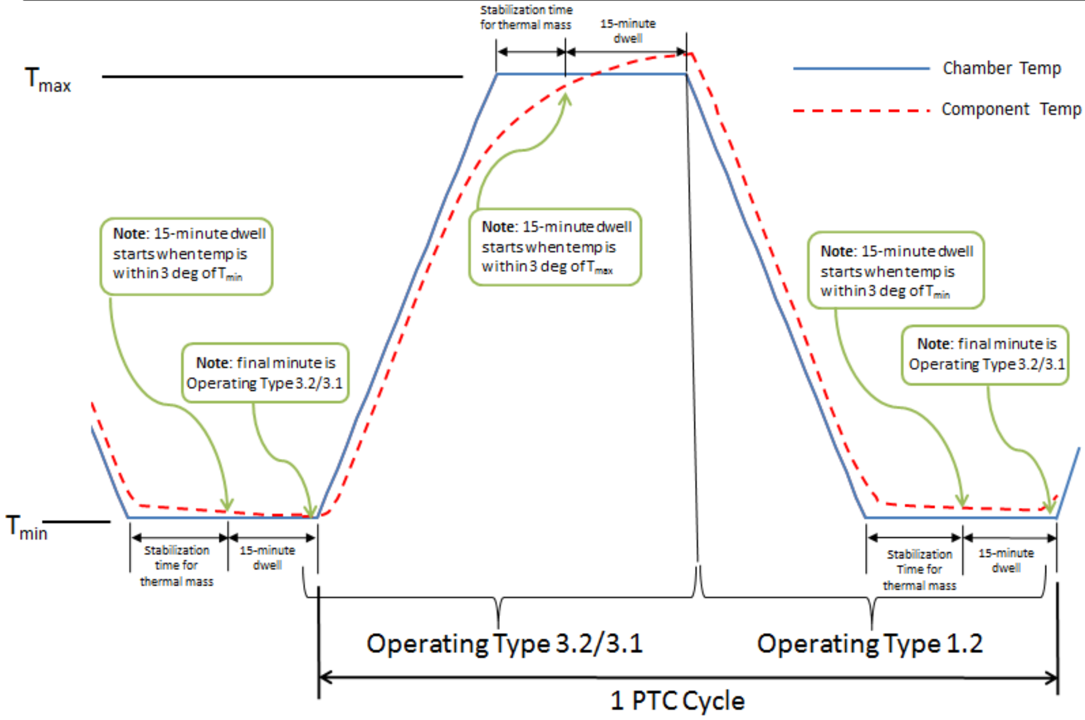


Table 37: Power Temperature Cycle Requirements

Description	Value
Temperature Range	T_{min} to T_{max}
Temperature Change Rate	(1 to 10) K/minute
Minimum number of PTC cycles	100. This shall be combined with the number of Thermal Shock Air-to-Air cycles to be in accordance with the total number of thermal cycles required by GMW3172.
Power Moding	Power OFF (Operating Type 1.2) starting with the negative thermal transition. At the beginning of the final minute of the 15-minute dwell at T_{min}, by default, begin cycling ON (Operating Type 3.2) for 100 s and Sleep/OFF (Operating Type 3.1) for 20 s until the next negative thermal transition begins.
Functional Cycling	The component shall be operated for as many Functional Cycles as possible during the PTC duration. Functional Cycling shall be applied during all voltage levels.
Supply Voltage	The test operating voltage shall be performed in the following order: U_{max} for 10 %, U_{nom} for 80 %, and U_{min} for 10 % of the cycles.

Criteria: Functional Status Classification shall be A.

9.4.4 Thermal Shock/Water Splash.

Purpose: This test shall verify the component's functionality during and after exposure to sudden changes in temperature due to a water splash.

Applicability: All components that are located in the area where a splash could occur while driving (e.g., low mounted on the engine).

Operating Type: 1.2/3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to ISO 16750-4, Ice water shock test, using the Splash water test method.

The water solution shall include a soluble Ultraviolet dye that can be detected with a UVA lamp (black light).

Criteria: Functional Status Classification shall be A. The component shall be opened and inspected for signs of water ingress as a part of the Visual Inspection and Dissection – DRBTR. An internal inspection using a UV light shall be performed. No water ingress shall be permitted inside the component and the connector.

9.4.5 Humid Heat Cyclic (HHC).

Purpose: This test shall verify the component's immunity to internal condensation that may lead to electrical sneak paths as well as functional and material degradation. The breathing effect produced by changes in humidity, condensation resulting from rapid changes in temperature, and the expansion effect of freezing water in cracks and fissures are the essential features of this test.

This test is also effective in evaluating components with seals.

Applicability: All components.

Operating Type: 2.1/3.2. The component shall be cycled between ON (Operating Type 3.2, operated in such a manner to minimize power dissipation) and Sleep/OFF (Operating Type 2.1) to avoid local drying.

As a default, the component shall be cycled between ON for 1 h and Sleep/OFF for 1 h continuously during the 10-day test.

A supply voltage of U_A shall be used during Operating Type 3.2 and a supply voltage of U_B during Operating Type 2.1.

Monitoring: During the ON state, Continuous Monitoring is required. During the Sleep/OFF state, continuous parasitic current is monitored and recorded over the 10-day test period to detect malfunctions during the test.

Procedure: Use test equipment according to IEC 60068-2-38, Test Z/AD, Composite temperature/ humidity cyclic test, and then perform the test as stated in Table 38.

Note: The component shall be mounted in vehicle orientation to simulate the condensation drip path.

Note: This profile is not intended to cause water drops to form or fall onto the circuit board. If this occurs, an adjustment in the profile according to IEC 60068-2-38 to slow down the ramp rate is allowed. This will result in shorter dwell times, in accordance to the IEC, in order to keep the overall 48 h cycle time.

Table 38: Cyclic Humidity Requirements

Description	Value
High Temperature	+65 °C
Middle Temperature	+25 °C
Low Temperature	-10 ºC
Duration	10 days

Figure 38 and Table 39 show a two-day cycle that shall be repeated a total of five times (2 x 5 = 10 days).

The humidity during high temperature is (93 ± 3) % and drops to 80 % during the transition from (+65 to +25) °C. At +25 °C, the humidity shall increase to (93 ± 3) %. The humidity is uncontrolled when < +25 °C.

Figure 38: Cyclic Humidity Profile

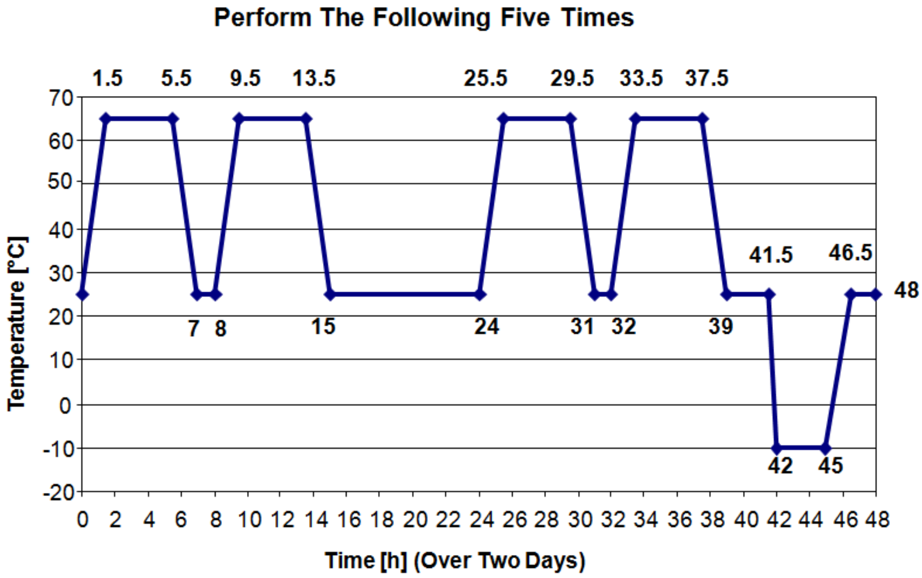


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Table 39: Cyclic Humidity Profile

Time	Temperature
0 h	+25 °C
1.5 h	+65 °C
5.5 h	+65 °C
7 h	+25 °C
8 h	+25 °C
9.5 h	+65 °C
13.5 h	+65 °C
15 h	+25 °C
24 h	+25 °C
25.5 h	+65 °C
29.5 h	+65 °C
31 h	+25 °C
32 h	+25 °C
33.5 h	+65 °C
37.5 h	+65 °C
39 h	+25 °C
41.5 h	+25 °C
42 h	-10 °C
45 h	-10 °C
46.5 h	+25 °C
48 h	+25 °C

Criteria: Functional Status Classification shall be A. The parasitic current shall not exceed the required limit or increase by > 50 % from the beginning of this test. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of electromigration or dendritic growth.

