SURFACE VEHICLE RECOMMENDED PRACTICE

J2962™-2 FEB2024

Issued 2019-07
Revised 2024-02

Superseding J2962-2 JUL2019

Communication Transceivers Qualification Requirements - CAN

RATIONALE

Historically, Original Equipment Manufacturers (OEMs) had their own communication transceiver qualification requirements that varied over time. The intent of this standard is to minimize test variation and to consolidate requirements among OEMs.

FOREWORD

The purpose of this SAE Recommended Practice is to define a common test plan for approval of ICs that contain controller area network (CAN) communication transceivers. This document will define test circuits, bus load requirements, test procedures, and pass/fail criteria to validate transceivers.

NOTE: Understanding of this document requires a working knowledge of ISO EMC publications and SAE J2284.

TABLE OF CONTENTS

1. SCOPE

This document covers the requirements for transceiver qualification. Requirements stated in this document will provide a minimum standard level of performance for the CAN transceiver in the IC to which all compatible transceivers shall be designed. No other features in the IC are tested or qualified as part of this recommended practice. This will assure robust serial data communication among all connected devices, regardless of supplier.

The goal of SAE J2962-2 is to commonize approval processes of CAN transceivers across OEMs.

The intended audience includes, but is not limited to, CAN transceiver suppliers, component release engineers, and vehicle system engineers.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2284-1 High-Speed CAN (HSC) for Vehicle Applications at 125 kbps

SAE J2284-2 High-Speed CAN (HSC) for Vehicle Applications at 250 kbps

SAE J2284-3 High-Speed CAN (HSC) for Vehicle Applications at 500 kbps

2.1.2 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 7498 Data Processing Systems - Open Systems Interconnection Standard Reference Model

ISO 7637-1 Road Vehicles - Electrical Disturbances from Conduction and Coupling - Part 1: Definitions and General Considerations

ISO 7637-2 Road Vehicles - Electrical Disturbances from Conduction and Coupling - Part 2: Electrical Transient Conduction Along Supply Lines Only

ISO 7637-3 Road Vehicles - Electrical Disturbances from Conduction and Coupling - Part 3: Electrical Transient Transmission by Capacitive And Inductive Coupling via Lines other Than Supply Lines

ISO 10605 Road Vehicles - Test Methods for Electrical Disturbances from Electrostatic Discharge

ISO 11452-4 Road Vehicles - Component Test Methods for Electrical Disturbances from Narrowband Radiated Electromagnetic Energy - Part 4: Harness Excitation Methods

ISO 11898-1 Road Vehicles - Controller Area Network (CAN) - Part 1: Data Link Layer and Physical Signaling

ISO 11898-2 Road Vehicles - Controller Area Network (CAN) - Part 2: High-Speed Medium Access Unit

2.1.3 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 62228-1 General Part and Conditions

IEC 62228-3 Integrated Circuits - EMC Evaluation of CAN Transceivers

2.1.4 Other Publications

Bosch CAN Specification 2.0, Parts A and B

CISPR 25 Limits and Methods of Measurement of Radio Disturbance Characteristics for the Protection of Receivers Used On-Board Vehicles

3. DEFINITIONS

The definitions provided in SAE J1213-1 apply to this document. Additional or modified definitions, acronyms, and abbreviations included in this document, or relevant to the communication of information in a vehicle, are catalogued in this section.

3.1 BUSOFF

This is the state that the CAN controller reaches after a number of errors have been detected on the link. The state is latched such that the bus remains in the recessive state until the CAN controller has been reset by application software.

3.2 CAN_H

The CAN_H bus wire is fixed to a mean voltage level during the recessive state and is driven in a positive voltage direction during the dominant bit state.

3.3 CAN_L

The CAN_L bus wire is fixed to a mean voltage level during the recessive state and is driven in a negative voltage direction during the dominant bit state.

3.4 CAN-FD MESSAGE

Bus message according to ISO 11898-1:2015(E) where the FDF bit is recessive. A CAN-FD message typically employs different bit rates in the data field and in the arbitration field.

3.5 DATA BIT TIME

Length of a single bit in those parts of CAN-FD messages where a dedicated separately configurable data bit time is used. The data bit time is not used anywhere in classical CAN messages and is not used in those CAN-FD messages where the BRS bit is dominant.

3.6 DATA LINK LAYER

Provides the reliable transfer of information across the physical layer. This includes message qualification and error control.

3.7 DATA SAMPLE POINT (t_{SAMPLE})

The sample point is the time within the bit period at which the single data sample captures the state of the bus. The programmable sample point is located between t_{SEG1} and t_{SEG2}. Equation 1 shows the relationship of t_{SAMPLE} to t_{SEG2}:

$$t_{SAMPLE} = t_{BIT} - t_{SEG2} \quad \text{(Eq. 1)}$$

3.8 DIAGNOSTIC LINK CONNECTOR

Provides the electrical connection between off-board and on-board ECUs. For some vehicles, the diagnostic link connector is the SAE J1962 connector.

3.9 DISABLING OF DLC MATCHING

When this functionality is supported and active, then the bus transceiver will not compare message data length code (DLC) values as to whether or not they match to configured DLC values when scanning messages for presence of valid wake-up requests.

3.10 DOMINANT STATE

The dominant state is represented by a differential voltage greater than a minimum threshold between the CAN_L and CAN_H bus wires. The dominant state overwrites the recessive state and represents a logic “0” bit value.

3.11 ELECTRONIC CONTROL UNIT (ECU)

An on- or off-vehicle electronic assembly from which CAN SAE J2284-4 messages may be sent and/or received.

3.12 MUST

The word “must” is used to indicate that a binding requirement exists on components or devices that are outside the scope of this specification.

3.13 PROTOCOL

Formal set of conventions or rules for the exchange of information between ECUs. This includes the specification of frame administration, frame transfer, and physical layer.

3.14 RADIATED EMISSIONS

Radiated emissions consist of energy that emanates from the CAN bus wires. Electric field strength in dBμV/m is the typical measure of radiated emissions.

3.15 RADIATED IMMUNITY

A property that ensures that the CAN bus wires will not suffer degraded functional operation within its intended electromagnetic environment.

3.16 RECESSIVE STATE

The recessive state is represented by an inactive state differential voltage that is approximately 0.0 V. The recessive state represents a logic “1” bit value.

3.17 SHALL

The word “shall” is to be used in the following ways:

a. To state a binding requirement on the CAN interfaces that comprise the ECU, which is verifiable by external manipulation and/or observation of an input or output.

b. To state a binding requirement upon an ECU that is verifiable through a review of the document.

3.18 SHOULD

The word “should” is used to denote a preference or desired conformance.

3.19 WILL

The word “will” is used to state an immutable law of physics.

4. ACRONYMS

ALSE	Absorber-Lined Shielded Enclosure
AM	Amplitude Modulation
BCI	Bulk Current Injection Testing
CAN	Controller Area Network
CAN-FD	CAN with Flexible Data Rate
CBCI	Common Mode BCI
CW	Continuous Wave Modulation
DBCI	Differential Mode BCI
DCC	Direct Capacitor Coupling
DLC	Data Length Code
DUT	Device Under Test
EMC	Electromagnetic Compatibility
ESD	Electrostatic Discharge
FD	Flexible Data Rate (Message Format)
FDF	Flexible Data Rate Format
INH	Inhibit State Output Signal
ISO	International Standardization Organization
kbps	Kilobits per Second
LED	Light Emitting Diode (Indicator)
Mbps	Megabits per Second

MCU Microprocessor Control Unit

PK Peak Limit

QP Quasi-Peak Limit

RE Radiated Emissions Testing

RF Radio Frequency

RXD Receive Data Signal Line

TVS Transient Voltage Suppression

TXD Transmit Data Signal Line

Vbatt Power Supply for the ECUs Present in a Communication Network (12 V nominal)

5. REQUIRED TEST CIRCUIT

5.1 Primary Device Under Test (DUT)

5.1.1 Microcontroller-Based Primary DUT Behavior

- Primary DUT responds to traffic from the monitoring DUT.
- Total bus bandwidth shall be a minimum of 90%.
- If the monitoring DUT and the primary DUT contain the same transceiver, the traffic shall be symmetrical during the test.
- If the monitoring DUT does not have the same transceiver as the primary DUT, the primary DUT shall contribute 80% of the bus traffic on average.
- The primary DUT shall indicate the state of health of the mother board (e.g., LED, fault output). Some examples of faults to be indicated are: microprocessor control unit (MCU) reset, loss of power, watchdog timeout, or anything else that can prevent the CAN controller from operating correctly.

5.1.2 Square Wave-Based Primary DUT Behavior

- Primary DUT traffic generated from a square wave connected to the transmit data signal line (TXD) with 50% duty cycle. Frequency of operation determined by each test setup.
- Total bus bandwidth shall be 100%.

5.1.3 Primary DUT Application Circuit

The primary DUT is configured as a non-terminated node (termination is provided in load simulator circuit).

