Bendix Commercial Vehicle Systems LLC **Elyria, Ohio** *- BENDIX CONFIDENTIAL -*		
GUIDELINE TITLE: Electronics Test Guideline Electrical Validation Tests ***Guideline Owner:*** *Thomas Legeza* **KE CVS Next Level Process:** Product and Process Validation	**DEPARTMENT**:	*Platform 8439*
	PLM Team:	*EEE1*
	Guideline Number:	Y203396
	REVISION:	
	ISSUE DATE:	10-Nov-2021
	PAGE:	1 of 81
	KE CVS next level #	TPD-30-40

Cover Sheet

DISTRIBUTION / PLM Scope:
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Where external reporting is needed, refer to industry specifications such as those by SAE or ISO.

PLM Scope:
☐ Group BCVS All Locations
☐ Group BCVS (excludes distribution centers)
☒ CoC (applies to all functions within a CoC): Electronics CoC 2.1
☐ Local (applies to a specific location): *(list which location)*
☒ Multi-Local (applies to more than 1 location, but not all): Elyria, Vancouver, Santa Ana

Please select the functional area(s) to which this instruction is applicable:

☐ All Departments				
☐ AME.	☐ Business Dev.	☐ Customer Svc.	☐ Global Change	☐ Sales / Mktg.
☐ HS&E	☐ HR	☐ IT	☐ Materials	☒ Engineering
☐ Purchasing	☐ Quality	☐ Finance	☐ Transportation	☐ Warranty
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	PAGE:	2 of 81
	KE CVS next level #	TPD-30-40

Please note: Revised text is in italics and underline.

Revised By	Approved By	Rev	Section	Description	Reason	Date
DPZ	TSL	000		Initial Release		19-July-2016
JAM	TSL	001	Header	Added Guideline Owner	Update	2-Nov-21
JAM	TSL	001	Header	Changed PLM Team	Update	2-Nov-21
JAM	TSL	001	Various	Remove number of units tested for each test	Clarification	27-Sept-2021
JAM	TSL	001	Various	Update J1455 to latest revision and section	Update	27-Sept-2021
JAM	TSL	001	Various	Update J1113-11, 12 and -13 to latest revision	Update	3-Nov-21
JAM	TSL	001	7.2	Update temperature for Chassis	Update	27-Sept-2021
JAM	TSL	001	7.7	Added temperature	Clarification	27-Sept-2021
JAM	TSL	001	7.12	Define file type	Clarification	27-Sept-2021
JAM	TSL	001	7.16	New Test Short Circuit VIN (Minimum Temperature, Maximum Voltage)	New Test	1-Nov-2021
JAM	TSL	001	7.19	New Test Short Circuit GND (Minimum Temperate, Maximum Voltage)	New Test	1-Nov-2021
JAM	TSL	001	7.20	Change power supply to batteries, Noise type updated to Internal	Update	27-Sept-2021
JAM	TSL	001	7.21	Hi Pot test added	New Test	27-Sept-2021
JAM	TSL	001	7.23	Updated pulse to 5C, added external resistance value	Clarification	27-Sept-2021
JAM	TSL	001	7.24	Updated schematic, revision number	Clarification	27-Sept-2021
JAM	TSL	001	7.26	Hot Swap test added	New Test	27-Sept-2021
JAM	TSL	001	7.27	Ignition Drop test added	New Test	27-Sept-2021

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	ISSUE DATE:	10-Nov-2021
	PAGE:	3 of 81
	KE CVS next level #	TPD-30-40

Revised By	Approved By	Rev	Section	Description	Reason	Date
JAM	TSL	001	7.30.1.2	Update J1113-12		
JAM	TSL	001	7.30.1	Update frequency range, pass criteria and table values	Update	27-Sept-2021
JAM	TSL	001	7.30.2	Update table values and note	Update	27-Sept-2021
JAM	TSL	001	7.30.4	Added ISO specification	Clarification	27-Sept-2021
JAM	TSL	001	7.30.6	Added ISO specification	Clarification	27-Sept-2021
JAM	TSL	001	8	Update flow chart and sample quantities	Update	27-Sept-2021
JAM	TSL	001	Various	Update Noise Type and Description	Update	10-Nov-2021

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	REVISION:	
	ISSUE DATE:	10-Nov-2021
	PAGE:	4 of 81
	KE CVS next level #	TPD-30-40

Table of Contents

1. Introduction

The purpose of this guideline is to provide a framework for standard product testing during the product development process. This document is to serve as a guide to how each test should be performed; engineers may customize individual tests to meet their product requirements.
This document shall be treated as confidential and for internal use only. Where external reporting is needed, refer to industry specifications such as those by SAE or ISO.

2. Scope

This guideline is applicable to all North American facilities and all functional areas of Bendix Commercial Vehicle Systems.

3. Related Documents

3.1. Reference Standards

- CISPR 25
- DRD100159
- SAE J1113-4
- SAE J1113-11
- SAE J1113-12
- SAE J1113-13
- SAE J1455

3.2. Reference Procedures

- Y249581

4. Definitions

A = Amperes
DC = direct current
DTC = Diagnostic Trouble Code
DUT = Device Under Test
Multivolt = operation across 12V and 24V system voltages
V = Volts

5. Tolerances

Unless otherwise specified, the tolerances within this document are:

- Pressure: ± 0.25 psi (± 0.02 bar)
- Voltage: ± 0.1 VDC
- Current: ± 10 milliamp
- Time: ± 0.5 milliseconds
- Temp: ± 1.0 °C

6. Noises- causes of failures

Each test has been denoted with 'Stressful Noise' information.

The 5 types of noises that disturb ideal function

		Noise factor	Caused by	Testing normally associated with noise
inner noises (capacity)	1	piece to piece variation of part properties (Such as dimensions)	production rate	performance testing with large range of samples
	2	Changes over time/mileage in dimensions or strengths	exposure to repetitive demand (Such as wear out, fatigue, chemical degradation)	Cycling/repetitive related testing
Outer Noises (demand)	3	customer usage and duty cycle	conditions of use	operating range tests, highly dependent on product spec
	4	external operating environment	climatic conditions/ Main power line/ Electromagnetic Env.	nominal operating tests, mixing of different types of test to create most extreme environment. That device operates in
	5	internal operating environment	component & system interactions and interfaces	Error states from one component being received as a noise factor from another

7. Design Validation Tests – Electrical

Test Method and Evaluation

Prior to performing any of the prescribed validation tests in this document, the responsible Engineer shall define:

1. all test harness lengths, connection points, and measurement points.
2. all DUT operating modes to be exercised during the test.
3. the pre- and post-test functional and inspection requirements to be used as part of the test acceptance criteria (pass/fail).

Except where noted otherwise, multivolt DUTs shall be tested with the test parameters listed for both 12V and the 24V system voltages.

Except where noted otherwise, the DUT shall be connected to a voltage supply source capable of providing at least 15A of current more than the DUT's maximum rated current.

Except where noted otherwise, an in-line fuse or circuit breaker shall not be used between the voltage source and the DUT. When using a fuse, the fuse rating shall be according to the product specification communicated to the customer.

All tests are performed per the "Input" and "Test" as listed in each section below. After each test (or as directed by the test Pass criteria), the units will be verified for normal operation by performing all of the tests listed in the "Pass" section.

Units must adhere to all expected outputs during the "Pass" verification steps to be considered passing the test.

7.1. **Operating Voltage**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. The input voltage will be set at, and between, the limits of the operating voltage range appropriate for the expected system voltage, according to Table 6.i. The DUT will not be damaged and will operate normally (as defined in "Pass" requirements) in each of the tested modes.

System Voltage	Minimum Voltage	Nominal Voltage	Maximum Voltage
12 V	8.0 ± 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 6.i

Test Standard Reference:
SAE J1455 REV *MAR2017*, Section *4.13.1.1.1* — Steady State Electrical Characteristics

TYPE	REQUIREMENTS
Input	Vin_{12V} = 8.0, 9.0, 10.0,12.0, 14.0, 16.0, 17.0, 18.0 ± 0.1 VDC Vin_{24V} = 18.0, 19.0, 20.0, 22.0, 24.0, 26.0, 28.0, 30.0, 32.0, 34.0, 35.0, 36.0 ± 0.1 VDC Multivolt use 12V and 24V levels.
Test	Apply Vin level to the DUT's power input pins for a minimum of 1 minute. Verify DUT meets Pass criteria Repeat for each of the selected DUT operating modes. Remove VIGN from DUT. Repeat for each VIGN input level.
Pass	The DUT shall meet all functional performance requirements during the test without generating voltage-related diagnostic trouble codes or producing visual fault indication (i.e. via warning lamps).

Noise Type: #4 External Operating Environments
Description: Device can be operated at the limits of voltage spec, going further to see where the device is expected to fail
Source: Environment

7.2. **Three Temp-Parametric Test**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. The DUT will be subjected to a Minimum, nominal 23°C, and Maximum temperature. At each temperature, the DUT will be subjected to the maximum and minimum system voltage, according to Table 6.i. The DUT will not be damaged and will operate normally (as defined in "Pass" requirements) in each of the tested modes.

Test Standard Reference:
SAE J1455 REV *MAR2017*, Section *4.13.1.1.1*— Steady State Electrical Characteristics

TYPE	REQUIREMENTS
Input	**DUT Location** / **Minimum Temp** / **Maximum Temp** Cab / -40°C / 85°C Chassis / -40°C / *125°C* Chassis (near heat source / -40°C / 150°C Engine Bay / -40°C / 125°C Engine Bay (near heat source / -40°C / 150°C **Parameters** / **12 Volt System** / **24 Volt System** V_{in} / 14.2 ± 0.1 V / 28.4 ± 0.1 V Multivolt test both voltages
Test	Apply Vin level to the DUT's power input pins for a minimum of 1 minute. Verify DUT meets Pass criteria Repeat for each of the selected DUT operating modes. Remove VIGN from DUT. Repeat for each V_{in} input level. Repeat at each temperature value
Pass	The DUT shall meet all functional performance requirements during the test without generating voltage-related diagnostic trouble codes or producing visual fault indication (i.e. via warning lamps).

Noise Type: #4 External Operating Environments
Description: Limits of temperature, simulating environment Put stress on all components
Source: Environment

7.3. **Reverse Polarity**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle.

The polarity of the V_{in} system voltage will be reversed. The DUT shall not be damaged by this application and operate normally, as defined in "Pass" requirements when the polarity is corrected.

Test Standard Reference:
SAE J1455 REV *MAR2017*, Section *4.13.1.1.1*— Steady State Electrical Characteristics

TYPE	REQUIREMENTS
Input	Vin_{12V} = - 25.2 ± 0.1 VDC Vin_{24V} = - 28.4 ± 0.1 VDC Multivolt use 24V levels.
Test	Remove Vin/GND from DUT Reverse Vin/GND polarity and apply to DUT for 5 ±1 minutes Remove Vin/GND from DUT Correct Vin/GND polarity and maintain for 10 ±1 minutes
Pass	The DUT shall revert to fail-safe operation during reverse polarity application. 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.

Noise Type: #5 Internal Operating Environments
Description: Wiring error due to user, must not destroy DUT
Source: Customer Error

7.4. **Upper Operating Voltage**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle.

The input voltage shall be set at the upper limit of the operating voltage range and applied to the DUT for at least two (2) hours after the unit is at its maximum operating temperature.

The DUT shall be exercised with the operating mode requiring the most current from the system voltage source for the duration of the test.

The DUT shall not be damaged and shall operate normally during the test.

Test Standard Reference:
SAE J1455 REV *MAR2017*, Section *4.13.1.1.1*— Steady State Electrical Characteristics

TYPE	REQUIREMENTS
Input	Vin_{12V} = 18.0 ± 0.1 VDC Vin_{24V} = 36.0 ± 0.1 VDC Ambient Temp = DUT maximum operating temperature Multivolt use 24V levels.
Test	Apply Vin to the DUT. Ramp the unit to its maximum operating temperature and allow unit to soak for one hour. Exercise the DUT with the operating mode(s) requiring the most current from the voltage source for two (2) hours while the DUT is at temperature. Remove Vin and the DUT from temperature.
Pass	The DUT shall meet all functional performance requirements during the test without generating diagnostic trouble codes or producing visual fault indication (i.e. via warning lamps). The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #4 External Operating Environments
Description: Test at high voltage, possible mis-wire
Source: Environment

7.5. **Over-Voltage / Jump Starting**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle.

The input voltage will be set beyond the upper limit of the operating voltage range and applied to the DUT. The DUT shall not be damaged and shall operate normally as defined in the "Pass" requirements when the voltage is returned to operating range.

Test Standard Reference:
SAE J1455 REV *MAR2017*, Section *4.13.1.1.1*— Steady State Electrical Characteristics

TYPE	REQUIREMENTS
Input	Vin_{12V} = 19.0, 21.0, 23.0, 25.2 ± 0.1 VDC Vin_{24V} = 37.0, 42.0, 46.0, 50.4 ± 0.1 VDC Multivolt use 24V levels.
Test	Set Vin input level. Apply Vin to DUT for 10 ± 0.5 minutes (For Vin_{12V} = 25.2V or Vin_{24V} = 50.4, increase Vin application time to 60 minutes.) Remove Vin from DUT. Set Vin to the nominal system voltage, as detailed in Table 6.i, for 10 ± 0.5 minutes. Verify correct operation at the nominal system voltage. Repeat for each Vin input level.
Pass	For each test level: 1. The DUT is not required to meet functional test requirements during the test. 2. Verify that the DUT produces correct voltage-related diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable. 3. Verify the DUT reverts to fail-safe operation during the overvoltage application. 4. The DUT shall meet all functional test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #3. Customer Usage
Description: User induced failure, condition of use if connected to main battery line (jump start)
Source: End Customer

7.6. **Under-Voltage**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle.

The input voltage will be set below the lower limit of the operating voltage range and applied to the DUT. The DUT will revert to a fail-safe mode and will operate normally as defined in the "Pass" requirements when the voltage is returned to normal.

