General Specification for Electrical/Electronic Components - Environmental/Durability

Contents

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), Component Technical Requirements and Specifications (CTRS), 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 lifetime.

This standard includes tests to ensure customer satisfaction of vehicular E/E component performance over a lifetime 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 60068-2-64	ISO 7637-2 (6/2004) **Note 1**	JEDEC JESD22-A110
IEC 60068-2-1	IEC 60068-2-78	ISO 8820-1	JEDEC JESD22-A121
IEC 60068-2-14	IPC-6012	ISO 12103-1	JEDEC JESD201A
IEC 60068-2-27	IPC-6013	ISO 16750-2	SAE USCAR-25
IEC 60068-2-30	IPC J-STD-001	ISO 16750-4	
IEC 60068-2-38	IPC-A-610	ISO 20653	
IEC 60068-2-52	IPC-TM-650	ISO/IEC 17025	

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	GMW14650	GMW16449
GMW3097	GMW8288	GMW14872	GMW16552
GMW3191	GMW14082 (LU)	GMW15725	GMW17388
GMW3286	GMW14444	GMW16044	GMW17695

(LU) = This standard is limited to use only with Global A Electrical Architecture applications.

2.3 Additional References.

- CG3043, supplement to this standard.
- "CG4209 GM 1927 03a SQ - Electrical & Electronic Modules & Assemblies SOR Appendix" available from GM SupplyPower, https://gmsupplypower.covisint.com, "Collaborate", "Document Library".

- "CG4338 GM1927-03 Supplier Quality Statement of Requirements" available from GM SupplyPower, https://gmsupplypower.covisint.com, "Collaborate", "Document Library".
- CTS, CTRS, SSTS, and/or other relevant requirements document, from the Statement of Requirements (SOR).
- GB14082 from the SOR.

3 Parametric Definitions

3.1 Temperature and Voltage Definitions. Refer to Table 1.

Table 1: Definitions Note 1

Phrase	Symbol	Definition
Minimum Temperature Note 2	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 Note 2	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 and 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 1: All voltage levels are defined at the component connector.
Note 2: All tests at T_{min} and T_{max} shall be performed after the component stabilizes at the target temperature. This stabilization time shall be included in the test report.

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

Table 2: Parameters and Tolerances

Parameter	Tolerance
Ambient Temperature	Specified (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 m/s^2_{RMS} (g_{RMS}) **Note 1**	Spec. ± 20% (Power Spectral Density (PSD) deviations from applicable tables are not permitted without GM approval)
Acceleration (Mechanical Shock), m/s^2 (g)	Spec. ± 10% (deviations are not permitted without GM approval)
Frequency	Spec. ± 1%
Force	Spec. ± 10%
Distance (Excluding Dimensional Check)	Spec. ± 5%

Note 1: RMS = Root Mean Square.

3.3 Operating Types. Refer to Table 3.

Table 3: Operating Types

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

3.4 Functional Status Classification (FSC). Refer to Table 4.

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 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 E/E Components. The Global Environmental Component 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, Heating, Ventilation, Air Conditioning (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 (in “Templates” section of CG3043) and test results to the GM Component EMc and ENvironmental Test (CEMENT) Database which is accessible through GM Supply Power. CEMENT also requires the Supplier to upload all component Electromagnetic Compatibility (EMC) test plans and test results (per GMW3097 as handled by the EMC Department).

The supplier is required to upload all GMW3172 Component Environmental Test Results to CEMENT. The supplier shall use the Test Report Template (TRT) (that is included in CG3043 under “Tools”).

In addition, the Supplier shall meet the requirement of “CG4209 GM 1927 03a SQ - Electrical & Electronic Modules & Assemblies SOR” available from GM SupplyPower, https://gmsupplypower.covisint.com, “Collaborate”, “Document Library”.

4.2 A/D/V Process Flow. The A/D/V Process Flow shall be followed as shown in Figure 1. Roles and responsibilities within the A/D/V Process Flow shall be shared by the GM Component Validation Engineer (CVE), i.e., Validation Engineer (VE) or Subsystem Validation Engineer (SVE), GM Environmental Subject Matter Expert (ENV SME), GM Design Release Engineer (DRE), GM Engineering Technical Leader (ETL), GM Technical Specialist, GM Supplier Quality Engineer (SQE), and the Supplier, as shown in Figure 2 and Figure 3.

Figure 1: A/D/V Process Flow Example

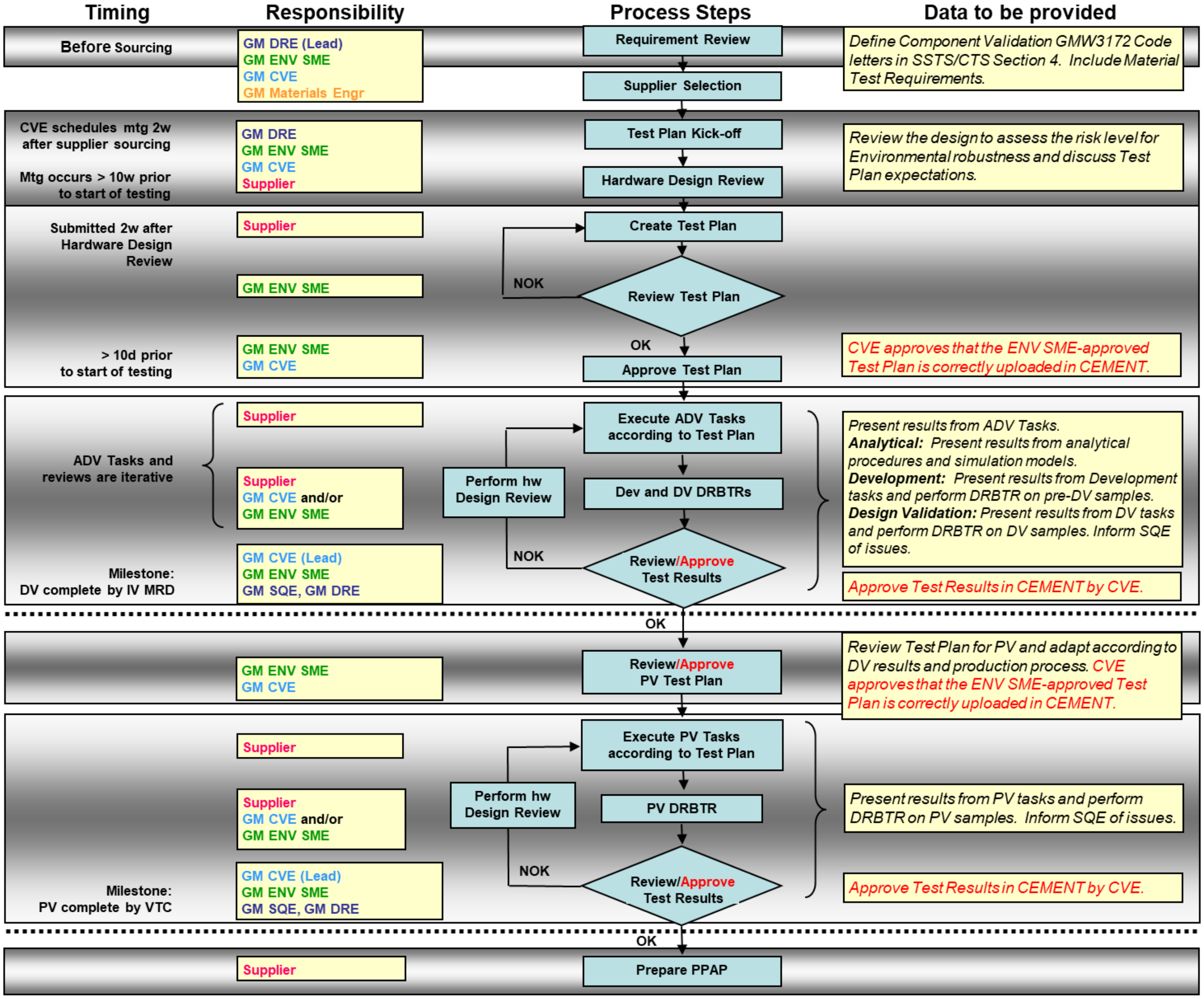

Figure 2: Shared Roles and Responsibilities in A/D/V Process Flow

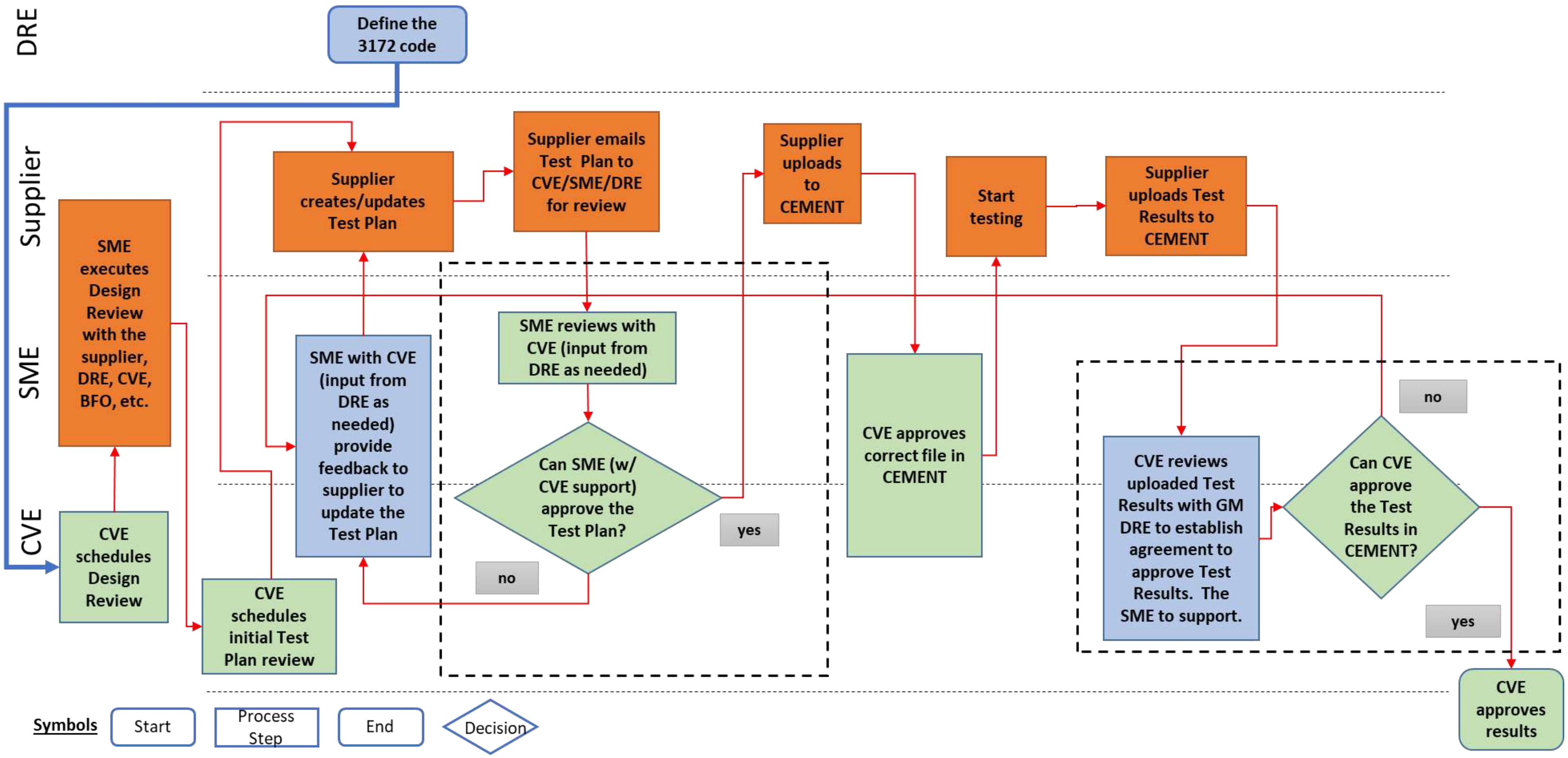

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Figure 3: Shared Roles and Responsibilities RASIC Chart

- Responsible: those solely and directly accountable for creating a work product
- Approving: the party (or parties) that reviews and assures the work product's quality
- Supporting: individuals or groups who help to create the work product
- Informed: those who are to be kept informed about proceedings
- Consulted: those who help design the product or put in place quality review criteria

Tasks ⇩	VE/CVE/SVE	SME	Supplier	DRE	BFO/TS	Comments
Create the GMW3172 code	c	C		R	A	BFO/TS defines code for BOM row family and DRE customizes for their specific application
Schedule Environmental Design Review	R	S	S	S	I	
Execute the Environmental Design Review check list ENV content	S	A	R			
Execute the Environmental Design Review check list (Paramters monitored/functional moding/additional activities)	A	S	R	S		
Schedule Initial Testplan Review	R	I	I	I		
Create/Update Testplan	s	S	R	C		
Email testplan to GM (CVE/DRE)	I	I	R	I		
Schedule testplan review (final if approved)	R	I	I	I		
Reviews submitted testplan ENV content	S	R	S	S		
Reviews submitted testplan paramters monitored/functional moding/6.1,6.2 (5 point and 1 point/parametric check), 6.3 (Continuous Monitoring), 6.4 (functional cycling)	A	R	S	S		SME develops the testplan. The CVE confirms that all CTS Requirments are captured. CVE focuses on CTS requirments, DFMEA coverage in testplan, customer critical functionallity and lessons learned. SME focuses on Env testing requirments. SME and CVE work together to finalize the testplan with supplier.
Reviews submitted testplan section 8 additional activities	R	C	S	S		The CVE is resonsible for additional activities.
Approve or Reject the Testplan, approving to be uploaded to CEMENT	R	A	I	C		VE responsible for testplan timing/status, SME approves plan
Provide Feedback to Supplier regarding Changes needed to testplan (if rejected)	S	R				
Upload testplan to cement	S	s	R	I		
Approve or Reject the Testplan file approved in row 14 is uploaded to CEMENT	R	S	I	C		VE clicks approve in cement verifing correct file was uploaded and timing met.
Execute the testing (supplier)	I	I	R	I		
Upload testresults to CEMENT	I	I	R	I		
CVE reviews uploaded test results with GM Design Release Engineer (DRE) to establish agreement to Sign-Off. The SME to support	R	S	S	A		Release has the "A" . This is the basis for the DRE to sign the GM3660. Validation has the R (is responsible for verifing the results are acceptable.)
Approve/Reject test results in CEMENT (Click the button)	R	I	I	I		

The A/D/V Process Tasks are as follows:

1 **Requirements Review.** The Requirements Review shall be performed within GM to define the GMW3172 Code letters. This GMW3172 Coding shall be documented in the CTS, CTRS, SSTS, and/or other relevant requirements document "Validation" section. The DRE/Technical Specialist shall define this information together with the ENV SME and CVE. The most appropriate Code according to 5.2.7 shall be used as a default. The VE shall review the CTS, CTRS, SSTS, and/or other relevant requirements document for alignment to GMW3172 prior to sourcing. Also, the GM Materials Engineer needs to provide the Material test requirements to determine the Chemical Loads Code. Supplier-proposed exemptions to the GMW3172 shall be approved by the ENV SME.

2 **Test Plan Kick-off Meeting/Environmental Hardware Design Review.** Two weeks after supplier sourcing, the dates for the Test Plan Kick-off Meeting and an initial Environmental Hardware Design Review meeting shall be scheduled by the VE to be completed jointly by the supplier and GM. These meetings generally occur on the same date but could be separate dates.

3 **Test Plan Kick-off Meeting.** The Test Plan Kick-off Meeting establishes contact between a supplier and GM. This meeting clarifies component environmental test expectations between a supplier and GM. This meeting also provides a supplier and GM an opportunity for early discussion of the development and approval process for the GMW3172 Component Environmental Test Plan (in "Templates" section of CG3043). This meeting shall be scheduled to be completed jointly by the supplier and GM. The VE will schedule the Test Plan Kick-off Meeting and the meeting is conducted by the ENV SME.

Prior to the meeting, the supplier shall obtain an editable version of the GMW3172 Component Environmental Test Plan (in "Templates" section of CG3043) through the IHS Markit Standards Store by S&P Global (www.global.ihs.com). CG3043 is a supplement to GMW3172 that is provided when GMW3172 is purchased through IHS Markit.

The required participants for this meeting are the DRE, VE, ENV SME, the Supplier's VE, and the Supplier's Project Manager.

The expectations for the Test Plan Kick-off Meeting are to:

a Discuss the GMW3172 process and ensure that it is understood.

b Review the GMW3172 Code Letters.

c Discuss the timing for completion of the GMW3172 Component Environmental Test Plan.

d Discuss the review/approval process of the GMW3172 Component Environmental Test Plan.

e Confirm that the Supplier's in-house and outside laboratories are ISO/IEC 17025 accredited, as required in the "CG4338 GM1927-03 Supplier Quality Statement of Requirements" available from GM SupplyPower, https://gmsupplypower.covisint.com, "Collaborate", "Document Library".

f Discuss the requirements for the Environmental Hardware Design Review. It is recommended that the Environmental Hardware Design Review be held at the same time as the Test Plan Kick-off Meeting.

4 **Environmental Hardware Design Review.** This meeting shall occur as soon as possible after the design is frozen (i.e., "Design Freeze" date), and no later than ten weeks prior to the start of testing. The purpose of this meeting is to review the design to assess the risk level for Environmental robustness, review the Analysis results, and discuss the expectations for the GMW3172 Component Environmental Test Plan (in "Templates" section of CG3043) based on the component design for Environmental robustness. In preparation for this meeting, the supplier shall complete all tabs of the Environmental Hardware Design Review Check List file (included in CG3043 under "Tools"), which can be obtained from the ENV SME. Refer to 4.2.2 for more detailed instructions.

5 **Create and Review Test Plan.** The initial GMW3172 Component Environmental Test Plan (in "Templates" section of CG3043) shall be submitted for review 2 weeks after the Environmental Hardware Design Review by the supplier and submitted in an electronic, editable format to GM. Approval in CEMENT shall occur at least 10 days prior to the start of testing.

6 **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 VE or ENV SME along with the SQE and DRE, shall review the test results and determine if another iteration of DV is required based on design or process changes. The VE or ENV SME shall then perform an Environmental Hardware Design Review. Based on the corrective action, the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043) shall be modified as required and approved in CEMENT.

7 **Execute Product Validation (PV) Tasks.** PV Tasks shall be successfully completed by Validation Test Complete (VTC). The GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043) shall be reviewed, adapted, and approved in CEMENT to comprehend design changes, production process variations/changes, and PV test results accordingly.

Each test result shall be uploaded in CEMENT for approval.

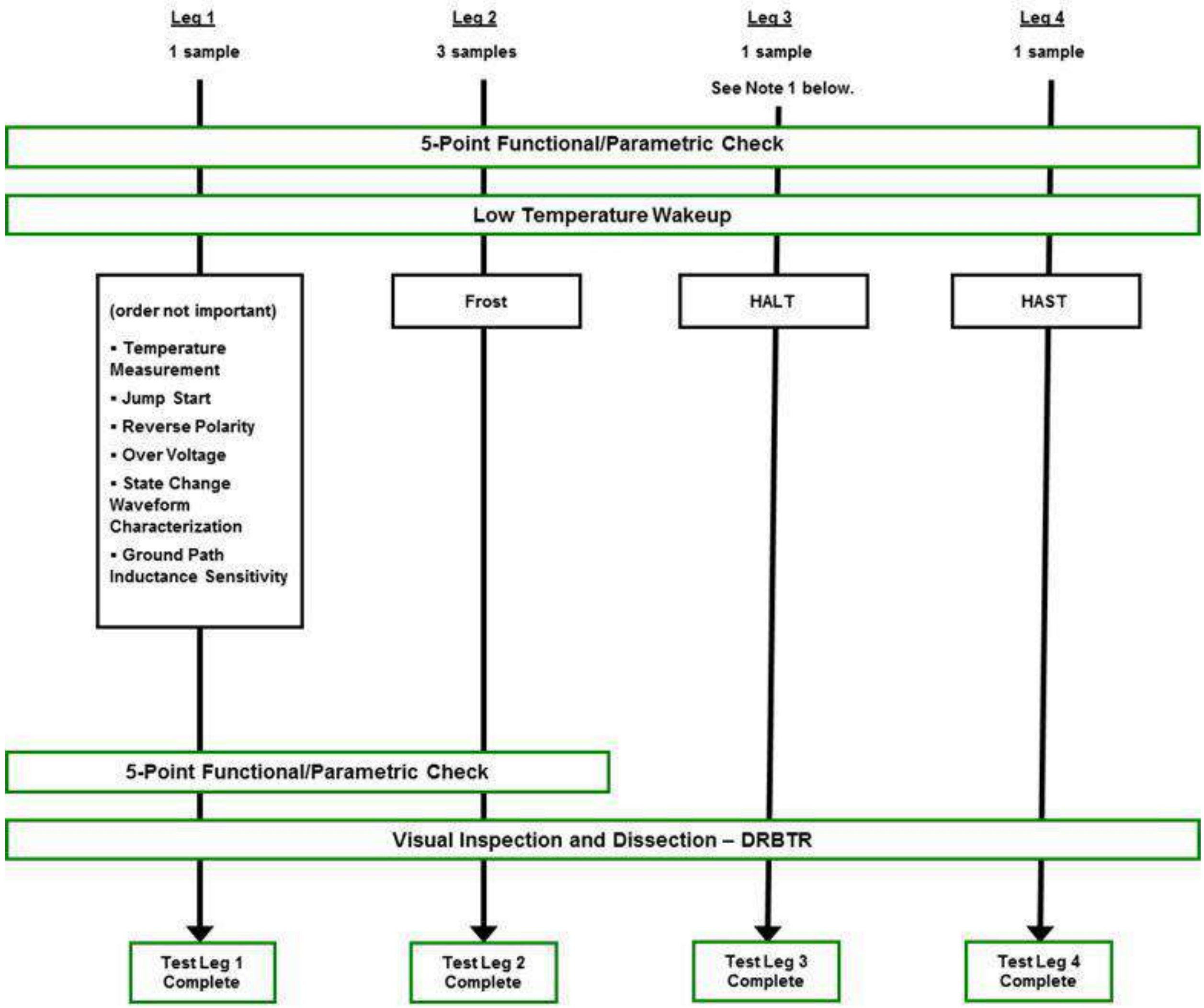
In case of nonconformance, the VE or ENV SME, along with the SQE and DRE, shall review the test results and determine if another iteration of PV is required based on design or process changes. The VE or ENV SME shall then perform an Environmental Hardware Design Review. Based on the corrective action, the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043) shall be modified and approved in CEMENT as required.

4.2.1 Test Flows. The Environmental/Durability Test Flows for Development, refer to Figure 4, DV, refer to Figure 5, and PV, refer to Figure 6, are critical elements of the Test Plan.

Some tests in the 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 circuit board material, as well as the production manufacturing processes and equipment for the housing and the circuit board. Any omissions from the PV Test Flow shall be agreed upon by the ENV SME.

The supplier shall include the Test Flows in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

Figure 4: 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 5: Environmental/Durability Test Flow for Design Validation (DV)

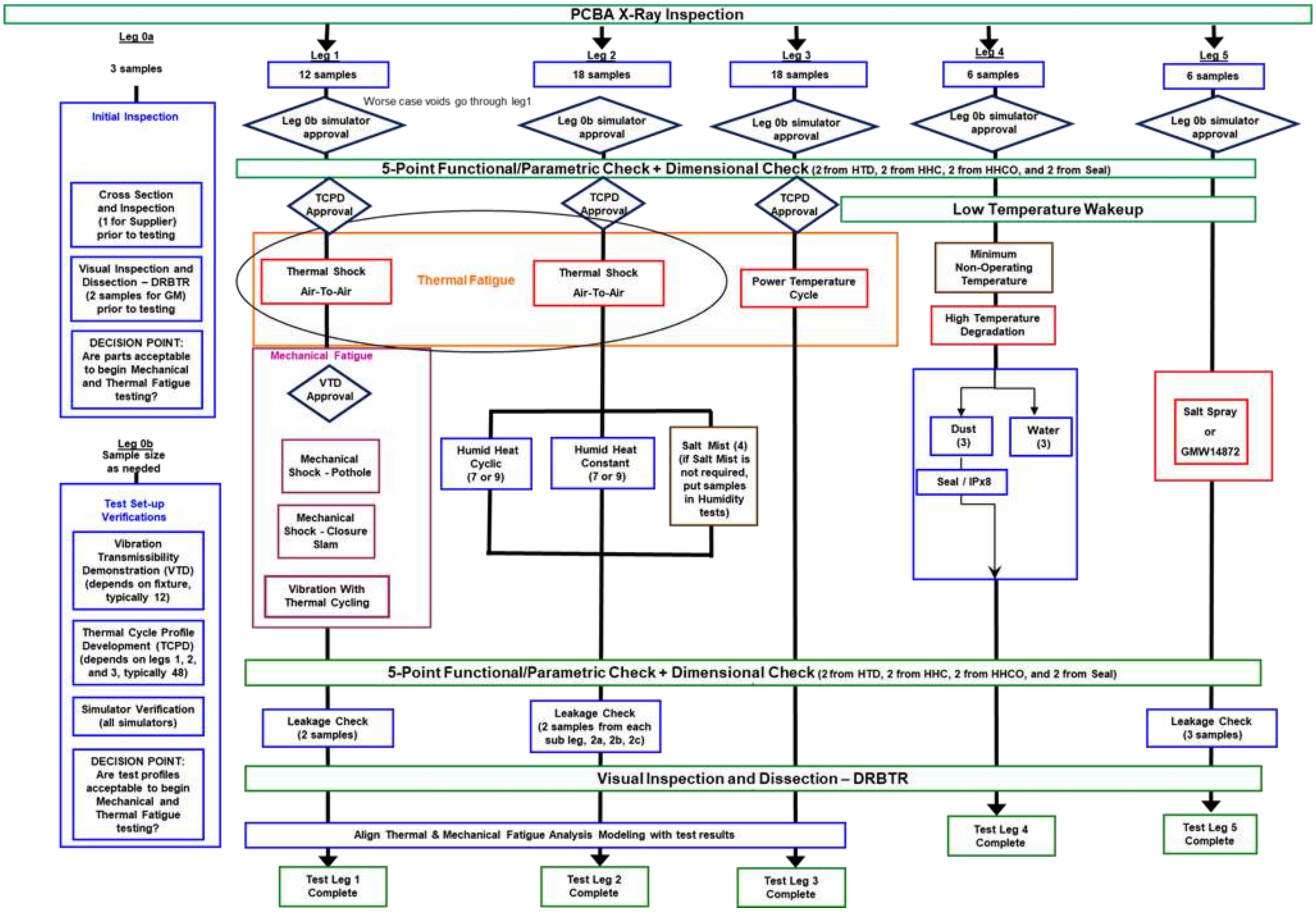


Figure 5: Environmental/Durability Test Flow for DV (continued)

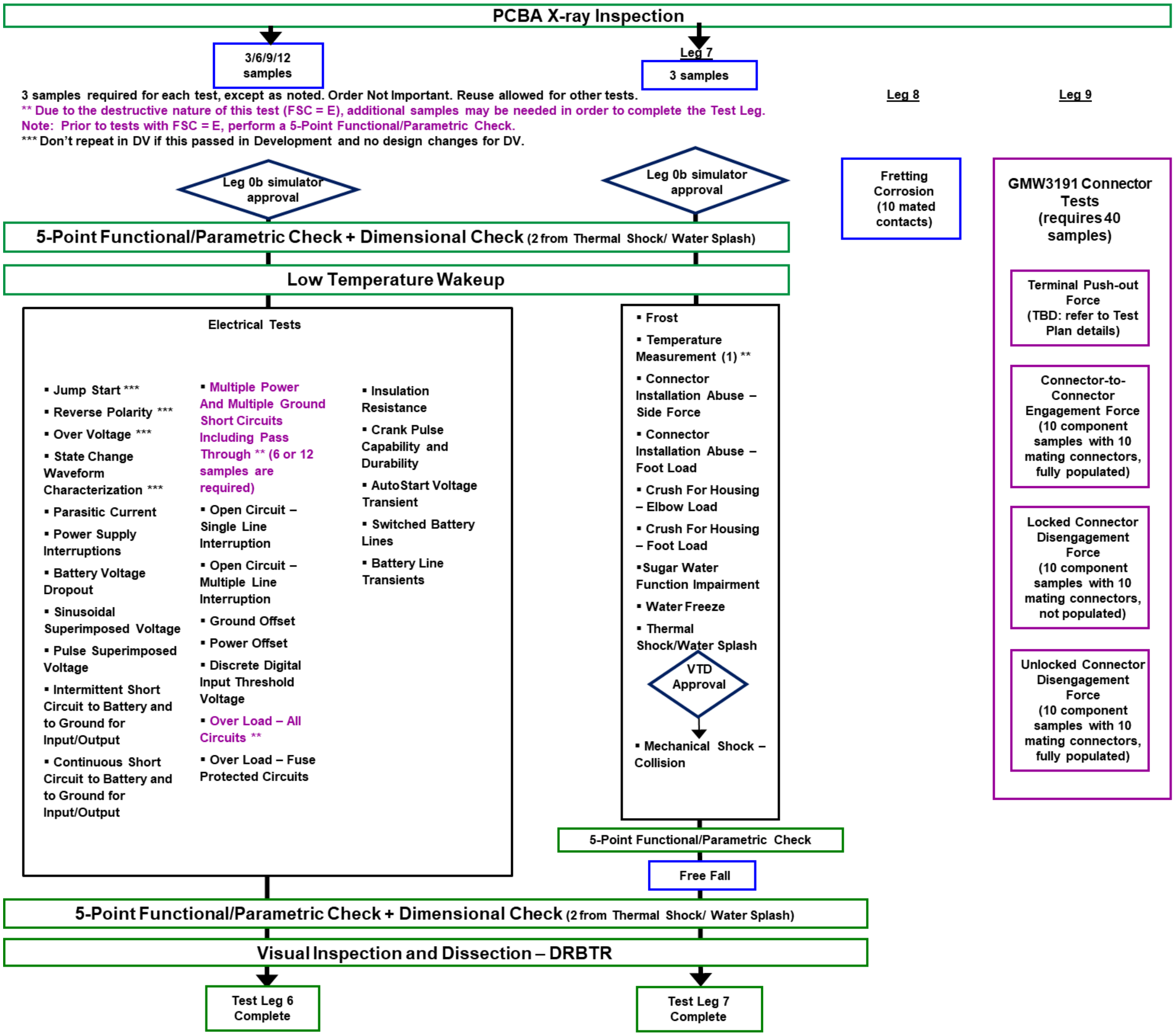


Figure 6: Environmental/Durability Test Flow for Product Validation (PV)

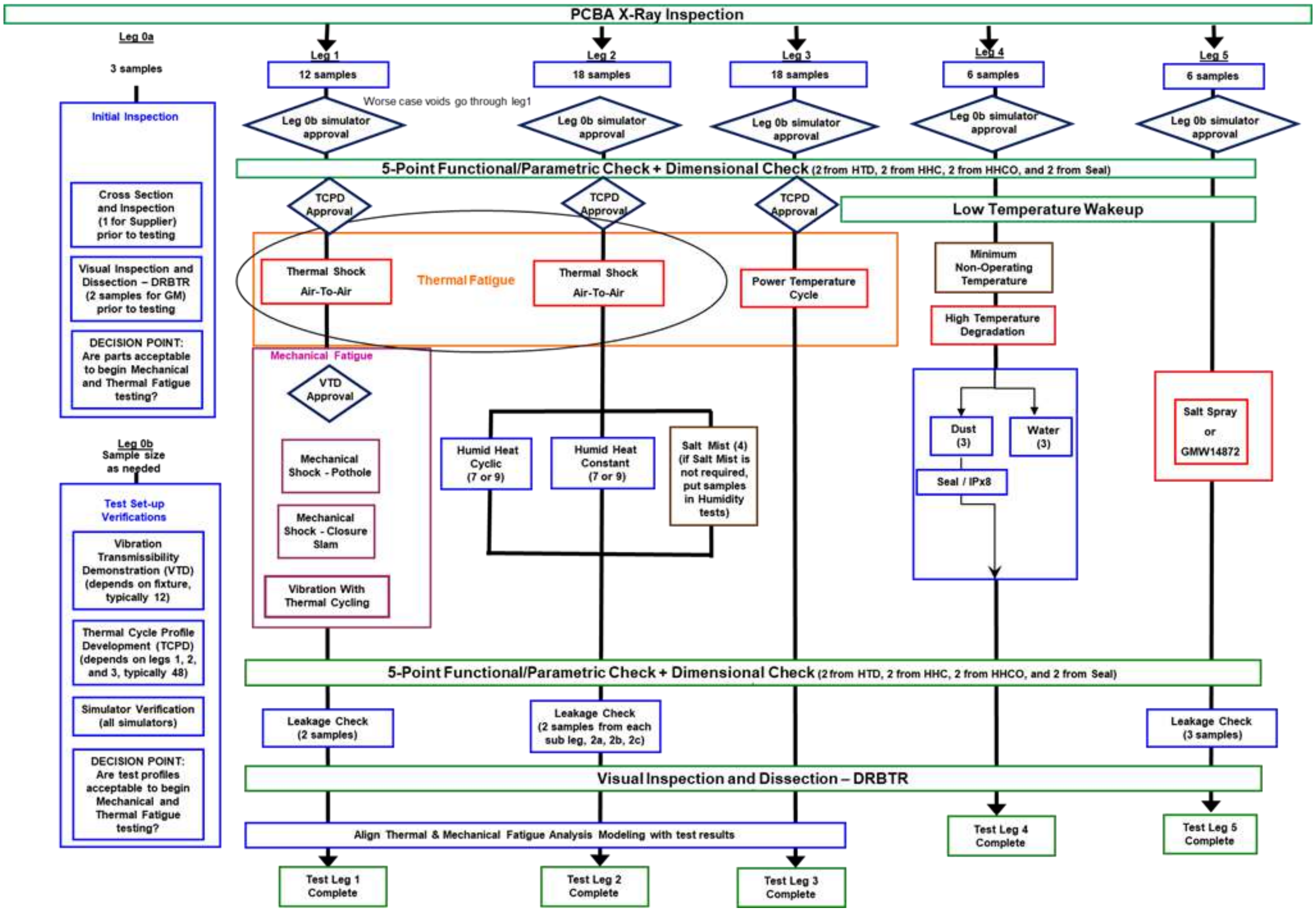
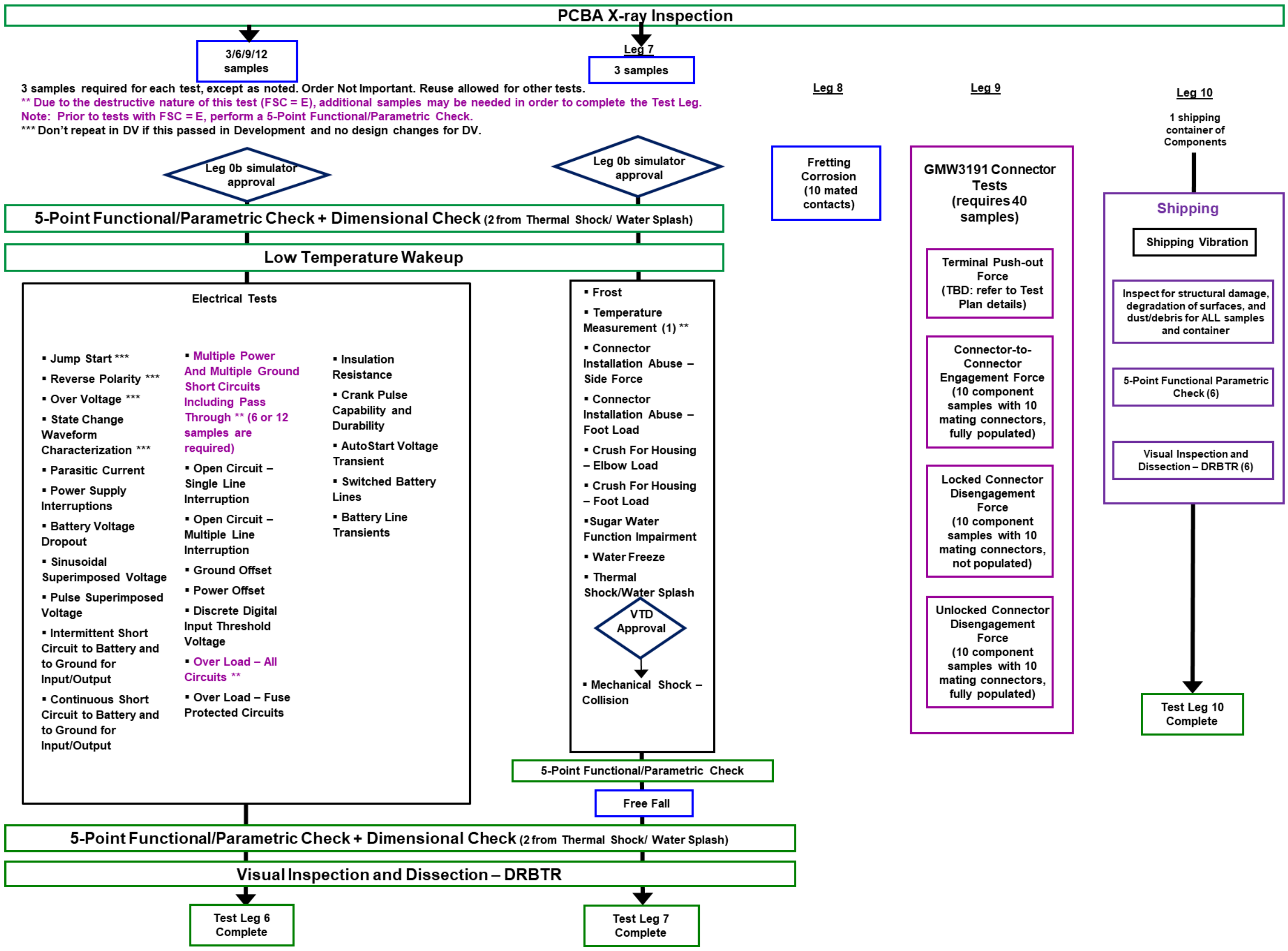


Figure 6: Environmental/Durability Test Flow for PV (continued)



4.2.2 Environmental Hardware Design Review. An Environmental Hardware Design Review, as shown in Figure 1, shall be conducted for all new components, changes during the Validation process, 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 substitutions 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 (refer to "Software Changes" following for more information). For semiconductor changes, refer to GMW16552.

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

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

- Confirm the GMW3172 Code Letters.
- Review component schematic design and circuit board layout.
- Review component assembly and mechanical construction.
- Review technical rationale of E/E 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 A1 Lead-Free Solder Considerations in Appendix A 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 related changes that may impact GMW3172. Refer to “Software Changes” following for more information.
- Review the results of the 7.4.2 Thermal and Mechanical Fatigue Analysis of PCBA and Housing, as well as all other Analysis activities.
- Establish the part number(s) and family association(s) for CEMENT.
- Review the Procedure Planning Tool. Refer to “Procedure Planning Tool” following for more information.

Software Changes:

If there is a software change that may impact GMW3172, the supplier shall update the GMW17388 Software Release Notes, (CG2999) when applicable, and the Software Changes Requiring Env And/or eMc (SCREAM) document in the “Tools” section of CG3043 (when applicable), along with the Environmental Hardware Design Review Checklist.

Procedure Planning Tool:

It is important to discuss what tests in GMW3172 are applicable for the design of a new component. Therefore, the supplier shall fill in the Procedure Planning Tool (PPT) document in the “Tools” section of CG3043. This is a list of activities in GMW3172. The supplier shall fill in the initial PPT for DV01 testing. The ENV SME shall review and approve the PPT. The PPT shall be reviewed to determine the applicability of each GMW3172 activity for the component. After that, the PPT shall be review for each iteration of DV and PV testing in order to document what tests are required for that test iteration.

Supplier Deliverables:

The Environmental Hardware Design Review Checklist shall be filled out in its entirety by the Supplier in preparation for the Environmental Hardware Design Review. If required, the Parts Substitution Matrix shall be filled out in its entirety by the supplier in preparation for the Environmental Hardware Design Review. These forms are available in the “Tools” section of CG3043, which is provided by IHS Markit Standards Store with the purchase/subscription of GMW3172.

