Design Requirement Document

Document No.	DR100159-06
Engineering Program No.	TBS – 1st program to comply will be used
Department No.	385395
System	EE Module
Subsystem	Modules and Components
Description	*Electronic Module and/or System Environmental Performance*

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1. Revision Summary Table

Revised By	Revision	Section	Description	Reason	Date
U00HEK2	00		Initial release. Formerly EEF-R1-020 Revision 6. No technical changes, includes formatting corrections.		19 May 2006
U00HRW2	01	2	Updated the dates for the SAE Document J1455 AUG94 to JUNE2006 and J551-1 JUN96 to OCT2006.	New updates from SAE.	24 Nov. 2008
U00HRW2	01	2	SAE Cancelled J1113-41 and replaced it with CISPR25.	SAE Cancelled J1113-41.	24 Nov. 2008
U00HRW2	01	2	Added SAE J1113-21 for EMI	SAE recommended.	24 Nov. 2008
U00HRW2	01	4.1.3.2	Added Salt Immersion Testing Section 4.1.3.2	New test from SAE.	24 Nov. 2008
U00HRW2	01	3.2	Replaced Region with Status functions.	New SAE nomenclature.	24 Nov. 2008
U00HRW2	01	3	Moved the module Classifications and Status from the EMI Section to their definition section.	Other tests now use the module Classification and status functions.	24 Nov. 2008
U00HRW2	01	3.1, 3.2, 3.3, 3.4	Removed sections 3.1 Features and Functions, 3.2 Performance, 3.3 Physical, 3.4 Electrical.	This in the product specifications.	24 Nov. 2008
U00HRW2	01	Was 3.5.1.4	Removed Thermal stress (Reliability Demonstration)	This will go in the new Reliability DRD.	24 Nov. 2008
U00HRW2	01	4.1.13.8.1, 4.1.13.8.2	Added Test Severity Level 4 to the Conducted and Coupled Transients Section.	New SAE test severity levels.	24 Nov. 2008
U00HRW2	01	4.2.1, 4.2.2	Added in cab and Chassis DV and PV test flow chart.	Recommended by the department.	24 Nov. 2008
U00HRW2	01	4.1.14.1.3.2	Added BCI Component Test per SAE 1113-4	SAE Recommended.	24 Nov. 2008
U00HRW2	01	Was 3.5.11.8	Ultraviolet Resistance was removed	This will be in the product specifications.	24 Nov. 2008
U00HRW2	01	4.1.13.3	Changed the voltage from -12.6vdc to -24vdc	SAE Changed the voltage from -12.6vdc to -24vdc	24 Nov. 2008

U00HRW2	02	4.1.13.8.1.2.1	Added Low Side Output Testing with Inductive Switching Pulse1.	Field Failures with Low Side Outputs bias with Ignition and connected in parallel with an Inductive load. Reference Pyxis 145948 and 8D #10034.	9 July 2009
U00HRW2	02	4.1.13.3	Remove the wording after 5 minutes at -24vdc.	Per Russell Smith Review	9 July 2009
U00HRW2	02	4.1.13.4	Remove the wording after 5 minutes at 9vdc.	Per Russell Smith Review	9 July 2009
U00HRW2	02	4.1.14.1.2	Changed class from 4 to 3.	Used the edition 2 tables should have used edition 3 CISPR 25	9 July 2009
U00HRW2	02	4.1.14.2.1	Changed class from 5 to 4.	Used the edition 2 tables should have used edition 3 CISPR 25	9 July 2009
U00U930	03	4.1.14.2.1	From CISPR 25 to CISPR 12	Was CISPR 25, 25 applies to modules, 12 is vehicle level	26 Feb 2010
U00U930	03	4.1.13.1 thru 7	Added 24V test levels	Update for global 24V system requirements	26 Feb 2010
U00U930	03	4.1.13.8.1.1.2	Change 10Ω to 200Ω	Reference Pyxis 145948 and 8D #10034, modified based upon 8D test results	26 Feb 2010
U023768	05	Was 4, 4.1, 4.1.2, 4.1.3, 4.1.10, 4.1.10.3, 4.1.11, 4.1.13.2.1, 4.1.13.2.2, 4.1.14, 4.1.14.1, 4.1.14.1.3, 4.1.14.2, 4.2, 4.1.14.2.2.1	Sections Removed	These sections were redundant when moved into the new document format	11 Jan 2013
U023768	05	2	Used to be Section 1	Formatting change	11 Jan 2013
U023768	05	3	Used to be Section 2	Formatting change	11 Jan 2013
U023768	05	3.1, 3.2	Included latest Industry Standards and Navistar Documents		11 Jan 2013
U023768	05	4.1	Included Functional Test Definition	Definition of procedure to be followed after test	11 Jan 2013
U023768	05	4.2	Included Parametric Test Definition	Definition of procedure to be followed after test	11 Jan 2013
U023768	05	4.3	Used to be Section 3.2	Formatting change	11 Jan 2013
U023768	05	4.4	Used to be Section 3.3	Formatting change	11 Jan 2013
U023768	05	4.5	Included table of nomenclature		11 Jan 2013

U023768	05	5	Created for all Environmental Tests	Formatting change	11 Jan 2013
U023768	05	5.1	Used to be Section 4.1.1 Added specific temperature ranges for various mounting locations	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.2	Included new requirement	Test sequence to be used as indicated in the test flow chart	11 Jan 2013
U023768	05	5.3	Used to be Section 4.1.1.1 Added specific temperature ranges	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.4	Used to be Section 4.1.1.2 Added specific test flow and parameters along with a new figure	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.5.1	Used to be Section 4.1.1.3 Added specific test flow and parameters along with a new figure	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.5.2	Included new requirement	This test will demonstrate long term reliability	11 Jan 2013
U023768	05	5.6.1	Used to be Section 4.1.2.1 Added specific test flow and parameters along with a new figure	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.6.2	Included new requirement	This test will demonstrate long term reliability	11 Jan 2013
U023768	05	5.6.3	Used to be Section 4.1.2.2 Included statement indicating frost condition may be introduced during Humidity testing	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.7	Used to be Section 4.1.3.1 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.8	Used to be Section 4.1.3.2 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.9	Used to be Section 4.1.4 Added specific test parameters and table of chemicals.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.10.1	Used to be Section 4.1.5 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.10.2	Used to be Section 4.1.5	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013

			Added specific test parameters. Separated from 5.10 to reduce confusion.		
U023768	05	5.11	Used to be Section 4.1.6 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.12.1	Used to be Section 4.1.9 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	5.12.2	Used to be Section 4.1.9 Added specific test parameters. Separated from 5.12 to reduce confusion.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	6	Created for all Mechanical Tests	Formatting change	11 Jan 2013
U023768	05	6.1	Used to be Section 4.1.7 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	6.2	Used to be Section 4.1.8 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	6.3	Used to be Section 4.1.12 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	6.4	Used to be Section 4.1.10.1 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	6.5	Used to be Section 4.1.10.2 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	6.6	Used to be Section 4.1.11.1 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	6.7	Used to be Section 4.1.11.2 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	6.8	Used to be Section 4.1.11.3 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	6.9	Used to be Section 4.1.11.4 Changed from SAE J1455 method to MIL-STD-202G method.	MIL-STD-202G offers a test that suits truck applications better than the SAE method.	11 Jan 2013
U023768	05	7	Created for all Electrical Tests	Formatting change	11 Jan 2013

U023768	05	7.1	Included section to indicated specific voltage requirements.	Previous revision did not make this information clear.	11 Jan 2013
U023768	05	7.2	Used to be Section 4.1.13.1 Updated verbiage	Formatting change	11 Jan 2013
U023768	05	7.3	Used to be Section 4.1.13.2 Updated verbiage Changed Vs to 4.5V for 12V systems and 6V for 24V systems.	Formatting change New requirements per direction of Eric Swenson provides a realistic simulation of a typical Navistar vehicle.	11 Jan 2013
U023768	05	7.4	Used to be Section 4.1.13.3 Updated verbiage Changed Reverse Voltage to -25.2V for 12V system and -28.4V for 24V system.	Formatting change New requirements simulate a reverse double battery condition	11 Jan 2013
U023768	05	7.5	Used to be Section 4.1.13.4 Updated verbiage	Formatting change	11 Jan 2013
U023768	05	7.6	Used to be Section 4.1.13.5 Updated verbiage	Formatting change	11 Jan 2013
U023768	05	7.7	Used to be Section 4.1.13.6 Updated verbiage	Formatting change Included new requirement to test at max temp and min voltage	11 Jan 2013
U023768	05	7.8	Used to be Section 4.1.13.7 Updated verbiage	Formatting change	11 Jan 2013
U023768	05	7.9	Used to be Section 4.1.13.8.1	Formatting change	11 Jan 2013
U023768	05	7.9.1	Used to be Section 4.1.13.8.1.1.1 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	7.9.2	Used to be Section 4.1.13.8.1.1.1 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	7.9.3	Used to be Section 4.1.13.8.1.1.1 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	7.9.4	Used to be Section 4.1.13.8.1.2 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	7.9.5	Used to be Section 4.1.13.8.1.2	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013

			Added specific test parameters.		
U023768	05	7.9.6	Used to be Section 4.1.13.8.1.1 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	7.9.7	Used to be Section 4.1.13.8.1.1.2 Updated verbiage	Formatting change	11 Jan 2013
U023768	05	7.10	Used to be Section 4.1.13.8.2	Formatting change	11 Jan 2013
U023768	05	7.10.1	Used to be Section 4.1.13.8.2.1 Renamed to Capacitive Coupling Clamp Added specific test parameters.	Name change to align with SAE J1113-12 To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	7.10.2	Used to be Section 4.1.13.8.2.2 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	7.11.1	Used to be Section 4.1.13.8.3 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	7.11.2	Included requirement for all HMI components	ESD issues were reported when components were powered	11 Jan 2013
U023768	05	7.12	Used to be Section 4.1.14.1.1 Updated verbiage	Formatting change	11 Jan 2013
U023768	05	7.13	Used to be Section 4.1.14.1.2 Changed upper frequency limit to 1.583 GHz	GPS operates at 1.583 GHz and we must ensure that components do not interfere with it	11 Jan 2013
U023768	05	7.14	Used to be Section 4.1.14.1.3.1 Changed frequency range to 10 kHz to 3 GHz	Upper limit was brought down to a more realistic testable value. 3 GHz covers most radiation sources the vehicle can be subjected to. Removed levels 1 and 2 as they were not realistic	11 Jan 2013
U023768	05	7.15	Used to be Section 4.1.14.1.3.2 Updated verbiage	Formatting change Removed levels 1 and 2 as they were not realistic	11 Jan 2013
U023768	05	8	Created for all Vehicle Level Tests	Formatting change	11 Jan 2013
U023768	05	8.1	Used to be Section 4.1.13.8.3.2 Added specific test parameters.	To reduce confusion amongst Engineers and Suppliers	11 Jan 2013
U023768	05	8.2	Used to be Section 4.1.14.2.1	Formatting change	11 Jan 2013

