GM WORLDWIDE ENGINEERING STANDARDS	**General Specification Electrical Function**	**GMW3172**

General Specification for Electrical/Electronic Components – Environmental/Durability

1 Scope

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.

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

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

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

2 References

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

2.1 External Standards/Specifications.

ASTM D4728
IEC 60068-2-1
IEC 60068-2-14
IEC 60068-2-27
IEC 60068-2-29
IEC 60068-2-30
IEC 60068-2-38
IEC 60068-2-52
IEC 60068-2-64
IEC 60068-2-78
ISO 8820
ISO 12103-1
ISO 16750-2
ISO 16750-3
ISO 16750-4
ISO 20653

2.2 GM Group Standards/Specifications.

GMN5345
GMW3091
GMW3097
GMW3103
GMW3191
GMW3431
GMW8287
GMW8288
GMW14082

2.3 Additional References.

EIA/JEDEC JESD22-A110-B

3 Terms and Definitions

Component: A piece of hardware delivered to General Motors with a unique GM Part Number.

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

3.1 Temperature and Voltage Definitions.

Table 1: Definitions

Phrase	Symbol	Definition
Minimum Temperature	T_{min}	Minimum limit value of the ambient temperature at which the component is required to operate.
Maximum Temperature	T_{max}	Maximum limit value of the ambient temperature at which the component is required to operate.
Post Heating Temperature (soak back)	T_{PH}	Maximum limit value of the ambient temperature which may temporarily occur after vehicle cut-off and at which the component may be operated for a brief period, i.e., on the engine and in its environment.
Repaint & Storage Temperature	T_{RPS}	Maximum temperature which can occur during repainting, but at which the component is not operated. Accounts for high temperature storage and paint booth exposure.
Room Temperature	T_{room}	Ambient room temperature.
Minimum Voltage	U_{min}	Minimum limit value of the supply voltage at which the component is required to operate during the test.
Nominal Voltage	U_{nom}	Nominal supply voltage at which the component is operated during the test.
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.

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

Table 2: Parameters and Tolerances

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

3.3 Operating Types.

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 connected with supply voltage U_B (battery voltage, generator not active) with all electrical connections made.	
	2.1	Component functions are not activated (e.g., sleep mode, OFF mode).
	2.2	Component with electric operation and control in typical operating mode.
3	The component is electrically operated with supply voltage U_A (engine/generator active) with all electrical connections made.	
	3.1	Component functions are not activated (e.g., sleep mode, OFF mode).
	3.2	Components with electric operation and control in typical operating mode.

3.4 Functional Status Classification (FSC). The FSC defines the functional performance of the component.

Table 4: FSC Definition

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

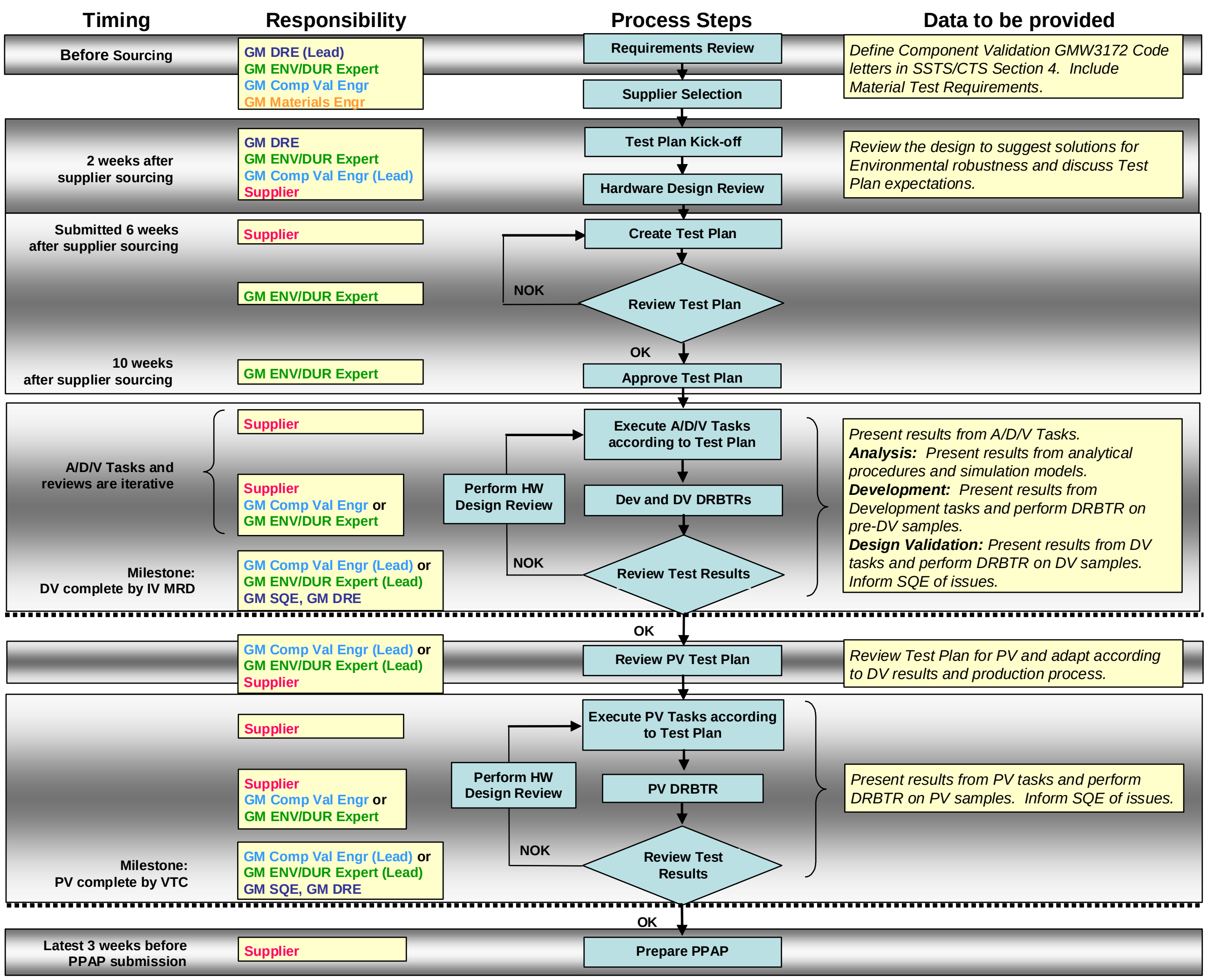
4 Process

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

Beginning in November 2008, all A/D/V test plans, test results, documentation, and data exchange between the supplier and GM related to Environment/Durability A/D/V activities shall be uploaded to GM's Global EMC/Environmental/Durability Database accessible through GM Supply Power.

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

Figure 1: A/D/V Process Flow



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

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

- **Test Plan Kick-off/Hardware Design Review.** A Test Plan Kick-off/Hardware Design Review meeting shall be completed jointly by the supplier and GM 2 weeks after supplier sourcing. The purpose of this meeting is to review the design to suggest solutions for Environmental robustness and discuss the Component Environmental Test Plan expectations. Refer to the “Hardware Design Review” section of this document for more detailed instructions.
- **Create and Review Test Plan.** Appendix B (Component Environmental Test Plan) shall be completed by the supplier and submitted in an electronic, editable format to GM 6 weeks after supplier sourcing. Approval shall occur 10 weeks after supplier sourcing.

  An editable version of Appendix B can be obtained by request from GM ENV/DUR Expert.
- **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 reported underneath each negotiated clause in the electronic editable Component Environmental Test Plan and submitted to the GM Component Validation Engineer (or GM ENV/DUR Expert) for evaluation and approval.

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

  Each test result shall be reported underneath each negotiated clause in the electronic editable Component Environmental Test Plan and submitted to the GM Component Validation Engineer (or GM ENV/DUR Expert) for evaluation and approval.

  In case of nonconformance, the GM Component Validation Engineer or GM ENV/DUR Expert, along with the GM SQE and DRE, shall review the test results and determine if another iteration of PV is required. The GM Component Validation Engineer or GM ENV/DUR Expert shall then perform a Hardware Design Review. Based on the corrective action, the Component Environmental Test Plan shall be modified as required.

4.2.1 Test Plan Negotiation. The supplier shall submit the completed Component Environmental Test Plan (Appendix B) in an electronic format editable with Microsoft Office to the GM ENV/DUR Expert for approval 6 weeks after supplier sourcing.

Note: The Universal Environmental/Durability Test Flows for Development (Figure 2), Design Validation (Figure 3), and Product Validation (Figure 4) are critical elements of the Test Plan. The supplier shall adapt and insert the Test Flows into the Component Environmental Test Plan (Appendix B).

Figure 2: Universal Environmental/Durability Test Flow for Development

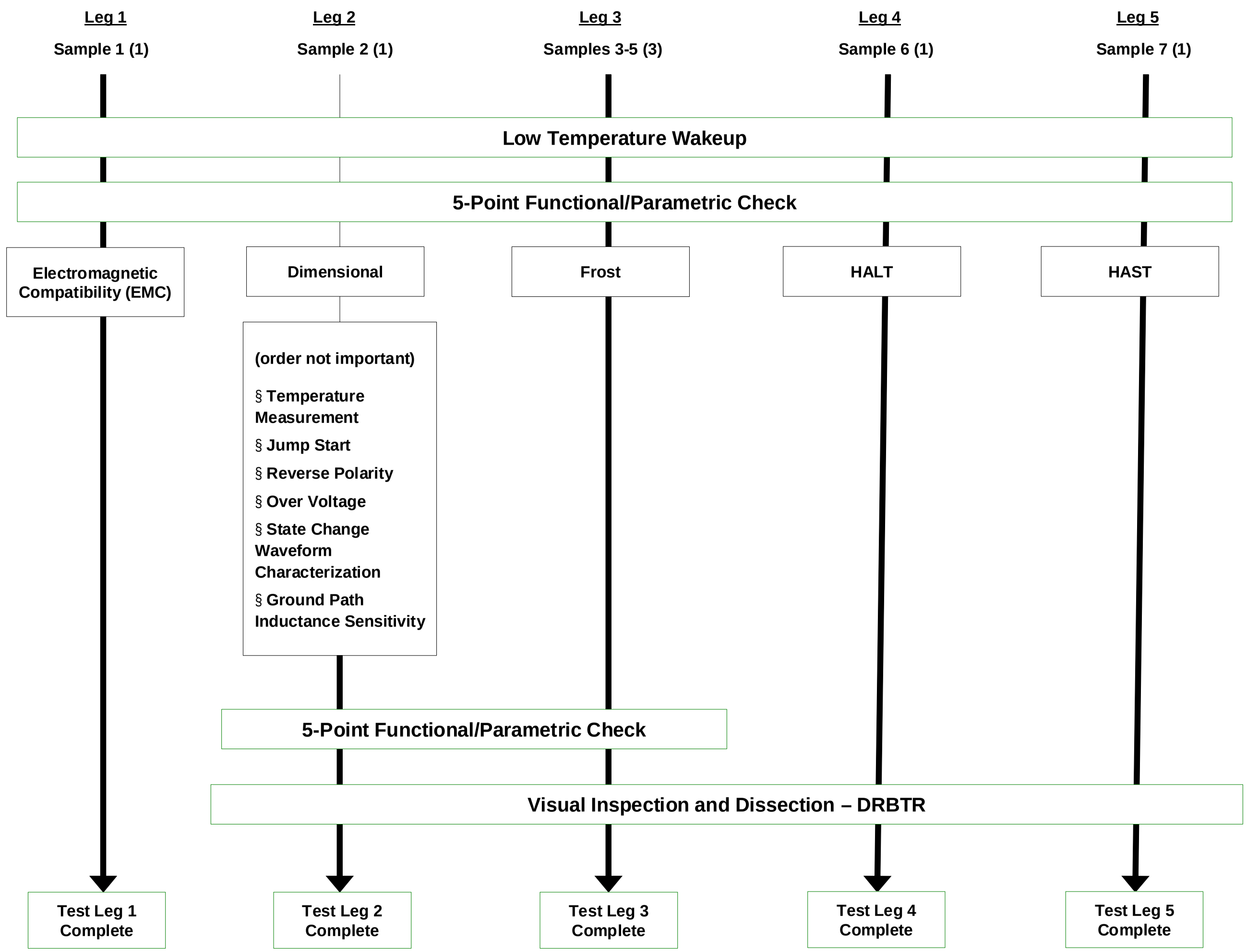


Figure 3: Universal Environmental/Durability Test Flow for Design Validation (DV)

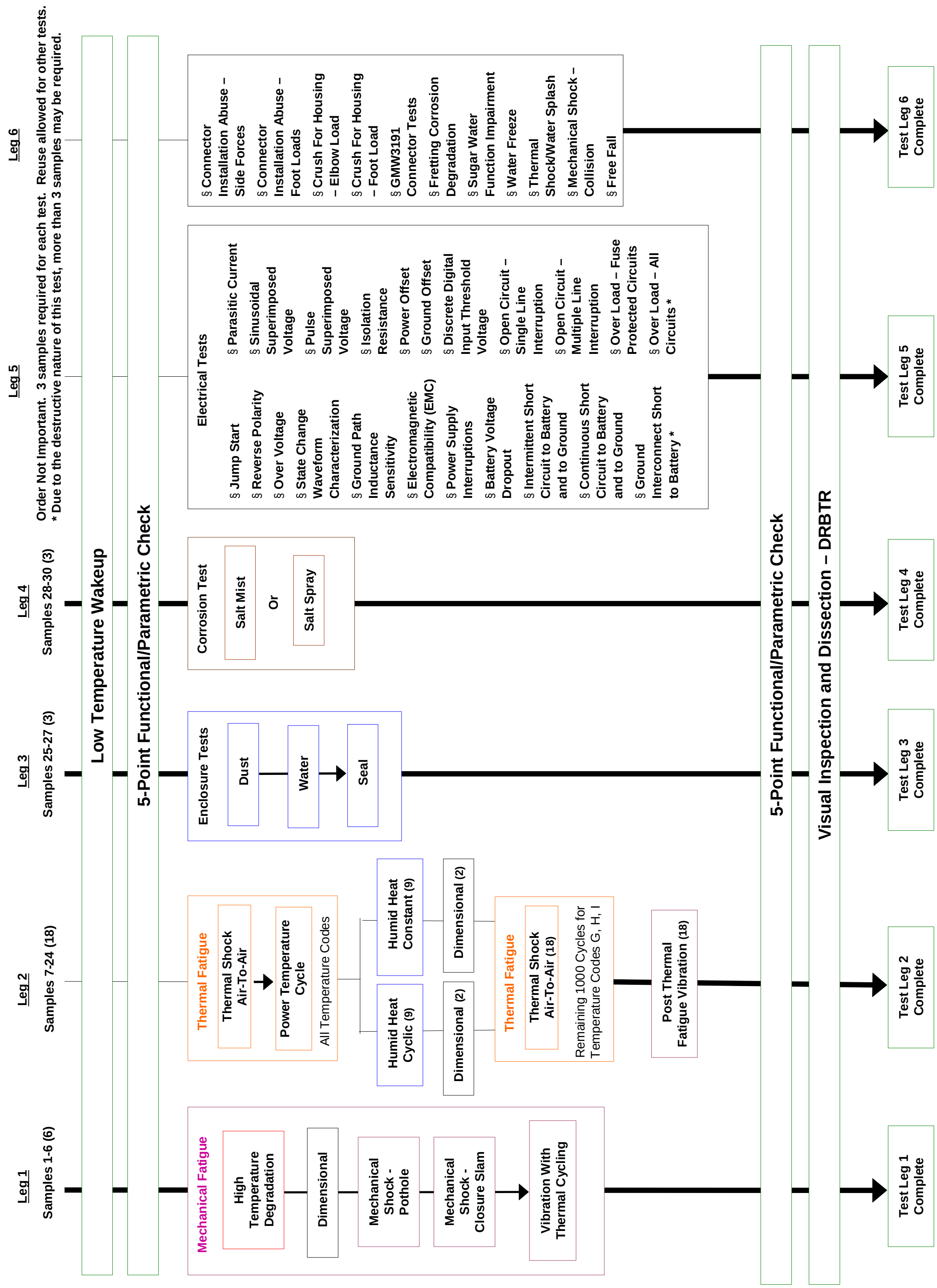
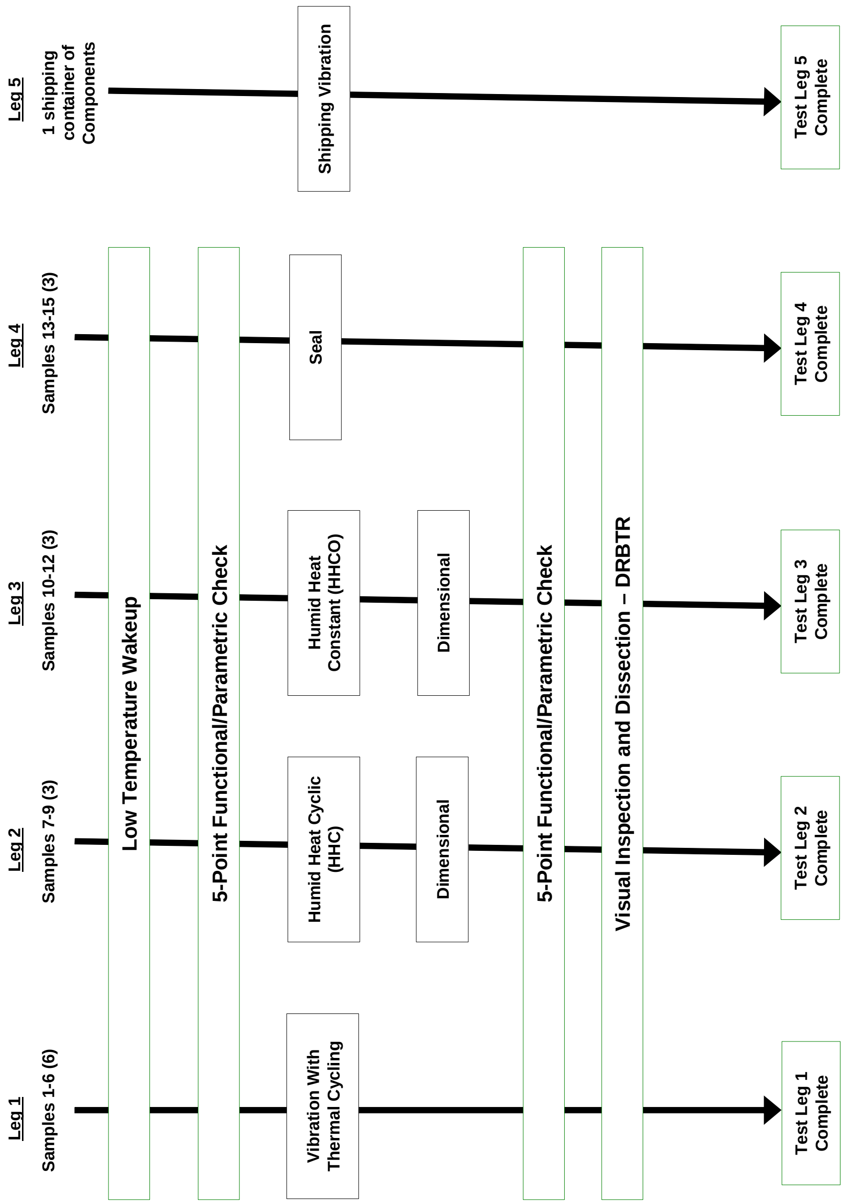


Figure 4: Universal Environmental/Durability Test Flow for Product Validation (PV)



Note: This is the minimum set of Product Validation (PV) activities.
Additional activities may be required based on the results of Design Validation (DV).