The following documentation shall be delivered to the 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
- Printed Circuit Board (PCB) 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.)
- Software Release Notes, CG2999 (when applicable), and the Software Changes Requiring Env And/or eMc (SCREAM) document in the “Tools” section of CG3043 (when applicable)
- Procedure Planning Tool (PPT) document in the “Tools” section of CG3043

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

Attendees:

GM:

- ENV SME
- Component-Responsible VE
- DRE
- EMC SME (for CEMENT-related discussion)
- SQE (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 GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043). Each analytical result shall be reported to the VE, 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 GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043). Each test result shall be reported to the VE, 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 VE (or 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 DV Activities. The supplier shall conduct DV and provide test samples (may include pre and post test samples) to GM according to the approved GMW3172 Component Environmental Test Plan (in “Templates” section of 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 VE (or 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 PV Activities. The supplier shall conduct PV and provide test samples (may include pre and post test samples) to GM according to the approved GMW3172 Component Environmental Test Plan (in “Templates” section of 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 VE (or 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 GMW3172 Component Environmental Test Plan (in "Templates" section of CG3043) with GM approval. The GM-approved GMW3172 Component Environmental Test Plan (in "Templates" section of 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 – Design Review Based on Test Results (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 (VTD)	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
Test Harness Requirements	DV, PV[1]	N/A	N/A	N/A	N/A
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

Activity	Phase	FSC	Operating Type	Continuous Monitoring	Functional Cycling
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
Thermal and Mechanical Fatigue Analysis of PCBA and Housing	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[1]
Reverse Polarity	D, DV, PV[1]	C	3.1, 3.2	Yes	No[1]
Over Voltage	D, DV, PV[1]	C	3.1, 3.2	Yes	No[1]
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
Mechanical					
Highly Accelerated Life Test (HALT)	D	N/A	3.2	Yes	Yes
Climatic					
Temperature Measurement	D, DV, PV[1]	N/A	3.2	N/A	Yes
Low Temperature Wakeup	D, DV, PV[1]	A	1.2, 3.2	Yes	No[1]
Frost	D, DV, PV[1]	A	1.2, 3.2	Yes	Yes
Highly Accelerated Stress Test (HAST)	D	A	3.2	Yes	Yes

Activity	Phase	FSC	Operating Type	Continuous Monitoring	Functional Cycling
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[1]
Battery Voltage Dropout	DV, PV[1]	A, C	2.1, 3.2	Yes	No[1]
Sinusoidal Superimposed Voltage	DV, PV[1]	A	3.2	Yes	No[1]
Pulse Superimposed Voltage	DV, PV[1]	A	3.2	Yes	No[1]
Intermittent Short Circuit to Battery and to Ground for Input/Output	DV, PV[1]	C	2.1, 3.2	Yes	No[1]
Continuous Short Circuit to Battery and to Ground for Input/Output	DV, PV[1]	C	3.2	Yes	No[1]
Multiple Power and Multiple Ground Short Circuits Including Pass Through	DV, PV[1]	D, E	3.2	Yes	No[1]
Open Circuit – Single Line Interruption	DV, PV[1]	C	3.2	Yes	No[1]
Open Circuit – Multiple Line Interruption	DV, PV[1]	C	3.2	Yes	No[1]
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	No[1]
Over Load – All Circuits	DV, PV[1]	D, E	3.2	Yes	No[1]
Over Load – Fuse Protected Circuits	DV, PV[1]	A	3.2	Yes	No[1]
Insulation Resistance	DV, PV[1]	C	1.1	N/A	N/A

Activity	Phase	FSC	Operating Type	Continuous Monitoring	Functional Cycling
Crank Pulse Capability and Durability	DV, PV[1]	A, C	2.1, 2.2, 3.2	Yes	No[1]
AutoStart Voltage Transient	DV, PV[1]	A	2.2, 3.2	Yes	No[1]
Switched Battery Lines	DV, PV[1]	C	2.1, 2.2	Yes	No[1]
Battery Line Transients	DV, PV[1]	A, C	2.2	Yes	No[1]
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	3.2	Yes	Yes
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]	Refer to GMW3191	Refer to GMW3191	N/A	N/A
GMW3191 Connector Tests: Connector-to-Connector Engagement Force	DV, PV[1]	Refer to GMW3191	Refer to GMW3191	N/A	N/A
GMW3191 Connector Tests: Locked Connector Disengagement Force	DV, PV[1]	Refer to GMW3191	Refer to GMW3191	N/A	N/A
GMW3191 Connector Tests: Unlocked Connector Disengagement Force	DV, PV[1]	Refer to GMW3191	Refer to GMW3191	N/A	N/A
Connector Installation Abuse – Side Force	DV, PV[1]	C	1.2	N/A	N/A
Connector Installation Abuse – Foot Load	DV, PV[1]	C	1.2	N/A	N/A
Free Fall	DV, PV[1]	C, E	1.1	N/A	N/A

Activity	Phase	FSC	Operating Type	Continuous Monitoring	Functional Cycling
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]	C	1.2	No	No
Alternate Salt Spray using GMW14872	DV, PV1	A	3.2	Yes	No[1]
Minimum Non-Operating Temperature	DV, PV[1]	A	2.1, 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	Yes
Sugar Water Function Impairment	DV, PV[1]	A	3.2	Yes	Yes

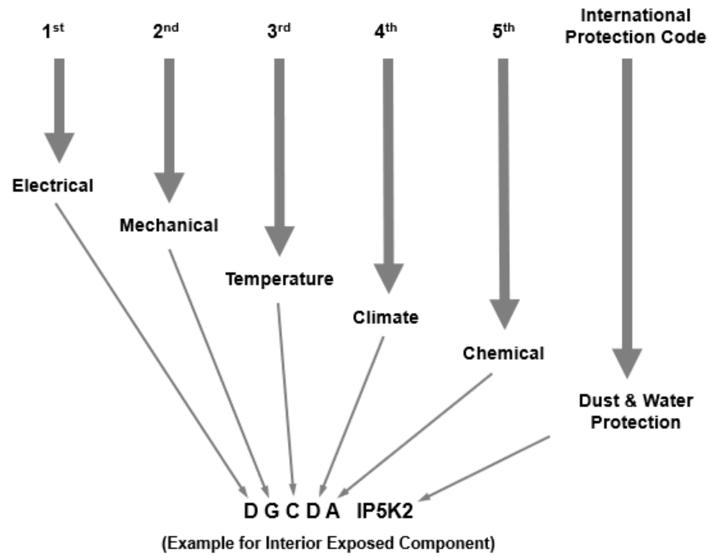
Activity	Phase	FSC	Operating Type	Continuous Monitoring	Functional Cycling
Product Validation (PV)					
Mechanical					
Shipping Vibration	PV[2]	C	1.1	N/A	N/A
Legend:					
A	Analysis				
D	Development				
DV	Design Validation				
N/A	Not applicable				
No[1]	Not required, unless determined necessary by GM				
PV	Product Validation				
PV[1]	These procedures may be omitted in PV with agreement of the 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 ENV SME.				
PV[3]	This procedure is required in PV for sealed components. Exceptions shall be agreed upon by the ENV SME.				

5 Requirements

5.1 Reliability. The Test Flows in this document demonstrate 99% reliability on test with a statistical confidence of 50%. In case of different reliability and confidence requirements, adjustments shall be made accordingly.

5.2 Quoting Requirements. Environmental requirements shall be assigned in the CTS, CTRS, SSTS, and/or other relevant requirements document according to Figure 7. In case that the Environmental requirements are missing in the CTS, CTRS, SSTS, and/or other relevant requirements document, the most appropriate code according to 5.2.7 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 “Additional Activities” in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

Figure 7: Code Letter Sequence Requirement



5.2.1 Code Letter for Electrical Loads. Table 6 defines the steady state minimum and maximum test voltages to be used as measured at the connector of the component. Table 6 should also be used in specifying the component criteria requirements unless otherwise specified in the CTS, CTRS, SSTS, and/or other relevant requirements document.

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	9 V	16 V
D (most common Battery Electric Vehicle (BEV))	9 V	18 V
E	10 V	16 V
F	12 V	16 V
G	4.5 V	5.5 V
H (most common Internal Combustion Engines (ICE))	6 V	18 V
Z	as agreed upon	

Note:

- In the range of the given code letter the FSC shall be A.

- In the range of -13.5 V to U_{min} and U_{max} to +26 V, the FSC shall be C.
- The test voltages for Electrical Code Letters A through F and H depend on the Operating Types as shown in Table 7.

Table 7: Test Voltages Note 1

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	Not applicable	2.1/2.2 (Generator not operating)

Note 1: For Electrical Code Letter G, U_{nom} is 5.0 V.

5.2.2 Code Letter for Mechanical Loads. Refer to 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 Note 2	Yes	No	Yes
H	Elbow Load and Foot Load	Truck Sprung Masses Note 2	Yes	No	Yes
I	Elbow Load	Truck Sprung Masses Note 2	Yes	Yes	Yes
J	Elbow Load	Truck Unsprung Masses Note 2	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 2: Vibration test durations for Heavy Duty Truck are different than Truck. Refer to 9.3.1 for more information.

Note:

1 The CTS, CTRS, SSTS, and/or other relevant requirements document or the Product Development Team (PDT) shall define the vehicle type (i.e., car, truck, or heavy duty truck).

2 Distinction between Car/Truck/Heavy Duty Truck and Sprung/Unsprung Masses:

- **a** Trucks are defined as pickup trucks or commercial vehicles (Body on Frame (BOF) vehicles, includes Full Size Sport Utility Vehicles (FS SUVs) based on a truck platform).
- **b** Heavy Duty Trucks are defined as 2500 and 3500 series or larger vehicles.
- **c** Cars are defined as passenger cars, SUVs, or Crossover Utility Vehicles (CUVs) (Body Frame Integral (BFI) vehicles, unibody; includes SUVs based on a car platform).
- **d** 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).
- **e** Unsprung Masses are defined as components attached to the wheels, tires, or moving suspension elements of a vehicle.

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

5.2.3 Code Letter for Temperature Loads. Refer to 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 1 h of the High Temperature Degradation test. Component is NOT 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			

5.2.4 Code Letter for Climatic Loads. Refer to 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	1000 h	No	No	Yes	Yes	Yes	Yes
B	1000 h	No	Yes	Yes	Yes	Yes	Yes
C	1000 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	1000 h	Yes	No	Yes	Yes	Yes	Yes
L Note 2	1000 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	1000 h	Yes	Yes	Yes	Yes	Yes	Yes
Z	as agreed upon						

Note 1: If Table 10 specifies the Seal test and/or the Water IP 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. Generally, 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.

5.2.5 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 (refer to 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 VE.

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

5.2.6 IP Code Letter for Enclosures. GM uses a subset of the IP Codes (refer to Table 12 and Table 13).

The IP Code definitions are like ISO 20653 "Road Vehicles – Degrees of Protection (IP Code) – Protection of Electrical Equipment Against Foreign Objects, Water and Access".

Table 12: IP Code Letter for Enclosures – Dust

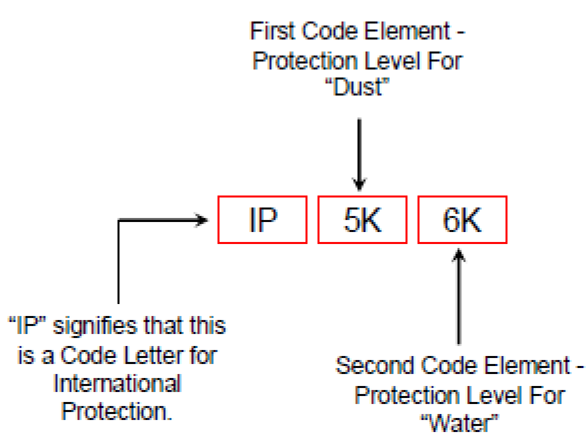
First Code Element	Brief Description	Requirements
X	Not required	None – Shall only be used in conjunction with Water IP Code 6K, 8K, or 9K.
5K	Dust-protected	Dust shall only penetrate in quantities which do not impair performance and safety.
6K	Dust-tight	Dust shall not penetrate.

Table 13: IP Code Letter for 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 15° 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 8 explains the use of letters in the IP Code. For details refer to ISO 20653 "Road Vehicles – Degrees of Protection (IP Code) – Protection of Electrical Equipment Against Foreign Objects, Water and Access".

Figure 8: IP Code Example



5.2.7 Code Designation by Location in the Vehicle. Table 14 following distinguishes between the vehicle 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 of Table 14. Table 14 should also be used in specifying the component GMW3172 sourcing code unless otherwise specified in the CTS, CTRS, SSTS, and/or other relevant requirements document.

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 (of internal combustion engines)						
High location, remote from engine and heat sources or mounted on intake manifold	A – H	C or G	F Note 1	B	E	IP6K9K and IP6K8
High location, close to engine or heat sources	A – H	C or G	H Note 1	B	E	IP6K9K and IP6K8
At/in engine	A – H	A or B	H or I Note 1	B	E	IP6K9K and IP6K8
At/in transmission	A – H	A or B	H or I Note 1	B	E	IP6K9K and IP6K8
Low	A – H	C, D, G, or H	F or H Note 1	B or O	E	IP6K9K and IP6K8
Drive Unit Compartment (Electric Vehicles)						
Electric vehicle drive unit compartment	D	C	C	J	E	IP6K9K and IP6K8
Passenger Compartment						
Low temperature load (under dashboard)	A – H	C or G	A, B or C	D	A or B	IP5K2
Normal temperature load (dashboard display or switch)	A – H	C or G	C or D	D	A or B	IP5K2
High temperature load (top of dashboard with sun load)	A – H	C or G	E or J	D	A or B	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 – H	C or G	D, E, or J	D	A or B	IP5K2
Mid-level passenger area (seats, pillars, etc.)	A – H	C or G	C	D	A or B	IP5K2
Low mount, more than 25 mm above carpet or floor pan (if no carpet)	A – H	D or H	A	D	A or B	IP5K2
Low mount, ≤ 25 mm above carpet or floor pan (if no carpet), or on/under carpeting, or in a tub/well/recessed space below common floor pan.	A – H	D or H	A	F (Seal required)	A or B	IP6K8
Brake, clutch, or accelerator pedal (i.e., water from operator's foot)	A – H	D or H	A	F	A or B	IP6K8
Center console area	A – H	C or G	A, B, or C	D	A or B	IP5K2
Passenger compartment high, roof	A – H	C or G	C or D	D	A or B	IP5K2
Other Locations						
Trunk/hatch area low mount < 25 mm from the main floor or carpet and below the main floor	A – H	D or H	A, B, or C	F	D	IP6K8
Trunk/hatch area high mount > 25 mm above carpet or floor	A – H	D or H	A, B, or C	D	D	IP5K2
Wells below floor level	A – H	D or H	A, B, or C	F	B or D	IP6K8
Inside doors and hatches (wet area)	A – H	E or I	B or C	J	C	IP6K8
Doors and hatches (dry area)	A – H	E or I	B or C	D	A, B, or C	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
Low exterior splash area	A – H	C or G	A, B, or C	J	F	IP6K9K and IP6K8
High exterior (above roof mount)	A – H	C or G	C or D	D	F	IP6K9K
Chassis and underbody not downstream of exhaust **Note 3**	A – H	C or G	A, B or C **Note 2**	J	F or G	IP6K9K and IP6K8
Chassis and underbody downstream of exhaust **Note 3**	A – H	C or G	F	J	F or G	IP6K9K and IP6K8
Inside the facia, front and rear	A – H	C or G	C, D, F, H or I **Note 4**	J	F	IP6K9K and IP6K8
Near the exhaust (< 300 mm)	A – H	C or G	H or I **Note 1**	J	F or G	IP6K9K and IP6K8
Above, or attached to, the exhaust	A – H	C or G	H or I **Note 1**	J	F or G	IP6K9K and IP6K8
Unsprung masses (wheels/suspension)	A – H	F or J	A, B or C	J	F or G	IP6K9K and IP6K8
Exterior at the base of the windshield inside the Plenum	A – H	C or G	D, E, F, G, or J	F or J	F	IP6K9K and IP6K8
Truck bed	A – H	D or H	C or D	F or J	F	IP6K9K and IP6K8
Truck bed storage compartment	A – H	C or G	C or D	F	F	IP6K9K and IP6K8

Note 1: May require consultation with the Thermal Vehicle Performance Owner (VPO), currently David Turner, as this may be different in certain situations depending on the mounting location proximity to the vehicle exhaust.
Note 2: For ICE, Codes A and B are not allowed. Must be C or greater. May require consultation with the Thermal Vehicle Performance Owner (VPO), currently David Turner.
Note 3: Downstream of exhaust is defined as any device in the airflow path of the exhaust.
Note 4: If above, attached, or near to (< 300 mm), the exhaust, Codes H or I (see Note 1). If downstream of exhaust, then Code F (see Note 3). Otherwise, Codes C or D.

6 Test Setup and Component Verification

6.1 Functional/Parametric Checks.

6.1.1 5-Point Functional/Parametric Check.

Purpose: This check shall verify full functionality of the component as defined in the CTS, CTRS, SSTS, and/or other relevant requirements document 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:

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

- **a** (T_{min}, U_{min}).
- **b** (T_{min}, U_{max}).
- **c** (T_{room}, U_{nom}), where U_{nom} is U_B for Operating Type 2.1, and U_A for Operating Type 3.2.
- **d** (T_{max}, U_{min}).
- **e** (T_{max}, U_{max}).

Note: The 5-Point Functional/Parametric Check may require additional check points to properly validate functional requirements for specific temperatures and voltages based on the CTS, CTRS, SSTS, and/or other relevant requirements document. For example, temperature derating limits, or functional derating based on voltage levels.

2 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.

3 The 5-Point Functional/Parametric Check shall be conducted with actual vehicle loads or equivalent. All loads shall be documented in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

4 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 (include all operating modes and parasitic modes), and timing levels for all inputs and outputs in order to verify that these levels meet the CTS, CTRS, SSTS, and/or other relevant requirements document, including tolerances.

3 Measure non-electrical parameters such as motor torque, Light Emitting Diode (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, CTRS, SSTS, and/or other relevant requirements document, including tolerances. These parameters shall be defined in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

4 Perform the Dimensional Check according to 6.6. 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, CTRS, SSTS, and/or other relevant requirements document, the supplier, the ENV SME or VE, and the DRE shall collaborate to define the degradation acceptance/failure criteria.

Criteria: FSC shall be A.

6.1.2 1-Point Functional/Parametric Check.

Purpose: This check shall verify full functionality of the component as defined in the CTS, CTRS, SSTS, and/or other relevant requirements document while exposed to a single temperature and single voltage.

Applicability: This check shall be performed during or after tests as defined in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

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

Monitoring: As defined in the following procedure.

Procedure:

1 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 GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

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

3 The 1-Point Functional/Parametric Check shall be conducted with actual vehicle loads or equivalent. All loads shall be documented in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

4 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 GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043), 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 GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043), in order to verify that these levels meet the CTS, CTRS, SSTS, and/or other relevant requirements document, 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, CTRS, SSTS, and/or other relevant requirements document, including tolerances. These parameters shall be defined in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

Criteria: FSC shall be A.

6.2 Continuous Monitoring.

Purpose: Continuous Monitoring shall detect the functional status of the component during and after exposure to the test environment. Continuous Monitoring shall sample all parameters under test at a rate such that all incorrect values are detectable throughout the entire duration of the test. The parameters monitored shall include the states of the outputs, the value of the input readings, serial data message content (transmitted and received), fault states, input/output commands, signals critical to specific functions or events, and the value of all hardware configuration registers (micros, Application Specific Integrated Circuits (ASICs)) required for proper Electronic Control Unit (ECU) operation. This shall be documented in detail in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

Applicability: This check shall be performed during the tests as defined in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

Operating Type: As defined in each individual test.

Monitoring: As defined in the GMW3172 Test Plan.

Procedure: Continuous Monitoring shall:

1 Detect all features and functionality by monitoring and recording that all outputs (both hardwired and on-vehicle data bus communications), or a subset thereof as defined in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043), 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 at the time of an event. Notification to GM (DRE, VE, and Test Plan approvers) shall be provided within 24 h of the event, including test conditions at the time of failure.

The monitoring sampling rate shall be defined in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043). If the entire sampling data set is extremely large due to the sampling rate, then the Supplier, at a minimum, shall save a record of the sampling data that occurs for a period of time (e.g., 1 h) before and after an event of an intermittent functionality and/or errors.

2 Monitor and record internal diagnostic status and codes, where available.

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

4 Monitor the values of the hardware configuration registers and event flags that exist within microprocessors and ASICs that are required for proper ECU operation and detect if these values are inappropriately changed under test. An example would be a short low voltage excursion, which resulted in a Reset Event which erroneously did not reconfigure the ECU completely and correctly leaving some configuration registers (or undervoltage flags) in an incorrect state and the ECU not perfectly functional.

5 Sample all parameters under test at a sample rate fast enough to capture any change of the following items:

- **a** Actuation signals,
- **b** Serial data messages,
- **c** Fault codes,
- **d** Configuration registers/event flags,
- **e** I/O commands and actual states.

The sample rate shall be verified to be correct at small enough intervals of time such that any intermittent behavior would be detectable. This interval of time will vary depending on the individual application and shall be agreed to by GM and clearly called out within the component GMW3172 Test Plan.

6 Monitor and record the specific voltage and current levels during all applicable operating modes and parasitic modes. For example, during Sleep state (Operating Type 2.1), parasitic current shall be monitored. If more than one parasitic mode exists, each parasitic mode shall be monitored and verified.

Note: Data logging of all continuous monitoring is expected to be included in the formal Test Report. If decisions are made to reduce data logging, agreement is required between the Test Plan Approver and Test Plan Data Reviewer (typically the ENV SME and VE).

Example: Video monitoring shall detect intermittent errors on each sample and shall be capable of adequate video processing to flag errors. Continuous Monitoring shall process each frame of video for errors on every sample for each frame, but may, upon agreement with the Test Plan Approver/Data Reviewer, only record (for the Test Report) errors with a period of time at least long enough to diagnose the event, typically 10 times the sampling rate before and after the event for evaluation, including additional information to document the failure. For example, record DUT, date, time, testing conditions (e.g., temperature of the thermal chamber, etc.), at the time of the event, and the trigger.

6.3 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 GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

Applicability: Functional Cycling shall be performed during the tests as defined in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

Operating Type: 2.1/2.2/3.1/3.2

Monitoring: As defined in the following procedure.

Procedure:

1 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.

2 The functional cycling rate shall be defined in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

3 Functional Cycling shall occur during any test that includes Operating Type 3.2. Exceptions shall be included in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043). 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.

4 The input/output cycling and monitoring shall be automatic.

6.4 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 housing, internal parts, and electrical connections at the completion of testing as specified in the 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 ENV SME or VE 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 ENV SME and VE shall perform the Visual Inspection and Dissection – DRBTR, along with the DRE, Resident DRE, SQE, and Supplier if needed. All parties shall be informed of observations and areas of concern.

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

After DV/PV Testing. The supplier shall perform the Visual Inspection and Dissection – DRBTR on all samples, except those for GM inspection from Step 2 following or as agreed upon, with the ENV SME and/or VE present, or as agreed upon. These agreements shall be made with the ENV SME and the VE. The DRE, Resident DRE, SQE, and Supplier should be present as well. All parties shall be informed of observations and areas of concern as defined in GMW16044.

Note: All samples shall be available for GM review upon request.

1 The following samples shall be kept assembled and reserved for the Visual Inspection and Dissection – DRBTR by the ENV SME or VE upon request:

- **a** One sample from the Mechanical Fatigue leg.
- **b** Two samples from the Thermal Fatigue leg (one from HHCO and one from HHC).
- **c** One sample from the Corrosion test leg.

2 The ENV SME and VE shall perform the Visual Inspection and Dissection – DRBTR, along with the DRE, Resident DRE, SQE, and Supplier if needed. All parties shall be informed of observations and areas of concern.

3 The Visual Inspection and Dissection – DRBTR is as follows:

- **a** Perform an external inspection of the component housing.

b Disassemble the component for an internal inspection.

c The inspection shall use visual aids (e.g., magnifiers, microscopes, dyes, etc.), as necessary.

Inspection Examples:

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, Foreign Matter, Residues, or Corrosion**: Melted plastic parts; degraded conformal coatings, solder masks or seals; circuit board delaminations, lifted circuit board traces, corrosion, organic growths, or environmental residues due to dust, salt, moisture, etc. All foreign matter or 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 GMW3172 Component Environmental Test Plan (in "Templates" section of 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, the whiskers shall be measured for total axial whisker length and whisker density range, as defined in JEDEC JESD22-A121 "Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes".

8 **Electromigration and Dendritic Growth:** The circuit board and all parts shall be free of current evidence or past evidence of electromigration and dendritic growth, as well as ionic contamination that may lead to electromigration or 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 as follows in the Criteria, test samples shall be inspected according to the specific tests that are listed.

Criteria:

1 **GMW16044:** A summary of each component condition shall be documented and reported to the ENV SME or VE, 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.

2 The pre-test and post-test samples shall comply with the acceptance criteria according to the latest versions of:

a IPC-A-610 "Acceptability of Electronic Assemblies"

b IPC-6012 "Qualification and Performance Specification for Rigid Printed Boards"

c IPC-6013 "Qualification and Performance Specification for Flexible/Rigid-Flexible Printed Boards"

Note: Class 3 shall be applied, unless the CTS, CTRS, SSTS, and/or other relevant requirements document states otherwise.

3 **Whiskers:** The total axial whisker length shall not exceed the acceptance criteria as stated in JEDEC JESD201A "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.

4 **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.), shall 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.

5 **Procedure Specific:** As defined by each of the following specific tests:

a **Vibration with Thermal Cycling, Mechanical Shock – Pothole, Mechanical Shock – Collision, and Mechanical Shock – Closure Slam:** There shall be no evidence of structural damage.

b **Connector Installation Abuse – Side Force and Connector Installation Abuse – Foot Load:** There shall be no damage to the connector(s), housing, and circuit board to which the connector is attached.

c **Crush for Housing – Elbow Load and Crush for Housing – Foot Load:** No contact between the case, Printed Circuit Board Assembly (PCBA), and other electrical parts shall be allowed. No damage to the housing, connector, PCBA, other electrical parts, and mechanical parts shall be allowed.

d **Free Fall:** For components with minor visible external damage, there shall be no internal damage. For components with significant visible external damage as judged by the VE, any internal damage shall be reported.

e **Open Circuit – Single Line Interruption, Open Circuit – Multiple Line Interruption, Intermittent Short Circuit to Battery and to Ground for Input/Output, and Continuous Short Circuit to Battery and to Ground for Input/Output:** There shall be no evidence of overheating.

f **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.

g **Over Load – Fuse Protected Circuits:** There shall be no evidence of discoloration from overheating.

h **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. A safety critical behavior (e.g., smoke, fire, melted plastics, etc.), is not allowed.

i **Frost, Humid Heat Cyclic (HHC), and Humid Heat Constant (HHCO):** There shall be no evidence of electromigration or dendritic growth.

j **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.

k **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.

- **l** **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.
- **m** **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.
- **n** **Seal:** Inspection shall be performed using a UV light. There shall be no evidence of water ingress inside the component and the connector.

6.5 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: Not applicable.

Procedure:

Determine the cross sections:

1 Based on the X-ray results from 6.6, additional cross sections may be added to Leg 0a. The supplier, together with the ENV SME, shall identify these specific cross sections to perform. The supplier shall perform this activity on one sample prior to testing, or as shown in the Test Flow. More than 1 sample is typically required for leadless parts to evaluate all four corner standoff heights.

Note: All cross sectional pictures shall be made available to GM.

2 The cross section points shall be identified in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043), as negotiated between the supplier and GM. Different items to be cross sectioned can be selected on each PCB. If possible, plan section cuts to include as many features of interest as possible, for example:

- **a** A row of solder balls.
- **b** A row of Plated Through Hole (PTH) vias.
- **c** A row of through-hole connector pins.
- **d** Large mass parts (e.g., electrolytic capacitors, etc.)
- **e** Through-hole parts.
- **f** Corner pins of Ball Grid Array (BGA) parts.
- **g** Surface Mount Device (SMD) parts having the largest relative footprints on the circuit board.
- **h** All leadless devices, such as Quad Flat No-Lead (QFN) and Dual Flat No-Lead (DFN) packages.
- **i** One of each sized electrical via and thermal via.

3 Perform cross sectioning on at least one of every type of solder joint, electrical connection, and via that exist on the PCB in Leg 0a. 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 Coefficient of Thermal Expansion (CTE) differentials or corner pins of surface mounted parts with large diagonal lengths. Vias most at risk are those with the smallest diameter.

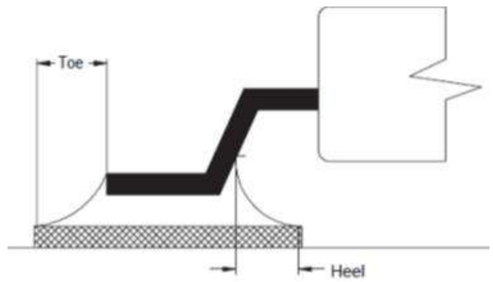
Note:

- 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 “Test Methods Manual” (https://www.ipc.org/test-methods), IPC-6012 “Qualification and Performance Specification for Rigid Printed Boards”, IPC-6013 “Qualification and Performance Specification for Flexible/Rigid-Flexible Printed Boards”, and IPC J-STD-001 “Requirements for Soldered Electrical and Electronic Assemblies” (https://shop.ipc.org/).

4 Cross section cuts shall be perpendicular to the PCB surface. The cross section cut shall be through the center of the solder joint and through the part encapsulation (so that the solder joint cut is in the heel-to-toe direction as shown in Figure 9). The cross section cut shall be through the center of the PTHs and vias.

Figure 9: Heel-to-Toe Direction



5 Sample selection shall be as follows:

- **a** One or more samples that is not subjected to testing shall be cross sectioned by the supplier.
- **b** 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 if cross sectioning is required, for example, if there are failures.

Attention:

- GM review and approval of the report is required before Mechanical and Thermal Fatigue testing (Legs 1, 2, and 3) can begin.
- 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 each new production line.
- As soon as available, update and rerun the analysis models in 7.4.2 Thermal and Mechanical Fatigue Analysis of PCBA and Housing with any information that may change the model, for example, cross section results that indicate the process variations, including minimum standoff height and non-symmetries in the standoff heights.

The following cross section procedure shall be used:

1 The component circuit board shall be removed from its housing and potting material shall be removed if applicable. Do this in a manner that will not add additional stress to the circuit board and solder joints. As an alternative, build samples for pre-test cross section without potting material if the ENV SME agrees.

2 Prior to cross sectioning:

- **a** Perform a surface examination according to IPC-TM-650 “TM 2.1.5 Surface Examination, Unclad and Metal-Clad Material”. Note any pinholes, scratches, wrinkles, inclusions, or other abnormalities, or pits and dents exceeding the point count. Provide pictures of the observations.
- **b** Refer to the results from 6.5.1 to identify the worst-case voids for additional cross sections.
- **c** Select the worst-case samples with the largest voids to cross section.
- **d** If the potting material is used, the supplier can select the worst-case samples for pre-test cross sectioning prior to being potted if the ENV SME agrees.

3 Perform cross sectioning of test samples according to IPC-TM-650 “TM 2.1.1 Microsectioning, Manual and Semi or Automatic Method” and “TM 2.1.1.1 Microsectioning, Ceramic Substrate”.

4 Evaluate the test section points as negotiated between GM and the supplier to provide detailed information as described as follows (in items 5, 6, 7, 8, 9, and 10).

5 For each solder joint – provide a picture of the entire view of the cross section to show the quality of the circuit board solder material fillets, hole fillings, voids, cracks, etc.

6 For each PTH and via – measure the minimum and average copper plating thicknesses, including pictures of the entire view of the cross section to show the quality of the plating, irregular plating, nodules, voids, and cracks.

7 For each PTH, via, and solder joint – provide measurements of any item that does not meet, or is close to not meeting, the acceptance criteria for crack length, void percentage, and via roughness.

8 For each PTH and solder joint – provide pictures of the average intermetallic bond thickness measurements (i.e., terminal-to-solder and solder-to-PCB/PTH side wall). This step is required only for pre-test samples.

9 For each leadless part (such as a DFN or QFN) – include pictures to verify that it has wettable flanks (per the GM requirements in the CTS, CTRS, SSTS, and/or other relevant requirements document/GB14082).

10 For each leadless part (such as a DFN and QFN) – provide pictures and measurements of the standoff heights for both of the slug sides and all four corner pins (refer to Figure 10) also showing measurements and titling. Also, include additional cross sections on the part such that all four corners of the leadless part are included in order to evaluate tilt. If needed, use an additional sample to complete the required cross sections.

Figure 10: Standoff Height Measurements (Pictorial)

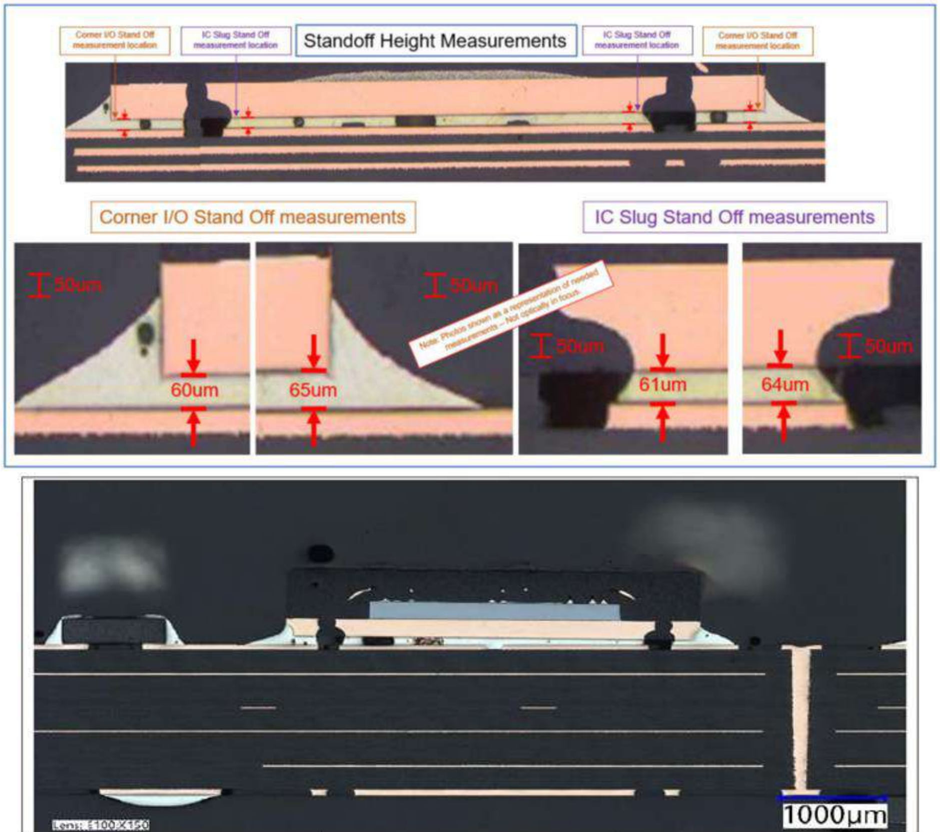


Figure ID	Condition	Magnification
A	As Polished	Stitched at 50X

11 A summary of each component cross section results shall be documented and reported to GM.

12 The supplier may be required to perform further investigation to determine the degree or type of degradation.

13 If required, perform measurements of suspect areas according to IPC-TM-650 “TM 2.2.2 Optical Dimensional Verification” and/or “TM 2.2.5 Dimensional Inspections Using Microsections”.

Criteria:

1 A summary of each component condition shall be documented and reported to the ENV SME or VE who will evaluate the reports and decide as to the necessity of corrective action.

2 The documentation shall include the following for each cross section:

- **a** For each PTH, via, and solder joint: Provide a picture of the entire view of the cross section.
- **b** For PTH and via: Provide pictures and measurements of the minimum and average copper plating thickness.
- **c** For each PTH and solder joint: Provide pictures of average intermetallic bond thickness measurements (i.e., terminal-to-solder and solder-to-PCB/PTH side wall).
- **d** For each leadless part (such as a DFN or QFN): Provide pictures of the wettable flanks.
- **e** For each leadless part (such as a DFN or QFN): Provide pictures and measurements of the standoff heights for both of the slug sides and all four corner pins (refer to Figure 10).
- **f** Measurements for via roughness if it does not meet, or is close to not meeting, the acceptance criteria.

3 No solder cracks are allowed.

4 Acceptability of the solder bonding strength shall be based on an average combined thickness of Copper-Tin intermetallic bonds of Cu_3Sn and Cu_6Sn_5 that shall be ≥ 1 µm and ≤ 6 µm (5 µm preferred) after all soldering procedures are completed. When Nickel-Tin systems are used, the Ni_3Sn_4 intermetallic thickness after all soldering processes are completed shall be (0.25 to 0.75) µm.

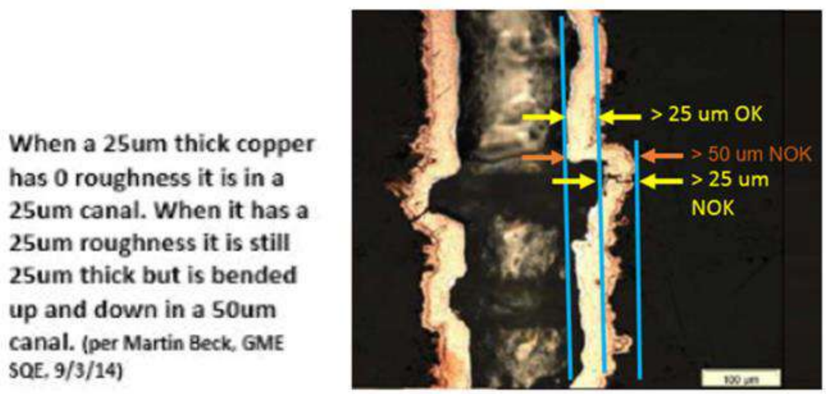
5 All samples shall comply with the acceptance criteria according to the latest versions of:

- **a** IPC-A-610 "Acceptability of Electronic Assemblies"
- **b** IPC-6012 "Qualification and Performance Specification for Rigid Printed Boards"
- **c** IPC-6013 "Qualification and Performance Specification for Flexible/Rigid-Flexible Printed Boards"
- **d** IPC J-STD-001 "Requirements for Soldered Electrical and Electronic Assemblies"

Note: Class 3 shall be applied, unless the CTS, CTRS, SSTS, and/or other relevant requirements document states otherwise.**6** For plated through holes and vias, the minimum average copper plating thickness shall be 25 µm (0.984 mils). The minimum thin area shall be ≥ 20 µm (0.787 mils).

7 For plated through holes and vias, the roughness of the copper plating shall be < 25 µm (as described in Figure 11 as follows as an example for via roughness).

Figure 11: Via Roughness Requirement (Pictorial)



Via Roughness can only be measured by cross-sectioning the via.

8 All leadless parts (such as QFNs and DFNs) shall have wettable flanks (per the GM requirements in the CTS, CTRS, SSTS, and/or other relevant requirements document/GB14082).

9 As a guideline, all leadless parts (such as QFNs and DFNs) should have a minimum standoff height of 75 um for both slug sides and for all four corner pins (refer to Figure 10). Any exceptions are acceptable if stated in the CTS, CTRS, SSTS, and/or other relevant requirements document.

10 If during post-validation root-cause analysis, cross sectioning is determined to be necessary, reference B1 Guidelines to Measure Solder Joint Crack Length in Appendix B for guidelines to measure solder joint crack length.

6.6 PCBA X-ray Inspection.

Purpose: PCBA X-ray Inspection shall inspect the quality of the solder joints to assess the solder voids of all components located on to the circuit board and identifies the requirement of additional cross sections so as to avoid post validation concerns owing to solder voids that may result in issues over a lifetime of component usage. This

PCBA X-ray Inspection shall be performed at the production facility prior to PCBA installation into the component assembly as part of normal SMT line operations or performed off-line if necessary.

Applicability: All components that have PCB(s).

Operating Type: 1.1

Monitoring: Not applicable.

Procedure: PCBA X-ray on a per pin bases is to be used to monitor void levels on all the SMT parts used for GMW3172 validation. All parts that are included in the Leg 0a Cross Sections, as well as all crystals, plated through hole parts, and parts that are covered in AEC-Q100 (e.g., BGAs, ASICs, DFNs, micros, etc.), and any additional locations identified by the test plan approver need to be monitored for solder voids.

1. Based on complexity of the module all or a subset of SMT parts (contains all types of parts) will be selected for X-ray analysis:
   - **a** This selection of a subset of SMT Parts will contain a representation of all types and be more heavily sampled based on all leadless SMT Parts (BGAs, DFNs, and QFNs). Also, include all new technologies and any previously identified at risk parts.
   - **b** This selection is to jointly be reviewed and determined with the Supplier, ENV SME, VE, and GM Hardware engineer if one exists.
2. This PCBA X-ray Inspection shall be performed at the production facility prior to PCBA installation into the component assembly as part of normal SMT line operations or performed off-line if necessary.
3. This PCBA X-ray Inspection is to be used to determine if GM requirements for Void levels are being met.
4. The data to be collected is for voids in pin solder connections and separately for the distribution and size of the voids in the slug under ICs for lead-less parts (i.e., BGAs, DFNs, QFNs, and others).
   - **a** This data is to contain Mean, Standard Deviation, Minimum, Maximum, and 3-sigma location (i.e., mean plus 3 sigma) for each individual solder joint for each part that is identified in the test plan.
   - **b** The standard deviation will determine if the production process is under control.

Note:

1. Additional cross sections may be required based upon PCBA X-ray Inspection review.
2. The supplier shall perform this activity on all the samples prior to testing.
3. Based on the PCBA X-ray Inspection results, the additional cross sections may be added to Leg 0a. The supplier, together with the ENV SME, shall identify these specific cross sections to perform.
4. Pictures of specific concerned areas of PCBA X-ray Inspection shall be made available to GM.
5. Review all samples and based on the PCBA X-ray Inspection results, choose worst case samples for cross sectioning in Leg 0a and for testing in Leg 1. For example, if 59 samples are being validated, all 59 samples will go through PCBA X-ray Inspection. The 13 worst-case voids will go in Leg 0a and Leg 1.
6. Based on the PCBA X-ray Inspection results (solder void variation), additional cross sections may be added to Leg 1 or any other Leg.
   - **a** All samples that will be subjected to testing shall be inspected under PCBA X-ray inspection by the supplier.
   - **b** PCBA X-ray inspection shall occur as soon as possible after the DV/PV build to find production issues quickly and begin the resolution process as soon as possible. This will serve as an early indicator of production issues due to solder voids.

Attention: GM review and approval of the report is required before any test leg testing begins.

Criteria:

- A summary of each component condition shall be documented and reported to the ENV SME or VE. GM Engineering will evaluate the reports and decide as to the necessity of corrective action.