9.4.6 Humid Heat Constant (HHCO).

Purpose: This test shall verify the component's immunity to high humidity that may lead to functional and material degradation.

The Humid Heat Constant test is also effective in evaluating water vapor diffusion through plastic encapsulations.

Applicability: All components.

Operating Type: 2.1/3.2. The component shall be cycled between ON (Operating Type 3.2, operated in such a manner to minimize power dissipation) and Sleep/OFF (Operating Type 2.1) to avoid local drying.

As a default, the component shall be cycled between ON for 1 h and Sleep/OFF for 1 h continuously during the 10-day test.

A supply voltage of U_A shall be used during Operating Type 3.2 and a supply voltage of U_B during Operating Type 2.1.

Monitoring: During the ON state, Continuous Monitoring is required. During the Sleep/OFF state, continuous parasitic current is monitored and recorded over the 10-day test period to detect malfunctions during the test.

Procedure: Use test equipment according to IEC 60068-2-78, Damp heat, steady state, and then perform the test as stated in Table 40.

Note: The component shall be mounted in vehicle orientation to simulate the condensation drip path.

Table 40: Constant Humidity Requirements

Description	Value
Temperature	(+65 ± 3) °C
Duration	10 days
Relative Humidity	(90 ± 5) %

Criteria: Functional Status Classification shall be A. The parasitic current shall not exceed the required limit or increase by > 50 % from the beginning of this test. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no evidence of electromigration or dendritic growth.

9.4.7 Salt Mist.

Purpose: This test shall verify the component's ability to withstand exposure to salt mist as experienced in coastal regions and salted road splash.

Applicability: All components located in the passenger and luggage area (interior of the vehicle).

Operating Type: 1.2/2.1/3.2

Monitoring: Continuous Monitoring during the time that the component is energized.

Procedure: For the Operating Test and Material Degradation Test, use the test setup and test methods according to IEC 60068-2-52, Test Kb, Salt mist, cyclic. Use applicable tests, durations, and number of cycles as defined in Table 41. Use the salt mist levels as defined for each test below. Perform tests with enclosure simulating vehicle mounting.

Table 41: Salt Mist Test Requirements

Component Type	Operating Test	Material Degradation Test
Non-sealed components with vent openings (IP Water Code 2)	Operating Type 3.2 (with internal fans turned off) 1 cycle. Each cycle equals 2 h salt. (FSC A)	**Not applicable**
Non-sealed components without vent openings (IP Water Code 2)	Operating Type 3.2 1 cycle. Each cycle equals 2 h salt. (FSC A)	Operating Type 1.2 3 cycles. Each cycle equals 2 h salt, 22 h humidity. (FSC C)
Non-sealed components without vent openings (IP Water Code 3 or 4K)	Operating Type 3.2 1 cycle. Each cycle equals 2 h salt. (FSC A)	Operating Type 2.1 6 cycles. Each cycle equals 8 h salt, 16 h humidity. (FSC C)
Sealed components with or without a pressure exchange membrane (IP Water Code 8)	Not applicable	Operating Type 3.2 10 cycles. Each cycle equals 8 h salt, 16 h humidity. (FSC A)

Operating Test:

Use a mist level of (0.25 to 0.5) ml/h on 80 cm^2.

Note: This test is a measure of the degradation of function resulting from a salty air environment with expectations of proper function of the component.

Material Degradation Test:

Use a mist level of (1.0 to 2.0) ml/h on 80 cm^2.

For FSC C, perform a 1-Point Functional Check following the Material Degradation Test.

Final Inspection (after completion of all tests):

Document the appearance of the component following the test. Perform a detailed inspection of damaged interior electronics. Inspect for loss of parent metal that may lead to loss of internal or external electrical connections. Also inspect for concentrated pitting corrosion. Inspect the integrity of all seals.

Criteria: Functional Status Classification shall be A or C, according to Table 41. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no liquid ingress and/or internal dendrites.

Based on the level of corrosion, GM Engineering will decide as to the necessity of corrective action.

9.4.8 Salt Spray.

Purpose: This test shall verify the component's ability to withstand exposure to salt spray as experienced in coastal regions and salted road splash.

Applicability: All non-interior components located on the vehicle. This includes under the hood, within the plenum at the base of the windshield, and within the doors (wet area).

Operating Type: 1.2/3.2

Monitoring: Continuous Monitoring during the time that the component is energized.

Procedure:

1 Mount the component in its intended orientation (if possible) with appropriate load and voltage applied as described below. The component shall be placed at an optimum distance from the salt spray nozzles to ensure that the salt spray has enough volume and force to wash away the products of corrosion that are created during the test. The salt spray shall be adjusted to create the maximum salt spray pattern (cone pattern) focusing on the identified target area(s).

2 The salt spray solution shall be 5 % salt by weight. The pH of the solution shall be maintained from 6.5 to 7.2 which should be checked once per day.

3 Soak the component for 1 h at a chamber temperature of +70 °C in the salt spray chamber with the component powered OFF (Operating Type 1.2). There shall be no salt spraying during this hour.

4 Adjust the spray chamber to a temperature of +35 °C. Power ON the component (Operating Type 3.2). Begin spraying immediately for a duration of 1h. The spray solution shall be at T_{room}.

5 Turn off the salt spray and Power OFF the component while allowing the chamber and component to cool for 1 h at T_{room}. Humidity is uncontrolled during this hour.

6 Repeat steps (3) to (5) three times for a total of 9 h.

7 Power ON the component and soak it for 15 h at T_{room}. Humidity is uncontrolled. There shall be no salt spraying during these 15 h.

8 This 24 h test sequence, steps (3) to (7), shall be repeated for multiple days as shown in Table 42.

9 All inspections shall be performed and documented, including photographs during the Visual Inspection and Dissection – DRBTR. Document the appearance of the component following the test. Perform a detailed inspection of damaged interior electronics. Inspect for loss of parent metal that may lead to loss of internal or external electrical connections. Also inspect for concentrated pitting corrosion. Inspect the integrity of all seals.

Table 42: Salt Spray Test Duration Requirements Based on Location

Location	Test duration	
Wet Side of Door Interior (IP Water Code 3 or 6K)	20 days	= 480 h
Non-Interior component with indirect exposure to salt spray (IP Water Code 6K or 8 or 9K)	30 days	= 720 h
Non-Interior component with direct exposure to salt spray (IP Water Code 6K or 8 or 9K)	40 days	= 960 h

Criteria: Functional Status Classification shall be A. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no liquid ingress and/or internal dendrites. Based on the level of corrosion, GM Engineering will decide as to the necessity of corrective action.

9.5 Enclosure.

9.5.1 Dust.

Purpose: This test shall verify that the component's enclosure sufficiently protects against dust intrusion. This can be from windblown sand, road dust, or other dust types. The accumulation of dust affects heat dissipation and electro-mechanical components.

Applicability: All components.