			Updated verbiage		
U023768	05	8.3	Used to be Section 4.1.14.2.2.2 Changed frequency range to 10 kHz to 3 GHz	Reference changed to ISO 11451-2. Upper limit was brought down to a more realistic testable value. 3 GHz covers most radiation sources the vehicle can be subjected to.	11 Jan 2013
U023768	05	8.4	Included new requirement	Documented SINAD test that was being performed on Navistar vehicles per regulation of certain U.S. States	11 Jan 2013
U023768	05	9	Used to be Section 4.2.1 Updated to separate electrical and mechanical tests. Included new tests.	Updated to reflect new test requirements	11 Jan 2013
U023768	05	9.1	Included to show test flow when using Combined Environmental testing to replace Temperature Cycling, Humidity, and Vibration	Updated to reflect new test requirements	11 Jan 2013
U023768	05	5.2	Included 60 min soak at each temperature	Test length was not clear previously	01 Jul 2013
U023768	05	5.7	Used to be Section 5.6.3. Frost testing method was not defined in SAE. Test structured based on prior lessons learned. Moved away from Humidity subsection	Test method was not defined in SAE	01 Jul 2013
U023768	05	5.12	Removed “Optional” wording	Removed “Optional” to make requirements more consistent with rest of DRD.	01 Jul 2013
U023768	05	7.15	Specified Calibrated Injection Probe Method as the method to test BCI	Method was not previously defined in DRD.	01 Jul 2013
U023768	05	9	Rearranged Test Flow	Moved more destructive tests near the end of test legs so they do not interrupt long testing	01 Jul 2013
U023768	05	9.1	Rearranged Test Flow	Moved more destructive tests near the end of test legs so they do not interrupt long testing	01 Jul 2013
U023768	05	10	Included Reliability Test Requirements	Was not required before. Shall be defined in component DRD	01 Jul 2013
U023768	05	7.4	Updated Reverse Polarity spec	Included new specifications for devices capable of driving external loads greater than 5 A.	31 Jul 2013
U023768	05	7.4	Updated Reverse Polarity spec	Changed specifications for devices capable of driving external loads	05 Aug 2013

U023768	05	7.14	Updated Radiated Immunity Spec	Changed frequency step size to cover SAE J1113-4 and ISO 11452-1 requirements	05 Aug 2013
U023768	05	7.15	Updated Bulk Current Injection Spec	Changed frequency step size to cover SAE J1113-4 and ISO 11452-1 requirements	05 Aug 2013
U023768	05	8.3	Updated Vehicle Level Radiated Susceptibility Spec	Changed frequency step size to cover SAE J1113-4 and ISO 11452-1 requirements	06 Aug 2013
u00ets1	06	3.1	Updated SAE J1455 Revision	Changed from Aug 2012 to MAR 2017	24 Apr 2019
u00ets1	06	7.13	Added extrapolation to CISPR 12 limits	DUT shall not exceed 54 – 2 dBu at 30MHz at 1 m antenna spacing	24 Apr 2019
u00ets1	06	7.7	Added minimum temperature to lab and maximum temperature to shorts test. Clarified repetition of ground voltage source for min and max temperatures.	Shorts were evaluated only at lab and maximum temperatures before. Similar tests are described in ISO 16750-2.	2 Jul 2019
u00ets1	06	5.8 and 5.9	Allow 3 parts NaCl plus 2 parts $MgCl_2$ to 95 parts water	Avoids setup charge while continuing use of $MgCl_2$	2 Jul 2019
u00ets1	06	7.9.7	Added example test circuit	Verbal description alone deemed inadequate	2 Jul 2019
u00ets1	06	7.9.6	The period shall be 45 s +/- 5 seconds.	No min or max time between load dump pulses was previously defined. Existing test equipment uses 45 s as the period.	2 Jul 2019
u00ets1	06	4.2	Added [0, 5) mA quiescent current requirement to parametric test discussion.	Ensure that quiescent current measurements are not omitted in DVP&Rs	2 Jul 2019
u00ets1	06	4.2	Added CAN Network segment error frame criteria to parametric test discussion	Ensure that network segment performance is monitored during tests	2 July 2019
u00ets1	06	6.5	Added ISO 15750-3 test profiles to random vibration test.	ISO 15750-3 test profiles are more recent than SAE J1455 profiles.	2 July 2019
u00ets1	06	7.1.2	Added intermittent power performance specification	Not all devices are engine controllers that must survive engine crank voltage curve	2 July 2019
u00ets1	06	5.2	Added intermittent power performance specification to minimum test requirements for 3 temperature parametric testing.	Mechanical shock testing can induce a failure to for the power interruption requirement.	11 July 2019
u00ets1	06	7.14 and 8.3	Added step sizes from table 2 of ISO 11452-1 and SAE J551-1	Existing step sizes were incomplete	11 July 2019
u00ets1	06	5.12	Added analysis to substitute for a fungal growth test	Analysis allowed in SAE J1455	11 July 2019
u00ets1	06	5.7	Clarify minimum lab temperature during test	Low temps limit available water vapor.	11 July 2019
u00ets1	06	4.5.1-4.5.2	Added explanation for test criteria: and acceptance criteria: as used in the body of the text.	Test criteria contain a blend of conditions and failure criteria, which must be applied in addition to acceptance criteria.	12 July 2019

u00ets1	06	7.8	Clarified batteryless operating voltages (and sweep) to better match 7.1.	Retaining old voltages was an error of omission when the minimum operating voltage was changed to 9V.	12 July 2019
u00ets1	06	7.14	Started test at 200 MHz instead of 10 kHz. Added threshold voltage determination as an outcome.	BCI is better from 10 kHz – 200 MHz. Cannot asses risk without threshold voltage.	12 July 2019
u00ets1	06	7.15	Refined BCI to overlap RI test (starting at 10 kHz) and updated step size.	Provides better alignment with industry practice for immunity testing.	12 July 2019
u00ets1	06	4.4	Clarified Status I as expected outcome in 4.4	Reinforces subsequent definitions in 4.5.	23 July 2019
u00ets1	06	5.1	Added requirement for a thermal analysis in 5.1	Provide an expectation of data for this standard practice.	23 July 2019

Table 1: Revision Summary

2. Scope

2.1. Purpose

This environmental specification is to be used in conjunction with the component and/or system specification to qualify the components and/or systems for application on Navistar vehicles.

This specification sets the testing parameters required to assure acceptable operation within the vehicle environment for electronic modules and/or systems, which are used on Navistar vehicles. This specification evaluates electronic modules and/or systems for acceptable life when those modules and systems must function on Navistar vehicles.

2.2. Description

This general environmental specification is a recommended requirement. The device(s) specification shall take precedence over this document. The device(s) specification shall indicate the Test Class and Status levels.

3. Applicable Documents

3.1. Industry Standards

Document	Revision	Title
CISPR 12	MAR 2009	Vehicles, boats and internal combustion engines. Radio disturbance characteristics. Limits and methods of measurement for the protection of off-board receivers
CISPR 25	MAR 2008	Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of on-board receivers
ISO 11451-2	FEB 2005	Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 2: Off-vehicle radiation sources
ISO 12103-1	DEC 1997	Road vehicles — Test dust for filter evaluation
ISO 16750-2	2012-12-15	Road Vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 2 Electrical loads
ISO 16750-3	2012-12-15	Road Vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 3 Mechanical loads
ISO 22241-1	OCT 2006	Diesel engines — NOx reduction agent AUS 32
MIL-STD-202G	FEB 2002	Department of Defense – Test Method Standard – Electronic and Electrical Component Parts
MIL-STD-810G	OCT 2008	Department of Defense – Test Method Standard – Environmental Engineering Considerations and Laboratory Tests
SAE J400	OCT 2012	Test for Chip Resistance of Surface Coatings
SAE J551-1	JUN 2010	Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (16.6 Hz to 18 GHz)
SAE J1113-1	MAR 2012	Electromagnetic Compatibility Measurement Procedures and Limits for Components of Vehicles, Boats (up to 15 m), and Machines (Except Aircraft) (16.6 Hz to 18 GHz)
SAE J1113-4	AUG 2004	Immunity to Radiated Electromagnetic Fields—Bulk Current Injection (BCI) Method
SAE J1113-11	JAN 2012	Immunity to Conducted Transients on Power Leads
SAE J1113-12	AUG 2006	Electrical Interference by Conduction and Coupling— Capacitive and Inductive Coupling via Lines Other than Supply Lines
SAE J1113-13	JUN 2011	Electromagnetic Compatibility Measurement Procedure for Vehicle Components - Part 13: Immunity to Electrostatic Discharge
SAE J1113-21	OCT 2005	Electromagnetic Compatibility Measurement Procedure for Vehicle Components— Part 21: Immunity to Electromagnetic Fields, 30 MHz to 18 GHz, Absorber Lined Chamber
SAE J1455	MAR 2017	Recommended Environmental Practices for Electronic Equipment Design in Heavy-Duty Vehicle Applications
UN ECE R 10-04	MAR 2012	Vehicles with regard to electromagnetic compatibility

Table 2: Industry Standards

3.2. Navistar Documents

Document	Revision	Title
EES-SE-V-0001	1.0	Vehicle System Requirements – Electrical
RA-SD-NDR-006	11	Vehicle Radio Frequency Emissions and Immunity

Table 3: Navistar Documents

4. Definitions and Nomenclature

4.1. Functional Test

The functional test is intended to be a very basic quick test that simply verifies that the DUT is operational. This test needs only to take attribute data. Items such as verifying that an output is on or off, that an output responds when an input signal is present, etc.

Functional testing shall monitor all CAN network segments supported by the DUT for network error frames. Observation of over 17 error frames per second as a result of the stimuli below shall constitute a failure. Observation of over 4 error frames per second shall be noted as an incident and explained.

4.2. Parametric Test

The parametric test is intended to be an extensive and detailed test that measures variable data on all the functionality intended by the DUT as well as each of the I/O of the DUT. The test steps shall measure variable data on items such as output voltage from high side drivers, saturation voltage on low side drivers, switching thresholds on digital inputs, leakage currents on output drivers, response curves on sensors, etc.

Parametric testing for devices with battery bus connections shall include quiescent current measurements for the off state and the sleep state (where supported). If there is no quiescent current limit defined in the DRD for the DUT, then 0.5 [0, 5) mA at 23 degrees Celsius shall be used as the success criteria for parametric testing of the off state.

Parametric testing shall monitor all CAN network segments supported by the DUT for network error frames. Observation of over 17 error frames as a result of the stimuli below shall constitute a failure. Observation of over 4 error frames shall be noted as an incident and explained.

4.3. Functional Class

This element classifies the operational status of the function for an electrical/electronic device within the vehicle:

- Class A — Any function that provides a convenience (e.g., entertainment, comfort).
- Class B — Any function that enhances, but is not essential, to the operation or control of the vehicle (e.g., TPMS).
- Class C — Any function that is essential to the operation or control of the vehicle (e.g., braking, engine management).

4.4. Status of Performance

This element defines the expected performance objectives of the device under test subjected to the test conditions.

- Status I—Normal Performance within the specification limits during and after exposure to a disturbance.
- Status II—Temporary degradation or loss of function or performance that which is self-recoverable after the disturbance is removed.
- Status III—Temporary degradation or loss of function or performance which requires operator intervention or system reset after the disturbance is removed.
- Status IV—The device/function shall not have sustained any damage after the disturbance is removed.

Normal performance or Status I is the expected passing outcome for all tests unless Status II, III, or IV is specifically allowed for a given test.

4.5. Nomenclature

4.5.1. Test Criteria

Test Criteria: defines the test conditions and the required outcome monitoring for the DUT while the test is being run. The test monitoring requirement is often the functional test described in 4.1. DUTs that fail the required test monitor during the test, fail the test.