- For each individual solder joint, the total area of solder void(s) in a solder joint is required to be < 20%. The mean plus Three Standard Deviation (3SD) percent void shall be < 25% for each solder joint. The standard deviation is based on all of the PCBAs being X-rayed and will be calculated for each solder joint under evaluation. For example, if 59 PCBAs are X-rayed for a 64-pin QFN, there will be 64 different SD calculations that are derived from the 59 samples.
- The size of the voids in the slug under ICs for lead-less parts should be < 20% of area by X-ray. The mean plus 3SD percent void shall be < 25% for each slug.
- The documentation shall include the X-ray pictures, the solder voids (%), and the mean plus 3SD for each pin or slug.

6.7 Dimensional Check.

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

Applicability: All components.

Operating Type: 1.1

Monitoring: Not applicable.

Procedure:

1 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.

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

3 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.

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

Criteria:

- FSC 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 (VTD).

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 (HALT), 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 following procedure.

Procedure:

1 Component Mounting Considerations:

a 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 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.

b 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 the harnesses do not influence the vibration input to the test samples.

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

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

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

3 **Test Fixture Transmissibility:**

a The test fixture, when loaded with the test samples, shall be shown to provide a vibration level (and mechanical shock input) that is representative of the test input at the mounting locations as measured on the test fixture.

b A control accelerometer shall be mounted on the test fixture, or directly on the vibration table, to serve as the reference point for the derivation of the control signal (as defined in IEC 60068-2-64 “Test Fh, Vibration, broadband random and guidance”). This signal is used to control the level of vibration (and mechanical shock) via closed-loop feedback to the vibration (and mechanical shock) control equipment.

c A test sample accelerometer shall be mounted on the test fixture as close as possible to the fixation point for **each** sample. Measure the vibration response (in the intended drive axis) for each accelerometer. This will show that the required vibration profile (and mechanical shock input) is replicated at each sample location on the fixture. The test sample accelerometer **cannot** be considered as the control accelerometer.

d Cross-axis acceleration shall be measured at the location of the accelerometer 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.

e The locations of the control accelerometer and the sample accelerometers for **each** sample, along with the data collected from the VTD shall be provided using the VTD tool located in the “Tools” section of CG3043. This information shall be **reviewed and approved** by the ENV SME prior to starting the test. This information shall be documented in the test report.

f A picture of the loaded test fixture, including the locations for the control and test sample accelerometers, shall be included in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

Criteria:

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

2 The true value of the Vibration profile, as measured in each intended axis at the accelerometer 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 × breakpoint) for lower tolerance and 144% (1.44 × breakpoint) for the upper tolerance. Figure 12 and Table 15, Table 16, Table 17, and Table 18 show an example of how to apply the Random Vibration Tolerance Bands and Cross-Axis Acceleration Upper Limit as described in this procedure. This example applies only to the Vibration profile for components that are sprung masses that are mounted in the passenger compartment (19.6 m/s^2_{RMS} (2.0 g_{RMS}), see C1 Vehicle Vibration Level Maps and Vibration Profiles in Appendix C, specifically Front of Dash, Passenger Compartment, and Rear Body in C1.1, C1.2, C1.3, C1.4 and C2.2). Refer to 9.3.1 to determine the appropriate Vibration profile based on the vehicle mounting location of the component under test, in order to align with the actual profile that will be used for testing.

Figure 12: Example of Acceleration Tolerance Bands and Cross-Axis Acceleration Limit for Random Vibration Profile - Sprung Masses in Front of Dash, Passenger Compartment, and Rear Body

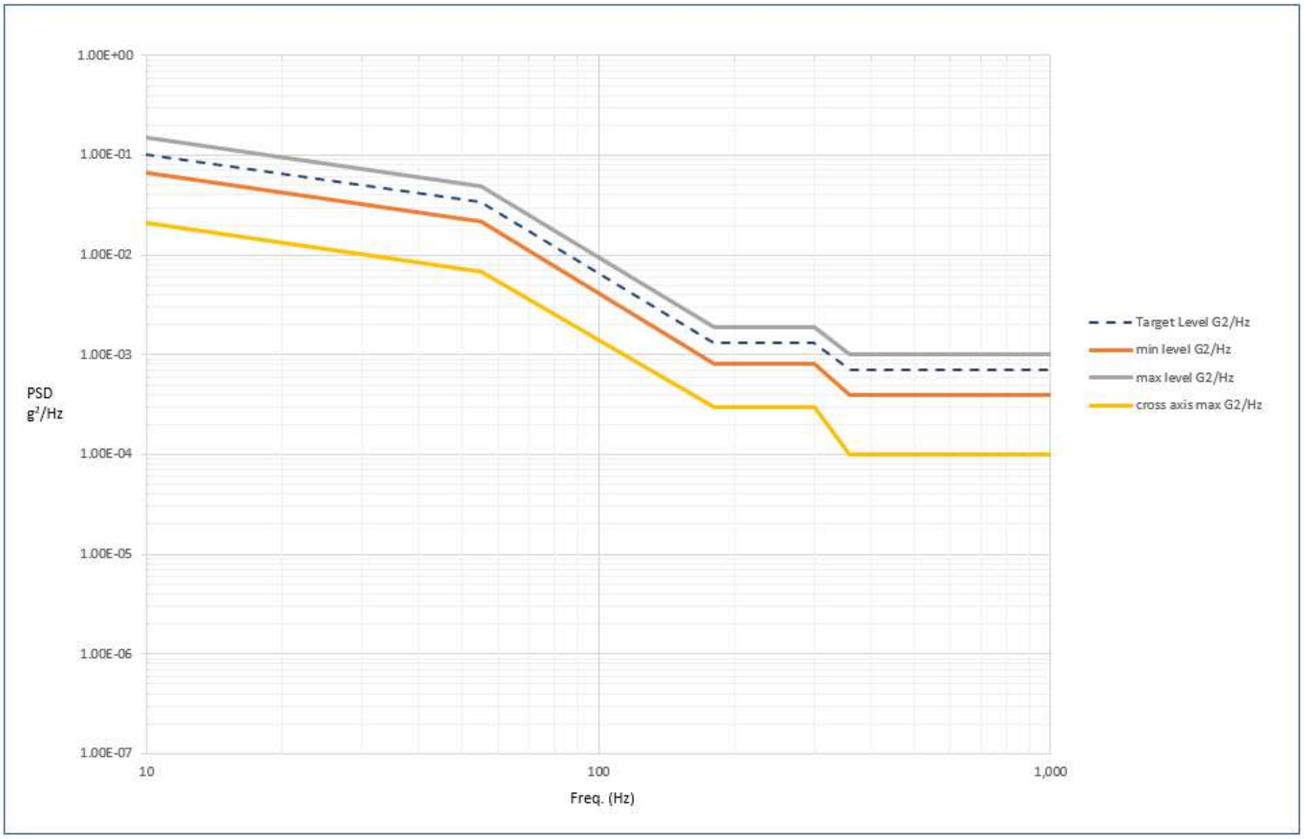


Table 15: Example of Lower Tolerance Band for Random Vibration Profile - Sprung Masses in Front of Dash, Passenger Compartment, and Rear Body Note 1

Frequency in Hz	PSD $(m/s^2)^2/Hz$	PSD 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

Note 1: Effective Acceleration is 15.7 m/s^2_{RMS} (1.6 g_{RMS}). Each break point is 64% of the original.

Table 16: Example of Upper Tolerance Band for Random Vibration Profile - Sprung Masses in Front of Dash, Passenger Compartment, and Rear Body Note 1

Frequency in Hz	PSD $(m/s^2)^2/Hz$	PSD 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

Note 1: Effective Acceleration is 23.5 m/s^2_{RMS} (2.4 g_{RMS}). Each break point is 144% of the original.

Table 17: Example of Target Level Random Vibration Profile - Sprung Masses in Front of Dash, Passenger Compartment, and Rear Body Note 1

Frequency 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

Note: 1: Effective Acceleration is 19.6 m/s^2_{RMS} (2.0 g_{RMS}).

Table 18: Example for Cross-Axis Acceleration Upper Limit for Random Vibration Profile - Sprung Masses in Front of Dash, Passenger Compartment, and Rear Body Note 1

Frequency 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

Note 1: Effective Acceleration is 8.8 m/s^2_{RMS} (0.9 g_{RMS}). Each break point is 20.25% of the original.

3 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 ≤ 0.45 times the acceleration m/s^2_{RMS} (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% (i.e., 0.2025 × breakpoint). An example of how this applies to the Random Vibration for Sprung Masses is shown as proceeding in Figure 12 and Table 18.

4 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.

5 The Test Report shall include:

- **a** Pictures of the test setup, including locations of the control and sample(s) accelerometers.
- **b** Data for the Random Vibration profile from the VTD tool located in the “Tools” section of CG3043.
- **c** Data for the Mechanical Shock – Pothole and Mechanical Shock – Collision profiles.

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), 1.2/2.1/3.2 (PTC)

Monitoring: Temperature logging.

Procedure:

1 Using the same PTC chamber model number that will be used in the DV/PV test, load the PTC chamber with the same number of samples that will be tested during PTC. Include fixturing and harnesses.

- **a** If separate thermal chambers are used for PTC, then perform separate Thermal Cycle Profile Development (TCPD) measurements.
- **b** If the same chamber is used for different quantities (e.g., 12, 18, or 30), then TCPD will be required for the different quantities.

2 Attach an internal thermocouple to the sample(s) PCB in or near the top side of the PCB as placed into the chamber. If there is < 5 °C gradient on the PCB during GMW8288, then a single Thermocouple (this thermocouple will be called $Thermocouple_{TCPD}$) may be used. If the gradient during GMW8288 is > 5 °C, then two thermocouples will be needed. The second thermocouple will be called $Thermocouple_{TSmaxmeasure}$. Locate the $Thermocouple_{TCPD}$ in a location near the center of the PCB that is closer the coolest part of the PCB while operating. If required, place a 2nd thermocouple ($Thermocouple_{TSmaxmeasure}$.) on the PCB near the hottest part of the PCB (on the PCB, not on chips, ASICs, etc. but adjacent/near) identified using GMW8288. If this requires placing $Thermocouple_{TSmaxmeasure}$ on the bottom side of the PCB, (typically heat rises so the top side) above said location should be at or within a few degrees of the same temperature such that placing on the top side will be the hottest location but if it is not, it may be placed at the hottest location on the PCB on the bottom side. $Thermocouple_{TSmaxmeasure}$ will be used to determine T_{maxTS} unless agreed otherwise by the test plan approver.

a If multiple shelves will be used to hold the samples, there shall be a thermocoupled sample from each shelf positioned in the center of the shelf.

b For the larger mass component with multiple PCBs, furthermore, the additional thermocouples shall be added on each PCB of the component.

c Add thermocouples to flexible PCBs.

d Ensure temperature tolerances (T_{min} +3 °C and T_{max} -3 °C) are achieved on all thermocouples. The ENV SME or CVE shall review and agree to the logged profiles based on temperature and time differences for the components to reach T_{max} and T_{min}.

3 Program the PTC chamber to cycle between T_{min} and T_{max} at a ramp rate of (1 to 15) K/minute that will be used during the PTC test.

4 Apply power to all samples and apply the agreed upon functional cycling and Operating Types that will be used in the PTC test.

5 Once the component temperature reaches T_{min} +3 °C/T_{max} -3 °C, dwell for 15 minutes. If multiple samples are thermocoupled, the 15-minute dwell starts when the last sample (i.e., worst case) reaches T_{min} +3 °C/T_{max} -3 °C.

If the rate of change of temperature of the fastest changing thermocouple on the component PCB is > 15 K/minute, decelerate the ramp rate to be < 15 K/minute. This shall apply if a part on the PCB is exposed to > 15 K/minute and at risk of failure during PTC due to an accelerated change of temperature.

6 Record data for 3 consecutive cycles.

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_{maxTS}. 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.

7 Using the same TS chamber model number that will be used in the DV/PV test, load the TS chamber with the same number of samples that will be tested during TS. Include fixturing and harnesses.

If separate thermal chambers are used for Leg 1 and Leg 2 TS, then perform separate TCPD measurements. Additionally, if the same chamber is used for different quantities (e.g., 12, 18, or 30), then TCPD will be required for the different quantities.

8 Using the same thermocoupled samples from PTC, place the samples in the center of the TS chamber. If multiple shelves will be used to hold the samples, there shall be a thermocoupled sample from each shelf positioned in the center of the shelf. Furthermore, for the larger mass component with multiple PCBs, the additional thermocouples shall be added on each PCB of the component to ensure temperature tolerances (T_{min} +3 °C and T_{max} -3 °C) are achieved on all thermocouples. The ENV SME/CVE shall review and agree to the logged profiles based on temperature and time differences for the component to reach T_{maxTS} and T_{min}.

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

10 Once the component temperature reaches T_{min} +3 °C/T_{maxTS} -3 °C, dwell for 15 minutes. If multiple samples are thermocoupled, the 15-minute dwell starts when the last sample (i.e., worst case) reaches T_{min} +3 °C/T_{maxTS} -3 °C.

It is recommended to replace TS with PTC if the rate of change of the fastest changing thermocouple on the component PCB is more than 15 K/minute. This shall apply if a part on the PCB is exposed to more than 15 K/minute and at risk of failure during TS due to an accelerated change of temperature.

11 Record data for 3 consecutive cycles. 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** Photograph/drawing showing location of all components in chamber, including the thermocouple components
- **d** Photograph/drawing showing location of component internal thermocouple

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 three cycles of PTC, and dwells for 15 minutes once it reaches T_{min} +3 °C and $T_{max\ TS}$ -3 °C, for at least three cycles of TS.

6.10 Test Harness Requirements.

6.10.1 Assembly or Procurement.

Purpose: Specifies requirements for the construction or procurement of test harnesses used in DV and PV testing.

Applicability: Applies to all test harnesses used in all GMW3172 tests.

Construction Requirements:

1 The component mating end of the DV and PV test harness shall be made only out of the part numbers used in the production mating harness. This includes, but is not limited, to the following:

- **a** Connectors
- **b** Connector Seals - when used in production
- **c** Terminals
- **d** Terminal Seals - when used in production
- **e** Connector Position Assurance (CPA) – when used in production
- **f** Terminal Position Assurance (TPA) – when used in production
- **g** Cavity Seals - where applicable
- **h** Wire

2 No additional sealants may be used (e.g., silicone, etc.)

3 A connector released for production may have unused cavities sealed over with material in the connector molding tool. Often, these specific connectors are not available for the component DV or PV test. If another connector from the same family with all cavities unsealed is made available by the supplier, it is acceptable to use this connector, sealing the unused cavities with cavity seals **approved** and provided by the production connector supplier.

4 The DV and PV test harness shall be made out of the same conductor type, wire size, diameter, and insulator as used in the production mating harness. The component supplier shall determine the length of the harness as needed for test purposes. The end of the harness intended to mate to instrumentation may be terminated by the component supplier as needed.

5 The DV test harness may be constructed by the component supplier as long as the supplier uses handheld wire strippers and terminal crimpers **approved** by the production mating harness supplier. The component supplier is not obligated to purchase automated tools for this task but may choose to procure wires terminated with such tools from the production mating harness supplier.

6 For high voltage applications (i.e., minimum 48 V vehicle systems), the DV/PV test harness shall be purchased from the production mating harness supplier.

7 If the component supplier assembles their own DV test harness (where allowed), and no DV failures are root caused to the test harness, the supplier may continue to construct their own test harnesses for PV testing (meeting the same requirements as preceding).

8 If the component supplier assembles their own DV test harness, and there are DV failures root caused to the test harness, then the component supplier shall procure test harnesses from the production mating harness supplier for subsequent iterations of DV and PV testing. The production intent mating harness supplier shall construct the component mating end of the DV/PV test harness out of the part numbers used in the production mating harness. Production intent tooling to strip and terminate the wires is preferred, otherwise the production harness supplier may use the same hand held tools authorized for harness repair. The end of the test harness intended to mate to instrumentation may be terminated by the component supplier. The component supplier shall determine the length of the harness as needed for test purposes.

6.10.2 Mate/Unmate Cycles.

Purpose: Specifies requirements for the maximum number of times that the test harness connectors may be reused.

Applicability: Applies to all test harness connectors used in all GMW3172 tests.

Requirement:

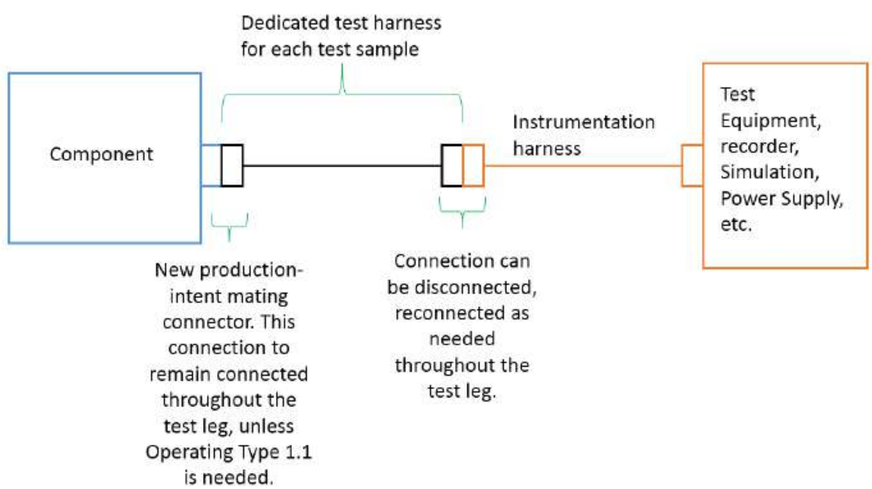
1 For each iteration of DV or PV testing, the terminated end of the test harness that connects to the component shall be re-terminated (i.e., replace terminals, including terminal seals if applicable). Also, the component end of the test harness shall be re-terminated if it exceeds 10 mate/unmate cycles during a DV or PV iteration. The instrumentation end of the test harness shall not exceed the number of mate/unmate cycles for which it is rated.

2 The connector body, CPAs, and other elements of the connector system may be reused. Connector seals and terminal seals shall be replaced for each iteration of DV or PV testing.

3 For test legs as follows:

a **Scenario 1:** For test legs that include Mechanical Fatigue, Thermal Fatigue, Salt Mist, Salt Spray, Water, Seal, and Leakage Check, the harness connector interface to the component shall not be disturbed during the test leg unless Operating Type 1.1 is required during the test leg. Therefore, there shall be a dedicated test harness for each sample, as shown in the Figure 13. The interface between the dedicated test harness and the instrumentation harness shall not exceed the number of mate/unmate cycles recommended by the manufacturer of that connection interface. Additionally, for Salt Mist and Salt Spray tests, the same harness connector to the component shall not be reused on subsequent samples.

Figure 13: Dedicated Test Harness for each Sample



b **Scenario 2:** For all other test legs not subject to the requirements in preceding Scenario 1, the harness connector interface to the component may be disconnected and reconnected a maximum number

10 mate/unmate cycles. The maximum number of mate/unmate cycles on the instrumentation side shall not exceed the rated number of mate/unmate cycles recommended by the manufacturer of that connection interface.

6.11 Simulator Verification.

Purpose: Simulator verification is required to assist in determining whether the simulators and representative/actual loads used in testing that perform functional cycling and continuous monitoring will provide repeatable and accurate results throughout Environmental testing.

Applicability: All components.

Functional Block Diagram: Provide an illustration (functional block diagram) showing the configuration of simulators and loads to inputs and outputs that will simulate the vehicle environment and place the component in the desired test mode(s). If actual vehicle loads are connected to the system, describe the loads by part number and design level. In case of simulated loads, a detailed definition is needed.

Procedure:

1 Perform trial runs of the equipment with fully populated test racks with component samples. This shall demonstrate that the system is capable to perform the automated test script used for functional cycling and continuous monitoring.

2 This trial shall be performed for one week of continuous operation using PTC cycles in the PTC Thermal Chamber with the voltage levels defined as follows at the facility where the testing will take place. This shall simulate the actual testing with data collection enabled.

3 The test operating voltage shall be performed in the following order:

- **a** U_{max} for 10%
- **b** U_{min} for 10%
- **c** U_{nom} for 80% of the cycles

Note: Simulator verification holds applicable for all types of simulators designed for performing all applicable tests in GMW3172.

Criteria: The supplier shall demonstrate compliance of the test system to the following items:

- Prove that the validation equipment can continuously monitor and test the part for extended durations without any memory leaks or hardware/software issues on tester.
- Prove that the test executive software will not crash for one week of continuous operation in an environment that simulates the actual testing with data collection enabled.
- Prove that the validation tester can store data for extended durations without being locked due to the file size it is stored to.
- Prove that the cycle time of the test script is not affected for continuous monitoring test.

7 Analysis

7.1 Mission. 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 GMW3172 Component Environmental Test Plan (in “Templates” section of 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.

Note: 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, CTRS, SSTS, and/or other relevant requirements document and GMW14082 for Common Architecture and Global A or GB14082 for Vehicle Intelligence Platform (VIP) also known as Global B.

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.

Note: 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 operating parameters as defined by the part data sheet (e.g., temperature, voltage, current, power dissipation, etc.), shall not be exceeded.
- 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 (FEA). 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 shall provide evidence of appropriate corrective action if the resonant frequency is < 150 Hz.
- The corrective action shall be reviewed with the CVE.

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 (FEA) 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. Therefore, perform the FEA to determine the internal burst pressure using T_{min} and T_{room} for the component. Select the worst-case (i.e., lowest) burst pressure from those two scenarios.

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 holding area of the airplane at 15 240 m, use 11 kPa.

DM: Design Margin = 4.

Criteria: The component (or part) burst pressure shall exceed the resulting internal pressure during air shipment by a factor of four (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 (FEA), 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:

1 Perform a Finite Element Analysis (FEA), or equivalent, to ensure that the requirements for the Crush for Housing test(s) are met.

2 The intended load shall 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 – Foot Load, as applicable for the component.

3 The loads to be applied to the component housing shall be identified in the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043), as negotiated between the supplier and GM.

Note: Include load locations in various areas on the housing, including on top of the highest profile parts on the circuit board and on top of parts that have the least clearance to the housing and focus on the areas of the housing that are the weakest and will deflect the most.

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 shall 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.

Note: 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.

Note: 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:

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

Where:

T_{max_part}: Maximum allowable temperature from part data sheet.

$T_{altitude}$: Calculated operating temperature of part at altitude.

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 19 are used to adjust the temperature rise for high altitude effects in the equation.

$T_{ambient}$: Ambient temperature at altitude (4572 m). Use +35 °C as the default value.

+10 °C: This is the safety margin.

Table 19: 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 1

Note 1: The 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 and Mechanical Fatigue Analysis of PCBA and Housing.

Purpose: This analysis shall identify solder fatigue weaknesses and structural failures of PCBA and Housing caused by cyclic temperature change, mechanical shock, and random vibration. For example, the different CTEs of circuit board parts result in fatigue stress to the interconnections (e.g., solder joints, open type inductor coil and lead wires). The expansion rates of different materials added to a circuit board assembly (e.g., potting and conformal materials) may also result in the unacceptable deformation of the interconnections and/or the structure of the component resulting in electrical or mechanical problems.

Applicability: All components having PCBA including solder joints in motors and actuators, power electronics substrates (e.g., Direct Bonded Copper (DBC), Metal Core Printed Circuit Board (MCPCB), Low Temperature Co-fired Ceramic (LTCC) soldered to PCB), and flexible PCBA(s).

Operating Type: Not applicable.

Monitoring: Not applicable.

Procedure:

1 This analysis shall require the latest version of PCBA Gerber file or equivalent computer models which comprises the Bill of Material (BOM), PCBA constraints from the mounting screws, heatsink, housing interfaces, potting/conformal materials, thermal compound, EMC shield, and underfills that stabilize the CTE expansions.

Note: As soon as available, update and rerun the analysis with any information that may change the model. Examples of items that may change the model include: DRBTR results, cross section results that indicate the process variations, including minimum standoff height and non-symmetries in the standoff heights, or if the conformal coating flows underneath the part, results from the Temperature Measurement test (GMW8288), etc.

2 Use an appropriate FEA analysis software such as Ansys Sherlock and Ansys Mechanical simulation, or any other equivalent software.

3 Perform a check on the FEA model to confirm BOM is updated for any missing packages and apply required electrical, mechanical, and thermal properties according to datasheets. Report and review with ENV SME for part properties that are not assigned in the Gerber for further action plan.

4 Import the correct thermal and mechanical fatigue profiles, also include the component self-heating profile as an input for the analysis. As soon as GMW8288 results are available, the Thermal and Mechanical Fatigue Analysis of PCBA and Housing shall be updated. Refer to Table 20.

Table 20: Parameters for Thermal and Mechanical Fatigue Analysis of PCBA and Housing

Analysis	**Thermal Fatigue**		**Mechanical Fatigue**	
Criteria: (As a minimum requirement)	2.5 times of TS test cycles	2.5 times of PTC test cycles	1.25 times of Random Vibration test duration per axis	1.25 times of Mechanical Shock per axis
Note:	As soon as available, add constant temperature rise to the TS profile due to self-heating based on previous project experience/design, other simulation results, or GMW8288 results.	As soon as available, add constant temperature rise to the PTC profile due to self-heating based on previous project experience/design, other simulation results, or GMW8288 results.	Profiles and duration to be confirmed by ENV SME, or Test Plan Approver, based upon mounting location in vehicle.	
Reference:	Refer to 9.4.2 and 9.4.3, as well as 9.3.1, 9.3.2, 9.3.3, and 9.3.4, for thermal, vibration, and mechanical shock profiles, cycles, and durations.			

5 FEA shall be performed on an appropriately meshed model to obtain better simulation results. Table 20 analysis tasks shall be performed independently.

6 In the event of change-based revalidation plan such as part substitution, part additions or dual sourced parts, supplier shall provide simulation results for the concerned package for risk assessment.

7 Analysis results shall be submitted to ENV SME to review the weaknesses in the design and for the approval of analysis results. In addition, the report should include the details of time to failure, damage, life prediction and probability of failures for the solder joints and other mechanical structures of the PCBA.

8 As an additional activity, perform the comparison between the analysis results with physical test failure if any, with the ENV SME. Update analysis modelling if needed.

Criteria:

- The calculated fatigue life of each package on the PCBA shall meet required life of the component as defined in Table 20.
- If there are no failure within the required cycles, run the analysis until first failure is observed.
- An additional follow up is required to evaluate the design improvements if analysis does not meet the criteria.

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:

1 Use A1 Lead-Free Solder Considerations in Appendix A as a reference to discuss potential impacts to the product design and manufacturing process.

2 Provide full disclosure throughout the supply chain regarding risks when lead-free solder is used.

3 All risks are to be addressed and mitigated through the Environmental Hardware Design Review.

Criteria:

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

8 Development

8.1 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 GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043).

8.2 Electrical. All component connector pins shall be defined as either a Battery, Ground, or I/O circuit. Refer to the “Electrical Test Circuit Types” document under “Tools” in CG3043 which describes the minimum GMW3172 tests that are required for each type of component connector pin. If there is an I/O circuit that is not shown, contact the ENV SME to determine what test is required.

8.2.1 Jump Start.

Purpose: This test shall verify the component 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., Platform to Powertrain Electrical Interface (PPEI) apply 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 UA.

Criteria: FSC shall be C, however, for all functions needed to start the engine, FSC shall be A during the test, if not stated differently in the CTS, CTRS, SSTS, and/or other relevant requirements document.

8.2.2 Reverse Polarity.

Purpose: This test shall verify the component 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, either directly or through an external component. 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, CTRS, SSTS, and/or other relevant requirements document.

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

Monitoring: Continuous Monitoring.

P**rocedure:**

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: FSC shall be C.

8.2.3 Over Voltage.

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

Note:

- A battery charging event can be, for example, a connection to a “quick charge battery charger” where the voltage exceeds +16 V.
- The 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, either directly or through an external component, and where U_{max} < 18 V.

Operating Type: 3.1/3.2 (with voltage as defined in Table 21).

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 21 with Operating Type 3.1.

4 Repeat Step 2 and Step 3 with Operating Type 3.2.

Table 21: 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: FSC 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 output signals are reviewed in graphical form with an oscilloscope or other equivalent measurement tool.

Procedure:

1 Change operation state.

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

3 Repeat Step 1 and Step 2 for all other possible state changes.

Criteria:

- FSC shall be A.
- Transients that occur as a result of state change transitions shall not produce disruptive levels of disturbance to downstream components.

Note: One consideration in analyzing the waveform is to detect inadvertent actuation of outputs and floating inputs.

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 DV 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 experience. 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 6.7 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:

1 Perform the measurement in the highest power consumption scenario possible, i.e., use infrared imaging or thermocouple measurements according to the procedure in GMW8288.

2 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:

- FSC 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 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 14

Monitoring: Continuous Monitoring during Operating Type 3.2 phases.

Procedure: Use the test methods according to IEC 60068-2-1 "Test Ab: Cold for non heat-disspipating specimens with gradual change of temperature". T_{min} of the operating temperature range is the low temperature that shall be used.

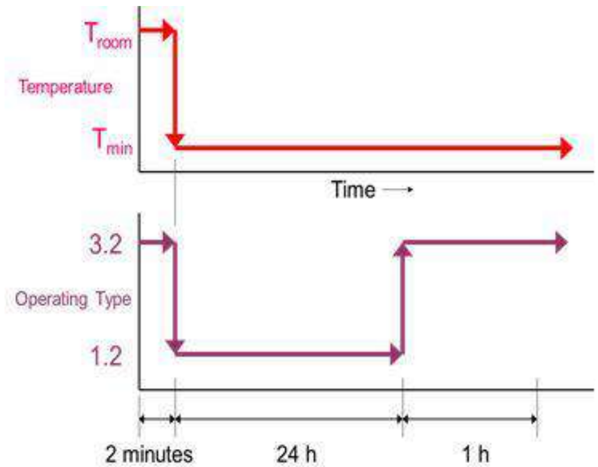
1 Prior to the start of a 24 h cycle, the component shall be energized at T_{room} for 2 minutes and evaluated for proper function at U_{nom}.

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 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 14: Low Temperature Wakeup Profile



Criteria: FSC 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 15.

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. Step 1 through Step 3 constitutes one cycle. Transfer the component into the cold chamber (-20 °C) for each additional required cycle within 3 minutes.

4 Repeat Step 1 through Step 3 for the remaining cycles as required by Table 22.

Figure 15: Frost Profile

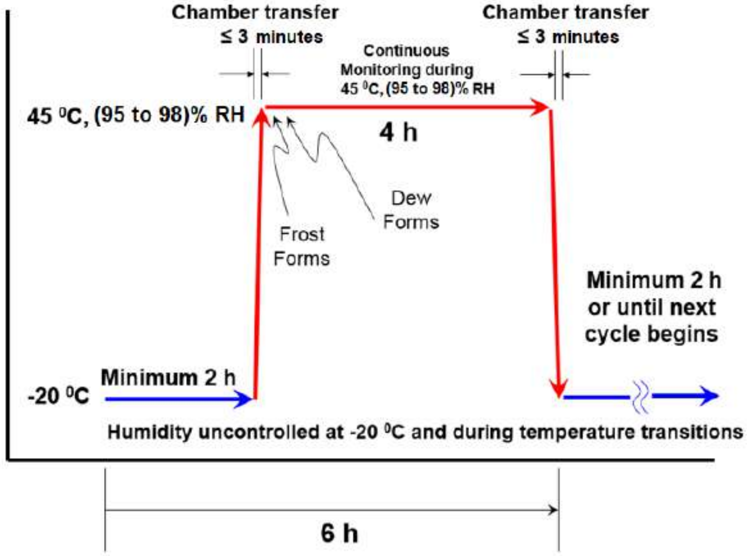


Table 22: Frost Test Requirements

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:

- FSC shall be A.
- 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 experience. 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, according to JEDEC JESD22-A110 "Highly-Accelerated Temperature and Humidity Stress Test (HAST)"). Intermediate readouts shall be performed at 50% and 75% of test duration.

Procedure: Use the test methods according to JEDEC JESD22-A110.

Criteria:

- FSC 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 Mission. 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). The production PCBA process and home line tools shall be used. Quick-turn PCBs and/or PCBAs are not allowed. All DV activities shall be documented in the GMW3172 Component Environmental Test Plan (in “Templates” section of 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. All component connector pins shall be defined as either a Battery, Ground, or I/O circuit. Refer to the “Electrical Test Circuit Types” document under “Tools” in CG3043 which describes the minimum tests that are required for each type of component connector pin. If there is an I/O circuit that is not shown, contact the ENV SME to determine what test is required.

9.2.1 Parasitic Current.

Purpose: This test shall verify that the component 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 12 V wiring system, either directly or through an external component.

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 shall 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.

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

Criteria:

- FSC is not applicable to this test.
- The maximum allowable average parasitic current shall be 0.125 mA if not provided in the CTS, CTRS, SSTS, and/or other relevant requirements document.
- 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 regulated power supplies (i.e., internal voltage regulators for 5 V, 3 V, 1.2 V, etc.) This test shall also be used for microprocessor-based components to quantify the robustness of the design to sustain short duration low voltage dwells.

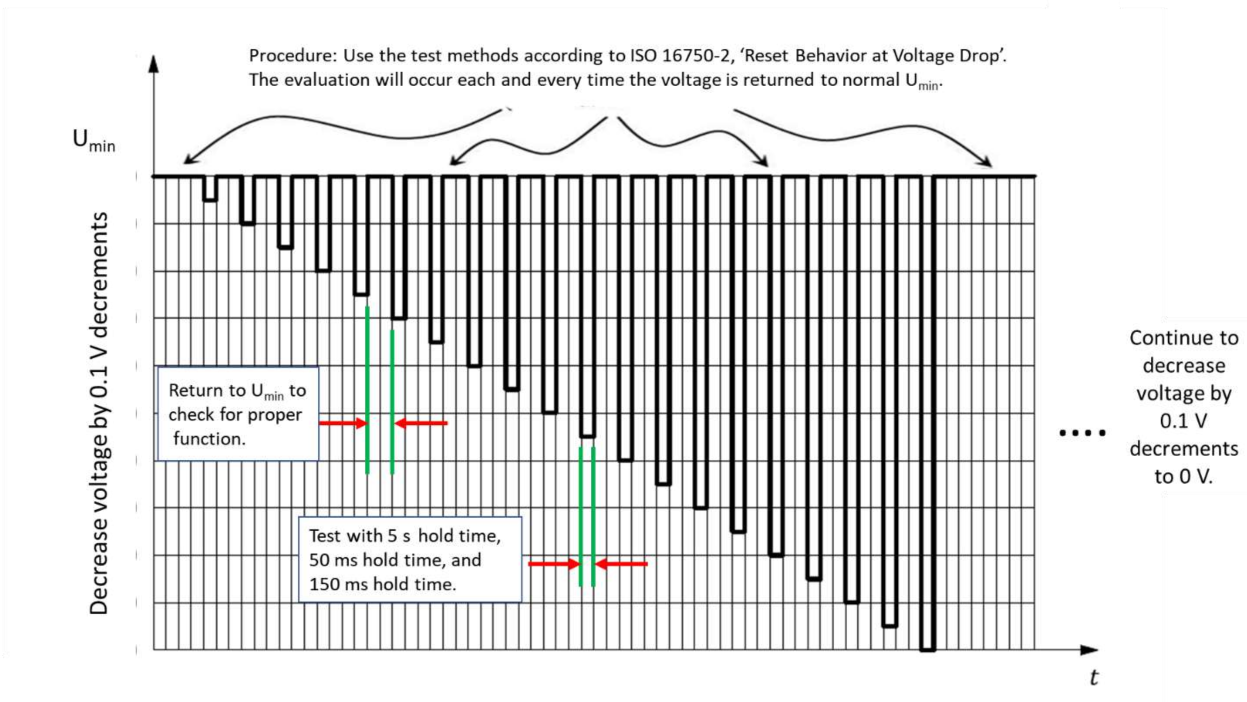
Applicability: All components that may be affected by a momentary drop in voltage. This includes components supplied by regulated voltage provided by other components. This test is particularly important for components that have microprocessors, clocks, or ASICs.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to ISO 16750-2 “Reset behavior at voltage drop” with the modifications as shown in Figure 16 for the execution of the procedure.

Figure 16: Power Supply Interruptions Profile Note 1



Note 1: Lower case “t” used for time. Upper case “T” used for temperature.

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 0.1 V and hold this decreased voltage for 5 s.

Note: Use a slew rate of 15 V/ms or faster.

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

4 Repeat Step 2 and Step 3 with a further decrease of 0.1 V decrements. Repeat this until 0 V is reached.

5 Repeat Step 2 through Step 4 with a test pulse hold time of 50 ms at each decreased voltage.

6 Repeat Step 2 through Step 4 with a test pulse hold time of 150 ms at each decreased voltage.

7 Repeat Step 2 through Step 6 for each supply voltage input separately in case of multiple supply voltage inputs, while maintaining the untested inputs at U_{min}.

8 Repeat Step 2 through Step 7 with the component at T_{max}.

Criteria:

- FSC shall be A after returning to U_{min} following each voltage drop and C elsewhere.
- Additional monitoring criteria for micros, ASICs, and other devices that have internal registers or error flags: To avoid the need of monitoring the ECU wake/sleep cycles, monitoring of the hardware states and reset/error flags shall be used to detect discontinuities in the power-up sequence when available.
- Criteria to Pass: After returning to U_{min}, hardware configuration registers (micro, ASICs, and other devices) are in their correct state and Partial Network (PN) and Controller Area Network (CAN) transceiver flags have been cleared appropriately.

9.2.3 Battery Voltage Dropout.

Purpose: This test shall verify the component 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, either directly or through an external component. 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 17.

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 23.

4 Repeat Step 3 three additional times with the Variation B, Variation C, and Variation D.

5 Repeat Step 2 through Step 4 at T_{max}.

Figure 17: Battery Voltage Dropout Profile

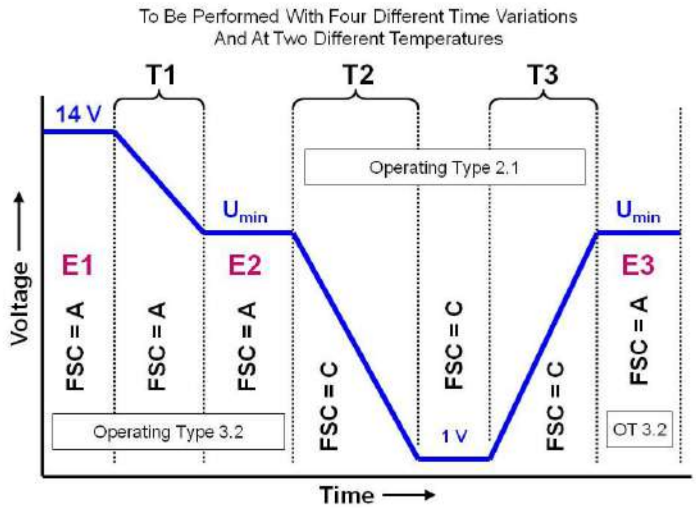


Table 23: Battery Voltage Dropout Values

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	3600 s	120 s
D	1 s	28 800 s	7200 s

Note:

- 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:

- FSC shall be as shown depending on the zone per Figure 17.
- There shall be no inadvertent behavior during the transitions.

9.2.4 Sinusoidal Superimposed Voltage.

Purpose: This test shall verify the component 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, either directly or through an external component.

Operating Type: 3.2, with voltage levels as defined in ISO 16750-2 “Superimposed alternating voltage with severity Level 2”

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to ISO 16750-2 “Superimposed alternating voltage with severity Level 2” (4 V_{p-p}).

Criteria: FSC shall be A.

9.2.5 Pulse Superimposed Voltage.

Purpose: This test shall verify the component 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 Pulse Width Modulation (PWM) controlled high loads.

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

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Refer to Figure 18, including the test setup definitions and parameters shown in Figure 18.

1 Connect the component to the U_o output.

2 Stabilize component at temperature T_{room}.

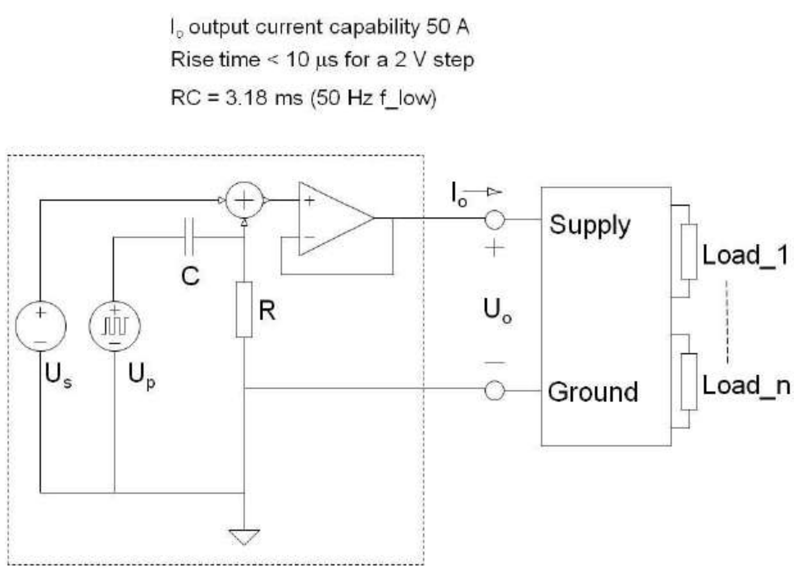
3 Set $U_s = U_{max} - 2$ V.