4.2.2 Hardware Design Review. A Hardware Design Review, as shown in Figure 1, shall be conducted for all new components, as well as for current production components with modifications, to ensure that the design meets Environmental/Durability compliance. This includes any hardware-related modifications (such as internal part swaps or material changes) and manufacturing process changes (such as tooling, solder process, or manufacturing location). Software changes that may affect GMW3172-related requirements shall also be considered.

Hardware Design Review(s) shall be scheduled and led by the GM Component Validation Engineer. It is recommended that this Hardware Design Review occurs at the same meeting as the EMC Design Review.

The objectives of the Hardware Design Review shall be to:

- Review component schematic design and circuit board layout
- Review component assembly and mechanical construction
- Review technical rational of Electrical/Electronic design concept, Mechanization design concept, and chosen materials
- Examine any prior relevant analysis, calculations, and test results
- Evaluate potential changes to the component design
- Propose solutions to problems and appropriate re-validation
- Verify that the proposed circuit board and assembly design satisfies component Environmental/Durability requirements
- Evaluate manufacturing processes and changes
- Evaluate software changes that may affect GMW3172-related requirements
- Perform Thermal Fatigue Analysis

Supplier Deliverables:

The following documentation shall be delivered to the GM ENV/DUR Expert and/or GM Component Validation Engineer at least 10 working days ahead of the scheduled meeting:

- Functional description
- Vehicle location
- Interface description(s), internal and external to the component
- 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
- PCB Layout
- Solder process description (solder alloy, solder temperature profile, cleaning material, process, etc.)
- Assembly Mechanization (assembly drawings, mounting/support locations, openings in housing, cooling concept, etc.)

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

Attendees:

GM:

- GMW3172 Environmental/Durability Expert
- Component Validation Engineer
- Design Release Engineer
- EMC Expert (optional)
- Supplier Quality Engineer (optional)

Supplier:

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

4.2.3 Analytical Activities. The supplier shall conduct Analytical Activities according to the approved Component Environmental Test Plan. Analytical models and assumptions shall be provided to GM, according to the Component Environmental Test Plan. Each analytical result shall be reported underneath each negotiated clause in the electronic editable Component Environmental Test Plan and submitted to the GM Component Validation Engineer (or GM ENV/DUR Expert) for evaluation and approval.

4.2.4 Development Activities. The supplier shall conduct Development Activities according to the approved Component Environmental Test Plan. Test samples shall be provided to GM, according to the Component Environmental Test Plan, and this may include parts before testing and parts after testing. Each test result shall be reported underneath each negotiated clause in the electronic editable Component Environmental Test Plan and submitted to the GM Component Validation Engineer (or GM ENV/DUR Expert) for evaluation and approval.

Components that have failed during a test shall be analyzed immediately by the supplier. The component shall not be repaired or further used in the Test Flow. The supplier shall contact the GM Component Validation Engineer (or GM ENV/DUR Expert) immediately to define further actions.

4.2.5 Design Validation Activities. The supplier shall conduct Design Validation (DV) according to the approved Component Environmental Test Plan. Test samples shall be provided to GM, according to the Component Environmental Test Plan, and this may include parts before testing and parts after testing. Each test result shall be reported underneath each negotiated clause in the electronic editable Component Environmental Test Plan and submitted to the GM Component Validation Engineer (or GM ENV/DUR Expert) for evaluation and approval.

Components that have failed during a test shall be analyzed immediately by the supplier. The component shall not be repaired or further used in the Test Flow. The supplier shall contact the GM Component Validation Engineer (or GM ENV/DUR Expert) immediately to define further actions.

4.2.6 Product Validation Activities. The supplier shall conduct Product Validation (PV) according to the approved Component Environmental Test Plan. Test samples shall be provided to GM, according to the Component Environmental Test Plan, and this may include parts before testing and parts after testing. Each test result shall be reported underneath each negotiated clause in the electronic editable Component Environmental Test Plan and submitted to the GM Component Validation Engineer (or GM ENV/DUR Expert) for evaluation and approval.

Components that have failed during a test shall be analyzed immediately by the supplier. The component shall not be repaired or further used in the Test Flow. The supplier shall contact the GM Component Validation Engineer (or GM ENV/DUR Expert) immediately to define further actions.

4.3 Summary of A/D/V Activities. Table 5 is a default summary of A/D/V activities that shall be used for defining tests that will be included in the Component Environmental Test Plan with GM approval. The GM-approved Component Environmental Test Plan is the only required set of activities.

Table 5: Summary of A/D/V Activities

Activity	Phase	FSC	Operating Type
Performance Verification			
5-Point Functional/Parametric Check	D, DV, PV	A	2.1, 3.2
1-Point Functional/Parametric Check	D, DV, PV	A	2.1, 3.2
Continuous Monitoring	D, DV, PV	N/A	As defined in each test
Functional Cycling	D, DV, PV	N/A	2.1, 2.2, 3.1, 3.2
Visual Inspection and Dissection – DRBTR	D, DV, PV	N/A	1.1
Analysis			
Electrical			
Nominal and Worst Case Performance Analysis	A	N/A	N/A
Short/Open Circuit Analysis	A	N/A	N/A
Mechanical			
Resonant Frequency Analysis	A	N/A	N/A
High Altitude Shipping Pressure Effect Analysis	A	N/A	N/A
Plastic Snap Fit Fastener Analysis	A	N/A	N/A
Crush Analysis	A	N/A	N/A
Temperature			
High Altitude Operation Overheating Analysis	A	N/A	N/A
Thermal Fatigue Analysis	A	N/A	N/A
Lead-Free Solder Analysis	A	N/A	N/A
Development			
Electrical			
Jump Start	D, DV	C	3.1, 3.2
Reverse Polarity	D, DV	C	3.1, 3.2
Over Voltage	D, DV	C	3.1, 3.2
State Change Waveform Characterization	D, DV	A	All transitions e.g., 1.2–>3.2, 3.2–>1.2
Ground Path Inductance Sensitivity	D, DV	A	3.2
Electromagnetic Compatibility (EMC)	D, DV	See GMW3103	See GMW3103
Mechanical			

Table 5: Summary of A/D/V Activities

Activity	Phase	FSC	Operating Type
Highly Accelerated Life Test (HALT)	D	N/A	3.2
Temperature			
Temperature Measurement	D	N/A	3.2
Low Temperature Wakeup	D, DV, PV	A	1.2, 3.2
Climatic			
Frost	D	A	1.2, 3.2
Highly Accelerated Stress Test (HAST)	D	N/A	3.2
Dimensional	D, DV, PV	N/A	1.1
Design Validation (DV)			
Electrical			
Parasitic Current	DV	N/A	2.1, 2.2
Power Supply Interruptions	DV	A, C	3.2
Battery Voltage Dropout	DV	A, C	2.1, 3.2
Sinusoidal Superimposed Voltage	DV	A	3.2
Pulse Superimposed Voltage	DV	A	3.2
Intermittent Short Circuit to Battery and to Ground	DV	D	3.2
Continuous Short Circuit to Battery and to Ground	DV	D	3.2
Ground Interconnect Short to Battery	DV	C, E	3.2
Open Circuit – Single Line Interruption	DV	C	3.2
Open Circuit – Multiple Line Interruption	DV	C	3.2
Ground Offset	DV	A	3.2
Power Offset	DV	A	3.2
Discrete Digital Input Threshold Voltage	DV	N/A	3.2
Over Load – All Circuits	DV	D, E	3.2
Over Load – Fuse Protected Circuits	DV	A	3.2
Isolation Resistance	DV	C	1.1
Mechanical			
Vibration With Thermal Cycling	DV, PV	A	3.2
Post Thermal Fatigue Vibration	DV	A	3.2
Mechanical Shock – Pothole	DV	A	3.2
Mechanical Shock – Collision	DV	C	1.2
Mechanical Shock – Closure Slam	DV	A	3.2
Crush For Housing – Elbow Load	DV	C	1.1

Table 5: Summary of A/D/V Activities

Activity	Phase	FSC	Operating Type
Crush For Housing – Foot Load	DV	C	1.1
GMW3191 Connector Tests: Terminal Push-out Force	DV	See GMW3191	See GMW3191
GMW3191 Connector Tests: Connector-to-Connector Engagement Force	DV	See GMW3191	See GMW3191
GMW3191 Connector Tests: Locked Connector Disengagement Force	DV	See GMW3191	See GMW3191
GMW3191 Connector Tests: Unlocked Connector Disengagement Force	DV	See GMW3191	See GMW3191
Connector Installation Abuse – Side Force	DV	C	3.2
Connector Installation Abuse – Foot Load	DV	C	3.2
Free Fall	DV	N/A	1.1
Fretting Corrosion Degradation	DV	N/A	1.2
Climatic			
High Temperature Degradation	DV	A	2.1, 3.2
Thermal Shock Air-To-Air (TS)	DV	A	1.1, 1.2
Power Temperature Cycle (PTC)	DV	A	3.2
Thermal Shock/Water Splash	DV	A	3.2
Humid Heat Cyclic (HHC)	DV, PV	A	3.2
Humid Heat Constant (HHCO)	DV, PV	A	3.2
Salt Mist	DV	A	1.2, 2.1, 3.2
Salt Spray	DV	A	1.2, 3.2
Enclosure			
Dust	DV	A	1.2
Water	DV	A	3.2
Seal	DV, PV	A	3.2
Water Freeze	DV	A	2.1, 3.2
Sugar Water Function Impairment	DV	A	3.2
Product Validation (PV)			
Shipping Vibration	PV	C	1.1
Legend for Phase: A = Analysis D = Development DV = Design Validation PV = Product Validation (A subset of the DV tests may reoccur in PV if required by the Component Environmental Test Plan)			

5 Requirements

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

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

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

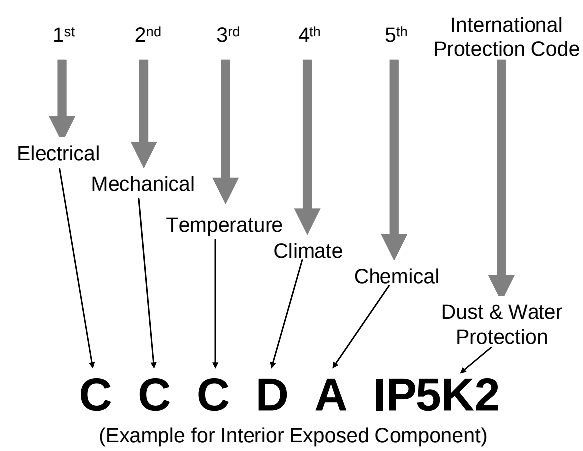
5.2 Reliability. All reliability values within this document are derived from calculations based on 97 % reliability with a statistical confidence of 50 %. In case of different reliability and confidence requirements, adjustments shall be made accordingly. Component reliability shall be demonstrated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

- Vibration fatigue (the vibration portion of “vibration with thermal”, relative to the target life in km or miles for customer usage) and
- Thermal fatigue (Thermal Shock combined with Power Temperature Cycle, relative to target life in years of environmental exposure).

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

5.3 Quoting Requirements. Environmental requirements shall be assigned in the CTS or SSTS according to Figure 5. In case that the Environmental requirements are missing in the CTS or SSTS the most appropriate code according to Table 14 shall be used as a default. Supplemental Environmental testing for failure mechanisms not covered by this document must be specified in addition to GMW3172 and documented in the Appendix B (Component Environmental Test Plan).

Figure 5: Code Letter Sequence Requirement



5.3.1 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.

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

Table 6: Code Letter for Electrical Loads

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

- In the range of the given code letter, the Functional Status Classification shall be A.
- In the range of (-13.5 V to U_{min}) and (U_{max} to +26 V), the Functional Status Classification shall be C.
- **Test Voltages:** The test voltages depend on the Operating Types as shown in Table 7.

Table 7: Test Voltages

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

5.3.2 Code Letter for Mechanical Loads.

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	Elbow Load	Engine or Transmission (without special balancing feature)	Yes	No	Yes
B	Elbow Load	Engine or Transmission (with special balancing feature)	Yes	No	Yes
C	Elbow Load	Car Sprung Masses	Yes	No	Yes
D	Elbow Load and Foot Load	Car Sprung Masses	Yes	No	Yes
E	Elbow Load	Car Sprung Masses	Yes	Yes	Yes
F	Elbow Load	Car Unsprung Masses	Yes	No	Yes
G	Elbow Load	Truck Sprung Masses	Yes	No	Yes
H	Elbow Load and Foot Load	Truck Sprung Masses	Yes	No	Yes
I	Elbow Load	Truck Sprung Masses	Yes	Yes	Yes
J	Elbow Load	Truck Unsprung Masses	Yes	No	Yes
Z	as agreed upon				

Note:

- Trucks are defined as pickup trucks or commercial vehicles.
- Cars are defined as passenger cars, SUVs, or crossover vehicles.
- Sprung Masses are defined as components attached to the body, frame, or sub-frame of a vehicle (i.e., mounted above the springs of a vehicle).
- Unsprung Masses are defined as components attached to the wheels, tires, or moving suspension elements of a vehicle.

5.3.3 Code Letter for Temperature Loads.

Table 9: Code Letter for Temperature Loads

Code Letter	T_{min}	T_{max}	T_{PH} Use for the first 5 % of total High Temperature Degradation test **Product is powered**	T_{RPS} Use for the first hour of the High Temperature Degradation test **Product 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
Z	as agreed upon			

5.3.4 Code Letter for Climatic Loads.

Table 10: Code Letter for Climatic Loads

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

Note:

- IP code definition supersedes the applicability of the Seal test as stated in the above table.
- Some rows are identical due to the deletion of the column for Xenon Arc from previous versions of this document.
- Frost test is not applicable for non-sealed components with vent openings.

5.3.5 Code Letter for Chemical Loads. The Coding defines the requirements related to the position of the component in the vehicle and the appropriate tests for chemical loads.

Table 11 identifies chemical origins that shall be covered by the appropriate material specification. No additional testing is required by this document.

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

5.3.6 Code Letter for International Protection by Enclosures. GM uses a subset of the International Protection (IP) Codes.

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

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

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

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

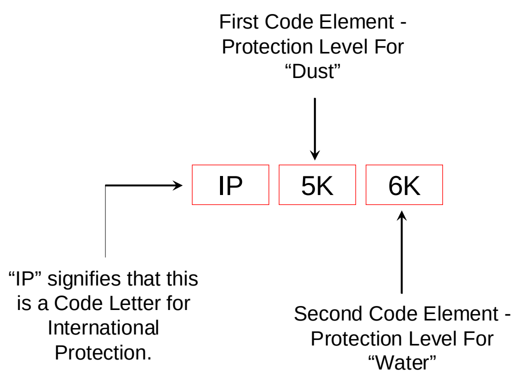
Second code element	Brief description	Requirements
2	Water drips with enclosure inclined by 15 °	Vertical drips shall not have any harmful effects, when the enclosure is tilted at any angle up to 15 ° on either side of the vertical
3	Water spray	Water spray which sprays against the enclosure from any direction at a 60 ° 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

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

Second code element	Brief description	Requirements
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 6 explains the use of letters in the IP-Code. For details see ISO 20653, *Protection of electrical equipment against foreign objects, water and access*.

Figure 6: IP-Code Example



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

Table 14: Code Letters Based on Location in the Vehicle

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

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
Low mount/under seat	A – F Typically C	D	A	D or F	B	IP5K2 or IP5K8
Other Locations						
Trunk low mount	A – F Typically C	C or D	A, B or C	F	D	IP5K8
Trunk high mount	A – F Typically C	C or D	A, B or C	D	D	IP5K2
Doors and hatches (wet area)	A – F Typically C	E	B or C	H	B	IP5K3
Doors and hatches (dry area)	A – F Typically C	E	B or C	E or D	A	IP5K3
Exterior splash area	A – F Typically C	C	A, B or C	J	F	IP6K9K
Chassis and underbody	A – F Typically C	C	A, B or C	I, J or N	F	IP6K8 or IP6K9K
Unsprung masses	A – F Typically C	F	A, B or C	J or N	F	IP6K8 and IP6K9K
Sealed body cavities	A – F Typically C	C	A, B or C	D	B	IP5K2
Unsealed body cavities	A – F Typically C	C	A, B or C	H or I	F	IP5K4K
Exterior at the base of the windshield inside the Plenum or inside the engine compartment	A – F Typically C	C	D, E, F or G	I	E	IP6K6K Also perform Seal Evaluation if in Plenum
Roof mounted inside the vehicle cabin	A – F Typically C	C	D	D	B	IP6K2 or IP5K2

6 Performance Verification

The supplier is responsible for developing 5-Point Functional/Parametric Check, 1-Point Functional/Parametric Check, Continuous Monitoring, and Functional Cycling for the component. These procedures shall be defined in the Component Environmental Test Plan.

6.1 5-Point Functional/Parametric Check.

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

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

Operating Type: 2.1/3.2

Monitoring: As defined in the following procedure.

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

1 (T_{min}, U_{min})

2 (T_{min}, U_{max})

3 (T_{room}, U_{nom})

4 (T_{max}, U_{min})

5 (T_{max}, U_{max})

The temperature shall be stabilized for at least 0.5 h prior to the 5-Point Functional/Parametric Check.

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

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

The 5-Point Functional/Parametric Check shall:

1 Validate functionality by monitoring and recording that all outputs (both hardwired and on-vehicle data bus communications) are in the correct state for a given set of inputs and timing conditions.

2 Measure parametric values by monitoring and recording the specific voltage, current, and timing levels for all inputs and outputs in order to verify that these levels meet the CTS/SSTS requirements, including tolerances.