Test Standard Reference:
SAE J1455 REV *MAR2017*, Section *4.13.1.1.1*— Steady State Electrical Characteristics

TYPE	REQUIREMENTS
Input	Vin_{12V} = 3.0, 5.0, 7.5 ± 0.1 VDC Vin_{24V} = 9.0, 13.0, 17.5 ± 0.1 VDC Multivolt use 12V levels.
Test	Apply Vin input level to the DUT's power input pins for a minimum of 1 minute. Verify DUT meets Pass criteria Repeat for each of the selected DUT operating modes. Remove VIGN from the DUT. Repeat for each VIGN input level.
Pass	For each test level: 1. The DUT is not required to meet functional test requirements during the test. 2. Verify that the DUT produces correct voltage-related diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable. 3. Verify the DUT reverts to fail-safe operation during the under-voltage application. 4. The DUT shall meet all functional test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #5 Internal Operating Environments
Description: Interaction of low battery voltage to DUT
Source: Error State of Battery

7.7. **Cold Cranking**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. The DUT will be subjected to several test pulses as outlined in figure 7 of J1113-11 Rev*JUN201*

During engine start devices can experience a voltage drop cause by the starter motor/solenoid. Battery charge state, ambient temperate, engine/starter characteristics will determine the waveform.
Test Standard Reference:
SAE J1113-11 REV*JUN2017*, Figure 7, —Test Pulse 4
SAE J1113-11 REV*JUN2017* Figure*C1*, Set up diagram
SAE J1455 REV *MAR2017 4.13.1.1.1*, *Cold Cranking*

TYPE	REQUIREMENTS		
Input	**Parameters**	**12 Volt System**	**24 Volt System**
	V_B	14.2 ± 0.1 V	28.4 ± 0.1 V
	V_s(from V_B)	-9.7(4.5 Nom)	-22.4 (6.0 Nom)
	V_a (from V_B)	-8.2 (6.0 Nom)	-16.4 (12.0 Nom)
	R_i	0-.02 Ω	0-0.02 Ω
	t_{10}	5 ms	5 ms
	t_7	200 ms	200 ms
	t_8	8 ms	8 ms
	t_9	30 s	30 s
	t_{11}	8 ms	8 ms
	Multivolt use 12V levels (lower voltage is the most extreme on power supply)		
Temp	*-40C*		
Test	Apply test pulse to the DUT's power input pins for 20 cycles Verify DUT meets Pass criteria Repeat for each of the selected DUT operating modes.		
Pass	For each test level: 1. The DUT is not required to meet functional test requirements during the test if the DUT is not a component required to start the vehicle. If the DUT is required to start the vehicle, the DUT will be required to meet all functional test requirements during each pulse 2. Verify that the DUT produces correct voltage-related diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable. 3. Verify the DUT reverts to fail-safe operation during the pulse application. 4. The DUT shall meet all functional test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.		

Noise Type: #4 External Operating Environments
Description: Standard Transient on conducted line
Source: Environment/ cold crank of the engine

7.8. Max Load

This test is to simulate a worst case scenario maximum load while the DUT is at maximum operating temperature conditions. The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. The DUT shall be configured to cycle all loads at the maximum possible duty cycle.

The input voltage shall be set at the upper limit of the operating voltage range and applied to the DUT. The DUT shall be placed in a thermal chamber capable of the temperatures in the input requirements below.

Test Standard Reference:
SAE J1455 REV *MAR2017*, Section *4.13.1.1.1*— Steady State Electrical Characteristics

TYPE	REQUIREMENTS
Input	Vin_{12V} = 18 ± 0.1 VDC Vin_{24V} = 36 ± 0.1 VDC $T_{max\ operating}$ = 85°C for cab-mount DUT, 125°C for chassis mount DUT Multivolt use 24V levels.
Test	Place the DUT and loads in a suitable thermal chamber. Soak the DUT and loads at $T_{max\ operating}$ for 1 hr. Power on the DUT and set it to cycle all loads at the maximum possible duty cycle. Maintain test for 168 hours (1 week). Monitor the DUT for diagnostic trouble codes and/or degraded performance.
Pass	The DUT shall meet all functional performance requirements during the test without generating diagnostic trouble codes or producing visual fault indication (i.e. via warning lamps). The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #3 External Operating Environments
Description: Standard Transient on conducted line
Source: Environment/ cold crank of the engine

7.9. **Voltage Regulator Failure**

This test is to simulate a voltage regulator failure on the vehicle alternator. The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle.

The input voltage will be set to the nominal voltage and applied to the DUT. The DUT will revert to a fail-safe mode and will operate normally as defined in the "Pass" requirements when the voltage is returned to normal.

Test Standard Reference:
SAE J1455 REV *MAR2017*, Section *4.13.1.1.1* — Steady State Electrical Characteristics

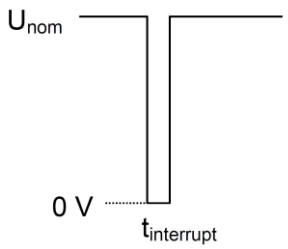
TYPE	REQUIREMENTS		
Input	**System voltage**	**Minimum Voltage**	**Maximum Voltage**
	12V	9.0 ± 0.1 V	18.0 ± 0.1 V
	24V	18.0 ± .01 V	36.0 ± .01 V
	Multivolt use 24V levels.		
Test	Apply Vin level to the DUT's power input pins for a minimum of 1 minute. Verify DUT meets Pass criteria Raise the Voltage to the Maximum specified in the above table Hold for 1 hour Return the voltage to nominal, repeat for the minimum voltage		
Pass	The DUT shall meet all functional performance requirements during the test. Low voltage and overvoltage alarms shall be accepted. The DUT shall not have sustained any physical damage following completion of the test.		

Noise type: #3 Duty Cycle
Description: Customer requires non destruction of DUT if Alternator (vehicle Voltage regulator) fails
Source: Error state of alternator

7.10. **Immunity to Micro Power Cuts**

This test is derived from issues with logic control circuits due to short-duration power cuts which can cause software-related glitches. The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle.

Test Standard Reference: Volvo

TYPE	REQUIREMENTS
Input	**Parameters** / **12 Volt System** / **24 Volt System** $V_{in\ nominal\ (U\ nom)}$ / 14.2 ± 0.1 V / 28.4 ± 0.1 V $t_{interrupt\ 1}$ / 100 µs / 100 µs $t_{interrupt\ 2}$ / 200 µs / 200 µs $t_{interrupt\ 3}$ / 400 µs / 400 µs $t_{transition\ hi\text{-}lo\ /\ lo\text{-}hi}$ / < 10 µs / < 10 µs  Multivolt use 12V levels.
Test	Identify all DUT operating modes to be tested. The harness connecting the DUT to the test fixture and transient pulse generator shall be ≤ 2000 mm in length. The power supply of the DUT tested shall be subjected to micro power cuts. During the micro power cut, the supply line shall be in open circuit. For each operating mode and power cut duration, apply Qty: 30 power cuts with a delay >1 s between each power cut.
Pass	1. The DUT shall be capable of uninterrupted operation when the micro power cuts are applied and without generating diagnostic trouble codes. 2. The DUT shall not have sustained any physical damage following completion of the test.

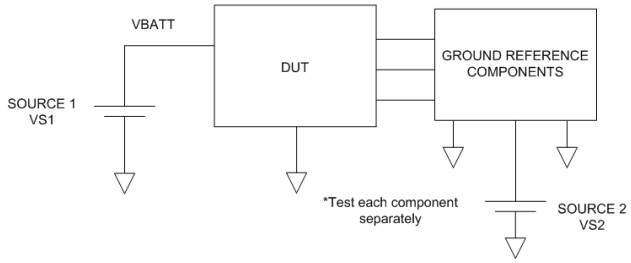
Noise type: #1 Part to part variation
Description: subcomponent failure
Source: Intermittent Power Connections

7.11. Ground Offset

Within the vehicle wiring system there may be up to a 2V potential difference in the electrical grounds at any two points. For dedicated ground lines, a potential ground difference of 0.5 is all that may be expected. Examples of this include warning lights that have an external, implied, ground. Please reference Bendix Spec Y249581 for a full testing procedure.

The unit shall be designed such that these ground voltage differences have no objectionable effect on the normal operation of the unit in the vehicle. Drastic effects such as resetting of a processor or large variances in DUT output will not be considered acceptable performance.

Ground Offset: External Components



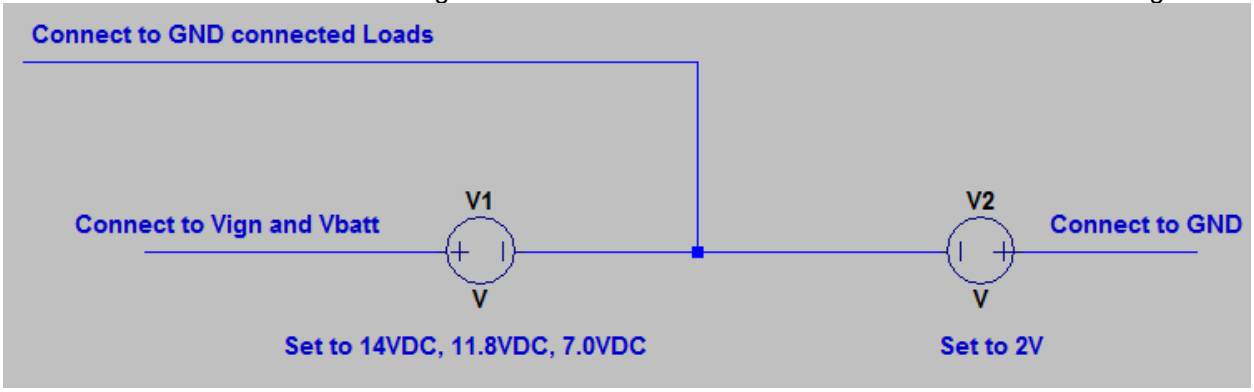
Test Standard Reference:

Y249581: “Bendix Ground Offset specification”

There are a total of four tests to be performed with the ground offset.

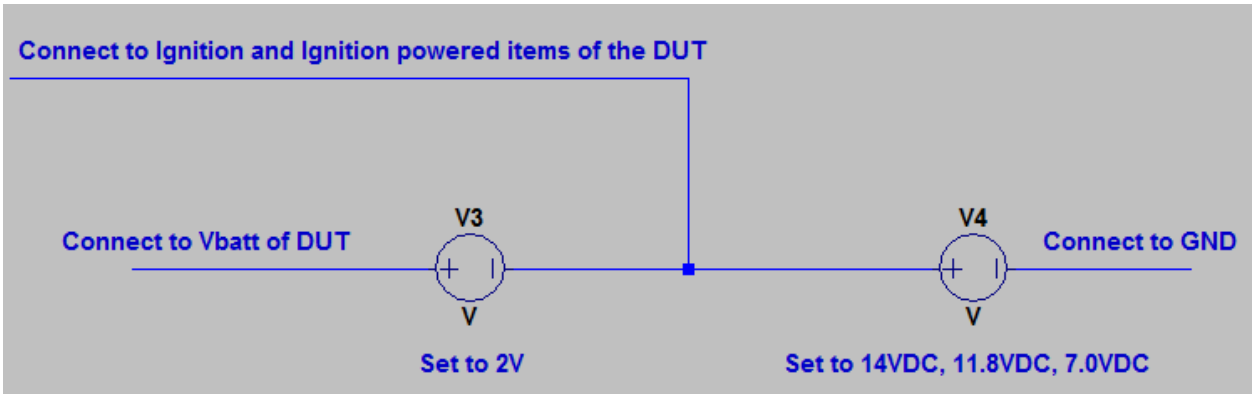
1. **$V_{IGNITION}$ & $V_{BATTERY}$ Normal Voltage**

Voltage of Ignition and Battery shall be at the nominal value.
Ground of the DUT shall be offset by +2V.
Ensure that ground connected loads are connected to the offset value of ground.