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

5 Decrease U_s by 1 V.

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

Figure 18: Pulse Superimposed Voltage Setup



7 Test setup definitions and parameters:

- **a** $U_0 = U_s + U_p$.
- **b** $U_s = (U_{min} + 2$ V) to ($U_{max} - 2$ V) DC voltage.
- **c** U_p = Square wave -1 V to +1 V 50% duty cycle (2 V_{p-p}).

d U_p frequency sweep range: 1 Hz to 4 kHz.

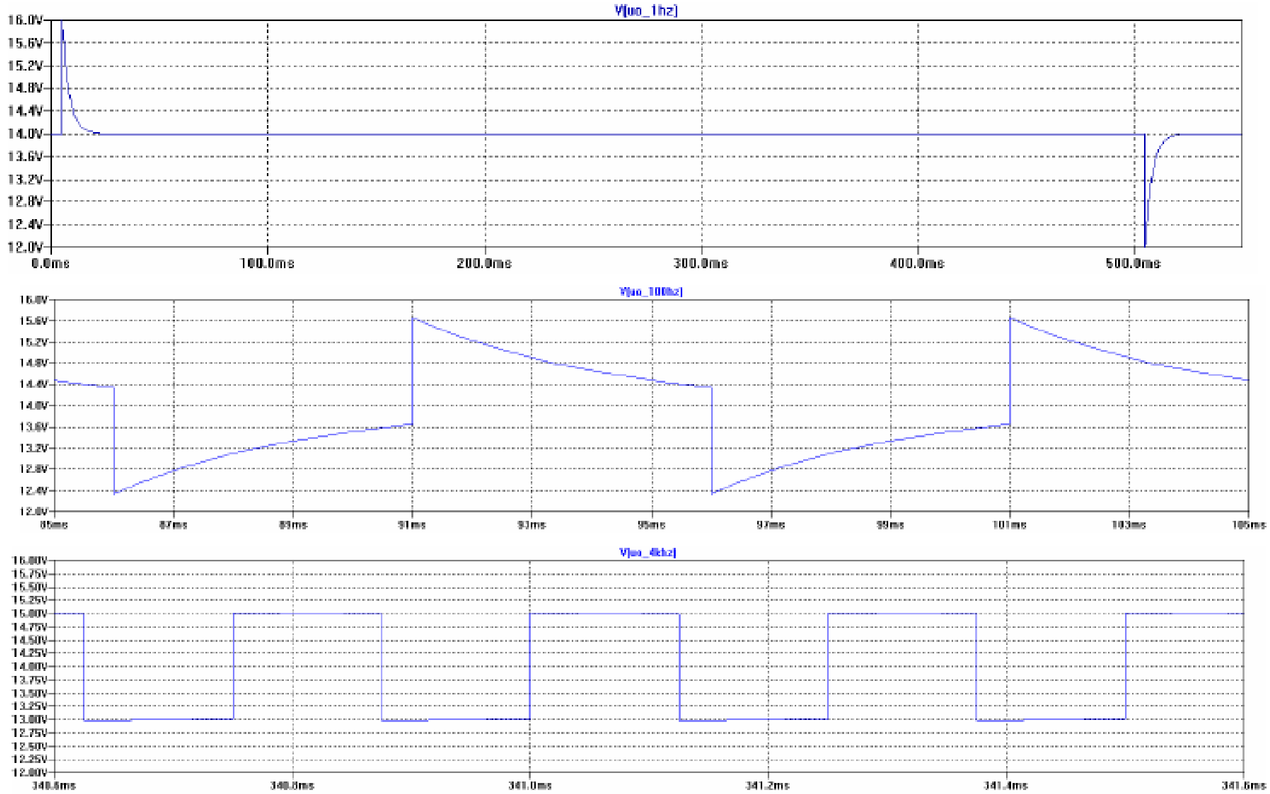
e Frequency sweep type: Logarithmic.

f Frequency sweep duration for one cycle: 120 s for 1 Hz to 4 kHz to 1 Hz.

Note:

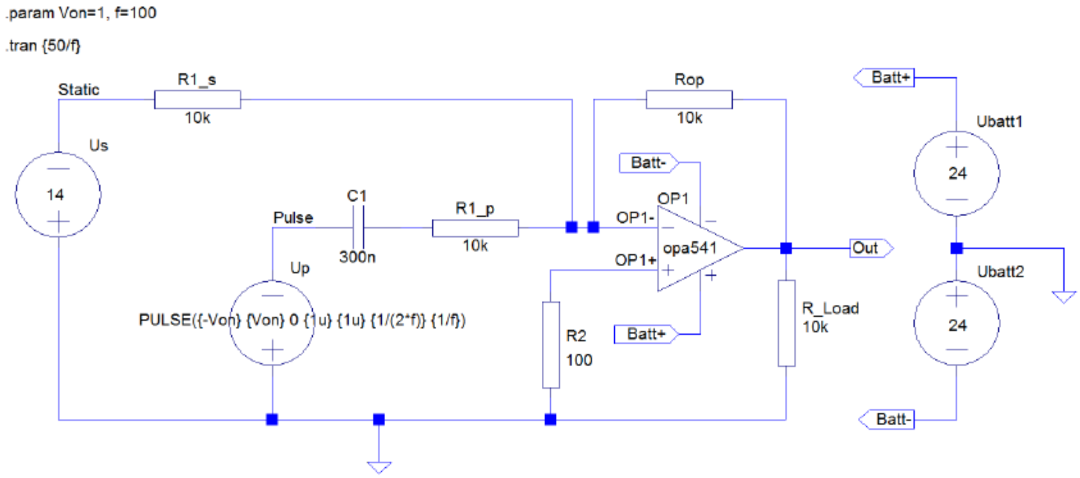
- The test shall be performed with real or equivalent loads connected (Load_1 to Load_n) and the output currents driven in the full range from I_load_min to I_load_max for each U_s step.
- The U_0 waveform will depend on the frequency. Figure 19 shows examples of the following frequencies: 1 Hz, 100 Hz and 4 kHz, with U_s = +14 V and U_p = +1 V/-1 V.

Figure 19: Examples for Pulse Waveforms



Example: The Pulse Superimposed Voltage test setup can be realized as shown in the electrical schematic of Figure 20, verified with SPICE simulation, http://bwrcs.eecs.berkeley.edu/Classes/IcBook/SPICE/.

Figure 20: Example for Pulse Superimposed Voltage Test Setup



Criteria: FSC shall be A.

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

Purpose: This test shall verify the component immunity to intermittent short circuit events on Input/Output (I/O) and Supply lines as well as the component ability to recover automatically from these events. A supply line shall be considered to be any line that is not an I/O or ground. Vehicle battery power and ground lines will be treated separately in 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: For this procedure a short circuit (Step 4 and Step 9) shall be applied. The first short circuit shall be to U_{max}, then a short circuit to U_{min}, then a short circuit to Ground, and for electrical device category G or Z, a short circuit to U_A.

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 (i.e., OFF) to 2.2/3.2 (i.e., ON). The inputs and outputs under test shall be in an electrical steady state condition before proceeding.
4. At t = 15 s, apply a short circuit of U_{max} to each applicable I/O for a duration of 1 minute and then remove the short circuit for a duration of 45 s. Refer to the following notes for further explanations.
5. Switch the Operating Type from 2.2/3.2 (i.e., ON) to 2.1/3.1 (i.e., OFF).
6. Repeat Step 3 through Step 5 until 15 cycles are complete.
7. Confirm the correct operation of the outputs with normal loads.
8. Switch the Operating Type to 2.1/3.1 (i.e., OFF) and wait 1 minute.
9. Apply a short circuit of U_{max} to each applicable I/O. See following Notes for further explanations.
10. Switch the Operating Type from 2.1/3.1 (i.e., OFF) to 2.2/3.2 (i.e., ON).
11. Verify the component transitions properly from 2.1/3.1 (i.e., OFF) to 2.2/3.2 (i.e., ON) with the I/O shorted. Confirm the correct operation of the inputs and outputs that are not shorted.
12. Remove the short circuit.

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

14 Repeat Step 8 through Step 13 until 15 cycles are complete.

15 Adjust the short circuit voltage to U_{min} and repeat Step 3 through Step 14.

16 Repeat Step 2 to Step 14 for short circuit to ground.

17 If applicable for those components that have a specific voltage supply line other than vehicle battery (i.e., Electrical Load Code Letters G or Z), adjust the short circuit to U_A (vehicle battery voltage with alternator on).

18 Repeat Step 3 to Step 14 for a short to U_A.

Note: For this step, the supply line shall be included in addition to the individual I/O lines.

19 Stabilize the chamber temperature to T_{max} and repeat Step 2 through Step 18.

Note:

- In Step 4 and Step 15, 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 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:

- FSC 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.
- 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 immunity to continuous short circuit events on Input/Output (I/O) lines. Vehicle battery power and ground lines will be treated separately in 9.2.8.

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 Step 2 through Step 5 for U_{min}.

7 Repeat Step 2 through Step 6 for short to ground.

8 Raise and stabilize the chamber temperature to T_{max} and repeat Step 2 through Step 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:

- FSC 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.
- 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 that the component does not show a dangerous behavior when a short circuit fault current is drawn through the component. It is not intended to test the vehicle wire harness, connector, and fuse. Fusing shall be replaced with a short and the power supply shall be set to provide enough current to represent the worst-case condition of the fuse prior to opening. An opened switch shall represent the opened fuse.

Applicability: This test applies to the following components:

- Containing multiple power lines.
- Containing interconnected multiple power lines, only one side connected to battery, without any internal current limiting elements (power line pass through circuit).
- Containing multiple ground lines.
- Containing interconnected multiple ground lines, only one side connected to ground, without any internal current limiting elements (ground pass through circuit).
- All pins that are not deemed to be an I/O line.

Note: If the multiple power (ground) lines are isolated from each other inside the module as shown in Figure 21 and Figure 22 (i.e., > 100 k-ohm as measured between the Battery/Ground lines), then this test can be "validated by analysis". The circuit design shall be reviewed with the Test Plan Approver to verify that this test can be validated by analysis.

Two test scenarios represent real vehicle short circuit failure modes:

- Low Resistive Short Circuit. i.e., current limit at 250% of the anticipated fuse rating.
- High Resistive Short Circuit. i.e., current limit at 130% of the anticipated fuse rating.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

Low Resistive Short Circuit:

1 Set up a power supply to U_{max} with a current limit at 250% of the anticipated fuse rating. The wires used shall have a resistance < 35 mΩ and be capable of handling the rated current. All inputs/outputs have to be connected to their specified loads.

   a For power lines, consider the largest anticipated fuse rating in vehicle applications (default value: 15 A for input ratings ≤ 10 A, 30 A for input ratings > 10 A).

   b For ground lines, consider a 30 A fuse rating.

2 At t = 0 s, turn on the component and operate it for 300 s.

3 At t = 300 s:

   a For power lines, apply a short to ground according to Figure 23 for a duration of 300 ms and set resistance to 0 Ω (e.g., a shunt). Note that in the test set-up that is shown in Figure 23, an open switch is used in order to represent the opened fuse that occurs due to the shorting event.

- **b** For ground lines, apply a short to battery according to Figure 24 for a duration of 300 ms and set resistance to 0 Ω (e.g., a shunt). Note that in the test set-up that is shown in Figure 24, an open switch is used in order to represent the opened fuse that occurs due to the shorting event.

4 Repeat Step 1 through Step 3 for all applicable lines.

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

High Resistive Short Circuit:

1 Set up a power supply to U_{max} with a current limit at 130% of the anticipated fuse rating. The wires used shall have a resistance < 35 mΩ and be capable of handling the rated current. All inputs/outputs shall be connected to their specified loads.

- **a** For power lines, consider the largest anticipated fuse rating in vehicle applications (default value: 15 A for input ratings ≤ 10 A, 30 A for input ratings > 10 A).
- **b** For ground lines, consider a 30 A fuse rating.

2 At t = 0 s, turn on the component and operate it for 300 s.

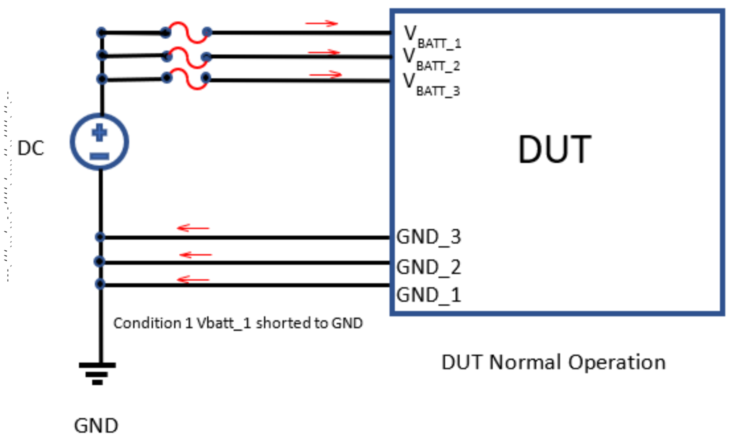
3 At t = 300 s:

- **a** For power lines, apply a short to ground according to Figure 23 for a duration of 10 minutes and set resistance to > 0 Ω to obtain a current of 130% of fuse rating. Note that in the test set-up that is shown in Figure 23, an open switch is used in order to represent the opened fuse that occurs due to the shorting event.
- **b** For ground lines, apply a short to battery according to Figure 24 for a duration of 10 minutes and set resistance to > 0 Ω to obtain a current of 130% of fuse rating. Note that in the test set-up that is shown in Figure 24, an open switch is used in order to represent the opened fuse that occurs due to the shorting event.

4 Repeat Step 1 through Step 3 for all applicable lines.

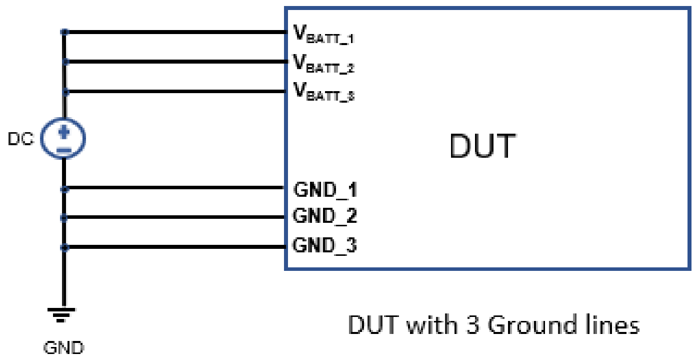
Note: The same sample may be used repeatedly if damage does not invalidate the test on other pass through circuits.

Figure 21: Component with Multiple Power Lines Showing Non-Fault Condition



If V_{batt1}, V_{batt2}, … V_{battN} are isolated from each other inside the module (i.e., greater than 100k-ohm as measured between the Battery lines), then this test can be deemed "N/A – validated by analysis". The circuit design shall be reviewed with the Test Plan Approver to verify that this test can be validated by analysis.

Figure 22: Component with Multiple Ground Lines – Isolated from Each Other



If GND_1, GND_2, and GND_3 are isolated from each other inside the module (i.e., greater than 100 k-ohm as measured between the Ground lines), then this test can be deemed "N/A – validated by analysis". The circuit design shall be reviewed with the Test Plan Approver to verify that this test can be validated by analysis.

Figure 23: Power Pass Through Short Circuit Setups

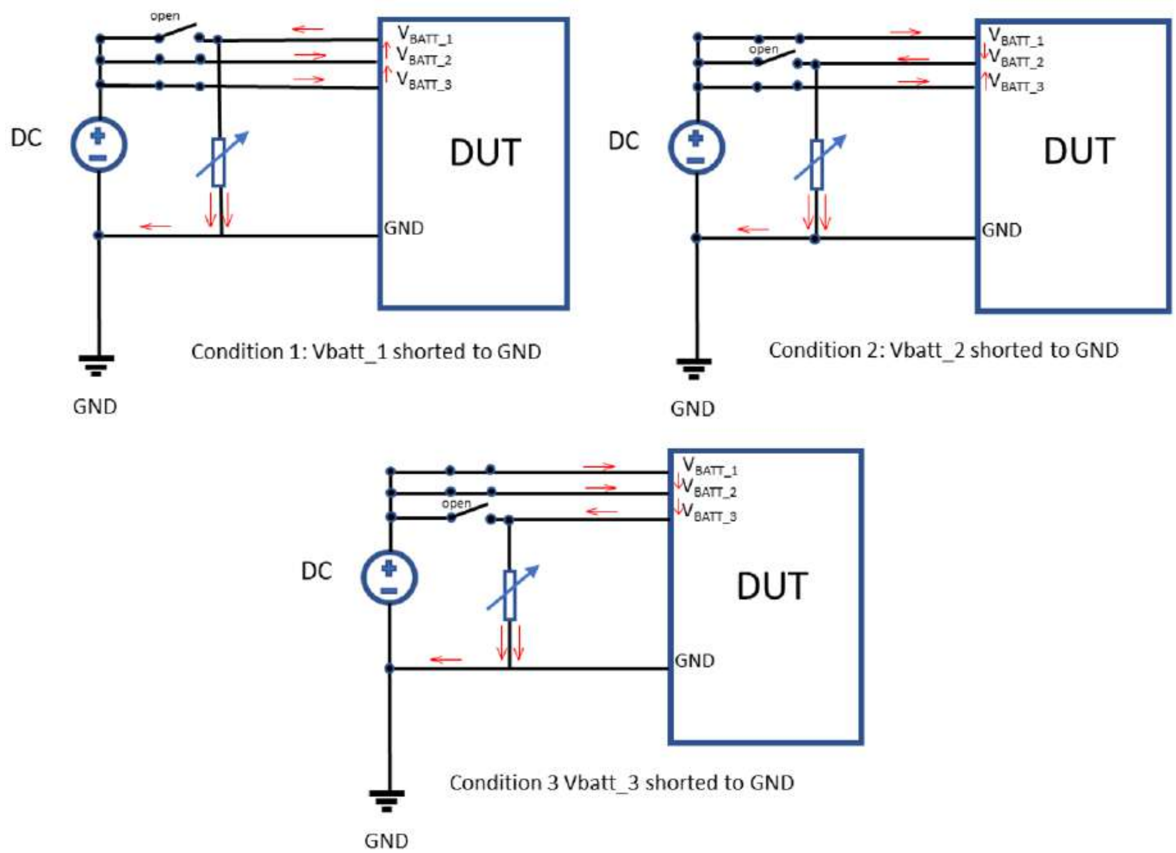
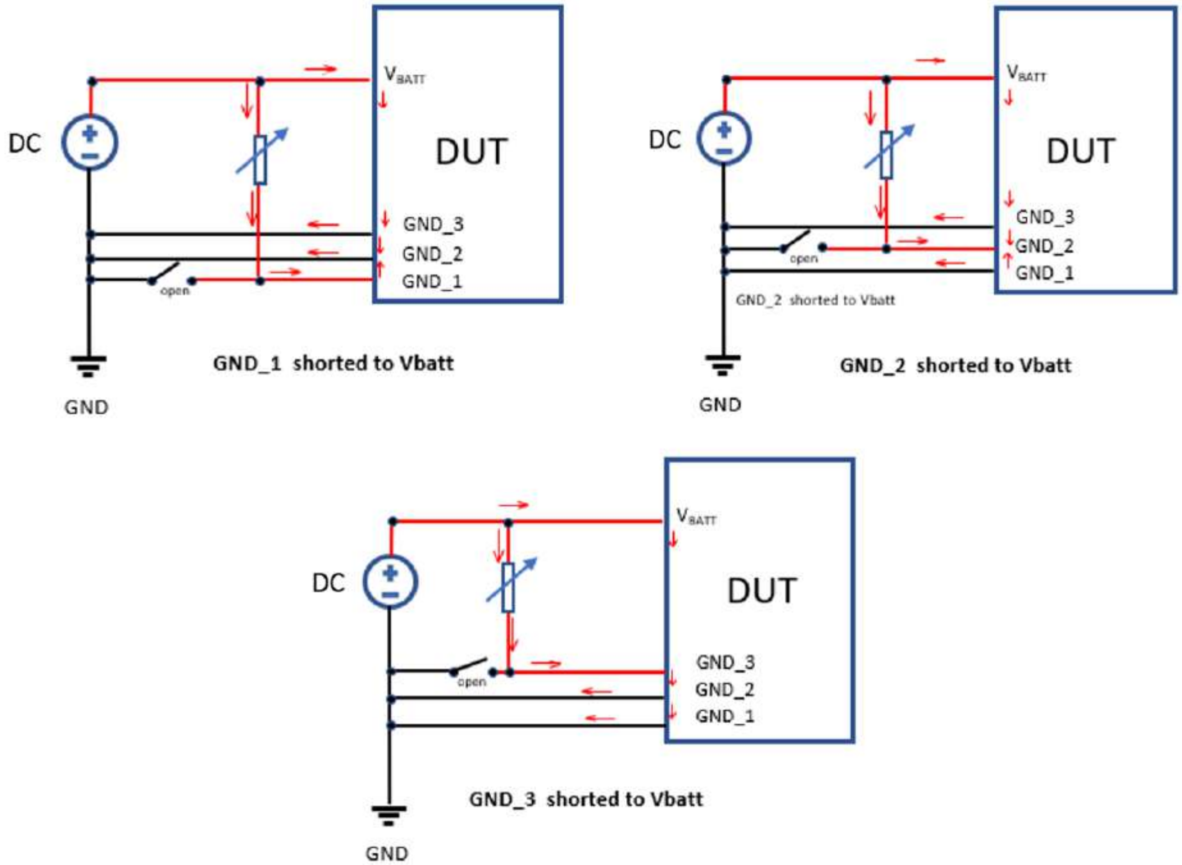


Figure 24: Ground Pass Through Short Circuit Setups



Criteria:

1 For the Low Resistive Short Circuit test:
   - **a** FSC shall be D.
   - **b** During the Visual Inspection and Dissection – DRBTR, there shall be no evidence of overheating.

2 For the High Resistive Short Circuit test:
   - **a** FSC shall be E.
   - **b** During the Visual Inspection and Dissection – DRBTR, minor amounts of carbon may appear near the open circuit. A safety critical behavior (e.g., smoke, fire, melted plastics, etc.), is not allowed.

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:

1 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.

2 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, test as a single line (interrupted simultaneously) and as separate lines.
- In the case of multiple ground lines, test as a single line (interrupted simultaneously) and as separate lines.

Criteria:

- FSC shall be C.
- 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”. Apply this procedure by disconnecting and reconnecting the connector of the component. In the case of multiple connectors, disconnect and reconnect each one separately.

Criteria:

- FSC shall be C.
- 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 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.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: As shown in the test setup in Figure 25, 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, CTRS, SSTS, and/or other relevant requirements document interface documentation of the component. If this information is not available, refer to GMW14082 for Common Architecture and Global A or GB14082 for Vehicle Intelligence Platform (VIP) also known as Global B 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.

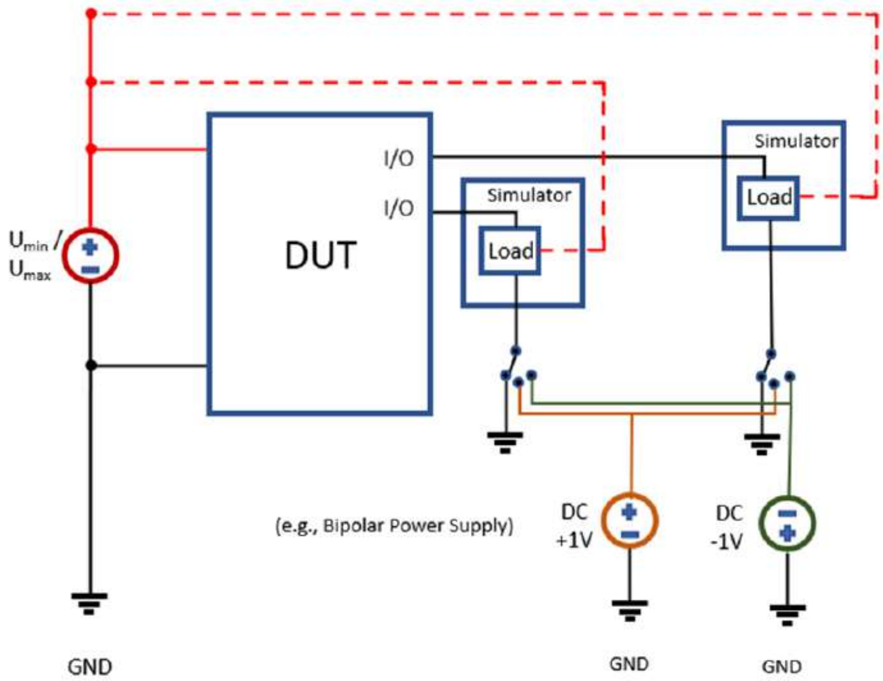
3 Repeat Step 2 for the next applicable I/O simulation device.

4 Repeat Step 2 for all I/O simulation devices simultaneously.

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

6 Repeat Step 2 through Step 5 with U_{max} instead of U_{min}.

Figure 25: Ground Offset Setup



Note:

- If a component has several ground lines that are electrically isolated from each other, this test has to be performed for each ground line.
- This test is also applicable for inputs that are switched to ground (i.e., Input Digital Low).

Criteria: FSC shall be A.

9.2.12 Power Offset.

Purpose: This test shall verify the component 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.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: As shown in the test setup in Figure 26, 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, CTRS, SSTS, and/or other relevant requirements document interface documentation of the component.

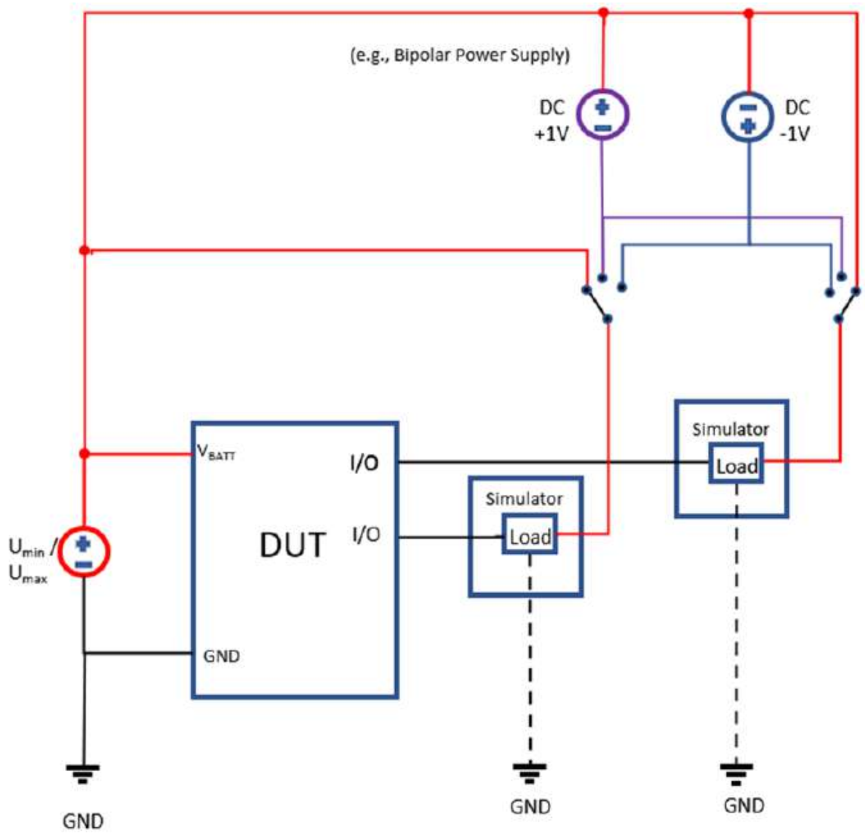
1. Apply U_{min} to the component.
2. Subject the applicable power line of one representative I/O simulation device to a +1.0 V offset relative to the component power.
3. Repeat Step 2 for the next applicable I/O simulation device.
4. Repeat Step 2 for all I/O simulation devices simultaneously.

5 Repeat Step 2 through Step 4 for each applicable power line individually if the component has more than one battery input.

6 Repeat Step 2 through Step 5 for a -1.0 V offset relative to the component power.

7 Repeat Step 2 through Step 6 with U_{max} instead of U_{min}.

Figure 26: Power Offset Setup



Note: This test is also applicable for inputs that are switched to power (i.e., Input Digital High).

Criteria: FSC 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.

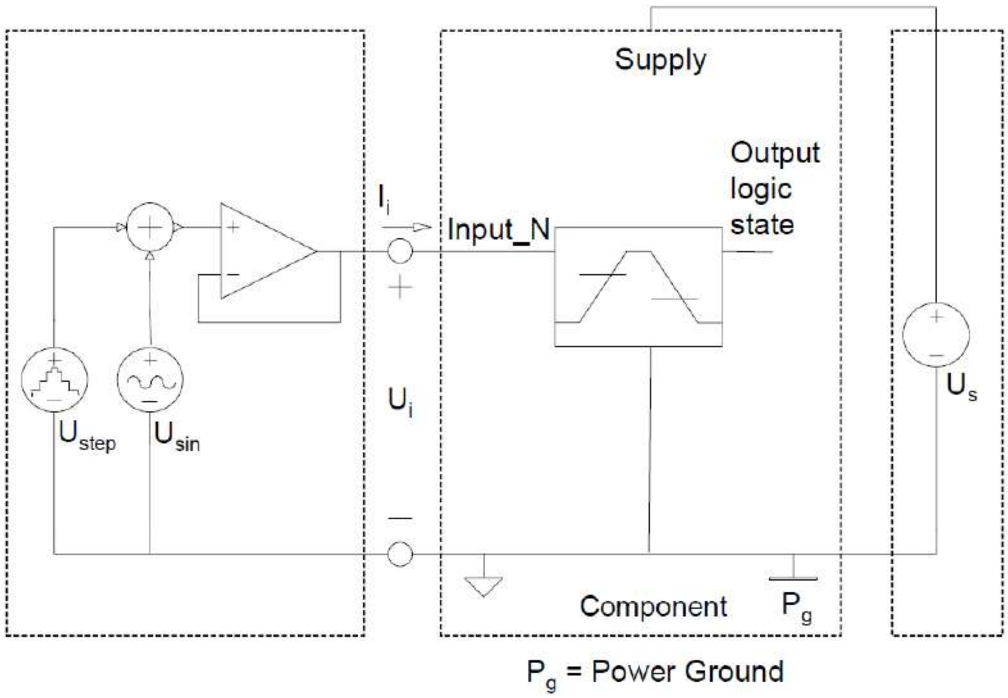
Applicability: Discrete digital input and switch input interfaces with transmitters grounded locally without signal return to receiver. It can be replaced by Analysis at Environmental Hardware Design Review.

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 27 and follow the given sequence.

Figure 27: Threshold Voltage Setup



1 At T_{room} perform the following sequence (refer to Figure 27).

2 Adjust Us 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} (refer to Figure 28).

11 Repeat Step 2 through Step 10 by replacing U_{min} with U_{max} and store the new U_{ih_rise} and U_{il_fall}.

12 Repeat Step 2 through Step 11 at T_{max} and T_{min} for the component.

13 Write a report including:

- **a** At T_{room} and U_{min}: U_{ih_rise}, Uil_fall and Nth_U_{min}
- **b** At T_{room} and U_{max}: U_{ih_rise}, U_{il_fall} and Nth_U_{min}
- **c** At T_{max} and U_{min}: U_{ih_rise}, U_{il_fall}
- **d** At T_{max} and U_{max}: U_{ih_rise}, U_{il_fall}

e At T_{min} and U_{min}: U_{ih_rise}, U_{il_fall}

f At T_{min} and U_{max}: U_{ih_rise}, U_{il_fall}

Figure 28: Threshold Voltage Waveform – All Steps

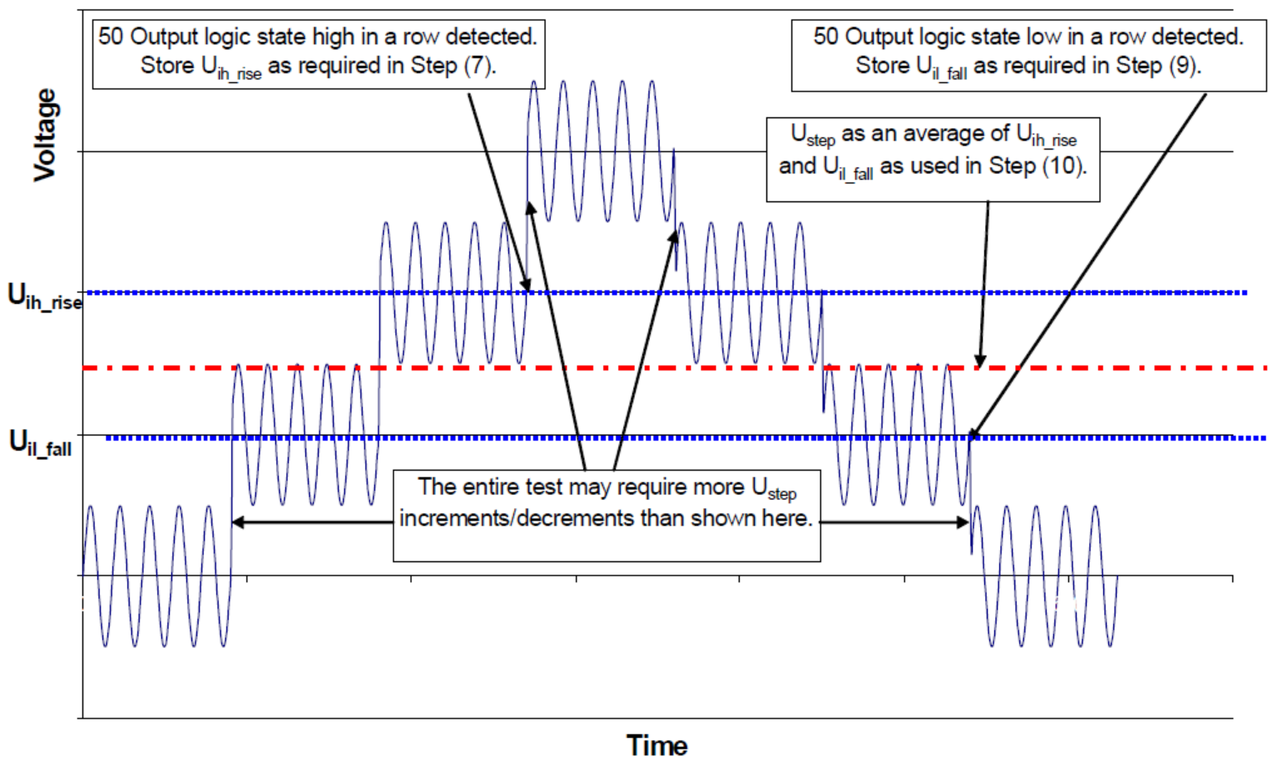
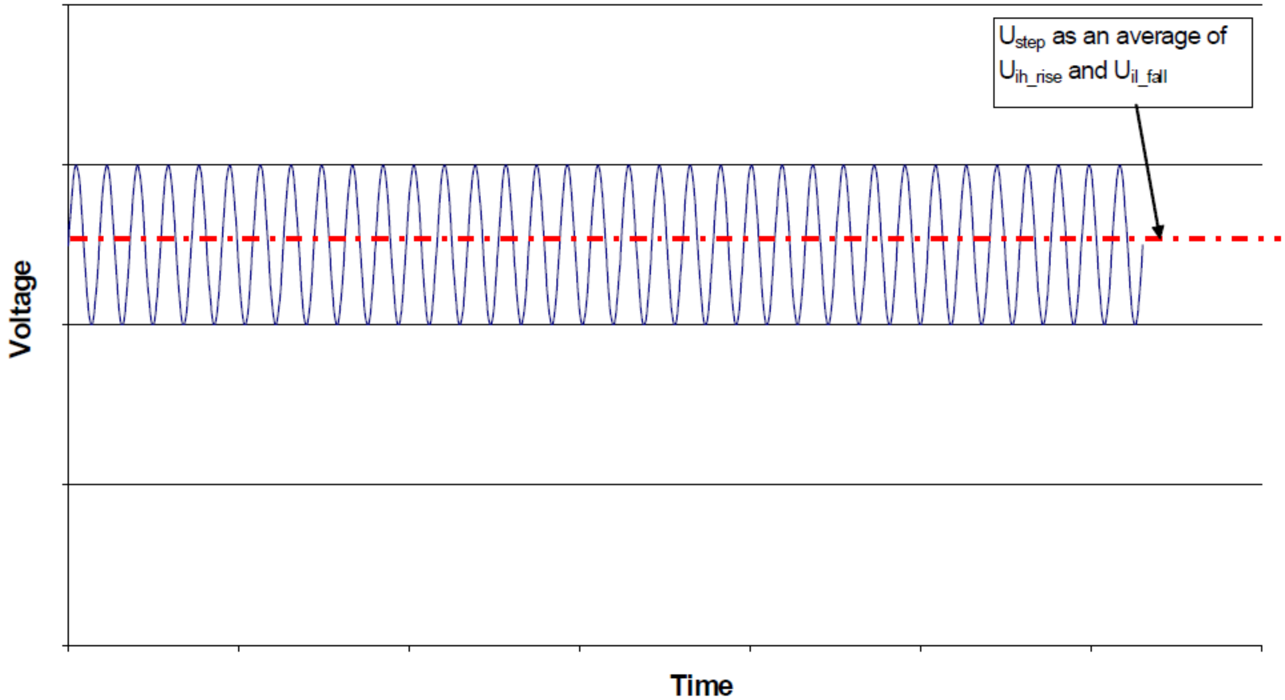


Figure 28: Threshold Voltage Waveform – Step (10)



Criteria:

1 FSC is not applicable to this test.

2 All discrete digital input interfaces shall be able to correctly detect the logic levels stated by CTS, CTRS, SSTS, and/or other relevant requirements document and GMW14082 for Common Architecture and Global A or GB14082 for Vehicle Intelligence Platform (VIP) also known as Global B:

   a Logic Low: $-1\ V < U_{il} < 2\ V$.

   b Logic High: $4.5\ V < U_{ih} < U_{max} + 1\ V$.

3 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.

4 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 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 $3 \times I_{max}$ is reached.

Note: Care has to be taken that the power supply has a current limitation (set to 50 A, if not otherwise specified) and that the test setup withstands the maximum current.

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 For those outputs in Step 5 that do not reach $3 \times I_{max}$ due to current limiting of the power supply in the test setup, then repeat Step 1 through Step 7 with each individual output reaching $3 \times I_{max}$.

9 Repeat Step 1 through Step 7 at T_{min}.

Criteria:

- If an output is over-current protected, then FSC shall be D for the associated function(s).
- If an output is not over-current protected, then FSC shall be E for the associated function(s) and 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 FSC 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 $1.35 \times I_{rp}$ (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 $2 \times I_{rp}$. 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 $3.5 \times I_{rp}$. Adjust the test duration accordingly as defined in ISO 8820-1 “Operating time rating”.

Criteria:

- FSC shall be A.
- 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 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. Refer to the note 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 rating voltage, a modified voltage will be necessary as noted as follows.

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 16750-2 test shall be replaced by the HHC test in Leg 2 of the Test Flow (use a minimum of 3 samples).

Criteria:

- FSC shall be C.
- The insulation resistance shall be > 10×10^6 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.

Applicability: All components that will be subjected to a crank pulse from a power line supplied by a 12 V source from either a battery and/or an ignition input that can originate from a vehicle starter either directly or through an external component.

Operating Type: 2.1 (off mode)/3.2 (after start)

Monitoring: Continuous Monitoring throughout the entire waveform.

Procedure: Subject the component to the waveforms defined in Table 24, Table 25/Figure 29, and Table 26/Figure 30 using the default number of cycles defined in Table 27.

Note:

- The required number of cycles may be modified in agreement with the ENV SME.
- The Crank Waveform Functional Test Cycles (Table 27) are required for all components.
- The Crank Waveform Durability Test Cycles (Table 27) 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 Crank Waveform Durability Test Cycles (Table 27) shall be performed at T_{min} and 10% of the Crank Waveform Durability Test Cycles (Table 27) shall be performed at T_{max}.
- The cycle time between pulses shall be adequate to verify function (abbreviated 1-Point Functional/Parametric Check) after each pulse in the Crank Waveform Functional Test Cycles (Table 27), and adequate to not create any failures due to an unrealistic pulse frequency.

Table 24: GM Specific Crank Waveform

Waveform A		Waveform B	
t (ms)	**U (V)**	**t (ms)**	**U (V)**
0.00	12.00	0.00	12.00
100.00	12.00	100.00	12.00
140.00	4.00	100.53	4.00
155.00	4.00	155.00	4.00
175.00	9.25	175.00	9.25
305.00	7.65	305.00	7.65
375.00	8.55	375.00	8.55
495.00	7.88	495.00	7.88
565.00	8.60	565.00	8.60
675.00	7.88	675.00	7.88
735.00	8.78	735.00	8.78
825.00	8.10	825.00	8.10
905.00	9.00	905.00	9.00
925.00	8.55	925.00	8.55
1005.00	9.90	1005.00	9.90
1425.00	12.00	1425.00	12.00
1825.00	12.00	1825.00	12.00

Table 25: Requirements Levels for the Immunity to ISO 7637-2 (6/2004) Pulse 4: Crank Pulse Note 1

Pulse Severity	U_S Note 2	U_a Note 2	t_9 Note 2	t_{11} Note 2
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

Note 1: Use t_{10}, t_7, and t_8 as defined in ISO 7637-2 (6/2004) shown in Figure 29. 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 2: As defined in ISO 7637-2 (6/2004).