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

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

Criteria: Functional Status Classification shall be A.

6.2 1-Point Functional/Parametric Check.

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

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

Operating Type: 2.1/3.2

Monitoring: As defined in the following procedure.

Procedure: The 1-Point Functional/Parametric Check shall be performed at (T_{room}, U_{nom}), unless otherwise specified in the Component Environmental Test Plan.

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

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

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

The 1-Point Functional/Parametric Check shall:

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

2 Measure parametric values by monitoring and recording the specific voltage, current, and timing levels for all inputs and outputs, or a subset thereof as defined in the Component Environmental Test

Plan, in order to verify that these levels meet the CTS/SSTS requirements, including tolerances.

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

Criteria: Functional Status Classification shall be A.

6.3 Continuous Monitoring.

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

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

Operating Type: As defined in each individual test.

Monitoring: N/A

Procedure:

Continuous Monitoring shall:

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

2 Monitor and record internal diagnostic codes, if available.

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

Criteria: Continuous Monitoring test setup shall be verified with respect to accurate and comprehensive data storage.

6.4 Functional Cycling.

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

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

Operating Type: 2.1/2.2/3.1/3.2

Monitoring: As defined in the following procedure.

Procedure:

1 While the component is exposed to the test environment, it shall be periodically cycled between Power OFF and Power ON. All component inputs/outputs (including on-vehicle data bus communications, as well as any mechanical actuations) shall be cycled and monitored for proper functional operation.

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

Criteria: Functional Cycling test setup shall be verified with respect to accurate and comprehensive component state changes.

6.5 Visual Inspection and Dissection – DRBTR.

Purpose: This activity shall identify any structural faults, material/component degradations or residues, and near-to-failure conditions caused by environmental testing. This activity supports the Design Review Based on Test Results (DRBTR) process as defined in GMN5345. The Visual Inspection and Dissection – DRBTR is a visual review of the component's housing and internal parts at the completion of testing as specified in the Universal Environmental/Durability Test Flows.

Applicability: All components.

Operating Type: 1.1

Monitoring: N/A

Procedure: The supplier shall perform this activity on all samples. All samples shall be available for GM review upon request. The following samples shall be submitted to GM Engineering upon request for dissection and inspection: one sample from Mechanical Fatigue, two samples from Thermal Fatigue (one from Constant Humidity and one from Cyclic Humidity), and one sample from Corrosion.

Perform an external inspection of the component housing. Then perform a dissection of the component followed by an internal inspection. The inspection shall use visual aids (e.g., magnifiers, microscopes, dyes, etc.) as necessary.

The following are examples of items the inspection shall examine for:

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

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

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

7 **The Formation of Whiskers When Tin, Zinc, or Silver is Used:** The Component Environmental Test Plan 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.

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

9 **Solder Joint Voids:** Selective solder joints shall be sectioned to ensure that the formation of voids is kept to an acceptable minimum level. Solder joints most at risk include interfaces with large CTE differentials or corner pins of surface mounted parts with large diagonal lengths.

Criteria: A summary of each component's condition shall be documented and reported to the GM ENV/DUR Expert or GM Component Validation Engineer. The supplier may be required to perform further investigation to determine the degree or type of degradation. GM Engineering will decide as to the necessity of corrective action.

7 Analysis

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

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: N/A

Monitoring: N/A

Procedure: Use a circuit analysis program to determine voltage, current and power dissipation for each part across the operation temperature and supply and I/O voltage range.

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 SSTS/CTS and GMW14082.

7.2.2 Short/Open Circuit Analysis.

Purpose: This analysis shall identify that the component withstands intermittent and continuous shorts to battery/supply voltages and to ground, and open circuit conditions.

Applicability: All components.

Operating Type: N/A

Monitoring: N/A

Procedure: Use a circuit analysis program to perform intermittent (default: 1 Hz 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 operation temperature, supply, and output current range.

Criteria: Verify ability of parts to withstand intermittent and continuous short/open circuit conditions. The analysis shall verify that the part's operating parameters as defined by the part's data sheet shall not be exceeded.

7.3 Mechanical.

7.3.1 Resonant Frequency Analysis.

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

Applicability: All components with a circuit board.

Operating Type: N/A

Monitoring: N/A

Procedure: Considering the circuit board mounting configuration, calculate the resonant frequency of the circuit board by using appropriate software such as Finite Element Analysis.

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

7.3.2 High Altitude Shipping Pressure Effect Analysis.

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

Applicability: All components or parts that are hermetically sealed and may be shipped at high altitude.

Operating Type: N/A

Monitoring: N/A

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

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

2 Use the following equation for the analysis:

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

P_{burst} : Component (or part) burst pressure

$P_{assembly}$: Internal pressure of component (or part) during assembly (this should be either the ambient air pressure at the assembly location, or it may be a different pressure if modified by the manufacturing process)

$P_{altitude}$: Pressure in the freight section of the airplane at 15 240 m, use 11 kPa.

Design Margin (DM): 4

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

7.3.3 Plastic Snap Fit Fastener Analysis.

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

- Adequate retention force.
- 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: N/A

Monitoring: N/A

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

1 Adequate retention force.

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: N/A

Monitoring: N/A

Procedure: Use finite element analysis to insure that the requirements for crush test, as defined as a physical test, are met. The intended load must be identified as being produced by a person's elbow or foot as described in the test portion for this concern.

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

7.4 Temperature.

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.

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

Operating Type: N/A

Monitoring: N/A

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

$T_{max\_part} \geq T_{altitude} = \Delta T_{part\_oper}$ x $Multiplier_{altitude} + T_{ambient} + 10\ ^{o}C$

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

- $T_{altitude}$: Calculated operating temperature of part at altitude.
- $T_{ambient}$: Ambient temperature at altitude. Use +35 °C as the default value.
- ΔT_{part_oper}: Temperature increase of part due to operation (this is the temperature difference of the component when the part is at sea level).
- $Multiplier_{altitude}$: The Multiplier value is based on altitude and air flow. The multipliers as noted in Table 15 are used to adjust the temperature rise for high altitude effects in the equation.
- +10 °C: This is the safety margin.

Table 15: Parameters for Overheating Analysis

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

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

Criteria: T_{max_part} must be greater than or equal to $T_{altitude}$. T_{max_part} is based on the operating specifications for the part generating heat and other affected parts nearby.

7.4.2 Thermal Fatigue Analysis.

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

Applicability: All components.

Operating Type: N/A

Monitoring: N/A

Procedure: Identify the package types of all the parts of the component.

Identify the Coefficient of Thermal Expansion (CTE) of each package type, and all variants within the package type, of the parts of the component.

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

Identify the analysis method used to determine the fatigue life and provide the evidence of the validation for that analysis method.

Perform the analysis to quantify fatigue life of the part junctions from the expansion and contraction during temperature cycling of the component.

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

7.4.3 Lead-Free Solder Analysis.

Purpose: This analysis shall identify solder joint weaknesses that may occur due to the use of lead-free solder. This analysis supports the Hardware Design Review to evaluate the soldering process.

Applicability: All components manufactured with lead-free solder.

Operating Type: N/A

Monitoring: N/A

Procedure: Use the Appendix A (Lead-Free Solder Considerations) as a reference to discuss potential impacts to the product design and manufacturing process. Use this as a basis to develop the Design Review Based on Failure Modes (DRBFM).

Provide full disclosure throughout the supply chain regarding risks when lead-free solder is used. All risks are to be addressed and mitigated through the design review and DRBFM process.

Provide the DRBFM to GM.

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

8 Development

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

Weaknesses detected during Development activities shall be corrected prior to validation. All Development activities shall be documented in the Component Environmental Test Plan, including results.

8.2 Electrical.

8.2.1 Jump Start.

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

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

Operating Type: 3.1/3.2 (with voltage as defined in Table 16).

Monitoring: Continuous Monitoring.

Procedure: Use the test method according to ISO 16750-2, *Overvoltage*, with the exceptions shown in Table 16. Repeat the test for both Operating Types.

Table 16: Jump Start Requirements

Test Voltage	Test Time
+26.0 V	1 minute

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

8.2.2 Reverse Polarity.

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

Applicability: All components that have power supplied by the vehicle battery 12 V wiring system. This test is not applicable to generators or components that have an exemption stated in the CTS.

Operating Type: 3.1/3.2 (with voltage as defined in Table 17).

Monitoring: Continuous Monitoring.

Procedure: Use the test method according to ISO 16750-2, *Reversed voltage*, with the exemption shown in Table 17. Repeat the test for both Operating Types.

Table 17: Reverse Polarity Requirements

Test Voltage	Test Time
-13.5 V	2 minutes

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

Criteria: Functional Status Classification shall be C.

8.2.3 Over Voltage.

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

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

Operating Type: 3.1/3.2 (with voltage as defined in Table 18).

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 Turn on the power supply and subject the component to the required test voltage for the required test time as noted in Table 18. All applicable power modes shall be executed during the test time.

Table 18: Over Voltage Requirements

Test Voltage	Test Time
Continuously cycle between +16 V and +18 V at 1 V/minute for components which contain over voltage protection circuits that switch off power consumption in this range.	60 minutes
Provide a constant +18 V for components which do not contain over voltage protection circuits that switch off power consumption.	60 minutes

Criteria: Functional Status Classification shall be C.

8.2.4 State Change Waveform Characterization.

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

Applicability: All components.

Operating Type: All transitions between possible operating types (e.g., 1.2 to 3.2 and 3.2 to 1.2).

Monitoring: Continuous Monitoring. Additionally, the voltage and current output is reviewed in graphical form with an oscilloscope.

Procedure:

1 Change operation state.

2 Record all output waveforms before, during, and after state changes. Evaluate output signal integrity for proper performance by using an oscilloscope.

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

Criteria: Functional Status Classification shall be A. State change transients shall not produce disruptive levels of disturbance to downstream components. One consideration in analyzing the waveform is to detect inadvertent actuation of outputs and floating inputs.

8.2.5 Ground Path Inductance Sensitivity.

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

Applicability: All components.

Operating Type: 3.2

Monitoring: Continuous Monitoring. Additionally, recording of ground line and I/O with an oscilloscope.

Procedure:

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

2 Cycle the component in such a way that the maximum current change rate over time at the ground path occurs. This may be achieved by simultaneously activating all inputs to the component that will generate outputs switching at the maximum rate of change.

3 Evaluate for proper function.

4 Operate the component such that the outputs are at the maximum change rate and speed possible. This includes relay switching.

5 Evaluate output signal integrity for proper performance by using oscilloscope.

Criteria: Functional Status Classification shall be A.

8.2.6 Electromagnetic Compatibility (EMC). The component shall meet the requirements of GMW3097, GMW3091, and GMW3103 and is handled by the EMC Department.

8.3 Mechanical.

8.3.1 Highly Accelerated Life Test (HALT).

Purpose: The HALT test shall identify structural and functional weaknesses due to vibration and temperature effects.

Applicability: This test applies to new technology. 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.

Criteria: Functional Status Classification is not applicable to this test. HALT test results shall support the Hardware Design Review to improve components and evaluate new hardware technologies and product improvements.

8.4 Temperature.

8.4.1 Temperature Measurement.

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

Applicability: All components where heat may be produced.

Operating Type: 3.2

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

Procedure: Perform the measurement in the highest power consumption scenario possible. This can be done by various methods, using infrared imaging or thermocouple measurements.

For infrared imaging, use the procedure in GMW8288. For non-accessible parts, use thermocouples (or equivalent) for part temperature measurement.

Quantify temperatures and evaluate design margin using the following equation:

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

$T_{part\_max\_spec}$: 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 min. (or as agreed upon by GM and supplier).

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

8.4.2 Low Temperature Wakeup.

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

Applicability: All components equipped with electronics.

Operating Type: 1.2/3.2 as shown in Figure 7.

Monitoring: Continuous Monitoring during Operating Type 3.2 phases.

Procedure:

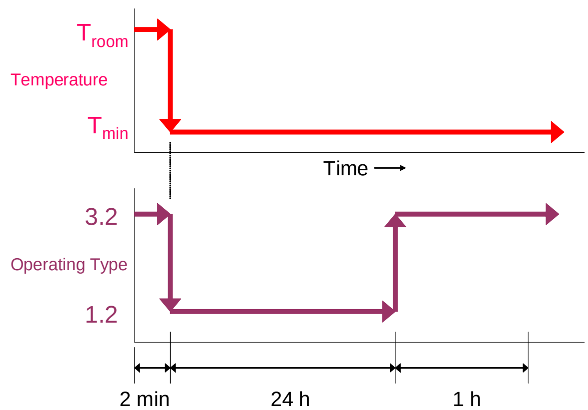
1 Use the test methods according to IEC 60068-2-1, Test Ab, *Cold*. T_{min} of the operating temperature range is the low temperature that is to be used.

2 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}.

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

4 At the end of 24 h, and while still at T_{min}, the component is to be turned ON and evaluated for proper function for 1 h at Operating Type 3.2.

Figure 7: Low Temperature Wakeup Profile



Criteria: Functional Status Classification shall be A.

8.5 Climatic.

8.5.1 Frost.

Purpose: This test shall evaluate that the component is robust against rapid temperature change in a high humidity environment. This can produce intermittent failures and sneak path circuits that may affect function.

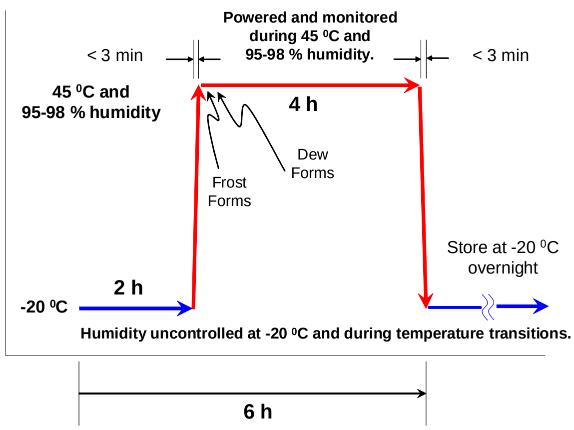
Applicability: All sealed or closed components.

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

Monitoring: Continuous Monitoring during the time it 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 8.

Figure 8: Frost Test Profile



Reference to Table 19 for the number of cycles performed.

Table 19: Frost Test Requirements

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

Criteria: Functional Status Classification shall be A. An inspection shall show no signs of electro-migration and dendritic growth.

8.5.2 Highly Accelerated Stress Test (HAST).

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

Applicability: This test applies to new technology. This test can also be used to evaluate product improvements.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to EIA/JEDEC JESD22-A110-B, *Highly-Accelerated Temperature and Humidity Stress Test (HAST)*.

Criteria: Functional Status Classification is not applicable to this test. The HAST test results shall support the Hardware Design Review to improve components and evaluate new hardware technologies and product improvements.

8.5.3 Dimensional.

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

Applicability: All components.

Operating Type: 1.1

Monitoring: N/A

Procedure: If this test is performed following High Temperature Degradation or Constant/Cyclic Humidity, then no additional pre-treatment is required. If this test is performed without prior exposure to temperature or humidity, then the component shall be pre-treated with 2 h at T_{max} or T_{RPS}, whichever is greater. The Dimensional Test shall be performed at T_{room}. All dimensional and physical requirements on the GM released part drawing shall be validated and documented unless indicated otherwise by GM Engineering.

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

9 Design Validation (DV)

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

9.2 Electrical.

9.2.1 Parasitic Current.

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

Applicability: All components directly connected to the vehicle battery.

Operating Type: 2.1/2.2

Monitoring: The current is measured in the various states of OFF Asleep and OFF Awake. The current value shall be stored graphically.

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

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

2 Place the component into OFF Asleep mode.

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

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

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

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

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

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

Criteria: Functional Status Classification is not applicable to this test. The maximum allowable average parasitic current shall be 0.250 mA if not provided in the CTS. Analyze the stored current waveforms for any random fluctuations.

9.2.2 Power Supply Interruptions.

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

Applicability: All components that may be affected by a momentary drop in voltage. This includes components supplied by regulated voltage provided by other components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to ISO 16750-2, *Reset behaviour at voltage drop*. According to GMW14082 (*Immunity to Power Supply Interruptions* section), select worst case dropout timings for the test.

Figure 9: Power Supply Interruptions Profile

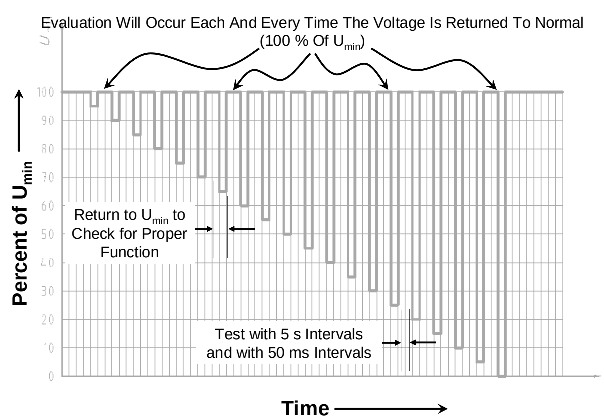


Figure 9 shows the execution of the procedure.

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

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

3 After each test pulse return to 100 % U_{min}.

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

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

6 Repeat steps (2) to (5) for each supply voltage input separately.

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

Criteria: Functional Status Classification shall be A after returning to U_{min} following each voltage drop and C elsewhere.

9.2.3 Battery Voltage Dropout.

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

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

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 10.

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 20 .

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

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

Figure 10: Battery Voltage Dropout Profile

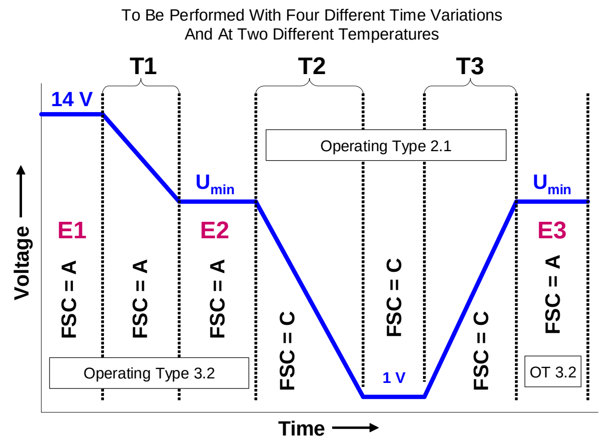


Table 20: Battery Voltage Dropout Test Values

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

Criteria: Functional Status Classification shall be as shown depending on the zone per Figure 10. There shall be no inadvertent behavior during the transitions.

9.2.4 Sinusoidal Superimposed Voltage.

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

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

Operating Type: 3.2

Monitoring: Continuous Monitoring.