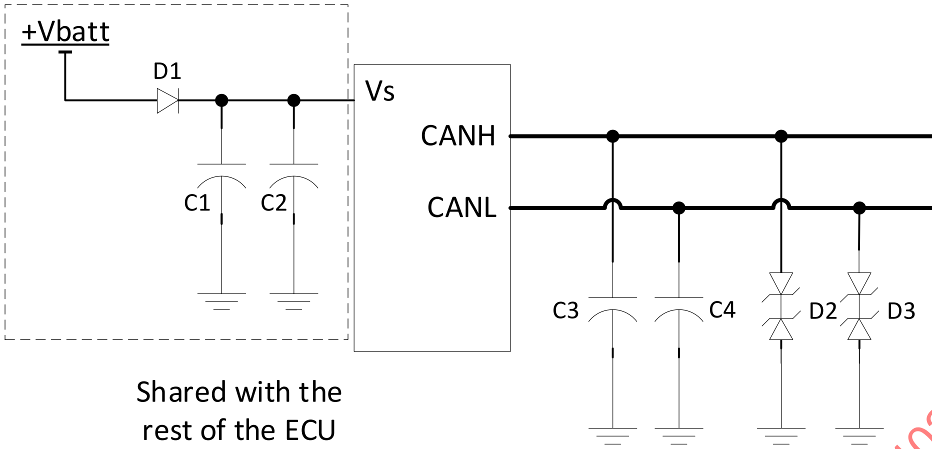


Figure 1 - Primary DUT with battery supply

Table 1 - Battery supply components

Component Name	Label	Parameter	Min	Max	Unit
Capacitor	C1		4.7% ± 10% 50 V	22% ± 10% 50 V	µF
Capacitor	C2		100% ± 10% 50 V		nF
Diode	D1	Forward Voltage Drop		1	Volts
		Reverse Breakdown Voltage	100		Volts
		Current	100		mA

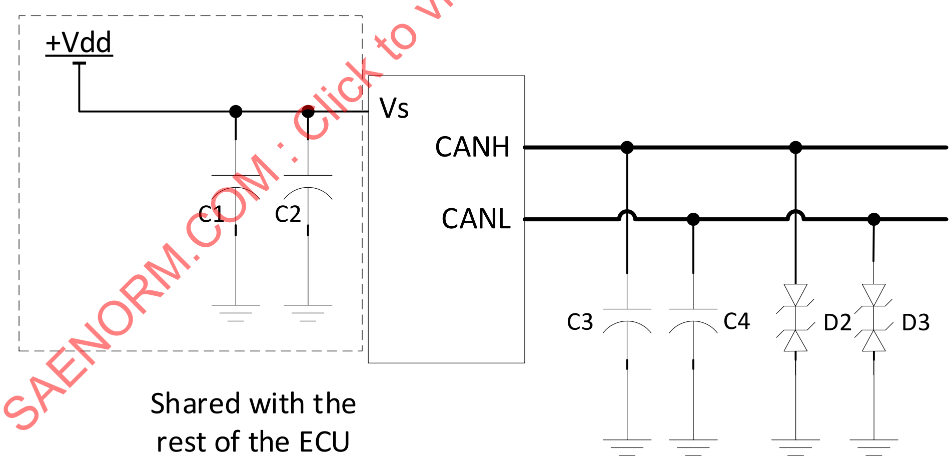


Figure 2 - Primary DUT with Vdd supply

Table 2 - Vdd supply components

Component Name	Label	Parameter	Min	Max	Unit
Capacitor	C1		Follow Vreg manufacturer's recommendations		
Capacitor	C2		100% ± 10% 35 V		nF

5.2 Electrostatic Discharge (ESD) Protection Options

Table 3A - Parameters for TVS component performance

	Option A	**Option B**
C_{MAX} (pF)	<20 pF	<50 pF
V_{RM}	>20 V	>20 V
V_{BR} min	≥24 V	≥24 V
Directionality	Bi-directional	Bi-directional
TLP **V_{CL} @ 16 A**	<80 V	<40 V
ESD_{MAX} **IEC 61000-4-2 contact**	≥15 kV	≥15 kV
Example Parts (but not limited to these)	**NXP** PESD1CAN (SOT23), **ST** ESDCAN04-2BLY (SOT23), **ST** ESDCAN04-2BWY (SOT323), **ST** ESDCAN03-2BWY (SOT323)	**On Semi** MMBZ27x (SOT23 or SOT323), **ST** ESDCAN01-2BLY (SOT23)

The ESD protection components shall be selected for performance according to Table 3A.

The specific transceiver circuit allows for a few options as recommended by the chipset supplier. At least one of the following three options as shown in Table 3B shall be tested.

Table 3B - ESD protection components

Option No.	**Component Name**	**Label**	**Maximum Value**
1	Capacitor	C3, C4	100 pF ± 5%(1,2,3) 100 V
	Zener, TVS	D2, D3	Not populated
2	Capacitor	C3, C4	82 pF ± 5%(1,2,3) 100 V
	Zener, TVS	D2, D3	Option A (see Table 3A)
3	Capacitor	C3, C4	47 pF ± 5%(1,2,3) 100 V
	Zener	D2, D3	Option B (see Table 3A)

(1) Over entire voltage and temperature operating range.

(2) According to SAE J2284-1, 6.3, the total ECU capacitance (C_{ECU}) must be lower than 130 pF:

$$130\ \text{pF} \geq C_{ECU} = C_{Transceiver} + C_{ESD\_protection} + (C3\ \text{or}\ C4)$$

The values for C3 or C4 shall be selected to respect maximum C_{ECU} capacitance.

(3) The values for C3 and C4 shall be greater than or equal to 47 pF. This minimum value may cause some transceivers with high input capacitance to be incompatible with external TVS selections (Options A and B).

NOTE: If any other protection components are required, the test setup has to be approved directly with the OEM.

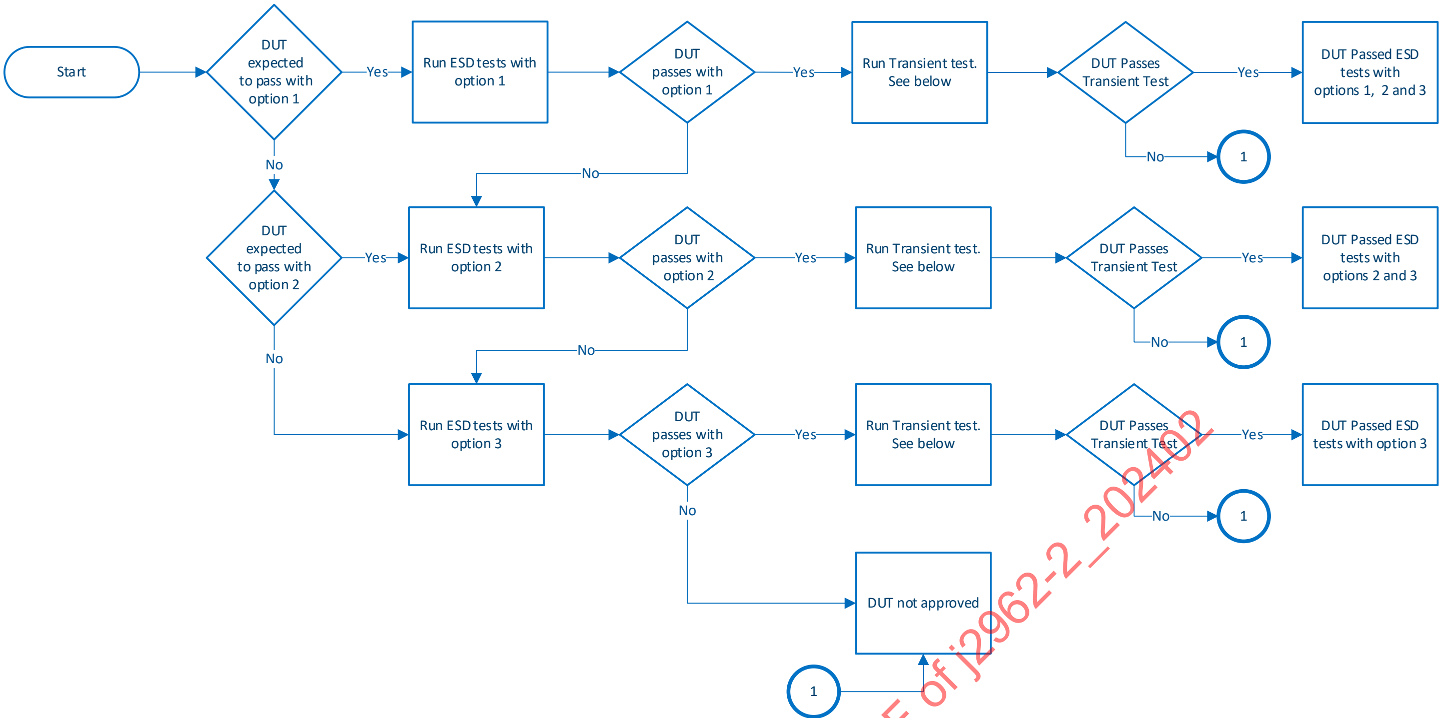


Figure 3 - ESD protection selection flowchart

5.3 Monitoring DUT

5.3.1 Microcontroller-Based Monitoring DUT Behavior

- Monitoring DUT initiates traffic and indefinitely reattempts communication.
- Total bus bandwidth shall be a minimum of 90%.
- If the monitoring DUT and the primary DUT contain the same transceiver, the traffic shall be symmetrical during the test.
- If the monitoring DUT does not have the same transceiver as the primary DUT, the primary DUT shall contribute 80% of the bus traffic on average.
- The monitoring DUT shall have the capability to indicate a communication fault (e.g., LED, fault output) when an active symbol error occurs.
    - The errors monitored by the monitoring DUT shall include:
        - BUSOFF condition from the microprocessor CAN module.
            - After logging the fault, the BUSOFF error will cause an immediate re-initialization of the CAN controller in the microcontroller clearing the BUSOFF condition. Some transceivers may need clearing of the BUSOFF condition as well.
        - The monitoring DUT receives less than 80% of expected responses from the primary DUT.
        - Incorrect CAN ID information, incorrect DLC, or incorrect data within the received message.
        - Unexpected RESET or status information.

- ○ The fault indication shall remain ON while the fault is present and shall flash five times at 1 Hz when the fault is removed.

- The monitoring DUT shall indicate the state of health of the mother board (LED, fault output). Some examples of faults to be indicated are: MCU reset, loss of power, watchdog timeout, or anything else that can prevent the CAN controller from operating correctly.

- How the errors shall be indicated shall be defined in the individual test plans.