Figure 29: ISO 7637-2 (6/2004) Pulse 4

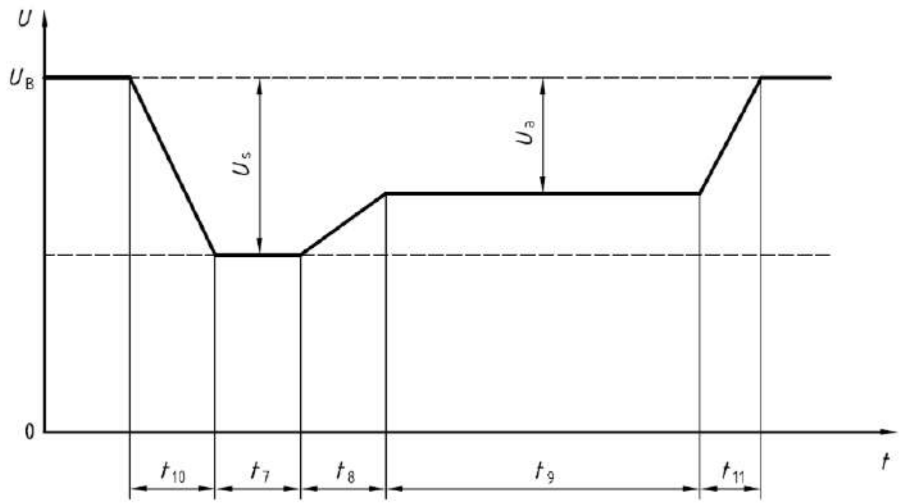
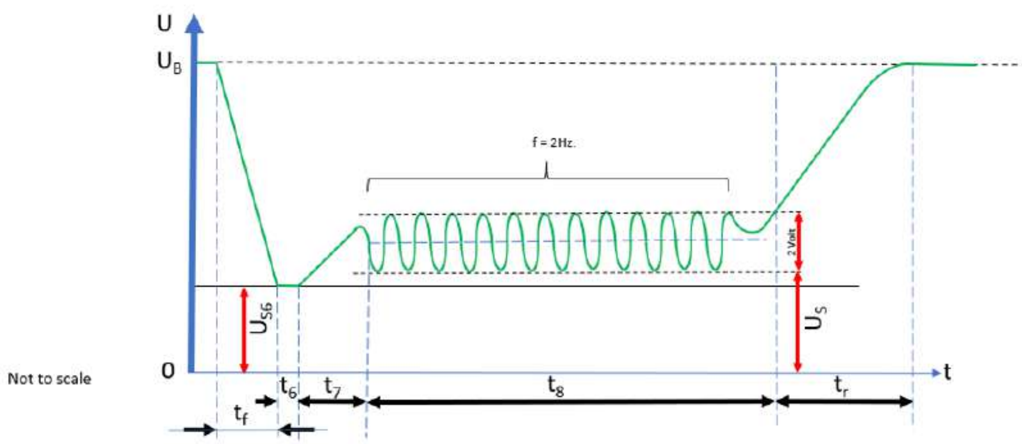


Figure 30: ISO 16750-2 Crank Waveform



Key

U	test voltage
U_B	supply voltage for generator not in operation
U_S	supply voltage
U_{S6}	supply voltage at t_6
t	time
t_f	falling slope
t_r	rising slope
$t_{6,7,8}$	duration parameters
f	Frequency of oscillation

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Table 26: ISO 16750-2 Crank Waveform

Parameter		Level			
		I	II	III	IV
Voltage V	U_{S6}	8 (-0.2)	4.5 (-0.2)	3 (-0.2)	6 (-0.2)
	U_S	9.5 (-0.2)	6.5 (-0.2)	5 (-0.2)	6.5 (-0.2)
Duration ms	t_f	5 (± 0.5)	5 (± 0.5)	5 (± 0.5)	5 (± 0.5)
	t_6	15 (± 1.5)	15 (± 1.5)	15 (± 1.5)	15 (± 1.5)
	t_7	50 (± 5)	50 (± 5)	50 (± 5)	50 (± 5)
	t_8	1000 (± 100)	10 000 (± 1000)	1000 (± 100)	10 000 (± 1000)
	t_r	40 (± 4)	100 (± 10)	100 (± 10)	100 (± 10)

Table 27: Crank Waveform Cycles

Crank Waveform Note 1	Crank Waveform Functional Test Cycles	Crank Waveform Durability Test Cycles
Waveform A	10	20 000
Waveform B	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
ISO 16750-2 Level I	10	5000
ISO 16750-2 Level II	10	5000
ISO 16750-2 Level III	10	5000
ISO 16750-2 Level IV	10	5000
Total	160	100 000

Note 1: For components that are not allowed to reset during crank Waveforms A, B, ISO 7637-2, and ISO 16750-2 Levels I, II, and IV, the initial fall rate for all waveforms, except Waveform A, shall be adjusted to 15 V/ms. For ISO 16750-2 Level III specifically, the component is allowed to reset, unless not allowed to reset by the CTS, CTRS, SSTS, and/or other relevant requirements document.

1 Perform all the Crank Waveform Durability Test Cycles (Table 27) first, if applicable.

2 After the completion of each individual row of the Crank Waveform Durability Test Cycles (Table 27), perform a 1-Point Functional/Parametric Check (total of 16 1-Point Functional/Parametric Checks).

3 Perform the Crank Waveform Functional Test Cycles (Table 27).

4 After the completion of each individual waveform of the Crank Waveform Functional Test Cycles (Table 27), perform an abbreviated 1-Point Functional/Parametric Check (total of 160 abbreviated 1-Point Functional/Parametric Checks).

Note:

- The time between durability test cycles shall be such that the internal voltages in the component shall have had time to stabilize.
- 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 1-Point Functional/Parametric Check shall be performed.

Criteria:

- FSC shall be A, except for the ISO 16750-2 Level III waveform (see note following).
- Temporary functional deviations (or resets) are only accepted if defined by the CTS, CTRS, SSTS, and/or other relevant requirements document.

Note: The FSC shall be C for the ISO 16750-2 Level III waveform but the component is allowed to reset, unless not allowed by the CTS, CTRS, SSTS, and/or other relevant requirements document.

9.2.18 AutoStart Voltage Transient.

Purpose: This test shall verify the functional capability and durability of components subjected to AutoStart transient waveforms that are generated by conventional starters controlled by the AutoStart system.

Applicability: All components that will be subjected to the AutoStart pulses on the power line supplied by the vehicle battery 12 V wiring system (both battery and/or ignition inputs).

Operating Type: 2.2 (during stop)/3.2 (after start)

Monitoring: Continuous Monitoring throughout the entire waveform.

Procedure:

Subject the component to the waveforms defined in Table 28 using the default number of cycles defined in Table 29.

Note:

- The required number of cycles may be modified in agreement with the ENV SME.
- The AutoStart Waveform Functional Test Cycles (Table 29) are required for all components.
- The AutoStart Waveform Durability Test Cycles (Table 29) 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 (as determined in 9.2.17 Crank Pulse Capability and Durability).
- 10% of the AutoStart Waveform Durability Test Cycles (Table 29) shall be performed at T_{min} and 10% of the AutoStart Waveform Durability Test Cycles (Table 29) shall be performed at T_{max}.
- The cycle time between pulses shall be adequate to verify function (abbreviated 1-Point Functional/Parametric Check) after each pulse in the AutoStart Waveform Functional Test Cycles (Table 29) and adequate to not create any failures due to an unrealistic pulse frequency.

Table 28: AutoStart Transient Waveforms

Waveform 1		Waveform 2		Waveform 3		Waveform 4	
t (ms)	U (V)	t (ms)	U (V)	t (ms)	U (V)	t (ms)	U (V)
0	12.00	0	12.00	0	12.00	0.00	12.00
100.00	12.00	100.00	12.00	100.00	12.00	100.00	12.00
105.00	6.00	100.40	6.00	101.00	6.00	100.40	6.00
150.00	6.00	150.00	6.00	102.00	6.00	102.00	6.00
280.00	9.25	280.00	9.25	202.00	9.00	202.00	9.00
410.00	8.50	410.00	8.50	702.00	10.00	702.00	10.00
480.00	9.50	480.00	9.50	703.00	12.00	703.00	12.00
600.00	8.75	600.00	8.75	1000.00	12.00	1000.00	12.00
670.00	9.55	670.00	9.55				
780.00	8.75	780.00	8.75				
840.00	9.76	840.00	9.76				
930.00	9.00	930.00	9.00				
1010.00	10.00	1010.00	10.00				
1030.00	9.50	1030.00	9.50				
1110.00	11.00	1110.00	11.00				
1530.00	12.00	1530.00	12.00				
1930.00	12.00	1930.00	12.00				

Table 29: AutoStart Transient Waveform Cycles

AutoStart Waveform	AutoStart Waveform Functional Test Cycles	AutoStart Waveform Durability Test Cycles
Waveform 1	10	10 000
Waveform 2	10	10 000
Waveform 3	10	10 000
Waveform 4	10	10 000
Total	40	40 000

1 Perform all the AutoStart Waveform Durability Test Cycles (Table 29) first, if applicable.

2 After the completion of each individual row of the AutoStart Waveform Durability Test Cycles (Table 29), perform a 1-Point Functional/Parametric Check (total of 4 1-Point Functional/Parametric Checks).

3 Perform the AutoStart Waveform Functional Test Cycles (Table 29).

4 After the completion of each individual waveform of the AutoStart Waveform Functional Test Cycles (Table 29), perform an abbreviated 1-Point Functional/Parametric Check (total of 40 abbreviated 1-Point Functional/Parametric Checks).

Note:

- The time between durability test cycles shall be such that the internal voltages in the component shall have had time to stabilize.
- 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 1-Point Functional/Parametric Check shall be performed.

Criteria:

- FSC shall be A.
- The component shall be capable of full functional operation at system voltages unless exceptions are approved by the 12 V StopStart Feature Owner, currently Scott J Chynoweth, for approval of exceptions.

9.2.19 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, either directly or through an external component.

Operating Type: Transition between 2.1 and 2.2

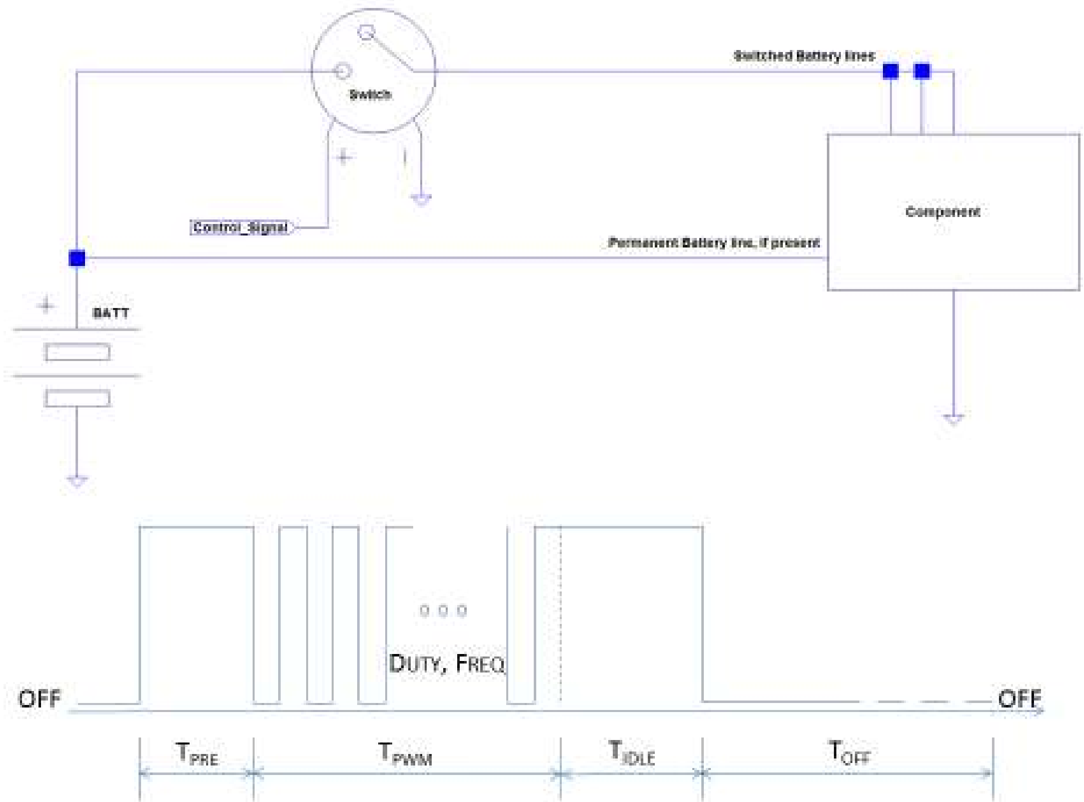
Monitoring: Continuous Monitoring. With special attention shall be given to the behavior of outputs, including regulated output voltages.

Procedure:

1 Connect the component to U_B to represent a vehicle battery. 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 31.

Note: The switch shall conduct only unidirectional current and shall be high impedance when off.

Figure 31: Switched Battery Lines Setup



2 Test setup definitions and parameters:

- **a** T_{PRE} = Pre-energizing period = 25 µs, 50 µs, 125 µs, 500 µs, 1 ms.
- **b** T_{PWM} = Relay emulated bouncing period = 50 µs, 100 µs, 250 µs, 500 µs, 1 ms.
- **c** PWM frequency = 5 kHz, 10 kHz, 20 kHz, 50 kHz, 100 kHz.
- **d** PWM duty cycle = 20%, 50%, 80%.
- **e** T_{IDLE} ≥ 100 ms: Transient completed, component in stable state and enough time for abbreviated functional check.
- **f** T_{OFF} ≥ 5 s: Off state time.
- **g** Number of PWM cycles ≥ 5.

3 Stabilize the component at T_{min}.

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

- **a** This test shall be performed in each parameter combination that leads to a minimum of 5 PWM cycles which is defined by T_{PWM} ≥ 5 × (1/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 30.
- **b** Each parameter combination shall be repeated 180 times.
- **c** An abbreviated functional check (which verifies the component completed power up initialization) shall be performed during T_{IDLE} after each parameter combination.

5 Repeat Step 4 at T_{room} and T_{max}.

Table 30: 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
		Total:	225

Criteria: FSC shall be C.

9.2.20 Battery Line Transients.

Purpose: This test shall verify the robustness of the component to the resulting transients that occur on all battery lines during a relay switching.

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

Operating Type: 2.2

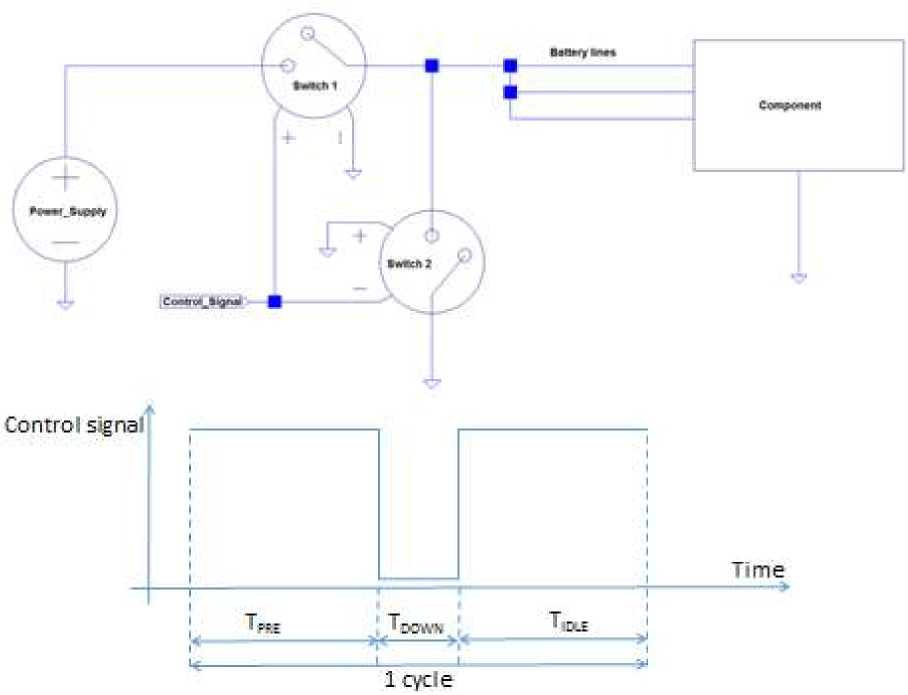
Monitoring: Continuous Monitoring.

Procedure:

1 Connect the component to the power supply through an electronically controllable switching unit with a switching time ≤ 1 µs. The switches of the switching unit shall be high impedance when opened. Control the switching unit with a signal as shown in Figure 32.

Note: The switching unit consists of two switches which are controlled by the same pulse signal. Switch 2 is synchronized with Switch 1, but is negated to it (i.e., Switch 2 closes after Switch 1 is opened completely, and Switch 1 closes after Switch 2 is opened completely). This simulates transients on all battery lines that occur during relay switching.

Figure 32: Battery Line Transients Setup



2 Test setup definitions and parameters:

- **a** T_{PRE} = Pre-energizing period = 5 s (Switch 1 closed, Switch 2 opened).
- **b** T_{DOWN} = 100 µs (Switch 1 opened, Switch 2 closed).
- **c** T_{IDLE} = 5 s: Transient completed, component in stable state and enough time for abbreviated functional check (Switch 1 closed, Switch 2 opened).
- **d** Number of cycles = 5.

  - **e** Short to ground resistance including Switch 2 ≤ 100 mΩ.

3 If the component has both Switched Battery and Permanent Battery lines the test shall be repeated in three different scenarios:

  - **a** Apply the switching only to permanent battery lines (the switched battery lines being connected to constant power supply).
  - **b** Apply the switching only to switched battery lines (the permanent battery lines being connected to constant power supply).
  - **c** Apply the switching to permanent and switched battery lines simultaneously.

Criteria: FSC shall be A when required by the CTS, CTRS, SSTS, and/or other relevant requirements document, otherwise FSC 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 vibration tests defined in Table 31 and Table 32 reference different test conditions for different mounting locations for:

- Car, SUV, or CUV (i.e., BFI),
- Light Duty Truck or FS LD SUV (i.e., BOF), and
- Heavy Duty Truck or FS HD SUV (i.e., BOF),

Refer to C1 Vehicle Vibration Level Maps and C2 Vibration Profiles in Appendix C for the detailed Vibration profiles.

Note:

1 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:

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

2 All vibration tests shall use the durations defined in Table 31 which includes the vibration time (h) that are required when 12 samples are used. This demonstrates a minimum 99% Reliability with 50% Confidence (R99/C50) on test. The 12 samples are the minimum allowable sample size. Consult with the ENV SME for requests to increase the sample size or to account for different reliability requirements.

3 All vibration tests shall have a superimposed thermal cycle as defined in 9.3.1.6 Thermal Cycle Profile Used During All Vibration Tests.

4 Refer to 6.7 Vibration Transmissibility Demonstration (VTD) for component mounting instructions.

5 Deceleration of the vibration profiles shown as follows and in C2 Vibration Profiles in Appendix C is required for rubber isolated mounted components in order to avoid “foolish failures”. Consult with the ENV SME and/or the ENV TIE for a reduced acceleration profile.

6 For all vibration tests for components mounted in specific locations of Underhood Sprung Masses, Specific Sprung Mass Locations, On Engine, On Transmission/In Transmission, On/In High Performance Flat Plan Crank Engine/Transmission Locations, and Unsprung Mass Locations, use the energy levels in m/s^2_{RMS} (g_{RMS}) defined in Table 32. Refer to C1 Vehicle Vibration Level Maps and C2 Vibration Profiles in Appendix C for the detailed Vibration profiles.

7 This procedure is intended to test the mounting features that are integral to the component case or housing. Stand-alone brackets (i.e., with unique GM part numbers) can be specific to certain applications and are not covered by this specification and shall not be used in the test. To test stand-alone brackets, refer to GMW17695.

Table 31: Duration for Each Axis (X, Y, and Z) for a Sample Size of 12

Location Energy Level	Car, SUV, CUV (BFI)	Truck, Full Size SUV (BOF)	Heavy Duty Truck Note 1
Underhood Sprung Masses Refer to Table 32 for m/s^2_{RMS} (g_{RMS})	19 h	19 h	57 h
Specific Sprung Mass Locations Note 2 Refer to Table 32 for m/s^2_{RMS} (g_{RMS})	19 h	43 h	57 h
On Engine 127 m/s^2_{RMS} (12.96 g_{RMS})	53 h	53 h	70 h
On Transmission/In Transmission 73.3 m/s^2_{RMS} (7.48 g_{RMS})	22 h	22 h	29 h
On/In High Performance Flat Plane Crankshaft Engine/Transmission Locations 233.5 m/s^2_{RMS} (23.81 g_{RMS})	53 h	53 h	70 h
Unsprung Mass Locations 107.3 m/s^2_{RMS} (10.95 g_{RMS})	19 h	43 h	57 h

Note 1: The vibration duration for Heavy Duty Truck, FS HD SUV shall be used only for a component that is unique vehicle content for Heavy Duty Trucks and/or FS HD SUVs, as determined by the program team. Otherwise, all non-unique components shall use the Truck, Full Size SUV (BOF) duration.
Note 2: Refer to Table 32 for specific sprung mass locations, which are identified as C2.2 through C2.11 in Table 32. For locations not identified, contact the ENV TIE.

Table 32: Energy Level for Specific Locations Note 1

See C2	Description	Car, SUV, CUV (BFI)	Truck, Full Size SUV (BOF)	Heavy Duty Truck		Car, SUV, CUV (BFI)	Truck, Full Size SUV (BOF)	Heavy Duty Truck
		g_{RMS}				m/s^2_{RMS}		
C2.1	Underhood (sprung, e.g., fender, radiator region) Note 2	3.14	3.14	2.78		30.4	30.4	27.5
C2.2	Front of Dash, Passenger Compartment, and Rear Body	2.0 Note 3	2.0 Note 4	2.0 Note 4		19.6 Note 3	19.6 Note 4	19.6 Note 4
C2.3	Roof	2.17	2.17	2.17		21.6	21.6	21.6
C2.4	Front Bumper or Fascia	3.50	7.55	7.55		34.3	73.5	73.5
C2.5	Rear Bumper or Fascia	2.0	4.31	5.45		19.6	42.2	59.3
C2.6	Front Frame	--	2.33	2.33		--	22.6	22.6
C2.7	Rear Frame	--	3.49	3.49		--	34.3	34.3
C2.8	Tailgate	--	4.35	9.36		--	43.1	92.2
C2.9	Pickup Box	--	3.49	6.23		--	34.3	60.8
C2.10	Liftgate Note 5	2.5	2.50	2.50		24.5	24.5	24.5
C2.11	Headlamps	3.4	2.56	2.56		33.3	25.5	25.5
C2.12	On Engine	12.96	12.96	12.96		127	127	127
C2.13	On Transmission/In Transmission	7.5	7.48	7.48		73.3	73.3	73.3
C2.14	On/In High Performance Flat Plane Crankshaft Engine/Transmission Locations	23.8	23.81	23.81		233.5	233.5	233.5
C2.15	Unsprung Mass Locations	10.9	10.95	10.95		107.3	107.3	107.3

Note 1: See Vehicle Vibration Level Maps, C1.1 Sedan or Coupe, C1.2 SUV or CUV, C1.3 Light Duty Truck, and C1.4 Heavy Duty Truck.
Note 2: E/E components mounted on body panels, e.g., fender, radiator region, etc. Does not include ICE components.
Note 3: Includes rear bumper or fascia. See C1 Vehicle Vibration Level Maps for clarification in Appendix C.
Note 4: Does NOT include rear bumper or fascia. See C1 Vehicle Vibration Level Maps for clarification in Appendix C.
Note 5: Includes Light Duty SUV and Heavy Duty SUV (i.e., BOF), vehicles, e.g., Chevrolet Suburban.

9.3.1.1 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 isolated from the road by the vehicle suspension system. Does not include ICE components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1. Use the test methods according to IEC 60068-2-64 “Test Fh, Vibration, broadband random and guidance”.
2. Refer to C1 Vehicle Vibration Level Maps and C2.1 through C2.11 for the detailed vibration profiles in Appendix C.
3. Refer to 6.8 Vibration Transmissibility Demonstration for component mounting instructions.

Criteria:

- FSC shall be A.
- 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 On Engine.

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

Applicability: All components attached to the engine, except for High Performance Flat Plane Crankshaft Engine/Transmission.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1. Use the test methods according to IEC 60068-2-64 “Test Fh, Vibration, broadband random and guidance”.
2. Refer to C1 Vehicle Vibration Level Maps and C2.12 On Engine for the detailed vibration profile in Appendix C.
3. Refer to 6.8 Vibration Transmissibility Demonstration for component mounting instructions.

Criteria:

- FSC shall be A.
- 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 On Transmission/In Transmission.

Purpose: This test shall verify that the component is immune from the effects of vibration when it is mounted on, or within, the transmission.

Applicability: All components attached on, or within, the transmission, except for High Performance Flat Plane Crankshaft Engine/Transmission.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1. Use the test methods according to IEC 60068-2-64 “Test Fh, Vibration, broadband random and guidance”.
2. Refer to C1 Vehicle Vibration Level Maps and C2.13 On Transmission/In Transmission for the detailed vibration profile in Appendix C.
3. Refer to 6.8 Vibration Transmissibility Demonstration for component mounting instructions.

Criteria:

- FSC shall be A.
- During the Visual Inspection and Dissection – DRBTR, there shall be no evidence of structural damage to the component.

9.3.1.4 Random Vibration – Mounting Location High Performance Flat Plane Crankshaft Engine/Transmission.

Purpose: This test shall verify that the component is immune from the effects of vibration when it is located on a high performance flat plane crankshaft engine/transmission.

Applicability: All components attached to the high performance flat plane crankshaft engine/transmission, such as the high performance Corvette.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1 Use the test methods according to IEC 60068-2-64 “Test Fh, Vibration, broadband random and guidance”.

2 Refer to C1 Vehicle Vibration Level Maps and C2.14 High Performance Flat Plane Crankshaft Engine/Transmission for the detailed vibration profile in Appendix C.

3 Refer to 6.8 Vibration Transmissibility Demonstration for component mounting instructions.

Criteria:

- FSC shall be A.
- During the Visual Inspection and Dissection – DRBTR, there shall be no evidence of structural damage to the component.

9.3.1.5 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 vehicle.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1 Use the test methods according to IEC 60068-2-64 “Test Fh, Vibration, broadband random and guidance”.

2 Refer to C1 Vehicle Vibration Level Maps and C2.15 Unsprung Mass Locations for the detailed vibration profile in Appendix C.

3 Refer to 6.8 Vibration Transmissibility Demonstration for component mounting instructions.

Criteria:

- FSC shall be A.
- During the Visual Inspection and Dissection – DRBTR, there shall be no evidence of structural damage to the component.

9.3.1.6 Thermal Cycle Profile Used During All Vibration Tests. Refer to Figure 33 and Table 33. Vehicle vibration stress can occur together with extremely low or high temperatures; therefore, a simultaneous temperature cycle profile shall be applied repetitively during the vibration tests.

Figure 33: Thermal Cycle Profile Used During All Vibration Tests

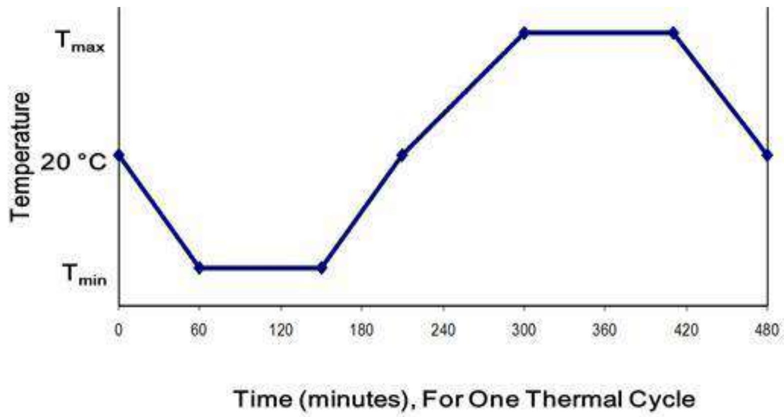


Table 33: Thermal Cycle Profile Used During All Vibration Tests Note 1

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

Note 1: If the required vibration time is < 480 minutes per axis, then the Thermal Cycle Profile shall be customized to match the duration of the vibration test in each axis. This shall be documented in the GMW3172 Component Environmental Test Plan (in "Templates" section of CG3043).

9.3.2 Mechanical Shock – Pothole.

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

Applicability: All components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1 Use the test methods according to IEC 60068-2-27 "Test Ea, Shock". Refer to Table 34 for details.

2 Use a half sine shock pulse.

3 Refer to 6.7 for component mounting instructions.

Table 34: Mechanical Shock – Pothole

Component Location	Peak	Duration	Number of Impacts Note 1
Unsprung Masses	981 m/s^2 (100 g)	11 ms	20 × 6 = 120
Sprung Masses	245 m/s^2 (25 g)	10 ms	400 × 6 = 2400
Sprung Masses(Passenger Compartment, if agreed upon by GM)	118 m/s^2 (12 g)	20 ms	400 × 6 = 2400

Note 1: The multiplier of 6 as noted in Table 34 refers to the six Cartesian directions of possible motion.

Criteria:

- FSC shall be A.
- 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 immunity to mechanical shock events produced by minor collisions (< 25.7 km/h or < 16 mph).

Applicability: All components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1. Use the test methods according to IEC 60068-2-27 “Test Ea, Shock”. Refer to Table 35 for details.
2. Perform a 1-Point Functional/Parametric Check.
3. Refer to 6.7 for component mounting instructions.

Table 35: Mechanical Shock - Collision

Description	Value
Acceleration	490 m/s^2 (50 g)
Nominal Shock Duration	11 ms
Nominal Shock Shape	half sine
Total Number of Shocks	6 × 6 directions (± X, ± Y, ± Z) = 36

Criteria:

- FSC shall be A.
- FSC shall be C if permitted by the CTS, CTRS, SSTS, and/or other relevant requirements document.
- 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 immunity to slam events (door, decklid, liftgate, endgate, and hood).

Applicability: Only for components located on a closure.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1 Use the test methods according to IEC 60068-2-27 “Test Ea, Shock”. Refer to Table 36, Table 37, and Table 38 for details.

2 Performed the test in all six Cartesian directions, where the Z direction is perpendicular to the plane of the closure when the slam occurs.

3 Refer to 6.7 for component mounting instructions.

Note:

- The acceleration values for 392 m/s^2 (40 g) and 883 m/s^2 (90 g) 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.
- The cycle counts are based on the requirements in the GM Closures CTS, CTRS, SSTS, and/or other relevant requirements document.

Table 36: Slam Based Mechanical Shock Loads

Description	Value
Side Door or Liftgate < 1 m in length	392 m/s^2 (40 g)
Side Door or Liftgate ≥ 1 m in length, or Rear Back Door	883 m/s^2 (90 g)
Decklid, Endgate, or Hood Latch Ajar Switch	392 m/s^2 (40 g)
Touch Pads or Side Door Latches	883 m/s^2 (90 g)
Nominal Shock Duration	6 ms
Nominal Shock Shape	half sine

Table 37: 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	3000

Table 38: 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)

Criteria:

- FSC shall be A.
- No structural damage to the component is permitted.
- 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.

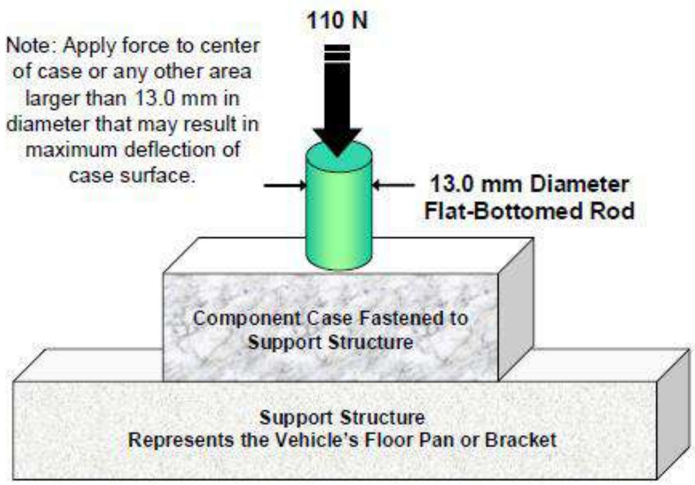
Procedure:

1 The component shall be set up to allow testing on all external surfaces with a ≥ 13.0 mm 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 34 (this represents the force applied by a person’s elbow).

2 The loads to be applied to the component housing shall be identified in the GMW3172 Component Test Plan, as negotiated between the supplier and GM. Plan to include load locations in various areas on the housing, including on top of the highest profile parts on the circuit board and on top of parts that have the least clearance to the housing. Also, focus on the areas of the housing that are the weakest and will deflect the most.

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

Figure 34: Elbow Load Applied to Component Housing.



Criteria:

- FSC shall be C.
- As part of the Visual Inspection and Dissection – DRBTR, the component shall be opened and inspected for any evidence of contact and signs of damage, including the housing, connector, and PCB assembly.
- 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.
- The deflection forces shall 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.

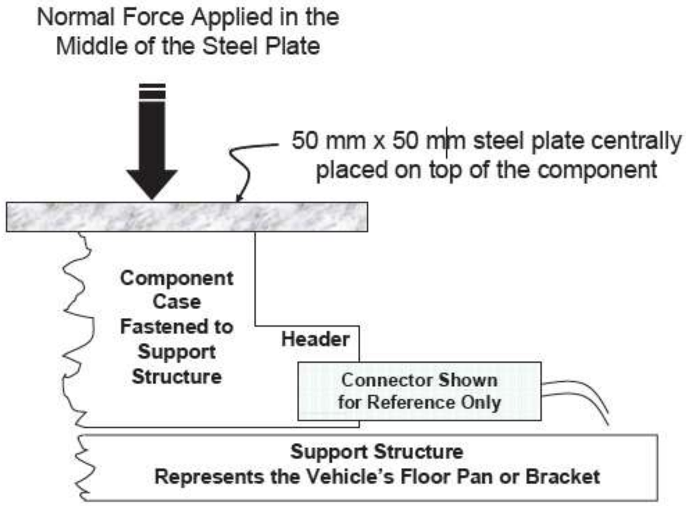
Procedure:

1 Locate a 50 mm × 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 35.

2 The loads to be applied to the component housing shall be identified in the GMW3172 Component Test Plan, as negotiated between the supplier and GM. Plan to include load locations in various areas on the housing, including on top of the highest profile parts on the circuit board and on top of parts that have the least clearance to the housing. Also, focus on the areas of the housing that are the weakest and will deflect the most.

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

Figure 35: Foot Load Applied to Applicable Surface of Component Housing



Criteria:

- FSC shall be C.
- As part of the Visual Inspection and Dissection – DRBTR, the component shall be opened and inspected for any evidence of contact and signs of damage, including the housing, connector, and PCB assembly.
- 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.
- The deflection forces shall 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 an external wiring 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 connector system or uses a connector that has never been tested by GMW3191 on this application, the minimum tests from GMW3191 are identified here in Procedure.
- 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: Refer to GMW3191

Monitoring: Refer to GMW3191.

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

Note: The test names (and numbers) are according to GMW3191 March 2019. The tests shall be performed according to the latest version of GMW3191.

1 **Terminal Push-out Force (4.5.2):** 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.
   - **a** This test will damage the component.
   - **b** Refer to GMW3191 to determine the number of test samples required.

2 **Connector to Connector Engagement Force (4.2.8):** This test verifies that the mating force of a connector system is not excessive (reference SAE USCAR-25 “Ergonomics Specification for Electrical Connections”) during the vehicle assembly process and service operations
   - **a** The connection system to mate a component connector(s) to the vehicle 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.
   - **b** This test should not damage the component.
   - **c** 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.

3 **Locked Connector Disengagement Force (4.2.18):** 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.
   - **a** 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.
   - **b** This test will damage the connector housing.
   - **c** 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.

4 **Unlocked Connector Disengagement Force (4.2.19):** 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.
   - **a** Connectors may need to be disengaged during vehicle service (i.e., to replace a failed component or make repairs to a component).
   - **b** 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.
   - **c** This test will damage the connector housing.
   - **d** This test requires 10 component samples with connectors that are fully populated with all terminals, wires, TPAs, and seals. 5 of these test samples will have the connector lock physically removed or otherwise disabled.

Criteria: Refer to 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:

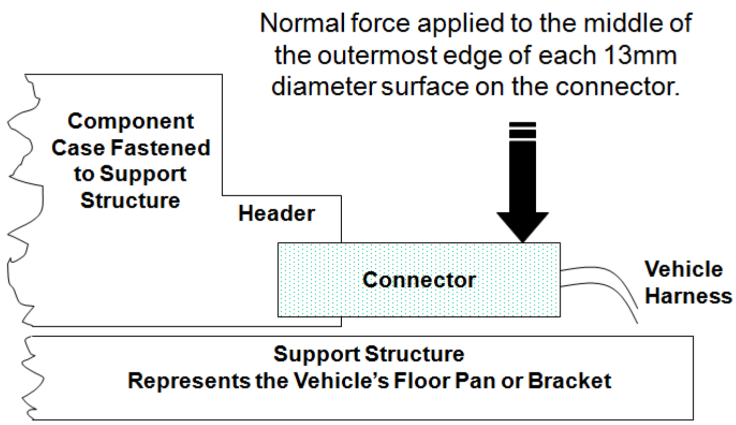
1 The component shall be set up according to Figure 36 to allow testing on the connector surface with a 13.0 mm or larger diameter area.

2 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 36.

3 Repeat this test for all applicable surfaces and connectors.

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

Figure 36: Side Force Connector Setup



Criteria:

- FSC shall be C.
- 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:

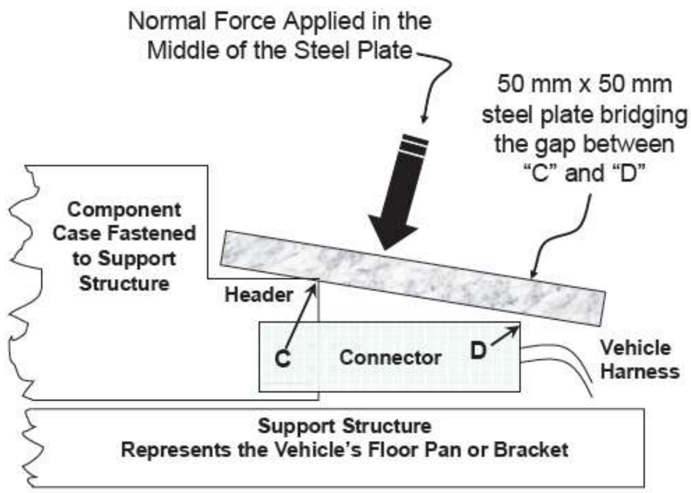
1 A simulated foot load of 890 N distributed force shall be applied normally through a (50 × 50) mm (or appropriately sized) rigid steel plate for 1 minute to the connector and connector header. See Figure 37.

Note: This plate represents the sole of a person's shoe.

2 Repeat this test for all applicable directions and connectors.

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

Figure 37: Foot Load Connector Setup



Criteria:

- FSC shall be C.
- 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:

- **a** Number of Test Samples: 3.
- **b** Drops per Test Sample: 2.
- **c** Temperature: $T_{room.}$
- **d** Drop Height: 1 m.
- **e** 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 Step 2 through Step 3 with the second sample in the Y-axis.

5 Repeat Step 2 through Step 3 with the third sample in the Z-axis.

6 Document all visual damage by pictures added 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. FSC shall be C. Additionally, during the Visual Inspection and Dissection – DRBTR, there shall be no internal damage.
- If there is significant visible external damage to the component as judged by the VE, 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. FSC shall be E. Additionally, during the Visual Inspection and Dissection – DRBTR, any internal damage shall be reported.

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 according to GMW3191 Dry Circuit Resistance (4.3.2).

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 according to GMW3191 Dry Circuit Resistance (4.3.2).

5 Subject the components to the environmental conditions stated in the HHCO for a duration of 1 day.

6 Measure the contact resistance according to GMW3191 Dry Circuit Resistance (4.3.2).

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 according to GMW3191 Dry Circuit Resistance (4.3.2).

Criteria:

- FSC 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 Step 4, Step 6, and Step 8 shall not increase more than 2 times the original resistive value measured in Step 2.

9.4 Climatic. Additional Climatic procedures for DV. Refer to Table 5 for applicable procedures for DV.

9.4.1 High Temperature Degradation.

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

Note:

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

1 The test duration of components that are Climatic coded as A, B, C, K, or L shall be 1000 h. All others shall be tested to 500 h.

Note:

- Components required to be exposed to 1000 h of high temperature reflects the longer operational time at high temperature as opposed to other areas of the vehicle. A longer duration shall be performed if required by the CTS, CTRS, SSTS, and/or other relevant requirements document.
- For components that contain internal fluids, grease, oil, coolant, etc., the component shall be mounted in vehicle orientation during the test.

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

- **a** Components that are Temperature coded as A, B, C, or D shall be tested to an elevated temperature level of +95 °C (i.e., T_{RPS}), for an additional 1 h at the beginning of the test, in Operating Type 2.1.
- **b** The duration of the test, as indicated in the Climatic Load Code (i.e., 500 h or 1000 h), at T_{max} 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.
- **c** Components that are Temperature coded as F or H shall be tested to an elevated post heating temperature level(i.e., T_{PH}), for 5% of the entire test duration, applied during the beginning of the U_{nom} portion of the test.
- **d** Functional Cycling, as defined in the item 3.4 of the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043), shall be applied during all voltage levels.
- **e** 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: FSC shall be A.