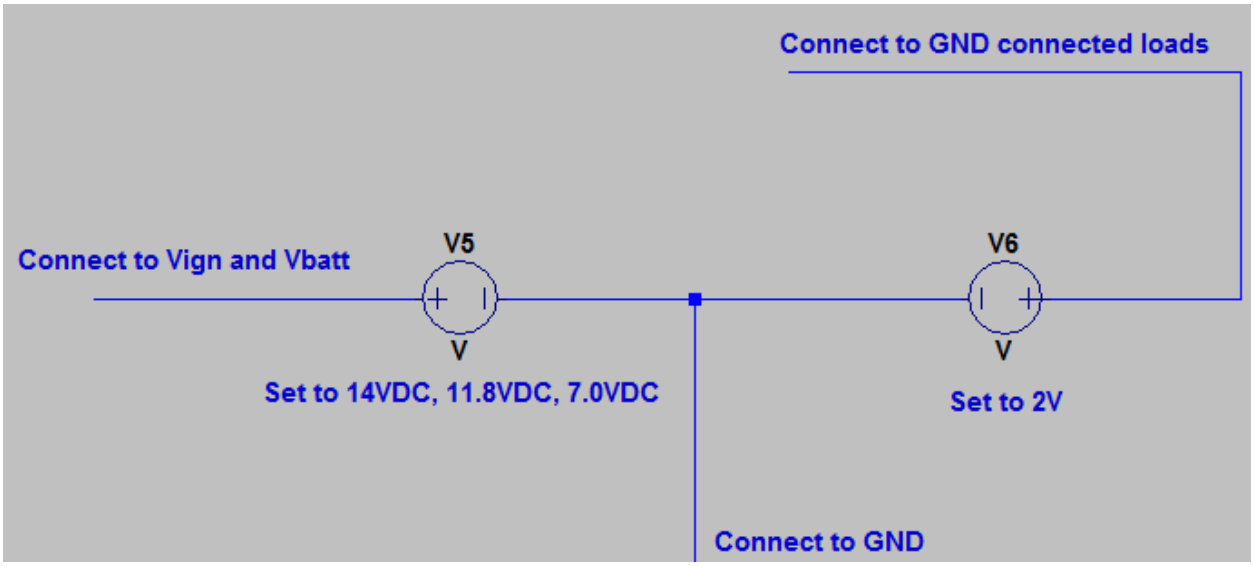
2. **$V_{BATTERY}$ Voltage Offset**

Battery Voltage of the DUT shall be offset by 2V
Ignition Voltage remains nominal
Ensure ignition voltage supplied items are connected to the nominal supply



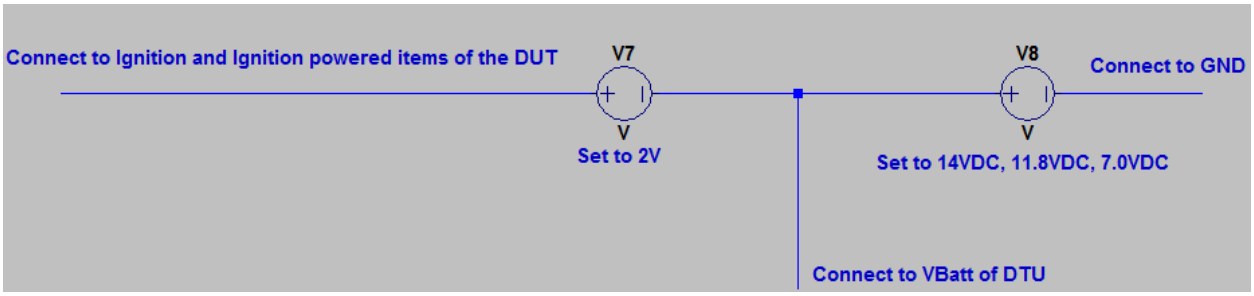
3. Ground Connected Loads Offset

Battery and Ignition voltage are nominal
Ground of DUT connected directly to GND
Ground connected loads are to be offset by 2V



4. $V_{IGNITION}$ Voltage Offset

Ground of the DUT shall be connected to GND
Battery voltage is nominal
Ignition voltage shall be offset by 2V
Ignition connected loads are to be offset by 2V



TYPE	REQUIREMENTS
Input	Vin_{12V} = 14.2 ± 0.1 V Vin_{24V} = 28.4 ± 0.1 V Multivolt use 24V levels.
Test	Apply Vin input level to the DUT's; Battery, Ignition Apply $Vsource_2$= -2, 0, +2V For each test scenario, exercise the system through all operating modes Disconnect power supplies
Pass	The DUT shall be required to operate during the test. The device shall functionally remain safe and perform as according to what is determined in the pretest. The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #4 External Environment

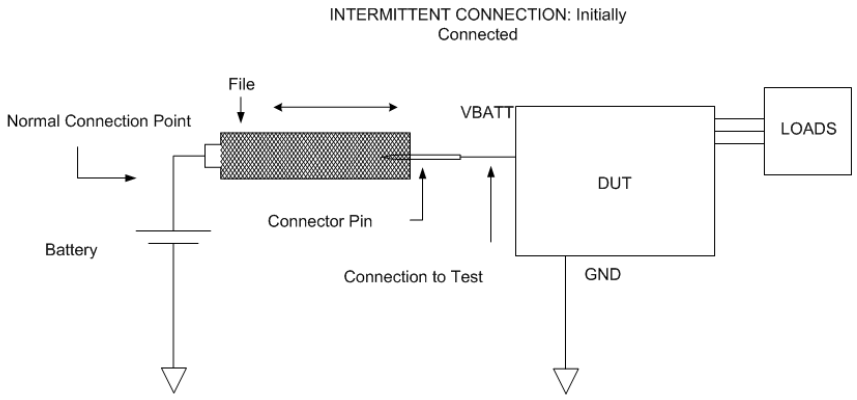
Description: Ground offsets occur if environment creates ground to chassis, voltage references to external components

Source: Voltage drops along long wiring can induce this problem

7.12. **Intermittent Connection**

Previous products have shown issues with fast intermittent power, ground, or other connection interrupts. This test is intended to replicate some of the conditions that can be seen in the field. Known causes of such events are loose connections, corrosion, or frayed wiring.

The DUT shall power up correctly, without faulty operation of the electronic hardware or software such as latch-ups or erroneous faults while experiencing the effects of intermittent ground or power transitions.



TYPE	REQUIREMENTS
Input	Vin_{12V} = 14.2 ± 0.1 V Vin_{24V} = 28.4 ± 0.1 V Multivolt use 24V levels.
Test	• Identify the file being used for test. • Apply Vin input level to the DUT's. • "Brush" the connector pin across a ***single cut*** bastard file to simulate a poor connection. Stop at the end of file and note any incorrect system behavior. • Power down the unit. • Repeat "Brush" steps 20 times using a sweeping motion, varying the rate of motion from approximately one every 2 seconds to one every one every .5 seconds. • Repeat the test removing the connector pin and using the bare frayed end of the wire • Repeat the test for VBatt, Ignition, GND, and other voltage supply inputs.
Pass	The DUT shall not be required to operate during the test. The device shall functionally remain safe and perform as according to what is determined in the pretest. The DUT shall not have sustained any physical damage following completion of the test.

Noise type: #5 Internal Environment
Description: Error state of wiring/Harness
Source: see Description

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7.13. **Open Circuit**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle.

Each connector pin will alternatingly be disconnected (i.e. one pin at-a-time) and then reconnected after a period of time (including circuit ground). The DUT will function normally as defined in "Pass" requirements after completion of all tests.

Test Standard Reference:
n/a

TYPE	REQUIREMENTS
Input	Vin_{12V} = 14.2 ± 0.1 VDC Vin_{24V} = 28.4 ± 0.1 VDC Multivolt use 24V levels.
Test	Connect the DUT to the power supply using a 3.3 ± 0.3 ft long harness. Use 16AWG wire or thicker. Disconnect each pin for at least five (5) minutes. Verify no sustained excessive current draw (i.e. > 0.5A). Verify DUT meets Pass criteria. Reconnect each pin. Reset test setup (reset any circuit breakers if necessary). Reset DUT at nominal voltage (all faults and history cleared). Repeat for all pins.
Pass	For each test: 1. The DUT is not required to meet functional test requirements during the test. 2. Verify that the DUT produces relevant diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable. 3. Verify the DUT reverts to fail-safe operation during a disconnection 4. The DUT shall meet all parametric test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #4 External Environment
Description: Input connections are disconnected
Source: Harness error

7.14. **Short Circuit – Vin (Room Temperature, Nominal Voltage)**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. An inline fuse or breaker, rated according to the customer Product Specification, can be used for this test.

Each connector pin will alternatingly have Vin power applied to it (i.e. one pin at-a-time). The DUT will function normally as defined in "Pass" requirements after completion of all tests.

Test Standard Reference:
n/a

TYPE	REQUIREMENTS
Input	Vin_{12V} = 14.2 ± 0.1 VDC Vin_{24V} = 28.4 ± 0.1 VDC Multivolt use 24V levels.
Test	Connect the DUT to the power supply using a 3.3 ± 0.3 ft long harness. Use 16AWG wire or thicker. Short Vin to a connector pin for at least five (5) minutes. Verify no sustained excessive current draw (i.e. > 0.5A). Verify DUT meets Pass criteria. Remove Vin from the shorted connector pin. Reset test setup (reset any circuit breakers if necessary). Reset DUT at nominal voltage (all faults and history cleared). Repeat for all pins.
Pass	For each test: 1.The DUT is not required to meet functional test requirements during the test. 2. Verify that the DUT produces relevant diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable. 3. Verify the DUT reverts to fail-safe operation during the Vin short application. 4.The DUT shall meet all parametric test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #5 Internal Environment
Description: Error state of wiring/harness.
Source: Harness error

7.15. **Short Circuit – Vin (High Temperature, Minimum Voltage)**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. An inline fuse or breaker, rated according to the customer Product Specification, can be used for this test.

Each connector pin will alternatingly have Vin power applied to it (i.e. one pin at-a-time). The DUT will function normally as defined in "Pass" requirements after completion of all tests.

Test Standard Reference:
n/a

TYPE	REQUIREMENTS
Input	Vin_{12V} = 8.0 ± 0.1 VDC Vin_{24V} = 18.0 ± 0.1 VDC Ambient Temp = DUT maximum operating temperature Multivolt use 12V levels.
Test	Connect the DUT to the power supply using a 3.3 ± 0.3 ft long harness. Use 16AWG wire or thicker. Short Vin to a connector pin for at least five (5) minutes. Verify no sustained excessive current draw (i.e. > 0.5A). Verify DUT meets Pass criteria. Remove Vin from the shorted connector pin. Reset test setup (reset any circuit breakers if necessary). Reset DUT at nominal voltage (all faults and history cleared). Repeat for all pins.
Pass	For each test: 1. The DUT is not required to meet functional test requirements during the test. 2. Verify that the DUT produces relevant diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable. 3. Verify the DUT reverts to fail-safe operation during the Vin short application. 4. The DUT shall meet all parametric test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #5 Internal Environment
Description: Error state of wiring/harness, made worse by min/max temp/voltage cond.
Source: See *Description*.

7.16. **Short Circuit – Vin (Minimum Temperature, Maximum Voltage)**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. An inline fuse or breaker, rated according to the customer Product Specification, can be used for this test.

Each connector pin will alternatingly have Vin power applied to it (i.e. one pin at-a-time). The DUT will function normally as defined in "Pass" requirements after completion of all tests.

Test Standard Reference:
n/a

TYPE	*REQUIREMENTS*
Input	*Vin_{12V} = 8.0 ± 0.1 VDC* *Vin_{24V} = 18.0 ± 0.1 VDC* *Ambient Temp = DUT maximum operating temperature* *Multivolt use 12V levels.*
Test	*Connect the DUT to the power supply using a 3.3 ± 0.3 ft long harness. Use 16AWG wire or thicker.* *Short Vin to a connector pin for at least five (5) minutes.* *Verify no sustained excessive current draw (i.e. > 0.5A).* *Verify DUT meets Pass criteria.* *Remove Vin from the shorted connector pin.* *Reset test setup (reset any circuit breakers if necessary).* *Reset DUT at nominal voltage (all faults and history cleared).* *Repeat for all pins.*
Pass	*For each test:* 5. *The DUT is not required to meet functional test requirements during the test.* 6. *Verify that the DUT produces relevant diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable.* 7. *Verify the DUT reverts to fail-safe operation during the Vin short application.* 8. *The DUT shall meet all parametric test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.*

Noise Type: #5 Internal Environment
Description: Error state of wiring/harness, made worse by min/max temp/voltage cond.
Source: See Description.

7.17. **Short Circuit – GND (Room Temperature, Nominal Voltage)**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. An inline fuse or breaker, rated according to the customer Product Specification, can be used for this test.

Each connector pin will alternatingly have Ground (GND) applied to it (i.e. one pin at-a-time). The DUT will function normally as defined in "Pass" requirements after completion of all tests.

Test Standard Reference:
n/a

TYPE	REQUIREMENTS
Input	Vin_{12V} = 14.2 ± 0.1 VDC Vin_{24V} = 28.4 ± 0.1 VDC Multivolt use 24V levels.
Test	Connect the DUT to the power supply using a 3.3 ± 0.3 ft long harness. Use 16AWG wire or thicker. Short GND to a connector pin for at least five (5) minutes. Verify no sustained excessive current draw (i.e. > 0.5A). Verify DUT meets Pass criteria. Remove GND from the shorted connector pin. Reset test setup (reset any circuit breakers if necessary). Reset DUT at nominal voltage (all faults and history cleared). Repeat for all pins.
Pass	For each test: 1. The DUT is not required to meet functional test requirements during the test. 2. Verify that the DUT produces relevant diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable. 3. Verify the DUT reverts to fail-safe operation during the GND short application. 4. The DUT shall meet all parametric test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #5 Internal Environment
Description: Error state of wiring/harness, made worse by min/max temp/voltage cond.
Source: See *Description*

7.18. **Short Circuit – GND (High Temperature, Minimum Voltage)**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. An inline fuse or breaker, rated according to the customer Product Specification, can be used for this test.

Each connector pin will alternatingly have Ground (GND) applied to it (i.e. one pin at-a-time). The DUT will function normally as defined in "Pass" requirements after completion of all tests.

Test Standard Reference:
n/a

TYPE	REQUIREMENTS
Input	Vin_{12V} = 8.0 ± 0.1 VDC Vin_{24V} = 18.0 ± 0.1 VDC Ambient Temp = Maximum Temperature, according to Section 6.2 Multivolt use 12V levels.
Test	Connect the DUT to the power supply using a 3.3 ± 0.3 ft long harness. Use 16AWG wire or thicker. Short GND to a connector pin for at least five (5) minutes. Verify no sustained excessive current draw (i.e. > 0.5A). Verify DUT meets Pass criteria. Remove GND from the shorted connector pin. Reset test setup (reset any circuit breakers if necessary). Reset DUT at nominal voltage (all faults and history cleared). Repeat for all pins.
Pass	For each test: 1. The DUT is not required to meet functional test requirements during the test. 2. Verify that the DUT produces relevant diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable. 3. Verify the DUT reverts to fail-safe operation during the GND short application. 4. The DUT shall meet all parametric test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #5 Internal Environment
Description: state of wiring/harness, made worse by min/max temp/voltage cond
Source: See *Description*

7.19. **Short Circuit – GND (Minimum Temperature, Maximum Voltage)**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. An inline fuse or breaker, rated according to the customer Product Specification, can be used for this test.

Each connector pin will alternatingly have Ground (GND) applied to it (i.e. one pin at-a-time). The DUT will function normally as defined in "Pass" requirements after completion of all tests.