5.3.2 Load-Only Monitoring DUT Behavior

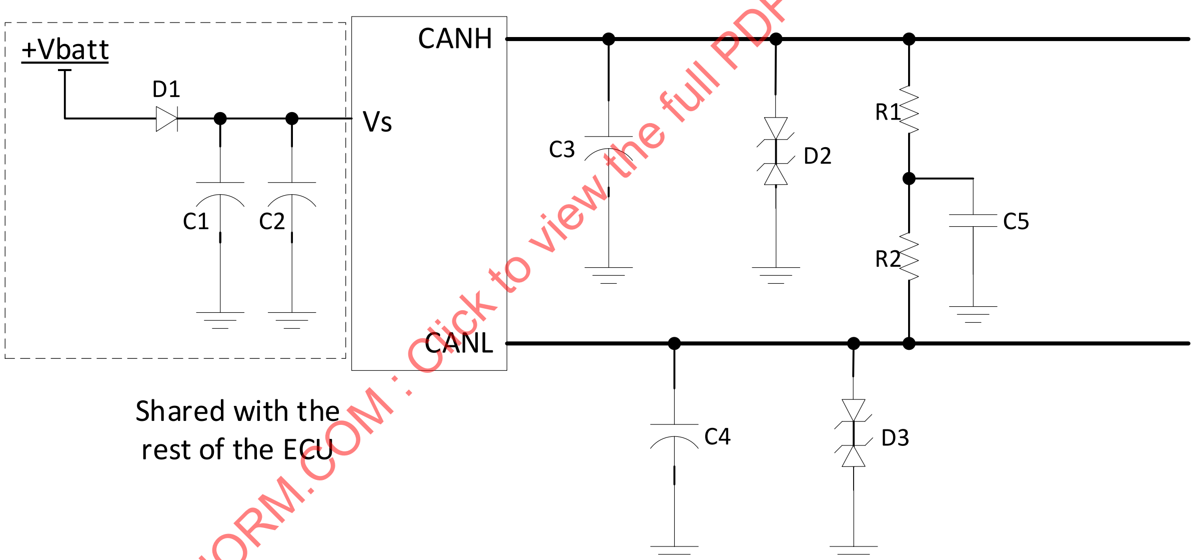
The load-only monitoring DUT has no behavior requirements. The load monitoring DUT shall consist of R1, R2, and C5, as defined in 5.3.3.

The load-only monitoring DUT shall not count as a second transceiver under test for bulk current injection (BCI) and radiated emissions (RE), even if it includes the transceiver since the load is not actively participating.

The load-only monitoring DUT shall only be used with a square wave-based primary DUT.

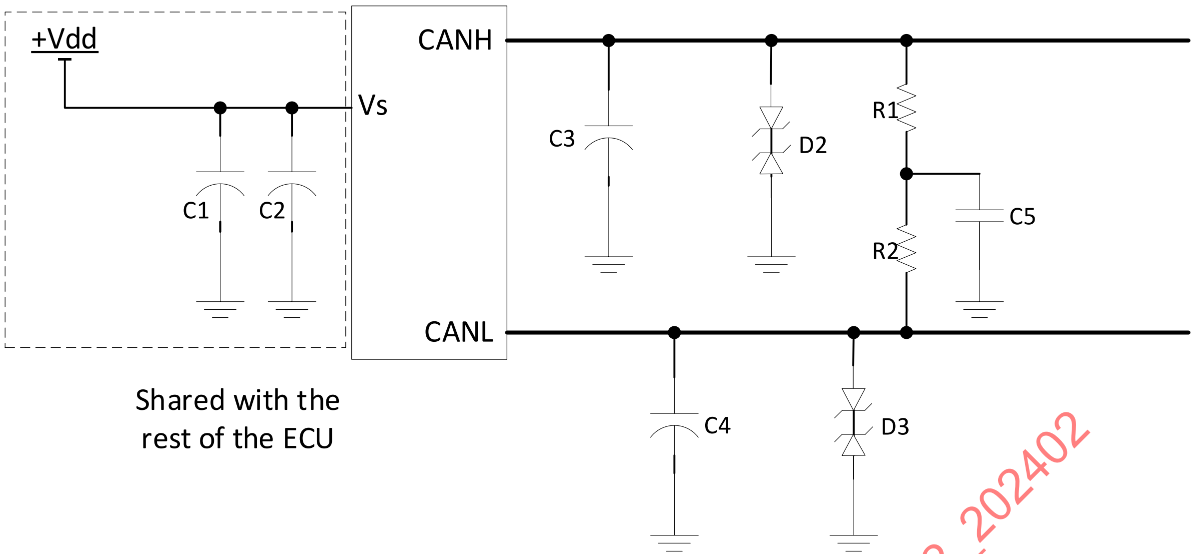
5.3.3 Monitoring DUT Application Circuit

The monitor DUT is configured as a termination node (with split R1/R2 termination).



For D1, C1, and C2 values, please see Table 1.

Figure 4 - Monitoring DUT with battery supply



For C1 and C2 values, please see Table 2.

Figure 5 - Monitoring DUT with Vdd supply

Table 4 - Termination components

Component Name	Label	Typical	Tolerance	Unit
Capacitor	C5	4.7	±10%	nF
Resistor	R1, R2	60.4	±1%	Ω

For the rest of the components' values, see 5.1.3.

5.4 Layout Best Practices

The following layout practices have shown to help DUTs improve test performance:

- Decoupling capacitor shall be as close to the transceiver as possible.
- CAN_H and CAN_L tracks should be routed adjacent to each other.
- Outside guard tracks for CAN_H and CAN_L.
- Outside guard tracks for receive data signal line (RXD) and TXD tracks from MCU to transceiver.
- Ground plane under transceiver.
- The CAH_H and CAN_L traces should be as short as possible, and avoid routing other signal traces between transceiver and edge connector.
- Transceiver should be located as close to edge connector as possible, and avoid placing other ICs between transceiver and edge connector.

5.5 Network Load Simulation Test Circuit

The network load simulation circuit emulates the maximum vehicle bus loading with a network cable.

The network load simulation circuit is specified in each test. See the text and diagrams in each section.

The load simulation box is different for CAN 500 kbps versus CAN-FD 2 Mb data rate. Instead of requiring the testing to be performed with an actual 40 m cable length, a load simulation circuit would electrically perform the same as the cable but would be easier to handle (than a long cable) for consistent tests.

The network load simulation box may be implemented external to the monitoring DUT. See Table 5 for component values.

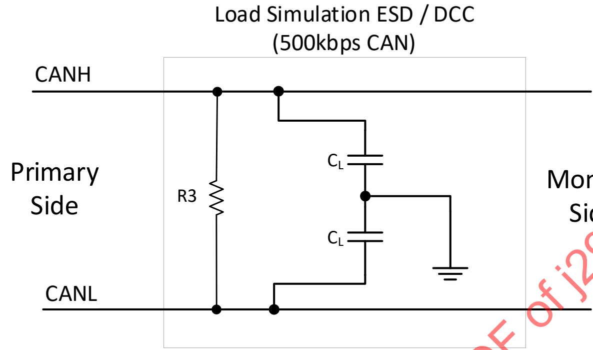


Figure 6A - Load simulation for 500 kbps CAN networks

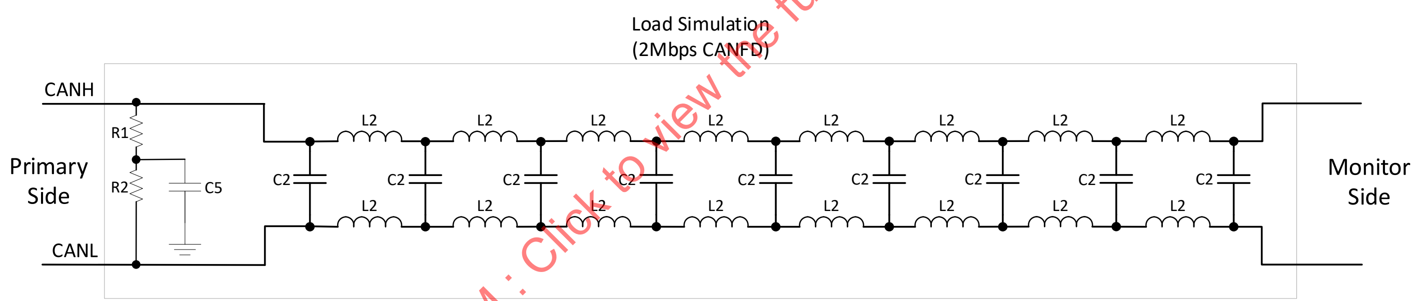


Figure 6B - Load simulation for 2 Mbps CAN-FD networks

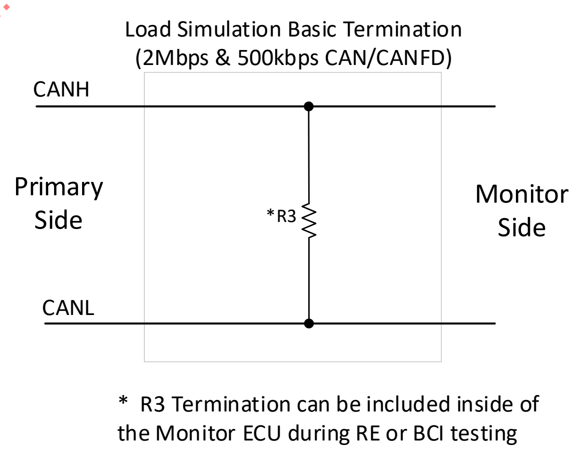


Figure 6C - Terminating load for testing

Table 5 - ESD and direct capacitor coupling (DCC) network load simulation box components

Component	Label	Typical	Tolerance	Unit	Notes
Capacitor	C_L	2000	±10%	pF	
Inductor	L2	1.6	±10%	µH	- Shielded inductor with equivalent series resistance of <0.5 Ω. - Self-resonant frequency >150 MHz; current rating ≥200 mA. - The component value can be achieved using multiple discrete devices in parallel.
Capacitor	C2	220	±5%	pF	
Resistor	R3	121	±1%	Ω	Provides primary side termination during measurements and testing.
Resistor	R1, R2				See Table 4.
Capacitor	C5				See Table 4.