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

Purpose: This test, in combination with PTC, shall verify that the component is immune to thermal fatigue and degradation that is caused by temperature changes and possible mismatching of the CTE of materials. TS and PTC tests shall be performed independently according to the DV or PV test flow to demonstrate the required level of reliability for thermal fatigue. The default number of samples to demonstrate thermal fatigue reliability is 48 samples.

Applicability: All components.

Operating Type: 1.1

Monitoring: Not applicable.

Procedure:

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

- **a** Manual transfer methods between chambers shall not be used.
- **b** The thermal test profiles shall be determined according to the 6.8. This information shall be approved by GM prior to starting the test.

2 Perform the required number of TS and PTC cycles according to Table 39 according to the Code Letter for Temperature using a sample size of 30 for TS and 18 for PTC. The required number of thermal cycles on 48 samples are used to demonstrate the required level of reliability for thermal fatigue. This demonstrates a minimum R99/C50 on test. Consult with the ENV SME for requests to modify the sample size or test flow or to account for different reliability requirements. Refer to Figure 38 regarding the definition of a TS cycle.

Note:

- Optionally, since TS is not monitored, it is acceptable to periodically stop the test to verify functionality.
- 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.
- 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.

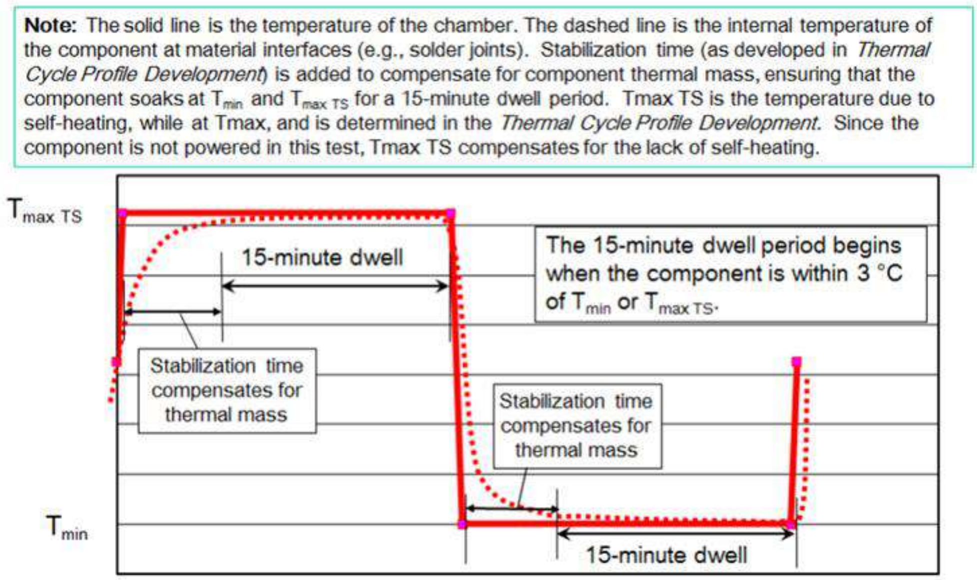
3 After the completion of the TS cycles, a 1-Point Functional/Parametric Check is required unless the ENV SME requires a 5-Point Functional/Parametric Check based on the component complexity, experience, etc.

Table 39: Number of Thermal Cycles for a Sample Size of 48 Note 1

Code	Temperature	Thermal Fatigue Cycles Required in Each Test Leg
A	-40 °C to +70 °C	234
B	-40 °C to +80 °C	353
C	-40 °C to +85 °C	415
D	-40 °C to +90 °C	477
J	-40 °C to +95 °C	518
E, F	-40 °C to +105 °C	664
G	-40 °C to +120 °C	557
H	-40 °C to +125 °C	571
I	-40 °C to +140 °C	387

Note 1: Refer to sample size for TS and PTC in 4.2.1 Test Flows.

Figure 38: TS Profile



Criteria: FSC shall be C.

9.4.3 Power Temperature Cycle (PTC).

Purpose: This test, in parallel with TS as defined in DV and PV test flows (refer to 4.2.1, Test Flows), shall verify that the component is immune to thermal fatigue and degradation that is caused by temperature changes and possible mismatching 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 reliability for thermal fatigue. This demonstrates a minimum reliability R99/C50 on test. Consult with the GM ENV SME for requests to modify the sample size or to account for different reliability requirements.

Applicability: All components.

Operating Type: 1.2/3.1/3.2 (refer to Table 40 “Power Moding”)

Monitoring: Continuous Monitoring.

Procedure:

1 Use the test methods according to IEC 60068-2-14 “Test N: Change in Temperature”, with the parameters from Table 40, along with the following requirements:

- **a** For components that contain internal fluids, grease, oil, coolant, etc. the component shall be mounted in vehicle orientation during the PTC test.
- **b** The thermal test profiles shall be determined according to the 6.8. This information shall be approved by GM prior to starting the test.
- **c** The electrical/mechanical loading shall reflect the normal usage in the vehicle application.

2 Perform the required number of PTC cycles according to Table 39 according to the Code Letter for Temperature using sample size of 30 for Thermal Shock and 18 for PTC. Refer to Figure 39 regarding the definition of a PTC.

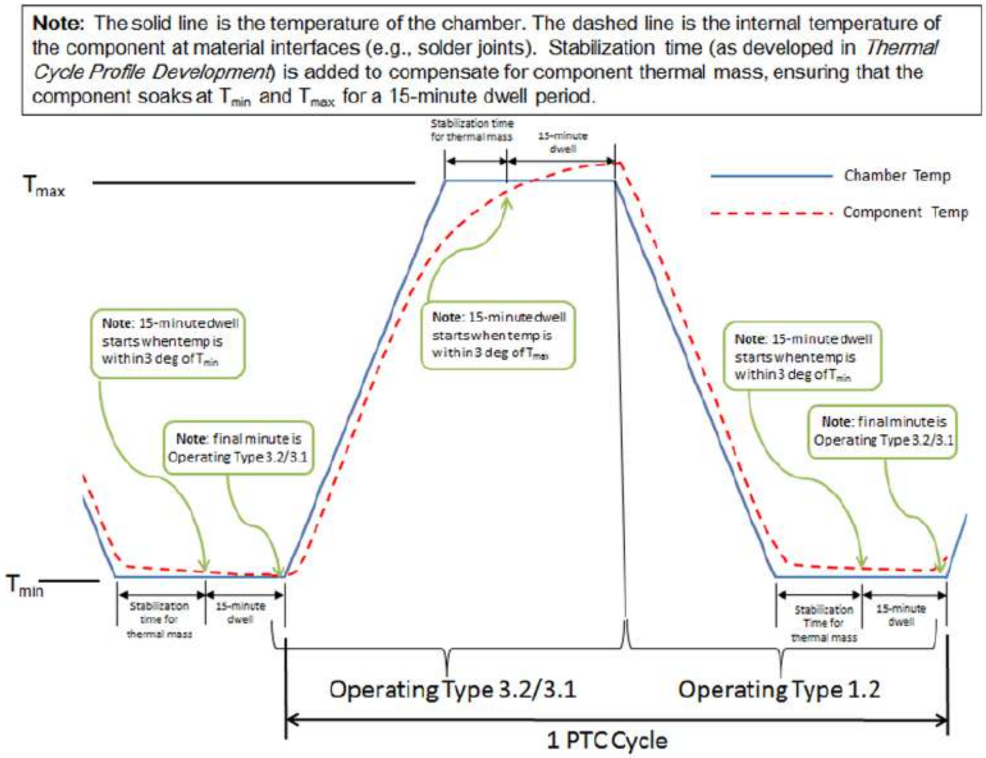
Note: If a component needs to be permanently removed during the test, it should be replaced with a dummy component in order to maintain the same thermal characteristics in the chamber

Table 40: PTC Requirements

Description	Value
Chamber Temperature Range	T_{min} to T_{max}
Chamber Temperature Change Rate	(1 to 15) K/minute **Note 1**
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	Functional Cycling, as defined in 3.4 of the GMW3172 Component Environmental Test Plan (in “Templates” section of CG3043), shall be applied during all voltage levels.
Supply Voltage	The test operating voltage shall be performed in the following order while in operating type 3.2: U_{max} for first 10% of total cycles, U_{min} for next 10% of the total cycles, U_{nom} for last 80% of total cycles.

Note 1: (1 to 15) K/minute according to IEC60068-2-14, i.e., same as (1 to 15) C/minute.

Figure 39: PTC Profile



Criteria: FSC shall be A.

9.4.4 Thermal Shock/Water Splash.

Purpose: This test shall verify the component 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, going through car wash, driving in heavy rain, etc. (e.g., low mounted on the engine, mounted in wet side of door panels (door inner cavity), etc.)

Operating Type: 1.2/3.2

Monitoring: Continuous Monitoring.

Procedure:

1 Use the test methods according to ISO 16750-4 “Ice water shock test”, using the Splash water test method.

2 The water solution shall include a soluble Ultraviolet dye that can be detected with a UV light.

Criteria:

- FSC shall be A.
- As a part of the Visual Inspection and Dissection – DRBTR, the component shall be opened and inspected for signs of water ingress.
- 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 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:

1 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 41.

Note:

- The samples shall be orientated in the vehicle orientation to test for the effects of moisture run-off and accumulation on the circuit board.
- 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 with IEC 60068-2-38, in order to keep the overall 48 h cycle time.

2 Table 42 and Figure 40 show a 2 day cycle that shall be repeated a total of five times (2 × 5 = 10 d).

3 The humidity shall be maintained at (93 ± 3)% except during the following conditions:

a During the transition from (+65 to +25) °C, the humidity shall be reduced to 80%.

b When the temperature cycle drops < +25 °C, the humidity is uncontrolled.

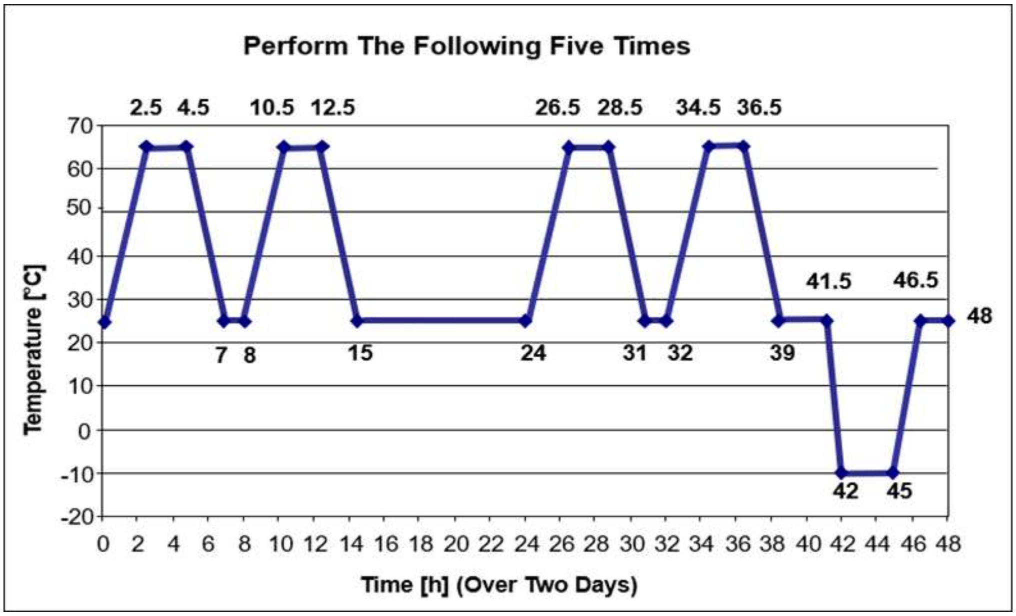
Table 41: Cyclic Humidity Requirements

Description	Value
High Temperature	+65 °C ± 2 °C
Middle Temperature	+25 °C ± 2 °C
Low Temperature	-10 ºC ± 2 °C
Duration	10 days

Table 42: Cyclic Humidity Profile

Time	Temperature
0 h	+25 °C
2.5 h	+65 °C
4.5 h	+65 °C
7 h	+25 °C
8 h	+25 °C
10.5 h	+65 °C
12.5 h	+65 °C
15 h	+25 °C
24 h	+25 °C
26.5 h	+65 °C
28.5 h	+65 °C
31 h	+25 °C
32 h	+25 °C
34.5 h	+65 °C
36.5 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

Figure 40: Cyclic Humidity Profile



Criteria:

- FSC shall be A.
- The parasitic current and active current shall not exceed the requirements in the CTS, CTRS, SSTS, and/or other relevant requirements document throughout the test.
- The maximum allowable average parasitic current shall be 0.125 mA (as stated in 9.2.1) if not provided in the CTS, CTRS, SSTS, and/or other relevant requirements document.
- 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 immunity to high humidity that may lead to functional and material degradation. The HHCO 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 43.

Note: The samples shall be orientated in the vehicle orientation to test for the effects of moisture run-off and accumulation on the circuit board.

Table 43: Constant Humidity Requirements

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

Criteria:

- FSC shall be A.
- The parasitic current shall not exceed the required limit or increase by > 50% from the beginning of this test.
- 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 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:

1 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”.

2 Use applicable tests, durations, and number of cycles as defined in Table 44.

3 Use the salt mist levels as defined for each test as follows:

- **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.

- **b** Material Degradation Test: Use a mist level of (1.0 to 2.0) ml/h on 80 cm^2.

4 Perform the tests with enclosure simulating vehicle mounting.

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

6 Final Inspection (after completion of all tests):

- **a** Document the appearance of the component following the test.
- **b** 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 44: Salt Mist Test Requirements

Component Type	Operating Test	Material Degradation Test
Non-sealed components with vent openings (Water IP 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 (Water IP 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 (Water IP 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 (Water IP Code 8)	Not applicable	Operating Type 3.2 10 cycles. Each cycle equals 8 h salt, 16 h humidity. (FSC A)

Criteria:

- FSC shall be A or C, according to Table 44.
- During the Visual Inspection and Dissection – DRBTR, there shall be no liquid ingress and/or internal dendrites.
- Based on the level of corrosion, GM will decide as to the necessity of corrective action.

9.4.8 Salt Spray.

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

Applicability: All non-interior components located on the vehicle, except components with current flowing on exposed surfaces, in which case 9.4.9 shall be used (e.g., buss electrical center). This includes under the hood, within the plenum at the base of the windshield, and within the doors (wet area).

Operating Type: 1.2

Monitoring: Not applicable.

Procedure:

1 A minimum of six test samples shall be subjected to a salt spray cycling test to emulate the vehicle mission.

Note: When units are planned to be removed at 50% and 75% of the total test cycles, more than six minimum test samples may be needed.

2 A salt spray chamber of sufficient size shall be used which will permit test samples to be positioned at a distance of 40 cm to 60 cm (11.8 in to 23.6 in) away from the directed salt-spray nozzles.

3 The test samples shall have production intent harness connectors installed, properly assembled with the correct wire sizes, terminals, and seals. See 6.9.

4 The wire harness shall contain no splices and shall exit the chamber such that the wire ends are protected from the salt spray.

5 The wire harness shall allow functional testing after completion of this corrosion test to verify electrical performance (Operating Type 1.2/3.2) without disturbing the connection system interface.

6 The test samples shall be oriented in the chamber in front of adequate number of spray nozzles to wet the complete area of the test samples in one minute. One nozzle should be used per test sample. If more than one nozzle is needed to fully wet each test sample, an overlapping spray pattern should be avoided.

7 The spray nozzle type used shall be a hollow cone type with a flow rate of approximately 2 L/minute.

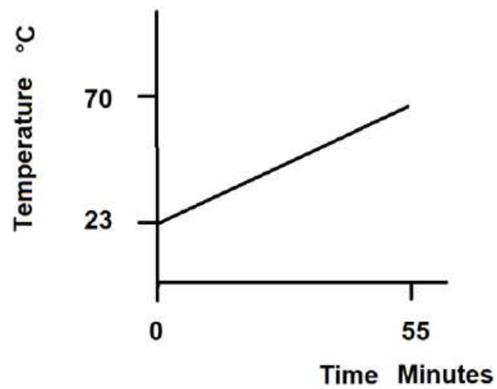
8 Minimum of at least two samples shall be oriented in the major vehicle orientation (upward/downward) and one sample with the connectors facing the nozzles which will spray a salt solution directly at the samples.

9 The salt water solution shall be 5 parts NaCl (± 1 part) by weight in 95 parts de-ionized water. The salt water solution measured during the test shall have a pH range of 6.5 to 7.2 according to GMW3286.

10 One cycle of 24 h test shall consist of the following

- **a** The unpowered test samples (Operating Type 1.2) are heated in the test chamber for 1 h to (70 ± 5) °C. The surface temperature of the test sample shall reach (70 ± 5) °C in (55 mi ± 5) minutes (Figure 41).

Figure 41: Surface Temperature of the Test Sample



- **b** With the heat turned OFF, the salt spray solution at T_{room} (23 ± 5) °C is sprayed for 1 h.
- **c** The test samples are allowed to dry 1 h in (23 ± 5) °C still air only by opening of the chamber lid/door or with a slight venting of the chamber.
- **d** Repeat Step a through Step c.
- **e** Repeat Step a and Step b then allow the units to dry in T_{room} still air for 16 h only by opening the chamber lid/door or with a slight venting of the chamber.

11 For components with appearance requirements, repeat the cycle and inspect the components to verify compliance to Appearance section of the CTS, CTRS, SSTS, and/or other relevant requirements document.

12 Repeat the cycle to complete the cycles as mentioned in Table 45.

13 After the completion of the Salt Spray cycles, conduct a 1-Point Functional/Parametric Check unless the ENV SME requires a 5-Point Functional/Parametric Check based on the component complexity, history, etc.

Table 45: Salt Spray Test Duration Requirements based on Location

Location	Test Duration		Test for Appearance
Wet side of Door Interior (Water IP Code 3 or 6K)	20 d	480 h	Not applicable
Non-Interior component with indirect exposure to salt spray (Water IP Code 6K or 8 or 9K)	30 d	720 h	Between day 4 and day 5
Non-Interior component with direct exposure to salt spray (Water IP Code 6K or 8K or 9K)	40 d	960 h	Between day 4 and day 5

Criteria:

- FSC shall be A.
- During the Visual Inspection and Dissection – DRBTR, include photographs. 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. There shall be no liquid ingress and/or internal dendrites. Based on the level of corrosion which impacts appearance, external mounting or electrical connections, GM will decide as to the necessity of corrective action.
- Two units may be removed at 50% and 75% of the total cycles to verify performance. There shall be no evidence of salt water beyond the sealing surfaces at the end of the test. There shall be no electrical performance degradation at the end of test.

9.4.9 Alternate Salt Spray using GMW14872.

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

Applicability: For non-interior components that have current flowing on exposed surfaces (e.g., bussed electrical centers), GMW14872 shall be used in lieu of 9.4.8. When using GMW14872, continuous monitoring and functional moding (FSC A) shall be used during the test unless agreed to otherwise by the ENV SME, VE, and DRE.

Operating Type: 3.2 unless agreed otherwise

Monitoring: Continuous.

Procedure: See GMW14872.

Criteria: Functional Status Classification shall be A during operating type 3.2.

9.4.10 Minimum Non-Operating Temperature.

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

Applicability: All components.

Operating Type: 2.1/3.2

Monitoring: Continuous Monitoring during Operating Type 3.2.

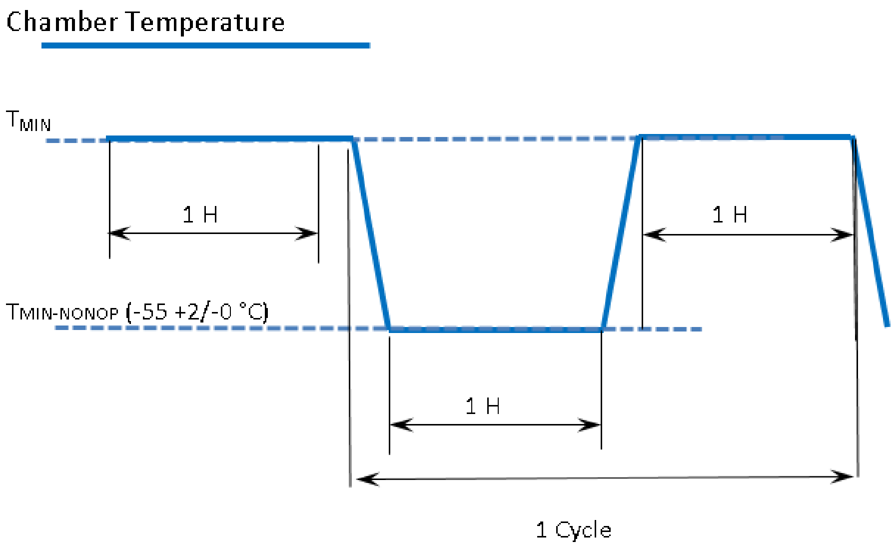
Procedure:

1 Soak the components at T_{min} for 1 h at Operating Type 2.1, then transition to Operating Type 3.2 at U_{nom} long enough to confirm FSC A. Transition back to Operating Type 2.1.

2 Cycle the test chamber between T_{min} and Minimum Non-Operating Temperature ($T_{min\text{-}nonop}$) 15 times as shown in Figure 42. The components shall be maintained at Operating Type 2.1 during this time. FSC is not applicable.

3 On the 15th cycle, after 1 h of Operating Type 2.1 at T_{min}, transition to Operating Type 3.2 at U_{nom} long enough to confirm FSC A.

Figure 42: Minimum Non-Operating Temperature Profile



Criteria: FSC shall be A during Operating Type 3.2.

9.5 Enclosure.

9.5.1 Dust.

Purpose: This test shall verify that the component 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 "Road Vehicles – Degrees of Protection (IP Code) – Protection of Electrical Equipment Against Foreign Objects, Water and Access".

2 Use the dust according to ISO 12103-1 "Arizona test dust, A2 fine test dust".

3 The test duration shall be 8 h.

Note: For some electromechanical components, the duration may be extended beyond 8 h where appropriate and the component can be tested in an enclosure simulating vehicle mounting.

4 Perform the 1-Point Functional/Parametric Check.

Criteria:

1 FSC shall be C.

2 The component shall be opened and inspected as a part of the Visual Inspection and Dissection – DRBTR:

  a For dust rating of 6K, no dust ingress is allowed.

  b 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 design sufficiently meets the IP requirement when specified by the second characteristic IP Code, except IPX8 (which is covered under GMW3172 9.5.3 Seal).

Applicability: All components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1 Use the test methods according to ISO 20653 "Road Vehicles – Degrees of Protection (IP Code) – Protection of Electrical Equipment Against Foreign Objects, Water and Access".

2 The water solution shall include a soluble Ultraviolet dye that can be detected with a UV light that fluoresces when dry.

3 An enclosure shall not be used as part of the Water test.

4 If a specific exception is included in a CTS, CTRS, SSTS, and/or other relevant requirements document to allow an enclosure to be used as part of the Water test setup, it shall not be allowed for components that are mounted in known wet/drip locations. The following are examples of known wet/drip locations and components near/under these locations shall be tested without any type of drip protection (enclosure, shield, etc.):

- **a** Defroster Duct.
- **b** Side Window Defogger Ducts.
- **c** Instrument Panel Vent Ducts.
- **d** First Row Heater Ducts.
- **e** Second Row Heater Ducts.
- **f** Third Row Heater Ducts.
- **g** Console Ducts.
- **h** Wireless Phone Charger Duct.
- **i** B/C/D Pillar HVAC Ducts.
- **j** Headliner Ducts - Plastic Ducts ONLY.
- **k** Instrument Panel HVAC Outlets.
- **l** Console HVAC Outlets.
- **m** Headliner Outlets.
- **n** B/C/D Pillar HVAC Outlets.
- **o** All HVAC Condensate Drain Tubes.
- **p** Front HVAC Module.
- **q** Rear HVAC Module.
- **r** Near or in the path of water management, such as water drain hoses as used in sunroof assemblies.

5 Following the procedure, the Visual Inspection and Dissection – DRBTR of the component shall be performed.

Criteria:

- FSC 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, IPX8.

Purpose: This test shall verify the component immunity to loss of seal that may lead to water ingress to test to test for IP Water Code rating IPX8.

Applicability: All sealed components.

Operating Type: 1.2

Monitoring: Not applicable.

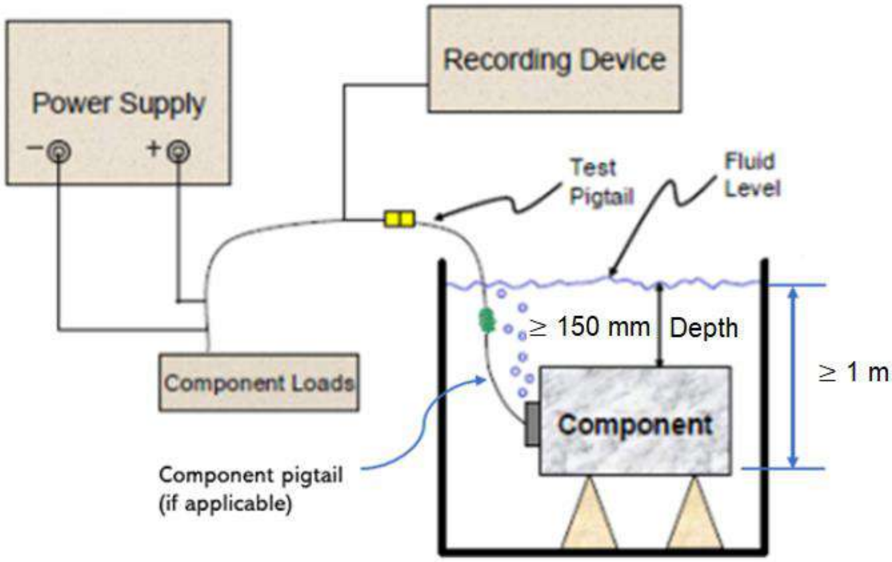
Procedure:

Note: The appropriate test method shall be agreed upon between the ENV SME and the supplier.

1 **Test Method 1** (1 m depth):
   - **a** 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 UV light.
   - **b** Place the component (including the pigtail, if applicable) in a temperature chamber at T_{max} for at least 30 minutes or long enough to ensure that T_{max} has been reached within the component.
   - **c** Remove the component from the temperature chamber.
   - **d** Immediately immerse the component (including the pigtail, if applicable) in the test solution such that the bottom of the component is at a depth of 1 m (deepest housing location). Or, if the housing is larger than 850 mm, then use 150 mm water above the highest location of the housing. See Figure 43 for details.
   - **e** After the component has been submerged for 30 minutes, remove the component from the test solution.
   - **f** Repeat Step b through Step e until 5 submerging cycles have occurred.

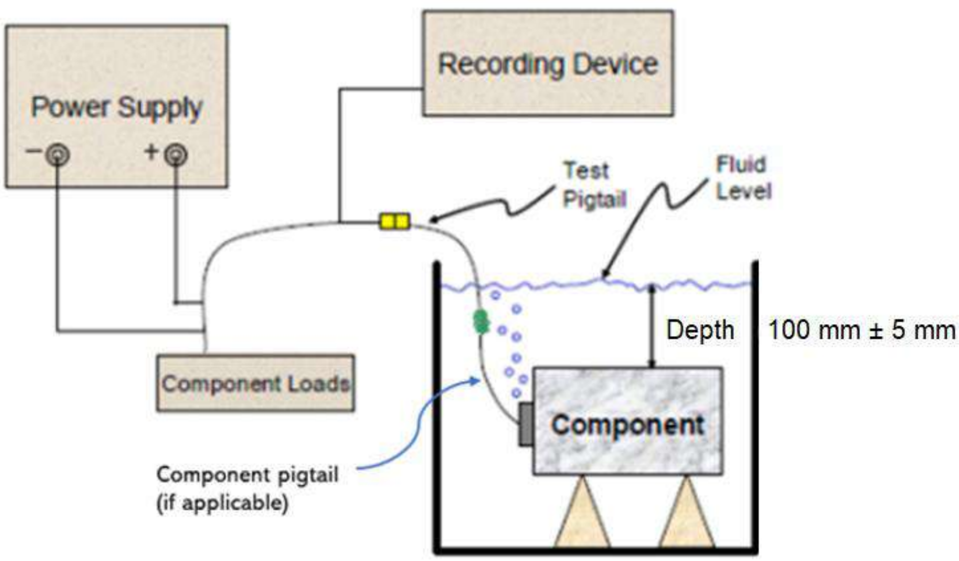
2 **Test Method 2** (100 mm depth):
   - **a** Prepare a test solution consisting of 5% saline in 0 °C water. The water solution shall include a soluble Ultraviolet dye that can be detected with a UV light.
   - **b** Place the component (including the pigtail, if applicable) in a temperature chamber at T_{max} for at least 30 minutes or long enough to ensure that T_{max} has been reached within the component.
   - **c** Remove the component from the temperature chamber.
   - **d** Immediately immerse the component (including the pigtail, if applicable) in the test solution such that the top of the component is at a depth of (100 ± 5) mm. See Figure 44 for details.
   - **e** After the component has been submerged for 30 minutes, remove the component from the test solution.
   - **f** Repeat Step b through Step e until 15 submerging cycles have occurred.

Figure 43: Method 1 Seal Test Setup for Components Note 1



Note 1: Tank is not to scale. Depth varies Test Method 1 (1 m) to Test Method 2 (100 mm).

Figure 44: Method 2 Seal Test Setup for Components



Criteria:

- FSC 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 seal integrity.

Applicability: All sealed components.

Operating Type: 1.2

Monitoring: Not applicable.

Procedure:

1 **Test Method 1** (component that can be pressurized without damage, e.g., has a vented header connector, etc. and has a leak rate defined as zero):

- **a** Pressurize the sample (default value 48 kPa (7 psi) above the ambient pressure) at room temperature.
- **b** Submerge the sample in room temperature water for a minimum of 5 minutes total while examining every face for bubble flow.

2 **Test Method 2** (component that cannot be pressurized without damage and/or has a non-zero leak rate): Repeat Test 2, Step a through Step b with a minimum pressure differential of 48 kPa (7 psi).

Note: Other methods are available to determine the rate (e.g., Air Vacuum Meter Method, Vacuum Chamber Method, etc.)

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, CTRS, SSTS, and/or other relevant requirements document.

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:

1 If this test is applied to a component which provides mechanical movement, setup the component in a simulated vehicle environment with all mechanical attachments in place.

2 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 approximately 2 L/minute to allow water pooling.

3 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.

4 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.

5 Repeat Step 1 to Step 3 five times.

Criteria: FSC shall be A.

9.5.6 Sugar Water Function Impairment.

Purpose: The test shall identify the component 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 compartment, trunk compartment, or on the vehicle exterior. This test is not applicable to underhood components.

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

Note:

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

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

Criteria:

- FSC shall be A for electrical functions.
- Degradation in operational forces or torque shall meet the CTS, CTRS, SSTS, and/or other relevant requirements document.

9.6 Material. None.

10 Product Validation (PV)

10.1 PV Mission. PV is a quantitative and qualitative verification that the component meets the requirements for Environmental, Durability, and Reliability when including the effects of production manufacturing. PV activities shall be executed using components from the production tooling, processes, and home line. Not all tests in the PV Test Flow may be required depending on the test results of DV, and if all the production intent materials, processes, and home line tools and location were used in DV. All exceptions shall be approved by the Test Plan Approver. All PV activities shall be documented in the GMW3172 Component Environmental Test Plan in CG3043.

10.2 Electrical. There are no new Electrical procedures for PV. All Electrical procedures are defined in the Development and DV sections. Refer to Table 5 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 DV sections. Refer to Table 5 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:

1 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.

2 Perform the production End-Of-Line (EOL) test.

3 This test shall be performed on one fully-populated final shipping container of production components. The shipping container shall include all interior packing material.

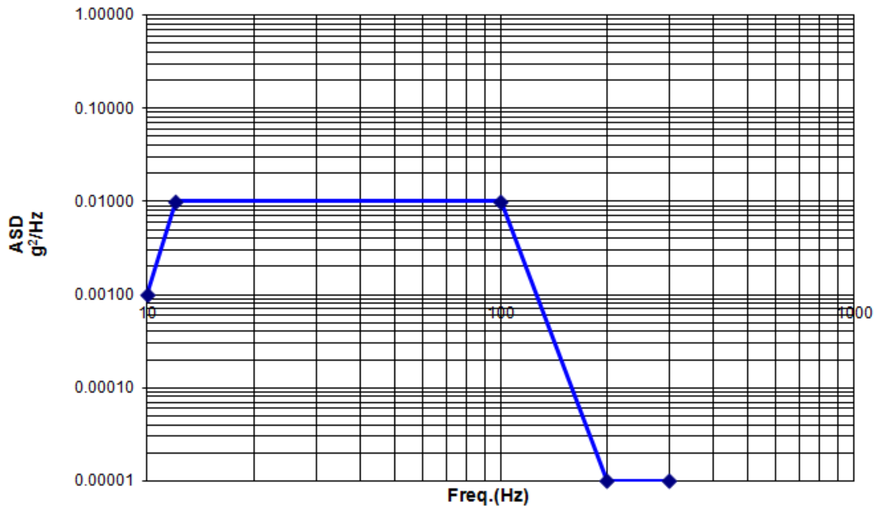
4 Vibrate the shipping container for 24 h in each of the three mutually perpendicular directions using the methods outlined in ASTM D4728 “Standard Test Method for Random Vibration Testing of Shipping Containers. If a supplier has access to a six degree of freedom vibration table, then run the test for 24 h only. Use the Random Vibration Profile shown in Figure 45 and Table 46.

5 Inspect all components for external structural damage, degradation of surfaces that are directly or indirectly visible to customers, and for dust/debris from the packaging materials both inside and outside of the component. Also, inspect the inside of the shipping container for structural damage.

6 Inspect all components for structural damage, degradation of surfaces visible to customers, and for debris from the packaging materials both inside and outside of the component.

7 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 45: Random Vibration Profile for Shipping Note 1



Note 1: Effective Acceleration is 9.81 m/s^2_{RMS} (1.0 g_{RMS}).

Table 46: Random Vibration Profile for Shipping

Frequency	PSD
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 damage. 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:

- FSC shall be C.

- Additionally, during the initial inspection after the test of all of the components, there shall be no external structural damage, or degradation of surfaces that are directly visible to customers, on any of the components.
- There shall be no degradation of surfaces that are not visible to customers, unless acceptable by GM.
- Additionally, no dust/debris from the packaging materials is allowed inside or outside of any of the components, unless acceptable by GM and the GM receiving location(s).
- Any structural damage of the inside of the shipping container shall be reported to GM DRE and the GM VE to determine if additional validation is required (e.g., reusable containers), improvements are needed, or if it is acceptable.
- During the Visual Inspection and Dissection – DRBTR, there shall be no internal or external structural damage, or dust/debris from the packaging materials inside or outside, to the six 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 DV sections. Refer to Table 5 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 DV sections. Refer to Table 5 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 (in "Templates" section of CG3043). **Note:** Some items, such as a motor, may be a "component" or a "part" depending on its application and test requirements.

Crossover Utility Vehicle (CUV): This is a BFI vehicle, unibody, built on a car platform, e.g., Chevrolet Trax.

Full Size Heavy Duty Sport Utility Vehicle (FS HD SUV): This is an SUV BOF, built on a truck platform, that has a greater weight rating and a stronger suspension and frame than a LD SUV, e.g., Heavy duty versions of the Chevrolet Tahoe, Chevrolet Suburban, etc. **Note:** Use the Heavy Duty Truck profile for the 9.3.1 test.

Full Size Light Duty Sport Utility Vehicle (FS LD SUV): This is a SUV BOF, built on a truck platform, e.g., Chevrolet Tahoe, Chevrolet Suburban, etc. **Note:** Use the Light Duty Truck profile for the 9.3.1 test.

Heavy Duty Truck (HD Truck): This is a pickup truck or commercial vehicle that is a BOF vehicle, that has a greater weight rating and a stronger suspension and frame than a LD truck, e.g., 2500 or 3500 (or larger) series of the Chevrolet Silverado, etc.

Light Duty Truck (LD Truck): This is a pickup truck or commercial vehicle that is a BOF vehicle, e.g., 1500 series of the Chevrolet Silverado, etc.

m/s^2_{RMS} (g_{RMS}): Square root of the area under the PSD vibration curve.

Part: An element that is used to construct a component such as a transistor, circuit board, housing, motor, and potting material, etc.

Sport Utility Vehicle (SUV): This is a BFI vehicle, unibody, built on a car platform, e.g., Chevrolet Traverse, etc.

Test Plan Approver: This term is used interchangeably for the Validation Engineer or ENV SME, which is the person that is responsible to approve the GMW3172 Component Environmental Test Plan in CG3043 from the supplier.

Validation Engineer (VE): This term is used interchangeably for the VE, CVE, or SVE, which is the person that is responsible to verify that the component is fully validated and sign off for production approval.

11.2 Acronyms, Abbreviations, and Symbols.

3SD	Three Standard Deviation

A/D/V	Analysis/Development/Validation
ASICs	Application Specific Integrated Circuits
BEV	Battery Electric Vehicle
BFI	Body Frame Integral
BGA	Ball Grid Array
BOF	Body on Frame
BOM	Bill of Material
CAN	Controller Area Network
CEMENT	Component EMc and ENvironmental Test
CPA	Connector Position Assurance
CTE	Coefficient of Thermal Expansion
CTRS	Component Technical Requirement and Specification
CTS	Component Technical Specification
CUV	Crossover Utility Vehicle
CVE	General Motors Component Validation Engineer (also can be referred to as the GM VE or SVE)
DBC	Direct Bonded Copper
DFN	Dual Flat No-Lead
DRBTR	Design Review Based on Test Results
DRE	General Motors Design Release Engineer
DTC	Diagnostic Trouble Code
DV	Design Validation
E/E	Electrical/Electronic
ECU	Electronic Control Unit
EMC	Electromagnetic Compatibility
ENV SME	Environmental Subject Matter Expert
EOL	End-Of-Line
ETL	Engineering Technical Leader
FEA	Finite Element Analysis
FS HD SUV	Full Size Heavy Duty Sport Utility Vehicle
FS LD SUV	Full Size Light Duty Sport Utility Vehicle
FSC	Functional Status Classification
GMNA	GM North America
HALT	Highly Accelerated Life Test
HAST	Highly Accelerated Stress Test
HD Truck	Heavy Duty Truck
HHC	Humid Heat Cyclic
HHCO	Humid Heat Constant
HVAC	Heating, Ventilation, Air Conditioning
ICE	Internal Combustion Engine
I/O	Input/Output
IP	International Protection

IV MRD	Integration Vehicle Material Required Date
LD Truck	Light Duty Truck
LED	Light Emitting Diode
LTCC	Low Temperature Co-fired Ceramic
MCPCB	Metal Core Printed Circuit Board
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
PDT	Product Development Team
PN	Partial Network
PPEI	Platform to Powertrain Electrical Interface
PPT	Procedure Planning Tool
PSD	Power Spectral Density
PTC	Power Temperature Cycle
PTH	Plated Through Hole
PV	Product Validation
PWM	Pulse Width Modulation
QFN	Quad Flat No-Lead
R99/C50	99% Reliability with 50% Confidence
RMS	Root Mean Square
SCREAM	Software Changes Requiring Env And/or eMc document
SMD	Surface Mount Device
SOR	Statement of Requirements
SQE	Supplier Quality Engineer
SSTS	Subsystem Technical Specification
SUV	Sport Utility Vehicle
SVE	General Motors Subsystem Validation Engineer (also can be referred to as the GM CVE or VE)
TCPD	Thermal Cycle Profile Development
TPA	Terminal Position Assurance
TRT	Test Report Template
TS	Thermal Shock Air-To-Air
VE	General Motors Validation Engineer (also can be referred to as the GM CVE or SVE)
VIP	Vehicle Intelligence Platform (also known as Global B)
VPO	Vehicle Performance Owner
VTC	Validation Test Complete
VTD	Vibration Transmissibility Demonstration

12 Additional Paragraphs

12.1 All parts or systems supplied to this standard shall comply with the requirements of GMW3059, **Restricted and Reportable Substances.**

12.2 References. Additional reference information may be obtained from the following sources:

- Azar, Kaveh: Electronics Cooling – Theory and Applications, Short Course, 1998.

- Clark, Dana W.: AFD and Inventive Troubleshooting, Ideation International Inc., 2000.
- Clech, Jean-Paul: Acceleration Factors and Thermal Cycling Test Efficiency for Lead-Free Sn-Ag-Cu Assemblies, SMTA International Conference, Chicago, Il. September 2005.
- Clech, Jean-Paul: SAC Solder Joint Reliability: Test Conditions and Acceleration Factors, SMT/Hybrid/Packaging Conference, Nurnberg, Germany, April 19, 2005.
- Clech, Jean-Paul: Solder Reliability Solutions: From LCCCS to Area-Array Assemblies, Proceedings from Nepcon West 1996.
- Giacomo, Giulio, et-al: CBGA and C4 Fatigue Dependence on Thermal Cycle Frequency, 2000 International Symposium on Advanced Packaging Materials, 2000.
- Hobbs, Gregg K.: Accelerated Reliability Engineering – HALT and HASS, John Wiley and Sons, 2000.
- IHS Markit Standards Store by S&P Global, www.global.ihs.com.
- IPC J-STD-001 “Requirements for Soldered Electrical and Electronic Assemblies”, https://shop.ipc.org/.
- IPC-TM-650 “Test Methods Manual”, https://www.ipc.org/test-methods.
- Lipson, Charles and Sheth, Narendra J.: Statistical Design and Analysis of Engineering Experiments, McGraw-Hill, 1973.
- Nelson, Wayne: Accelerated Life Testing, John Wiley and Sons, 1990.
- Peck, D. Steward: Comprehensive Model for Humidity Testing Correlation, IEEE Catalog 86CH2256-6, 1986.
- Steinberg, Dave S.: Vibration Analysis for Electronic Equipment, Third Edition, John Wiley and Sons, 2000.
- White, F.M.: Fluid Mechanics, Second Edition, Page 60, McGraw-Hill, New York, 1986.
- Yamamoto, Toshio: Technology Report Number 5 Fundamental Concepts of Environmental Testing in Electricity and Electronics, Tabai Espec Corp., 1998.