4.5.2. Acceptance Criteria

Acceptance Criteria: define post-test (exposure) evaluations that the DUT shall meet in addition to the test criteria to pass a given test. Often this will include a parametric test, run at nominal voltage and laboratory temperature, like that described in section 4.2.

4.6. Abbreviations

Abbreviation/Acronym	Description
A	Amp
CISPR	Special international committee on radio interference
dB	Decibel
DC	Direct Current
DUT	Device(s) Under Test
DV	Design Validation
GHz	Gigahertz
HMI	Human Machine Interface
ISO	International Organization for Standardization
kHz	Kilohertz
m	Meter
mA	Milliamp
MHz	Megahertz
mS	Millisecond
nS	Nanosecond

Abbreviation/Acronym	Description
Ω	Ohm
pF	Picofarad
PV	Process Validation
RF	Radio Frequency
SAE	Society of Automotive Engineers
S	Second
µS	Microsecond
µV	Microvolt
V	Volt

Table 4: Definitions and Nomenclature

5. Climatic Environment

5.1. Operational Temperature

The DUT shall be capable of operating in the ambient temperature ranges listed in Table 5: Temperature based on the mounting location.

Mounting Location	Minimum Temperature	Maximum Temperature
In Cab	-40^{0}C	85^{0}C
Chassis	-40^{0}C	125^{0}C
Chassis (near heat source)	-40^{0}C	150^{0}C
Engine Bay	-40^{0}C	125^{0}C
Engine Bay (near heat source)	-40^{0}C	150^{0}C

Table 5: Temperature Based on the Mounting Location

Prior to DV testing, the design agency shall provide an operating temperature analysis of any newly designed assembly(ies) to show that the design limits for temperature for internal components (e.g. T_j for semiconductor devices) and materials will not be exceeded during the operation of the assembly in a vehicle.

5.2. Three Temperature Parametric Test

The DUT shall be subjected to Three Temperature Parametric Tests to confirm functionality prior and post DV/PV testing. These tests shall implement the principles and requirements in Section 4.2. The DUT shall first be soaked at 23^0 ± 1^{0}C for 60 minutes before taking parametric measurements. The DUT shall then be soaked at the minimum temperature as described in Section 5.1 for 60 minutes before taking parametric measurements. The DUT shall finally be soaked at the maximum temperature as described in Section 5.1 for 60 minutes before taking parametric measurements.

Test Criteria: The DUT shall be subjected to the nominal voltage, minimum voltage, and maximum voltage as described in Section 7.1 during the test. The DUT shall meet all parametric test requirements during the test. The DUT shall be subjected to the voltage outages described in section 7.1 at 23 degrees Celsius, the DUT shall meet the status descriptions given in table 11-2.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: N/A

5.3. Storage Temperature Test

The DUT shall be subjected to a low storage temperature of -55^{0}C for 24 hours and a high storage temperature of 95^{0}C for 48 hours.

Test Criteria: The DUT is not required to meet functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.1.1.6, *"Ambient Conditions Before Installation Due to Storage and Transportation Extremes"*
MIL-STD-810G REV OCT2008, Part One Annex C Table C-I, *"Summary of climatic conditions and daily cycles of temperature, solar radiation, and relative humidity"*

5.4. Thermal Cycle Test

The DUT shall be subjected to the test cycle outlined in Figure 1: Temperature Cycle Test. One test cycle consists of varying temperature levels for 24 hours. The DUT shall be subjected to a total of 30 cycles (720 hours). The DUT shall be subjected to the minimum operating temperature to the maximum operating temperature as described in Section 5.1. A typical fall time from 23^{0}C to -40^{0}C, MAX^{0}C to 23^{0}C should take approximately 1 hour. A typical rise time from -40^{0}C to MAX^{0}C should take approximately 2 hours.

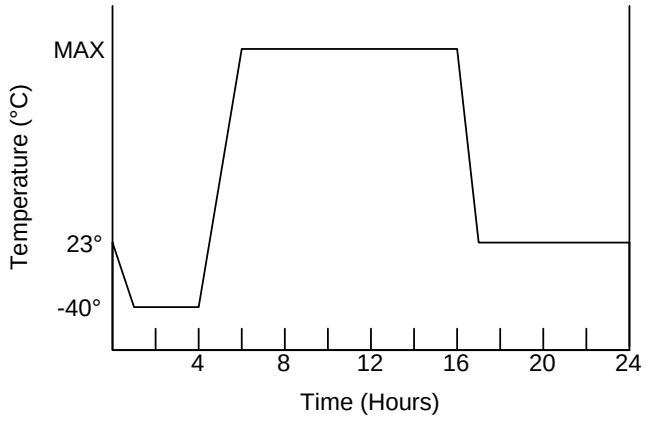

Figure 1: Thermal Cycle Test

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.1.3.1, *"Temperature Cycle Test"*
SAE J1455 REV MAR2017, Figure 2A, *"24 Hour Thermal Cycle Test"*

5.5. Thermal Shock Test

5.5.1. Thermal Shock Test (Short)

The DUT shall be subjected to the test cycle outlined in Figure 2: Thermal Shock Test. One test cycle consists of a 1 hour soak at the minimum operating temperature as described in Section 5.1 followed by a transfer to the hot chamber for a 1 hour soak at the maximum operating temperature as described in Section 5.1. Each transfer shall occur in 1 minute or less. The DUT shall be subjected to a total of 84 cycles (168 hours).

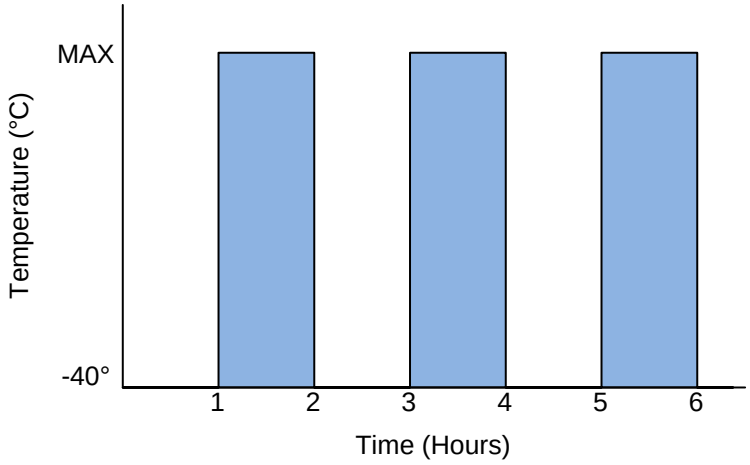

Figure 2: Thermal Shock Test

Test Criteria: The DUT is not required to be operational during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.1.3.2, *"Thermal Shock Test"*
SAE J1455 REV MAR2017, Figure 2C, *"Thermal shock"*

5.5.2. Thermal Shock Test (Long)

The DUT shall be subjected to the test cycle outlined in Figure 2: Thermal Shock Test. One test cycle consists of a 1 hour soak at the minimum operating temperature as described in Section 5.1 followed by a transfer to the hot chamber for a 1 hour soak at the maximum operating temperature as described in Section 5.1. Each transfer shall occur in 1 minute or less. The DUT shall be subjected to a total of 500 cycles (1000 hours). This test is required for all Class C devices.

Test Criteria: The DUT is not required to meet functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.1.3.1, *"Temperature Cycle Test"*
SAE J1455 REV MAR2017, Figure 2A, *"24 Hour Thermal Cycle Test"*

5.6. Humidity Test

5.6.1. Humidity Test (Short)

The DUT shall be subjected to the test cycle outlined in Figure 3: Humidity Test (Short). One test cycle consists of varying temperature and humidity levels for 24 hours. The DUT shall be subjected to a total of 7 cycles (168 hours). A typical fall time from 23^{0}C to -40^{0}C, 85^{0}C to 40^{0}C, or 40^{0}C to 23^{0}C should take approximately 30 minutes. A typical rise time from -40^{0}C to 85^{0}C should take approximately 45 minutes.

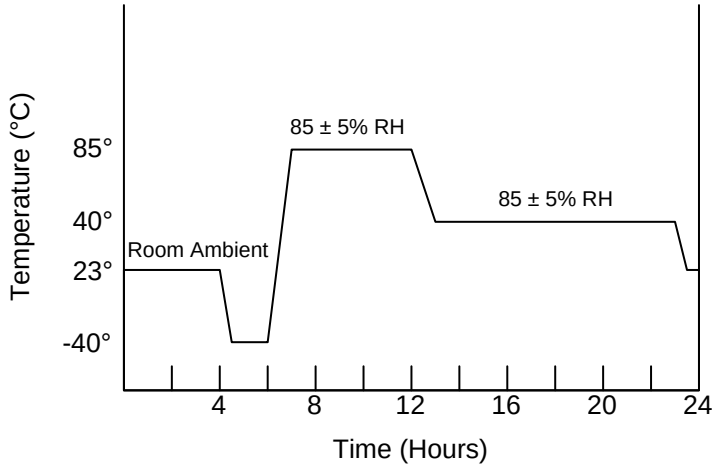

Figure 3: Humidity Test (Short)

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.2, *"Humidity"*
SAE J1455 REV MAR2017, Figure 4b, *"24 h Humidity Cycle"*

5.6.2. Humidity Test (Long)

The DUT shall be subjected to a constant 85^0C with 85% ± 5% Relative Humidity. The DUT shall be subjected for a total of 1000 hours. This test is required for all Class C devices.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.2, *"Humidity"*

5.7. Frost Test

The DUT shall be soaked at -40^0C for 60 minutes. With laboratory humidity at a minimum of 40% relative humidity, and the room temperature no less than 22 degrees Celsius, the environmental chamber shall be powered off with the door fully open to induce frost on the DUT. Testing shall be performed within 5 minutes of the environmental chamber door being opened.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all functional test requirements during the test. The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.2, *"Humidity"*

5.8. Salt Spray Test

The DUT shall be subjected to a salt spray consisting of 5 parts NaCL to 95 parts water at 35^0C. The DUT shall be subjected to the number of hours outlined in Table 6: Salt Spray Test depending on mounting location for each salt solution. This test shall be repeated with 5 parts of $MgCL_2$ to 95 parts water at 35^0C. The DUT shall be rinsed in deionized water between each salt exposure. The DUT shall be mated with a sealed connector for this test. The use of unsealed connectors must be approved in writing by Navistar Engineering. Periodic inspections during an ASTM B117 test are needed to avoid oxygen depletion in the test chamber. The units under test shall be observed daily to affirm test equipment function and facilitate oxygen replenishment. Oxygen depletion limits corrosion reactions.

Mounting Location	Hours of Exposure
In Cab	96 Hours
Chassis	240 Hours
Engine Bay	240 Hours

Table 6: Salt Spray Test

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.3.3.1, *"Salt Spray (Fog)"*

Note: This test may be conducted using 3 parts NaCl plus 2 parts $MgCl_2$ to 95 parts water (by weight) at 35ºC for twice the hours of exposure listed in Table 6. SAE J2721 may be considered as a substitute to ASTM B117.

5.9. Immersion Test

The DUT shall be subjected to a water immersion consisting of 5 parts NaCl to 95 parts water at 74^0C for 1 hour, then immediately transferred to the same salt water solution at 0^0C for 1 hour. The DUT shall be immersed at a depth of 1 meter. This test shall be repeated with 5 parts of $MgCL_2$ to 95 parts water. The DUT shall be rinsed in deionized water between each salt exposure. The DUT shall be mated with a sealed connector for this test. The use of unsealed connectors must be approved in writing by Navistar Engineering.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.
Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.3.3.2, *"Immersion Testing"*

Note: This test may be conducted using 3 parts NaCl plus 2 parts $MgCl_2$ to 95 parts water at 35ºC when this option is used for test 5.8.