Test Standard Reference:
n/a

TYPE	*REQUIREMENTS*
Input	*Vin_{12V} = 8.0 ± 0.1 VDC* *Vin_{24V} = 18.0 ± 0.1 VDC* *Ambient Temp = DUT maximum operating temperature* *Multivolt use 12V levels.*
Test	*Connect the DUT to the power supply using a 3.3 ± 0.3 ft long harness. Use 16AWG wire or thicker.* *Short Vin to a connector pin for at least five (5) minutes.* *Verify no sustained excessive current draw (i.e. > 0.5A).* *Verify DUT meets Pass criteria.* *Remove Vin from the shorted connector pin.* *Reset test setup (reset any circuit breakers if necessary).* *Reset DUT at nominal voltage (all faults and history cleared).* *Repeat for all pins.*
Pass	*For each test:* 9. *The DUT is not required to meet functional test requirements during the test.* 10. *Verify that the DUT produces relevant diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable.* 11. *Verify the DUT reverts to fail-safe operation during the Vin short application.* 12. *The DUT shall meet all parametric test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.*

Noise Type: #5 Internal Environment
Description: Error state of wiring/harness, made worse by min/max temp/voltage cond.
Source: See Description.

7.20. **Short Circuit – Pin-to-Pin (Room Temperature, Minimum Voltage)**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. An inline fuse or breaker, rated according to the customer Product Specification, can be used for this test.

Each connector pin pair combination will be short circuited (i.e. each connector pin alternatively shorted to all other pins). The DUT will function normally as defined in "Pass" requirements after completion of all tests.

Test Standard Reference:
n/a

TYPE	REQUIREMENTS
Input	Vin_{12V} = 8.0 ± 0.1 VDC Vin_{24V} = 18.0 ± 0.1 VDC Multivolt use 12V levels.
Test	Connect the DUT to the power supply. Use a 3.3 ± 0.3 ft long jumper, 16AWG wire or thicker, to create the short. Short two connector pins together for at least five (5) minutes. Verify no sustained excessive current draw (i.e. > 0.5A). Verify DUT meets Pass criteria. Remove the short from the pin pair. Reset test setup (reset any circuit breakers if necessary). Reset DUT at nominal voltage (all faults and history cleared). Repeat for all pin pairs.
Pass	For each test: 1. The DUT is not required to meet functional test requirements during the test. 2. Verify that the DUT produces relevant diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable. 3. Verify the DUT reverts to fail-safe operation during the short application to the connector pair. 4. The DUT shall meet all parametric test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #5 *Internal* Environment
Description: state of wiring/harness, made worse by min/max temp/voltage cond.
Source: See *Description*

7.21. **Connector Pin Exchange – (Room Temperature, Nominal Voltage)**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. An inline fuse or breaker, rated according to the customer Product Specification, can be used for this test.

All connector pin pairs shall be defined and tested. Pins sharing common rails (i.e. common Vin or GND pins) shall be treated as separate. Each pin position on each connector will have its lead swapped with every other connector position on the DUT, one pair at a time. The DUT will function normally as defined in "Pass" requirements after completion of all tests.

Test Standard Reference:
n/a

TYPE	REQUIREMENTS
Input	Vin_{12V} = 14.2 ± 0.1 VDC Vin_{24V} = 28.4 ± 0.1 VDC Multivolt use 24V levels.
Test	Connect the DUT to the power supply using a 3.3 ± 0.3 ft long harness. Use 16AWG wire or thicker. Swap leads for a pair of pin positions for 5 +1/-0 minutes. Verify no sustained excessive current draw (i.e. > 0.5A). Verify DUT meets Pass criteria. Turn off power and correct the pin connections. Reset test setup (reset any circuit breakers if necessary). Reset DUT at nominal voltage (all faults and history cleared). Repeat for all pin pairs.
Pass	For each test: 1. The DUT is not required to meet functional test requirements during the test. 2. Verify that the DUT produces relevant diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable. 3. Verify the DUT reverts to fail-safe operation during the pin exchange. 4. The DUT shall meet all parametric test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #5 Internal Environment
Description: Error state of Wiring/harness, made worse by min/max temp/voltage cond.
Source: See *Description*.

7.22. **Input Power Capability**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. The individual VIGN and GND inputs will be miswired to determine DUT current capabilities and failure modes. The DUT shall not be damaged and shall operate normally as defined in the "Pass" requirements when the miswire is corrected and the voltage is returned to operating range.

For this test, *a battery or batteries in parallel with charger for* 100A at the designated voltage shall be used.

For this test, a 30A circuit breaker shall be used in line with the DUT power connection(s).

Test Standard Reference:
n/a

TYPE	REQUIREMENTS
Input	Vin_{12V} = 14.2 ± 0.1 VDC Vin_{24V} = 28.4 ± 0.1 VDC Multivolt use 24V levels.
Test	This test shall be done individually to each Vin and GND input separately. Connect the DUT to the power supply using a 3.3 ± 0.3 ft long harness. Use 14AWG wire or thicker for all Vin and GND pins. Remove a lead from a Vin or GND pin. Connect a lead with the opposite polarity from the power supply to the same pin position for 5 +1/-0 minutes. Verify DUT meets Pass criteria. Turn off power and correct the pin connections. Reset test setup (reset any circuit breakers if necessary). Reset DUT at nominal voltage (all faults and history cleared). Repeat for all remaining Vin and GND pins.
Pass	For each test: 1. The DUT is not required to meet functional test requirements during the test. 2. Verify that the DUT produces relevant diagnostic trouble codes or visual fault indication (i.e. via warning lamps), if applicable. 3. Verify the DUT reverts to fail-safe operation during the pin exchange. 4. The DUT shall meet all parametric test requirements following completion of each test level without degradation of performance. The DUT shall not have sustained any physical damage following completion of the test.

Noise Type: #5 Internal environment
Description: state of wiring/harness, made worse by min/max temp/voltage cond.
Source: worse case internal condition + worse case environment

7.23. ***Hi Pot Test***

7.23.1 Hi Pot Test Option 1

Hi Pot test determines the electrical insulation strength of wire harness or splice.

TYPE	*REQUIREMENTS*
Pre / Post Test	*Inspect all products before and after the test. Note: Test can either be done with a DUT attached or a mating connector with plugs* *Subject cables to 1kV Hi-Pot (High-Potential) – Product Engineer to provide levels if different then listed*
Test	*Submerse all DUTs (Devices Under Test)* *Temperature of 5% salt water is 6°C* *Always keep the electrical connectors dry and free of saltwater.* *Time in chilled salt water for (30) minutes* *h. Set the Hi-Pot meter to apply a 1kV test voltage* *i. Apply a 1kV test voltage to each DUT for two (2) minutes continuously* *j. Record the measured resistance across the DUT* *k. Remove the DUT from the saltwater and pat dry, being careful not to get the electrical connector wet*
Pass	*1. The DUT insulation resistance should measure 11.0 ±1 GΩ (Giga ohms) at 1000 ±50 volts.*

7.23.2 Hi Pot Test Option 2 – Wheel Speed Sensor from the field

TYPE	*REQUIREMENTS*
Pre / Post Test	*Inspect all products before and after the test. Note: Test can either be done with a DUT attached or a mating connector with plugs* *Subject cables to 750V Hi-Pot (High-Potential) – Product Engineer to provide levels if different then listed*
Test	*Submerse all DUTs (Devices Under Test) 5% salt water* *Always keep the electrical connectors dry and free of saltwater.* *Time in chilled salt water for 1 to 3 seconds* *h. Set the Hi-Pot meter to apply a 750V test voltage* *i. Apply a 750V test voltage to each DUT* *j. Record the measured resistance across the DUT* *k. Remove the DUT from the saltwater and pat dry, being careful not to get the electrical connector wet*
Pass	*1. The DUT insulation resistance should measure greater than 850 ±1 MΩ (Mega ohms) at 750 ±50 volts.*

Test Procedure:

Attach the negative (-) Hi-Pot meter lead to either a bare wire or a wire with both ends stripped. Submerse the unattached end of the wire at least six inches below the water surface of the saltwater solution

. Attach the positive (+) Hi-Pot meter lead to each of the DUTs connections. When connecting the positive meter lead to each of the DUTs, connect the lead simultaneously to all the pins on the DUT harness

7.24. Conducted Immunity- Transients

7.24.1. Inductive Switching – Pulse 1 Positive

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle and according to Figure 1B, Transient Immunity Test Set-Up – Pulse Injection, in SAE J1113-11 Section 5.

A transient over-voltage pulse, similar to SAE J1113-11 REV *JUN2017* Figure 2, —Test Pulse 1, but of opposite polarity, shall be commonly applied to all DUT lines connected to Ignition voltage and Battery voltage.

All Ignition and Battery line lengths between the pulse generator and the DUT shall have a length of 1 ± 0.1 m.

The DUT shall function normally as defined in the “Pass” requirements during and after completion of the test.

Test Standard Reference:
SAE J1113-11 REV*JUN2017*, Section 5, —Test Procedure

TYPE	REQUIREMENTS		
Input	**Parameters**	**12 Volt System**	**24 Volt System**
	V_A	14.2 ± 0.1 V	28.4 ± 0.1 V
	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[a]	0.5 s	0.5 s
	t_2	200 ms	200 ms
	t_3[b]	< 100 µs	< 100 µs
	Multivolt use 12V parameters. a. t_1 shall be chosen such that the device under test is correctly initialized before the application of the next pulse. b. t_3 shall be the smallest possible time necessary between the disconnection of the supply source and the application of the pulse.		
Test	The DUT shall be subjected to 5000 pulses, evenly divided between all defined operating modes.		
Pass	2. The DUT shall maintain correct operation without faults during the test. 3. The DUT shall meet all parametric functional 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.		

Noise type: #4 Ext. Environment
Description: Standard transient on conducted line
Source: relays/solenoid disconnected in parallel

7.24.2. Inductive Switching – Pulse 1 Negative

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle and according to Figure 1B, Transient Immunity Test Set-Up – Pulse Injection, in SAE J1113-11 Section 5.

A transient under-voltage pulse, similar to SAE J1113-11 REV *JUN2017*, Figure 2, —Test Pulse 1, shall be commonly applied to all DUT lines connected to Ignition voltage and Battery voltage.

All Ignition and Battery line lengths between the pulse generator and the DUT shall have a length of 1 ± 0.1 m.

The DUT shall function normally as defined in the “Pass” requirements during and after completion of the test.

Test Standard Reference:

SAE J1113-11 REV *JUN2017*, Section 5, —Test Procedure
SAE J1113-11 REV *JUN2017*, Figure 2, —Test Pulse 1

TYPE	REQUIREMENTS		
Input	**Parameters**	**12 Volt System**	**24 Volt System**
	V_A	14.2 ± 0.1 V	28.4 ± 0.1 V
	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[a]	0.5 s	0.5 s
	t_2	200 ms	200 ms
	t_3[b]	< 100 µs	< 100 µs
	Multivolt use 12V parameters. c. t_1 shall be chosen such that the device under test is correctly initialized before the application of the next pulse. d. t_3 shall be the smallest possible time necessary between the disconnection of the supply source and the application of the pulse.		
Test	The DUT shall be subjected to 5000 pulses, evenly divided between all defined operating modes.		
Pass	1. The DUT shall maintain correct operation without faults during the test. 2. The DUT shall meet all parametric functional 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.		

Noise type: #4 External Environment
Description: Standard transient on conducted line
Source: relays/solenoid disconnected in parallel

7.24.3. Inductive Switching – Pulse 2a

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle and according to Figure 1B, Transient Immunity Test Set-Up – Pulse Injection, in SAE J1113-11 Section 5.

A transient over-voltage pulse, similar to SAE J1113-11 REV *JUN2017*, Figure 3, —Test Pulse 2a, shall be commonly applied to all DUT lines connected to Ignition voltage and Battery voltage.

All Ignition and Battery line lengths between the pulse generator and the DUT shall have a length of 1 ± 0.1 m.

The DUT shall function normally as defined in the “Pass” requirements during and after completion of the test.

Test Standard Reference:

SAE J1113-11 REV *JUN2017*, Section 5, —Test Procedure
SAE J1113-11 REV *JUN2017*, Figure 3, —Test Pulse 2a

TYPE	REQUIREMENTS		
Input	**Parameters**	**12 Volt System**	**24 Volt System**
	V_A	14.2 ± 0.1 V	28.4 ± 0.1 V
	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[a]	0.2 s	0.2 s
	Multivolt use 24V parameters. [a] t_1 shall be chosen such that the device under test is correctly initialized before the application of the next pulse.		
Test	The DUT shall be subjected to 5000 pulses, evenly divided between all defined operating modes.		
Pass	1. The DUT shall maintain correct operation without faults during the test. 2. The DUT shall meet all parametric functional 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.		

Noise type: #4 Ext. Environment
Description: Standard transient on conducted line
Source: Current in harness inductance disconnect

7.24.4. Inductive Switching – Pulse 2b

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle and according to Figure 1B, Transient Immunity Test Set-Up – Pulse Injection, in SAE J1113-11 Section 5.

A transient under-voltage pulse, similar to SAE J1113-11 REV *JUN2017*, Figure 4, —Test Pulse 2b, shall be commonly applied to all DUT lines connected to Ignition voltage and Battery voltage.

All Ignition and Battery line lengths between the pulse generator and the DUT shall have a length of 1 ± 0.1 m.

The DUT shall function normally as defined in the “Pass” requirements during and after completion of the test.

Test Standard Reference:

SAE J1113-11 REV *JUN2017*, Section 5, —Test Procedure
SAE J1113-11 REV *JUN2017*, Figure 4, —Test Pulse 2b

TYPE	REQUIREMENTS		
Input	**Parameters**	**12 Volt System**	**24 Volt System**
	V_A	14.2 ± 0.1 V	28.4 ± 0.1 V
	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%
	Multivolt use 24V parameters.		
Test	The DUT shall be subjected to 100 pulses, evenly divided between all defined operating modes.		
Pass	1. The DUT shall maintain correct operation without faults during the test. 2. The DUT shall meet all parametric functional 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.		