Operating Type: 1.2

Monitoring: Not applicable

Procedure:

1 Use the test methods according to ISO 20653, "Protection of Electrical Equipment against Foreign Objects, Water and Access". This test shall be performed using the dust in ISO 12103-1, Arizona test dust, A2 fine test dust. The test duration shall be 8 h. For some electromechanical components, the duration may be extended beyond 8 h where appropriate. The component can be tested in an enclosure simulating vehicle mounting.

2 Perform the 1-Point Functional/Parametric Check.

Criteria: Functional Status Classification shall be C. The component shall be opened and inspected as a part of the Visual Inspection and Dissection – DRBTR. For dust rating of 6K, no dust ingress is allowed. For a dust rating of 5K, the quantity and location of dust shall be evaluated for potential risk.

9.5.2 Water.

Purpose: This test shall verify that the component's enclosure sufficiently meets the International Protection requirement when specified by the second characteristic IP Code.

Applicability: All components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to ISO 20653, Protection of electrical equipment against foreign objects, water and access.

The water solution shall include a soluble Ultraviolet dye that can be detected with a UVA lamp (black light).

The component can be tested in an enclosure simulating vehicle mounting/orientation.

Following the procedure, a detailed dissection and inspection of the component shall be performed.

Criteria: Functional Status Classification shall be A. The component shall be opened and inspected for signs of water ingress as a part of the Visual Inspection and Dissection – DRBTR. An internal inspection using a UV light shall be performed.

For non-sealed components, water shall never reach electric/electronic parts or connector terminals. There shall be no drops of water on the circuit board. Additionally, water shall not accumulate within the component housing and reach the electric/electronic parts or connector terminals.

For sealed components, no water shall pass any seal.

9.5.3 Seal.

Purpose: This test shall verify the component's immunity to loss of seal that may lead to water ingress.

Applicability: All sealed components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1 Prepare a test solution consisting of 5 % saline in 0 °C water. The water solution shall include a soluble UltraViolet dye that can be detected with a UVA lamp (black light).

2 Place the component in a temperature chamber at T_{max} for at least 30 minutes or long enough to ensure that Tmax has been reached within the component.

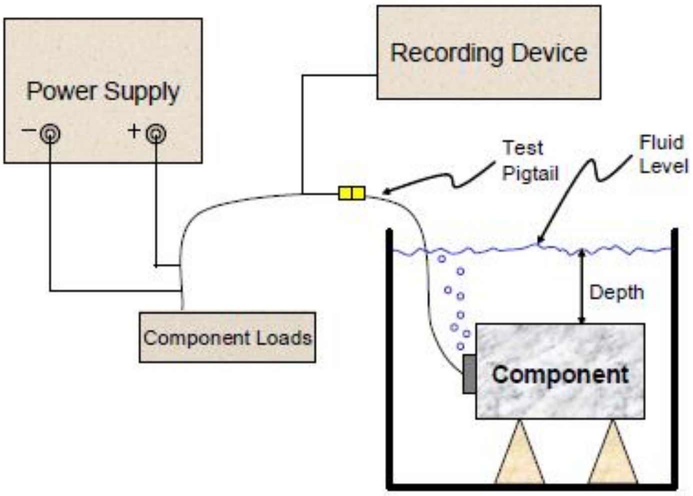
3 Remove the component from the temperature chamber.

4 Immediately immerse the component in the test solution such that the top of the component is at a depth of (76 ± 5.0) mm. See Figure 39 for details.

5 After the component has been submerged for 30 minutes, remove the component from the test solution.

6 Repeat steps (2) to (5) until 15 submerging cycles have occurred.

Figure 39: Seal Test Setup for Components without Ground Wires or Splices



For a component that is connected to a vehicle wiring harness containing a ground wire terminal or any wiring splice that is exposed to water, the following test shall be performed:

1 Reconfigure the test set-up as shown in Figure 40 or Figure 41 with the production-intent ground connection or splice submerged to a depth of (76 ± 5.0) mm.

2 Use new component(s).

3 Repeat steps (1) to (6) from the previous test.

Figure 40: Seal Test Setup for Components with a Ground Wire

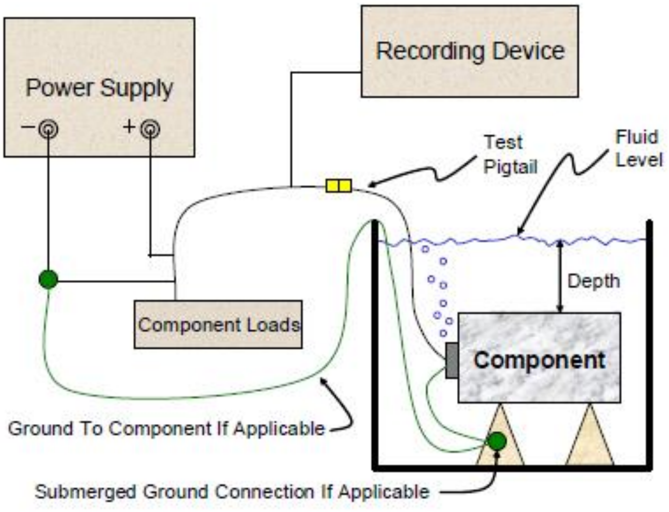
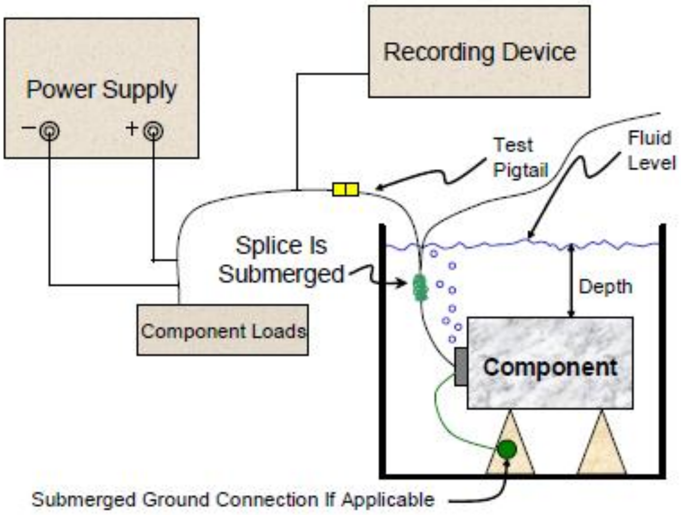


Figure 41: Seal Test Setup for Components with a Splice



Criteria: Functional Status Classification shall be A. The component shall be opened and inspected for signs of water ingress as a part of the Visual Inspection and Dissection – DRBTR. An internal inspection using an UV light shall be performed. No water ingress shall be permitted inside the component and the connector.

9.5.4 Leakage Check.

Purpose: This check shall verify the sealant integrity.

Applicability: All sealed components.

Operating Type: 1.2

Monitoring: Not applicable

Procedure:

Test Method 1: For components that can be pressurized and have a leak rate defined as zero the samples shall be pressurized (default value 48 kPa (7 psi)) and submerged under water for a minimum of 5 minutes with every face up and observe for any bubble flow.

Test Method 2: For components that cannot be pressurized and/or have a non-zero leak rate other methods are available to determine the actual rate (e.g., Air Vacuum Meter Method).

If this test is applied to a component which provides mechanical movement, the test shall be set up in a simulated vehicle environment with all mechanical attachments in place.

Criteria: The leakage rate limit shall be defined in advance and shall not be exceeded. As a default, the leakage rate shall be zero or as defined in the CTS/SSTS.

9.5.5 Water Freeze.

Purpose: This test shall verify component performance after water exposure followed by low temperature. This test simulates the effect of ice formation around the component.

Applicability: All components that may allow water pooling on housings or mechanical linkages, with the exclusion of components located in the passenger compartment.

Operating Type: 2.1/3.2

Monitoring: Continuous Monitoring during Operating Type 3.2.

Procedure: If this test is applied to a component which provides mechanical movement, the test shall be set up in a simulated vehicle environment with all mechanical attachments in place.

1 Apply the Water test at T_{room} according to the IP Code in Operating Type 3.2, then also gradually pour 2 l of water on the component at a rate of ≈ 2 l/minute to allow water pooling.