5.10. Exposure to Chemicals and Oils

The DUT shall be subjected to a chemical exposure of a selection of the chemicals listed in Table 7: Chemicals and Oils. The device(s) DRD shall list all applicable chemicals based on the mounting location.

For Chassis and Engine mounting locations, the DUT shall be subjected to 100% coverage using 80^0 flat fan nozzles located 20 to 25 cm away. The DUT shall be subjected to 200kPa of pressure with a flow rate of 2650 cm^3/min. One test cycle consists of 5 minutes exposure to the chemical followed by 5 minutes of no exposure. The DUT shall be subjected to a total of 2 cycles (20 minutes).

For In-Cab mounting locations, the DUT shall be subjected to liberal coating of the chemical via a chemically compatible brush. The DUT with the chemical applied shall be allowed to stand for 24 hours before being inspected.

Chemical Immersion may be necessary for certain mounting locations. The DUT shall be subjected to chemical immersion for 5 to 10 minutes. The DUT with the chemical applied shall be allowed to stand for 24 hours before being inspected.

Chemicals and Oils	
Engine Oils and Additives	Battery Acid
Transmission Oil	Waxes
Rear Axle Oil	Kerosene
Power Steering Fluid	Freon / R134A
Brake Fluid	Spray Paint
Axle Grease	Paint Strippers
Window Washer Solvent	Ether
Gasoline	Dust Control Agents ($MgCl_2$)
Diesel Fuel	Moisture Control Agents ($CaCl_2$)
Fuel Additives	Vinyl Plasticizers
Alcohol	Undercoating Material
Anti-Freeze Water Mixture	Muriatic Acid
Degreasers	Ammonia
Soap and Detergents	Steam
Diesel Exhaust Fluid (ISO 22241) (32.5% solution of high-purity urea in de-mineralized water i.e. Aqueous Urea Solution 32)	

Table 7: Chemicals and Oils

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.4, *"Exposure to Chemicals and Oils"*
ISO 22241-1 REV OCT2006, *"Diesel engines — NOx reduction agent AUS 32"*

5.11. Steam Cleaning and Pressure Washing

5.11.1. Pressure Washing

The DUT shall be subjected to a pressure wash. The device(s) DRD shall state the applicable test. The DUT shall be mated with a sealed connector for this test. This test is not required for unsealed modules with unsealed connectors.

The DUT shall be subjected to 1400 kPa with a flow rate of 9460 cm^3/min of non-heated tap water. The DUT shall be placed 20 to 30 cm away from the nozzles. The DUT shall be subjected to spray for 3 seconds on each side of the component with a 15^0 fan nozzle. The DUT shall be subjected to a total of 378 sprays.

The DUT shall be subjected to 7000 kPa with a flow rate of 9460 cm^3/min of a wash solution with detergent heated to 40^0C. The DUT shall be placed 20 to 30 cm away from the nozzles. The DUT shall be subjected to spray for 3 seconds on each side of the component with a 15^0 fan nozzle. The DUT shall be subjected to a total of 378 sprays.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.5, *"Steam Cleaning and Pressure Washing"*

5.11.2. Steam Cleaning

The DUT shall be subjected to a pressure wash. The device(s) DRD shall state the applicable test. The DUT shall be mated with a sealed connector for this test. This test is not required for unsealed modules with unsealed connectors.

The DUT shall be subjected to 1400 kPa with a flow rate of 9460 cm^3/min of tap water heated to 93^0C. The DUT shall be placed 20 to 30 cm away from the nozzles. The DUT shall be subjected to spray for 3 seconds on each side of the component with a 15^0 fan nozzle. The DUT shall be subjected to a total of 378 sprays.

The DUT shall be subjected to 7000 kPa with a flow rate of 9460 cm^3/min of a wash solution with detergent heated to 93^0C. The DUT shall be placed 20 to 30 cm away from the nozzles. The DUT shall be subjected to spray for 3 seconds on each side of the component with a 15^0 fan nozzle. The DUT shall be subjected to a total of 378 sprays.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.5, *"Steam Cleaning and Pressure Washing"*

5.12. Fungus

The DUT shall be subjected to a fungal spore mixture as described in MIL-STD-810G Method 508.6. The DUT shall be inoculated with the fungal spore and allowed to incubate under cyclic temperature and humidity conditions to promote growth. The fungal spore shall be allowed 30 days for growth. Data from prior products may be used to support an analysis that the device does not support fungal growth. Any product with an untested (or unsupported) material shall be tested.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: MIL-STD-810G REV OCT2008, Method 508.6, *"Fungus*
SAE J1455 REV MAR2017, Section 4.6, *"Fungus"*

5.13. Altitude

5.13.1. Altitude (Operating)

The DUT shall be subjected to atmospheric conditions of 15,000 feet (4,372 meters) with 8.3 PSI (57.2 kPa) Absolute Pressure. The DUT shall be subjected for these atmospheric conditions for 24 hours. The DUT shall be subjected to temperature conditions of the Thermal Cycle Test as described in Section 5.4.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: MIL-STD-810G REV OCT2008, Part Three Section 5.13, *"High elevations and upper air conditions"*

5.13.2. Altitude (Non-Operating)

The DUT shall be subjected atmospheric conditions of 50,000 feet (15,240 meters) with 1.45 PSI (10 kPa) Absolute Pressure. The DUT shall be subjected for these atmospheric conditions for 24 hours. The DUT shall be subjected to -55^{0}C.

Test Criteria: The DUT is not required to meet functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: MIL-STD-810G REV OCT2008, Part Three Section 5.13, *"High elevations and upper air conditions"*

6. Mechanical Environment

6.1. Dust and Sand

The DUT shall be subjected a Dust and Sand Test using dust conforming to ISO 12103-1 A2 fine grade. The DUT shall be subjected to 23° ± 1°C. The DUT shall be subjected to an air/dust concentration of 0.88 g/m^3 for 24 hours.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.7, *"Dust and Sand"*
ISO 12103-1 REV DEC1997, *"Road vehicles — Test dust for filter evaluation"*

6.2. Gravel Bombardment

The DUT shall be subjected to a gravel bombardment with gravel being able to pass through a 15.86 mm (0.62 in) space screen but retained on a 9.53 mm (0.38 in) space screen. The test shall be performed at 23° ± 1°C. The test shall follow the procedure outlined in SAE J400 REV NOV2002, Section 5. The DUT shall be mounted such that it replicates the proposed mounting location on the vehicle.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J400 REV OCT2012, *"Test for Chip Resistance of Surface Coatings"*

6.3. Combined Environmental Testing

The DUT shall be subjected to a combined environmental test. One test cycle consists of the profile as described in SAE J1455 Figure 14. The DUT shall be subjected to the Random Vibration test as described in Section 6.5. The DUT shall be subjected to 3 test cycles.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.12, *"Combined Environmental Testing"*
SAE J1455 REV MAR2017, Figure 14, *"Combined Test Profile"*

6.4. Swept Sine Vibration Test

The DUT shall be subjected to a swept sine vibration test with a g-force value as outlined in Table 8: Swept Sine Vibration Test depending on the mounting location. One test cycle consists of the DUT being subjected to a sweep from 10 Hz to 2 kHz with a sweep rate of ½ octave per minute in each axis. The DUT shall be subjected to 3 cycles in each axis. The DUT shall dwell for 30 minutes at each of the major resonance frequencies.

Mounting Location	g-force
In Cab	5 g (49 m/s^2)
Chassis	5 g (49 m/s^2)
Engine Bay	6 g (58.8 m/s^2)

Table 8: Swept Sine Vibration Test

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.10.4.1, *"Swept Sine Vibration Tests"*
SAE J1455 REV MAR2017, Figure A1, *"Maximum Expected Truck Acceleration Levels"*

6.5. Random Vibration Testing

The DUT shall be subjected to a random vibration test. Ideally the anticipated power spectral density [or PSD] has been estimated for the intended mounting location(s) and that data is available to be used for the random vibration test. Use of substitute data is not recommended for engine mounted components. Generic data like that provided in SAE J1455 is inferior to directly measured data. ISO 16750-03 profiles are more recently complied than SAE J1455 profiles.

Data acquired from the vehicle mounting location shall be used when available. Where estimated data is not available, the DUT shall be subjected to the ISO 16750-3 (preferred) or SAE J1455 vibration profile as outlined in Table 9: Random Vibration Test, depending on the mounting location. The DUT shall be subjected to the number of hours in each axis outlined in Table 9: Random Vibration Test depending on mounting location.

Mounting Location	ISO 16750-3 Vibration Profile	ISO 15750-3 Hours	SAE J1455 Vibration Profile	SAE J1455 Hours
In Cab	Test VIII Figure 12, Table 14	32	Figure 6, 7, 8	22
Chassis	Test IV (Sprung Masses) Figure 11, Table 12 & 13	32	Figure 10, 11	22
	Test IX (Unsprung Masses) Figure 16, Table 15	32		
Engine Bay	[Test VI, Figure 9, Table 9]	94	Figure 9	22

Table 9: Random Vibration Test

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: ISO 16750-3 Road vehicles — Environmental conditions and testing for electrical and electronic equipment —Part 3: Mechanical loads
SAE J1455 REV MAR2017, Section 4.10.4.2, *"Random Vibration Testing"*
SAE J1455 REV MAR2017, Figure 6, *"SAMPLE CAB MOUNTED VIBRATION PSD CLASS 8 TRUCK, VERTICAL AXIS"*
SAE J1455 REV MAR2017, Figure 7, *"SAMPLE CAB MOUNTED VIBRATION PSD TRANSVERSE AXIS"*
SAE J1455 REV MAR2017, Figure 8, *"SAMPLE CAB MOUNTED VIBRATION PSD CLASS 8 TRUCK, LONGITUDINAL AXIS"*
SAE J1455 REV MAR2017, Figure 9, *"SAMPLE ENGINE VIBRATION DATA (VERTICAL), HEAVY-DUTY TRUCK"*
SAE J1455 REV MAR2017, Figure 10, "*CHASSIS VIBRATION DATA, PSD, BOBTAIL VERTICAL MID FRAME, HEAVY-DUTY TRUCK"*
SAE J1455 REV MAR2017, Figure 11, *"CHASSIS VIBRATION DATA, PSD, BOBTAIL VERTICAL REAR FRAME, HEAVY-DUTY TRUCK"*

6.6. Handling Drop Test

The DUT shall be subjected to a handling drop test from a 1 meter height onto a level concrete surface two times in each of the three mutually perpendicular planes. The DUT shall be dropped on both the positive and negative plane under test (e.g. ± x for the first DUT, ± y for the second DUT, ± z for the third DUT).

Test Criteria: The DUT is not required to meet functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance if there is no obvious physical damage. The DUT is not required to meet parametric test requirements following completion of the test if there is obvious physical damage (e.g. cracked housing, broken connector).