5.6 Preferred Order for Testing Execution

ESD tests - both unpowered and powered (see 6.1 and 6.2) - and DCC (see Section 7) shall be performed prior to any other testing. The remaining tests for RE and BCI (see Sections 8 and 9) may be performed in any order.

All DUT test samples shall each pass all EMC tests using the same default configuration settings; it is not allowed to change settings for any test.

6. ELECTROSTATIC DISCHARGE TESTING

ESD testing shall be performed before the rest of the tests with the Handling test performed first. See guidance in 5.6.

The same hardware configuration shall be used for all tests.

Two transceivers must pass all tests with the same external components for ESD protection with the primary DUT configuration.

6.1 ESD Handling (Unpowered)

6.1.1 Requirements

The component shall be immune to ESD events that occur during normal handling and assembly. These requirements are listed in Table 6.

Table 6 - ESD handling requirements

Discharge Sequence	Type of Discharge	Test Voltage Level	Minimum Number of Discharges at Each Polarity	Plots
0	None	Pre-test	N/A	Before Test **Required**
1	Contact discharge C = 150 pF, R = 2 kΩ	+4 kV	3	After Test Optional
2		-4 kV	3	After Test **Required**

6.1.2 ESD Handling Test Setup

Two transceivers must pass all tests with the same external components for ESD protection with the primary DUT configuration.

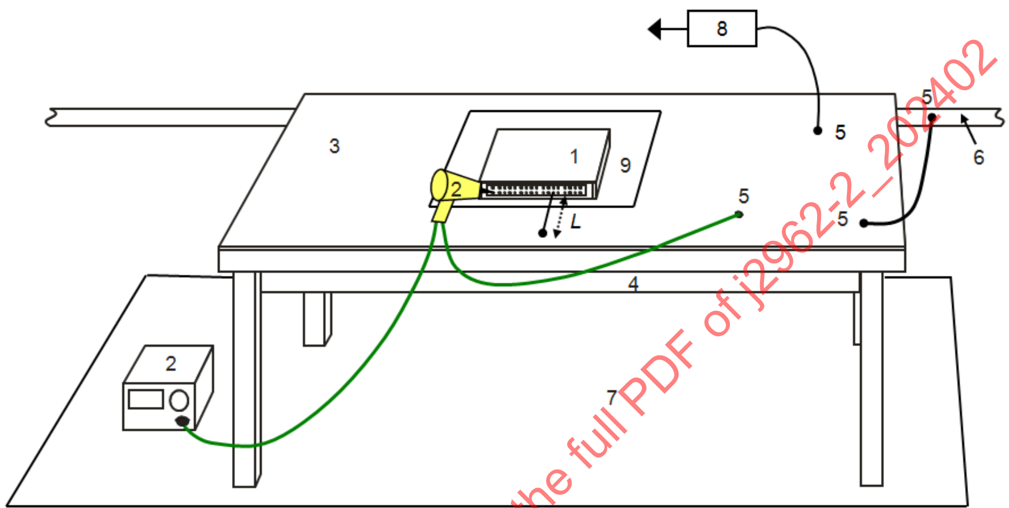
Testing shall be performed in accordance with ISO 10605, except where noted in this specification. The test facility shall be maintained at an ambient temperature of 23 °C ± 5 °C, and a relative humidity from 0 to 40%.

6.1.3 The standard test setup for handling tests is illustrated in Figure 7. The primary DUT shall be placed directly on a dissipative mat and unpowered.

6.1.4 For sequences 1 and 2 from Table 6, apply discharges to the primary DUT connector pins, where all primary DUT power return terminals shall be connected to the ground plane via a grounding strap or wire with a maximum length of 200 mm.

6.1.5 All discharge points shall be specified in the EMC test plan.

6.1.6 Network load simulator is only used when reading waveforms during the pre- and post-tests; the load simulator is not used when applying the test pulses.



1. Primary DUT
2. ESD simulator
3. Ground plane
4. Wooden table
5. Ground plane connection
6. Test facility ground connection
7. Floor test facility
8. ~1 MΩ bleed-off resistor
9. Dissipative mat
L. Ground wire length ≤200 mm

Figure 7 - ESD handling test setup

6.1.7 ESD Test Procedure

Between individual discharges, the remaining charge shall be bled off using the bleed-off resistor (approximately 1 MΩ resistance) by touching the discharge point and the ground plane.

6.1.8 ESD Pass/Fail Criteria

Before- and after-test scope plots must be provided with test results per setup in Figure 8. Set the scope to 1 μs/div horizontal and 0.5 V/div vertical.

The plots must contain at least one dominant-to-recessive edge and one recessive-to-dominant edge as transmitted by the primary DUT. The waveform plot edge-to-edge timing shall show arbitration bit waveforms at 500 kbps. For example, the captured waveforms edges shall show a 50% duty cycle square wave with a frequency of 250 kHz.

All after-test plots shall be compared with the plot taken before the test.

The overlay of the before- and after-test plots shall not deviate by more than ±10% of the nominal recessive voltage, as shown in Figure 9.