2 Within 5 minutes, transfer the component while maintaining the vehicle position to a cold chamber and soak at T_{min} for 24 h at Operating Type 2.1.

3 At the end of 24 h, and while still at T_{min}, the component shall demonstrate proper function for 1 h at Operating Type 3.2.

4 Repeat steps (1) to (3) five times.

Criteria: Functional Status Classification shall be A.

9.5.6 Sugar Water Function Impairment.

Purpose: The test shall identify the component's immunity to spilled beverages containing dissolved sugar.

Applicability: All components with mechanical moving parts, such as knobs or buttons, which are customer accessible and are located in the passenger or trunk compartments.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1 The component shall be mounted in its intended orientation with all bezels and covers in place.

2 Sugar water is defined as 200 ml of water with 10 g of sugar fully dissolved.

3 Apply the sugar water onto the component from a distance of 30 cm and wipe away any standing or surface liquid.

4 The sugar water liquid shall be applied (as a single splash) onto horizontal components from the vertical direction, and onto vertical components from a horizontal direction.

5 The component shall remain powered, undisturbed, and allowed to dry at (+23 ± 5) °C for 24 h prior to the evaluation of function.

Criteria: Functional Status Classification shall be A for electrical functions. Degradation in operational forces or torque shall meet the CTS requirements.

9.6 Material. None.

10 Product Validation (PV)

10.1 PV Mission. The Product Validation (PV) shall be a quantitative and qualitative verification that the component meets the requirements for Environmental, Durability, and Reliability when including the effects of production manufacturing. The PV activities shall be executed using components from the production tooling and processes. All PV activities shall be documented in the Component Environmental Test Plan (CG3043).

10.2 Electrical. There are no new Electrical procedures for PV. All Electrical procedures are defined in the Development and Design Validation sections. See Table 5 "Summary of A/D/V Activities" for applicable procedures for PV.

10.3 Mechanical. Shipping Vibration is the only new Mechanical procedure for PV. All other Mechanical procedures are defined in the Development and Design Validation sections. See Table 5 Summary of A/D/V Activities for applicable procedures for PV.

10.3.1 Shipping Vibration.

Purpose: This test shall verify the robustness of the component together with the packaging during shipping.

Applicability: All components (with and without surfaces visible to customers) where the component supplier is responsible for container design.

Note: When GM is responsible for container design, the component supplier is responsible to provide components and any applicable supplier designed inserts to be tested.

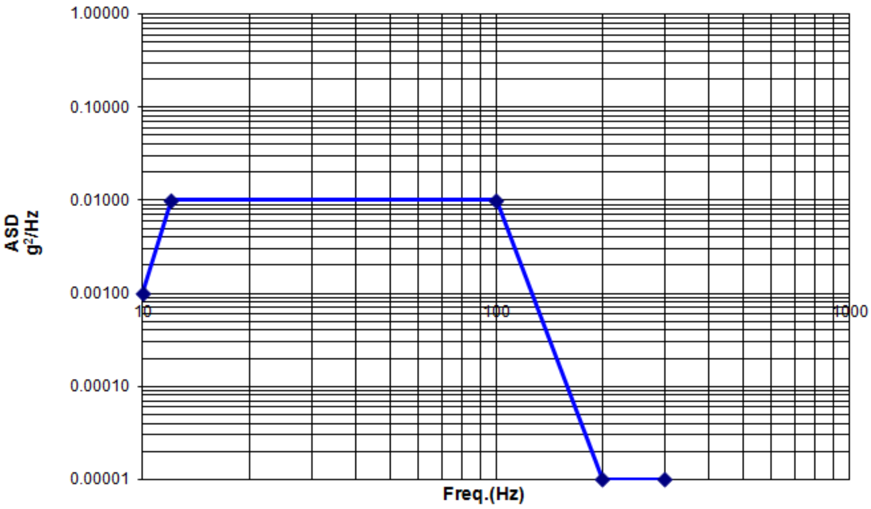
Operating Type: 1.1

Monitoring: Not applicable

Procedure: Use a vibration test fixture that allows the shipping container to move freely in the vertical axis of the vibration table. One possible fixture consists of a base plate with four upright posts that are slightly larger than the shipping container. Provisions shall be made to allow placement of the shipping container in all three directions.

1. Vibrate the shipping container for 24 h in each of the three mutually perpendicular directions using the methods outlined in ASTM D4728. If a supplier can use a vibration table with 6 Degrees Of Freedom, then the test can be run for 24 h only once. This test shall be performed on one fully-populated container of production-intent components in their final shipping container. The shipping container shall include all interior packing material. Use the Random Vibration Profile shown in Table 43 and Figure 42.
2. Inspect all components for structural damage and degradation of surfaces visible to customers.
3. Select components (6 samples as a default) from the highest stress area of the shipping container to perform the 5-Point Functional/Parametric Check.

Figure 42: Random Vibration Profile for Shipping



Effective Acceleration = 9.81 m/s^2 = 1.0 G_{RMS}

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Table 43: Random Vibration Profile for Shipping

Frequency	Power Spectral Density
10 Hz	0.096170 $(m/s^2)^2/Hz$ = 0.00100 g^2/Hz
12 Hz	0.963627 $(m/s^2)^2/Hz$ = 0.01002 g^2/Hz
100 Hz	0.963627$(m/s^2)^2/Hz$ = 0.01002 g^2/Hz
200 Hz	0.000962 $(m/s^2)^2/Hz$ = 0.00001 g^2/Hz
300 Hz	0.000962 $(m/s^2)^2/Hz$ = 0.00001 g^2/Hz

Note: This test is not a life fatigue test for vibration, but rather an evaluation of the ability of the shipping container to provide adequate transport of the component(s) without damaging them. The Vibration with Thermal Cycle test is the life test for the component to demonstrate reliability and confidence for vibration fatigue. This test does not prove vibration fatigue reliability.

Criteria: Functional Status Classification shall be C. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no external visible damage to any of the components. And there shall be no internal damage to the 6 selected components that were functionally tested.

10.4 Climatic. There are no new Climatic procedures for PV. All Climatic procedures are defined in the Development and Design Validation sections. See Table 5 Summary of A/D/V Activities for applicable procedures for PV.

10.5 Enclosure. There are no new Enclosure procedures for PV. All Enclosure procedures are defined in the Development and Design Validation sections. See Table 5 Summary of A/D/V Activities for applicable procedures for PV.

10.6 Material. None

11 Notes

11.1 Glossary.

Component: A level of hardware made up of various parts that are combined to perform an electrical/electronic function and it is the focus of the GMW3172 Component Environmental Test Plan (CG3043).

Part: An element that is used to construct a component such as a transistor, circuit board, housing, motor, and potting material, etc.

Note: Some items, such as a motor, may be considered to be a “component” or a “part” depending on its application and test requirements.

11.2 Acronyms, Abbreviations, and Symbols.

A Ampere

A/D/V Analysis/Development/Validation

ASTM American Society for Testing & Material

CEMENT **C**omponent **E**MC and **EN**vironmental **T**est Database

cm Centimeter

CTE Coefficient of Thermal Expansion

CTS Component Technical Specification

CVE Component Validation Engineer

DRBTR Design Review Based on Test Results

DRE Design Release Engineer

DTC Diagnostic Trouble Code

DV Design Validation

E/E Electrical/Electronic

EMC Electromagnetic Compatibility

ENV SME Environmental Subject Matter Expert

FSC Functional Status Classification

GM General Motors

g Standard acceleration of free fall (Gravitational Constant) 9.80665 m/s^2

G_{RMS} Square root of the area under the PSD vibration curve

h Hour

Hz Hertz

HALT Highly Accelerated Life Test

HAST Highly Accelerated Stress Test

HHC Humid Heat Cyclic

HHCO Humid Heat Constant

HVAC Heating Ventilation Air Condition

IEC International Electrotechnical Commission

IP International Protection

I/O Input/Output

ISO International Standards Organization

IV MRD Integration Vehicle Material Required Date

JEDEC Joint Electron Devices Engineering Council

kPa Kilopascal

l Liter

LED Light Emitting Diode

m Meter

mA Milliampere

ml Milliliter

mm Millimeter

ms Millisecond

mV Millivolt

mΩ Milliohm

Pa Pascal

PCB Printed Circuit Board

PDT Product Development Team

PPEI Platform to Powertrain Electrical Interface

PSD Power Spectral Density

PTC Power Temperature Cycle

PV Product Validation

PWM Pulse Width Modulation

RMS Root Mean Square

s Second

SAE Society of Automotive Engineers

SQE Supplier Quality Engineer

SSTS Subsystem Technical Specification

TS Thermal Shock Air-To-Air

V Volt

VTC Validation Test Complete

Ω Ohm

12 Additional Paragraphs

12.1 All parts or systems supplied to this standard must comply with the requirements of GMW3059, Restricted and Reportable Substances for Parts.