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

Criteria: Functional Status Classification shall be A.

9.2.5 Pulse Superimposed Voltage.

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

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

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Refer to Figure 11.

1 Connect the component to the U_0 output.

2 Raise ambient temperature to T_{max}, then stabilize the component.

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

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

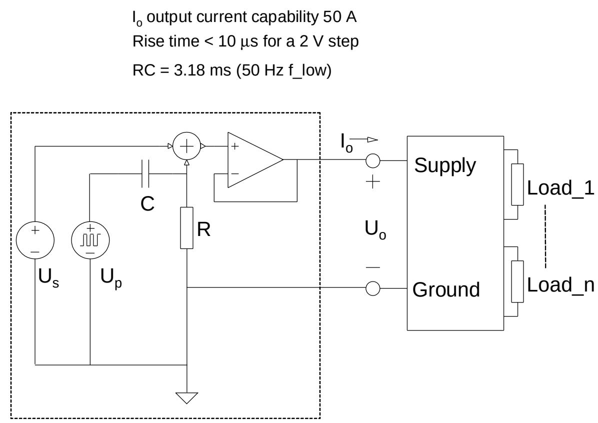
5 Decrease U_s by 1 V.

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

7 Repeat steps (3) to (6) at T_{room}.

8 Repeat steps (3) to (6) at T_{min}.

Figure 11: Pulse Superimposed Voltage test setup



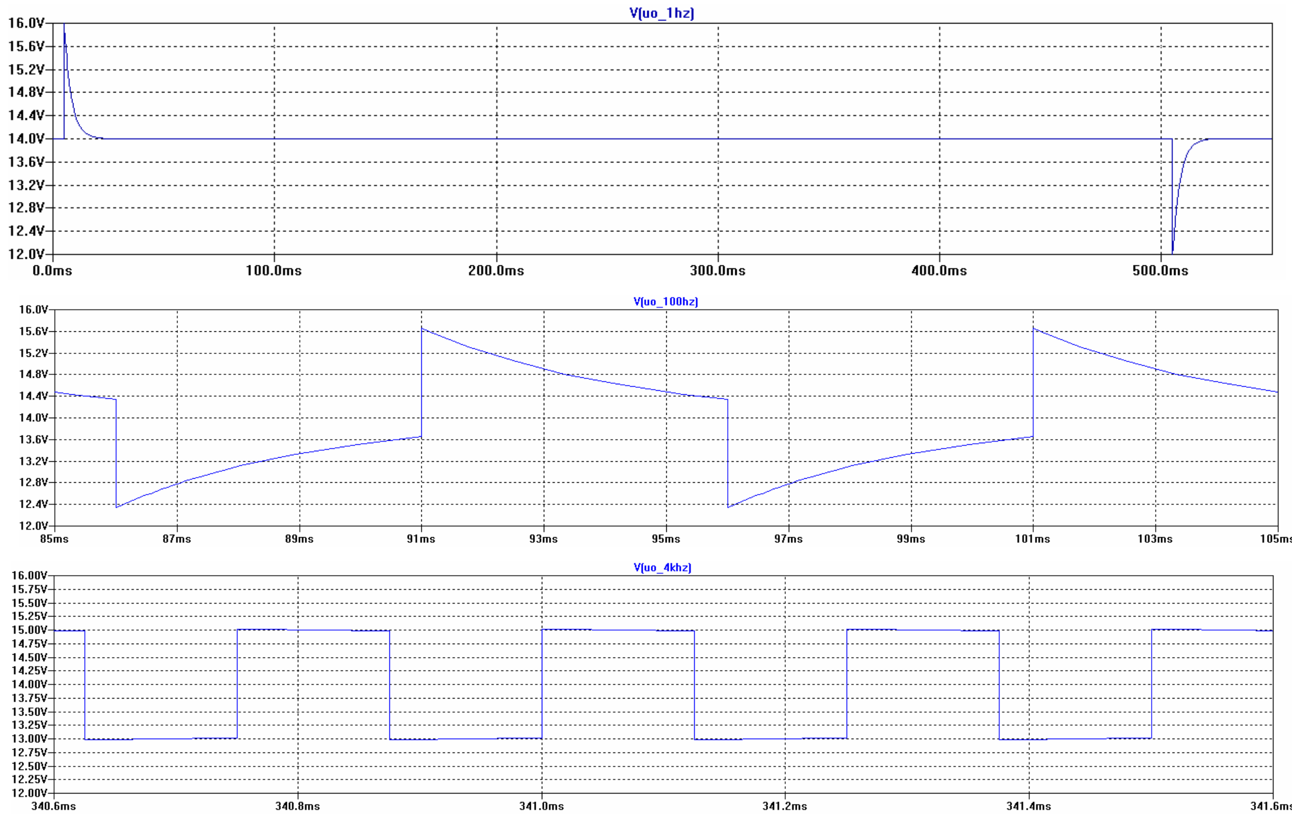
Test Setup Definitions/Parameters:

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

Note:

- For components with power output drivers, 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 12 shows examples of the following frequencies: 1 Hz, 100 Hz and 4 kHz (U_s = +14 V, U_p = +1 V / -1 V).

Figure 12: Examples for Pulse Waveforms



Criteria: Functional Status Classification shall be A.

9.2.6 Intermittent Short Circuit to Battery and to Ground.

Purpose: This test shall verify the component's immunity to intermittent short circuit events.

Applicability: All components equipped with internal short circuit protection of I/O. Short circuit tests to supply and ground lines from the vehicle 12 V battery system are excluded from this test.

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

Monitoring: Continuous Monitoring. Additionally, monitor for overheating. I/O recording needs to be done with oscilloscope.

Procedure:

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

2 Apply U_{max} to the component.

3 At t = 0 s, power mode the component from OFF to ON. The inputs and outputs under test shall be activated no later than t = 5 s.

4 At t = 15 s, apply a short circuit to battery condition for all applicable inputs and outputs for a 5 minutes period and then remove all short circuits for 2 minutes and 45 s (the combination of steps (3) and (4) shall equal 8 minutes).

5 Power mode the component from ON to OFF.

6 Repeat steps (3) through (5) until 60 cycles are complete (total short circuit time equals 8 h). After completing the 60 cycles, perform any required re-initialization conditions and confirm the correct operation of the outputs with normal loads.

7 Adjust the battery voltage to U_{min} and repeat steps (3) through (6).

8 Repeat steps (2) to (7) for short circuit to ground condition.

9 Stabilize the chamber temperature to T_{max} and repeat steps (1) through (8).

Note:

- If multiple shorts are applied simultaneously, then the supplier shall make sure that the test is valid for single shorts as well.
- Care has to be taken that the power supply has a current limitation (set to 50 A if not otherwise specified) and that test setup withstands the maximum current.

Criteria: Functional Status Classification shall be D. Fuse replacements are not permitted. For components with micro-controllers, the micro-controller must remain functional during the short circuit event. Short circuit related trouble codes shall be stored in the micro-controller accordingly. Overheating is not permitted.

9.2.7 Continuous Short Circuit to Battery and to Ground.

Purpose: This test shall verify the component's immunity to continuous short circuit events.

Applicability: All components equipped with internal short circuit protection of I/O. Short circuit tests to supply and ground lines from the vehicle 12 V battery system are excluded from this test.

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

Monitoring: Continuous Monitoring. Additionally, monitor for overheating. I/O recording needs to be done with oscilloscope.

Procedure:

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

2 Apply U_{max} to the component.

3 Apply a continuous short circuit of all inputs and outputs to battery. Keep this short circuit condition applied until the component temperature is stable. The short circuit duration is defaulted to 1 h, but may be shorter or longer depending on the protection design.

4 Remove the short circuit condition for battery and return the component to full function by performing all required re-initializations conditions and confirm the correct operation of the outputs with normal loads.

5 Repeat steps (2) through (4) for U_{min}.

6 Repeat steps (2) through (5) for short to ground condition.

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

8 Repeat steps (2) through (6).

Note:

- If multiple shorts are applied simultaneously, then the supplier shall make sure that the test is valid for single shorts as well.
- Care shall be taken that the power supply has a current limitation (set to 50 A if not otherwise specified) and that test setup withstands the maximum current.

Criteria: Functional Status Classification shall be D. Fuse replacements are not permitted. For components with micro-controllers, the micro-controller must remain functional during the short circuit event. Short circuit related trouble codes shall be stored in the micro-controller accordingly. Overheating is not permitted.

9.2.8 Ground Interconnect Short to Battery.

Purpose: This test shall verify that the component will experience an open circuit of the ground pass-through trace in a safe manner.

Applicability: All components that have a ground pass-through.

Operating Type: 3.2

Monitoring: Continuous Monitoring. Additionally, monitor for overheating.

Procedure:

1 This test is to be performed at T_{max}. A power supply with a current limitation set to 50 A (if not otherwise specified) shall be used. Connect the power supply ground to the component ground.

2 Use a production-intent (or equivalent) connector and associated wire size.

3 Apply U_{max} to the other side of the ground pass-through trace until an open circuit condition exists or for a maximum of 10 minutes.

Criteria: If this ground pass-through trace is over-current protected, then Functional Status Classification shall be C. If this ground pass-through trace is not over-current protected, then Functional Status Classification shall be E. Minor amounts of carbon may appear near the open circuit; however, amounts beyond this on the circuit board are not permitted.

9.2.9 Open Circuit – Single Line Interruption.

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

Applicability: All components.

Operating Type: 3.2

Monitoring: Continuous Monitoring. Additionally, monitor for overheating.

Procedure: Use the test methods according to ISO 16750-2, *Single line interruption*. Apply this procedure for all I/O.

For supply power and ground lines, interruption duration shall be 15 minutes.

Note:

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

Criteria: Functional Status Classification shall be C. Overheating is not permitted.

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. Additionally, monitor for overheating.

Procedure: Use the test methods according to ISO 16750-2, *Multiple line interruption*. In the case of multiple connectors, they shall be tested separately.

Criteria: Functional Status Classification shall be C. Overheating is not permitted.

9.2.11 Ground Offset.

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

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

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: As shown in the test setup in Figure 13, the offset shall be applied to each ground line of the I/O simulation device separately and simultaneously. The simulation device shall be constructed according to the CTS interface documentation. If this information is not available, refer to GMW14082 for simulator construction.

1 Apply U_{min} to the component.

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

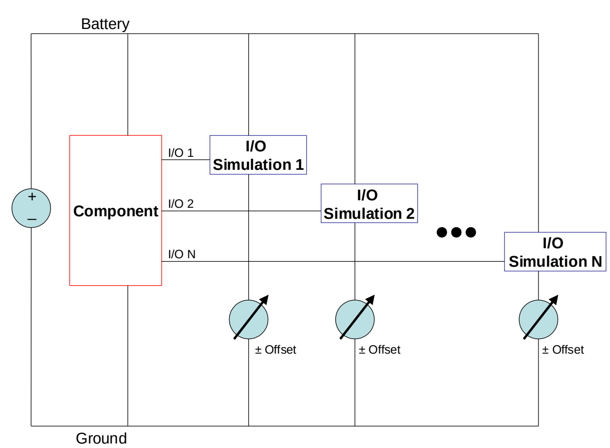
3 Repeat step (2) for the next applicable I/O simulation device.

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

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

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

Figure 13: Ground Offset Test Setup



Criteria: Functional Status Classification shall be A.

9.2.12 Power Offset.

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

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

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: As shown in the test setup in Figure 14, the offset shall be applied to each power line of the I/O simulation device separately and simultaneously. The simulation device shall be constructed according to the CTS interface documentation. If this information is not available, refer to GMW14082 for simulator construction.

1 Apply U_{min} to the component.

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

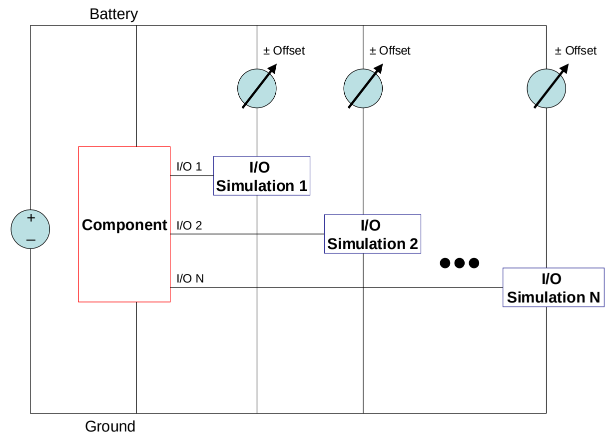
3 Repeat step (2) for the next applicable I/O simulation device.

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

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

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

Figure 14: Power Offset Test Setup



Criteria: Functional Status Classification shall be A.

9.2.13 Discrete Digital Input Threshold Voltage.

Purpose: This test shall verify the performance of discrete digital input interfaces (including switch interfaces).

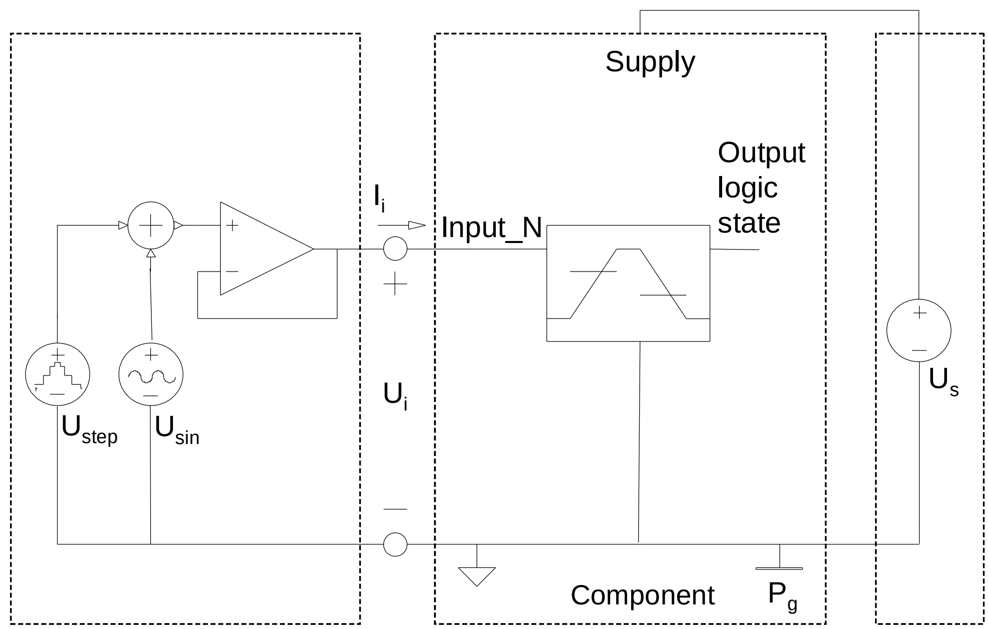
Applicability: Discrete digital input and switch input interfaces with transmitters grounded locally without signal return to receiver. It can be replaced by Analysis at Hardware Design Review.

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 15 and follow the given sequence.

Figure 15: Threshold Voltage Test Setup



1 At T_{room} perform the following sequence (see Figure 16).

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

3 Adjust U_{step} to 0 V.

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

5 Read logic output state and store.

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

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

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

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

10 Rise voltage U_{step} to $(U_{ih\_rise}+U_{il\_fall})/2$ and record the number of state changes during a 5 s time period as Nth_U_{min} (see Figure 17).

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

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

13 Write a report including:

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

Figure 16: Threshold Voltage Waveform – All Steps

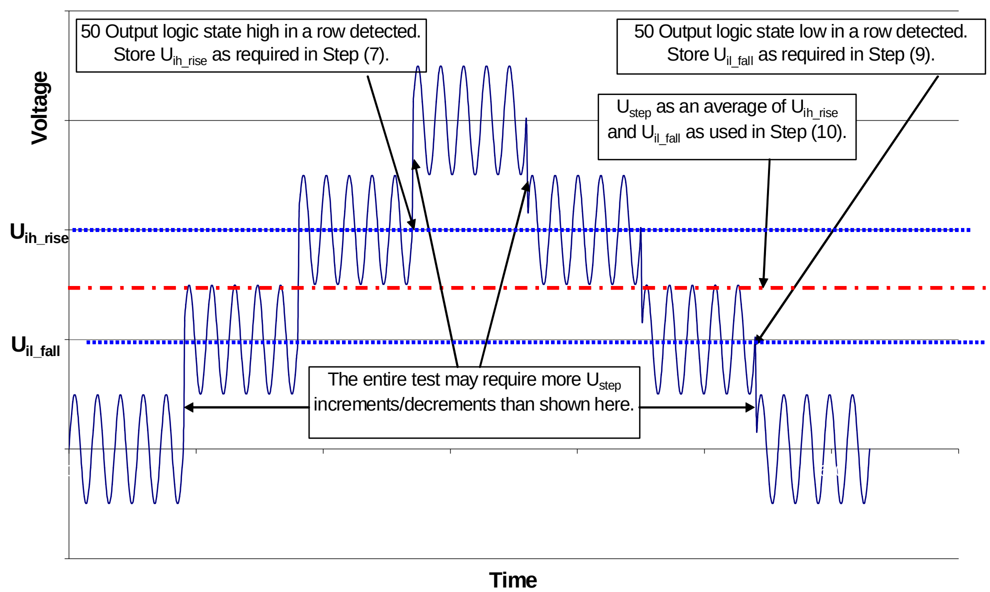
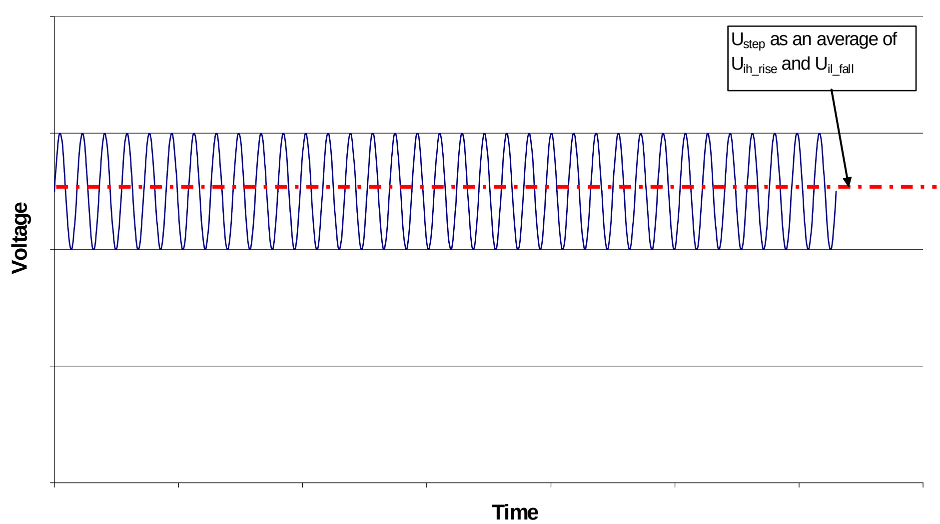


Figure 17: Threshold Voltage Waveform – Step (10)



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

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

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

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

9.2.14 Over Load – All Circuits.

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

Applicability: All components with or without internal over-current protection. 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. Additionally, monitor for overheating. I/O recording needs to be done with an oscilloscope.