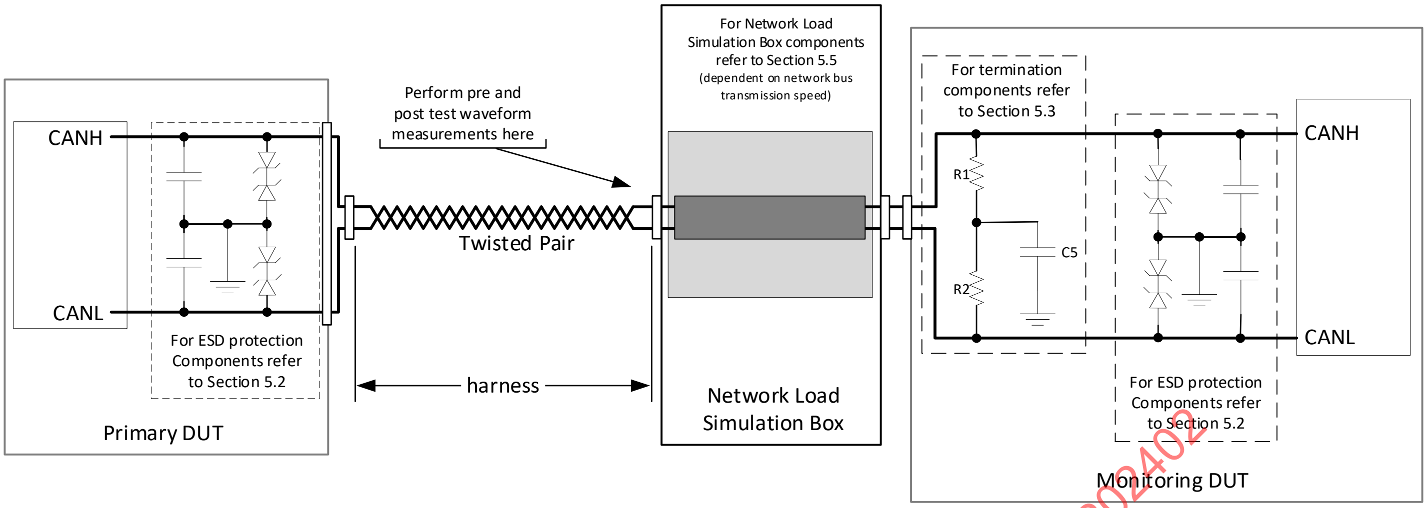


Figure 8 - ESD handling measurement circuit with load simulator diagram

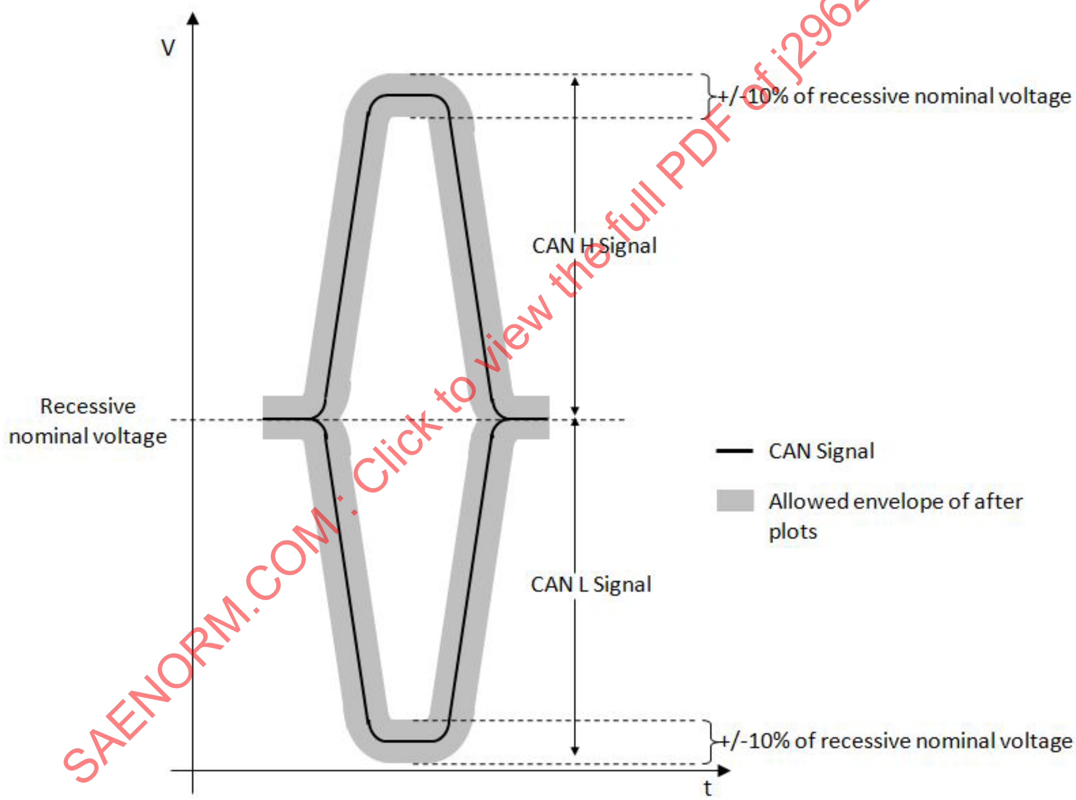


Figure 9 - Pass/fail criteria for after plots

6.2 ESD-Powered

6.2.1 ESD Requirements

Table 7 - ESD-powered requirements

Discharge Sequence	Type of Discharge	Test Voltage Level	Minimum Number of Discharges at Each Polarity	Plots
0	None	Pre-test	N/A	Before Test - **Required**
1	Air discharge	+4 kV	3	After Test - Optional
2	C = 330 pF, R = 2 kΩ	-4 kV	3	After Test - Optional
3	Contact discharge	+4 kV	3	After Test - Optional
4	C = 330 pF, R = 2 kΩ	-4 kV	3	After Test - Optional
5	Air discharge	+6 kV	3	After Test - Optional
6	C = 330 pF, R = 2 kΩ	-6 kV	3	After Test - Optional
7	Contact discharge	+6 kV	3	After Test - Optional
8	C = 330 pF, R = 2 kΩ	-6 kV	3	After Test - Optional
9	Air discharge	+8 kV	3	After Test - Optional
10	C = 330 pF, R = 2 kΩ	-8 kV	3	After Test - Optional
11	Contact discharge	+8 kV	3	After Test - Optional
12	C = 330 pF, R = 2 kΩ	-8 kV	3	After Test - Optional
13	Air discharge	+15 kV	3	After Test - Optional
14	C = 330 pF, R = 2 kΩ	-15 kV	3	After Test - **Required**

6.2.2 ESD-Powered Test Setup

Two transceivers must pass all tests with the same external components for ESD protection with the primary DUT configuration.

Testing shall be performed in accordance with ISO 10605, except where noted in this specification. The test facility shall be maintained at an ambient temperature of 23 °C ± 5 °C and a relative humidity from 0 to 40%.

6.2.3 Figure 10 illustrates the standard setup used when the primary DUT is powered and functioning.

6.2.4 The primary DUT and any electronic hardware in the monitor DUT shall be powered from an automotive battery 12.5 to 13.5 V.

6.2.5 The battery negative terminal shall be connected to the ground plane bench. The battery may be located on, or under, the test bench.

6.2.6 The primary DUT and its attached test harness shall be placed on a clean dielectric support that is 50 mm thick. The insulator lies directly on the ground plane.

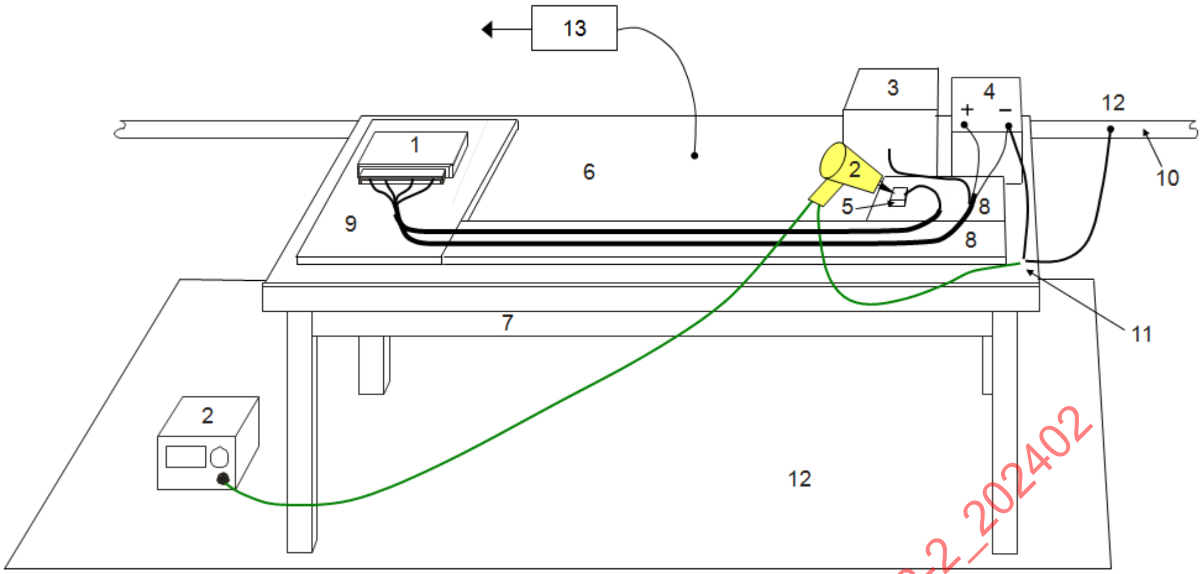
6.2.7 The test harness connecting the primary DUT and the monitor DUT shall be 1700 mm (+300 mm/-0 mm) in length.

6.2.8 The monitoring DUT shall be placed on the ground plane and electrically connected to the ground plane during the test.

6.2.9 Wiring for communication bus circuits shall be configured such that the wiring is routed and connected directly to the primary DUT.

During powered ESD testing the load termination circuit, Figure 6C shall be used.

Injection pulses shall be injected at end of harness stub as shown in Figures 10 and 11.



1. Primary DUT
2. ESD simulator
3. Monitoring DUT
4. Automotive battery
5. Discharge point
6. Ground plane
7. Wooden bench
8. Harness insulator support
9. DUT insulator support
10. Test facility ground
11. Ground plane reference termination (within 5 cm from primary DUT table corner)
12. Ground plane connection; refer to ISO 10605
13. ~1 MΩ bleed-off resistor

Figure 10 - Powered ESD test setup

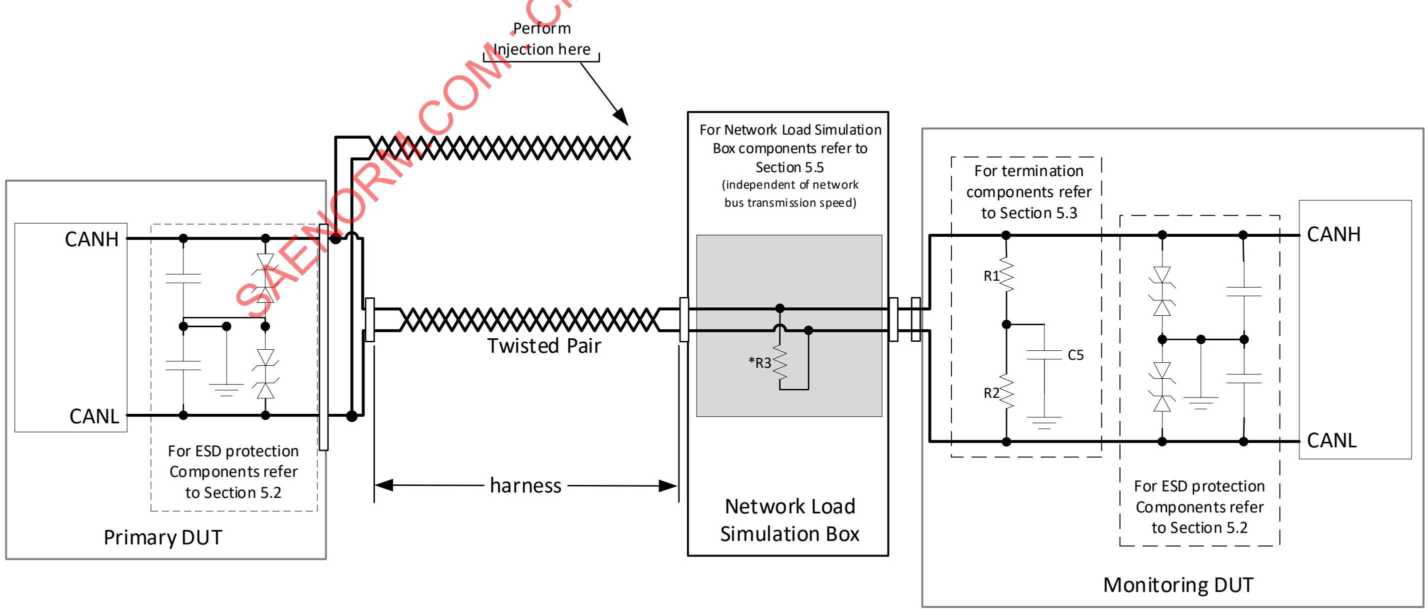


Figure 11 - Powered ESD testing circuit

6.2.10 ESD-Powered Test Procedure

Between individual discharges, the remaining charge shall be bled off using the bleed-off resistor (approximately 1 MΩ resistance) by touching the discharge point and the ground plane.

Primary DUT and monitoring DUT shall be continuously powered and functional throughout the complete test sequence and pass/fail verification. Bus functionality is expected to be disrupted during the ESD discharges. Communication shall recover without power cycling or resetting the DUTs once the ESD discharges are completed.

6.2.11 ESD-Powered Pass/Fail Criteria

See Figure 12; dependent on CAN transmit speed (500 kbps or 2 Mbps), the appropriate network load simulation box from Figure 6A or 6B shall be used for all measurements.

Before- and after-test scope plots, with the bus speed at 500 kbps or 2 Mbps, must be provided with test results according to Table 7.

The plots must contain at least one dominant-to-recessive edge and one recessive-to-dominant edge during arbitration phase as transmitted by the primary DUT. The oscilloscope trace shall include 500 kbps arbitration bits as transmitted by the primary DUT plotted with 1 µs/div horizontal and 0.5 V/div vertical. A digital scope that can decode specific CAN IDs could be used to trigger the readings.