Reference: SAE J1455 REV MAR2017, Section 4.11.3.1, *"Handling Drop Test"*

6.7. Transit Drop Test

The DUT shall be placed into the container that it will be normally shipping in. The container shall be fully loaded as it would be in shipping. The container shall be subjected to a drop from a height as outlined in Table 10: Transit Drop Test. The container shall be subjected to drops in the following order:

- The corner formed by the right side, bottom, and near end
- The shortest edge radiating from that corner
- The next longest edge radiating from that corner
- The longest edge radiating from that corner
- Flat on one of the smallest faces
- Flat on the opposite small face
- Flat on one of the medium faces
- Flat on the opposite medium face
- Flat on one of the largest faces
- Flat on the opposite large face

Package Weight	Drop Height
0.45 kg to 9.52 kg	76 cm
9.53 kg to 18.59 kg	61 cm
18.60 kg to 27.66 kg	46 cm
27.67 kg to 53.31 kg	31 cm

Table 10: Transit Drop Test

Test Criteria: The DUT is not required to meet functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test. The container shall be able to provide reasonable protection to the contents following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.11.3.2, *"Transit Drop Test"*

6.8. Installation Harness Shock Test

The DUT shall be attached to a 1 meter long harness. The DUT and the far end of the harness shall be elevated to a height so that the DUT will not impact the ground once released. One test cycle consists of the DUT being released causing the device(s) to swing in a pendulum motion. The DUT shall be subjected to 20 test cycles.

Test Criteria: The DUT is not required to meet functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.11.3.3, *"Installation Harness Shock Test"*

6.9. Operational Shock

The DUT shall be subjected a shock as described in MIL-STD-202G Method 213b. The DUT shall be subjected to the sawtooth pulse with a peak of 30G for 11ms. The DUT shall be subjected to 18 pulses.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: MIL-STD-202G REV FEB2002, Method 213B, *"Shock (Specified Pulse)"*
MIL-STD-202G REV FEB2002, Figure 213-2, "Tolerances for terminal-peak sawtooth shock pulse"

7. Electrical Environment

7.1. Operational Voltage

7.1.1. Operational Voltage Ranges

The DUT shall be capable of operating in the voltage ranges listed in Table 11: Voltage based on the system voltage.

System Voltage	Minimum Voltage	Nominal Voltage	Maximum Voltage
12 V	9.0 ± 0.1 V	14.2 ± 0.1 V	18.0 ± 0.1 V
24 V	18.0 ± 0.1 V	28.4 ± 0.1 V	36.0 ± 0.1 V

Table 11-1: Voltage Ranges

The DUT shall be subjected to the voltages described in Section 7.1.1 during testing. Both tests conducted before environmental exposures and tests conducted after environmental exposures shall use the minimum, nominal and maximum voltages listed in Table 11-1.

7.1.2. Intermittent Power Specification

Class C and Class B DUTs shall accept the following schedule of power interruptions with the effects listed. Individual DRDs may provide a product specific schedule for a given DUT. The duty cycle of the power is assumed to exceed 84% when intermittent interruptions are observed. Class A devices are exempt from this requirement.

Power Supply Interruption		Operating Status by Device Class	
Length	Period	Class C	Class B
100 us	667 us	Status I	Status I
1 ms	6.67 ms	Status I	Status I
10 ms	66.7 ms	Status I	Status I
20 ms	133.3 ms	Status I	Status II
50 ms	333.33 ms	Status I	Status II
100 ms	666.67 ms	Status II	Status II (may reset)
150 ms	1 000 ms	Status II	Status II (may reset)
200 ms	1.333 s	Status II	Status II (may reset)
500 ms	3.333 s	Status II (may reset)	Status II (may reset)
1000 ms	6.667 s	Status II (may reset)	Status II (may reset)
2000 ms	13.333 s	Status II (may reset)	Status II (may reset)

Table 11-2: Loss of Power Impact

The DUT need not be subjected to the outages described in Section 7.1.2 during an environmental test. However, both tests conducted before environmental exposures and tests conducted after environmental exposures shall evaluate the DUT's ability to sustain the interruption pulses listed in Table 11-2 The DUT shall be exposed to each pulse 5 times from nominal voltage to ground at a temperature of 23 degrees Celsius. The minimum period between interruption pulses is 20/3 times the interruption duration. This method is similar to, but different from, ISO 16750-2 paragraph 4.6.2, which may be used to establish performance to the minimum voltage.

7.2. Jump Starting

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to the jump start voltage as outlined in Table 12: Jump Starting for 5 minutes. The DUT shall then return to the nominal voltage as described in Section 7.1.1 for 10 minutes.

System Voltage	Jump Start Voltage
12 V	25.2 ± 0.1 V
24 V	50.4 ± 0.1 V

Table 12: Jump Starting

Test Criteria: The DUT shall meet all functional test requirements during the test for device functions that are required to start the vehicle. The DUT is not required to meet functional test requirements during the test for device functions that are not required to start the vehicle.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.13.1.1, *"Steady State Electrical Characteristics"*

7.3. Cold Cranking

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected test cycle outlined in Figure 4: Cold Cranking. One test cycle consists of varying voltage levels. The DUT shall be subjected to a total of 20 cycles. The DUT shall then return to the nominal voltage as described in Section 7.1 for 10 minutes.

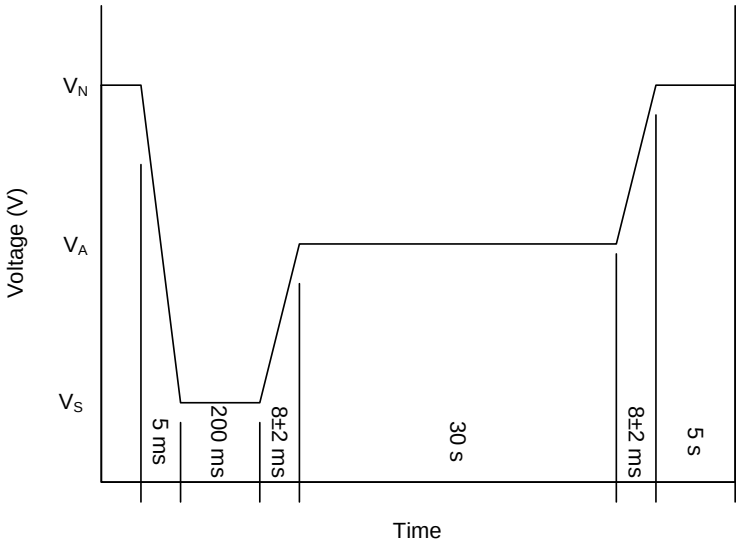

Figure 4: Cold Cranking

System Voltage	V_A	V_S	V_N
12 V	6.0 ± 0.1 V	4.5 ± 0.1 V	12.2 ± 0.1 V
24 V	12.0 ± 0.1 V	6.0 ± 0.1 V	24.4 ± 0.1 V

Table 13: Cold Cranking

Test Criteria: The DUT shall meet all functional test requirements during the test for device functions that are required to start the vehicle. The DUT is not required to meet functional test requirements during the test for device functions that are not required to start the vehicle.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.13.1.1, *"Steady State Electrical Characteristics"*
SAE J1113-11 REV JAN2012, Figure 7, *"Test Pulse 4"*

7.4. Reverse Polarity

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to the reverse battery voltage as outlined in Table 14: Reverse Polarity for 5 minutes. The DUT shall then return to the nominal voltage as described in Section 7.1 for 10 minutes. A power device is considered to be any device that drives an external load. All analog and digital logic circuitry on power devices shall be protected against -28.4 ± 0.1 V.

System Voltage	Reverse Voltage
Power Devices	-14.2 ± 0.1 V
Non-Power Devices	-28.4 ± 0.1 V

Table 14: Reverse Polarity

Test Criteria: The DUT is not required to meet functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.13.1.1, *"Steady State Electrical Characteristics"*

7.5. Voltage Regulator Failure

The DUT shall be setup with all signal lines to sources and loads as it would be in the vehicle. The DUT shall be subjected to the minimum voltage as outlined in Table 15: Voltage Regulator Failure for 1 hour. The DUT shall then return to the nominal voltage as outlined in Table 15: Voltage Regulator Failure for 10 minutes. The DUT shall then be subjected to the maximum voltage as outlined in Table 15: Voltage Regulator Failure for 1 hour. The DUT shall then return to the nominal voltage as described in Section 7.1 for 10 minutes.

System Voltage	Minimum Voltage	Maximum Voltage
12 V	9.0 ± 0.1 V	18.0 ± 0.1 V
24 V	18.0 ± 0.1 V	36.0 ± 0.1 V

Table 15: Voltage Regulator Failure

Test Criteria: The DUT shall meet all functional test requirements during the test for device functions that are required to start the vehicle. The DUT is not required to meet functional test requirements during the test for device functions that are not required to start the vehicle.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1455 REV MAR2017, Section 4.13.1.1, *"Steady State Electrical Characteristics"*

7.6. Open Circuit

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to the nominal voltage as described in Section 7.1. Disconnect one lead for at least 5 minutes then reconnect the lead. This test shall be repeated for each lead.

Test Criteria: The DUT is not required to meet functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: N/A

7.7. Short Circuit

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. When short circuit conditions are checked for an individual connection, the individual connection (ECM pin) of the DUT shall be connected in parallel with a 3 foot long 16 AWG lead. This standardizes the resistance and inductance of the interface to the voltage source. To avoid destructive testing of the test harness, an external voltage source may be disconnected when the ECM pin is to be shorted to ground. Also, an external ground may be disconnected when the ECM pin is to be shorted to a voltage source.

The DUT shall be subjected to the nominal voltage as described in Section 7.1 after a temperature soak at 23 degrees Celsius.

1. Connect one lead at a time to ground for at least 5 minutes. This test shall be repeated for each lead.

2. Connect one lead at a time to the nominal voltage as described in Section 7.1 for at least 5 minutes. This test shall be repeated for each lead.

[Observe parametric data]. Soak the DUT to the maximum temperature described in section 5.1 until stabilized at the maximum temperature (no less than 1 hour) and the provide the minimum voltage described in 7.1.

3. Connect one lead at a time to ground for at least 5 minutes. This test shall be repeated for each lead.

4. Connect one lead at a time to the minimum voltage as described in Section 7.1 for at least 5 minutes. This test shall be repeated for each lead.

[Observe parametric data]. Soak the DUT to the minimum temperature described in section 5.1 until stabilized at the minimum temperature (no less than 1 hour) and the provide the maximum voltage described in 7.1.

5. Connect one lead at a time to ground for at least 5 minutes. This test shall be repeated for each lead.

6. Connect one lead at a time to the maximum voltage as described in Section 7.1 for at least 5 minutes. This test shall be repeated for each lead.

Observe parametric data.

Test Criteria: The DUT is not required to meet functional test requirements during the test. Circuit protection devices may be activated.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. Parametric checks may be made after each temperature exposure in addition to the last temperature exposure. The DUT shall not have sustained any physical damage following completion of the test.

Reference: ISO 16750-2 section 4.9, Open Circuit Tests
ISO 16750-2 section 4.10 Short circuit protection.

7.8. Operation without Batteries

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to the operation without batteries voltage as outlined in Table 16: Operation without Batteries for 5 minutes. During these 5 minutes ω shall sweep between 400 and 2400 radians/s between 2 and 5 times. Only sweep rates that divide evenly (without a remainder) into the 5 minute exposure period shall be used. The DUT shall then return to the nominal voltage as described in Section 7.1 for 10 minutes.