Noise type: #4 External Environment
Description: Standard transient on conducted line
Source: DC motors acting as generators after ignition switch off

7.24.5. Switching Spikes – Pulse 3a

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle and according to Figure 1B, Transient Immunity Test Set-Up – Pulse Injection, in SAE J1113-11 Section 5.

A transient under-voltage pulse, similar to SAE J1113-11 REV *JUN2017*, Figure 5, —Test Pulse 3a, shall be commonly applied to all DUT lines connected to Ignition voltage and Battery voltage.

The leads between the terminals of the test pulse generator and the device under test shall be laid out in a straight parallel line, shall have a height of 50 mm + 10/–0 mm from the ground plane, and shall have a length of 0.5 m ± 0.1 m.

The DUT shall function normally as defined in the “Pass” requirements during and after completion of the test.

Test Standard Reference:

SAE J1113-11 REV *JUN2017*, Section 5, —Test Procedure
SAE J1113-11 REV *JUN2017*, Figure 5, —Test Pulse 3a

TYPE	REQUIREMENTS		
Input	**Parameters**	**12 Volt System**	**24 Volt System**
	V_A	14.2 ± 0.1 V	28.4 ± 0.1 V
	V_S (from V_A)	- 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 ns ± 30%
	t_1	100 µs	100 µs
	t_4	10 ms	10 ms
	t_5	90 ms	90 ms
	Multivolt use 24V parameters.		
Test	The DUT shall be subjected to 7200 pulses (2 hours), evenly divided between all defined operating modes.		
Pass	1. The DUT shall maintain correct operation without faults during the test. 2. The DUT shall meet all parametric functional 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.		

Noise type: #4 Ext. Environment
Description: Standard transient on conducted line
Source: ~10kHz switching noise on the power line

7.24.6. Switching Spikes – Pulse 3b

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle and according to Figure 1B, Transient Immunity Test Set-Up – Pulse Injection, in SAE J1113-11 Section 5.

A transient over-voltage pulse, similar to SAE J1113-11 REV *JUN2017*, Figure 6, —Test Pulse 3b, shall be commonly applied to all DUT lines connected to Ignition voltage and Battery voltage.

The leads between the terminals of the test pulse generator and the device under test shall be laid out in a straight parallel line, shall have a height of 50 mm + 10/–0 mm from the ground plane, and shall have a length of 0.5 m ± 0.1 m.

The DUT shall function normally as defined in the “Pass” requirements during and after completion of the test.

Test Standard Reference:

SAE J1113-11 REV *JUN2017*, Section 5, —Test Procedure
SAE J1113-11 REV *JUN2017*, Figure 6, —Test Pulse 3b

TYPE	REQUIREMENTS		
Input	**Parameters**	**12 Volt System**	**24 Volt System**
	V_A	14.2 ± 0.1 V	28.4 ± 0.1 V
	V_S (from V_A)	+ 100 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 ns ± 30%
	t_1	100 µs	100 µs
	t_4	10 ms	10 ms
	t_5	90 ms	90 ms
	Multivolt use 24V parameters.		
Test	The DUT shall be subjected to 7200 pulses (2 hours), evenly divided between all defined operating modes.		
Pass	1. The DUT shall maintain correct operation without faults during the test. 2. The DUT shall meet all parametric functional 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.		

Noise type: #4 External Environment
Description: Standard transient on conducted line
Source: ~10kHz switching noise on the power line

7.25. **Heavy Truck Load Dump – Pulse *5c***

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle and according to Figure 1B, Transient Immunity Test Set-Up – Pulse Injection, in SAE J1113-11 Section 5.

A transient over-voltage pulse, similar to SAE J1113-11 REV *JUN2017*, Table 8 —Test Pulse 5c, shall be commonly applied to all DUT lines connected to Ignition voltage and Battery voltage.

No external transient suppression elements (i.e. TVSS diodes) or external parallel load resistors (i.e Rv) shall be permitted for this test, unless otherwise agreed upon with the customer.

The DUT shall function normally as defined in the “Pass” requirements during and after completion of the test.

Test Standard Reference:

SAE J1113-11 REV *JUN2017*, Section 8, —Test Procedure
SAE J1113-11 REV *JUN2017*, Table 10, —Test Pulse 5c

TYPE	REQUIREMENTS		
Input	**Parameters**	**12 Volt System**	**24 Volt System**
	V_A	14.2 ± 0.1 V	28.4 ± 0.1 V
	V_S (from V_A)	+ 87 V	+ 174 V
	R_i	0.4 Ω	0.4 Ω
	t_d	400 ms	400 ms
	t_r	5 ms +0/–5 ms	5 ms +0/–5 ms
	Pulse Rate	10 s intervals	10 s intervals
	External R Network	*1 Ω*	*1 Ω*
	Multivolt use 24V parameters.		
Test	The DUT shall be subjected to 50 pulses, evenly divided between all defined operating modes.		
Pass	1. The DUT shall maintain correct operation without faults during the test. 2. The DUT shall meet all parametric functional 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.		

Noise type: #4 External Environment
Description: Error of battery wiring
Source: bad battery wiring + heavy charge loading

7.26. **Low-Side Output Bias by Ignition or Accessory**

DRD100159-6 Section 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. 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."

Pulse injection points shall be made along the DUT harness and within 1 ± 0.1 m of length from the DUT. See Figure 7.8.a. The DUT shall function normally as defined in the "Pass" requirements during and after completion of the test.

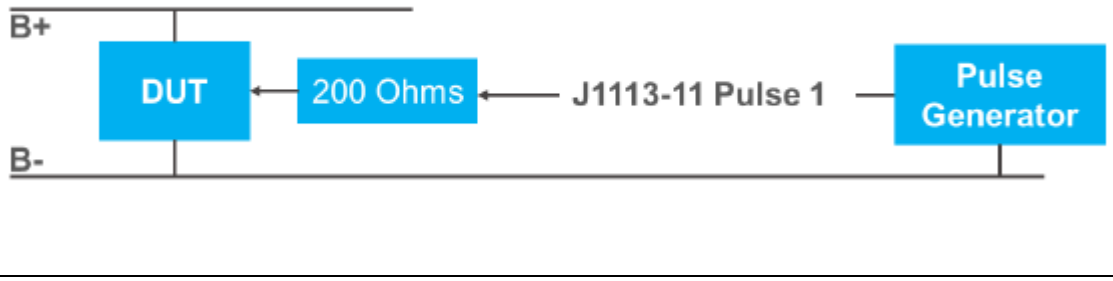


Figure 7.8.a – Drawing for Interpretation of , Low Side Output Bias by Ignition or Accessory.

Low-Side Output Bias by Ignition or Accessory - Continued

Test Standard Reference:
SAE J1113-11 REV *JUN2017*, Section 5, —Test Procedure
SAE J1113-11 REV *JUN2017*, Figure 2, —Test Pulse 1
DRD100159 – *06*, Section 7.9.7

TYPE	REQUIREMENTS
Input	Interpreted Conditions: 1. DUT supplied with Vbatt, Vign, and GND 2. Applicable loads are isolated from Vign with Test Switches (TS) 3. Low-side drivers are 'off' 4. Test pulse is applied to DUT-side of individual loads through a 200 Ohm resistance.
Test	The DUT shall be subjected to 3 pulses per pin.
Pass	1. The DUT shall maintain correct operation without faults during the test. 2. The DUT shall meet all parametric functional 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.

Noise type: #4 External Environment
Description: Standard Transient on conducted line
Source: See pulse 1b, on non Vbat lines

7.27. **Powerline Noise**

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle and according to Figure 1B, Transient Immunity Test Set-Up – Pulse Injection, in SAE J1113-11 Section 5.

A continuous, superimposed AC signal shall be commonly applied to all DUT lines connected to Ignition voltage and Battery voltage. The DUT shall maintain correct operation without faults during the test.

Sine Waveform:

$x_{sine} = V_{dc} + V_p(\sin(2.\pi.ft)$

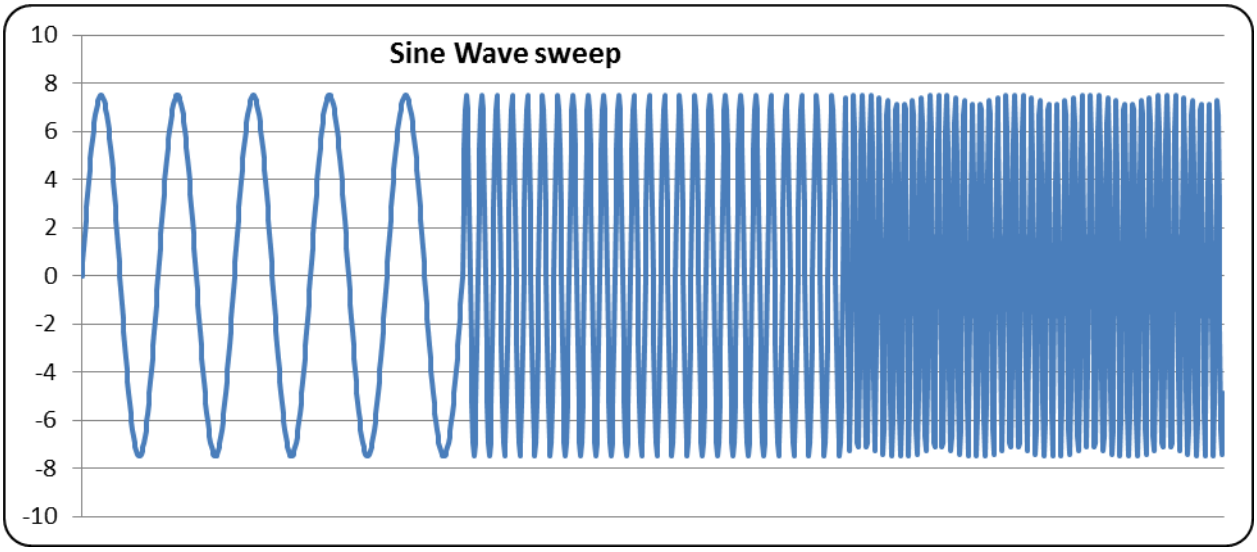
In the above equation,

V_{dc} is the DC offset voltage,

Vp is the peak amplitude of the signal

Each of the frequency will be applied for duration of 1 second. The frequency will be incremented from 50Hz through 10.05 KHz in the step of 200Hz.

Following picture depicts the sinusoidal waveforms with incremental frequencies. Duration of each frequency is same. DC offset and amplitude of the waves can be adjusted as per the requirement.

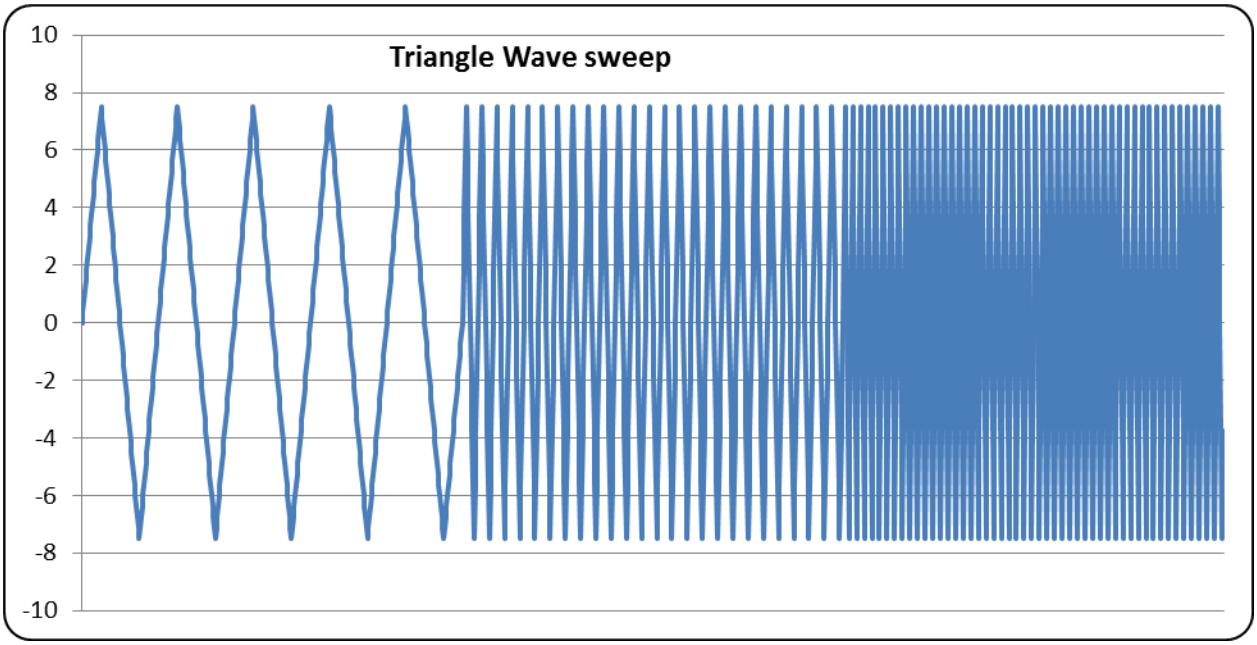


Triangular Waveform:

$$x_{triangle} = V_{dc} + K.\frac{8}{\pi^2}\left\{(\sin(2.\pi.ft) - \frac{1}{9}\sin(6.\pi.ft) + \frac{1}{25}\sin(10.\pi.ft) - \frac{1}{49}\sin(14.\pi.ft) + \frac{1}{81}\sin(18.\pi.ft)\right\}$$

In the above equation,
V_{dc} is the DC offset voltage,
K is scale factor deciding the peak amplitude of the signal