All after-test plots shall be compared with the plot taken before the test. The overlay of the before- and after-test plots shall not deviate by more than ±10% of the nominal recessive voltage as shown in Figure 9.

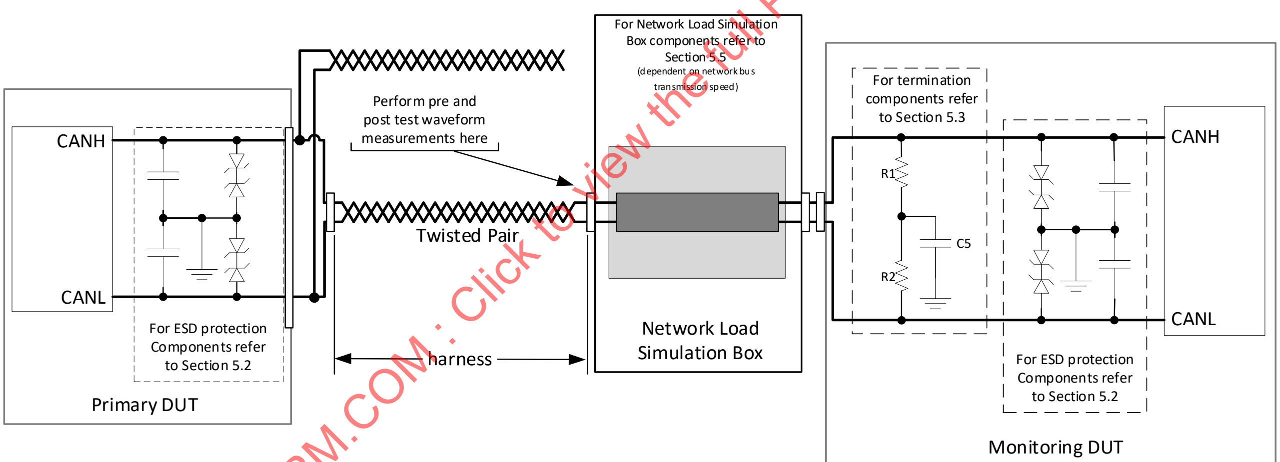


Figure 12 - Powered ESD measurement circuit with load simulator

7. COUPLED TRANSIENTS TESTING

The same hardware configuration shall be used for all tests.

The purpose of this test is to ensure that the primary DUT will not be damaged as a result of excessive transients that may occur as a result of unique inductive wiring harness crosstalk.

7.1 Slow Transient Coupling (DCC) Requirements

The component shall not be damaged when exposed to DCC per ISO 7637-3 for the “Slow Transient Pulse,” with an amplitude of ±30 V (e.g., Us = ±30 V). Coupling capacitors shall be 100 nF.

The primary DUT shall withstand 10 pulses with a minimum of 2 seconds between pulses (e.g., t_1 = 2 seconds) on both CAN_H and CAN_L simultaneously.

NOTE: Bus functionality is expected to be disrupted when using a 100 nF coupling capacitor during injection.

7.2 DCC Test Setup

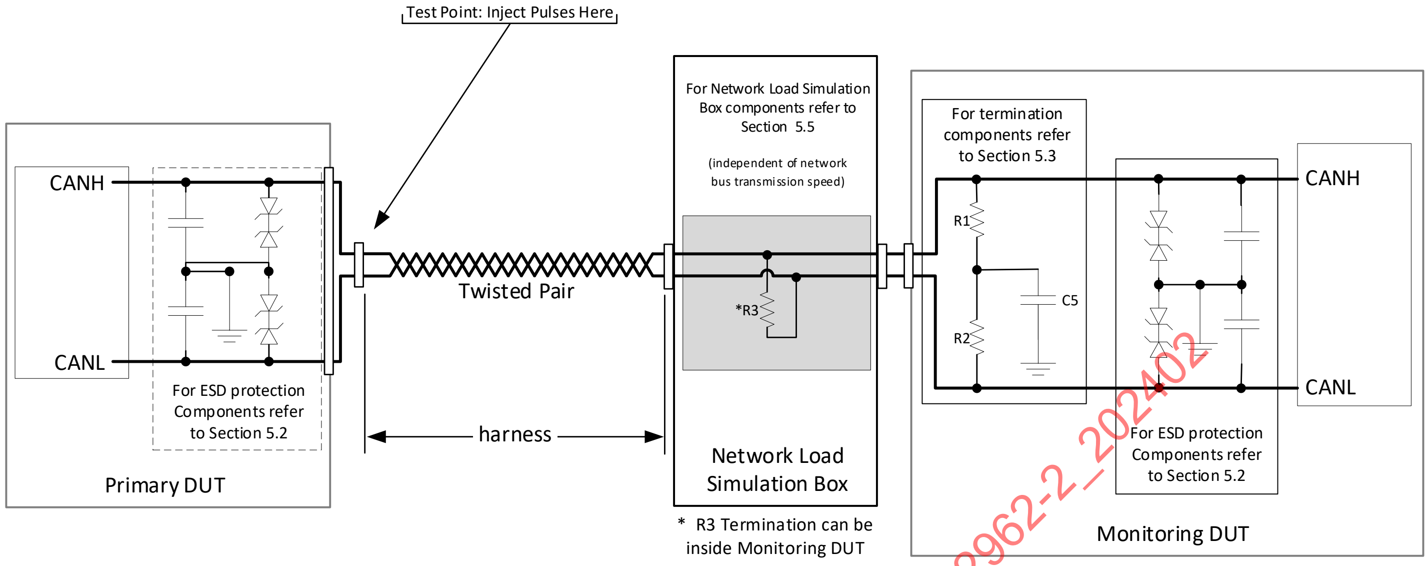


Figure 13 - DCC test circuit setup

7.2.1 See Figure 13.

7.2.2 Two transceivers must pass all tests with the same external components for ESD protection with the primary DUT configuration.

7.2.3 The test setup shall comply with ISO 7637-3 for the definition of "Slow Transient Pulse."

7.2.4 The total harness length shall be 1700 mm (+300/-0 mm).

7.2.5 The primary DUT and the test harness shall be placed on an insulated support 50 mm above the ground plane.

7.2.6 The primary DUT shall be isolated from ground.

7.2.7 The monitoring DUT shall be placed on the ground plane and electrically connected to the ground plane during the test.

7.2.8 The primary DUT and any electronic hardware in the monitor DUT shall be powered from an automotive battery 12.5 to 13.5 V.

7.2.9 The battery negative terminal shall be connected to the ground plane bench. The battery may be located on, or under, the test bench.

7.2.10 If the monitor DUT does not have secondary termination, then the network shall be terminated with the load termination box (see Figure 6C) during the DCC test.

7.2.11 If the monitor DUT contains secondary termination, then neither the load simulation nor the load termination boxes will be connected during the DCC test.

7.3 DCC Test Procedure

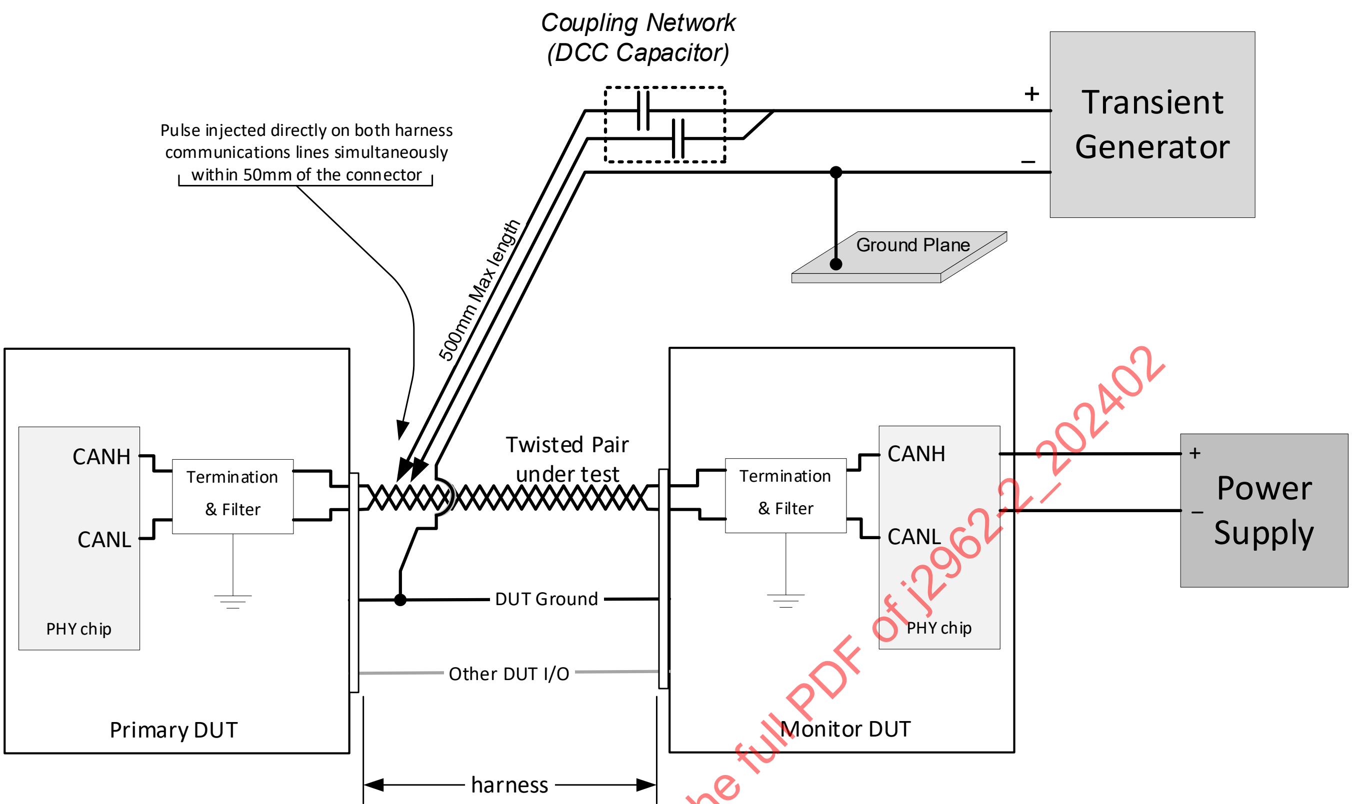


Figure 14 - DCC injection detail: load simulator is not used during pulse injection

Primary DUT and monitoring DUT shall be continuously powered and functional throughout the complete test sequence and pass/fail verification. Bus functionality is expected to be disrupted when using a 100 nF coupling capacitor. Communication shall recover without power cycling or resetting the DUTs once the DCC probes are removed.