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, CTRS, SSTS, and/or other relevant requirements document appears in this document.

14 Release and Revisions

This standard was originated in September 1998. It was first approved by GM North America (GMNA) in December 2000. It was first published in December 2000.

Issue	Publication Date	Description (Organization)
15	NOV 2022	Corrected original Release and Revisions paragraph origination date. Updated Introduction. Updated 4.2 A/D/V Process Flow: Added Process Flow and RASIC. Revised 4.2.1 DV/PV Test Flows: Added X-Ray Inspection of PCBA for all samples, Simulator Verification, Mechanical and Thermal fatigue in series Leg 1, spread Thermal Fatigue over Leg 1, 2, and 3, moved HTD to Leg 4, increased total number of samples to shorten test time, merged Enclosure and Seal legs, corrected typo for sample size in Leg 5, eliminated LTW from Leg 1, 2 and 3 post Cross Section and Inspection and Ground Path Inductance Sensitivity test, added AutoStart Voltage Transient in Leg 6. Updated Table 14, 6.3 Continuous Monitoring procedure, and 6.6 Cross Section and Inspection procedure: Added requirement for wettable flanks and standoff heights. Added PCBA X-ray Inspection to identify additional Cross Section for Leg 0a. Removed void requirements and moved to PCBA x-ray Inspection. Added 6.7 PCBA x-ray Inspection procedure. Updated 6.8 Vibration with Thermal Cycling: Added vehicle mounting locations, updated the g_{RMS} values and durations for 12 samples in the table for the new test flows. Added Appendix C vibration profiles. Updated 6.9 Thermal Cycle Profile Development: Added 6.10 Simulator Verification and updated Thermal Fatigue analysis to include Mechanical Fatigue. Updated 8.2/9.2: Added reference to the “Electrical Test Circuit Types” document. Updated 9.1/10.1 DV/PV Mission to clarify quick-turn boards are not allowed in DV and the production home line is required for PV. Updated 9.2.2 Power Supply Interruptions to add procedure to reset regulators. Updated 9.2.8 Multiple Power and Multiple Ground Short Circuits including Pass Through to clarify test applicability, test setup and figures. Updated 9.2.11 Ground Offset figure. Updated 9.2.12 Power Offset figure. Updated 9.2.17 Crank Pulse Capability and Durability to remove items related to AutoStart, added Waveform B and items from ISO 16750-2 standard, moved Waveform 1 and 2 to 9.2.18 AutoStart Voltage Transient test (new). Updated 9.3.1 Vibration with Thermal Cycling: Added vehicle mounting locations, updated g_{RMS} values, durations, and sample size, added Appendix C vibration profiles. Updated 9.4.1 High Temperature Degradation for 1000 h. Updated 9.4.2 TS: Updated table to capture the test cycles for 48 unit test. Updated 9.4.3 PTC: Added new power moding profile in table, proposed temperature change rate to 7-15 K/minute instead of 1 to 15 K/minute during the test. Updated 9.4.5 HHC: Humidity profile and criteria for parasitic current. Updated 9.4.6 HHCO: Parasitic current. Updated 9.4.7 Salt Mist: Removed words “test methods” for the IEC 60068-2-52. Updated 9.4.8 Salt Spray procedure. Updated 9.5.2 Water: Clarified it does not apply to Water Code IPX8. Updated 9.5.3 Seal: Added reference to IPX8, changed Operating Type to 1.2, Monitoring to “not applicable”. and Immersion Depth to 1 m. Updated 10.3.1 Shipping Vibration: Added inspect for “dust” (along with debris, which was already stated) in the packaging materials, added inspect the inside of the shipping container for structural damage. Updated the Glossary and Acronyms. (Validation - Electrical Hardware (Components) Validation)

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 as follows. The component Environmental Hardware Design Review shall include the following lead-free considerations:

1 **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.

2 **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.

3 **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.

4 **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.

5 **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:

   a Low melting point of solder joint (e.g., +96 °C).

   b Pad-lifting, due to asymmetrical cooling of two different solder alloys on the part attachment.

   c Significant reduction of thermal fatigue life.

6 **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).

7 **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).

8 **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 Environmental/Durability Test Flow places the High Temperature Degradation test prior to the first Mechanical Shock test specifically to address this concern.

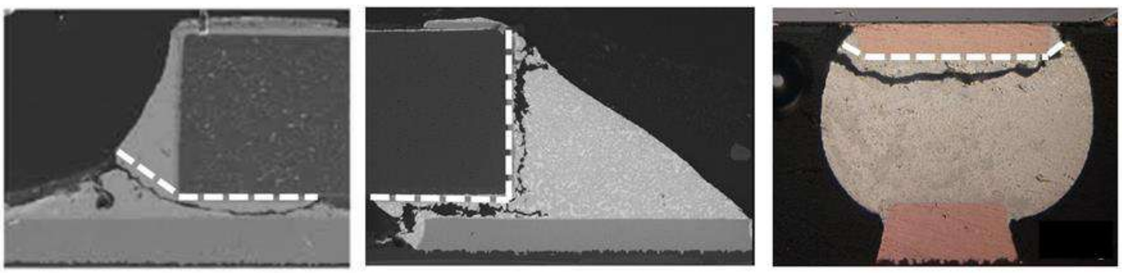
Appendix B

B1 Guidelines to Measure Solder Joint Crack Length

During post-validation root-cause analysis, if cross sectioning is determined to be necessary, the following guidelines shall be used to measure the solder joint crack length:

- For measurement solder cracks of the cross sectional length across the solder joint, the defined length of the solder joint consists of the horizontal vector of the solder joint along the edge of the part that is parallel to the PCB plus the 45-degree directional vector from the bottom corner of the part to the outer edge of the fillet. If the crack is along the side of the part, use the parallel vectors along the bottom and the side of the part. For example, the defined length of the solder joint is shown by the white dotted line in Figure B1 as follows. Note that the actual crack in a solder joint might not follow the exact same path as the defined length of the solder joint. Voids in the solder joint shall not be included in the length of the solder joint and the length of the solder crack.

Figure B1: Defined Length of the Solder Joint



- For QFNs and DFNs solder cracks measurement of the cross sectional length across the solder joint, do not include the length of the lead that is not plated (i.e., non-wettable flank), in the length of the solder joint and the length of the solder crack. Voids in the solder joint shall not be included in the length of the solder joint and the length of the solder crack.
- If there is evidence of a solder crack, then cross sectioning may be required at different depths on that solder joint or additional cross sections may be required on adjacent solder joints or on similar parts. Additionally, during the Visual Inspection and Dissection – DRBTR, if there is evidence of a solder crack or partial PTH fill (or other concern), additional cross sectioning may be required.

Appendix C

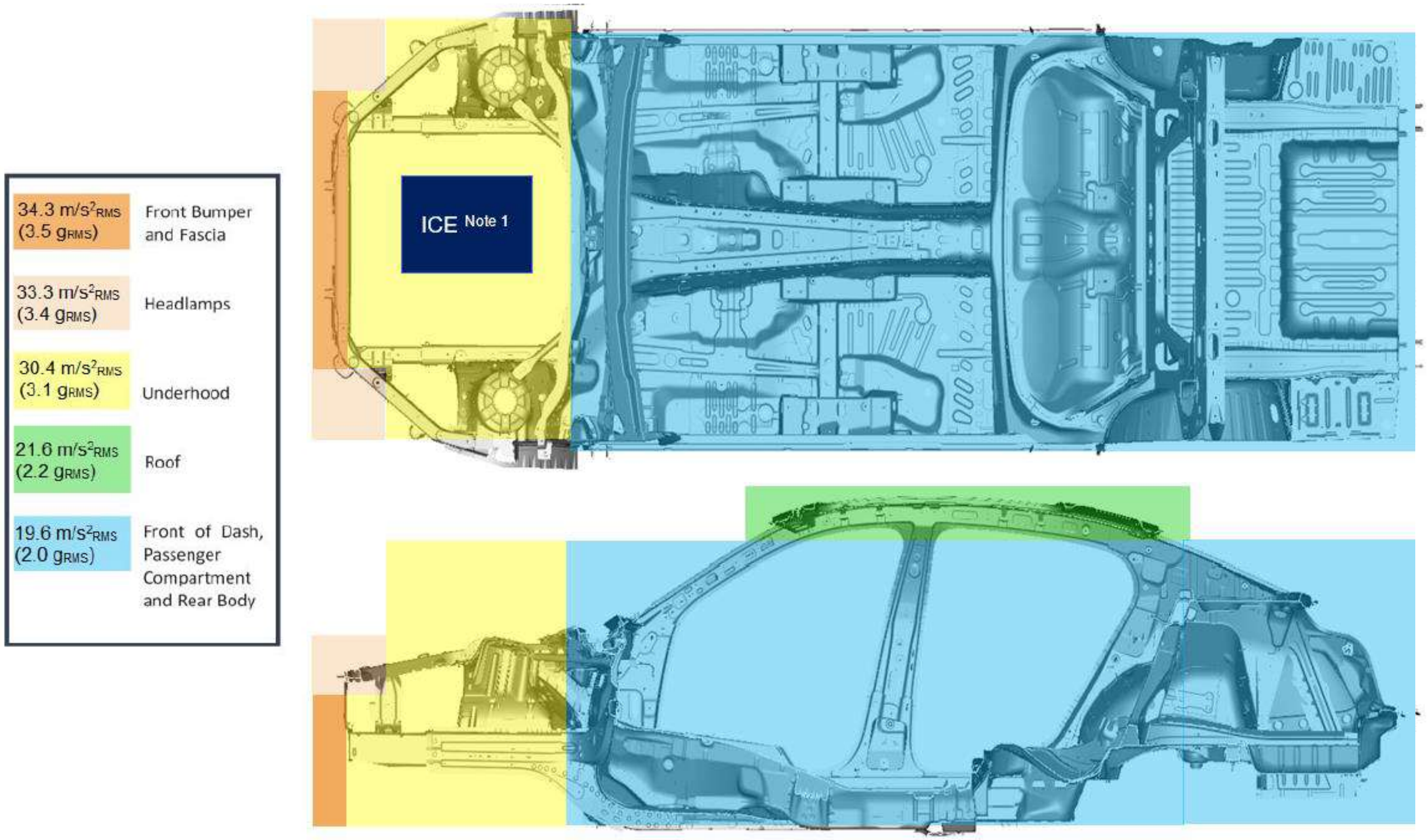
Appendix C contains Vehicle Vibration Maps indicating the PSD level in m/s^2_{RMS} (g_{RMS}) for particular areas of various vehicle types as shown in C1, C1.1 through C1.4. The specific vibration profiles are shown in C2 as follows:

- Sprung Masses, C2.1 through C2.11.
- On-Engine, C2.12.
- On-Transmission/In-Transmission, C2.13.
- High Performance Flat Plane Crank Engine/Transmission, C2.14.
- Unsprung Masses, C2.15.

C1 Vehicle Vibration Level Maps

C1.1 Sedan or Coupe. See Figure C1.1.

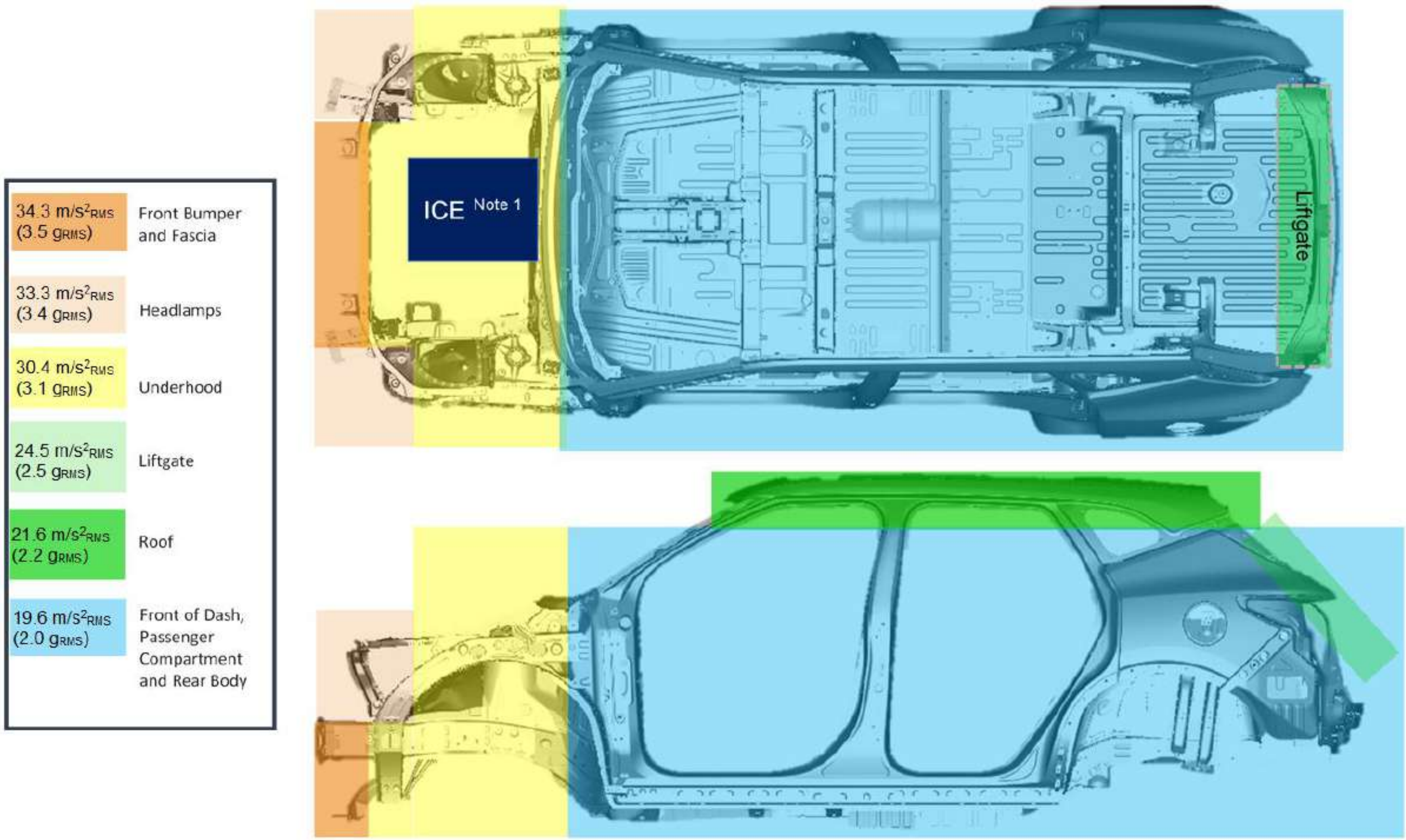
Figure C1.1: Sedan or Couple Energy Level Map



Note 1: Internal Combustion Engine, Transmission, Exhaust, and Suspension are Not covered by the Underhood Profile.

C1.2 SUV or CUV. See Figure C1.2.

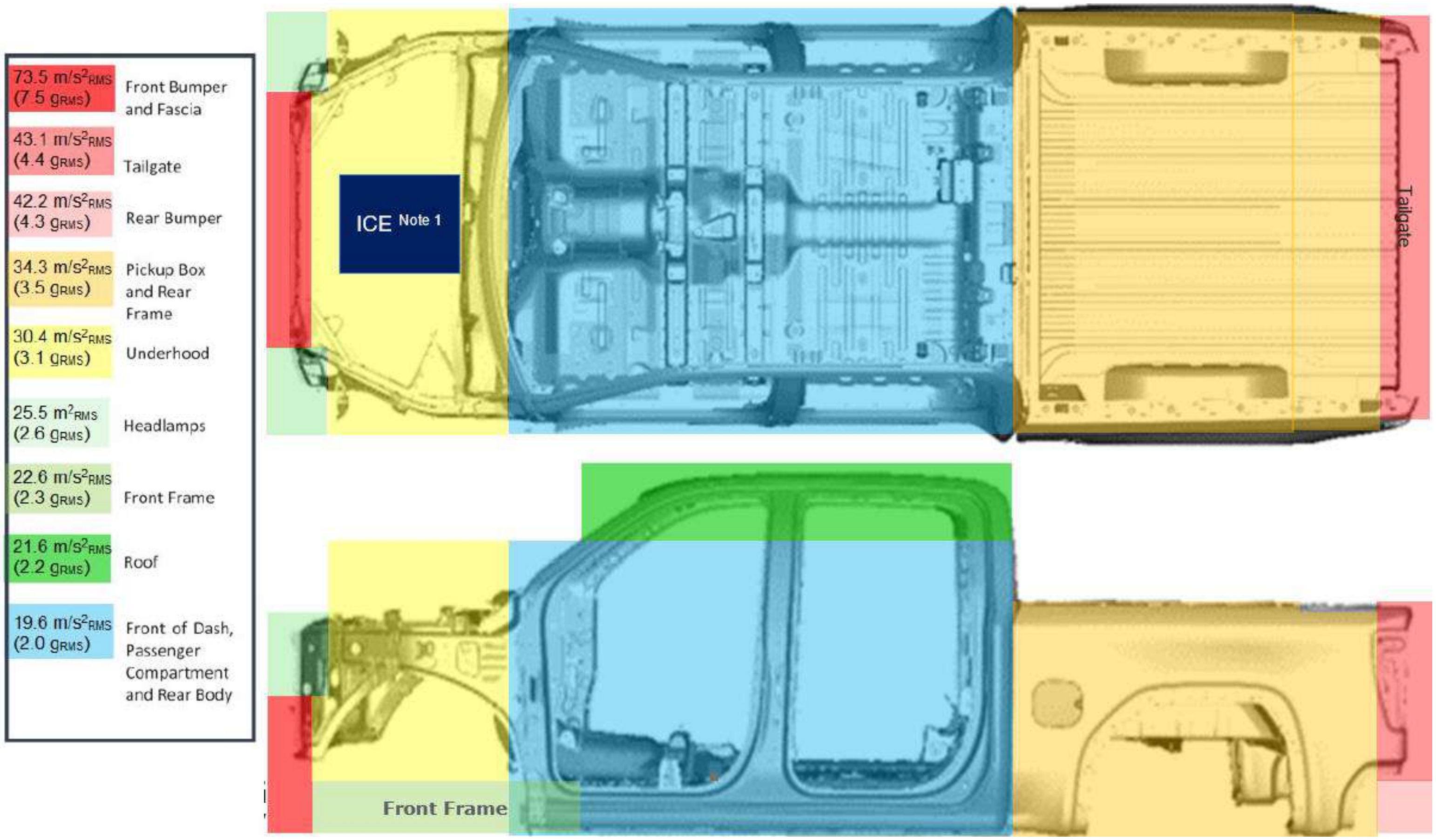
Figure C1.2: SUV or CUV Energy Level Map



Note 1: Internal Combustion Engine, Transmission, Exhaust, and Suspension are Not covered by the Underhood Profile.

C1.3 Light Duty Truck. See Figure C1.3.

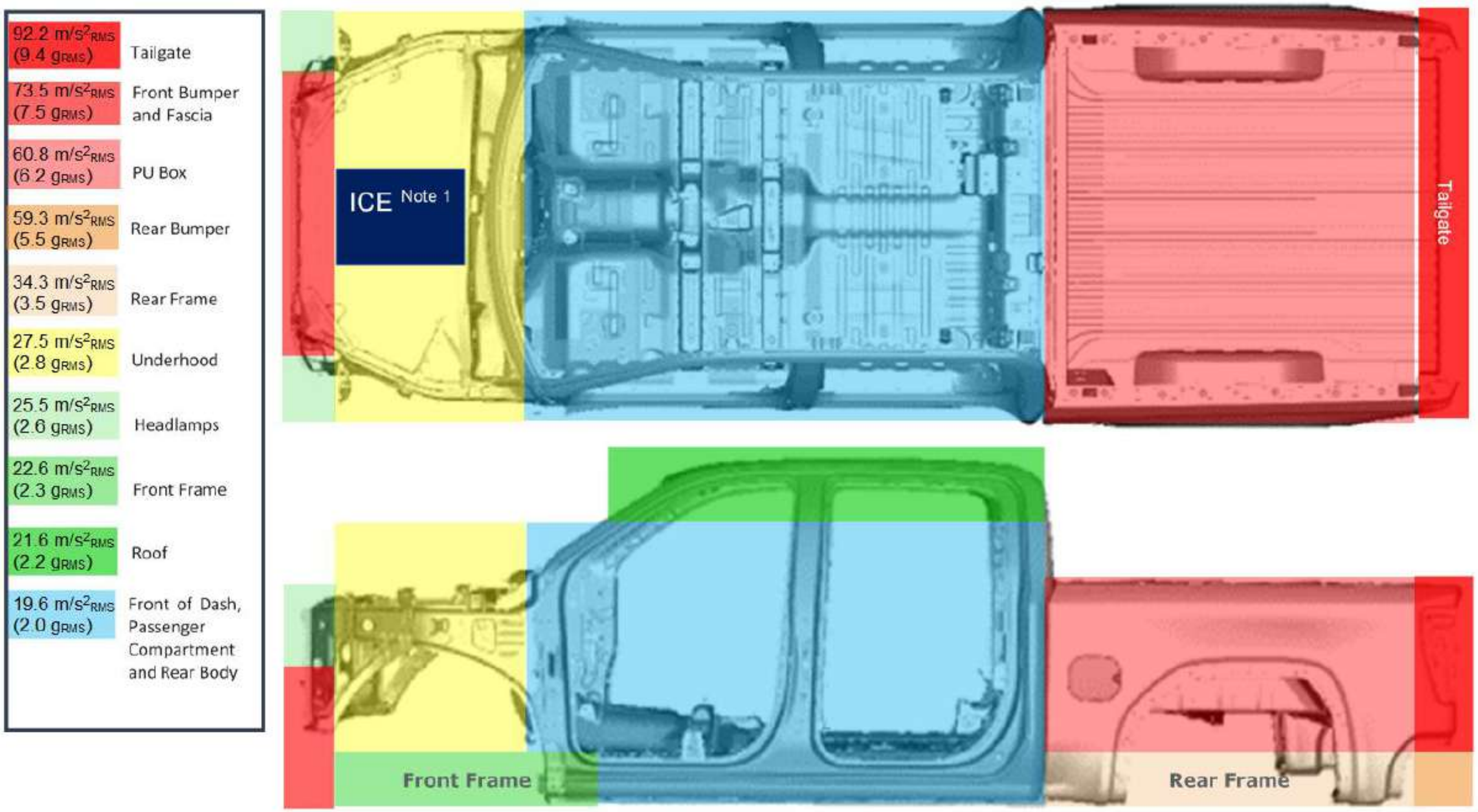
Figure C1.3: Light Duty Truck Energy Level Map



Note 1: Internal Combustion Engine, Transmission, Exhaust, and Suspension are Not covered by the Underhood Profile.

C1.4 Heavy Duty Truck. See Figure C1.4.

Figure C1.4: Heavy Duty Truck Energy Level Map



Note 1: Internal Combustion Engine, Transmission, Exhaust, and Suspension are Not covered by the Underhood Profile.

C2 Vibration Profiles

C2.1 Underhood. See Table C2.1a and Figure C2.1a, Table C2.1b and Figure C2.1b.

Table C2.1a: All Directions Underhood, Sedan, Coupe, SUV, CUV, and Light Duty Truck Note 1

Frequency Hz	PSD Note 2 $(m/s^2)^2/Hz$	PSD Note 2 g^2/Hz
10	12.00	0.12478
12	16.00	0.16637
20	1.50	0.01560
110	6.00	0.06239
230	1.00	0.01040
1000	0.10	0.00104

Note 1: E/E components mounted on body panels, e.g., fender or radiator region, etc. Does not include ICE components.
Note 2: Vehicle Energy Level: 30.4 m/s^2_{RMS} (3.1 g_{RMS}). See Figure C1.1 through Figure C1.3.

Figure C2.1a: All Directions Underhood, Sedan, Coupe, SUV, CUV, and Light Duty Truck

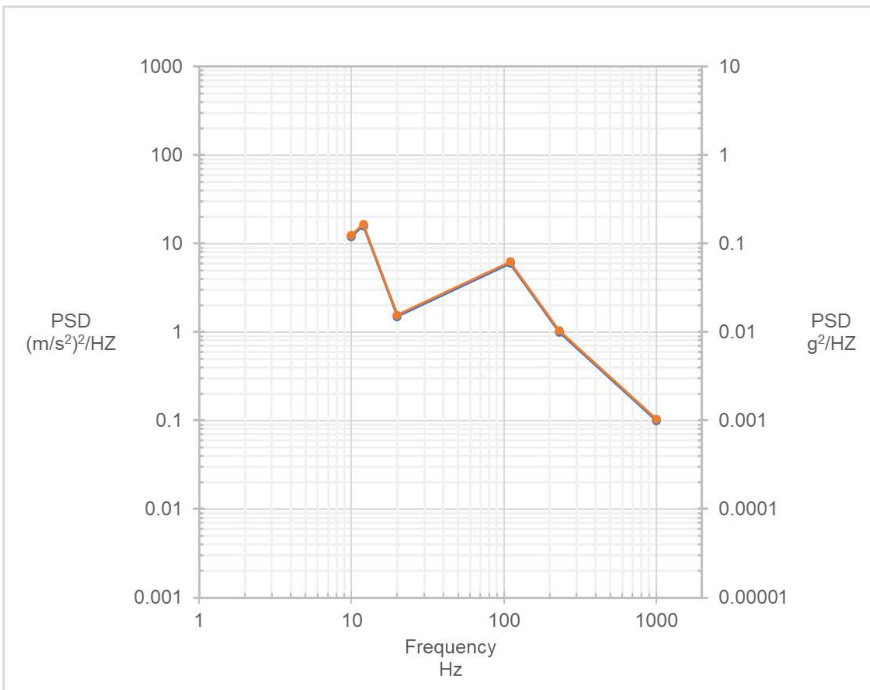


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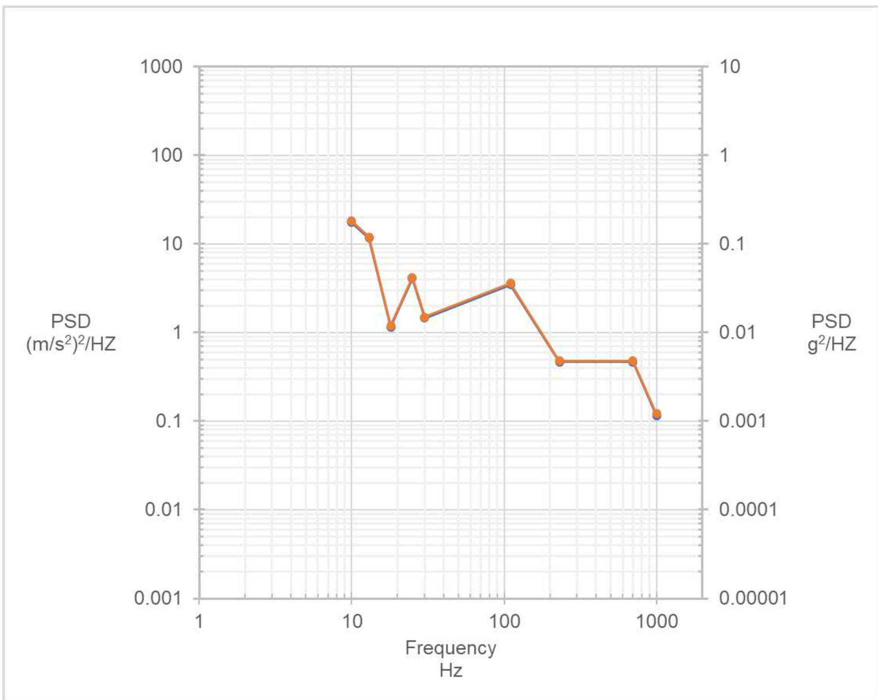
Table C2.1b: All Directions Underhood, Heavy Duty Truck Note 1

Frequency Hz	PSD Note 2 $(m/s^2)^2/Hz$	PSD Note 2 g^2/Hz
10	17.400	0.18093
13	11.600	0.12062
18	1.160	0.01206
25	4.060	0.04222
30	1.450	0.01508
110	3.480	0.03619
230	0.464	0.00482
700	0.464	0.00482
1000	0.116	0.00121

Note 1: E/E components mounted on body panels, e.g., fender or radiator region.
Note 2: Vehicle Energy Level: 27.5 m/s^2_{RMS} (2.8 g_{RMS}). See Figure C1.4.

Figure C2.1b: All Directions Underhood, Heavy Duty Truck



C2.2 Front of Dash, Passenger Compartment, and Rear Body. See Table C2.2a and Figure C2.2a, Table C2.2b and Figure C2.2b.

Table C2.2a: All Directions Front of Dash, Passenger Compartment, and Rear Body, Sedan, Coupe, SUV, and CUV Note 1

Frequency Hz	PSD Note 2 $(m/s^2)^2/Hz$	PSD Note 2 g^2/Hz
10	9.91998	0.10315
55	3.22844	0.03357
180	0.12406	0.00129
300	0.12406	0.00129
360	0.06924	0.00072
1000	0.06924	0.00072

Note 1: Includes rear bumper or fascia.
Note 2: Vehicle Energy Level: 19.6 m/s^2_{RMS} (2.0 g_{RMS}). See Figure C1.1 and Figure C1.2.

Figure C2.2a: All Directions Front of Dash, Passenger Compartment, and Rear Body, Sedan, Coupe, SUV, and CUV

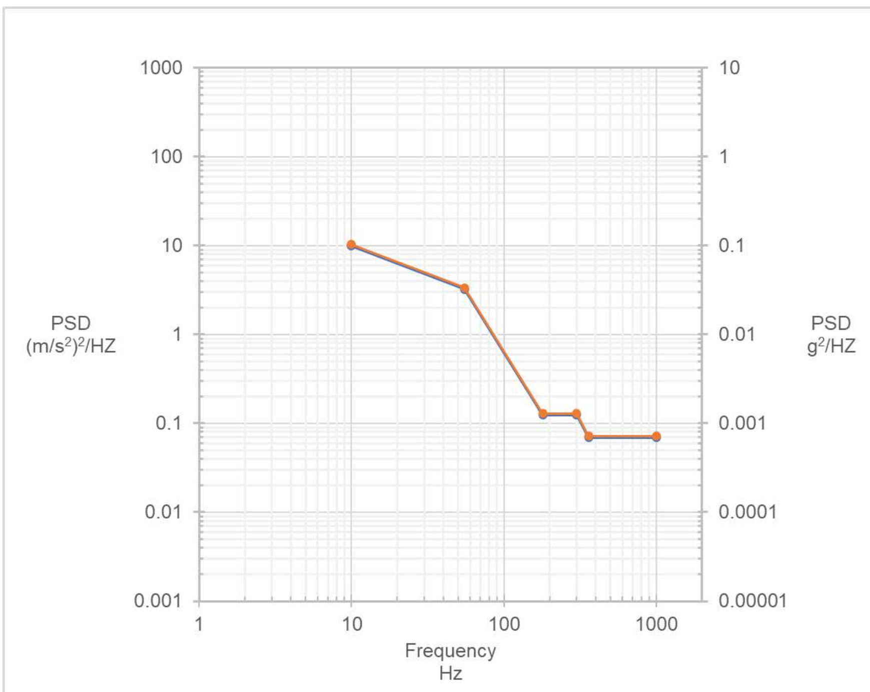


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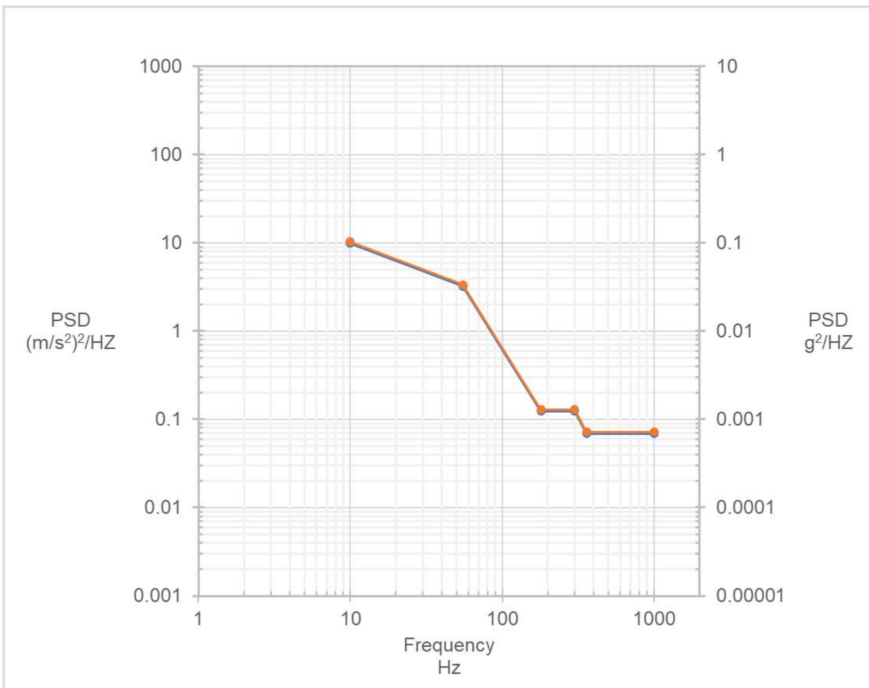
Table C2.2b: All Directions Front of Dash, Passenger Compartment, and Rear Body, Light Duty Truck and Heavy Duty Truck Note 1

Frequency Hz	PSD Note 2 $(m/s^2)^2/Hz$	PSD Note 2 g^2/Hz
10	9.91998	0.10315
55	3.22844	0.03357
180	0.12406	0.00129
300	0.12406	0.00129
360	0.06924	0.00072
1000	0.06924	0.00072

Note 1: Does NOT include rear bumper or fascia.
Note 2: Vehicle Energy Level: 19.6 m/s^2_{RMS} (2.0 g_{RMS}). See Figure C1.3 and Figure C1.4.

Figure C2.2b: All Directions Front of Dash, Passenger Compartment, and Rear Body, Light Duty Truck and Heavy Duty Truck



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C2.3 Roof. See Table C2.3a and Figure C2.3a, Table C2.3b and Figure C2.3b.

Table C2.3a: All Directions Roof, Sedan, Coupe, SUV, and CUV

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	20.0000	0.20796
12	18.0000	0.18717
15	8.0000	0.08319
55	3.2200	0.03348
150	0.2000	0.00208
200	0.5000	0.00520
240	0.5000	0.00520
360	0.0700	0.00072
1000	0.0700	0.00072

Note 1: Vehicle Energy Level: 21.6 m/s^2_{RMS} (2.2 g_{RMS}). See Figure C1.1 and Figure C1.2.

Figure C2.3a: All Directions Roof, Sedan, Coupe, SUV, and CUV

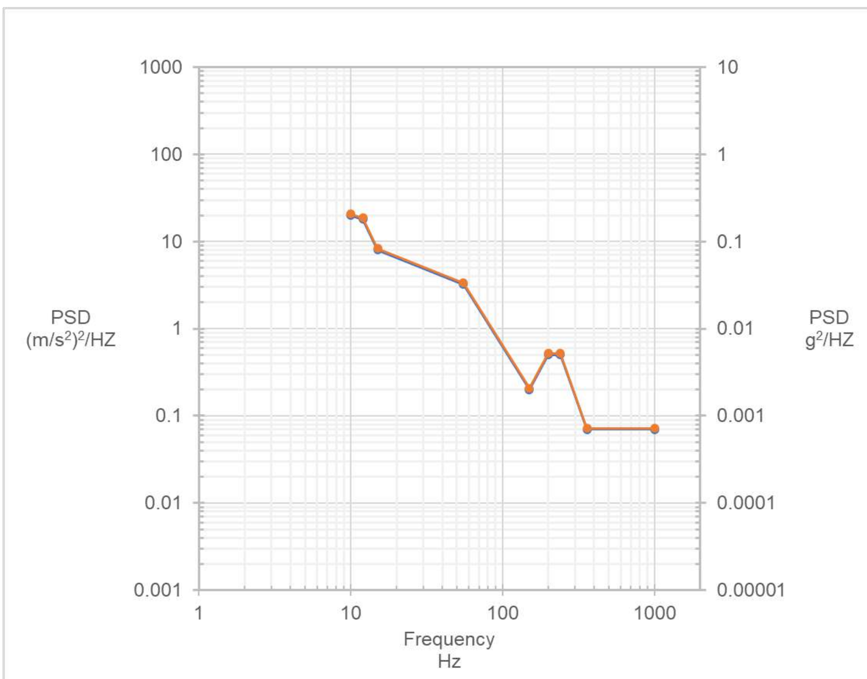
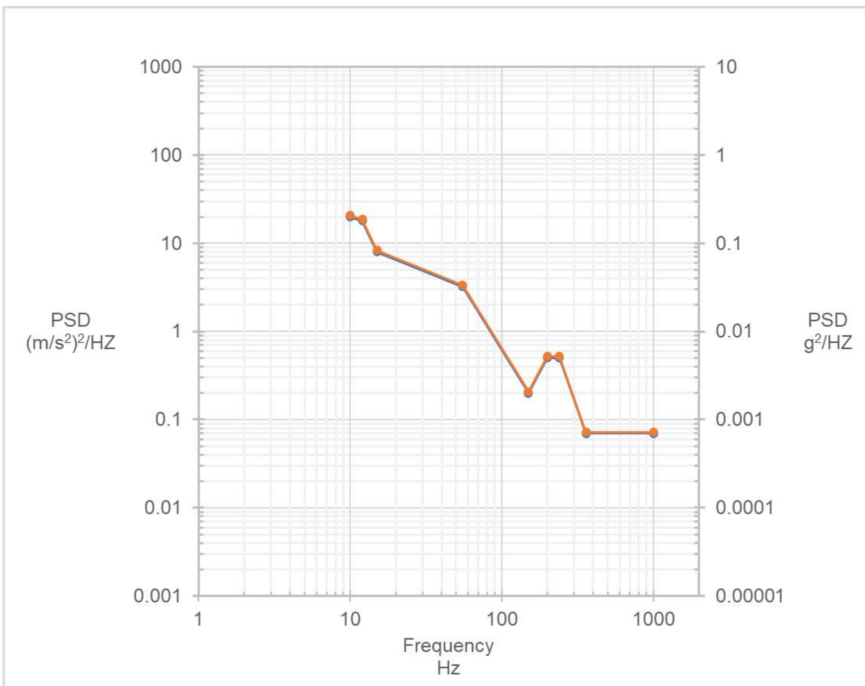


Table C2.3b: All Directions Roof, Light Duty Truck and Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	20.0000	0.20796
12	18.0000	0.18717
15	8.0000	0.08319
55	3.2200	0.03348
150	0.2000	0.00208
200	0.5000	0.00520
240	0.5000	0.00520
360	0.0700	0.00072
1000	0.0700	0.00072

Note 1: Vehicle Energy Level: 21.6 m/s^2_{RMS} (2.2 g_{RMS}). See Figure C1.3 and Figure C1.4.

Figure C2.3b: All Directions Roof, Light Duty Truck and Heavy Duty Truck



C2.4 Front Bumper or Fascia. See Table C2.4a and Figure C2.4a, Table C2.4b and Figure C2.4b.

Table C2.4a: All Directions Front Bumper or Fascia, Sedan, Coupe, SUV, and CUV

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
7	2.20	0.02288
12	9.00	0.09358
95	9.00	0.09358
120	2.00	0.02080
600	0.14	0.00146
1000	0.14	0.00146

Note 1: Vehicle Energy Level: 34.3 m/s^2_{RMS} (3.5 g_{RMS}). See Figure C1.1 and Figure C1.2.