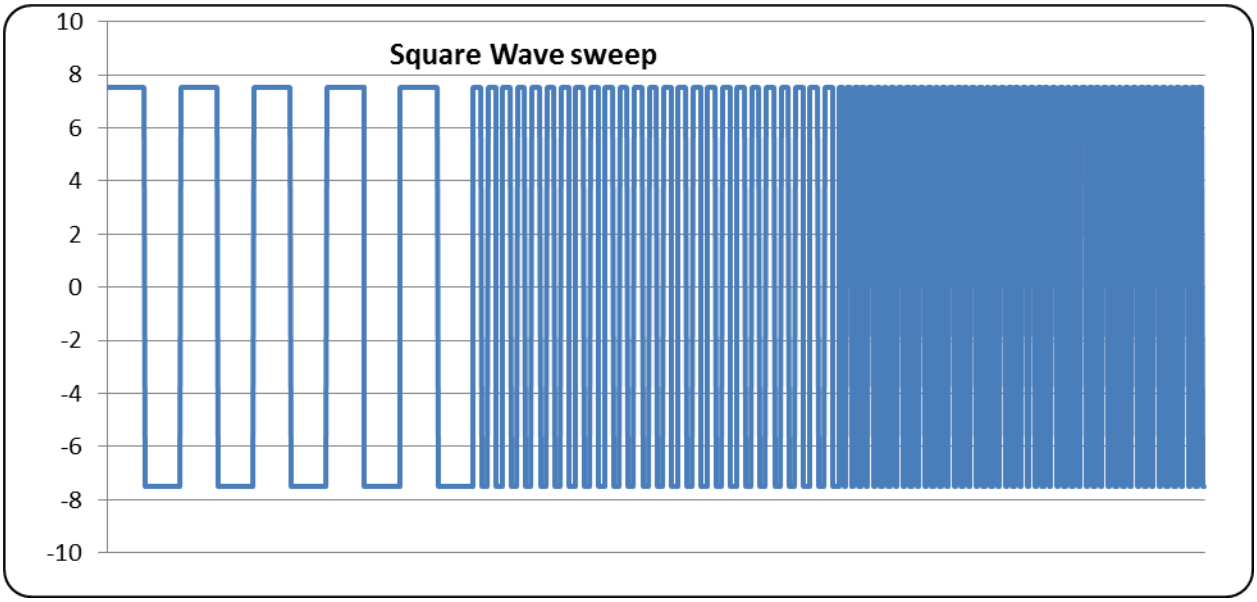
Following picture depicts the triangular waveforms with incremental frequencies. Duration of each frequency is same. DC offset and amplitude of the waves can be adjusted as per the requirement.



Square Wave

$$x_{square} = V_{dc} + \frac{4}{\pi}.K\left\{(\sin(2.\pi.ft) + \frac{1}{3}\sin(6.\pi.ft) + \frac{1}{5}\sin(10.\pi.ft) + \frac{1}{7}\sin(14.\pi.ft) + \frac{1}{9}\sin(18.\pi.ft)\right\}$$

In the above equation,
V_{dc} is the DC offset voltage,
K is scale factor deciding the peak amplitude of the signal



All Ignition and Battery line lengths between the voltage generator and the DUT shall have a length of 1 ± 0.1 m.

The DUT shall function normally as defined in the “Pass” requirements during and after completion of the test.

Test Standard Reference:
SAE J1113-11 REV *JUN2017*, Section 5, —Test Procedure
SAE J1113-11 REV *JUN2017*, Figure 5, —Test Pulse 3a

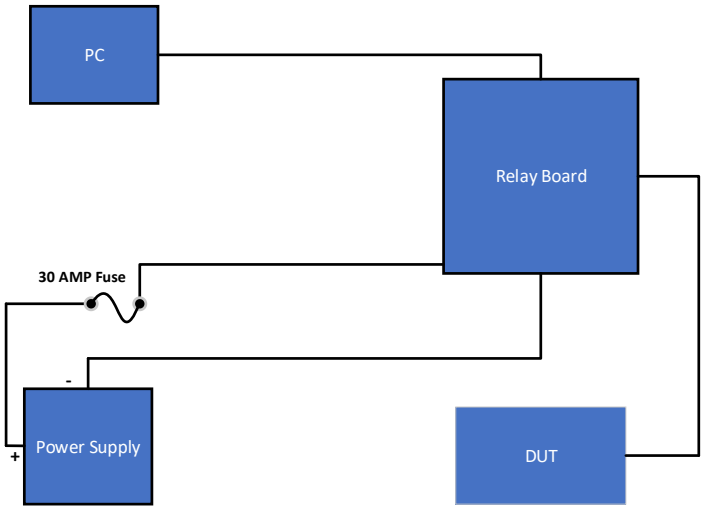
TYPE	REQUIREMENTS
Input	**AC Type** / V_{dc} **12V System** / V_{dc} **24V System** / **K** / **Frequency (Hz)** sine: 12, 14.2, 16 / 24, 28, 32 / 7.5 / 50 ≤ f ≤ 10,000 square: 12, 14.2, 16 / 24, 28, 32 / 7.5 / 50 ≤ f ≤ 10,000 triangle: 12, 14.2, 16 / 24, 28, 32 / 7.5 / 50 ≤ f ≤ 10,000 Vin = Vdc +/- 0.5 VDC modulated with 50 Hz to 10 kHz; 7.5 +/- 0.5 Vp-p; sine, triangle, and square swept at 200 +/- 10 Hz /s . This modulated Vin is applied to system voltage and NOT individually to each input connecting to Vign/Vbatt. Multivolt test with both 12V and 24V parameters.
Test	For each DC offset voltage level and pulse type, the DUT shall be subjected to two(2) hours of superimposed AC voltage, evenly divided between all defined operating modes.
Pass	The DUT shall maintain correct operation without faults during the test. The DUT shall meet all parametric functional 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.

Noise
type: #4 Ext. Environment
Description: Large oscillating voltage is placed on the input of power supply - "Operation without Batteries"
Source: bad battery wiring + heavy charge loading

7.28. ***Hot Swap Test***

The purpose of this test is to cover any faults that could be generated from hot swapping an electrical component on the vehicle. Hot swapping is when an electrical component is plugged or unplugged while the vehicle is still receiving power. The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle. A relay control board should be connected between each pin. Two test profiles should be created. The power supply should be a fully charged vehicle battery for the respect input voltage level.

Test Standard Referenced: N/A, from historical lessons learned



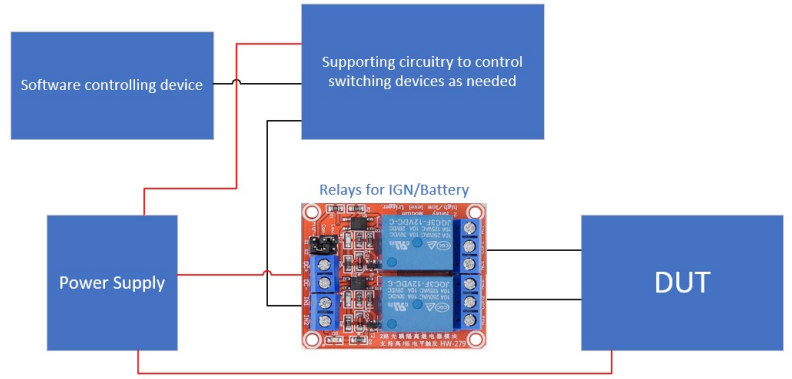
TYPE	*REQUIREMENTS*
Input	*Vin_{12V} = 14.2 ± 0.1 V* *Vin_{24V} = 28.4 ± 0.1 V* *Multivolt use 24V levels.* *The harness should be made with the relays as close to the pins as possible, no longer than 3" length when physically possible*
Test	*Each of the 3 profiles must be tested:* 1. *Full hot swap* • *All relays start in the open position. With the power supply turned on, all relays should be switched from open to closed.* • *Complete 100 cycles. A 1-minute cooldown should be allowed between each cycle* 2. *GND pin hot swap* • *All relays start in the open position. With the power supply on, close all pins except ground to simulate improper ground connection. The ground should be closed between 0.3-1 second after.* • *Complete 100 cycles, varying the delay by 10 ms each cycle. A 1-minute cooldown should be allowed between each cycle* 3. *Individual pin hot swap* • *All relays start in the open position. With the power supply on, close all pins except for one signal pin (that is not GND) that will be closed 0.3-1 second later.* • *Repeat this for every pin for 1k cycles, varying the delay by 10 ms each cycle. A 1-minute cooldown should be allowed between each cycle*
Pass	*For each test:* 1. *The DUT is not required to meet functional test requirements during the test* 2. *Verify that the DUT operates as intended after the cycles are complete* 3. *The DUT shall not have sustained any physical damage following completion of the test.* 4. *Check for pass criteria at cycle #s 10, 50, 100*

7.29. ***Ignition Dropout***

The DUT shall set up with all signal lines connected to sources and loads as it would be in the vehicle. In order to develop the timing for these tests, it is required to know the startup and shutdown sequences of the DUT. It should be known how long it takes for each signal to enter normal operating mode so the dropouts can be placed within the appropriate range. Once timing is determined, IGN and battery should be dropped out at random points within that range, like a micro power-cut. If ECU is not self-diagnosing, software must be used to monitor for faults and errors during testing.

The power supply and micro power-cut device must meet the equipment specifications to preform ISO 16750-2 tests. Switching relays or MOSFETS should be used to cycle power to the DUT. Must use software compatible with the ISO compliant power-cut device. The software needs to be able to run multiple cycles without need of human intervention. Paired with this, the switching device must also be automated with a compatible software (such as Arduino, Procomm, etc.).

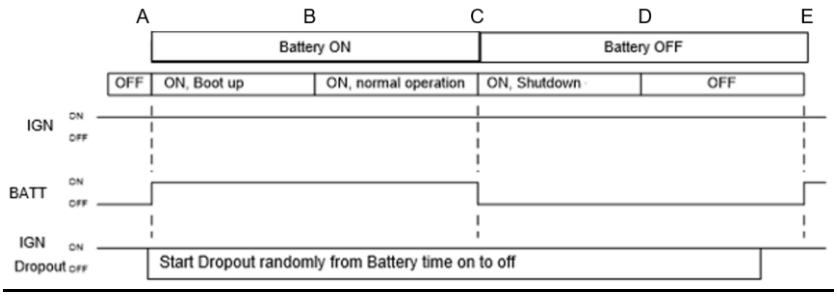
Test Standard Referenced: N/A, from historical lessons learned
NOTE: Engineer to provide startup and shutdown sequence

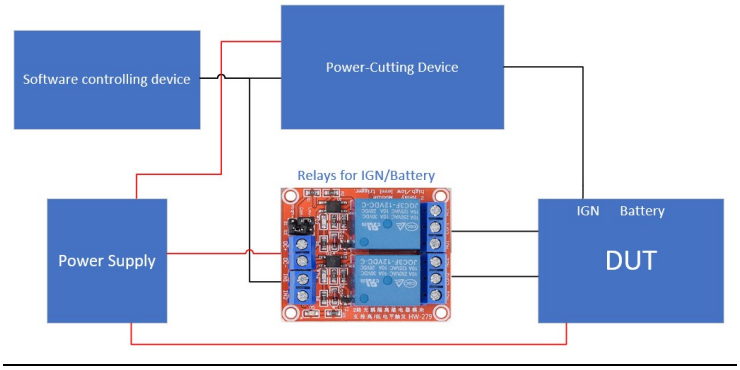


There is a total of 3 testing cycles that need to be run.

1. ***Random Ignition Dropout***

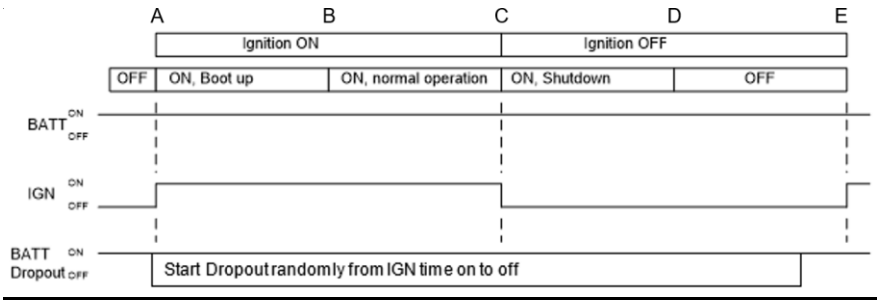
   The profile below should be run 100-150k times to simulate the worst-case ignition life of a vehicle for reliability. Ensure that the ignition is connected to the micro power-cutting device.

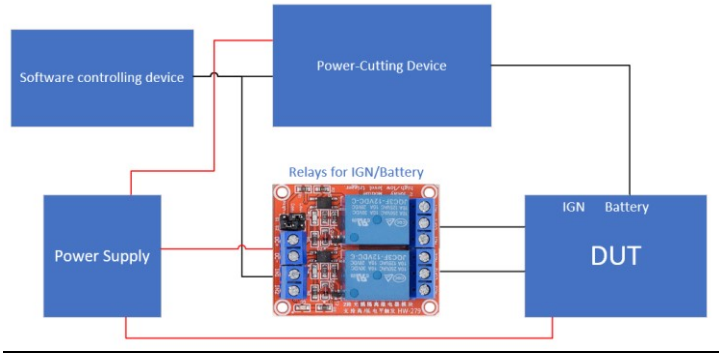




2. ***Random Battery Dropout***

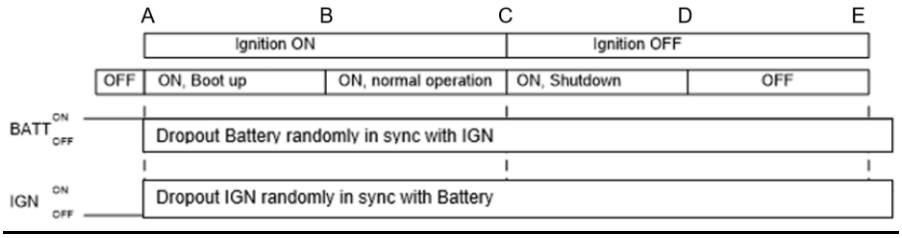
The profile below should be ran 15-20k times to simulate nominal vehicle start-ups. Ensure that the battery is connected to the micro power-cutting device.