7.4 Fast Transient Coupling (CCC or DCC) to I/O (Excludes Nominal 12-V Lines)

If test results are already available according to IEC 62228-3, then those results shall be provided with the documentation package. In this case, it will not be necessary to perform the following test described in 7.4.1.

7.4.1 The purpose of this test is to ensure that transients that can be inductively or capacitively coupled to inputs and outputs (I/O) of the DUT do not disturb any functionality and/or memory functions. Specifically excluded are battery, ignition, or accessory inputs that provide the operating currents for the DUT and possibly its loads and are subject to the powerline transients. The typical sources of such transients include the high-frequency (fast) relay contact arcing events when de-energizing an inductive load.

7.4.1.1 Equipment

The test equipment shall comply with ISO 7637-1 and ISO 7637-3.

7.4.1.2 Fast Transient Coupling Procedure

Use test methods according to the relevant sections of ISO 7637-3 with the following specification:

- Use only test pulse 3a and 3b.

Each twisted pair shall be tested individually (a single twisted pair being the only lines in the coupling clamp).

NOTE: Consistent with ISO 7637-3, coupling clamp (CCC) method, DUT battery (B+) and switched battery lines along with DUT supply return (B-) line(s) shall be routed outside the clamp, unless otherwise stated in the test plan.

Table 8 - Requirements of CCC and (Optional) DCC

Pulse Number	Level (V_{peak})[1]	Application Time	Time Between Bursts	(Optional) DCC Coupling Capacitance
3a	-200	10 minutes	90 ms	220 pF
3b	+200			

[1] Test level established across a 50 Ω load terminating the clamp (no harness cables routed through the clamp).

7.5 DCC Pass/Fail Criteria

See Figure 15; dependent on CAN transmit speed (500 kbps or 2 Mbps), the appropriate network load simulation box from Figures 6A or 6B shall be used for all measurements.

The 100 nF coupling capacitor shall be removed for all measurements of the waveforms post-test.

Before- and after-test scope plots, with the bus speed at 500 kbps or 2 Mbps, must be provided with test results.

The plots must contain at least one dominant-to-recessive edge and one recessive-to-dominant edge during arbitration phase as transmitted by the primary DUT. The oscilloscope trace shall include 500 kbps arbitration bits as transmitted by the primary DUT plotted with 1 µs/div horizontal and 0.5 V/div vertical. A digital scope that can decode specific CAN IDs could be used to trigger the readings.

All after-test plots shall be compared with the plot taken before the test. The overlay of the before- and after-test plots shall not deviate by more than ±10% of the nominal recessive voltage as shown in Figure 9.

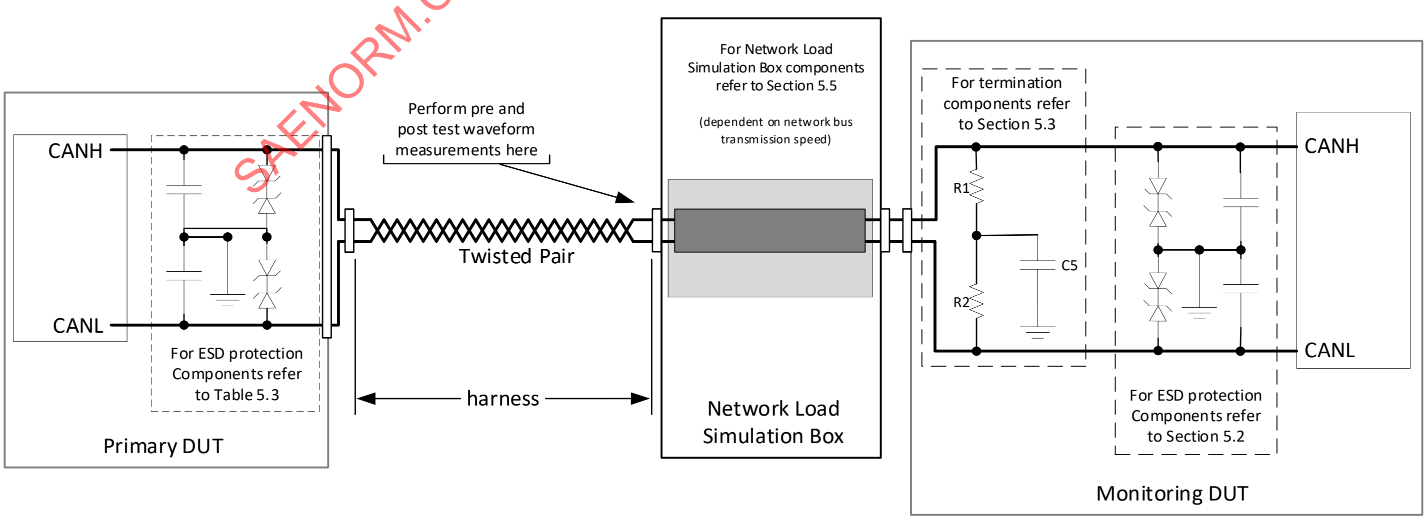


Figure 15 - DCC test measurement circuit setup with load simulator

For Fast Transient tests, the DUT functions may only deviate at peak levels greater than those shown in Table 8. During testing, it is allowed to have a momentary, self-recoverable deviation during the test at levels at or below those shown in Table 8. Before- and after-test scope plots, with the bus speed at 500 kbps or 2 Mbps, must be provided with test results.

All after-test plots shall be compared with the plot taken before the test. The overlay of the before- and after-test plots shall not deviate by more than ±10% of the nominal recessive voltage as shown in Figure 9.

8. RADIATED EMISSIONS (RE)

Two transceivers must pass the test.

One test may prove both transceivers if the same transceiver is used in primary DUT and microcontroller-based monitoring DUT. A load-only monitor DUT shall not be used to prove out a second transceiver.

8.1 RE Requirements

The field strength level of the RE shall not exceed the levels of Table 9.

Table 9 - RE level requirements

ID No.	RF Service (User Band)	Requirement Frequency Range (MHz)	Limit (dBμV/m)	Scanning Receiver Parameters	Antenna	Notes
2	Medium Wave/AM	0.53 to 1.71	30 PK 24 AVG	RBW 9 kHz PK/AVG Max Step Size ≤ 5 kHz Time/Step ≥ 1 second	Monopole	Measurement in vertical orientation only.
5	FM I	75.2 to 90.9	20 PK and 12 AVG 24 QP	RBW 9 kHz PK/AVG Max Step Size ≤ 5 kHz Time/Step ≥ 1 second	Biconical	Measurement in horizontal and vertical orientations.
6	FM II	86.6 to 109.1	20 PK and 12 AVG 24 QP	RBW 120 kHz QP Max Step Size ≤ 60 kHz Time/step ≥ 1 second		

Note 1: For spectrum parameters, refer to CISPR 25 - 5th Edition.
Note 2: Table 9 only applies to transceiver qualification. Individual OEM requirements could list more bands that an ECU must not exceed in order to pass overall emissions levels at the module level.

8.2 RE Test Setup

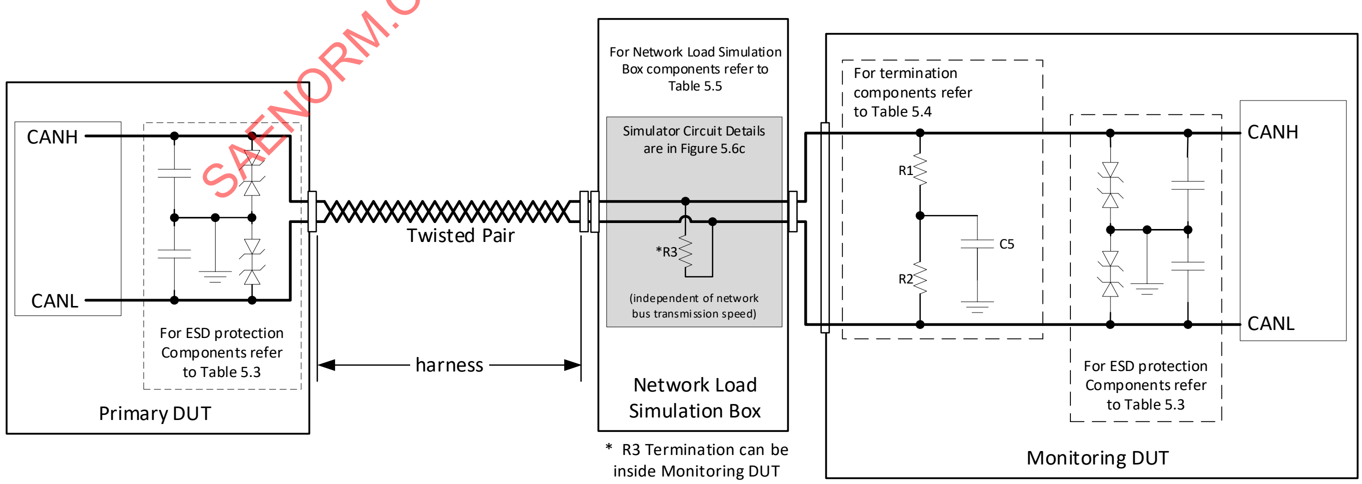


Figure 16 - RE test setup

The requirements of CISPR 25 - 5th Edition, ALSE method, shall be used for verification of the primary DUT performance, except where noted in this specification.