System Voltage	Operation without Batteries Voltage	Frequency (rad/s)
12 V	13 + 5 [cos ωt]	400 ≤ ω ≤ 2400
24 V	26 + 10 [cos ωt]	400 ≤ ω ≤ 2400

Table 16: Operation without Batteries

Test Criteria: The DUT shall meet all functional test requirements during the test. The A/D channel performance for all individual A/D signals shall be monitored for aliased signals and other noise [positively] correlated to the AC wave component [cos ωt] during the five minute sweep. The DUTs intended mux schedule for A/D shall be used. The signal [cos ωt] shall be observed only on those inputs directly measuring the power input to the DUT. It [cos ωt] shall not be observed on any other input.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: ISO 16750-2 Section 4.4

7.9. Conducted Transients

7.9.1. Inductive Switching - Pulse 1

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to SAE J1113-11 Pulse 1 with the parameters as outlined in Table 17: Pulse 1. The DUT shall be subjected to 5000 pulses.

Parameters	12 Volt System	24 Volt System
V_S	-600 V	-600 V
R_i	20 Ω	50 Ω
t_d	1 ms	1 ms
t_r	1 µs +0/-50%	3 µs +0/-50%
t_1	0.5 s	0.5 s
t_2	200 ms	200 ms
t_3	< 100 µs	< 100 µs

Table 17: Pulse 1

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-11 REV JAN2012, Section 5, *"Test Procedure"*
SAE J1113-11 REV JAN2012, Figure 2, *"Test Pulse 1"*

7.9.2. Inductive Switching - Pulse 2a

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to SAE J1113-11 Pulse 2a with the parameters as outlined in Table 18: Pulse 2a. The DUT shall be subjected to 5000 pulses.

Parameters	12 Volt System	24 Volt System
V_S	+75 V	+75 V
R_i	2 Ω	2 Ω
t_d	0.05 ms	0.05 ms
t_r	1 µs +0/-50%	1 µs +0/-50%
t_1	0.2 s	0.2 s

Table 18: Pulse 2a

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-11 REV JAN2012, Section 5, *"Test Procedure"*
SAE J1113-11 REV JAN2012, Figure 3, *"Test Pulse 2a"*

7.9.3. Inductive Switching - Pulse 2b

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to SAE J1113-11 Pulse 2b with the parameters as outlined in Table 19: Pulse 2b. The DUT shall be subjected to 10 pulses.

Parameters	12 Volt System	24 Volt System
V_S	10 V	20 V
R_i	≤ 0.05 Ω	≤ 0.05 Ω
t_d	2 s	2 s
t_1	1 ms ± 50%	1 ms ± 50%
t_r	1 ms ± 50%	1 ms ± 50%
t_6	1 ms ± 50%	1 ms ± 50%

Table 19: Pulse 2b

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1Section 7.1.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-11 REV JAN2012, Section 5, *"Test Procedure"*
SAE J1113-11 REV JAN2012, Figure 4, *"Test Pulse 2b"*

7.9.4. Switching Spikes - Pulse 3a

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to SAE J1113-11 Pulse 3a with the parameters as outlined in Table 20: Pulse 3a. The DUT shall be subjected to the pulse for 1 hour.

Parameters	12 Volt System	24 Volt System
V_S (from nominal voltage)	-150 V	-200 V
R_i	50 Ω	50 Ω
t_d	0.1 µs +100/-0%	0.1 µs +100/-0%
t_f	5 ns ± 30%	5 s ± 30%
t_1	100 µs	100 µs
t_4	10 ms	10 ms
t_5	90 ms	90 ms

Table 20: Pulse 3a

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-11 REV JAN2012, Section 5, *"Test Procedure"*
SAE J1113-11 REV JAN2012, Figure 5, *"Test Pulse 3a"*

7.9.5. Switching Spikes - Pulse 3b

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to SAE J1113-11 Pulse 3b with the parameters as outlined in Table 21: Pulse 3b. The DUT shall be subjected to the pulse for 1 hour.

Parameters	12 Volt System	24 Volt System
V_S (from nominal voltage)	+100 V	+200 V
R_i	50 Ω	50 Ω
t_d	0.1 µs +100/-0%	0.1 µs +100/-0%
t_r	5 ns ± 30%	5 ns ± 30%
t_1	100 µs	100 µs
t_4	10 ms	10 ms
t_5	90 ms	90 ms

Table 21: Pulse 3b

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-11 REV JAN2012, Section 5, *"Test Procedure"*
SAE J1113-11 REV JAN2012, Figure 6, *"Test Pulse 3b"*

7.9.6. Load Dump - Pulse 5a

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to SAE J1113-11 Pulse 5a with the parameters as outlined in Table 22: Pulse 5a. The DUT shall be subjected to 40 pulses. The period for pulse 5a shall be 45 s +/- 5 seconds [40, 50] s.

Parameters	12 Volt System	24 Volt System
V_S (from nominal voltage)	87 V	174 V
R_i	1 Ω	1 Ω
t_d	400 ms	350 ms
t_r	10 ms ± 5 ms	10 ms ± 5 ms

Table 22: Pulse 5a

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1Section 7.1.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-11 REV JAN2012, Section 5, *"Test Procedure"*
SAE J1113-11 REV JAN2012, Figure 8, *"Test Pulse 5a & 5c"*

7.9.7. Low Side Outputs Bias by Ignition or Accessory

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to SAE J1113-11 Pulse 1 on the active low side output channels for each low side driver output. A load resistance of 200 Ω shall be used on each output and connected through the bias side of the load, as shown in Figure 5. The DUT shall be subjected to the pulse on the biased side of the load while the biasing supply is switched off. The desired effect is to simulate and inductive load flyback voltage on the low side output cause by disruption of the ignition or accessory power to the loads.

Figure 5: Low Side Bias Test Circuit

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-11 REV JAN2012, Section 5, *"Test Procedure"*
SAE J1113-11 REV JAN2012, Figure 2, *"Test Pulse 1"*

7.10. Coupled Transients

7.10.1. Capacitive Coupling Clamp

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to SAE J1113-12 Pulse A and Pulse B with the parameters as outlined in Table 23: Capacitive Coupling Clamp. The DUT shall be subjected to 10 seconds of pulses on each signal line.

	Parameters	12 Volt System	24 Volt System
Pulse A	V_S	0 V to -60 V	0 V to -80 V
	R_{s1}	50 Ω	50 Ω
	T	0.1 µs +100/-0%	0.1 µs +100/-0%
	T_r	5 ns ± 50%	5 ns ± 50%
	t_1	100 µs	100 µs
	t_2	10 ms	10 ms
	t_3	≥ 90 ms	≥ 90 ms
Pulse B	V_S	0 V to +40 V	0 V to +80 V
	R_{s1}	50 Ω	50 Ω
	T	0.1 µs +100/-0%	0.1 µs +100/-0%
	T_r	5 ns ± 50%	5 ns ± 50%
	t_1	100 µs	100 µs
	t_2	10 ms	10 ms
	t_3	≥ 90 ms	≥ 90 ms

Table 23: Capacitive Coupling Clamp

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-12 REV AUG2006, Section 4.1, *"Capacitive Coupling Clamp"*
SAE J1113-12 REV AUG2006, Figure 2, *"Test Pulse A"*
SAE J1113-12 REV AUG2006, Figure 3, *"Test Pulse B"*

7.10.2. Chattering Relay

The DUT shall be setup with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be subjected to SAE J1113-12 Chattering Relay test. The DUT shall be subjected to 10 seconds of pulses on each signal line.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-12 REV AUG2006, Section 4.2, *"Chattering Relay"*

7.11. Electrostatic Discharge

7.11.1. Electrostatic Discharge (Unpowered)

The DUT shall be subjected to contact and air electrostatic discharge. The DUT shall be subjected to 23° ± 1°C. The DUT shall not be powered during the test. The DUT shall be subjected to the direct contact and air contact electrostatic discharge values on the housing and each pin of the DUT as outlined in Table 24: Electrostatic Discharge (Unpowered). The DUT shall be subjected to an ESD Simulator with a 150 pF capacitance. The DUT shall be subjected to 30% ± 10% relative humidity. The DUT shall be subjected to the test sequence as outlined in Table 24: Electrostatic Discharge (Unpowered). The DUT shall be subjected to 3 pulses in each test sequence.

Test Sequence	Discharge Type	Voltage Level
1	Contact	± 4 kV
2	Contact	± 6 kV
3	Air	± 8 kV
4	Contact	± 8 kV
5	Air	± 15 kV
6	Air	± 25 kV

Table 24: Electrostatic Discharge (Unpowered)

Test Criteria: The DUT is not required to meet functional test requirements during the test. A functional test shall be performed after each test sequence.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-13 REV JUN2011, Section 5, *"Test Setup and Procedure for Packaging and Handling Sensitivity Classification Test (Non-Powered Mode Test)"*
SAE J1113-13 REV JUN2011, Table 1, *"ESD Test Sequence and Voltage Levels"*

7.11.2. Electrostatic Discharge (Powered)

The DUT shall be subjected to contact and air electrostatic discharge. The DUT shall be subjected to 23° ± 1°C. The DUT shall be subjected to the nominal voltage as described in Section 7.1. The DUT shall be subjected to the direct contact and air contact electrostatic discharge values as outlined in Table 25: Electrostatic Discharge (Powered) on each housing face and all HMI elements that are exposed to touch. The DUT shall be subjected to an ESD Simulator with a 330 pF capacitance. The DUT shall be subjected to 30% ± 10% relative humidity. The DUT shall be subjected to the test sequence as outlined in Table 25: Electrostatic Discharge (Powered). The DUT shall be subjected to 3 pulses in each test sequence. Device(s) with a human interface (e.g. switches, gauges, radios) are required to pass this test.

Test Sequence	Discharge Type	Voltage Level
1	Contact	± 2 kV
2	Contact	± 4 kV
3	Contact	± 6 kV
4	Contact	± 8 kV
5	Air	± 15 kV

Table 25: Electrostatic Discharge (Powered)

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-13 REV JUN2011, Section 4, *"Test Setup and Procedure for Powered Mode Component Tests"*
SAE J1113-13 REV JUN2011, Table A1, *"ESD Test Sequence and Voltage Levels"*

7.12. Conducted Emissions

The DUT shall be subjected to conducted emissions testing as described in CISPR 25. The DUT shall be subjected to CISPR 25 conducted emissions from components/modules using the voltage method. The DUT shall meet CISPR 25 Class 4 Limits for Peak Detector and CISPR 25 Class 4 Limits for Average Detector. The DUT shall be subjected to the frequency range from 150 kHz to 108 MHz.

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: CISPR 25 Ed. 3 2008-03, Section 6.2, *"Conducted Emissions from components/modules – Voltage Method"*
CISPR 25 Ed. 3 2008-03, Table 5, *"Examples of quasi-peak or peak limits for conducted disturbances – Voltage Method"*
CISPR 25 Ed. 3 2008-03, Table 6, *"Examples of average limits for conducted disturbances – Voltage Method"*

7.13. Radiated Emissions

The DUT shall be subjected to a measurement of radiated emissions testing as described in CISPR 25. The DUT shall be subjected to CISPR 25 radiated emissions from components/modules using the ALSE method. The DUT shall meet CISPR 25 Class 3 Limits for Peak Detector and CISPR 25 Class 3 Limits for Average Detector. In addition, for all chassis or engine compartment mounted components, the DUT shall not exceed the limits for CISPR 12 extrapolated to 1 m antenna spacing, as shown in Figure 6. The DUT shall be subjected to the frequency range from 150 kHz to 1.583 GHz.