Figure C2.4a: All Directions Front Bumper or Fascia, Sedan, Coupe, SUV, and CUV

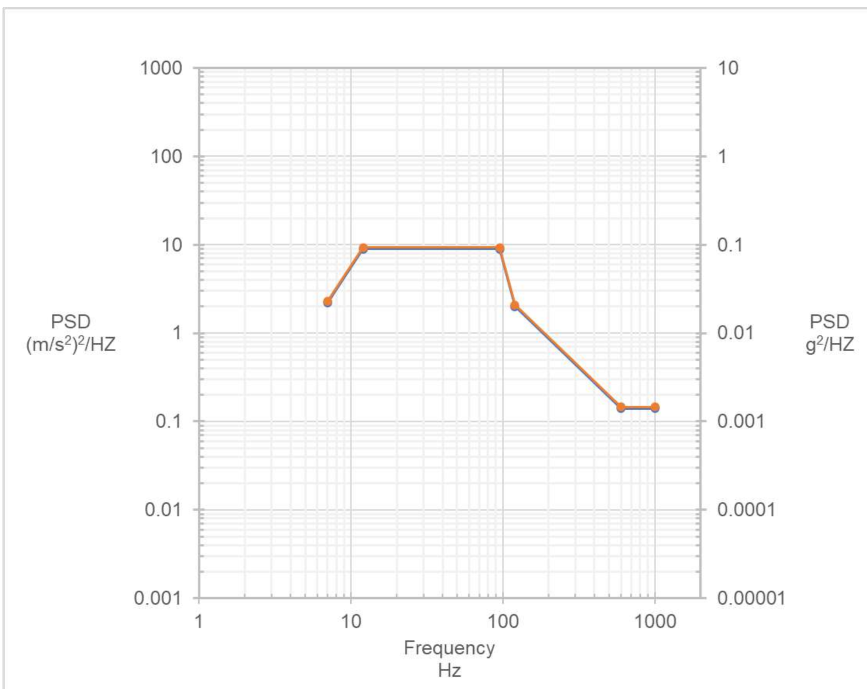
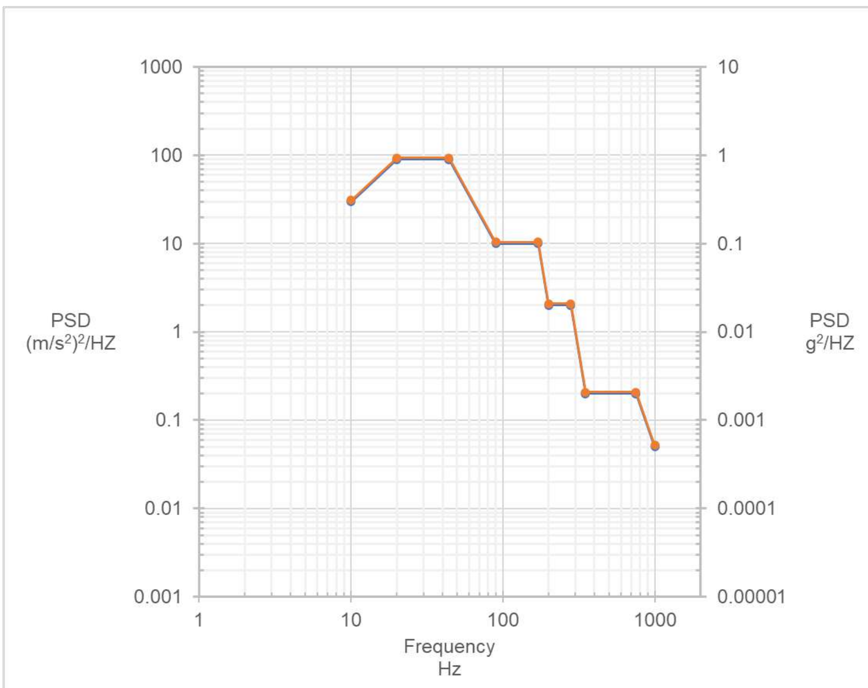


Table C2.4b: All Directions Front Bumper or Fascia, Light Duty Truck and Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	30.0	0.31195
20	90.0	0.93584
44	90.0	0.93584
90	10.0	0.10398
170	10.0	0.10398
200	2.00	0.02080
280	2.00	0.02080
350	0.20	0.00208
750	0.20	0.00208
1000	0.050	0.00052

Note 1: Vehicle Energy Level: 73.5 m/s^2_{RMS} (7.5 g_{RMS}). See Figure C1.3 and Figure C1.4.

Figure C2.4b: All Directions Front Bumper or Fascia, Light Duty Truck and Heavy Duty Truck



C2.5 Rear Bumper or Fascia. See Table C2.5a and Figure C2.5a, Table C2.5b and Figure C2.5b, Table C2.5c and Figure C2.5c.

Table C2.5a: All Directions Rear Bumper or Fascia, Sedan, Coupe, SUV, and CUV

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	9.91998	0.10315
55	3.22844	0.03357
180	0.12406	0.00129
300	0.12406	0.00129
360	0.06924	0.00072
1000	0.06924	0.00072

Note 1: Vehicle Energy Level: 19.6 m/s^2_{RMS} (2.0 g_{RMS}). See Figure C1.1 and Figure C1.2.

Figure C2.5a: All Directions Rear Bumper or Fascia, Sedan, Coupe, SUV, and CUV

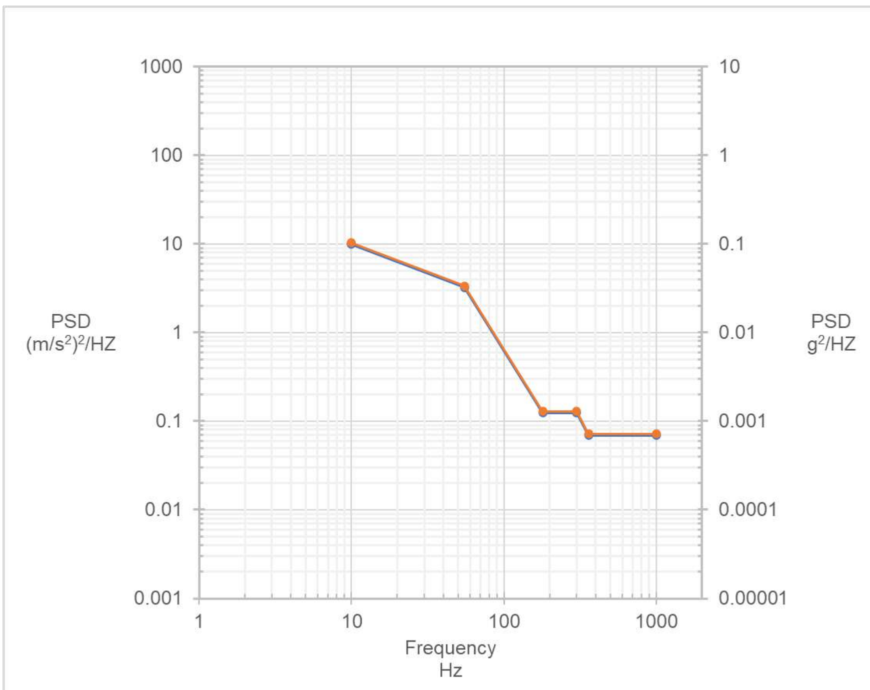


Table C2.5b: All Directions Rear Bumper or Fascia, Light Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	30.00	0.31195
13	45.00	0.46792
16	8.00	0.08319
24	8.00	0.08319
35	50.00	0.51991
50	50.00	0.51991
130	0.15	0.00156
190	0.15	0.00156
280	0.04	0.00042
1000	0.04	0.00042

Note 1: Vehicle Energy Level: 42.2 m/s^2_{RMS} (4.3 g_{RMS}). See Figure C1.3.

Figure C2.5b: All Directions Rear Bumper or Fascia, Light Duty Truck

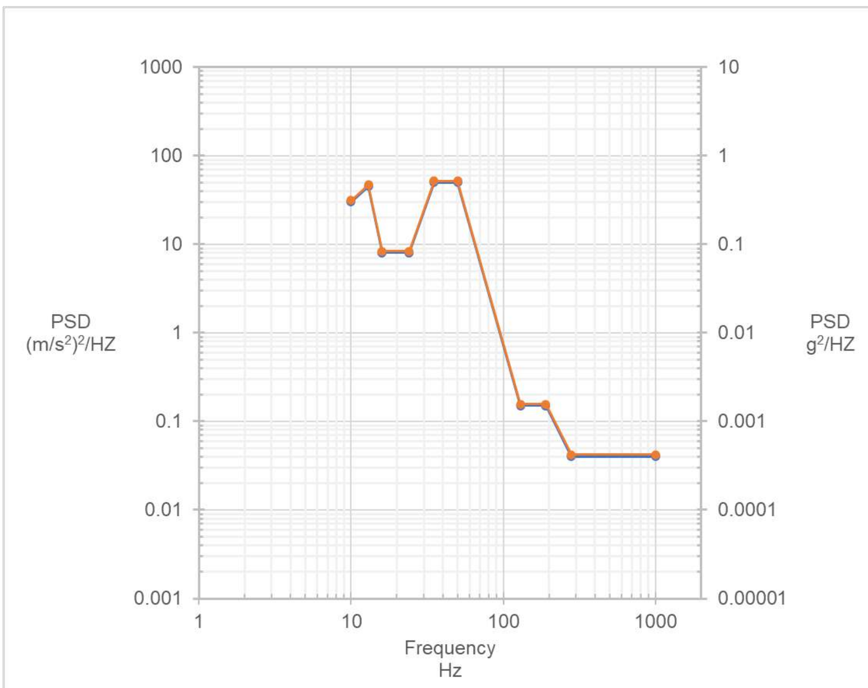
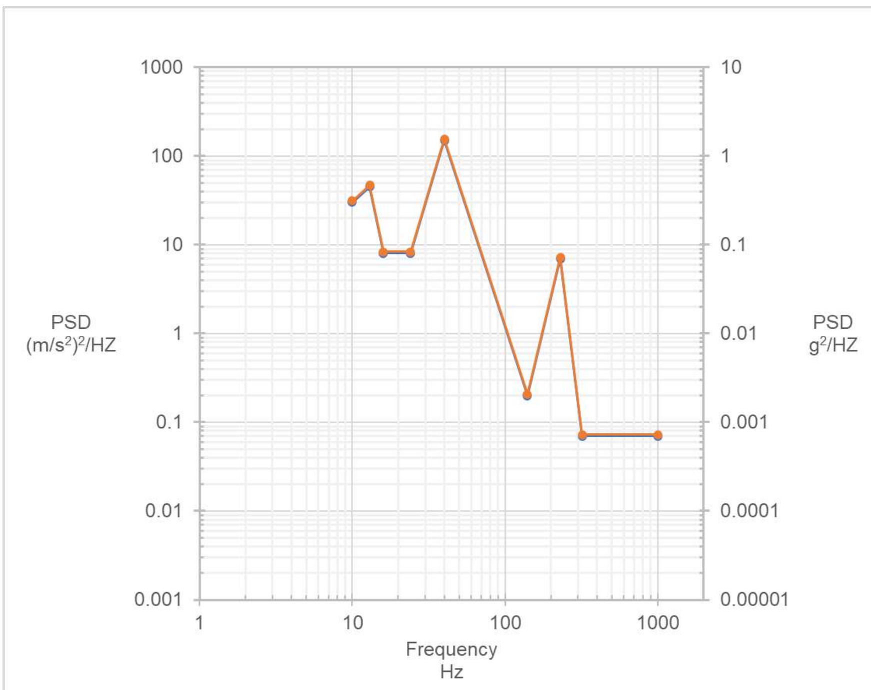


Table C2.5c: All Directions Rear Bumper or Fascia, Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	30.00	0.31195
13	45.00	0.46792
16	8.00	0.08319
24	8.00	0.08319
40	150.00	1.55973
140	0.20	0.00208
230	7.00	0.07279
320	0.07	0.00073
1000	0.07	0.00073

Note 1: Vehicle Energy Level: 59.3 m/s^2_{RMS} (5.5 g_{RMS}). See Figure C1.4.

Figure C2.5c: All Directions Rear Bumper or Fascia, Heavy Duty Truck



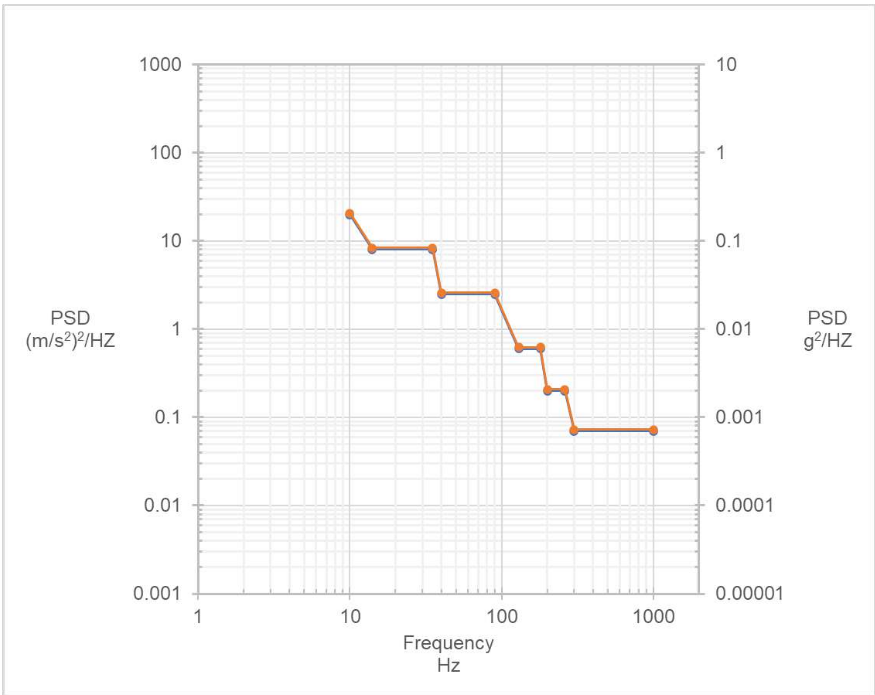
C2.6 Front Frame. See Table C2.6 and Figure C2.6.

Table C2.6: All Directions Front Frame, Light Duty Truck and Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	20.0	0.20796
14	8.0	0.08319
35	8.0	0.08319
40	2.5	0.02600
90	2.5	0.02600
130	0.6	0.00624
180	0.6	0.00624
200	0.2	0.00208
260	0.2	0.00208
300	0.07	0.00073
1000	0.07	0.00073

Note 1: Vehicle Energy Level: 22.6 m/s^2_{RMS} (2.3 g_{RMS}). See Figure C1.3 and Figure C1.4.

Figure C2.6: All Directions Front Frame, Light Duty Truck and Heavy Duty Truck



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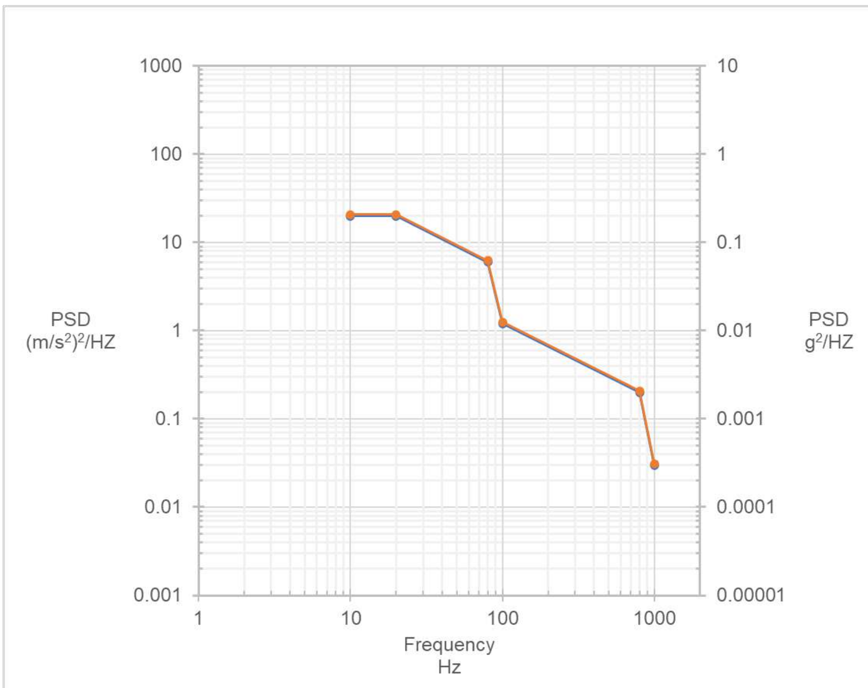
C2.7 Rear Frame. See Table C2.7 and Figure C2.7.

Table C2.7: All Directions Rear Frame, Light Duty Truck and Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	20.00	0.20796
20	20.00	0.20796
80	6.00	0.06239
100	1.20	0.01248
800	0.20	0.00208
1000	0.03	0.00031

Note 1: Vehicle Energy Level: 34.2 m/s^2_{RMS} (3.49 g_{RMS}). See Figure C1.3 and Figure C1.4.

Figure C2.7: All Directions Rear Frame, Light Duty Truck and Heavy Duty Truck



C2.8 Tailgate. See Table C2.8a and Figure C2.8a, Table C2.8b and Figure C2.8b.

Table C2.8a: All Directions Tailgate, Light Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	30.000	0.31195
12	50.000	0.51991
24	16.000	0.16637
33	45.000	0.46792
42	30.000	0.31195
61	4.000	0.04159
240	2.000	0.02080
360	0.069	0.00072
1000	0.069	0.00072

Note 1: Vehicle Energy Level: 43.1 m/s^2_{RMS} (4.4 g_{RMS}). See Figure C1.3.

Figure C2.8a: All Directions Tailgate, Light Duty Truck

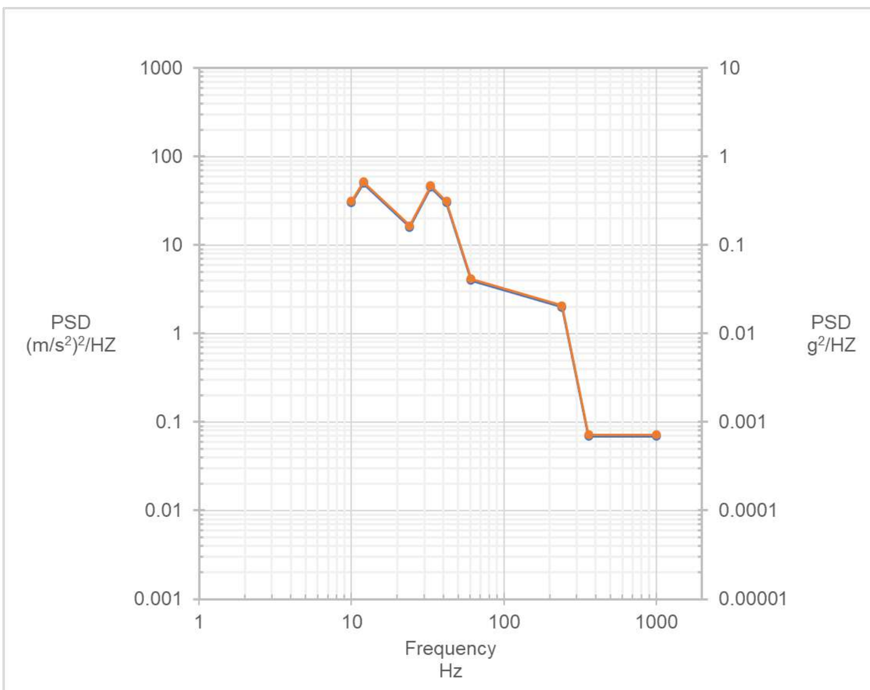
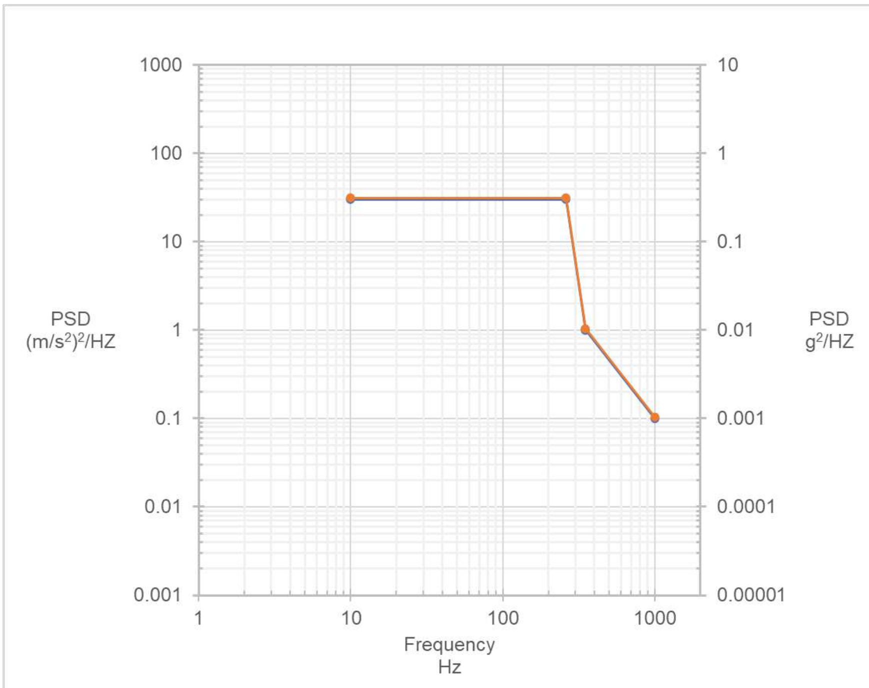


Table C2.8b: All Directions Tailgate, Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	30.0	0.31195
260	30.0	0.31195
350	1.0	0.01040
1000	0.1	0.00104

Note 1: Vehicle Energy Level: 92.2 m/s^2_{RMS} (9.4 g_{RMS}). See Figure C1.4.

Figure C2.8b: All Directions Tailgate, Heavy Duty Truck



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C2.9 Pickup Box. See Table C2.9a and Figure C2.9a, Table C2.9b and Figure C2.9b.

Table C2.9a: All Directions Pickup Box, Light Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	20.00	0.20796
20	20.00	0.20796
80	6.00	0.06239
100	1.20	0.01248
800	0.20	0.00208
1000	0.03	0.00031

Note 1: Vehicle Energy Level: 34.3 m/s^2_{RMS} (3.5 g_{RMS}). See Figure C1.3.

Figure C2.9a: All Directions Pickup Box, Light Duty Truck

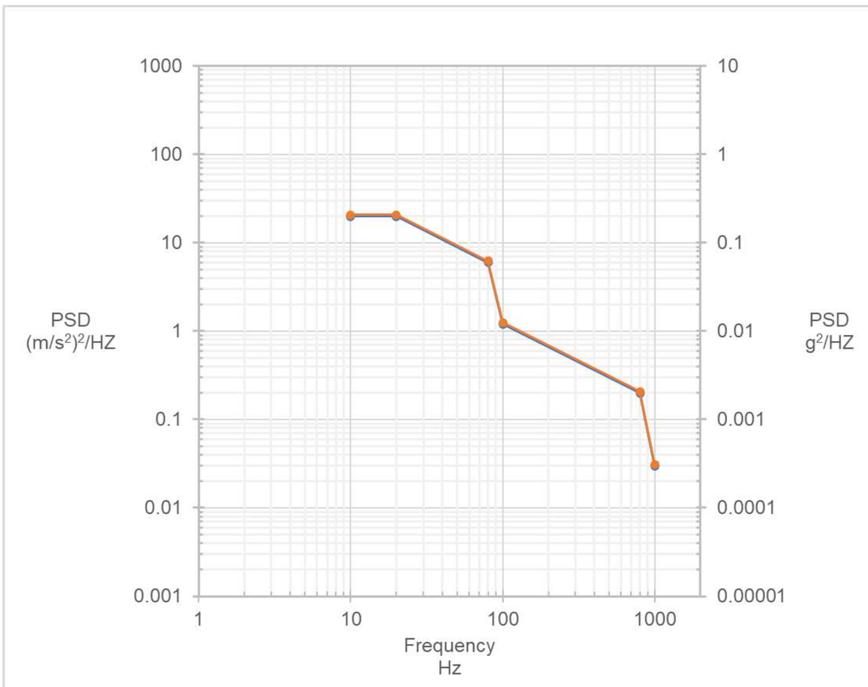
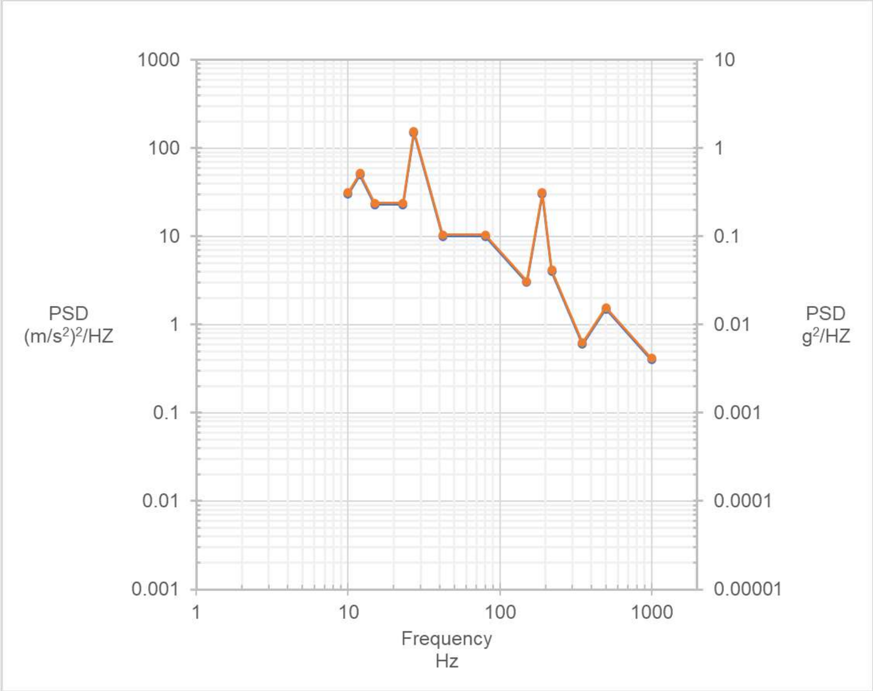


Table C2.9b: All Directions Pickup Box, Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	30.00	0.31195
12	50.00	0.51991
15	23.00	0.23916
23	23.00	0.23916
27	150.00	1.55973
42	10.00	0.10398
80	10.00	0.10398
150	3.00	0.03119
190	30.00	0.31195
220	4.00	0.04159
350	0.60	0.00624
500	1.50	0.01560
1000	0.40	0.00416

Note 1: Vehicle Energy Level: 60.8 m/s^2_{RMS} (6.2 g_{RMS}). See Figure C1.4.

Figure C2.9b: All Directions Pickup Box, Heavy Duty Truck



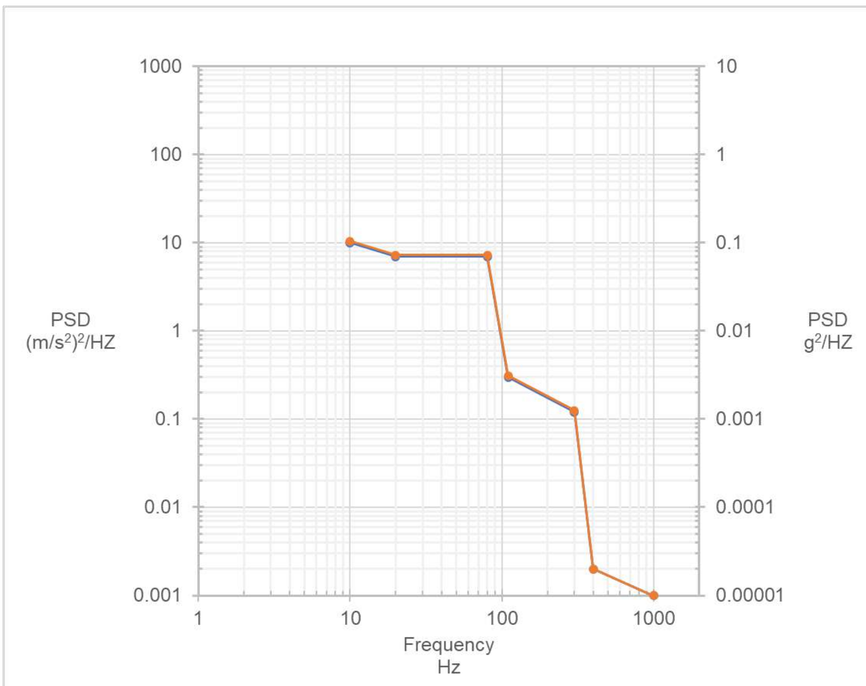
C2.10 Liftgate. See Table C2.10 and Figure C2.10.

Table C2.10: All Directions Liftgate, SUV and CUV Note 1

Frequency Hz	PSD Note 2 $(m/s^2)^2/Hz$	PSD Note 2 g^2/Hz
10	10.000	0.10398
20	7.000	0.07279
80	7.000	0.07279
110	0.300	0.00312
300	0.120	0.00125
400	0.002	0.00002
1000	0.001	0.00001

Note 1: Includes Light Duty SUV and Heavy Duty SUV, i.e., BOF vehicles, e.g., Chevrolet Suburban.
Note 2: Vehicle Energy Level: 24.5 m/s^2_{RMS} (2.5 g_{RMS}). See Figure C1.2.

Figure C2.10: All Directions Liftgate, SUV and CUV



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C2.11 Headlamps. See Table C2.11a and Figure C2.11a, Table C2.11b and Figure C2.11b.

Table C2.11a: All Directions Headlamps, Sedan, Coup, SUV and CUV

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	15.00	0.15597
55	3.00	0.03119
80	3.00	0.03119
120	8.00	0.08319
140	1.50	0.01560
300	1.50	0.01560
1000	0.05	0.00052

Note 1: Vehicle Energy Level: 33.3 m/s^2_{RMS} (3.4 g_{RMS}). See Figure C1.1 and Figure C1.2.

Figure C2.11a: All Directions Headlamps, SUV and CUV

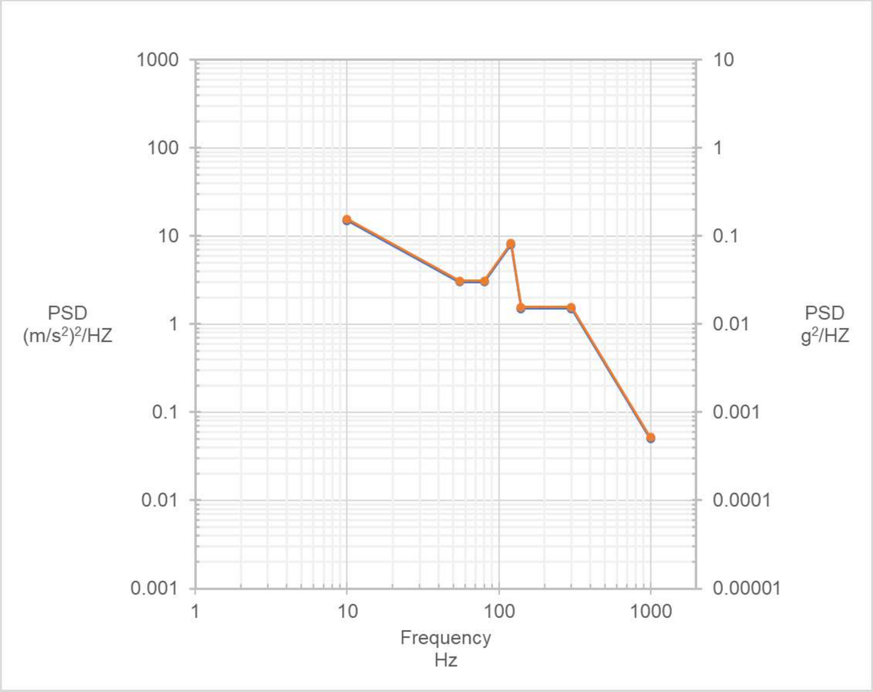
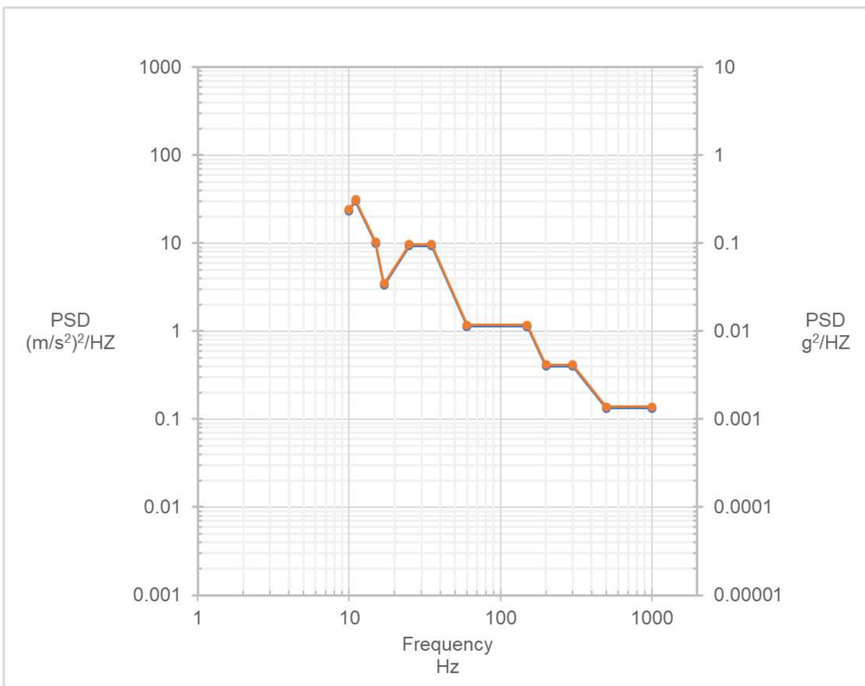


Table C2.11b: All Directions Headlamps, Light Duty Truck and Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	23.3333	0.24262
11	30.00	0.31195
15	10.000	0.10398
17	3.333	0.03468
25	9.333	0.09705
35	9.333	0.09705
60	1.133	0.01178
150	1.133	0.01178
200	0.400	0.00416
300	0.400	0.00416
500	0.133	0.00139
1000	0.133	0.00139

Note 1: Vehicle Energy Level: 25.5 m/s^2_{RMS} (2.6 g_{RMS}). See Figure C1.3 and Figure C1.4.

Figure C2.11b: All Directions Headlamps, Light Duty Truck and Heavy Duty Truck



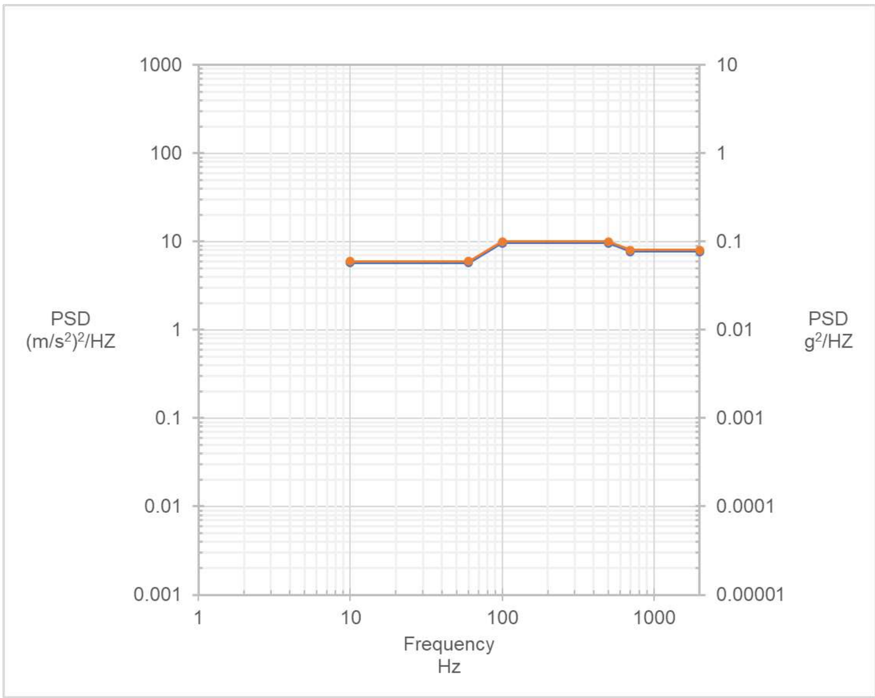
C2.12 On Engine. See Table C2.12 and Figure C2.12.

Table C2.12: All Directions On Engine, Sedan, Coup, SUV, CUV, Light Duty Truck and Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
10	5.7702	0.06
60	5.7702	0.06
100	9.617	0.1
500	9.617	0.1
700	7.6936	0.08
2000	7.6936	0.08

Note 1: Vehicle Energy Level: 127 m/s^2_{RMS} (13.0 g_{RMS}).

Figure C2.12: All Directions On Engine, Sedan, Coup, SUV, CUV, Light Duty Truck and Heavy Duty Truck



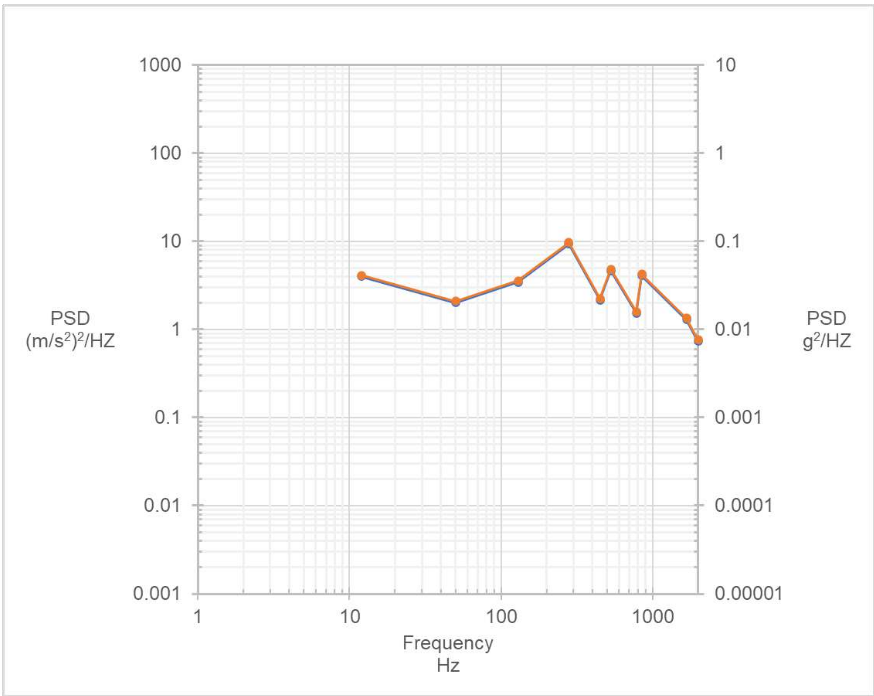
C2.13 On Transmission/In Transmission. See Table C2.13 and Figure C2.13.

Table C2.13: All Directions on Transmission/In Transmission, Sedan, Coup, SUV, CUV, Light Duty Truck and Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
12	3.9815	0.04104
50	2.0196	0.02100
130	3.4237	0.03560
280	9.3478	0.09720
450	2.1542	0.02240
530	4.6354	0.04820
780	1.5291	0.01590
850	4.0969	0.04260
1680	1.2887	0.01340
2000	0.7347	0.00764

Note 1: Vehicle Energy Level: 73.3 m/s^2_{RMS} (7.5 g_{RMS}).

Figure C2.13: All Directions On Transmission/In Transmission, Sedan, Coup, SUV, CUV, Light Duty Truck and Heavy Duty Truck



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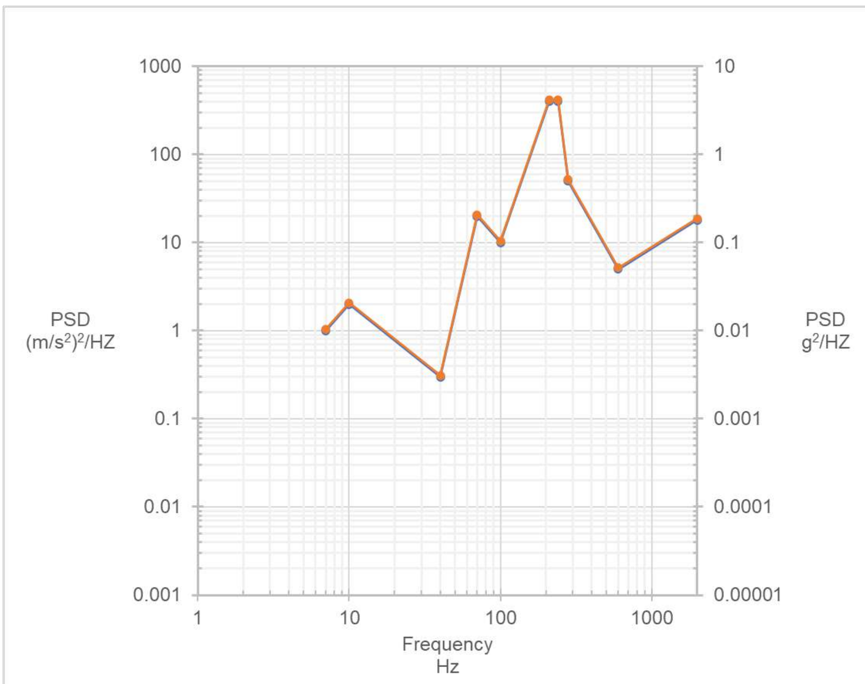
C2.14 High Performance Flat Plane Engine/Transmission Locations. See Table C2.14 and Figure C2.14.

Table C2.14: All Directions High Performance Flat Plane Engine/Transmission Locations, Sedan, Coup, SUV, CUV, Light Duty Truck and Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
7	1.0	0.01040
10	2.0	0.02080
40	0.3	0.00312
70	20.0	0.20796
100	10.0	0.10398
210	400.0	4.15928
240	400.0	4.15928
280	50.0	0.51991
600	5.0	0.05199
2000	18.0	0.18717

Note 1: Vehicle Energy Level: 233.5 m/s^2_{RMS} (23.8 g_{RMS}).

Figure C2.14: All Directions High Performance Flat Plane Engine/Transmission Locations, Sedan, Coup, SUV, CUV, Light Duty Truck and Heavy Duty Truck



C2.15 Unsprung Mass Locations. See Table C2.15 and Figure C2.15.

Table C2.15: All Directions Unsprung Mass Locations, Sedan, Coup, SUV, CUV, Light Duty Truck and Heavy Duty Truck

Frequency Hz	PSD Note 1 $(m/s^2)^2/Hz$	PSD Note 1 g^2/Hz
20	200.2748	2.0825
40	200.2748	2.0825
300	0.5001	0.0052
800	0.5001	0.0052
1000	3.0005	0.0312
2000	3.0005	0.0312

Note 1: Vehicle Energy Level: 107.3 m/s^2_{RMS} (10.9 g_{RMS}).

Figure C2.15: All Directions Unsprung Mass Locations, Sedan, Coup, SUV, CUV, Light Duty Truck and Heavy Duty Truck