8.2.1 Co-location of multiple receiving antennas in the same test chamber to support automated testing for reduced test times is not permitted.

8.2.2 The primary DUT and any electronic hardware shall be powered from an automotive battery 12.5 to 13.5 V connected through an Artificial Network. The battery negative lead shall be connected to the ground plane bench. The battery may be located on, or under, the test bench.

8.2.3 The total harness length shall be 1700 mm (+300/-0 mm). The harness shall lie on an insulated support 50 mm above the ground plane.

8.2.4 The monitoring DUT shall be placed closer to the power supply.

8.2.5 The primary DUT shall be placed on an insulated support 50 mm above the ground plane. The primary DUT shall be isolated from ground.

8.2.6 The monitoring DUT shall be placed on the ground plane and electrically connected to the ground plane during the test.

8.2.7 For some DUTs, deviations from the standard test setup may be necessary to facilitate testing. If testing setup deviations are required, the test setup has to be approved directly with applicable OEMs.

8.2.7.1 If the maximum baud rate configuration is 500 kbps or less, only one of the following two methods shall be tested:

- Classic CAN messages shall be sent at 500 kbps.
- Square wave at 250 kHz. This will provide the highest radiated emissions.

8.2.7.2 If testing to qualify for CAN-FD data rates of 2 Mbps (the RE test and limits are the same), below are three methods to test this. Only one of the three methods shall be tested:

- CAN-FD with 500 kbps arbitration rate and 2 Mbps data rate with a minimum of 8 data bytes per message. The data should be random. If it is fixed, $AA or $55 should be used.
- Classic CAN messages at 2 Mbps.
- Square wave at 1 MHz. This will provide the highest radiated emissions.

8.2.8 If the primary DUT has an embedded voltage regulator, the regulator shall be operating during all tests.

8.2.9 If the voltage regulator is a switching regulator, all frequencies of operation desired to be approved shall be tested.

8.2.10 If the monitor DUT does not have secondary termination, then the network shall be terminated with the load termination box (see Figure 6C) during RE testing.

8.2.11 If the monitor DUT contains secondary termination, then neither the load simulation nor the load termination boxes will be connected during RE testing.

8.3 RE Test Procedure

8.3.1 One primary DUT orientation is required for all frequencies.

8.3.2 Measurement of primary DUT radiated emissions shall be performed over all frequency bands listed in Table 9.

8.4 RE Pass/Fail Criteria

Any emissions above the specified limit lines will not be accepted as long as at least one transceiver from any supplier is able to pass. Plots showing peak and/or average emissions as required for all frequency ranges and all antenna orientations shall be included in the report. Plots shall include limit lines as defined in Table 9.

9. BULK CURRENT INJECTION (BCI)

Two transceivers must pass the test.

One test may prove both transceivers if the same transceiver is used in primary DUT and monitoring DUT.

9.1 BCI Requirements

Component functional performance shall meet the acceptance criteria delineated in Table 10B (illustrated in Figure 17) using the step sizes defined in Table 10A.

Table 10A - RF immunity test frequency steps

Frequency Range (MHz)	Frequency Step Size (MHz)
1 to 30	0.5
30 to 200	2
200 to 400	5

Table 10B - BCI immunity testing limits and modulation

Frequency Range (MHz)	Immunity Level Requirement (dBµA)	Modulation
1 to 2	90	CW and AM 80%
2 to 15	90 to 106	
15 to 60	106	
60 to 400	106 to 100	

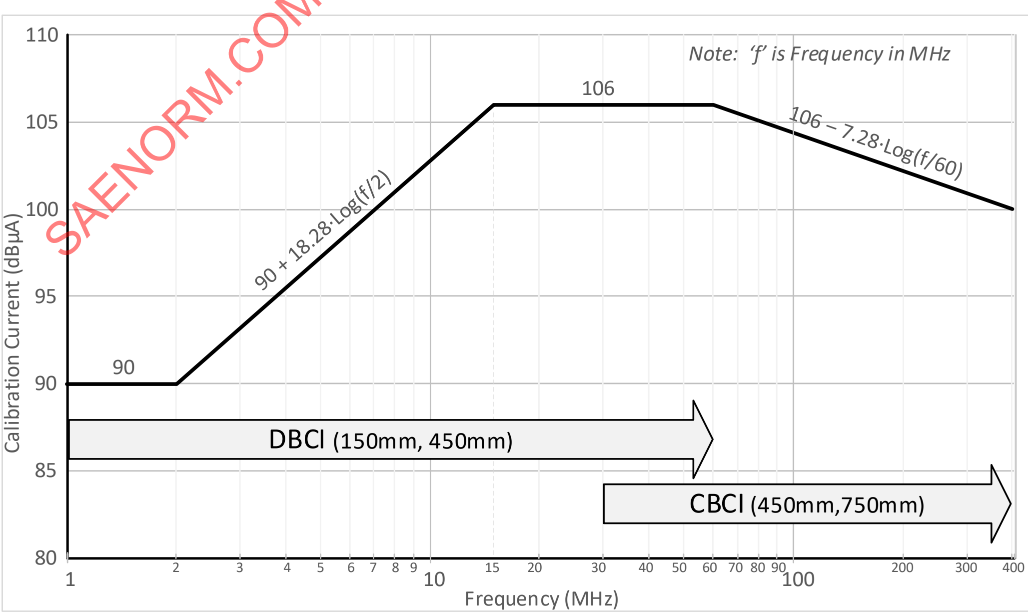


Figure 17 - BCI immunity testing limits

9.2 BCI Test Setup

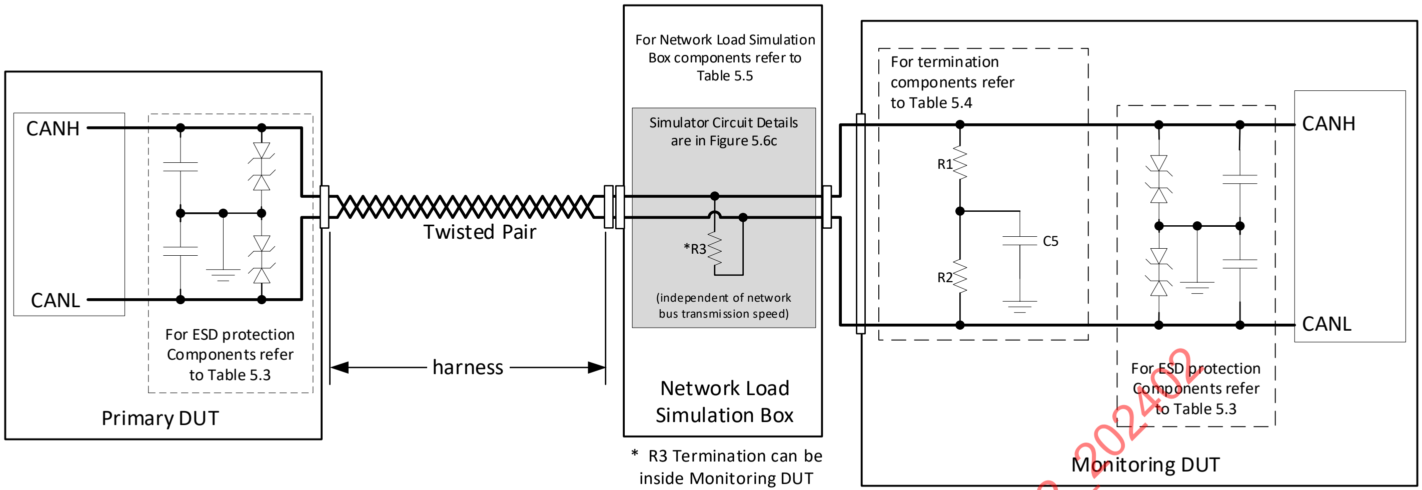


Figure 18 - BCI test circuit setup

Verification of component performance shall be in accordance with the BCI (substitution method) per ISO 11452-4 for remotely grounded devices, except where delineated in this specification.

9.2.1 The primary DUT and any electronic hardware in the monitoring DUT shall be powered from an automotive battery 12.5 to 13.5 V. The battery positive and negative connections shall be routed through the artificial networks to the harness near the monitor/load box DUT. The battery may be located on, or under, the test bench.

9.2.2 The battery positive and negative connections shall be routed through artificial networks to the harness near the monitor/load box DUT. The battery positive line is then routed with the harness from the monitor/load DUT through the injection probe to the primary DUT. The artificial network chassis are tied to the ground plane.

9.2.3 The test bench shall include a sufficiently large ground plane, such that the test harness lies in a straight line. Spacing between the edge of the ground plane and the test harness, primary DUT, monitoring DUT, etc., shall conform to ISO 11452-4.

9.2.4 The total harness length shall be 1700 mm (+300/-0 mm). The harness shall lie on an insulated support 50 mm above the ground plane.

9.2.5 The primary DUT housing shall be placed on an insulated support 50 mm above the ground plane. Primary DUT signal ground return shall be connected as described in 9.2.8 and 9.2.9.

9.2.6 The monitoring DUT housing shall be placed on the ground plane and any enclosure electrically connected to the ground plane during the test. Monitor DUT ground return shall be connected to the ground plane.

9.2.7 The distance between the test setup and all other conductive structures (such as the walls of the shielded enclosure), with the exception of the ground plane, shall be 500 mm.

9.2.8 Differential Mode BCI (DBCI)

In the frequency range from 1 to 60 MHz, the power return ground wire of the primary DUT wiring harness shall be terminated directly to the ground plane (DBCI) as illustrated in Figure 19A. The length of the wiring shall be 200 mm ±50 mm. No power return ground wiring shall be routed around the BCI injection probe.