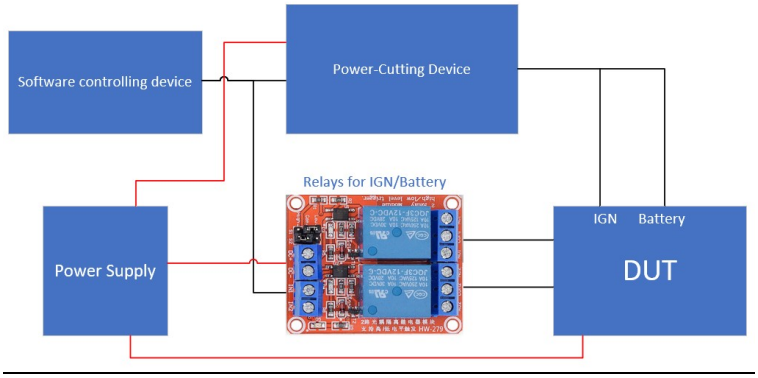




3. ***Ignition and Battery Synchronous Dropout***

The profile below should be ran 15-20k times to simulate nominal vehicle start-ups. Ensure that both the ignition and battery are connected to the micro power-cutting device.





TYPE	*REQUIREMENTS*
Input	1. *Connect all applicable loads and sources to signal lines.* 2. *Refer to above figures for setup.*
Test	1. *For each of the 3 profiles, the DUT must be subjected to the listed amount of cycles in that configuration.* 2. *Power-cuts should occur equally between stages A-B and C-D for each profile.*
Pass	1. *During the exposer time, verify that no warnings are generated, that no discrete outputs behave erratically.* 2. *Verify the DUT does not sustain any physical damage.*

N
Noise type: #3 Duty Cycle/ Customer Usage
Description: Usage over time can cause integrity failure

7.30. Conducted Immunity -Coupled Transients

7.30.1. Capacitive coupling clamp

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle and according to Figure 9, TEST SETUP WITH CAPACITIVE COUPLING CLAMP, in SAE J1113-12 Section 6.The signal lines will be run across the CAPACITIVE COUPLING CLAMP (Figure 1.)

A transient under/over-voltage pulse, similar to SAE J1113-12 REV *AUG2006*, Figure 2 and 3, —Test Pulse A and B, shall be commonly applied to the DUT harness via the capacitive clamp. The DUT shall function normally as defined in the "Pass" requirements during and after completion of the test.

Test Standard Reference:

SAE J1113-12 REV *AUG2006,* Section 4.1.2, —Test Procedure
SAE J1113-12 REV *AUG2006*, Figure 2&3, —Test Pulse A & B

TYPE	REQUIREMENTS		
Input	**Parameters**	**12 Volt System**	**24 Volt System**
	Test Pulse A		
	V_r	14.2 ± 0.1 V	28.4 ± 0.1 V
	V_S	- 60 V	-80 V
	R_i	50 Ω	50 Ω
	T	.1 µs +100/-0%	.1 µs +100/-0%
	t_r	5ns +/-50%	5ns +/-50%
	t_1	100 µs	100 µs
	t_2	10 ms	10 ms
	t_3	≥90 ms	≥90 ms
	Test Pulse B		
	V_r	14.2 ± 0.1 V	28.4 ± 0.1 V
	V_S	+ 40 V	+80 V
	R_i	50 Ω	50 Ω
	T	.1 µs +100/-0%	.1 µs +100/-0%
	t_r	5ns +/-50%	5ns +/-50%
	t_1	100 µs	100 µs
	t_2	10 ms	10 ms
	t_3	≥90 ms	≥90 ms
	Multivolt use 24V parameters.		
Test	The DUT shall be subjected to 10 minutes of pulses for each operating mode.		
Pass	1. The DUT shall maintain correct operation without faults during the test. 2. The DUT shall meet all parametric functional 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.		

Noise type: #4 External Environment
Description: Standard transient on conducted line
Source: Induced due to poor harnessing

7.30.2. Chattering Relay

The DUT shall be set up with all signal lines connected to sources and loads as it would be in the vehicle and according to Figure 7, TEST SETUP WITH CHATTERING RELAY, in SAE J1113-12 Section 4.2. The signal lines will be run across the CHATTERING RELAY test plane (Figure 7.) The relay to be used is 12 VAC Relay Potter & Brumfield KUP-14A15-12 (or equivalent)

Relay transients must be monitored and verified to be at least 300V.
NOTE: Since this is a statistical test, the magnitude of the transients do vary with time. Verifying the transient levels at the beginning and end of the test is sufficient to ensure that the intent of the test is met.

The DUT shall function normally as defined in the "Pass" requirements during and after completion of the test.

Test Standard Reference:
SAE J1113-12 REV *AUG2006,* Section 4.2, —Test Procedure
SAE J1113-12 REV *AUG2006*, Figure 7, —Test Setup

TYPE	REQUIREMENTS
Input	**Parameters** / **12 Volt System** / **24 Volt System** Vb / 14.2 ± 0.1 V / 28.4 ± 0.1 V Relay Transients / ≥300V / ≥300V Multivolt use 24V parameters.
Test	The DUT shall be subjected to 10 seconds of pulses, on each signal line. Repeat for each operating mode.
Pass	1. The DUT shall maintain correct operation without faults during the test. 2. The DUT shall meet all parametric functional 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.

Noise type: #4 Ext. Environment
Description: Standard Transient on conducted line
Source: Failing relaying inducting errors

7.31. Conducted Immunity- Transients- Electrostatic Discharge

7.31.1. ESD Unpowered

The DUT shall be set up with no connection placed on any of the input pins (i.e. floating) and the DUT frame placed on a static-dissipating mat. Below the mat shall be a ground plane as specified in J1113-13 Figure 5.

The DUT shall not be required to function normally during test. Following completion of the test, the DUT is required to meet the "Pass" requirements.

Test Standard Reference:

SAE J1113-13 REV *FEB2015*, Section 5, "Test Setup and procedure for packaging and handling sensitivity classification Test (non- powered Mode Test)"

SAE J1113-13 REV *FEB2015*, Table 1, "ESD Test Sequence and Voltage Levels"

TYPE	REQUIREMENTS		
Input	**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
	Simulation parameters: C_i = 150 pF R_i = 2000 Ω Temperature = 23°C +/- 3°C Humidity = 20-50%		
Test	The DUT shall be subjected to a minimum of 3 pulses to a maximum of 10 pulses of each polarity and level on each DUT pin and on each specified housing location.		
Pass	The DUT shall meet all parametric functional 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.		

Noise type: #3 changes over time

Description: destructive transient cause by built up charge

Source: See pulse 1b, on non Vbat lines

7.31.2. ESD Powered

The DUT shall be set up with power applied and all other pins shall have inputs to place the DUT in a functioning mode of operation. Test standard J1113-13 Figure 3 shows the appropriate test set up. If the DUT's chassis is isolated in normal operation, an insulator will exist between the DUT and the ground plane. All chassis mounted components will be placed directly on the ground plane.

The DUT shall be required to function normally during test. Following completion of the test, the DUT is required to meet the "Pass" requirements.

Test Standard Reference:

SAE J1113-13 REV *FEB2015*, Section 4, "Test Setup and procedure for Powered Mode Component Tests"

SAE J1113-13 REV *FEB2015*, Table 1, "ESD Test Sequence and Voltage Levels"

TYPE	REQUIREMENTS
Input	**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 Simulation parameters: C_i = 330 pF R_i = 2000 Ω Temperature = 23°C +/- 3°C Humidity = 20-50%
Test	The DUT shall be subjected to a minimum of 3 pulses and a maximum of 10 pulses of each polarity and level at each specified location.
Pass	The DUT shall be required to function normally during test without interruption or generation of diagnostic trouble codes. The DUT shall meet all parametric functional 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.

Noise type: #3 changes over time

Description: Destructive transient cause by built up charge

Source: Physical touch from end user/installer

7.31.3. ESD Vehicle

*This test is performed by the end customer with the assistance of Bendix engineering based on customer request.

The DUT shall be connected to a vehicle as intended for normal operation. Each connection pin must be functioning. Only devices with human interface (switches, buttons, gauges) are required to pass this test.

The DUT shall be required to function normally during test. Following completion of the test, the DUT is required to meet the "Pass" requirements.

Test Standard Reference:

SAE J1113-13 REV *FEB2015*, Section 4, "Test Setup and procedure for Powered Mode Component Tests"

SAE J1113-13 REV *FEB2015*, Table 1, "ESD Test Sequence and Voltage Levels"

TYPE	REQUIREMENTS		
Input	**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
	Simulation parameters: C_i = 330 pF R_i = 2000 Ω Temperature = 23°C +/- 3°C Humidity = 20-50%		
Test	The DUT shall be subjected to a minimum of 3 pulses and a maximum of 10 pulses of each polarity and level at each specified location.		
Pass	The DUT shall be required to function normally during test without interruption or generation of diagnostic trouble codes. The DUT shall meet all parametric functional 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.		

Noise type: #3 changes over time

Description: destructive transient cause by built up charge

Source: Induced from road built up charge

7.32. Electromagnetic Field Testing

7.32.1. Conducted Emissions - Component

This test shall follow the Conducted Emissions requirements as specified in CISPR 25 rev*4*. This test is intended to evaluate radio frequency emitted disturbances generated by the DUT and its wiring using the voltage measurement method.

The DUT shall exceed CISPR 25 Class 5 limits for peak detection and CISPR 25 class 5 limits for average detection. Additionally, frequency bands beyond those specified in CISPR 25 shall be tested. A comprehensive list of the frequency bands and limits are outlined in the Frequency Band Requirements table below.

Prior to performing the emission scans, the test engineer shall specify all relevant DUT operating modes and require a complete emission scan for each mode. The operating modes shall include a state where maximum emission occurs (i.e. the DUT would exercise inductive loads). The DUT shall be electrically set up as it would be used on a vehicle and connected to a load simulator to place the DUT in the appropriate operating mode for each scan. The DUT shall be scanned for emissions in the frequency range from 150 kHz to 3 GHz for compliance according to the levels specified in the test input requirements

Any frequency bands containing emissions higher than the prescribed limits in the Input Requirements shall be reported. The scan shall be repeated for non-compliant frequency bands to report the DUT's maximum CISPR 25 compliance class level. For example, a DUT may not be compliant to the requirement levels below but may meet CISPR Class 4 requirements. Follow the "Exceptions Summary" table example included below.

Test Standard Reference:
CISPR 25 Rev*4* 6.*3* "Conducted Emissions from components modules – voltage method"
CISPR 25 Rev*4* 6.*3.3* Figure *9* – "Conducted Emissions- Test Set up- remotely grounded"
CISPR 25 Rev*4* 6.*3.4* Table 5 - Examples of quasi-peak or peak limits for conducted disturbances – Voltage method

CE Summary - Ground Lead

Service or Band	Frequency Range(s) MHz	Excessive Average Emissions (Class 6)	Excessive Peak Emissions (Class 5)	Maximum CISPR 25 Class Met
LW	0.15 - 0.3			5
MW	0.53 - 1.8			5
SW	5.9 - 6.2			5
CB	26 - 28			5
FM	76 - 108			5
TV Band I	41 - 88	Yes	Yes	1
VHF	30 - 54	Yes		1
VHF	68 - 87	Yes		1

Legend	
Symbols	**Description**
Yes	Excessive Emissions (Non-Compliant)
	No Excessive Emissions (Compliant)
-	Not Required (No Limits)

Figure – Abbreviated example of an Exceptions Summary table for a non-specific DUT's Ground conductor. Note the column reporting the maximum compliance class.

TYPE	REQUIREMENTS
Input	**Parameters** **12 Volt System** **24 Volt System** V_A 14.2 ± 0.1 V 28.4 ± 0.1 V Multivolt use 24V parameters. Scan across the frequency bands in the tables below for each operating mode.
Test	The DUT shall be scanned at each frequency band and have the emissions measured in dB (µV) for each lead connected to battery, ignition, and ground. - Frequency range: 150 kHz – *108MHz*, divided into bands specified by the Input requirements. - Peak detector and average detector measurements shall be reported. - Peak and average detection corresponding to broadband and narrowband measurements shall be reported. Frequency bands outside of CISPR 25 bands are also included and are not shaded in the Requirements table below. In the range 30-*108 MHz* with 100/120 kHz bandwidth, the measurements using average detection can be conducted with a bandwidth of 9/10 kHz if the ambient electromagnetic noise level measured at 100/120 kHz is not at least 6 dB lower than the applicable limit. Unless otherwise defined in CISPR 25, edition 0*4*, the measurement time (receiver) or sweep time (spectrum analyzer) shall be increased if low recursive frequency must be measured.
Pass	Emission levels shall be below the prescribed amount in the Conducted Emissions Requirements table below for each operating mode. *NOTE: Limits in table are more severe than CISPR 25.*

Conducted Emissions - Frequency Band Requirements

Band	Frequency Band (MHz)	Peak Detector		Average Detector	
		Limit Value dB (µV)	BW (kHz)	Limit Value dB (µV)	BW (kHz)
LW 1)	0.15 - 0.30	*70*	9/10	*50*	9
2)	0.30 - 0.53	*70*	9/10	*50*	9/10
MW 1)	0.53 - 1.8	*54*	9/10	*34*	9/10
2)	1.8 - 5.9	*54*	9/10	*34*	9/10
SW 1)	5.9 - 6.2	*53*	9/10	*33*	9/10
2)	6.2 – 26	*53*	9/10	*33*	9/10
CB 3)	26 – 28	*44*	9/10	*24*	9/10
2)	28 – 30	*44*	9/10	*24*	9/10
VHF 3)	30 – 54	*44*	100/120	*24*	100/120
TV Band 1 1)	41 – 88	*34*	100/120	*24*	100/120
VHF 3)	68 – 87	*38*	100/120	*18*	100/120
FM 1)	76 – 108	*38*	100/120	*18*	100/120

1) Broadcast
2) Free band
3) Mobile services band

Noise type: #3 Customer Usage
Description: Customer req. to minimize noise transmitted through power line
Source: internal operation of the device

7.32.2. Radiated Emissions- Component

This test shall follow the Radiated Emissions requirements as specified in CISPR 25 rev*4* section 6.*5* "Radiated emissions from components/modules". It is a radiated emissions test that utilizes the ALSE (absorber lined shielded enclosure) method.