Procedure:

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

2 Apply U_{nom} to the component.

3 Load each output through an appropriate variable resistive load to draw a maximum operating load current (I_{max}) for 10 minutes.

4 Using a power supply capable of supplying 3 x I_{max}, but ≥ 50 A, increase the current in increments of 10 % of I_{max} by changing the variable resistive load. Apply each increased current for a 10 minutes dwell period.

5 As step (4) is executed, continue increasing the current until an open circuit condition exists or a component with built-in protection begins limiting current. For all other cases, increase current until 3 x I_{max}, but ≥ 50 A, is reached.

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

7 Return the component to full function by performing all required re-initializations conditions and confirm the correct operation with normal loads.
Note: Components without current protection may not return to correct operation for the output under test.

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

Criteria: If this component is over-current protected, then Functional Status Classification shall be D. If this component is not over-current protected, then Functional Status Classification shall be E. Minor amounts of carbon may appear near the open circuit; however, amounts beyond this on the circuit board are not permitted.

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. Additionally, monitor for overheating.

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

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

2 Apply U_{nom} to the component.

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

4 Apply an overload circuit condition to the circuit so that the load current is 1.35 x I_{rp} (nominal current of the circuit protection feature) for the required test duration. Use the test duration as derived from the corresponding fuse protection characteristic curve

(ISO 8820, *Operating time rating*), considering the upper tolerance plus 10 %.

5 Repeat step (4) with an overload circuit condition so that the load current is 2 x I_{rp}, and again with 3.5 x I_{rp}. Adjust the test duration accordingly.

Criteria: Functional Status Classification shall be A. There shall be no degradation of isolation or increase of pass-through resistance. Overheating is not permitted.

9.2.16 Isolation Resistance.

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

Applicability: All components that generate voltages > 30 V. See **Note** listed below in the procedure.

Operating Type: 1.1

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

Procedure:

1 As a pre-treatment, subject the component to the environmental conditions stated in the Humid Heat Constant test (HHCO) with Operating Type 1.1.

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

3 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 isolation requirements exceed 500 V.

Criteria: Functional Status Classification shall be C. The isolation resistance shall be > 10 x 10^6 Ω.

9.3 Mechanical.

9.3.1 Vibration With Thermal Cycling. This test shall verify that the component is immune to vibration that occurs in the vehicle. The following vibration tests reference different test conditions for mounting locations as well as for cars and trucks. The vibration portion of this test demonstrates 97 % reliability, with a statistical confidence of 50 % for vibration fatigue, relative to a target life requirement of 160 900 km (100 000 miles) for customer usage.

For statistical reasons, adjustments must be made for vibration testing for a longer target life. For example, a 150 000-mile requirement shall dictate 1.5 times the number of hours of vibration testing. Adjustments are also required for a different sample size.

All components that have internal contacts such as fuse holders, press fit connections, PCB-to-PCB connections, etc, shall be measured for contact resistance where applicable. The measurements shall be performed per the *Dry Circuit Contact Resistance* measurement test procedure as specified in GMW3431. The measurements, at a minimum, shall be taken before and after the vibration test.

All vibration tests shall have a superimposed thermal cycle as defined in paragraph 9.3.1.4 ("Thermal Cycle Profile Used During All Vibration Tests").

All vibration tests shall use the durations defined in Table 21.

Table 21: Duration for Vibration Test for a Sample Size of 6

Location	Body Style	Duration		
		X-Axis	Y-Axis	Z-Axis
Engine or Transmission	Car or Truck	44 h	44 h	44 h
Sprung Masses	Car	16 h	16 h	16 h
Sprung Masses	Truck	36 h	36 h	36 h
Unsprung Masses	Car	16 h	16 h	16 h
Unsprung Masses	Truck	36 h	36 h	36 h

9.3.1.1 Random Vibration – Mounting Location Engine or Transmission.

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

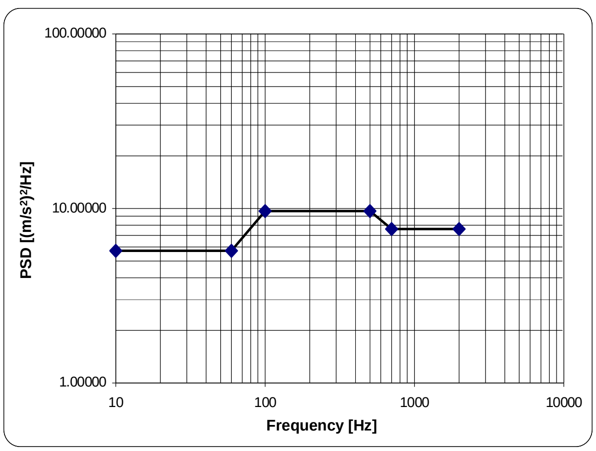
Applicability: All components attached to the engine or transmission.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

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

Figure 18: Random Vibration Profile for Engine or Transmission



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

Table 22: Random Vibration Profile for Engine or Transmission

Fre-quency	Power Spectral Density
10 Hz	5.7624 $(m/s^2)^2/Hz$ = 0.0600 G^2/Hz
60 Hz	5.7624 $(m/s^2)^2/Hz$ = 0.0600 G^2/Hz
100 Hz	9.6040 $(m/s^2)^2/Hz$ = 0.1000 G^2/Hz
500 Hz	9.6040 $(m/s^2)^2/Hz$ = 0.1000 G^2/Hz
700 Hz	7.6832 $(m/s^2)^2/Hz$ = 0.0800 G^2/Hz
2000 Hz	7.6832 $(m/s^2)^2/Hz$ = 0.0800 G^2/Hz

Criteria: Functional Status Classification shall be A.

All *Dry Circuit Contact Resistance* measurements taken shall meet the requirement as stated in the CTS. Additionally, the increase of resistance shall not exceed 3 times the resistance measurements taken before the test. This increase in resistance is due to wearout degradation.

9.3.1.2 Random Vibration – Mounting Location Sprung Masses.

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

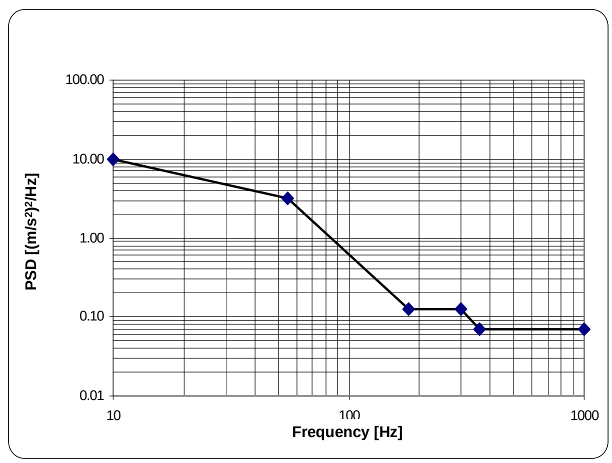
Applicability: All components attached to the body, frame, or sub-frame of a car or truck.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

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

Figure 19: Random Vibration Profile for Sprung Masses



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

Table 23: Random Vibration Profile for Sprung Masses

Frequency	Power Spectral Density	
10 Hz	9.9069 $(m/s^2)^2/Hz$	= 0.1032 G^2/Hz
55 Hz	3.2245 $(m/s^2)^2/Hz$	= 0.0336 G^2/Hz
180 Hz	0.1238 $(m/s^2)^2/Hz$	= 0.0013 G^2/Hz
300 Hz	0.1238 $(m/s^2)^2/Hz$	= 0.0013 G^2/Hz
360 Hz	0.0695 $(m/s^2)^2/Hz$	= 0.0007 G^2/Hz
1000 Hz	0.0695 $(m/s^2)^2/Hz$	= 0.0007 G^2/Hz

Criteria: Functional Status Classification shall be A.

All *Dry Circuit Contact Resistance* measurements taken shall meet the requirement as stated in the CTS. Additionally, the increase of resistance shall not exceed 3 times the resistance measurements taken before the test. This increase in resistance is due to wearout degradation.

9.3.1.3 Random Vibration – Mounting Location Unsprung Masses.

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

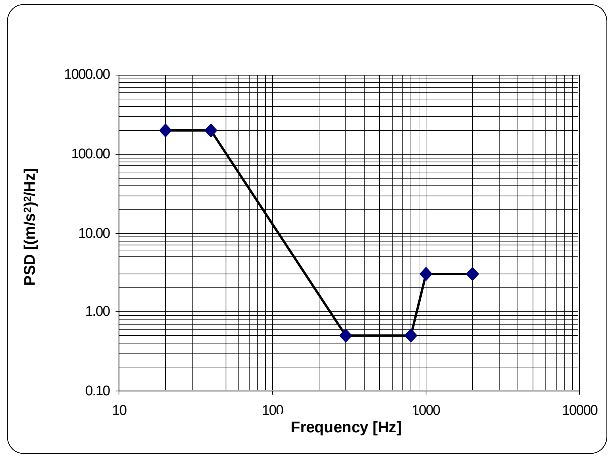
Applicability: All components attached to the wheels, tires, or moving suspension elements of a car or truck.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

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

Figure 20: Random Vibration Profile for Unsprung Masses



Effective Acceleration = 107.3 m/s^2 = 10.95 G_{RMS}

Table 24: Random Vibration Profile for Unsprung Masses

Frequency	Power Spectral Density	
20 Hz	200.0 $(m/s^2)^2/Hz$	= 2.0825 G^2/Hz
40 Hz	200.0 $(m/s^2)^2/Hz$	= 2.0825 G^2/Hz
300 Hz	0.5 $(m/s^2)^2/Hz$	= 0.0052 G^2/Hz
800 Hz	0.5 $(m/s^2)^2/Hz$	= 0.0052 G^2/Hz
1000 Hz	3.0 $(m/s^2)^2/Hz$	= 0.0312 G^2/Hz
2000 Hz	3.0 $(m/s^2)^2/Hz$	= 0.0312 G^2/Hz

Criteria: Functional Status Classification shall be A.

All *Dry Circuit Contact Resistance* measurements taken shall meet the requirement as stated in the CTS. Additionally, the increase of resistance shall not exceed 3 times the resistance measurements taken before the test. This increase in resistance is due to wearout degradation.

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

Figure 21: Thermal Cycle Profile Used During All Vibration Tests

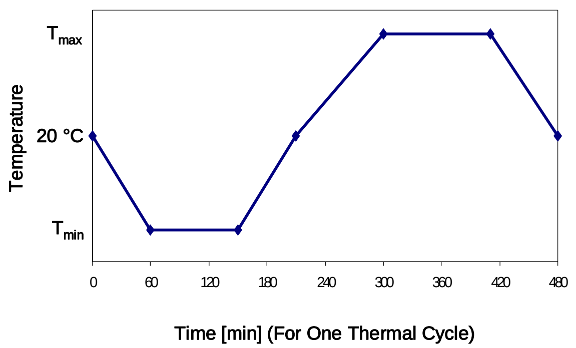


Table 25: Thermal Cycle Profile Used During All Vibration Tests

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

9.3.2 Post Thermal Fatigue Vibration.

Purpose: This test shall detect intermittent failures that are caused by the Thermal Fatigue tests. This test shall be performed after Humidity tests as shown in the Universal Environmental/Durability Test Flow.

Applicability: All components.

Operating Type: 3.2

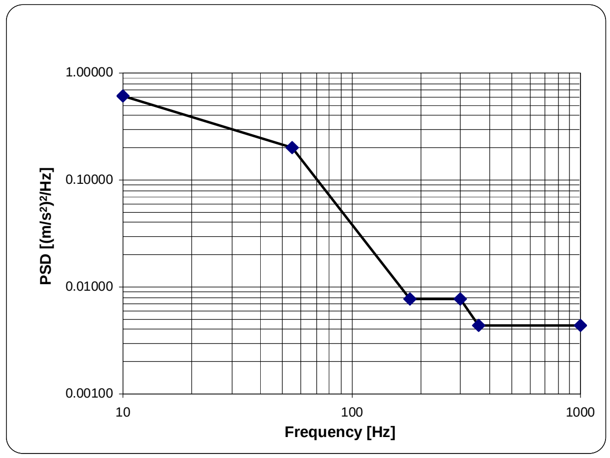
Monitoring: Continuous Monitoring.

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

Vibration shall occur while the component is exposed to a full thermal transition from T_{min} to T_{max} as shown below. Typically, this is 1 h, but could be more or less based on the thermal mass of the component. There is no need to dwell at the temperature extremes other than to ensure that the product actually reaches the target temperature.

As a default, apply vibration in the axis perpendicular to the circuit board plane.

Figure 22: Post Thermal Fatigue Vibration Profile

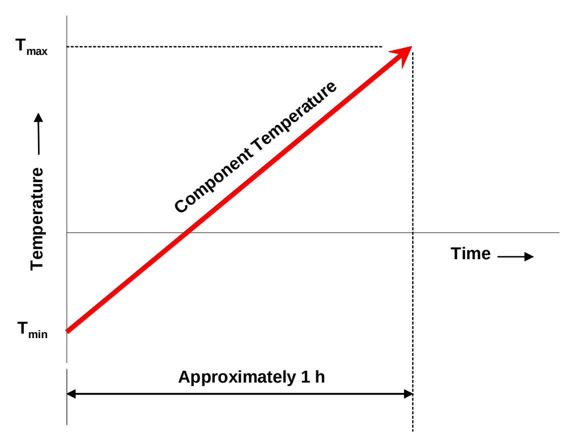


Effective Acceleration = 4.9 m/s^2 = 0.5 G_{RMS}

Table 26: Post Thermal Fatigue Vibration Profile

Fre-quency	Power Spectral Density	
10 Hz	0.619 $(m/s^2)^2/Hz$	= 0.00645 G^2/Hz
55 Hz	0.202 $(m/s^2)^2/Hz$	= 0.00210 G^2/Hz
180 Hz	0.008 $(m/s^2)^2/Hz$	= 0.00008 G^2/Hz
300 Hz	0.008 $(m/s^2)^2/Hz$	= 0.00008 G^2/Hz
360 Hz	0.004 $(m/s^2)^2/Hz$	= 0.00004 G^2/Hz
1000 Hz	0.004 $(m/s^2)^2/Hz$	= 0.00004 G^2/Hz

Figure 23: Thermal Cycle Applied During Post Thermal Fatigue Vibration



Criteria: Functional Status Classification shall be A.

9.3.3 Mechanical Shock – Pothole.

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

Applicability: All components, but different requirements depending on vehicle location.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to IEC 60068-2-29, Test Eb, *Bump*. Refer to Table 27 for details.

Table 27: Mechanical Shock – Pothole

Component Location	Peak	Duration	Number of Impacts
Unsprung Masses	100 G	11 ms	20 x 6 = 120
Sprung Masses (Passenger Compartment)	12 G	20 ms	400 x 6 = 2400
Sprung Masses (All other areas, including Cradles and Frames)	25 G	10 ms	400 x 6 = 2400

Note: The multiplier of 6 as noted in Table 27 refers to the six Cartesian directions of possible motion. Components that will or cannot be mounted in all possible directions shall be tested only in the applicable directions of force.

Criteria: Functional Status Classification shall be A.

9.3.4 Mechanical Shock – Collision.

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

Applicability: All components.

Operating Type: 1.2

Monitoring: N/A

Procedure: Use the test methods according to IEC 60068-2-27, Test Ea, *Shock*. Refer to Table 28 for details.

Perform a 1-Point Functional/Parametric Check.

Table 28: Mechanical Shock - Collision

Description	Value
Acceleration	100 G
Nominal shock duration	11 ms
Nominal shock shape	half sine
Total Number of shocks	3 x 6 directions = 18

Criteria: Functional Status Classification shall be C. No structural damage to the component is permitted.

9.3.5 Mechanical Shock – Closure Slam.

Purpose: This test shall verify the component's immunity to slam events (door, trunk lid, hatchback, and hood).

Applicability: Required only for components located in closure areas.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to IEC 60068-2-29, Test Eb, *Bump.*

Refer to Table 29 and Table 30 for details.

Table 29: Slam Based Mechanical Shock Loads

Description	Value
Acceleration	40 G
Nominal shock duration	6 ms
Nominal shock shape	half sine

Table 30: Quantity of Mechanical Shocks for Closures

Closure	**Number of shocks** (in the direction that the primary forces are being applied)
Driver's Door	100 000
Passenger Door/Hatch Lid	50 000
Trunk Lid	30 000
Rear Doors	20 000
Drop Gate	10 000
Hood	1 500

Criteria: Functional Status Classification shall be A. No structural damage to the component is permitted.

9.3.6 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 by elbow loads.

Applicability: All components.

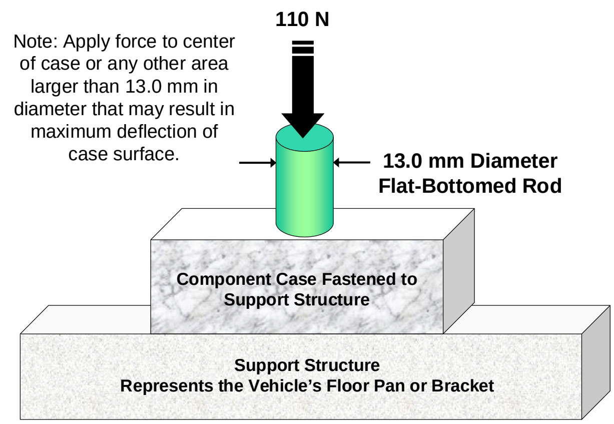
Operating Type: 1.1

Monitoring: Measure case deflection during loading to insure case clearances to parts on the circuit board.

Procedure: The component shall be set up to allow testing on all external surfaces with a 13.0 mm or larger diameter area. Subject the component to an evenly distributed 110 N force about any 13.0 mm diameter area for 1.0 s as shown in Figure 24 (this represents the force applied by a person's elbow).

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

Figure 24: Elbow Load Applied to Top of Component Housing



Criteria:

1 The component shall survive without electrical degradation or permanent physical damage (Functional Status Classification = C).