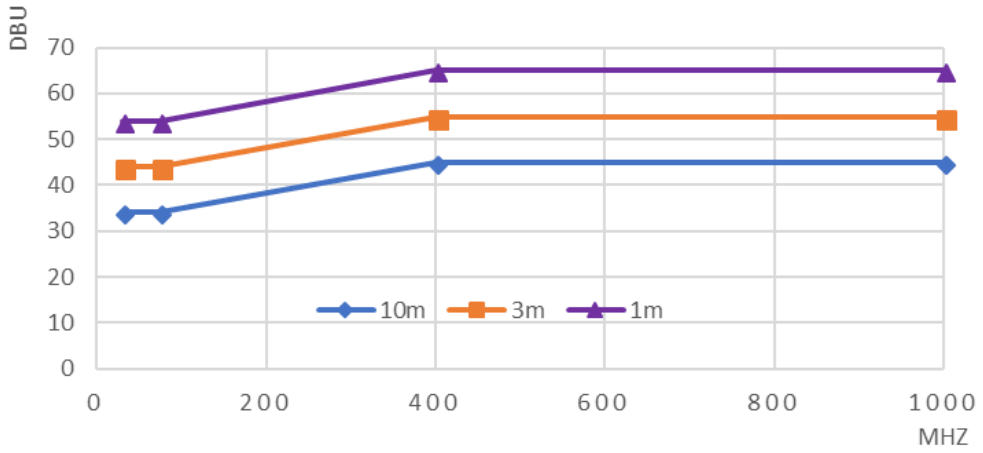

Figure 6: Extrapolation of CISPR 12 Emission Limits to 1 m Antenna Spacing in dBuV

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: CISPR 25 Ed. 3 2008-03, Section 6.4, *"Radiated Emissions from components/modules – ALSE Method"*
CISPR 25 Ed. 3 2008-03, Table 9, *"Examples of quasi-peak or peak limits for radiated disturbances – ALSE"*
CISPR 25 Ed. 3 2008-03, Table 10, *"Examples of average limits for radiated disturbances – ALSE"*
SAE J551-1 REV JUN2010, *"Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (16.6 Hz to 18 GHz)*

7.14. Radiated Immunity

The DUT shall be subjected to radiated immunity testing as described in SAE J1113-21. The DUT shall be subjected to a Continuous Wave test with the frequency range from 200 MHz to 3 GHz. The frequency range shall be swept with step sizes as outlined in Table 26: Radiated Immunity – Step Size. The test shall be repeated with the DUT subjected to a carrier, amplitude modulated by a 1 kHz tone at 80%. The DUT shall be subjected to the test severity levels as outlined in Figure 7: Radiated Immunity. The DUT shall be subjected to the test severity levels as outlined in Table 27: Radiated Immunity. The threshold voltage shall be identified for any observed behavior not compliant to Figure 7.

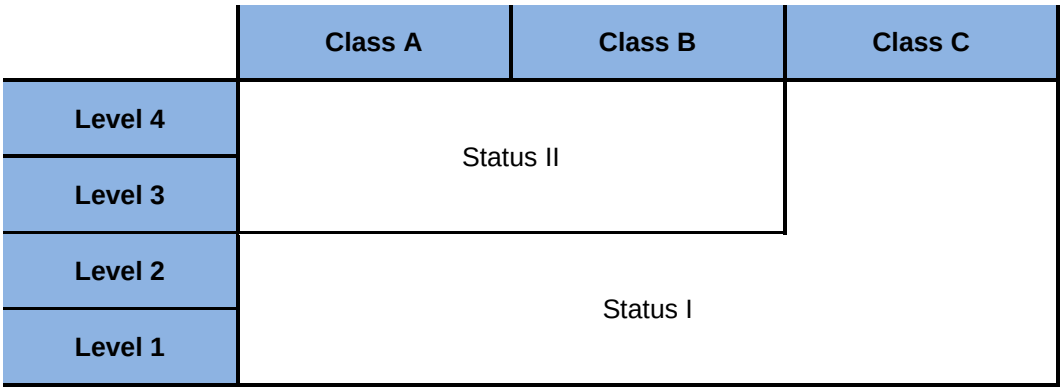

Figure 7: Radiated Immunity

Frequency band MHz	Linear steps MHz	Logarithmic steps %
> 200 to 400	10	5
> 400 to 1 000	20	2
> 1 000 to 3 000	40	2

Table 26: Radiated Immunity – Step Size

Test Severity Level	E-Field Strength
Level 4	200 V/m
Level 3	160 V/m
Level 2	120 V/m
Level 1	100 V/m

Table 27: Radiated Immunity

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-21 REV OCT2005, *"Electromagnetic Compatibility Measurement Procedure for Vehicle Components – Part 21: Immunity to Electromagnetic Fields, 30 MHz to 18 GHz, Absorber-Lined Chamber"*

7.15. Bulk Current Injection

The DUT shall be subjected bulk current injection testing as described in SAE J1113-4. The DUT shall be subjected to a Continuous Wave test with the frequency range from 10 kHz to 400 MHz. The frequency range shall be swept with step sizes as outlined in Table 28: Bulk Current Injection – Step Size. The Calibrated Injection Probe Method (Substitution Method) shall be used. The injection probe shall be positioned at 150 mm, 450 mm, and 750 mm. The test shall be repeated (at each injection probe position) with the DUT subjected to a

carrier, amplitude modulated by a 1 kHz tone at 80%. The DUT shall be subjected to the test severity levels as outlined in Figure 8: Bulk Current Injection. The DUT shall be subjected to the test severity levels as outlined in Table 29: Bulk Current Injection.

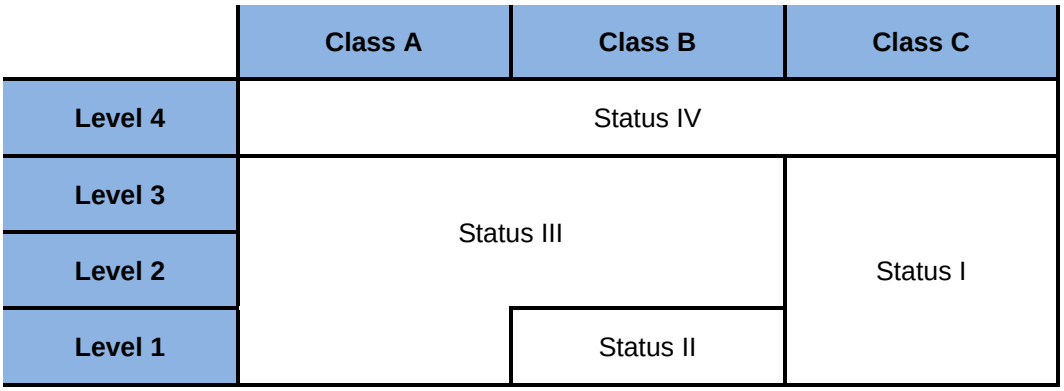

Figure 8: Bulk Current Injection

Frequency	Step Size	Expected values of Q
10 – 100 kHz	10 kHz	0.6 -- 6
100 kHz – 1 MHz	100 kHz	0.6 -- 6
1 MHz – 10 MHz	1 MHz	0.6 -- 6
10 MHz – 200 MHz	2 MHz	3 – 60
200 MHz – 400 MHz	10 MHz	NA

Table 28: Bulk Current Injection – Step Size

Test Severity Level	RF Current
Level 4	(100, 120] mA
Level 3	(80, 100] mA
Level 2	(60, 80] mA
Level 1	[0, 60] mA

Table 29: Bulk Current Injection

Test Criteria: The DUT shall be subjected to the nominal voltage as described in Section 7.1 during the test. The DUT shall meet all functional test requirements during the test.

Acceptance Criteria: The DUT shall meet all parametric test requirements following completion of the test without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-4 REV AUG2004, *"Immunity to Radiated Electromagnetic Fields – Bulk Current Injection (BCI) Method"*

8. Vehicle Level

The following tests are the responsibility of Navistar to complete. The supplier shall design the device(s) such that they shall pass these tests. The supplier shall provide support to Navistar during these tests.

8.1. Electrostatic Discharge

The vehicle shall be subjected to contact and air electrostatic discharge. The vehicle shall be subjected to 23° ± 1°C. The vehicle shall be subjected to the nominal voltage as described in Section 7.1. The vehicle shall be subjected to the direct contact electrostatic discharge values on all exposed elements of the DUT as outlined in Table 30: Electrostatic Discharge (Vehicle). The vehicle shall be subjected to the air electrostatic discharge values on all exposed elements of the DUT as outlined in Table 30: Electrostatic Discharge (Vehicle). The DUT shall be subjected to the test sequence as outlined in Table 30: Electrostatic Discharge (Vehicle). The DUT shall be subjected to 3 pulses in each test sequence.

Test Sequence	Discharge Type	Voltage Level
1	Contact	± 2 kV
2	Contact	± 4 kV
3	Contact	± 6 kV
4	Contact	± 8 kV
5	Air	± 15 kV

Table 30: Electrostatic Discharge (Vehicle)

Test Criteria: The vehicle shall be subjected to the nominal voltage as described in Section 7.1 during the test. The vehicle shall meet all functional test requirements during the test.

Acceptance Criteria: The vehicle shall meet all parametric test requirements following completion of the test without degradation of performance. The vehicle shall not have sustained any physical damage following completion of the test.

Reference: SAE J1113-13 REV JUN2011, Section 4, *"Test Setup and Procedure for Powered Mode Component Tests"*
SAE J1113-13 REV JUN2011, Table A1, *"ESD Test Sequence and Voltage Levels"*

8.2. Radiated Emissions

The vehicle shall be subjected to a measurement of radiated emissions as described in UN ECE Regulation 10-04 and CISPR 12. The vehicle shall be subjected to the quasi-peak and average detector methods of CISPR 12 as outlined in Table 31: Rated Emissions (Vehicle).

Frequency (MHz)	Average Detector Limit 120 kHz Bandwidth (10 m Antenna Distance)	Average Detector Limit 120 kHz Bandwidth (3 m Antenna Distance)
30 – 230	22 dB (µV/m)	32 dB (µV/m)
230 – 1000	33 dB (µV/m)	43 dB (µV/m)

Table 31: Radiated Emissions (Vehicle)

Test Criteria: The vehicle shall be subjected to the nominal voltage as described in Section 7.1 during the test. The vehicle shall meet all functional test requirements during the test.

Acceptance Criteria: The vehicle shall meet all parametric test requirements following completion of the test without degradation of performance. The vehicle shall pass the test with a 2 dB margin as described in CISPR 12 Section 6.2.1. The vehicle shall not have sustained any physical damage following completion of the test.

Reference: UN ECE Regulation 10-04 March 6, 2012, *"Vehicles with regard to electromagnetic compatibility*
CISPR 12 Ed. 6.1 2009-03, Section 6.4.1, *"Single Sample"*
CISPR 12 Ed. 6.1 2009-03, Figure 2, *"Limit of disturbance (peak and quasi-peak detector) at 10 m antenna distance"*
CISPR 12 Ed. 6.1 2009-03, Figure 3, *"Limits of disturbance (average detector) at 10 m antenna distance"*
SAE J551-1 REV JUN2010, *"Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (16.6 Hz to 18 GHz)*

8.3. Radiated Susceptibility - Off Vehicle Source

The vehicle shall be subjected to ISO 11451-2 Off Vehicle Source Method. The vehicle shall be subjected to a Continuous Wave test with the frequency range from 10 kHz to 3 GHz. The frequency range shall be swept with step sizes as outlined in Table 32: Off Vehicle Source – Step Size. The test shall be repeated with the vehicle subjected to a carrier wave that is amplitude modulated by a 1 kHz tone at 80%. Vehicle behavior shall comply with Figure 9.