12.2 Environmental References. Additional environmental reference information may be obtained from the following sources:

- Steinberg, Dave S.: Vibration Analysis for Electronic Equipment, Third Edition, John Wiley and Sons, 2000.
- Hobbs, Gregg K.: Accelerated Reliability Engineering – HALT and HASS, John Wiley and Sons, 2000.
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- Clark, Dana W.: AFD and Inventive Troubleshooting, Ideation International Inc., 2000.
- Giacomo, Giulio, et-al: CBGA and C4 Fatigue Dependence on Thermal Cycle Frequency, 2000 International Symposium on Advanced Packaging Materials, 2000.
- Clech, Jean-Paul: SAC Solder Joint Reliability: Test Conditions and Acceleration Factors, SMT/Hybrid/Packaging Conference, Nurnberg, Germany, April 19, 2005.
- Clech, Jean-Paul: Acceleration Factors and Thermal Cycling Test Efficiency For Lead-Free Sn-Ag-Cu Assemblies, SMTA International Conference, Chicago, Il. September 2005.

13 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Example: GMW3172 C C C D A IP5K2

Detailed explanation for coding and inclusion into CTS/SSTS documents appears in this document.

14 Release and Revisions

This standard was originated in September 2000. It was first approved by GM North America (GMNA) in December 2000. It was first published in December 2000.

Issue	Publication Date	Description (Organization)
1	DEC 2000	Initial publication. (McCullen-GMNA)
2	DEC 2001	Complete rework. (McCullen-GMNA)
3	AUG 2004	Complete rework. (Edson-GMNA)
4	JUL 2004	Rewritten to address lead-free solder and improve prior content. (Edson-GMNA)
5	SEP 2005	Complete rework. (Armbrust/Edson/Kurdian/Lange)
6	FEB 2007	Complete rework. (Andreasson/Edson/Kurdian/Lange)
7	AUG 2008	Complete rework and text rephrased. (GMW3172 Global Community)
8	JUL 2010	Added Crank Pulse Capability and Durability test. (GMW3172 Global Community)
9	NOV 2012	Complete rework for added clarity and to incorporate lessons learned. Also: • Added Cross-Section Inspection • Replaced Ground Interconnect Short to Battery test with Multiple Power and Multiple Ground Short Circuits Including Pass Through test • Added Switched Battery Lines test • Added Vibration Transmissibility Demonstration • Deleted Post Thermal Fatigue Vibration • Added Thermal Cycle Profile Development • Added Appendix C - Requirements for GMW3172 Test Reporting • Moved Dimensional Check to Visual Inspection • Modified DV/PV Test Flows (GMW3172 Global Community)
10	AUG 2014	Updates to the following specific procedures: • Simplified Thermal Cycle Profile Development based on DFSS and lessons learned. • Changed Thermal Shock Air-to-Air due to the changes in Thermal Cycle Profile Development. • Changed Power Temperature Cycle due to the changes in Thermal Cycle Profile Development. • Crank Pulse Capability and Durability Test, simplified and reduced cycle count based on DFSS and lessons learned. Eliminated the reference to GMW3097 and referenced the ISO documents directly. • Shipping Vibration changes to only be required when the supplier is responsible for shipping container design. • Mechanical Shock Collision, reduced peak to 50G and increased the number of pulses based on industry comparisons and actual crash data. • Updated version reference for GMW3191. • For High Altitude Shipping Pressure Effect Analysis, modified applicability to include all components that would have concerns with shipping by air to cover emergency situations. • Corrected tolerance error in Vibration Transmissibility Demonstration and added details to be able to calculate the tolerance correctly. • Clarified the correct number of ½ sine pulses required for Mechanical Shock – Closure. • Eliminated magnification required reference for Cross Section and Inspection since one value is not adequate. • Added reference for CG3814 that was created for the Design Review Checklist. (GMW3172 Global Community)
11	OCT 2014	Republished to include Figures 4 thru 8. Corrected Reference information. (Electrical-EMC/Environmental/Durability Global Subsystem Leadership Team)

Appendix A

A1 Lead-Free Solder Considerations

Due to legal regulations in several countries, the use of lead in electrical/electronic components, including solder, is prohibited. Industry has responded with an alternative solder that is lead-free. The most commonly used lead-free solder consists of tin/silver/copper (Sn/Ag/Cu). The use of lead-free solder creates additional risks as described below. The component Environmental Hardware Design Review shall include the following lead-free considerations:

- **Fatigue Life:** Lead-free solder joints may have a reduced fatigue life as compared to lead-based solder joints, even though the tensile strength of lead-free solder is greater than lead-based solder. Lead-free solder joints also may have greater variability in fatigue life as compared to lead-based solder joints.
- **Temperature Solder Process:** Due to higher temperatures of the soldering process which may be associated with lead-free alloys, part aging and “popcorning” shall be considered. “Popcorning” may occur due to trapped humidity inside plastic encapsulated parts which heats up and creates high pressure during the soldering process. This can cause the plastic case or internal die to crack. The humidity ingress can be caused by the part production process or by the uncontrolled environment. Efforts may be necessary to control the humidity of the environment of stored components awaiting assembly.
- **Brittle Solder Alloy:** Brittle solder alloy affects the interconnection of the parts on the PCB. This phenomenon can appear due to an improper PCB manufacturing process (e.g., thin layered Electroless Nickel Immersion Gold solder surfaces) or to solder alloys that change from a ductile nature to a brittle nature in the operational temperature range (e.g., lead-free solder at a temperature of -30 °C). This can represent a significant risk in high mechanical shock areas such as the door, engine, and locations on unsprung masses.
- **Ionic Contamination:** Flux residues from lead-free solder may be more inclined to produce ionic contamination when compared to lead-based fluxes, and special attention shall be given to the frost and humidity testing of lead-free solder assemblies.
- **Bismuth-based solder alloys:** Bismuth-Tin solder alloys may be used to achieve a similar melting point temperature to lead-based solders. Therefore, the parts are exposed to lower melting temperatures. However, the use of Bismuth in lead-free solder may present problems if any leaded components are used on the circuit board. The combination of Bismuth/Tin/Lead can result in a ternary phase material with the following risks:
  1) Low melting point of solder joint (e.g., +96 °C)
  2) Pad-lifting, due to asymmetrical cooling of two different solder alloys on the part attachment
  3) Significant reduction of thermal fatigue life
- **Tin Whiskers:** A detrimental tin-based phenomenon, known as “Tin Whisker Formation”, may occur on solder and on parts. This phenomenon will occur without any special environmental condition being imposed. Parts on the shelf at room temperature will develop tin-whisker formation almost as quickly as parts in service. Whisker formation can be minimized by the use of a boundary layer between the copper and tin (e.g., nickel-plating).
- **Tin Pest:** Another tin-based phenomenon, known as “Tin-Pest”, is also possible when pure tin (> 99.99 %) is used. Wart-like formations on the tin will begin to appear in cold temperatures and will degrade the tin into a gray powder. The “tin-pest” phenomenon is cold temperature driven starting at (-13 °C) and reaches a maximum reaction rate at (-30 °C).
- **Kirkendall Voids:** Thermal aging (time at elevated temperature) can lead to the formation of Kirkendall Voids at the interfaces of tin and copper. The formation of a string of these voids can produce a perforated tear line that represents a significant weakness relative to mechanical shock. The Universal Environmental/Durability Test Flow places the High Temperature Degradation test prior to the first Mechanical Shock test specifically to address this concern.