2 The case deflection during loading cannot contact any parts on the circuit board, except the connector.

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

9.3.7 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.

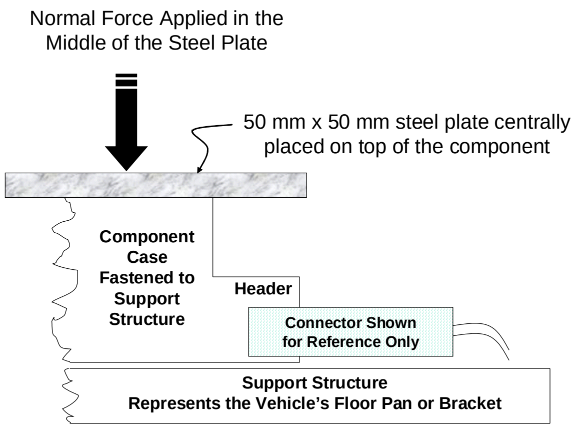
Operating Type: 1.1

Monitoring: Measure case deflection during loading to insure case clearances to parts on the circuit board.

Procedure: Locate a (50 x 50) mm (or appropriately sized) rigid steel plate on top of the component. Subject the component to an evenly distributed 890 N force applied normally to the top of the component through the steel plate for 1 minute as shown in Figure 25.

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

Figure 25: Foot Load Applied to Top of Component Housing



Criteria:

1 The component shall survive without electrical degradation or permanent physical damage (Functional Status Classification = C).

2 The case deflection during loading cannot contact any parts on the circuit board, except the connector.

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

9.3.8 GMW3191 Connector Tests.

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

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

Operating Type: See GMW3191.

Monitoring: See GMW3191.

Procedure:

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

- Terminal Push-out Force
- Connector-to-Connector Engagement Force
- Locked Connector Disengagement Force
- Unlocked Connector Disengagement Force

Note: The above test names are according to GMW3191, revision December 2007. The tests shall be performed according to the latest version of GMW3191.

Criteria: See GMW3191.

9.3.9 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 13 mm of area contained in a circle.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: The component shall be set up to allow testing on the connector surface with a 13.0 mm or larger diameter area. Subject the connector to an evenly distributed 110 N force about each 13.0 mm diameter area for 1.0 s.

Criteria: Functional Status Classification shall be C. The connector, housing, and circuit board to which the connector is attached shall be able to withstand the above mechanical stress without any shear or yield or loss of electrical isolation.

9.3.10 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 as a result of side forces during assembly or service operations.

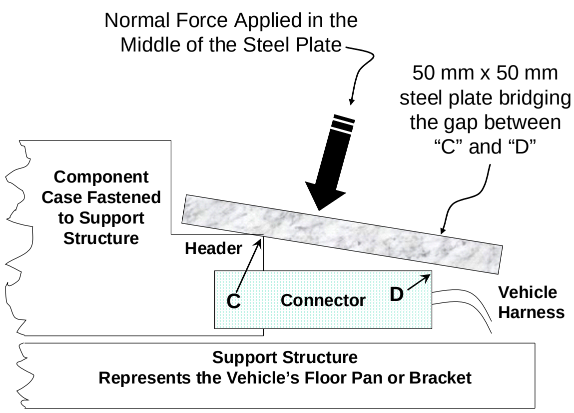
Applicability: All components that may experience foot loads during vehicle assembly or servicing.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: A simulated foot load of 890 N of a distributed force shall be applied normally through a (50 x 50) mm (or appropriately sized) rigid steel plate for 1 minute to the connector and connector header as shown in Figure 26. This plate represents the sole of a person's shoe.

Figure 26: Foot Load Connector Setup



Criteria: Functional Status Classification shall be C. The connector-header system shall be able to withstand the above mechanical stress without any shear or yield or loss of electrical isolation. Additionally, there shall be no degradation of the circuit board resulting from any of the forces that may be transmitted by this test.

9.3.11 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: N/A

Procedure: Use the test methods according to ISO 16750-3, *Free fall*.

Criteria:

- Functional Status Classification is not applicable to this test.
- If there is no visible external damage to the component, then the component shall have no internal damage and shall pass the 1-Point Functional/Parametric Check at the end of test.
- If there is visible external damage to the component and if the damage is judged by the GM Component Validation Engineer to be:
  - *Insignificant*, then the component shall have no internal damage and shall pass the 1-Point Functional/Parametric Check at the end of test.
  - *Significant*, 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.

9.3.12 Fretting Corrosion Degradation.

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

Applicability: All components that have internal contacts such as fuse holders, press fit connections, PCB-to-PCB connections, etc.

Operating Type: 1.2

Monitoring: N/A

Procedure:

1 Measure the contact resistance per the *Dry Circuit Contact Resistance* measurement test procedure as specified in GMW3431.

2 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.

3 Measure the contact resistance per the *Dry Circuit Contact Resistance* measurement test procedure as specified in GMW3431.

4 Subject the component to the environmental conditions stated in the Humid Heat Constant test (HHCO) for a duration of 1 day with Operating Type 1.1.

5 Measure the contact resistance per the *Dry Circuit Contact Resistance* measurement test procedure as specified in GMW3431.

6 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.

7 Measure the contact resistance per the *Dry Circuit Contact Resistance* measurement test procedure as specified in GMW3431.

Criteria:

- Functional Status Classification is not applicable to this test.

- The resistance measured in step (1) shall meet the requirement as stated in the CTS.
- The resistance measured in steps (3), (5), and (7) shall not increase more than 3 times the original resistive value measured in step (1).

9.4 Climatic.

9.4.1 High Temperature Degradation.

Purpose: This test shall verify the component's immunity to degradation resulting from the effects of high temperature. The 1 h temperature repaint and storage portion of the test (T_{RPS}) is designed to evaluate structural warpage effects. The temperature post heat portion of the test (T_{PH}), which is 5 % of the total test time, adds to the thermal degradation resulting from elevated post heat temperatures.

Applicability: All components.

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

Monitoring: Continuous Monitoring.

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

Components that are Temperature coded as F or H shall be tested to an elevated post heating temperature level (T_{PH}) for the first 5 % of the entire test duration.

Components that are Temperature coded as A, B, C, or D shall be tested to an elevated post heating temperature level of 95 °C (T_{RPS}) for the first hour of the entire test duration.

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

The test operating voltage shall be U_{nom} for 80 %, U_{min} for 10 % and U_{max} for 10 % of the functional cycles.

The component shall be exercised for a maximum amount of electrical operational cycles during the High Temperature test duration. The electrical loading shall account for the normal usage in the vehicle application.

The functional cycling scheme shall exercise the component and allow for detection of degradation or failure.

Criteria: Functional Status Classification shall be A.

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

Purpose: This test in combination with Power Temperature Cycling (PTC) shall verify that the component is immune to thermal fatigue and contact degradation that is caused by temperature changes and possible miss-matching of the CTE of materials. The combination of PTC and TS is used to demonstrate the required level of 97 % reliability and 50 % confidence.

Applicability: All components.

Operating Type: 1.1 or 1.2

Monitoring: N/A

Procedure: Use the test methods according to ISO 16750-4, *Temperature cycling*. The temperature cycle testing shall be performed according to IEC 60068-2-14, Test Na, *Change of temperature*.

All components that have internal contacts such as fuse holders, press fit connections, PCB-to-PCB connections, etc, shall be measured for contact resistance where applicable. The measurements shall be performed per the *Dry Circuit Contact Resistance* measurement test procedure as specified in GMW3431. The measurements, at a minimum, shall be taken before and after the Thermal Shock test.

The temperature range used in the Thermal Shock test shall be adjusted for components that generate significant internal heat to compensate for the lost temperature change with a non-energized component. For example: If a component shall be tested from (-40...+85) °C per this specification, and generates an additional 10 °C from self heat, then the Thermal Shock test shall be performed from (-40...+95) °C.

The following steps need to be taken to determine the duration of the TS thermal cycle profile:

1 Measure temperature by applying a thermocouple to the highest thermal mass part in the component.

2 Apply one thermal cycle and record the temperature of the thermocouple to determine the total duration needed for one thermal cycle. The dwell time at high or low temperature shall be 10 minutes. The dwell time starts when the thermocouple reaches T_{max} - 3 °C or T_{min} + 3 °C (see Figure 27).

Perform the required number of Thermal cycles per Table 31. The sample size and distribution of cycles between TS and PTC are the recommended default values.

Figure 27: Thermal Shock Profile

The example shown below is for Temperature Code Letter “C”.

Note: The solid line is the temperature of the chamber. The dotted line is the temperature of the component. Extra dwell time is needed to compensate for component thermal inertia to ensure that the component receives the required duration of dwell.

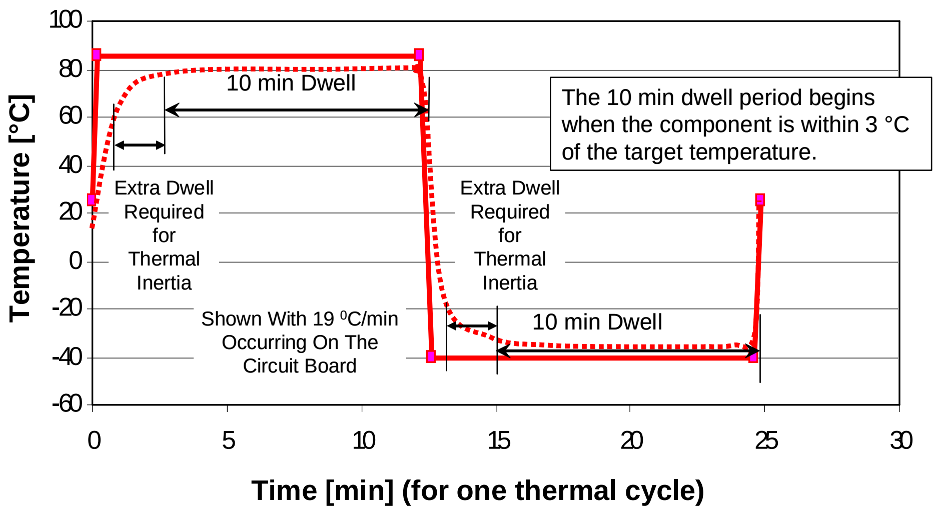


Table 31: Number of Thermal Cycles for a Sample Size of 18

Code Letter For Temperature	Location In The Vehicle	Combined Number of TS + PTC Cycles	Number Of TS Cycles	Number Of PTC Cycles
A, B, C, and D	Inside the passenger compartment, luggage compartment, or attached to the exterior of the vehicle but not under the hood or above the exhaust system	843	632	211
E and F	Under the hood of the vehicle	1236	927	309
G, H, and I	Attached to or inside the engine (total cycles = 2248)	1248	1000	248
		Cyclic Humidity and Constant Humidity		
		1000	1000	0

Note for components that are temperature coded as “G”, “H”, and “I”:

1 Perform 1000 TS cycles.

2 Perform 248 PTC cycles.

3 Perform the Humidity tests.

4 Perform 500 TS cycles.

5 Perform a 1-Point Functional/Parametric Check.

6 Perform 500 TS cycles.

7 Perform a 1-Point Functional/Parametric Check.

Criteria: Functional Status Classification shall be A.

All *Dry Circuit Contact Resistance* measurements taken shall meet the requirement as stated in the CTS. Additionally, the increase of resistance shall not exceed 3 times the resistance measurements taken before the test. This increase in resistance is due to wearout degradation.

9.4.3 Power Temperature Cycle (PTC).

Purpose: This test, in combination with Thermal Shock (TS), shall verify that the component is immune to thermal fatigue and contact degradation that is caused by temperature changes and possible miss-matching of the CTE of materials. The combination of PTC and TS is used to demonstrate the required level of 97 % reliability and 50 % confidence.

Applicability: All components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure: Use the test methods according to ISO 16750-4, *Temperature cycling*. The temperature cycle testing shall be performed according to IEC 60068-2-14, Test Nb, *Change of temperature*.

All components that have internal contacts such as fuse holders, press fit connections, PCB-to-PCB connections, etc., shall be measured for contact resistance where applicable. The measurements shall be performed per the *Dry Circuit Contact Resistance* measurement test procedure as specified in GMW3431. The measurements, at a minimum, shall be taken before and after the Power Temperature Cycle test.

The electrical loading shall account for the normal usage in the vehicle application.

The following steps need to be taken to determine the duration of the PTC thermal cycle profile:

1 Measure temperature by applying a thermocouple to the highest thermal mass part in the component.

2 Apply one thermal cycle and record the temperature of the thermocouple to determine the total duration needed for one thermal cycle. The dwell time at high or low temperature shall be 10 minutes. The dwell time starts when the thermocouple reaches T_{max} - 3 °C or T_{min} + 3 °C (see Figure 28).

Perform the required number of PTC cycles per Table 31. The sample size and distribution of cycles between TS and PTC are the recommended default values.

Figure 28: Example of a Power Temperature Cycle

The example shown below is for Temperature Code Letter “C”.

Note: The solid line is the temperature of the chamber. The dotted line is the temperature of the component. Extra dwell time is needed to compensate for component thermal inertia to ensure that the component receives the required duration of dwell.

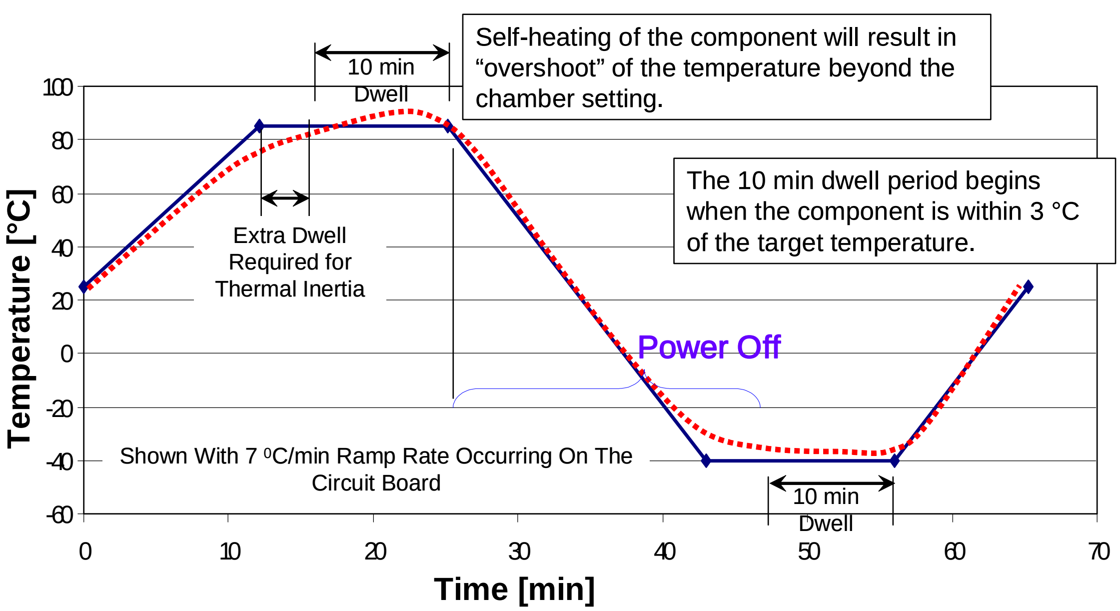


Table 32: Power Temperature Cycling Requirements

Description	Value
Temperature Range	T_{min} to T_{max}
Temperature transition rate	(2...15) °C/minute with the approval of GM Engineering
Minimum number of PTC cycles	100
Power Moding	Power OFF starting with the negative thermal transition. Once T_{min} + 3 °C is reached, by default, begin cycling ON 100 s and OFF 20 s until the next negative thermal transition begins.
Supply Voltage	The test operating voltage shall be U_{nom} for 80 %, U_{min} for 10 %, and U_{max} for 10 % of the cycles.

Criteria: Functional Status Classification shall be A.

All *Dry Circuit Contact Resistance* measurements taken shall meet the requirement as stated in the CTS. Additionally, the increase of resistance shall not exceed 3 times the resistance measurements taken before the test. This increase in resistance is due to wearout degradation.

9.4.4 Thermal Shock/Water Splash.

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

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

Operating Type: 3.2

Monitoring: Continuous Monitoring.

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

Criteria: Functional Status Classification shall be A.

9.4.5 Humid Heat Cyclic (HHC).

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

Applicability: All components.

Operating Type: 3.2 with the component powered and cycled between ON (operated in such a manner to minimize power dissipation) and Sleep mode to avoid local drying. In case the component does not have Sleep capability, switch OFF instead.

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

A supply voltage of U_{nom} shall be used.

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

Procedure: Use test equipment according to IEC 60068-2-38, Test Z/AD, *Composite temperature/humidity cyclic test*, and then perform the test as stated in Table 33.

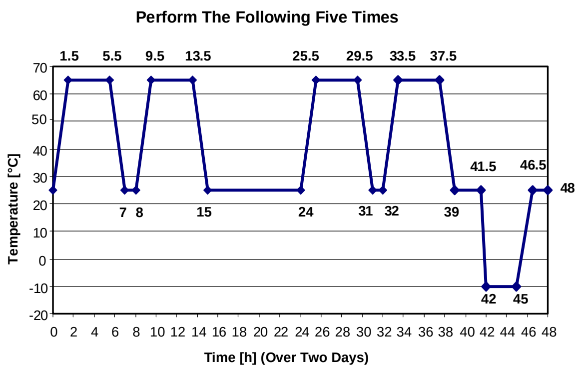
Table 33: Cyclic Humidity Requirements

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

Figure 29 and Table 34 show a two days cycle that is to be repeated a total of five times (2 x 5 = 10 days).

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

Figure 29: Cyclic Humidity Profile



Pay attention to anomalies resulting from condensation of moisture.

Table 34: Cyclic Humidity Profile

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

Criteria: Functional Status Classification shall be A. There shall be no increase greater than 50 % in parasitic current. An inspection shall show no signs of electro-migration or dendritic growth.

9.4.6 Humid Heat Constant (HHCO).

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

Applicability: All components.

Operating Type: 3.2 with the component powered and cycled between ON (operated in such a manner to minimize power dissipation) and Sleep mode to avoid local drying. In case the component does not have Sleep capability, switch to OFF instead.

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

A supply voltage of U_{nom} shall be used.

Monitoring: During the ON state, Continuous Monitoring is required. During the Sleep/OFF state, continuous parasitic current is monitored and recorded over the 10 days 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 35.

Table 35: Constant Humidity Requirements

Description	Value
Temperature	(+85 ± 3) °C
Duration	10 days
Relative Humidity	(90 ± 5) %

Criteria: Functional Status Classification shall be A. There shall be no increase greater than 50 % in parasitic current. An inspection shall show no signs of electro-migration or dendritic growth.