<table>
<tr><th>Field Strength / Device Class</th><th>0 to 60 V/m [0, 60]</th><th>60+ to 80 V/m (60, 80]</th><th>80+ to 150 V/m (80, 150]</th></tr>
<tr><td>Class A — Any function that provides a convenience (e.g., entertainment).</td><td>Shall recover any disturbances at or below 60 V/m without intervention.</td><td colspan="2">May require operator intervention to recover any disturbances.

[Loss of function is limited to the disturbed unit. No cascaded disruption of any other function or device].</td></tr>
<tr><td>Class B — Any function that enhances, but is not essential to, the operation or control of the vehicle (e.g., TPMS).</td><td>Shall not be disturbed at or below 60 V/m field strengths.</td><td>Shall recover any disturbances at or below 80 V/m without intervention.</td><td>May require operator intervention to recover any disturbances.

[Loss of function is limited to the disturbed unit. No cascaded disruption of any other function or device].</td></tr>
<tr><td>Class C — Any function that is essential to the operation or control of the vehicle (e.g., braking, engine management).</td><td colspan="2">Shall not be disturbed during testing at or below 80 V/m field strengths.</td><td>Shall recover any disturbances at or below 150 V/m without intervention. An engine shall not stall at or below 100 V/m (inclusive of 100 V/m).</td></tr>
</table>

Figure 9: Off Vehicle Source

Frequency	Step Size
10 – 100 kHz	10 kHz
100 – 1000 kHz	100 kHz
1 MHz – 10 MHz	1 MHz
10 MHz – 200 MHz	2 MHz
200 MHz – 1 GHz	20 MHz
1 GHz- 3 Ghz	200 MHz

Table 32: Off Vehicle Source – Step Size --- As Described by SAE J551-1 Appendix C.

Test Criteria: The vehicle shall be subjected to the nominal voltage as described in Section 7.1 during the test. The vehicle shall meet all functional test requirements during the test.

Acceptance Criteria: The vehicle shall meet all parametric test requirements following completion of the test without degradation of performance. The vehicle shall not have sustained any physical damage following completion of the test.

Reference: ISO 11451-2 REV FEB2005, *"*Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 2: Off-vehicle radiation sources"
SAE J551-1 REV JUN2010, *"Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (16.6 Hz to 18 GHz)*

8.4. SINAD Test

The vehicle shall be subjected to TEX-1160-U Radio Frequency Interference Testing, as described in this reference. Alternate frequencies within the subject bands listed in Appendix A of TEX-1160-U will be employed to support customers other than the Texas Department of Transportation.

Test Criteria: The vehicle shall be subjected to the nominal voltage as described in Section 7.1 during the test. TEX-1160-U defines the operation of the vehicle during the test. The vehicle shall meet all functional test requirements during the test. The ambient noise level shall comply with Section 5.0 of TEX-1160-U.

Acceptance Criteria: The vehicle shall not interfere with the radio according to the provisions in TEX-1160-U. The vehicle shall not have sustained any damage and shall meet all parametric test requirements following completion of the test without degradation of performance.

Reference: TEX-1160-U, *"Radio Frequency Interference Testing"*

9. Test Flow

The tests specified in this document shall be performed in order accordance to Figure 8: Test Flow. Three additional device(s) shall be built for DV testing and six additional device(s) shall be built for PV testing to serve as control units.

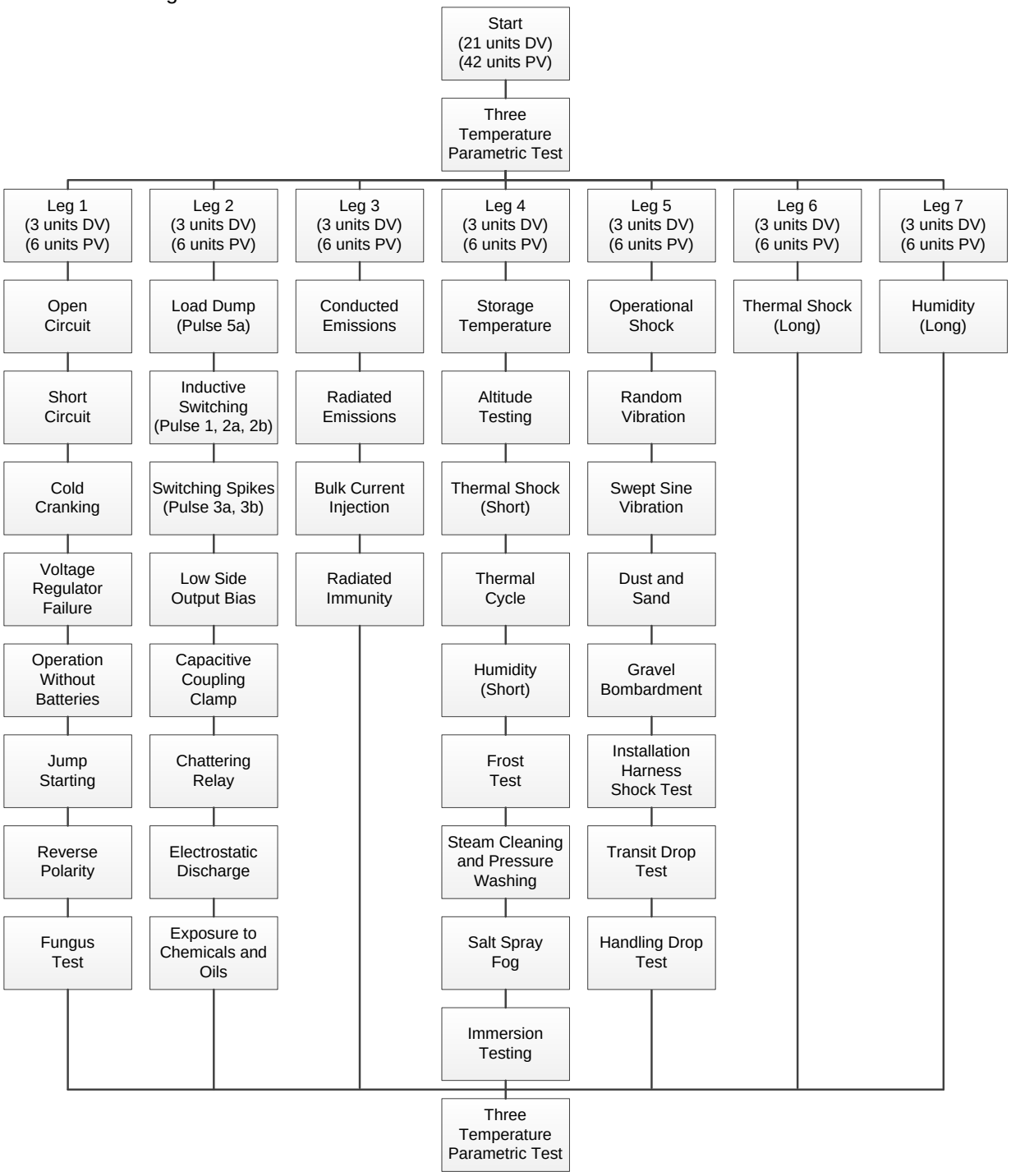

Figure 8: Test Flow

9.1. Test Flow with Combined Environmental Testing

The tests specified in this document shall be performed in order accordance to Figure 9: Test Flow with Combined Environmental, only if Combined Environmental Testing will be performed. Three additional device(s) shall be built for DV testing and six additional device(s) shall be built for PV testing to serve as control units.

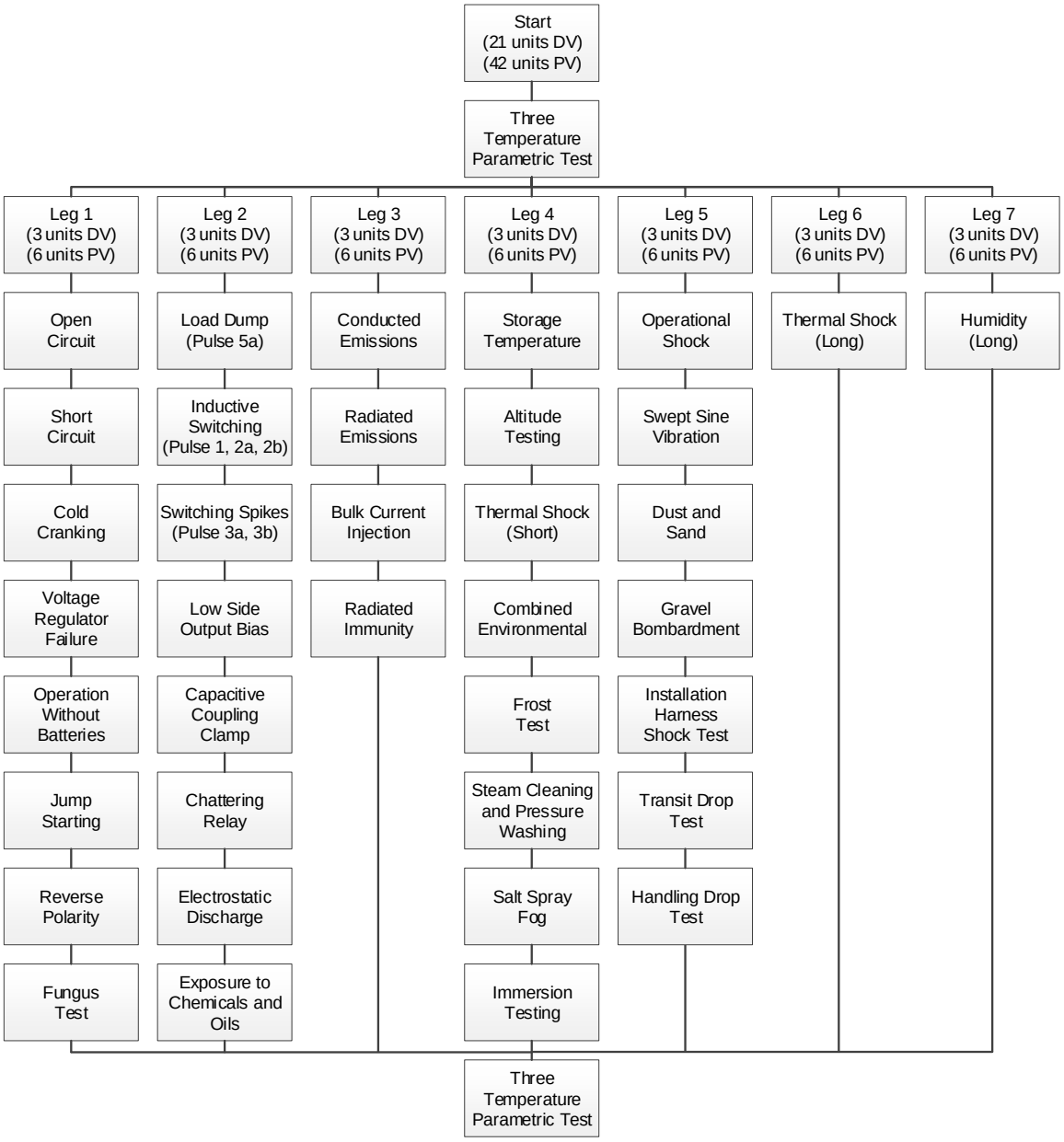

Figure 9: Test Flow with Combined Environmental

10. Reliability Life Test

Reliability Life Test shall be defined in the device(s) specification.