Appendix B

B1 GMW3172 Component DV/PV Environmental Test Plan (CG3043)

Component Name (no abbreviations): (TBD)	**Revision Date:** (TBD)	**Revision Number:** (TBD)
CEMENT Family Name: (TBD: model year_lead program_component_supplier) Note: The family name needs to be agreed upon by the GM DRE, CVE, ENV SME, and EMC SME.	**Component Manufacturer:** (TBD: engineering address)	
Component Part Number(s): (TBD)	**Project:** First vehicle application: (TBD: model year and program) Additional vehicle applications: (TBD: model year and programs)	
Drawing Number: (TBD)	**Mounting Location in Vehicle:** (TBD)	
Prepared by (Supplier): (TBD, name, e-mail, phone)	**Test Plan Approved by GM Responsible Engineer:** GMW3172 ENV SME: (TBD name and e-mail), approves GMW3172 procedures. GM Validation Engineer: (TBD name and e-mail), approves “Additional Activities” in this Test Plan.	
Approved by (Supplier): (TBD, name, e-mail, phone)	**Test Results Will be Approved by GM Responsible Engineer:** ☐ Validation Engineer (typically) ☐ GMW3172 ENV SME	

Revision History

Date	Revision Number	Test Iteration (e.g., DV01, DV02, PV01, etc.)	Description (include changes made to the Test Plan, as well as changes to the design and/or manufacturing processes)	Author
(TBD)	(TBD)	(TBD)	(TBD)	(TBD)

Note: Appendix B content is an incomplete, partial representation of the Component Environmental Test Plan (CG3043). The full version, in editable format is available in its entirety from the GM Component Validation Engineer, the GM ENV SME, or from the Web site www.GMSupplyPower.com.

B1.1 Introduction. This Test Plan shall be completed by the supplier and submitted to GM 6 weeks after supplier sourcing for approval by the GM ENV SME. All sections shall be included as stated in the outline, only additions of new sections are allowed. If a section is not applicable, this shall be stated in this Test Plan along with supporting justification in the relevant section description.

B1.2.1 Purpose. The purpose of this Test Plan documents the component operation and test procedures for all tests according to GMW3172. It describes all test set-ups and the procedures to verify the environmental/durability robustness of the design.

B1.2.2 Guideline for Test Descriptions. Provide specific test set-up information and information to the component, including block diagrams, photographs, etc. indicating component connections to the facility and test equipment. Do not include copies of generic set-up diagrams from IEC/ISO/SAE or other standards as long as you refer to the documents.

All sections shall be completed by the supplier using the following guidelines:

- The information inside each section shall include as much detailed information as necessary for the completion of the test and its traceability/repeatability.
- Sections as shown in the template shall stay in the same order. Sections shall not be deleted.
- The supplier shall modify areas marked (TBD) or shown in blue font, or as needed to customize the Test Plan for their application.
- All supplier inputs shall appear in blue font.
- If a test section is not applicable to the component or the Test Plan, provide a technical reason, such as the example shown below.

Example for the Free Fall test

Applicable Standard: GMW3172, Aug. 2012, § 9.3.11

Operating Type: 1.1

Monitoring: N/A

Parameters: N/A

Procedure:

1 Perform the test using the following parameters:

- Number of test samples: 3
- Drops per test sample: 2
- T_{room}
- Drop Height: 1 m
- Drop Surface: Concrete

1 Choose the X-axis for the first drop. Following the drop, perform a 1-Point Functional/Parametric Check.

2 Repeat the drop with the same axis, but in the opposite direction. Following the drop, perform a 1-Point Functional/Parametric Check.

3 Repeat steps (2) and (3) with the second sample in the Y-axis.

4 Repeat steps (2) and (3) with the third sample in the Z-axis.

5 Document all visual damage by pictures and add them to the test report.

Note: If significant damage occurs in the first of a drop in a given axis, then a new sample needs to be used for the drop in the opposite direction of that axis.

Criteria: Minor visible external damage to the component is permitted as long as it does not affect the performance, the attachment interface to the vehicle, or the surfaces visible to the customer. The component shall pass the 5-Point Functional/Parametric Check at the end of the test. Functional Status Classification shall be C.

If there is significant visible external damage to the component as judged by the GM Component Validation Engineer, then the component does not have to meet the performance and functional requirements. The 1-Point Functional/Parametric Check shall still be executed for engineering judgment. Functional Status Classification shall be E.

Note: The Component Environmental Test Plan (CG3043) shown above is an incomplete, partial representation of the entire document. The full version, in editable format is available in its entirety from the GM Component Validation Engineer, the GM ENV SME, or from the Web site www.GMSupplyPower.com.

Appendix C

C1 Requirements for GMW3172 Test Reporting.

C1.1 Foreword. Reporting results of validation testing is a standard delivery requirement for suppliers of components for GM vehicles. This section summarizes General Motors preferred practices in format and content for effectively reporting the results of GMW3172-related testing.

C1.2 Test Report Contents. To insure that all of the required information is contained within test report documents, certain information must be included. Some information will only be listed on title pages, while some is repeated as header or footer information on all pages. Other information, pertaining to specifics of the test, must be included to constitute a valid report. A test report may be specific for one test or may include multiple tests. This information may be included in the Test Report itself or in an additional cover page, if necessary. As a minimum, the test report must contain the following information:

Title Page Content

- Test Laboratory (Name and Address, and Details of Accreditation, if applicable)
- Name of Component (e.g., Global A BCM)
- Person(s) Responsible for the Test Report (name and signature)
- Test Standard and Edition (e.g., GMW3172 July 2010, Humid Heat Cyclic)
- Test Dates (when test was run)

Header/Footer Content

- Test Laboratory (Name)
- Page Number

Required Content

- **GM Part Number** – The 8-digit GM part number shall match the part number on the GMW3172 Component Environmental Test Plan (CG3043).
- **Test Equipment** – All equipment shall be uniquely identified, e.g., manufacturer, model number, serial number, laboratory specific identification method, etc. Additionally, the calibration information (Due Dates) shall be shown for test equipment that requires calibration.
- **Test Sample Description –** Each test sample shall have a unique serial number. Verify that the serial numbers represent the correct sample size for the test according to the test flow in the GMW3172 Component Environmental Test Plan.
- **Pictures of setups** – Ensure that pictures of setups are included for the following tests to ensure that the setup was proper: Vibration with Thermal Cycle, Mechanical Shock (Pothole, Minor Collision, and Closure Slam), Thermal Shock Air-to-Air, Power Temperature Cycle, Humidity, Salt Mist/Spray, Water, and High Temperature Degradation. Other pictures are acceptable.
- **Summary of Test Results** – Ensure that a statement exists indicating that the component performance met the requirements for each procedure. Deviations shall be stated.
- **Test Procedure/Method** – The test procedure/method shall match the details from the GMW3172 Component Environmental Test Plan – or a clear statement that the GMW3172 Component Environmental Test Plan was followed.
- **Test Plan Procedure Deviations** – Any procedures that were not executed according to the GMW3172 Component Environmental Test Plan shall be clearly identified.
- **Measured Test Parameters** – The required measured test parameters shall be included for the following tests: Vibration with Thermal Cycling, Mechanical Shock (Pothole, Minor Collision, and Closure Slam), Thermal Shock Air-to-Air, and Power Temperature Cycle.
- **Initial and Final Functional/Parametric Check** – Ensure that the defined parameters/checks from the GMW3172 Component Environmental Test Plan are included as well as the required limits. Ensure that the limits have not been exceeded. Confirm degradation between initial and final parametric checks meet requirements if defined by the GMW3172 Component Environmental Test Plan. Deviations shall be stated.