9.4.7 Salt Mist.

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

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

Operating Type: 1.2/2.1/3.2

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

Procedure: Use the test setup according to IEC 60068-2-52, Test Kb, *Salt mist, cyclic*. Tests and durations are based on component types as stated in Table 36.

Table 36: Salt Mist Test Requirements

Component Type	Operating Test	Material Degradation Test
Non-sealed components with vent openings (IP Water Code 2)	Yes, with enclosure (simulating vehicle mounting, with internal fans turned off)	N/A
Non-sealed components without vent openings (IP Water Code 2)	Yes, with enclosure (simulating vehicle mounting)	Operating Type 1.2 3 cycles. Each cycle equals 2 h salt, 22 h humidity.
Non-sealed components without vent openings (IP Water Code 3 or 4K)	Yes, with enclosure (simulating vehicle mounting)	Operating Type 2.1 6 cycles. Each cycle equals 8 h salt, 16 h humidity.
Sealed components with or without a pressure exchange membrane (IP Water Code 8)	N/A	Operating Type 3.2 10 cycles. Each cycle equals 8 h salt, 16 h humidity.

Operating Test:

Use the test methods according to IEC 60068-2-52, Test Kb, for a duration of 2 h at a mist level of (0.25...0.5) ml/h on 80 cm^2 with the component energized and Operating Type 3.2.

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

Material Degradation Test:

Use the test methods according to IEC 60068-2-52, Test Kb, with the level of mist as defined in IEC 60068-2-52, Test Kb, according to the cycles defined in Table 36.

Final Inspection (after completion of all tests):

All inspections shall be documented, including photographs. Document the appearance of the component following the test. Disassemble the component. Perform a detailed inspection of damaged interior electronics. Inspect for loss of parent metal or concentrated pitting corrosion. Inspect the integrity of all seals.

Criteria: Functional Status Classification shall be A. There shall be no critical loss of parent metal that may lead to loss of internal or external connections. For sealed components, there shall be no signs of salt mist intrusion.

9.4.8 Salt Spray.

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

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

Operating Type: 1.2/3.2

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

Procedure:

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

2 The salt spray solution shall be 5 % salt by weight. The pH of the solution shall be from 6.5 to 7.2.

3 Soak the component for 1 h at a temperature between (+50...+70) °C in the salt spray chamber with the component powered OFF (Operating Type 1.2). There shall be no salt spraying during this hour.

4 Turn off the chamber heat and Power ON the component (Operating Type 3.2) while spraying for 1 h. The spray booth shall be +35 °C with the spray solution at T_{room}.

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

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

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

8 This 24 h test sequence, steps (3) to (7), shall be repeated for multiple days as shown in Table 37.

9 All inspections shall be documented, including photographs. Document the appearance of the component following the test. Disassemble the component. Perform a detailed inspection of damaged interior electronics. Inspect for loss of parent metal or concentrated pitting corrosion. Inspect the integrity of all seals.

Table 37: Salt Spray Test Requirements

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

Criteria: Functional Status Classification shall be A. There shall be no liquid ingress and/or internal dendrites.

9.5 Enclosure.

9.5.1 Dust.

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

Applicability: All components.

Operating Type: 1.2

Monitoring: N/A

Procedure:

1 Use the test methods according to ISO 20653, *Protection of electrical equipment against foreign objects, water and access*. This test shall be conducted using the dust in ISO 12103-1, *Arizona test dust*, A2 *fine test dust*. Other dusts may be used where appropriate (reference SSTS/CTS for alternate dust). The test duration shall be 8 h. For some electromechanical components, the duration may be extended beyond 8 h where appropriate. The component can be tested in an enclosure simulating vehicle mounting.

2 Perform the 1-Point Functional/Parametric Check.

Criteria: Functional Status Classification shall be A.

9.5.2 Water.

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

Applicability: All components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

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

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

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

Criteria: Functional Status Classification shall be A. The component shall show no degradation of function or material. Water shall never reach electric/electronic parts or connectors. There shall be no drops of water on the circuit board. Additionally, water shall not accumulate within the container and reach the electric/electronic parts or connectors.

9.5.3 Seal.

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

Applicability: All sealed components.

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

1 Prepare a test solution consisting of 5 % saline in 0 °C water with a soluble ultra-violet dye.

2 Place the component 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.

3 Remove the component from the temperature chamber.

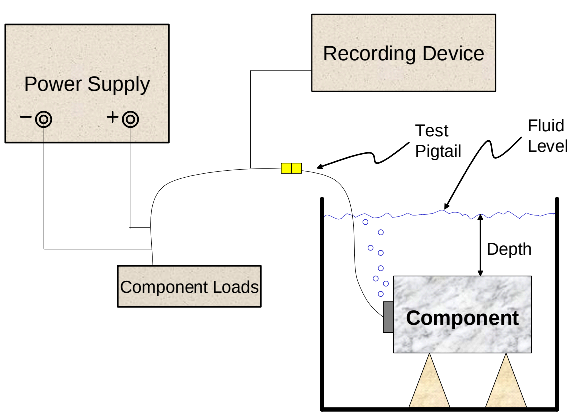
4 Immediately immerse the component in the test solution such that the top of the component is at a depth of (76 ± 5.0) mm. See Figure 30 for details.

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

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

7 Disassemble the component. Use an ultra-violet light source to detect the potential ingress of the saline solution containing ultra-violet dye.

Figure 30: Seal Test Setup for Components without Ground Wires or Splices



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

1 Reconfigure the test set-up as shown in Figure 31 or Figure 32 with the production-intent ground connection or splice submerged.

2 Use new component(s).

3 Repeat steps (1) to (7) from the previous test.

Figure 31: Seal Test Setup for Components with a Ground Wire

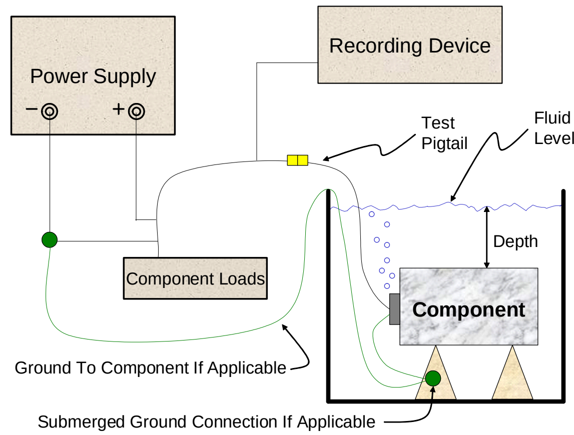
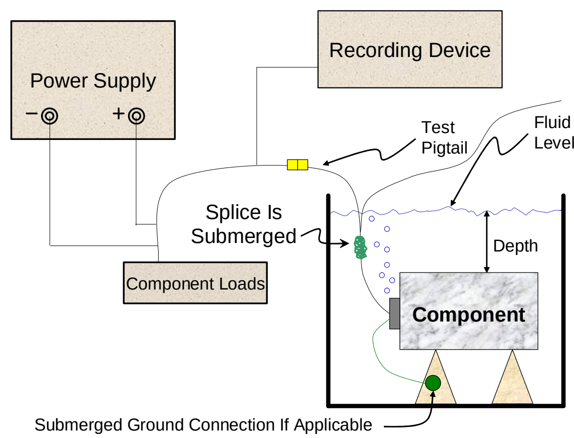


Figure 32: Seal Test Setup for Components with a Splice



Criteria: Functional Status Classification shall be A. The component shall be opened and inspected for signs of water ingress. No water ingress shall be permitted.

9.5.4 Water Freeze.

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

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

Operating Type: 2.1/3.2

Monitoring: Continuous Monitoring during Operating Type 3.2.

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

1 Apply the Water test at T_{room} according to the IP Code in Operating Type 3.2 as a default.

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

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

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

Criteria: Functional Status Classification shall be A.

9.5.5 Sugar Water Function Impairment.

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

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

Operating Type: 3.2

Monitoring: Continuous Monitoring.

Procedure:

- The component shall be mounted in its intended orientation with all bezels and covers in place.
- Sugar water is defined as 200 ml of water with 10 g of sugar fully dissolved.
- Apply the sugar water onto the component from a distance of 30 cm and wipe away any standing or surface liquid.
- 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.
- The component shall remain powered, undisturbed, and allowed to dry at (+23 ± 5) °C for 24 h prior to the evaluation of function.

Criteria: Functional Status Classification shall be A for electrical functions. Degradation in operational forces or torque shall meet the CTS requirements.

10 Product Validation (PV)

10.1 PV Mission.

The Product Validation (PV) shall be a quantitative and qualitative verification that the component meets the requirements for Environmental, Durability, and Reliability when including the effects of production manufacturing. The PV activities shall be executed using components from the production tooling and processes. All PV activities shall be documented in the Component Environmental Test Plan, including results.

10.2 Shipping Vibration.

Purpose: This test shall verify the robustness of the component together with the packaging during shipping.

Applicability: All components with surfaces visible to customers.

Operating Type: 1.1

Monitoring: N/A

Procedure: Use a vibration test fixture that allows the shipping container (one box of components) to move freely in the vertical axis of the vibration table. One possible fixture consists of a base plate with four upright posts that are slightly larger than the shipping container.

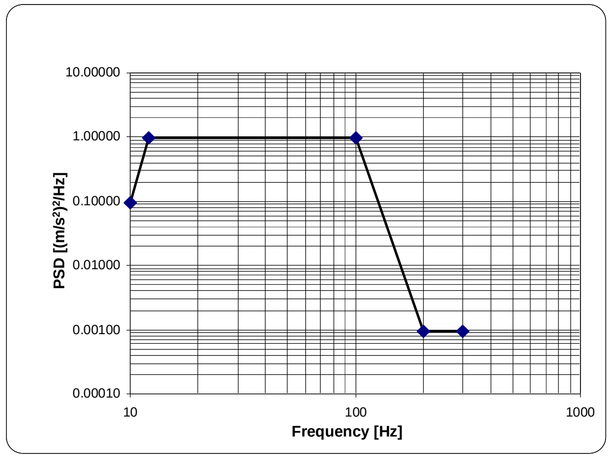
Provisions shall be made to allow placement of the shipping container in all three directions.

1 Vibrate the shipping container for 24 h in each of the three mutually perpendicular directions using the methods outlined in ASTM D4728, *Standard Test Method for Random Vibration Testing of Shipping Containers*. This test is to be conducted on one box of components in their final shipping container. The shipping container shall include all interior packing material. Use the Random Vibration Profile shown in Table 38 and Figure 33.

2 Inspect all components for structural damage and degradation of surfaces visible to customers.

3 Select components (6 samples as a default) from the highest stress area of the shipping container to perform the 5-Point Functional/Parametric Check.

Figure 33: Random Vibration Profile for Shipping



Effective Acceleration = 9.81 m/s^2 = 1.0 G_{RMS}

Table 38: Random Vibration Profile for Shipping

Frequency	Power Spectral Density	
10 Hz	0.096000 $(m/s^2)^2/Hz$	= 0.00100 G^2/Hz
12 Hz	0.962000 $(m/s^2)^2/Hz$	= 0.01002 G^2/Hz
100 Hz	0.962000 $(m/s^2)^2/Hz$	= 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

Criteria: Functional Status Classification shall be C. There shall be no visible damage to any of the components.

11 Abbreviations and Symbols

A Ampere

A/D/V Analysis Development Validation

ASTM American Society for Testing & Material

CTE Coefficient of Thermal Expansion

CTS Component Technical Specification

DRBFM Design Review Based on Failure Modes

DRBTR Design Review Based on Test Results

DRE Design Release Engineer

DV Design Validation

E/E Electrical/Electronic

EIA Electronic Industries Alliance

EMC Electromagnetic Compatibility

ENV/DUR Environmental/Durability

FSC Functional Status Classification

GM General Motors

G Standard acceleration of free fall (Gravitational Constant), 9.80665 m/s^2

G_{RMS} Square root of the area under the PSD vibration curve

h Hour

H Henry

Hz Hertz

HALT Highly Accelerated Life Test

HAST Highly Accelerated Stress Test

HHC Humid Heat Cyclic

HHCO Humid Heat Constant

HVAC Heating Ventilation Air Condition

IEC International Electrotechnical Commission

IP International Protection

I/O Input/Output

ISO International Standards Organization

IV MRD Integration Vehicle Material Required Date

JEDEC Joint Electron Devices Engineering Councils Solid State Technology Association

l Liter

LED Light Emitting Diode

m Meter

N/A Not Applicable

Pa Pascal

PCB Printed Circuit Board

PPAP Production Part Approval Process

PSD Power Spectral Density

PTC Power Temperature Cycle

PV Product Validation

PWM Pulse Width Modulation

RMS Root Mean Square

s Second

SAE Society of Automotive Engineers

SQE Supplier Quality Engineer

SSTS Sub-System Technical Specification

TS Thermal Shock Air-To-Air

V Volt

VTC Validation Test Complete

Ω Ohm

12 Deviations

Global consensus has been achieved without deviations.

13 Notes

13.1 Environmental References. Additional environmental reference information may be obtained from the following sources:

- Steinberg, Dave E.: Vibration Analysis For Electronic Equipment, Third Edition, John Wiley and Sons, 2001.
- Hobbs, Gregg K.: Accelerated Reliability Engineering – HALT and HASS, John Wiley and Sons, 2000.
- Lipson, Charles and Sheth, Narendra J.: Statistical Design and Analysis of Engineering Experiments.
- Nelson, Wayne: Accelerated Life Testing, John Wiley and Sons, 1990.
- Peck, D. Steward: Comprehensive Model for Humidity Testing Correlation, IEEE Catalog # 86CH2256-6, 1986.
- Technology Report #5 Fundamental Concepts of Environmental Testing in Electricity and Electronics, Tabai Espec Corp., 1998.
- Azar, Kaveh: Electronics Cooling – Theory and Applications, Short Course, 1998.
- White, F.M.: Fluid Mechanics, Second Edition, Pg. 60, McGraw-Hill, New York, 1986.

- Clech, Jean-Paul: Solder Reliability Solutions: From LCCCS to Area-Array Assemblies, Proceedings from Nepcon West 1996.
- Clark, Dana W.: AFD and Inventive Troubleshooting, Ideation International Inc., 2000.
- Giacomo, Giulio, et-al: CBGA and C4 Fatigue Dependence On Thermal Cycle Frequency, 2000 International Symposium on Advanced Packaging Materials, 2000.
- Clech, Jean-Paul: SAC Solder Joint Reliability: Test Conditions and Acceleration Factors, SMT/Hybrid/Packaging Conference, Nurnberg, Germany, April 19, 2005.
- Clech, Jean-Paul: Acceleration Factors And Thermal Cycling Test Efficiency For Lead-Free Sn-Ag-Cu Assemblies, SMTA International Conference, Chicago, Il. September 2005.

14 Additional Paragraphs

Not applicable.

15 Coding System

This standard shall be referenced in other documents, drawings, etc. as follows:

Example: “GMW3172 C C C D A IP5K2”

Detailed explanation for coding and inclusion into CTS/SSTS documents appears in this document.

16 Release and Revisions

16.1 Release. This document was first approved and published in DEC 2000 to replace GM9123P and GMI12558.

16.2 Revisions.

Rev.	Date	Description (Org.)
B	DEC 2001	Complete Rework (McCullen-GMNA)
C	AUG 2004	Complete Rework (Edson-GMNA)
D	JUL 2004	Rewritten to address lead-free solder and improve prior content (Edson-GMNA)
E	SEP 2005	Complete Rework (Armbrust/Edson/Kurdian/Lange)
F	FEB 2007	Complete Rework (Andreasson/Edson/Kurdian/Lange)
G	AUG 2008	Complete Rework // Revision Code F; text rephrased (GMW3172 Global Community)

Appendix A – Lead-Free Solder Considerations

Due to legal regulations in several countries, the use of lead in electrical/electronic components, including solder, is prohibited. Industry has responded with an alternative solder that is lead-free. The most commonly used lead-free solder consists of tin/silver/copper (Sn/Ag/Cu).

The use of lead-free solder creates additional risks as described below. The component Hardware Design Review shall include the following lead-free considerations:

- **Fatigue Life:** Lead-free solder joints may have a reduced fatigue life as compared to lead-based solder joints, even though the tensile strength of lead-free solder is greater than lead-based solder. Lead-free solder joints also may have greater variability in fatigue life as compared to lead-based solder joints.
- **Temperature Solder Process:** Due to higher temperatures of the soldering process which may be associated with lead-free alloys, part aging and "popcorning" needs to be considered.
  "Popcorning" may occur due to trapped humidity inside plastic encapsulated parts which heats up and creates high pressure during the soldering process. This can cause the plastic case or internal die to crack. The humidity ingress can be caused by the part production process or by the uncontrolled environment. Efforts may be necessary to control the humidity of the environment of stored components awaiting assembly.
- **Brittle Solder Alloy:** Brittle solder alloy affects the interconnection of the parts on the PCB. This phenomenon can appear due to an improper PCB manufacturing process (e.g., thin layered Electroless Nickel Immersion Gold solder surfaces) or to solder alloys that change from a ductile nature to a brittle nature in the operational temperature range (e.g., lead-free solder at a temperature of -30 °C). This can represent a significant risk in high mechanical shock areas such as the door, engine, and locations on unsprung masses.
- **Ionic Contamination:** Flux residues from lead-free solder may be more inclined to produce ionic contamination when compared to lead-based fluxes, and special attention shall be given to the frost and humidity testing of lead-free solder assemblies.
- **Bismuth-based solder alloys:** Bismuth-Tin solder alloys may be used to achieve a similar melting point temperature to lead-based solders. Therefore, the parts are exposed to lower melting temperatures.
  However, the use of Bismuth in lead-free solder may present problems if any leaded components are used on the circuit board. The combination of Bismuth/Tin/Lead can result in a ternary phase material with the following risks:
  1) Low melting point of solder joint (e.g., +96 °C),
  2) Pad-lifting, due to asymmetrical cooling of two different solder alloys on the part attachment,
  3) Significant reduction of thermal fatigue life.
- **Tin Whiskers:** A detrimental tin-based phenomenon, known as "Tin Whisker Formation", may occur on solder and on parts. This phenomenon will occur without any special environmental condition being imposed. Parts "on the shelf" at room temperature will develop tin-whisker formation almost as quickly as parts in service. Whisker formation can be minimized by the use of a boundary layer between the copper and tin (e.g., nickel-plating).