The DUT shall meet or exceed all CISPR 25 Class 5 limits for the peak detector method of scanning (Table 9) and CISPR 25 class 5 limits for the average detector method of scanning (Table 10). These limits are summarized in the table below. Additionally, frequency bands beyond those specified in CISPR 25 shall be tested. A comprehensive list of the frequency bands and limits are outlined in the Frequency Band Requirements table below.

The test setup shall use linearly polarized electric filed antennas with nominal 50Ω impedance. Section 6.*5*.2.1 of CISPR 25 rev*4* outlines the types of antennas for specific frequency ranges. Test set up is outlined in CISPR 25 figures *15, 16, 17 and 18.*

Prior to performing the emission scans, the test engineer shall specify all relevant DUT operating modes and require a complete emission scan for each mode. The operating modes shall include a state where maximum emission occurs (i.e. the DUT would exercise inductive loads). The DUT shall be electrically set up as it would be used on a vehicle and connected to a load simulator to place the DUT in the appropriate operating mode for each scan. The DUT shall be scanned for emissions in the frequency range from 150 kHz to 3 GHz for compliance according to the levels specified in the Frequency Band Requirements table below.

Any frequency bands containing emissions higher than the prescribed limits in the Input Requirements shall be reported. The scan shall be repeated for non-compliant frequency bands to report the DUT's maximum CISPR 25 compliance class level. For example, a DUT may not be compliant to the requirement levels below, but may meet CISPR Class 4 requirements. Follow the "Exceptions Summary" table example included below for reporting the maximum CISPR25 compliance class.

Test Standard Reference:
CISPR 25 rev*4* section 6.*5*

TYPE	REQUIREMENTS
Input	**Parameters** **12 Volt System** **24 Volt System** V_A 14.2 ± 0.1 V 28.4 ± 0.1 V Multivolt use 24V parameters. Scan across the frequency bands in the tables below for each operating mode.
Test	The DUT shall be scanned at each frequency band, each operating mode, and have the emissions measured in dB (µV). - Frequency range: 150 kHz – 3.0 GHz, divided into bands specified by the Input requirements. - Peak detector and average detector measurements shall be reported. - Peak and average detection corresponding to broadband and narrowband measurements shall be reported. - Frequency bands outside of CISPR 25 bands are also included, and are not shaded in the Requirements table. In the range 30-2500 MHz with 100/120 kHz bandwidth, the measurements using average detection can be conducted with a bandwidth of 9/10 kHz if the ambient electromagnetic noise level measured at 100/120 kHz is not at least 6 dB lower than the applicable limit. Unless otherwise defined in CISPR 25, edition 0*4*, the measurement time (receiver) or sweep time (spectrum analyzer) shall be increased if low recursive frequency must be measured. In a component test, the actuator, sensors, switches, etc., connected to the tested component/system shall be the ones intended for the production, as far as possible. In a component test, the component/system with its actuator, sensors, switches, etc., shall be connected to the ground plane in the same way as the installation is intended to be in the vehicle.
Pass	Emission levels shall be below the prescribed amount in the Radiated Emissions Requirements table below for each operating mode. *NOTE: Limits in table are more severe than CISPR 25.*

Radiated Emissions - Frequency Band Requirements

Band	Frequency Band (MHz)	Peak Detector		Average Detector	
		Limit Value dB (µV)	BW (kHz)	Limit Value dB (µV)	BW (kHz)
LW1 1)	0.15 - 0.30	*46*	9/10	*26*	9/10
2)	0.30 - 0.53	*46*	9/10	*26*	9/10
MW 1)	0.53 -1.8	*40*	9/10	*20*	9/10
2)	1.8 - 5.9	*40*	9/10	*20*	9/10
SW 1)	5.9 - 6.2	*40*	9/10	*20*	9/10
2)	6.2 - 26	*40*	9/10	*20*	9/10
CB 3)	26 - 28	*40*	9/10	20	9/10
2)	28 - 30	*40*	9/10	20	9/10
VHF 3)	30 - 54	*40*	100/120	20	100/120
TV Band 1 1)	41 - 88	*28*	100/120	*18*	100/120
VHF 3)	68 - 87	*35*	100/120	*15*	100/120
FM 1)	76 - 108	*38*	100/120	*18*	100/120
2)	108 - 137	*38*	100/120	*18*	100/120
VHF 3)	137 - 175	35	100/120	*15*	100/120
TV Band 3 1)	174 - 230	*32*	100/120	*22*	100/120
DAB 3 1)	171 - 245	*26*	100/120	*16*	100/120
2)	245 - 300	*32*	100/120	*18*	100/120
RKE 3)	300 - 330	*32*	100/120	*18*	100/120
2)	330 - 380	*32*	100/120	*18*	100/120
RKE 3)	420 - 450	*32*	100/120	*18*	100/120
UHF 3)	380 - 512	*38*	100/120	*18*	100/120
DTTV 1)	470 - 770	*45*	100/120	*35*	100/120
TV Band 4/5 1)	468 - 944	*41*	100/120	*31*	100/120
UHF 3)	820 - 960	*44*	100/120	*24*	100/120
GSM 800 3)	860 - 895	*44*	100/120	*24*	100/120
GSM 900 3)	925 - 960	*44*	100/120	*24*	100/120
2)	960 - 1447	*44*	100/120	*24*	100/120
DAB L Band 1)	1447 - 1494	*28*	100/120	*18*	100/120
2)	1494 - 1567	*44*	100/120	*18*	100/120

Radiated Emissions - Frequency Band Requirements Continued

Band	Frequency Band (MHz)	Peak Detector		Average Detector	
		Limit Value dB (µV)	BW (kHz)	Limit Value dB (µV)	BW (kHz)
GPS 3)	1567 - 1583	*44*	9/10*	*10*	100/120
2)	1583 - 1803	*44*	100/120	*24*	100/120
GLONASS 3)	*1591-1616*	*44*	*100/120*	*10*	*100/120*
GSM 1800 3)	1803 - 1882	*44*	100/120	*24*	100/120
GSM 1900 3)	1850 - 1990	*44*	100/120	*24*	100/120
UMTS (3G) 3)	1900 - 2172	*44*	100/120	*24*	100/120
2)	2172-*2320*	*44*	100/120	*24*	100/120
SDARS 1)	2320 - 2345	*34*	100/120	*24*	100/120
2)	2345 - 2400	*44*	100/120	*24*	100/120
Bluetooth /WLAN 3)	2400 - 2500	*44*	100/120	*24*	100/120
2)	2500 - 300*0*	*44*	100/120	*24*	100/120

1) Broadcast
2) Free band
3) Mobile services band

Noise type: #3 Customer Usage
Description: Customer req. to minimize noise transmitted through power line
Source: internal operation of the device
** If lab can't perform test omit this range from average detection*

7.32.3. Radiated Emissions- Vehicle

This test is outlined in CISPR 12. Vehicle-level EMC testing is not normally performed by BCVS.

Support customer testing as agreed upon in DVP&R discussions.

Noise type: #3 Customer Usage
Description: Customer req. to minimize noise transmitted through power line
Source: internal operation of the device

7.32.4. Radiated Immunity- Component

The system (which includes the DUT, all inputs, and output loads) will be subjected to radiated field testing in an absorber-lined, semi-echoic (ALSE) chamber from 10 kHz to 18 GHz.

Testing from 10 GHz to 18 GHz represents robustness testing. The DUT shall function as defined in the "Pass" requirements during and after completion of all tests.

TYPE	REQUIREMENTS
Input	**Parameters** **12 Volt System** **24 Volt System** V_A 14.2 ± 0.1 V 28.4 ± 0.1 V Multivolt use 24V parameters.
Test	Setup test according to SAE J1113/21. Identify all DUT operating modes to exercise during the test. For each operating mode: 1. Subject the DUT to frequencies from 10 kHz to 18 GHz. 2. Perform logarithmic *steps per ISO11452* and dwell for a minimum of two (2) seconds at each frequency step. 3. Use a field strength of 250 V/m(1). 4. Test with both vertical (V) and horizontal (H) field polarization. 5. Test with a continuous wave (CW) and then repeat for the modulation schemes in the table below:

Modulation Description	Frequency Range	Comments
Amplitude Modulation: 1 kHz 80% AM	10 kHz to 18 GHz	Required
Pulse Modulation: T_{on} 577 µs, period 4600 µs (217 Hz/12 %)	800 MHz to 12.4 GHz	Optional

(1) Equipment constraints may limit field strength capability at lower frequencies. If low-frequency capability is a concern, test at frequencies from 10 kHz to 200 MHz at maximum threat capability greater than or equal to 200 V/M. Test at frequencies from 200 MHz to 18 GHz at 250 V/M.

Radiated Immunity - Component - Continued

Pass	**For frequencies of 10 kHz to 10 GHz:** Verify visually, by sound, or by other means during the test that the DUT was not reading invalid signals or inappropriately exercising loads during the application of the field. For Levels >200 V/m to 250 V/m: Unit may deviate from design: DUT shall operate normally or revert to fail-safe operation during the application of field. Report field-induced Diagnostic-Trouble Codes. No false cycling of any load/modulator/solenoid is allowed. Unit will return to normal operation (no latched faults) after the field has been removed and the DUT has been power cycled. Record the minimum V/m thresholds for any noted deviations. For Levels ≤ 200V/m: Unit will operate as designed during and after exposure. Report field-induced Diagnostic-Trouble Codes. Record the minimum V/m thresholds for any noted deviations. **For frequencies of 10 GHz to 18 GHz:** Note any deviations from design that fall below 200V/m. Record the minimum V/m thresholds for any noted deviations. Deviations from 10 GHz to 18 GHz do not constitute a failure of the unit and are to be reviewed by BCVS for potential improvement.

Noise type: #4

Description: Induced transient through antennas

Source: environment inducing electromagnetic waves on device

7.32.5. Radiated Immunity- Vehicle

Vehicle-level EMC testing is not normally performed by BCVS.

Support customer testing as agreed upon in DVP&R discussions.

7.32.6. Coupled Immunity - Component - Bulk Current Injection

The DUT shall be subjected to bulk current injection as described in SAE J1113-4.

Test Standard Reference:

SAE J1113-4 REV APR2014 Figure 1, "BCI Test Setup"

SAE J1113-4 REV APR2014, Table A.1, "Functional Status…Severity level for immunity testing"

TYPE	REQUIREMENTS
Input	**Parameters** **12 Volt System** **24 Volt System** V_A 14.2 ± 0.1 V 28.4 ± 0.1 V Multivolt use 24V parameters.
Test	Setup test according to SAE J1113-4. Identify all DUT operating modes to exercise during the test. For each operating mode: 1. Subject the DUT to frequencies from 1 MHz to 400 MHz. 2. Perform logarithmic *steps per ISO11452* and dwell for a minimum of two (2) seconds at each frequency step. 3. Use a field strength of 300 mA. 4. *Common mode only* 5. Test at an injection point along the harness located 150 mm from the outermost edge of the DUT connector (measured from the center of the probe) as shown in Figure 1. 6. Repeat for injection points at 450mm and 750 mm. 7. Test with a continuous wave (CW) and then repeat for the modulation schemes in the table below:

Modulation Description	Frequency Range	Comments
Amplitude Modulation: 1 kHz 80% AM	1 MHz to 400 MHz	Required

Bulk Current Injection - Component - Continued

Pass	**For frequencies of 1 MHz to 400 MHz:** Verify visually, by sound, or by other means during the test that the DUT was not reading invalid signals or inappropriately exercising loads during the application of the field. For Levels >100 mA: Unit may deviate from design: DUT shall operate normally or revert to fail-safe operation during the application of field. Report field-induced Diagnostic-Trouble Codes. No false cycling of any load/modulator/solenoid is allowed. Unit will return to normal operation (no latched faults) after the field has been removed and the DUT has been power cycled. Record the minimum V/m thresholds for any noted deviations. For Levels ≤ 100 mA: Unit will operate as designed during and after exposure. Report field-induced Diagnostic-Trouble Codes. Record the minimum V/m thresholds for any noted deviations.

Noise type: #4 External Environments
Description: Induced transient on power lines
Source: Environment inducing current on harness

7.32.7. High-Power HAM/CB

Vehicle-level EMC testing is not normally performed by BCVS.

Support customer testing as agreed upon in DVP&R discussions.

Reference: ISO 11451-3.

Noise type: #4 Ext. Environment
Description: Induced transient through HAM/CB
Source: End customer using a high power radio incorrectly

7.32.8. SINAD

Vehicle-level EMC testing is not normally performed by BCVS.

Support customer testing as agreed upon in DVP&R discussions.

Reference: TEX-1160-U, —Radio Frequency Interference Testing

TYPE	REQUIREMENTS
Input	The vehicle shall be subjected to TEX-1160-U Radio Frequency Interference Testing. Alternate frequencies within the subject bands listed in Appendix A of TEX-1160-U may be employed to support customers other than the Texas Department of Transportation. **Parameters** **12 Volt System** **24 Volt System** Vin 14.2 ± 0.1 V 28.4 ± 0.1 V Multivolt use 24V parameters.
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.
Pass	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.

Noise type: #4 External Environment
Description: Induced Transient according to TDOT
Source: *See Description*

8. Example Test Sequence

Sequence and test sample quantity to be determined by the product group.