- **Functional Status Classification (FSC)** – Ensure that a clear statement indicating the Functional Status Classification level required agrees with the GMW3172 Component Environmental Test Plan and that it was met. For tests that require FSC A, ensure that a Continuous Monitoring data summary or a clear statement is provided indicating that the Continuous Monitoring requirements have been met **DURING** the environmental exposure. Deviations shall be stated.
- **DRBTR** – Ensure that following information is contained: listing of tests that were executed on the sample, description of any observations of abnormalities, including pictures.
- **Non-conformances, anomalies, or other observations during test** – Ensure that any non-conformance, anomaly, etc. are clearly documented. Details shall include the issue description, point of occurrence in the test, conditions at the time of incident, whether it was continuous or intermittent, and description of the test operator response.

C1.3 Elements of the Test Report.

C1.3.1 Title Page. The title page summarizes all information related to the component, platform, subsystem, tests, and associated test specifications. This page in a glance informs the Validation Engineer or test reviewer all information about the component and the test being reported. Minimum information expected to appear on this page is:

- Supplier, Name and Address
- Customer, Name and Address
- Name of Component (e.g., Global A BCM)
- Test Dates (when test was run)
- Test Standard and Edition (e.g. GMW3172 July 2010, Humid Heat Cyclic)
- GM Part Number

C1.3.2 Test Set-Up Documentation. The test setup pages should show in considerable detail the arrangement of equipment applied in the test of the component. A verbal description of the setup, with detail specific to the test and an accompanying block diagram or graphical representation to clarify. For example: "*The SAMPLE is installed in a temperature controlled chamber with the signal and power harnesses routed through the sidewall. The power harness is fed through a current sensor to continuously monitor VBat current during operation. The load box is positioned on an equipment cart outside the temperature chamber, with the power supply*. *Figure X shows the harness, current sensor, load box and power supply outside the temperature chamber*."

- Provide an electrical interconnect diagram of the component to the simulated and/or real loads, power supply, monitoring equipment, etc. Provide labels for all electrical signals, loads and sensors, and power supply lines.
- Describe the Test Equipment used for the test.

C1.3.2.1 Equipment Lists – Calibration and Traceability. Reports shall include a list of all calibratible test equipment used in the validation process (chamber, measurement devices, amplifiers, power supplies, etc.), with the associated manufacturer, model number, serial number, last calibration date, due date of next calibration, and name of calibration lab. All equipment that requires calibration must be within its calibration period and be traceable to NIST (National Institute of Standards and Technology) or other equivalent national standard laboratory organized and operated according to ISO 17025.

Table C1 shows an example of all test equipment used in the testing of an electronic module for compliance to GM requirements for Vibration and Mechanical Shock stresses. The column titled 'Cert #' summarizes the suppliers file of certificates of traceability to NIST standards for each piece of equipment. A similar list of equipment (actuators, accelerometers, and amplifiers, etc.) should be compiled for calibratable instrumentation used in GMW3172-related tests, such as temperature, shock, and vibration.

Table C1: Equipment List with Traceability References for Test Equipment in Vibration/Shock Tests

Item Description	Model #	Serial #	Cert #	Cal Due
3-Axis Random Vibration Test with Temperature				
Unholtz-Dickie Electrodynamic Shaker	H560B-16	7128	E0689	12-Jul-12
Unholtz-Dickie Vibration Controller	400AT	1892	E0541	11-Apr-12
Unholtz-Dickie Amplifier	SAI120	1446	E0759	10-Jul-12
Unholtz-Dickie Signal Conditioner	D33PM	2238	E0741	06-Mar-12
PCB Piezotronics Tri-Axial Accelerometer	3713B1230G	1211	E0779	13-Mar-12
PCB Handheld Calibrator	394C06	17144	E0748	01-Jun-12
Thermotron Thermal Chamber	F-40CHMV-25-25-2	1008	E0768	14-Jul-12
Shock Tests				
Unholtz-Dickie Electrodynamic Shaker	H560B-16	7825	E0729	12-Jul-12
Unholtz-Dickie Amplifier	SAI120	1442	E0759	10-Jul-12
Unholtz-Dickie Signal Conditioner	D33PM	2214	E0738	12-Mar-12
PCB Piezotronics Accelerometer	628F01	9128	E0832	22-Jan-12
PCB Piezotronics Handheld Calibrator	394C06	15288	E0626	20-Dec-11
Spectral Dynamics Controller	SD1700	21784	E0774	18-May-12
Thermotron Thermal Chamber	F-40CHMV-25-25-2	1002	E0763	02-Jul-12

C1.3.2.2 Photographs. To clarify and support the verbal description of the test setup, provide photographs of the test setups (from multiple angles), detailing fixtures, electrical harnesses, power supplies, load boxes or simulators, monitoring equipment, benches, and test chambers as applied in the test. Detail the placement, orientation, fixturing, and interconnection of the test sample(s) with the test setup. Photographs should be of at least 3.2 megapixel resolution.

At a minimum, pictures shall be provided for the following tests:

- Vibration with Thermal Cycling
- Mechanical Shock (Pothole, Minor Collision, and Closure Slam)
- Thermal Shock Air-to-Air
- Power Temperature Cycle
- Humidity
- Salt Mist/Spray
- Water
- High Temperature Degradation

Other pictures are acceptable.

C1.3.3 Description of Test Procedure. To illustrate that the supplier has complied with the customer test requirements in detail, suppliers must provide at least this minimum information in reporting the validation test procedure.

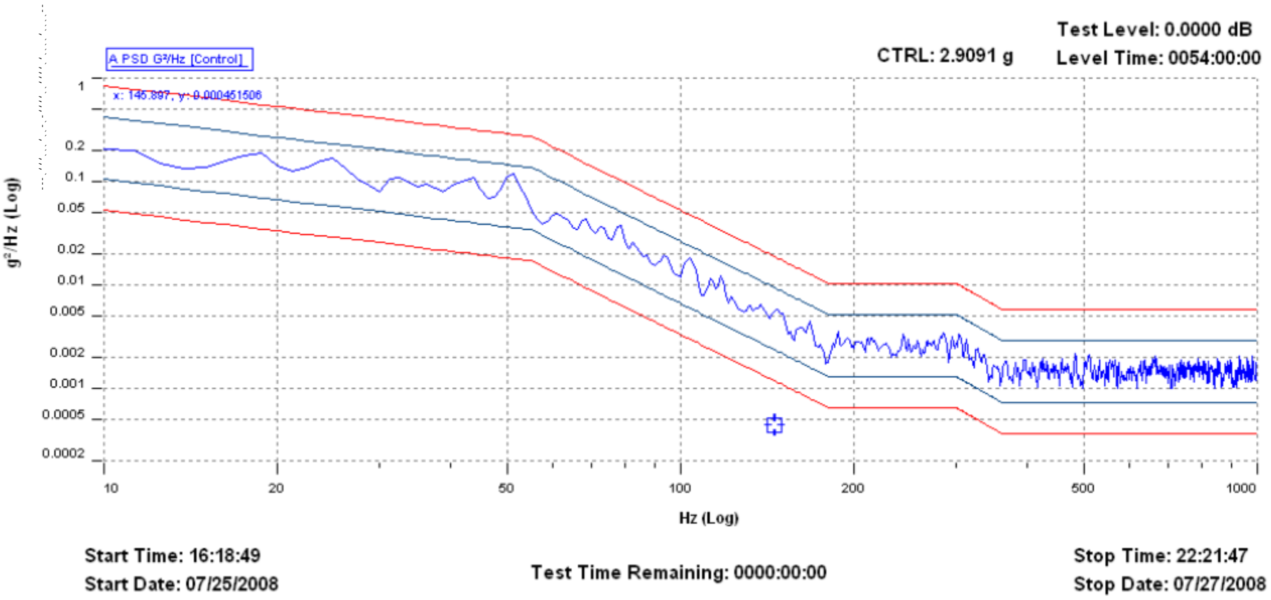
- Reference a Test Plan by number, revision, and revision date
- Specify test methods according to ISO, etc. standards
- State all test conditions (e.g., thermal cycle with vibration)
- State test duration per condition (e.g., vibration in hours per axis X-Y-Z)

- Document the use of continuous monitoring
- Cite appropriate reference conditions (example: Z-axis is perpendicular to internal circuit board)
- Deviations made to specified Test Plan

C1.3.4 Reporting of Stress Inputs. The following tests require environmental stress data that is measured during the test to confirm that the proper profiles were used:

- Vibration With Thermal Cycling (show the random vibration spectra as measured at the check point, which is at the attachment point of one of the samples to the test fixture, as power spectral density (PSD) in units of g^2/Hz vs. frequency in Hz)
- Mechanical Shock – Pothole (show the shock characterization as measure at the check point, which is at the attachment point of one of the samples to the test fixture, as a representation of peak acceleration, duration, and half sine shape of the shock pulse)
- Mechanical Shock – Collision (show the shock characterization as measure at the check point, which is at the attachment point of one of the samples to the test fixture, as a representation of peak acceleration, duration, and half sine shape of the shock pulse)
- Mechanical Shock – Closure Slam (show the shock characterization as measure at the check point, which is at the attachment point of one of the samples to the test fixture, as a representation of peak acceleration, duration, and half sine shape of the shock pulse)
- Thermal Shock Air-To-Air (show the temperature cycle profile for one cycle, as measured on one test sample)
- Power Temperature Cycle (PTC) (show the temperature cycle profile for one cycle, as measured on test sample)

Test reports must include graphs of stress inputs that were applied to the component. See the figure below for an example of vibration stress inputs.



C1.3.5 Test Results.

C1.3.5.1 Tests Requiring Continuous Monitoring. Indicate compliance of test sample to requirements for Continuous Monitoring (e.g., performance limits met with no incidents or issues). Any non-conformances that occurred during continuous monitoring (signal dropouts, loss of function, etc.) shall be reported.

C1.3.5.2 Conformance to FSC (Functional Status Classification) Criteria. Include a statement in the test report to indicate conformance or non-conformance to the specific Functional Status Classification required for that test. Example: Functional Performance was in compliance with FSC A.

C1.3.5.3 Test Requiring 1-Point Functional / Parametric Check. Some tests require functional and parametric testing after exposure to the test stress. All monitored parameters are to be reported, along with the performance limits listed as Criteria (minimum and maximum listed, with units reported). Indicate the test sample number. Table C2 shows an example for a standalone HVAC control IP module, having four illuminated pushbutton switches and one PWM-driven DC motor. Note that all measured parameters are reported. Non-conformances shall be reported.

Table C2: Performance Test Results (Sample #14)

	Criteria			1-Point Functional/Parametric Check	
Items	**Min**	**Max**	**Units**	**Test**	**Pass/Fail**
LED 1 Intensity	180	220	mcd	193	Pass
LED 2 Intensity	180	220	mcd	192	Pass
LED 3 Intensity	180	220	mcd	172	FAIL
LED 4 Intensity	180	220	mcd	192	Pass
SW1 Actuation Force	2.2	2.6	N	2.4	Pass
SW2 Actuation Force	2.2	2.6	N	2.3	Pass
SW3 Actuation Force	2.2	2.6	N	2.3	Pass
SW4 Actuation Force	2.2	2.6	N	2.3	Pass
+VB1 Current (mode 1)	450	550	mA	480	Pass
+VB1 Parasitic Current (mode 3)	0.5	1.5	mA	0.95	Pass
IOB1 PWM Frequency (50 % DC)	31	33	Hz	32	Pass
IOB1 Active Low (500 Ω Load, +13.5 V)	0.5	1.1	V	0.7	Pass
IOB1 Inactive (500 Ω Load, +13.5 V)	13.0	13.5	V	13.3	Pass

C1.3.5.4 Initial and Final 5-Point Functional / Parametric Check Results. 5-Point functional and parametric testing involves verifying that the component functions within specified limits before and after the test stress. All monitored parameters are to be reported, along with the performance limits reported as Criteria (minimum and maximum listed, with units reported). Indicate the test sample number. Table C3 shows an example for a standalone HVAC control IP module, having four illuminated pushbutton switches and one PWM-driven DC motor. Note that all monitored parameters are reported. Non-conformances shall be reported.

Table C3: Performance Test Results (Sample #13)

	Criteria			– 40 °C, +9 V		
Items	**Min**	**Max**	**Units**	**Pre Test**	**Post Test**	**Pass/Fail**
LED 1 Intensity	180	220	mcd	193	195	Pass
LED 2 Intensity	180	220	mcd	192	191	Pass
LED 3 Intensity	180	220	mcd	192	101	FAIL
LED 4 Intensity	180	220	mcd	192	191	Pass
SW1 Actuation Force	2.2	2.6	N	2.4	2.4	Pass
SW2 Actuation Force	2.2	2.6	N	2.3	2.3	Pass
SW3 Actuation Force	2.2	2.6	N	2.3	2.3	Pass
SW4 Actuation Force	2.2	2.6	N	2.3	2.3	Pass
+VB1 Current (mode 1)	450	550	mA	480	490	Pass
+VB1 Parasitic Current (mode 3)	0.5	1.5	mA	0.95	0.92	Pass
IOB1 PWM Frequency (50 % DC)	31	33	Hz	32	32	Pass
IOB1 Active Low (500 Ω Load, +13.5 V)	0.5	1.1	V	0.7	0.8	Pass
IOB1 Inactive (500 Ω Load, +13.5 V)	13.0	13.5	V	13.3	13.3	Pass

C1.3.5.5 Visible Inspection and Dissection - DRBTR Results. Report external and internal inspection observations of the samples after the test. Include the following information:

- Include a list of the tests that were executed on each sample.
- Cite the pass/fail criteria (e.g., no visible damage, no discoloration, no water intrusion, etc.)
- Report the state of the component after the test, indicating if the component meets the criteria or indicating where it does not.
- Provide digital photographs documenting any observed abnormalities. For samples with damage, capture the detail with zoom/microscopic images and identifying marks (highlight, annotate).

C1.3.6 Pass/Fail Summary Report. The test report shall include a summary of the component response to individual tests with a Pass/Fail assessment. If the component does not meet GM requirements, detail the specific anomaly (e.g., failed in the Z-axis Mechanical Shock – Pothole test, or failed the Post Thermal Fatigue Vibration.) An example of a Pass/Fail Summary Report is shown in Table C4 below.

Table C4: Pass/Fail Summary Report

TEST NUMBER	TEST DESCRIPTION	PASS/FAIL
	Vibration Tests	
9.3.1	Vibration With Thermal Cycling	PASS
9.3.1.1	Random Vibration – Mounting Sprung Masses	PASS
	Mechanical Shock Test	
9.3.2	Mechanical Shock – Pothole	FAIL
9.3.3	Mechanical Shock – Collision	PASS
9.3.4	Mechanical Shock – Closure Slam	PASS

C1.3.7 Description of Non-Conformances. Provide explicit detail of any observed incident in which the test sample did not comply to the requirements. Required detail shall include:

- Description of the non-conformance in detail (e.g., loss of function, signal dropout, which functions and/or signals were non compliant, was the issue continuous or intermittent, what sample number exhibited the non-conformance, etc.)
- Point in the test that the non-conformance was detected (i.e., number of hours or days into the test; applied stress at the time)
- Description of the test operator's response to the non-conformance (e.g., removed sample from the test leg, took action to restore function, etc.).
- Note if the test sample returns to normal function when the applied stress is removed or reduced.

C1.4 Storage of Records. Test reports and raw data supporting the results must be stored in accordance with GMW15920 using the records retention period for Material and Performance Test Results.