- **Tin Pest:** Another tin-based phenomenon, known as "Tin-Pest", is also possible when pure tin (> 99.99 %) is used. Wart-like formations on the tin will begin to appear in cold temperatures and will degrade the tin into a gray powder. The "tin-pest" phenomenon is cold temperature driven starting at (-13 °C) and reaches a maximum reaction rate at (-30 °C).
- **Kirkendall Voids:** Thermal aging (time at elevated temperature) can lead to the formation of Kirkendall Voids at the interfaces of tin and copper. The formation of a string of these voids can produce a perforated tear line that represents a significant weakness relative to mechanical shock. The Universal Environmental/Durability Test Flow places the High Temperature Degradation test prior to the first Mechanical Shock test specifically to address this concern.

Appendix B – Component Environmental Test Plan

Component Name (no abbreviations): *(TBD)*	Revision Date: *(TBD)*	Revision Number: *(TBD)*
Component Part Number(s): *(TBD)*	Component Manufacturer: *(TBD)*	
Drawing Number: *(TBD)*	Project: *(TBD: First vehicle application, including model year and programs)*	
Prepared by (Supplier): *(TBD)*	Mounting Location in Vehicle: *(TBD)*	
Approved by (Supplier): *(TBD)*	Approved by GM Responsible Engineer: *(TBD)*	

Revision History

Date	Revision Number + Description
(TBD)	*(TBD)*
This Test Plan is approved with the following corrections and/or added conditions:	

1 Introduction

This Test Plan shall be completed by the supplier and submitted to GM 6 weeks after supplier sourcing for approval by the ENV/DUR Expert. All sections shall be included as stated in the outline, only additions of new sections are allowed. If a section is not applicable, this shall be stated in this Test Plan along with supporting justification in the relevant section description.

1.1 Purpose

The purpose of this Test Plan documents the component operation and test procedures for all tests according to GMW3172. It describes all test set-ups and the procedures to verify the environmental/durability robustness of the design.

1.2 Guideline for Test Descriptions

Provide specific test set-up information and information to the component, including block diagrams, photographs, etc. indicating component connections to the facility and test equipment. Do not include copies of generic set-up diagrams from IEC/ISO/SAE or other standards as long as you refer to the documents.

All sections shall be completed by the supplier. The information inside each section shall include as much detailed information as necessary for the completion of the test and its traceability/repeatability. Sections as shown in the template shall stay in the same order.

Example for the Free Fall Test:

Applicable Standard:	GMW3172, paragraph 9.3.11
Operating Type:	1.1
Monitoring:	N/A (refer to paragraph 3.3 when applicable)
Parameters:	Temperature: (+23 ± 5) °C Height: 1 m of free fall Surface: Concrete
Procedure:	1. Choose the X-Axis for the first fall. 2. Repeat the fall with the same axis, but in the opposite direction. 3. Repeat steps (1) and (2) with the next sample in Y-Axis. 4. Repeat steps (1) and (2) with the third sample in Z-Axis. 5. Document all visual damages by picture and add them to the test report. 6. Perform a 1-Point Functional/Parametric Check.
Criteria:	If there is no visible external damage to the component, then the component shall have no internal damage and shall pass the 1-Point Functional/Parametric Check at the end of test. If there is visible external damage to the component and if the damage is judged by GM Validation Engineer to be: – *Insignificant*, then the component shall have no internal damage and shall pass the 1-Point Functional/Parametric Check at the end of test. – *Significant*, 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.
Result:	

1.3 Quoting Requirements

According to the Component Technical Specification (CTS) or the Subsystem Technical Specification (SSTS), the GMW3172 Code Letters are defined as follows:

Electrical Loads	Mechanical Loads	Temperature Loads	Climatic Loads	Chemical Loads	Dust and Water Protection
(TBD)	*(TBD)*	*(TBD)*	*(TBD)*	*(TBD)*	*(TBD)*

The Code Letter definitions are referenced in **GMW3172 (August 2008)**.

This Classification results in following Parameters:

U_{min}	=	*(TBD)* ± 0.1 V	T_{min}	=	*(TBD)* ± 3 °C
U_A	=	*(TBD)* ± 0.1 V	T_{max}	=	*(TBD)* ± 3 °C
U_B	=	*(TBD)* ± 0.1 V	T_{PH}	=	*(TBD)* ± 3 °C
U_{max}	=	*(TBD)* ± 0.1 V	T_{RPS}	=	*(TBD)* ± 3 °C

Deviations from the above mentioned requirements shall be agreed by the responsible GM ENV/DUR Expert Engineer and need to be described in this document.

1.4 Parameter and Tolerance Requirements

Unless stated otherwise, the following shall define the test environment parameters and tolerances to be used for all validation testing:

Parameter	**Tolerance**
Ambient Temperature	Spec. ± 3 °C
Room Temperature	(+23 ± 5) °C
Test Time	Spec. ± 0.5 %
Room Ambient Relative Humidity	(30...70) %
Chamber Humidity	Spec. ± 5 %
Voltage	Spec. ± 0.1 V
Current	Spec. ± 1 %
Resistance	Spec. ± 10 %
Random Acceleration (G_{RMS})	Spec. ± 20 % (PSD deviations from applicable tables are not permitted)
Acceleration (Mechanical Shock, G)	Spec. ± 20 %
Frequency	Spec. ± 1 %
Force	Spec. ± 10 %
Distance (Excluding Dimensional Check)	Spec. ± 5 %

1.5 Test Requirements

Identify any non-applicable activities in the following table as “N/A”.

	Analysis	Development Number of samples	Design Validation Number of samples	Product Validation Number of samples
Analysis				
Electrical				
Nominal and Worst Case Performance Analysis				
Short/Open Circuit Analysis				
Mechanical				
Resonant Frequency Analysis				
High Altitude Shipping Pressure Effect Analysis				
Plastic Snap Fit Fastener Analysis				
Crush Analysis				
Temperature				
High Altitude Operation Overheating Analysis				
Thermal Fatigue Analysis				
Lead-Free Solder Analysis				
Development				
Electrical				
Jump Start				
Reverse Polarity				
Over Voltage				
State Change Waveform Characterization				
Ground Path Inductance Sensitivity				
Electromagnetic Compatibility (EMC)				
Mechanical				
Highly Accelerated Life Test (HALT)				
Temperature				
Temperature Measurement				

	Analysis	Development Number of samples	Design Validation Number of samples	Product Validation Number of samples
Low Temperature Wakeup				
Climatic				
Frost				
Highly Accelerated Stress Test (HAST)				
Dimensional				
Design Validation (DV)				
Electrical				
Parasitic Current				
Power Supply Interruptions				
Battery Voltage Dropout				
Sinusoidal Superimposed Voltage				
Pulse Superimposed Voltage				
Intermittent Short Circuit to Battery and to Ground				
Continuous Short Circuit to Battery and to Ground				
Ground Interconnect Short to Battery				
Open Circuit – Single Line Interruption				
Open Circuit – Multiple Line Interruption				
Ground Offset				
Power Offset				
Discrete Digital Input Threshold Voltage				
Over Load – All Circuits				
Over Load – Fuse Protected Circuits				
Isolation Resistance				
Mechanical				
Vibration With Thermal Cycling				
Post Thermal Fatigue Vibration				
Mechanical Shock – Pothole				

	Analysis	Development Number of samples	Design Validation Number of samples	Product Validation Number of samples
Mechanical Shock – Collision				
Mechanical Shock – Closure Slam				
Crush For Housing – Elbow Load				
Crush For Housing – Foot Load				
GMW3191 Connector Tests : Terminal Push-out Force				
GMW3191 Connector Tests : Connector-to-Connector Engagement Force				
GMW3191 Connector Tests: Locked Connector Disengagement Force				
GMW3191 Connector Tests: Unlocked Connector Disengagement Force				
Connector Installation Abuse – Side Force				
Connector Installation Abuse – Foot Load				
Free Fall				
Fretting Corrosion Degradation				
Climatic				
High Temperature Degradation				
Thermal Shock Air-To-Air (TS)				
Power Temperature Cycle (PTC)				
Thermal Shock/Water Splash				
Humid Heat Cyclic (HHC)				
Humid Heat Constant (HHCO)				
Salt Mist				
Salt Spray				
Enclosure				
Dust				
Water				

	Analysis	Development Number of samples	Design Validation Number of samples	Product Validation Number of samples
Seal				
Water Freeze				
Sugar Water Function Impairment				
Product Validation (PV)				
Shipping Vibration				
Additional Activities				
(TBD)				

1.6 Test Flows

1.6.1 Analysis

(TBD: test flow)

1.6.2 Development

(TBD: test flow)

1.6.3 Design Validation (DV)

(TBD: test flow)

1.6.4 Product Validation (PV)

(TBD: test flow)

2 Component Description

2.1 Component Family Description

Provide a brief component product family description, including any similarities and differences of planned hardware and software within the family. In some cases, it may make sense to select a specific sample for test that represents the entire component family. Please state the justification and rationale for doing this.

(TBD: e.g., sample selection chosen)

2.2 Component Physical Description

Provide a description of the component hardware including drawings and orientation in the vehicle.

(TBD: e.g., CAD drawing/photos/component orientation showing X-, Y-, and Z-axis)

2.3 Component Functional Description

Provide a brief overview of the component functions, including component interfaces. Use wording that describes the component to those not familiar with the component. Define all abbreviations. Provide a list of all used connector pins and their function. Provide an exceptions list for any functions/features that are not available for Development and DV.

(TBD: e.g., circuit diagram/connection to vehicle/pin definition/functionality)

2.4 Operating Types

The following table reflects the electrical operating type of GMW3172. Describe the I/O states for each Operating Type. Provide any additional clarification for component specific Electrical State as necessary.

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 connected with supply voltage U_B (battery voltage, generator not active) as in a vehicle with all electrical connections made.	
	2.1	Component functions are not activated (e.g., sleep mode, OFF mode).
	2.2	Component with electric operation and control in typical operating mode.
3	The component is electrically operated with supply voltage U_A (engine/generator active) with all electrical connections made.	
	3.1	Component functions are not activated (e.g., sleep mode, OFF mode).
	3.2	Components with electric operation and control in typical operating mode.

2.5 Functional Status Classification (FSC)

The FSC defines the functional performance of the component.

Class	Definition of FSC Class
A	All functions of the component perform as designed during and after the test.
B	All functions of the component perform as designed during the test. However, one or more of them may go beyond the specified tolerance. All functions return automatically to within normal limits after the test. Memory functions shall remain FSC A. 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.

3 Performance Verification

3.1 1-Point Functional/Parametric Check

Provide details of the 1-Point Functional/Parametric Check that is used during or after tests as defined in this Test Plan. This check shall be performed at T_{room}, U_{nom}.

Note: U_{nom} includes U_A and U_B, depending on Operating Type 2.1 or 3.2.

1) List all functions that will be verified by monitoring and recording all outputs (both hardwired and on-vehicle data bus communications), or a subset thereof, and their states for a given set of inputs and timing conditions. List appropriate tolerances and acceptance criteria.
2) List all parametric values, along with their tolerances, for all inputs and outputs, or a subset thereof, that will be monitored and recorded (e.g., voltages, currents, and timing levels).
3) List all non-electrical parameters, along with their tolerances, that will be monitored and recorded (e.g., LED brightness, motor torque, etc.).

(TBD)

3.2 5-Point Functional/Parametric Check

Provide details of the 5-Point Functional/Parametric Check that is used at the beginning and at the end of all test legs at the following temperature/voltage points:

1. (T_{min}, U_{min})
2. (T_{min}, U_{max})
3. (T_{room}, U_{nom})
4. (T_{max}, U_{min})
5. (T_{max}, U_{max})

Note: U_{nom} includes U_A and U_B, depending on Operating Type 2.1 or 3.2.

1) List all functions that will be verified by monitoring and recording all outputs (both hardwired and on-vehicle data bus communications) and their states for a given set of inputs and timing conditions. List appropriate tolerances and acceptance criteria.
2) List all parametric values, along with their tolerances, for all inputs and outputs that will be monitored and recorded (e.g., voltages, currents, and timing levels).
3) List all non-electrical parameters, along with their tolerances, that will be monitored and recorded (e.g., LED brightness, motor torque, etc.).
4) List all selected parameters that will be measured before and after testing in order to determine performance degradation.

(TBD)

3.3 Continuous Monitoring

Provide details for Continuous Monitoring that shall detect the functional status of the component during and after exposure to the test environment. Continuous Monitoring shall detect false actuation signals, erroneous serial data messages, fault codes, or other erroneous I/O commands or states. Describe the procedure, setup, and criteria that will be used for Continuous Monitoring.

1) Define the outputs (both hardwired and on-vehicle data bus communications) that will be monitored and recorded. Define the correct state for each monitored output for a given state of inputs and timing conditions. Define the monitoring sampling rate.
2) List the internal diagnostic codes that will be monitored and recorded.
3) List any specific component functionality that will be periodically observed, such as optical monitoring of test patterns. Define the frequency of the observations.

(TBD)

3.4 Functional Cycling

Provide details for the Functional Cycling that shall simulate customer usage during and after exposure to the test environment. List the tests where Functional Cycling will occur.

1) List the inputs/outputs (including on-vehicle data bus communications, as well as any mechanical actuations) that will be automatically cycled and monitored for proper functional operation. Define the cycling rate for inputs/outputs.
2) List the tests where power cycling (Ignition) will occur. Define the Power ON/Power OFF cycle rate.

(TBD)

3.5 Simulations and Loads

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 them by part number and design level. In case of simulated loads, a detailed definition is needed.

(TBD: e.g., Seat Motor – GM Part Number 55521213A, Speaker Load Simulation – 4 Ω, 5 % tolerance, 5 W, GMLAN Simulator – CANOE)

3.6 Visual Inspection and Dissection – DRBTR

The Visual Inspection and Dissection is a microscopic review of the component's case and internal parts at the completion of validation testing. Identify any structural faults, material/component/part degradations or residues, and near-to-failure conditions caused by environmental testing.
For each item listed below, describe the detailed aspects of what will be examined, and the procedure to do the examination:

1) Mechanical and Structural Integrity
(TBD: e.g., Cracks)

2) Solder/Part Lead Fatigue Cracks or Creep or Pad-Lift
(TBD: e.g., Pad lift in high flexure areas of the circuit board)

3) Damaged Surface Mount Parts
(TBD: e.g., SMD cracks near circuit board edges)

4) Large Part Integrity and Attachment
(TBD: e.g., Leaky electrolytic capacitors)

5) Material Degradation, Growth, or Residues of Corrosion
(TBD: e.g., Degraded conformal coatings)

6) Other Abnormal or Unexpected Conditions
(TBD: e.g., Changes in appearance)

7) The Formation of Whiskers When Tin, Zinc, or Silver is Used
(TBD: e.g., Tin-whiskers in close-pitched parts)

8) Absence of Dendritic Growth
(TBD: e.g., Signs of dendritic growth)

9) Solder Joint Voids
(TBD: e.g., Solder joint voids)

4 Analysis

4.1 Electrical

4.1.1 Nominal and Worst Case Performance Analysis

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

4.1.2 Short/Open Circuit Analysis

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

4.2 Mechanical

4.2.1 Resonant Frequency Analysis

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

4.2.2 High Altitude Shipping Pressure Effect Analysis

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

4.2.3 Plastic Snap Fit Fastener Analysis

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

4.2.4 Crush Analysis

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

4.3 Temperature

4.3.1 High Altitude Operation Overheating Analysis

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

4.3.2 Thermal Fatigue Analysis

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

4.3.3 Lead-Free Solder Analysis

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5 Development

5.1 Electrical

5.1.1 Jump Start

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5.1.2 Reverse Polarity

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5.1.3 Over Voltage

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5.1.4 State Change Waveform Characterization

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5.1.5 Ground Path Inductance Sensitivity

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5.1.6 Electromagnetic Compatibility (EMC)

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5.2 Mechanical

5.2.1 Highly Accelerated Life Test (HALT)

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5.3 Temperature

5.3.1 Temperature Measurement

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5.3.2 Low Temperature Wakeup

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5.4 Climatic

5.4.1 Frost

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5.4.2 Highly Accelerated Stress Test (HAST)

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

5.4.3 Dimensional

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6 Design Validation (DV)

6.1 Electrical

6.1.1 Parasitic Current

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.1.2 Power Supply Interruptions

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.1.3 Battery Voltage Dropout

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.1.4 Sinusoidal Superimposed Voltage

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.1.5 Pulse Superimposed Voltage

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.1.6 Intermittent Short Circuit to Battery and to Ground

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.1.7 Continuous Short Circuit to Battery and to Ground

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.1.8 Ground Interconnect Short to Battery

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.1.9 Open Circuit – Single Line Interruption

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.1.10 Open Circuit – Multiple Line Interruption

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.1.11 Ground Offset

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.1.12 Power Offset

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.1.13 Discrete Digital Input Threshold Voltage

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.1.14 Over Load – All Circuits

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.1.15 Over Load – Fuse Protected Circuits

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.1.16 Isolation Resistance

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.2 Mechanical

6.2.1 Vibration With Thermal Cycling

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.2.2 Post Thermal Fatigue Vibration

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.2.3 Mechanical Shock – Pothole

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.2.4 Mechanical Shock – Collision

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.2.5 Mechanical Shock – Closure Slam

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.2.6 Crush For Housing – Elbow Load

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.2.7 Crush For Housing – Foot Load

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.2.8 GMW3191 Connector Tests: Terminal Push-out Force

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.2.9 GMW3191 Connector Tests: Connector-to-Connector Engagement Force

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.2.10 GMW3191 Connector Tests: Locked Connector Disengagement Force

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.2.11 GMW3191 Connector Tests: Unlocked Connector Disengagement Force

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.2.12 Connector Installation Abuse – Side Force

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.2.13 Connector Installation Abuse – Foot Load

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.2.14 Free Fall

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.2.15 Fretting Corrosion Degradation

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.3 Climatic

6.3.1 High Temperature Degradation

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.3.2 Thermal Shock Air-To-Air (TS)

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.3.3 Power Temperature Cycle (PTC)

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.3.4 Thermal Shock/Water Splash

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.3.5 Humid Heat Cyclic (HHC)

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.3.6 Humid Heat Constant (HHCO)

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

6.3.7 Salt Mist

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.3.8 Salt Spray

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.4 Enclosure

6.4.1 Dust

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.4.2 Water

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.4.3 Seal

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.4.4 Water Freeze

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

6.4.5 Sugar Water Function Impairment

Applicable Standard:

Operating Type:

Monitoring:

Parameters:

Procedure:

Criteria:

Result:

7 Product Validation (PV)

7.1 Shipping Vibration

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result:

8 Additional Activities

8.1 TBD

Applicable Standard:
Operating Type:
Monitoring:
Parameters:
Procedure:
Criteria:
Result: