SURFACE VEHICLE STANDARD

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Electrical Interference by Conduction and Coupling - Capacitive and Inductive Coupling via Lines Other than Supply Lines

RATIONALE

The technical committee determines that the using community is moving towards newer technology and would like to alert users that this newer technology exists which may want to be considered for new design. However, because the technical committee has no complete visibility of where and how a technical report is being used, and because a technical report may be necessary to support legacy platforms or design reuse, the technical report should not be cancelled but rather stabilized with a rationale statement that alerts users to new technology.

The EMC standards committee have determined that this standard contains similar documentation as ISO 7637-3 and also has the section 5.4 Transient Pulse Generator (the capacitive/inductive coupling (CIC) method).

Because of the inclusion of 5.4, it is realized that the LD vehicle as a whole is moving away from mechanical switching devices and towards a newer technology of solid state switching devices.

However, because the EMC standards committee sees it necessary to support legacy platforms or design reuse, SAE J1113-12 should not be cancelled but stabilized at this time.

STABILIZED NOTICE

This document has been declared “STABILIZED” by SAE Electromagnetic Compatibility (EMC) Standards Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1. SCOPE

This SAE Standard establishes test methods for the evaluation of devices and equipment in vehicles against transient transmission by coupling via lines other than the power supply lines. The test methods demonstrates the immunity of the instrument, device, or equipment to coupled fast transient disturbances, such as those caused by switching of inductive loads, relay contact bouncing, etc. Four test methods are presented in SAE J1113-12:

- the capacitive coupling clamp (CCC) method
- the direct capacitive coupling (DCC) method
- the inductive coupling clamp (ICC) method
- the capacitive/inductive coupling (CIC) method

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 ISO Publication

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

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 11452-4 Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Harness excitation methods.

3. TERMS AND DEFINITIONS

For the purposes of this document, the terms and definitions given in ISO 7637-1 apply.

4. TEST METHODS

4.1 General

This clause describes bench test methods for testing the immunity of electrical system components or devices under test (DUTs) against coupled transient pulses. These tests shall be performed in the laboratory.

The defined transient pulses represent the characteristics of most of the known transient pulses which may occur in the vehicle.

Some transient pulses tests may be omitted if a device, depending on its function or its configuration, is not subjected to comparable transient pulses in the vehicle. It is part of the vehicle manufacturer's responsibility to define the transient pulses tests needed for specific components.

A test plan shall be written to define:

- the test methods to be used;
- the transient pulses tests to be applied;
- the transient pulses levels;
- the number of transient pulses to be applied;
- the DUT operating modes;

- the wiring harness (test versus production);
- the wires to be included in the capacitive coupling clamp, if used;
- thewires to be tested using the direct coupling capacitor method, if used;
- the capacitance values to be used, if the direct coupling capacitor method is used for specific communication lines;
- the wires to be included in the inductive coupling clamp, if used; and
- the type of inductive coupling clamp, if the inductive coupling method is used.

For CCC, DCC and ICC methods, suggested values for the evaluation of immunity of DUTs can be chosen from Tables E1, E2. The transient pulses test severity levels should be mutually agreed upon between the vehicle manufacturer and the supplier prior to the test.

The applicability of the four different test methods is indicated in Table 1. When considering use of CCC, DCC or ICC methods, it is sufficient to select one test method for slow transient pulses and one test method for fast transient pulses. When considering use of the CIC method, test pulses A and B should both be selected

Table 1 - Test method applicability

Transient Type	**Test Method**			
	CCC	**DCC**	**ICC**	**CIC**
Slow transient pulses 2a of 5.3.2		✓	✓	
Fast transient pulses 3a and 3b of 5.3.3	✓	✓		
Pulses A and B of 5.4.3				✓

4.2 Standard Test Conditions

Standard test conditions shall be according to ISO 7637-1 for the following:

- test temperature;
- supply voltage.

Unless otherwise defined in this part of ISO 7637, the tolerance on test severity levels is (-0 / +10) %

4.3 Ground Plane

The ground plane shall be made of 0.5 mm thick (minimum) copper, brass or galvanized steel.

Unless otherwise specified in the test plan, the minimum width of the ground plane shall be 1000 mm, or underneath the entire set-up width (excluding power supply and transient pulse generator) plus 200 mm, whichever is larger.

Unless otherwise specified in the test plan, the minimum length of the ground plane shall be 2000 mm, or underneath the entire set-up length (excluding power supply and transient pulse generator) plus 200 mm, whichever is larger.

4.4 General Test Set-Up Conditions

The DUT is arranged and connected according to its requirements. The DUT should be connected to the original operating devices (loads, sensors, etc.) using the test setup described in 4.5.4, 4.6.4, 4.7.4 and 4.8.4 unless otherwise agreed between the vehicle manufacturer and the supplier.

If the actual DUT operating signal sources are not available they may be simulated.

The DUT shall be placed on a non-conductive, low relative permittivity (dielectric-constant) material ($\varepsilon_r \leq 1,4$), at (50 ± 5) mm above the ground plane, unless the DUT case is connected to the chassis and has its own ground connection.

Grounding of the DUT case to the ground plane shall reflect the vehicle installation and shall be defined in the test plan.

Unless otherwise stated for a specific test method, all harnesses shall be placed on a non-conductive, low relative permittivity (dielectric-constant) material ($\varepsilon_r \leq 1,4$), at (50 ± 5) mm above the ground plane.

Unless otherwise specified in the test plan, all loads, sensors, etc. are connected to the ground plane using the shortest possible length.

NOTE: To minimize extraneous capacitive coupling to the DUT, it is advisable that the minimum distance between the DUT and all other conductive structures, such as walls of a shielded enclosure (with the exception of the ground plane underneath the test set-up), should be more than 0,5 m.

4.5 CCC Method

4.5.1 General

The CCC method is suitable for coupling the fast transient pulses, particularly for DUTs with a moderate or large number of leads to be tested. It will not couple the slow transient pulses.

4.5.2 Generator Verification

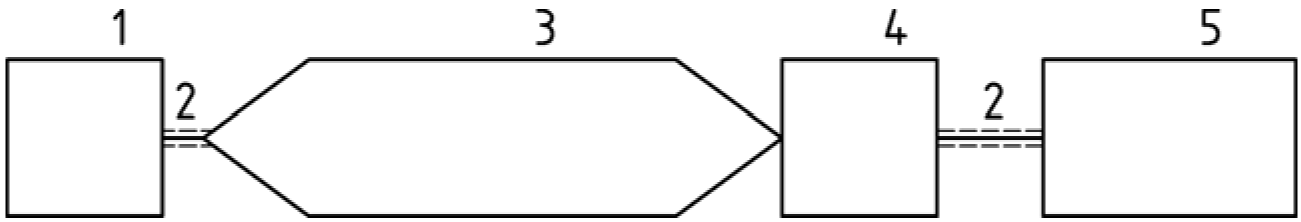
The transient pulse parameters (of Figures 11 and 12) shall be verified prior to the test according to ISO 7637-2. Verification shall be performed with the 50 Ω load condition only.

4.5.3 Transient Pulses Level Adjustment

The transient pulse generator shall be connected as shown in Figure 1.

The transient pulse level is adjusted with a 50 Ω input oscilloscope connected through a 50 Ω coaxial cable to a 50 Ω attenuator which is mounted to the coupling clamp as shown in Figure 1. There shall be no lines routed through the coupling clamp during adjustment. Examples of test severity levels are listed in Appendix E.

NOTE: The open circuit voltage of the transient pulses generator is approximately twice the value of the specific test voltage, due to 50 Ω loading of the attenuator and the oscilloscope.



Key

1 transient pulses generator
2 50 Ω coaxial cable (≤ 1 m)
3 CCC
4 50 Ω attenuator
5 oscilloscope (50 Ω input)

Figure 1 - Set-up for transient pulses level adjustment - CCC method

4.5.4 DUT Test

The test method using the CCC is shown in Figure 2. The coupling circuit consists of a CCC through which lines of the DUT are installed as agreed between the vehicle manufacturer and the supplier and documented in the test plan. The coupling length is 1 m.

The DUT 12 / 24 V supply lines (ground and supply) should not be included in the CCC. Any other ground or supply line delivered by the DUT to an auxiliary equipment (sensors, actuators) shall be included in the CCC. If the auxiliary equipment is locally grounded, this local ground connection shall be excluded from the CCC. Any exception about ground or supply lines included in the CCC shall be stated in the test plan.

The lines which are included in the CCC shall be limited to the maximum number of lines which can be placed flat in a single layer in the CCC (typically 10 to 20 lines); this may require multiple tests to be performed in order to test all the DUT lines.

The hinged lid of the CCC shall be placed as flat as possible to ensure contact with the test harness which should be positioned as flat as possible.

Twisted and shielded wire configurations shall be maintained inside the CCC.

The test conditions for a DUT with multiple connectors (single test on all the branches or test on individual branch) or for a harness with more than 10 to 20 lines shall be specified in the test plan.

NOTE: For special applications a flat harness with maximum 10-20 lines inside the CCC may be agreed upon in the test plan.

The distance between the DUT and the CCC, and between peripheral devices and the CCC, shall be greater or equal than 300 mm. The portions of the lines being tested which are outside the CCC shall be placed at a distance of (50 ± 5) mm above the ground plane and oriented 90° ± 15° to the longitudinal CCC axis.

The DUT shall be placed on a (50 ± 5) mm height insulating support.

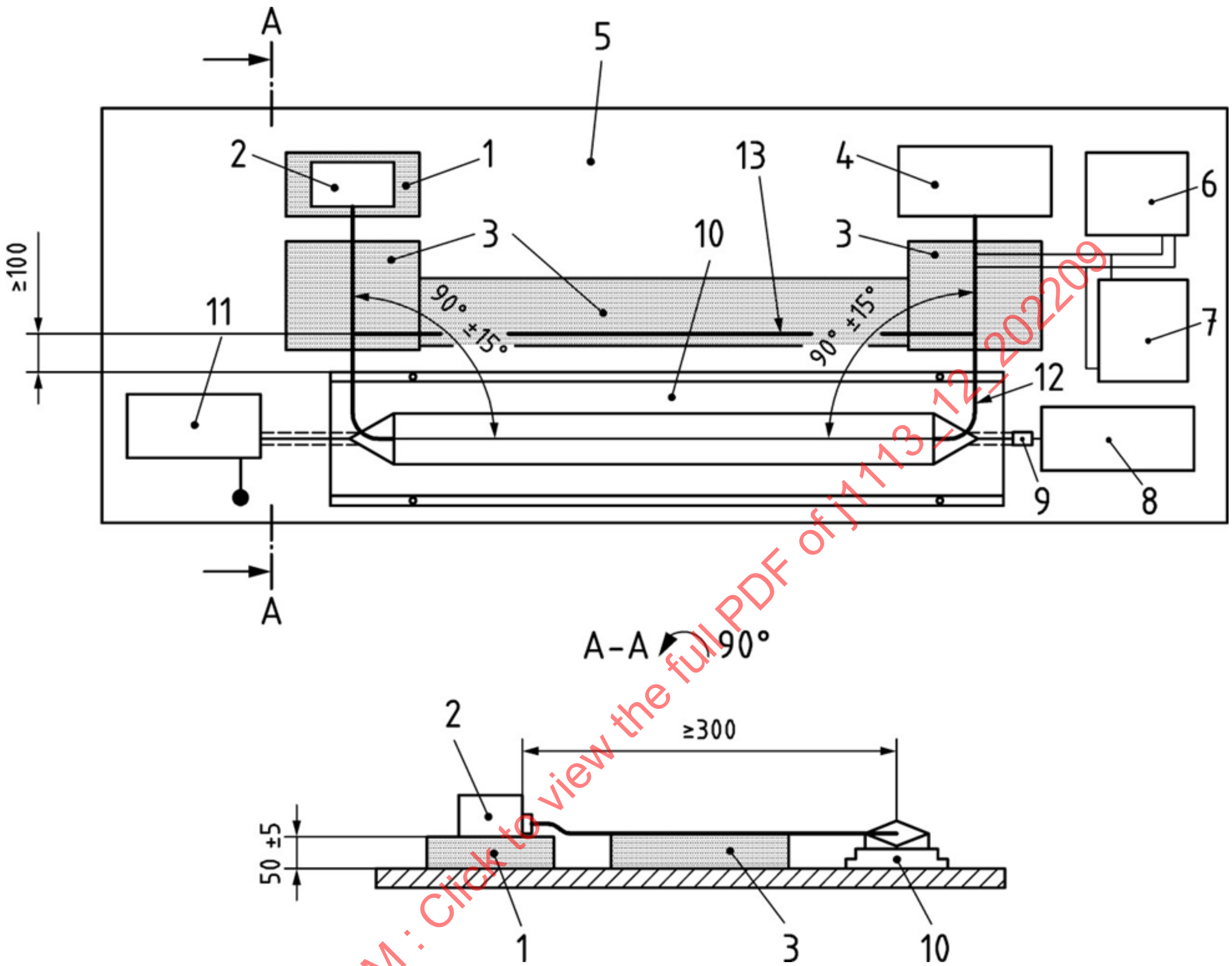
The case of the DUT shall not be grounded to the ground plane unless it is intended to simulate the actual vehicle configuration.

The lines which are not under CCC test are routed outside the coupling clamp. They shall be placed on a (50 ± 5) mm height insulating support and shall be placed at a minimum distance of 100 mm to the coupling clamp.

NOTE: It is not necessary for lines which are not under the CCC, to be placed in a straight line as illustrated in Figure 2. Arrangement due to additional length should be defined in test plan.

The DUT shall be placed on the same end of the CCC as the transient pulses generator. The test shall be performed with a total harness length of 1700 mm (+300 mm / 0 mm).

Dimensions in millimeters



Key

1 insulation support
2 DUT (grounding as specified in test plan)
3 insulating supports for test harness
4 load simulator
5 ground plane
6 power supply
7 battery
8 oscilloscope (50 Ω input)
9 50 Ω attenuator
10 CCC
11 transient pulses generator
12 lines to be tested
13 lines not to be tested

Figure 2 - Test set-up for CCC method – DUT test

4.6 DCC Method

4.6.1 General

The DCC method uses capacitors for transient coupling. The values of capacitors are defined in Table 2 except for coupling to communication lines (e.g., CAN BUS) for which specific values shall be defined in the test plan.

Table 2 - Capacitor values for DCC test method

Test pulse	Capacitor value
Slow transient pulses	0,1 µF
Fast transient pulses	100 pF
The characteristics of the non-polarized capacitors are defined as follows: tolerance of ± 10 %, rating of at least twice the maximum applied voltage, and dissipation factor less or equal than 1%.	

4.6.2 Generator Verification

The transient pulse parameters (of Figures 9, 10, 11 and 12) shall be verified (per ISO 7637-2) prior to performing the test. Verification shall include measurement of open circuit and loaded conditions.

NOTE: When verifying fast transient pulse characteristics under open circuit conditions, it is recommended to use a 1 kΩ to 50 Ω adapter, with an oscilloscope configured for 50 Ω input. This minimizes the oscillations that may result when measuring a transient pulse with significantly short transient pulse rise time and duration into an open-circuit condition.

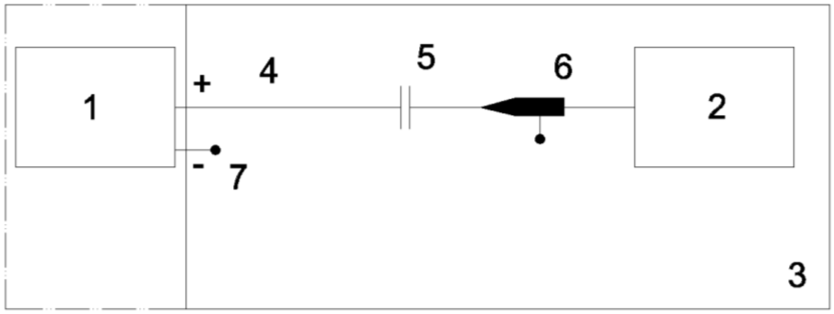
4.6.3 Transient Pulses Level Adjustment

Prior to testing, the transient pulse level shall be adjusted at the output of the capacitor. Examples of test severity levels are listed in Appendix E.

- For slow transient pulses use the setup shown in Figure 3a. The transient pulse level shall be measured using a high impedance passive probe.

- For fast transient pulses use the setup shown in Figure 3b. The output of the capacitor shall be connected to the 1 kΩ to 50 Ω adapter. The adaptor is connected to an oscilloscope configured for 50 Ω input. The measured peak pulse level is corrected for this adaptor. The capacitor shall be placed in a shielded box which shall be grounded. The 50 Ω coaxial cable shall be connected to this box.

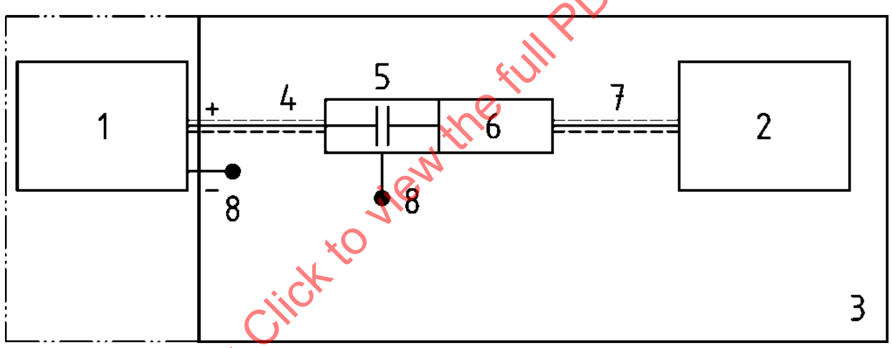
The generator ground shall be bonded to the ground plane with a DC resistance ≤ 2,5 mΩ and a bond length of less than 100 mm.



Key

1 transient pulses generator
2 high impedance input oscilloscope
3 ground plane
4 connecting wiring
5 coupling capacitor
6 high impedance passive voltage probe
7 ground connection (maximum length of 100 mm)

Figure 3A - Set-up for slow transient pulses level adjustment - DCC method



Key

1 transient pulses generator
2 50 Ω impedance oscilloscope
3 ground plane
4 50 Ω coaxial cable (maximum length of 500 mm)
5 coupling capacitor
6 1 kΩ to 50 Ω adapter
7 50 Ω coaxial cable
8 ground connection (maximum length of 100 mm)

Figure 3B - Set-up for fast transient pulses level adjustment - DCC method

Figure 3

4.6.4 DUT Test

The DCC method is shown schematically in Figure 4a (for slow transient) and Figure 4b (for fast transient). The length of the harness shall be 1700 mm (+300 mm/0 mm).

For fast transient test, the generator shall be connected to the capacitor using a 50 Ω coaxial cable with a length not greater than 500 mm.

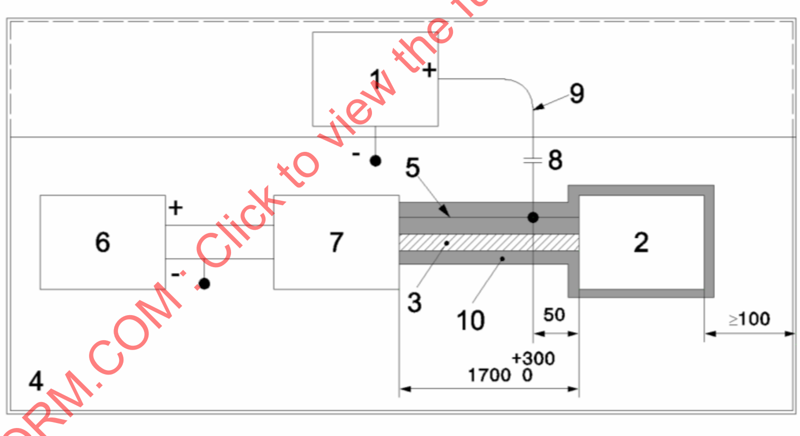
When using the DCC method, each DUT line is tested individually. However, when testing twisted and balanced symmetrical lines (e.g., bridge audio, CAN communications), the DCC method shall be modified to excite all lines identically at the same time (see Figure 5a for slow transient and Figure 5b for fast transient). Care shall be taken to ensure that intended DUT signals are not distorted by use of the DCC method.

The DUT shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the ground plane. If the DUT is locally grounded (maximum length of 200 mm), then the DUT's ground supply line shall be connected to the ground plane as defined in the test plan.

The case of the DUT shall not be grounded to the ground plane unless it is intended to simulate the actual vehicle configuration.

For slow and fast transient pulses test, the lines/harness shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the ground plane.

Dimensions in millimeters



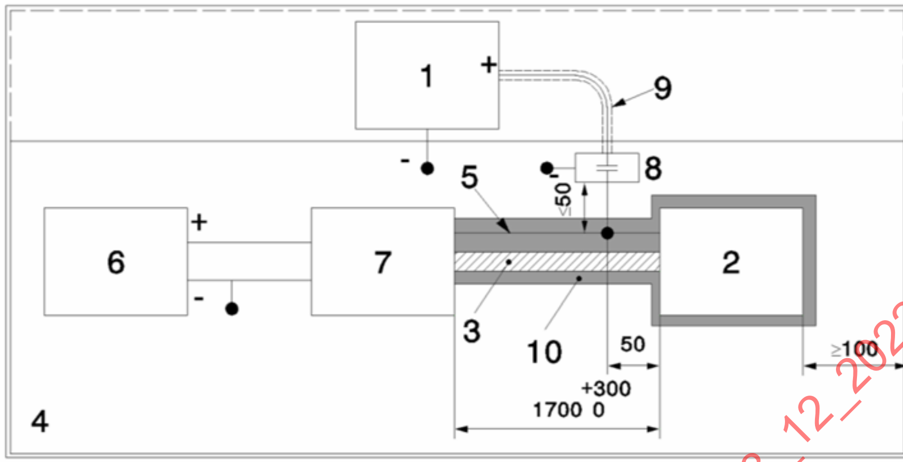
Key

1 transient pulses generator
2 DUT
3 wiring harness
4 ground plane
5 I/O line under test
6 power supply
7 load simulator
8 high-voltage non polarized leaded capacitor (see 4.6.1)
9 injection line
10 Insulation support with low relative permittivity material ($\varepsilon_r \leq 1{,}4$)

NOTE: For the value of the capacitor, see Table 2

Figure 4A - Test set-up for DCC method – Slow transients - DUT test

Dimensions in millimeters



Key

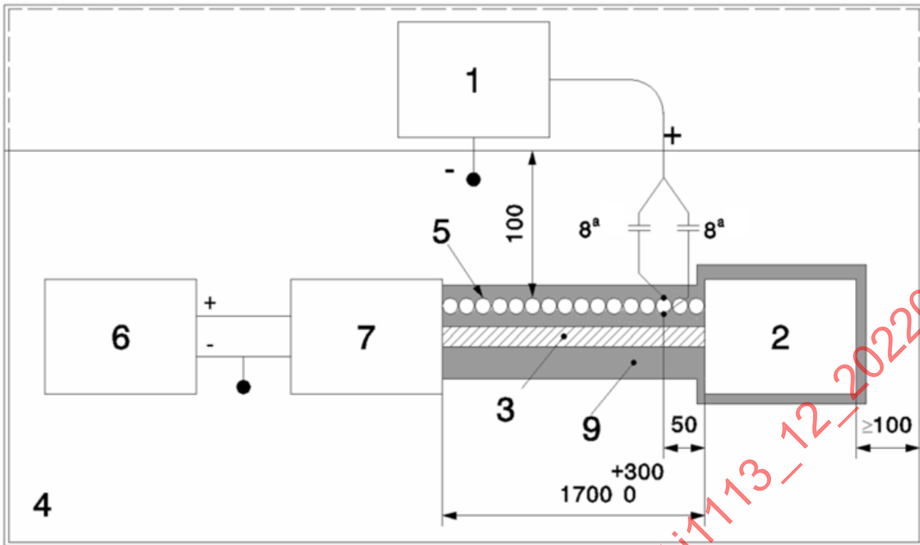
1 transient pulses generator
2 DUT
3 wiring harness
4 ground plane
5 I/O line under test
6 power supply
7 load simulator
8 high-voltage non polarized leaded capacitor (see 4.6.1)
9 50Ω coaxial cable (length not greater than 500 mm)
10 Insulation support with low relative permittivity mater
11 Insulation support with low relative permittivity material (ε_r ≤1,4)

NOTE: For the value of the capacitor, see Table 2.

Figure 4B - Test set-up for DCC method – Fast transients - DUT test

Figure 4

Dimensions in millimeters

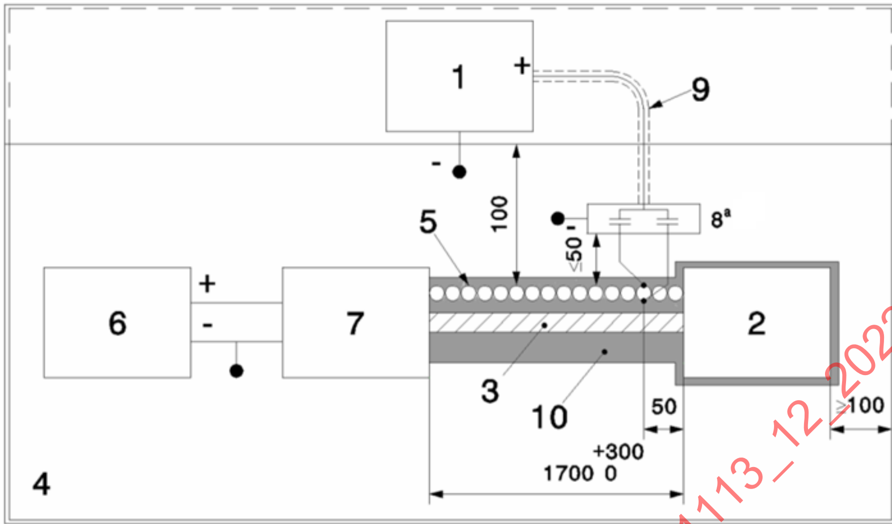


Key

1 transient pulses generator
2 DUT
3 wiring harness
4 ground plane
5 Balanced symmetrical lines
6 power supply
7 load simulator
8 high-voltage non polarized leaded capacitor
9 Insulation support with low relative permittivity material ($\varepsilon_r \leq 1,4$)
a The capacitor values are selected to ensure that the communication signals are not disturbed and that the transient pulses can still be coupled to these lines. For slow transient pulses test, the recommended capacitor value is 470 pF.

Figure 5A - Example of test setup for balanced symmetrical lines - Slow transients - DUT test

Dimensions in millimeters



Key

1 transient pulses generator
2 DUT
3 wiring harness
4 ground plane
5 Balanced symmetrical lines
6 power supply
7 load simulator
8 high-voltage non polarized leaded capacitor
9 50Ω coaxial cable (length not greater than 500 mm)
10 Insulation support with low relative permittivity material ($\varepsilon_r \leq 1,4$)

a The capacitor values are selected to ensure that the communication signals are not disturbed and that the transient pulses can still be coupled to these lines. For fast transient pulses test, the recommended capacitor value is 100 pF.

Figure 5B - Example of test setup for balanced symmetrical lines - Fast transients – DUT test

Figure 5

4.7 ICC Method

4.7.1 General

The ICC method is suitable for coupling the slow transient pulses, particularly for DUTs with a moderate or large number of lines to be tested.

4.7.2 Generator Verification

The generator verification is not required because the transient pulse levels are adjusted as defined in 4.7.3.

4.7.3 Transient Pulses Level Adjustment

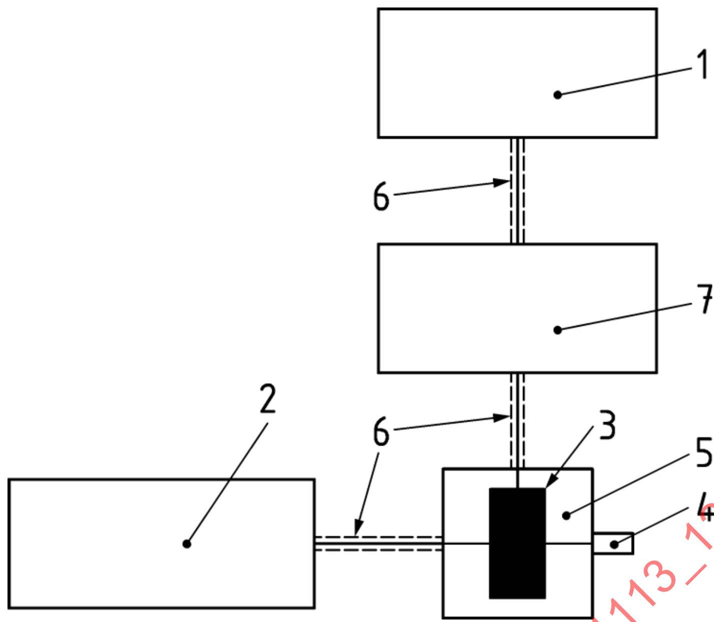
The transient pulses, as described in Figures 9 and 10, applied to the injection probe and measured with a high impedance oscilloscope according to the verification test set-up defined in Figure 6 shall fulfil the requirements stated in Table 3.

An optional matching network may be necessary to achieve the pulse characteristics. Additionally, pulse generator settings like pulse amplitude and R_i may be changed to fulfil the requirements.

The generator output voltage shall be adjusted by using the calibration fixture described in Figure 6. Examples of test severity levels are listed in Appendix E. Information on the process used for estimating the inductive coupling factor is described in Appendix F.

Table 3 - ICC - Characteristics of the coupled transient pulses

Parameters	12 V system	24 V system
t_d	7 µs ± 30 %	7 µs ± 30 %
t_r	≤ 1,2 µs	≤ 1,2 µs



Key

1 transient pulses generator
2 high impedance oscilloscope
3 ICC
4 short circuit
5 calibration fixture (see Appendix B)
6 50 Ω coaxial cable
7 matching network (optional)

Figure 6 - Set-up for transient pulses level adjustment - ICC method

4.7.4 DUT Test

The test method using the ICC is shown in Figure 7. The coupling circuit consists of an ICC which enfolds all signal lines. The DUT 12 / 24 V power lines (ground and supply) should not be included in the ICC. Any other ground or supply line delivered by the DUT to an auxiliary equipment (sensors, actuators) shall be included in the ICC. If the auxiliary equipment is locally grounded, this local ground connection shall be excluded from the ICC. Any exception about ground or supply lines included in the ICC shall be stated in the test plan.

The test can be performed either as shown in Figure 7 or with a straight harness as implemented in ISO 11452-4.

The test conditions for a DUT with multiple connectors (single test on all the branches or test on individual branch) shall be specified in the test plan.

The DUT shall be placed on a non-conductive, low relative permittivity (dielectric-constant) material ($\varepsilon_r \leq 1,4$), at (50 ± 5) mm above the ground plane.

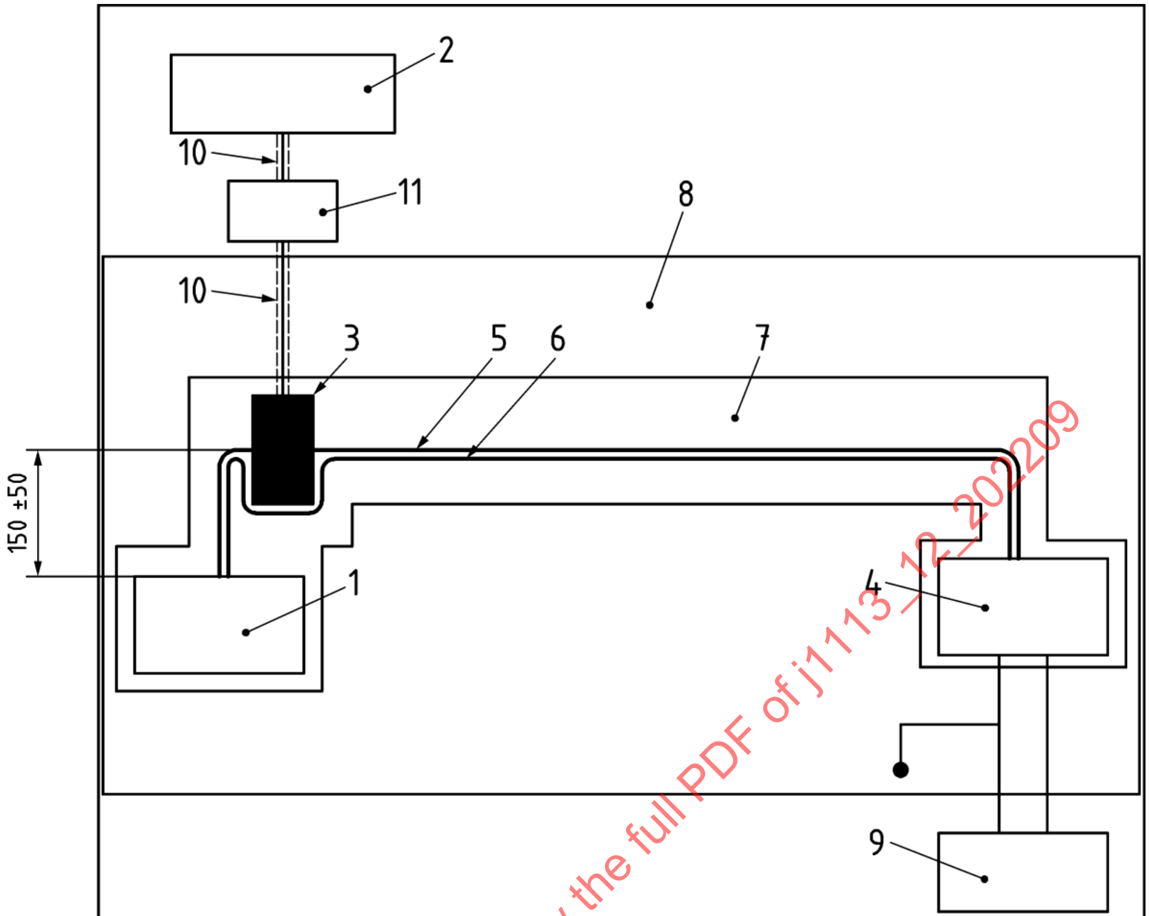
The case of the DUT shall not be grounded to the ground plane unless it is intended to simulate the actual vehicle configuration.

The harness shall be placed on a non-conductive, low relative permittivity (dielectric-constant) material ($\varepsilon_r \leq 1,4$), at (50 ± 5) mm above the ground plane."

The length of the harness shall be 1700 mm (+300 mm / 0 mm).

Centre of the ICC shall be placed (150 ± 50) mm from the connector of the DUT.

For the ICC method, negative transient pulse polarity may be achieved by reversing the injection probe on the wiring harnesses.



Key

1 DUT
2 transient pulses generator
3 ICC
4 load simulator
5 test harness (except DUT power lines)
6 DUT power lines
7 Insulation support with low relative permittivity material (□r ≤1,4)
8 ground plane
9 power supply
10 50 Ω coaxial cable
11 matching network (optional)

Figure 7 - Test set-up for ICC method – DUT test

4.8 CIC Method

4.8.1 General

The CIC method uses actual switched inductive loads to produce both fast and slow and transient pulses with combined positive and negative polarities. This is the result of mechanical and electromechanical switch contact arcing and contact bounce. Transients produced in this manner have non-linear source impedances which can induce transient voltages and currents via both capacitive and inductive coupling. Unlike the other three methods, I/O line source/load impedances can affect the dominant coupling mechanism and ultimately the actual transient disturbance seen by the DUT.

CIC also produces transient events that are random in occurrence. This random behavior has been found to have significant impact to microprocessor based DUTs. This is because the transient events timing has a greater likelihood to align with certain critical points in the DUT software execution.

4.8.2 General Verification

The CIC method utilizes the test generator described in Appendix C.

4.8.3 Transient Pulse Level Adjustment

Unlike the CCC, DCC, and ICC methods, there is no adjustment of transient pulse level.

4.8.4 DUT Test

The test setup using the CIC is shown in Figure 8.

The DUT and any electronic hardware in the load simulator shall be powered from a vehicle battery and/or power supply. The battery or power supply negative terminal shall be connected to the ground plane bench. The battery/power supply may be placed on the floor below or adjacent to the test bench.

The DUT power shall be connected to the battery/power supply via Artificial Networks (AN). The DUT power return shall be terminated to the ground plane at the Load Simulator.

The transient pulse generator shall be powered from a vehicle battery, separate from that used for the DUT and load simulator. The wire length between the transient pulse generator and battery shall be less than 500 mm. The metal case of the transient pulse generator shall be connected directly to the ground plane. See Appendix C regarding details of the transient pulse generator.

The DUT and all parts of the test setup shall be a minimum of 100 mm from the edge of the ground plane.

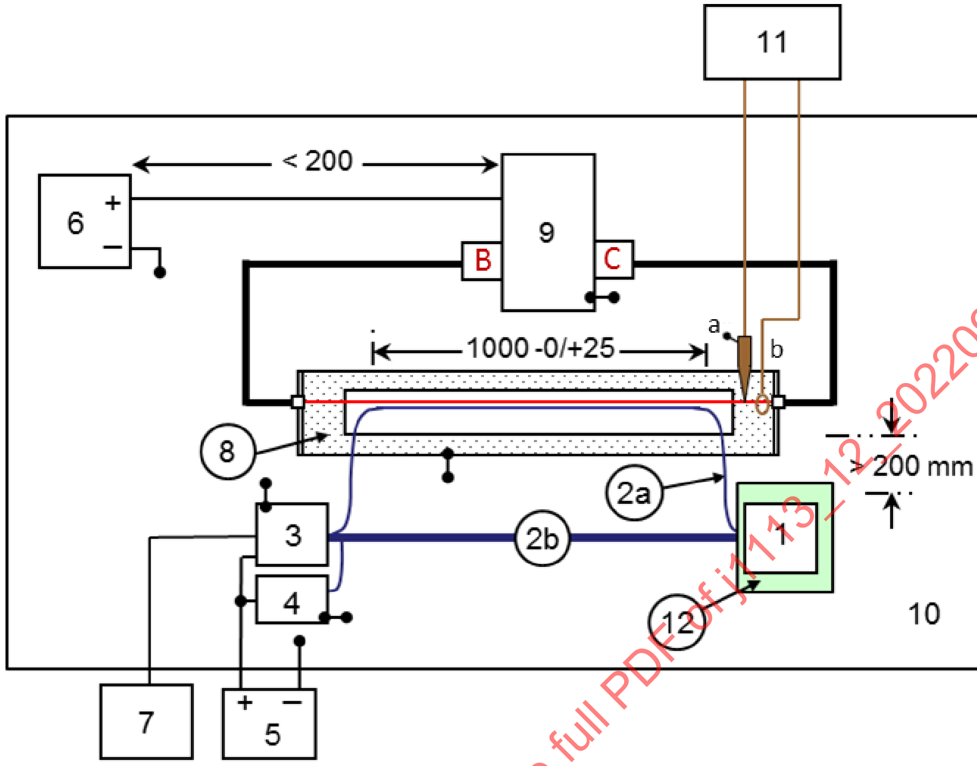
Wiring not being tested shall be bundled together and lie directly on the ground plane. The distance between the untested wires and the test fixture shall be greater than 200 mm.

Prior to performing DUT testing, configure the transient pulse generator for the required test pulse and test mode (see Appendix C). Without any DUT wiring present in the test fixture, verify the magnitude of the test pulse waveform measured at the test point (see Figure 8) is comparable to pulse characteristics illustrated in Figures 14 and 15.

Place an individual DUT circuit wire, wire pair, or wire trio in the test fixture in the appropriate test slots documented in the test plan (see 5.8 for slot description and usage).

Expose each circuit wire, wire pair or wire trio for a time agreed to between the vehicle manufacturer and the supplier (60 second duration is recommended). This information shall be documented in the EMC test plan. Verify that DUT performance is not affected.

Testing shall be repeated with all test pulses and test modes.



Key

1 DUT

2a. DUT circuit wire to be tested

2b. DUT wire harness

3 Load simulator (e.g., sensors, load, accessories), mounted as in the vehicle

4 Artificial network

5 Automotive battery or linear power supply (Powers DUT and Load Simulator)

6 Automotive battery (used for power to transient pulse generator)

7 Support and monitor equipment

8 CIC test fixture (See Appendix F)

9 Transient pulse generator (see Appendix C for details of this generator). Generator connected to CIC test fixture via 50 Ω coaxial cables. Case of generator is electrically connected to the ground plane.

10 Ground plane

11 Digital oscilloscope (see section 5.2)

- a) High impedance probe (100X). Ground reference connected to ground plane
- b) Current Probe

12 Insulation support with low relative permittivity material ($\varepsilon_r \leq 1,4$)

Figure 8 - Test setup for CIC method

5. TEST INSTRUMENT DESCRIPTION AND SPECIFICATION

5.1 Power Supply

The power supply defined in ISO 7637-2 shall be used for these tests.

5.2 Oscilloscope

Unless otherwise specified, the oscilloscope and probes defined in ISO 7637-2 shall be used for these tests. The CIC test method requires a 100X passive probe in addition to a current probe with a bandwidth > 10 MHz with a peak current measurement capability of 30 amperes or greater.

5.3 Transient Pulse Generator (CCC, DCC, ICC Methods)

5.3.1 General

The transient pulses generator of ISO 7637-2 shall be used and the wave shapes shall be verified according to ISO 7637-2.

The test voltage U_A of ISO 7637-2 shall be set to 0 V.

5.3.2 Slow Transient Pulses 2a (Positive and Negative)

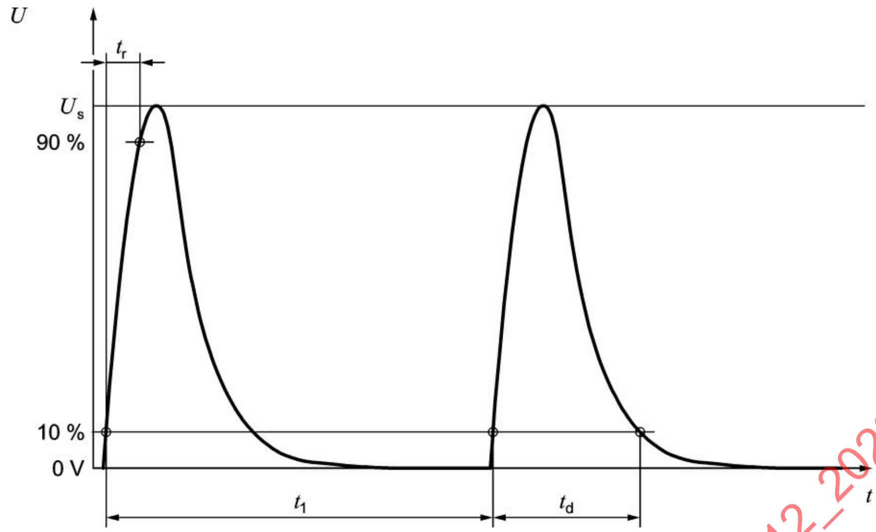
The slow transient pulses are a simulation of transient pulses which occur as a result of breaking the circuit to larger inductive loads, such as a radiator fan motor, air conditioning compressor clutch, etc.

The negative transient pulse may be realized by switching the generator output connection. The transient pulse shapes and parameters are given in Figures 9 and 10.

5.3.3 Fast Transient Pulses 3a and 3b

The fast-transient pulses tests are a simulation of transient pulses which occur as a result of the switching processes. The characteristics of these transient pulses are influenced by distributed capacitance and inductance of the wiring harness.

The transient pulses shapes and parameters are given in Figures 11 and 12.



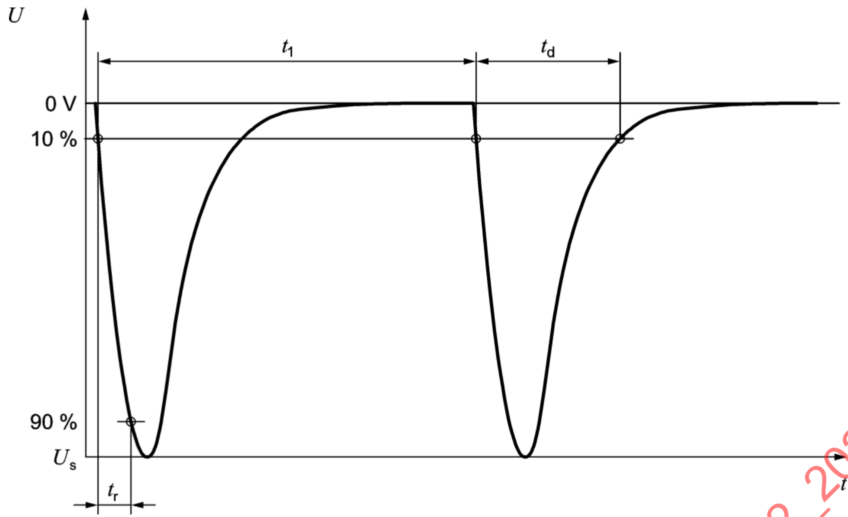
Key

t time

U voltage, in volts

Parameters	
U_s	To be defined in test plan
t_r	≤ 1 µs
t_d	0,05 ms
t_1	0,5 s to 5 s
R_i	2 Ω

Figure 9 - Slow transient pulse - Positive 2a



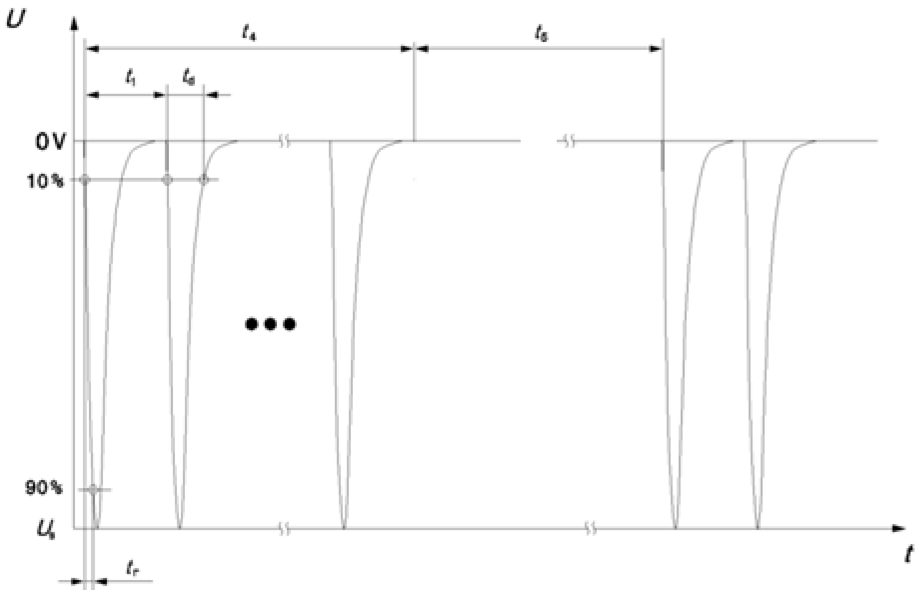
Key

t time

U voltage, in volts

Parameters	
U_s	To be defined in test plan
t_r	≤ 1 µs
t_d	0,05 ms
t_1	0,5 s to 5 s
R_i	2 Ω

Figure 10 - Slow transient pulse - Negative 2a



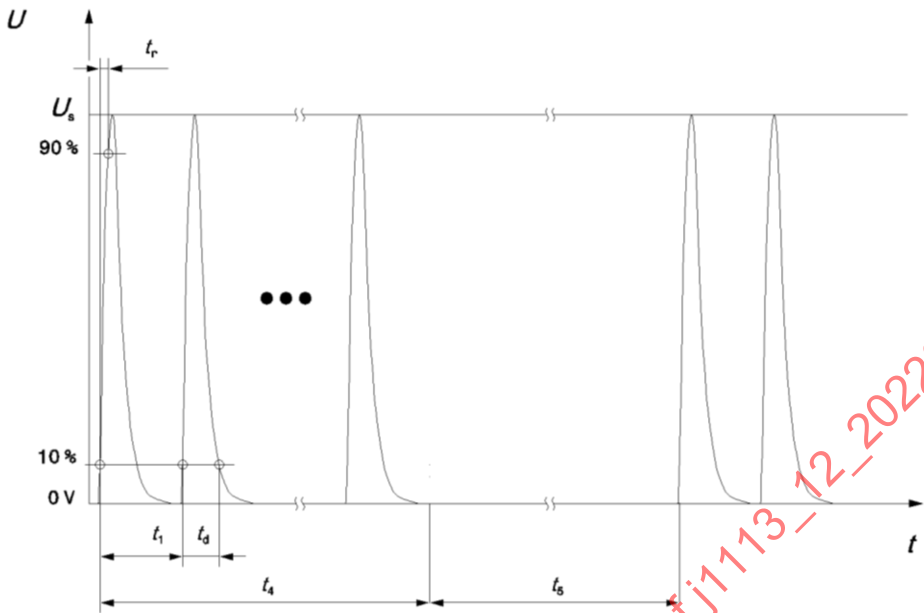
Key

t time

U voltage, in volts

Parameters	12 V system	24 V system
U_s	See Table B.1	See Table B.2
t_r	(5 ± 1,5) ns	(5 ± 1,5) ns
t_d	(0,15 ± 0,045) µs	(0,15 ± 0,045) µs
t_1	100 µs	100 µs
t_4	10 ms	10 ms
t_5	90 ms	90 ms
R_i	50 Ω	50 Ω

Figure 11 - Fast transient pulse 3a



Key

t time

U voltage, in volts

Parameters	12 V system	24 V system
U_S	See Table B.1	See Table B.2
t_r	(5 ± 1,5) ns	(5 ± 1,5) ns
t_d	(0,15 ± 0,045) µs	(0,15 ± 0,045) µs
t_1	100 µs	100 µs
t_4	10 ms	10 ms
t_5	90 ms	90 ms
R_i	50 Ω	50 Ω

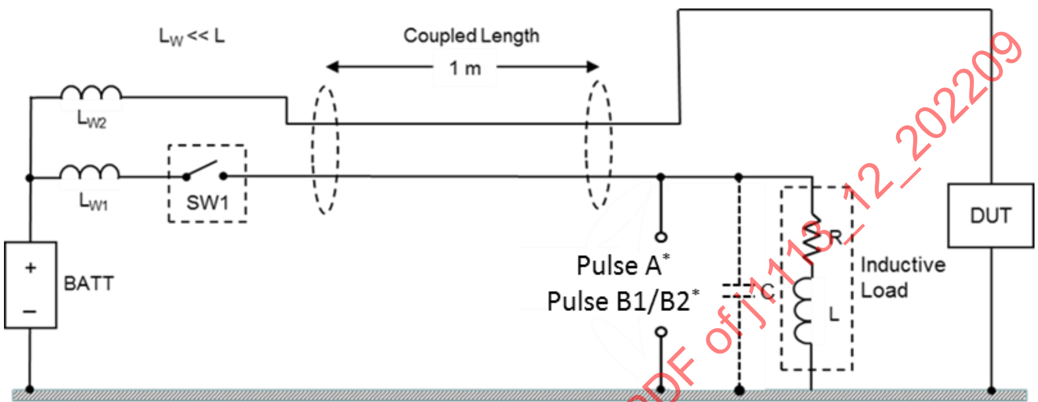
Figure 12 - Fast transient pulse 3b

5.4 Transient Pulse Generator (CIC Method)

The transient pulses used for the CIC method are generated via electromechanical switching of an inductive load. Transients created from this approach are unique because they are highly affected by a number of factors including but not limited to resistive/capacitive loads sharing the same circuit as the switched inductive load. Also, consecutive transient pulses produced in this manner can vary in both magnitude and event duration as compared to test pulses used for CCC, DCC and ICC methods.

5.4.1 General

Three types of transient pulses can be produced during the switching of the inductive load. Figure 13 illustrates a simplified automotive circuit consisting of a mechanical switch (SW1) used to activate or deactivate the inductive load (e.g., power door lock). L_{W1} and L_{W2} represent the series wiring inductance between the battery/SW1 and battery/DUT. The load inductance "L" is significantly greater than the inductance of the wiring, which is typically 1 uH/meter. The capacitance “C” represents an external capacitance due to the wiring and/or other reactive loads sharing the same circuit as the inductive load. The capacitor may also represent the filter capacitor of the inductive load.



* See Figure 8 regarding measurement location for these transient pulses

Figure 13 - Simplified automotive circuit for transient immunity

Presence or absence of this external capacitance can affect the characteristics of the transient waveforms produced. In general, these waveforms can be represented by three transient pulses. They are:

Transient Pulse A

Occurs when there is a switched inductive load with no parallel external capacitance is present

Transient Pulses B1 and B2

Occurs when there is a switched inductive load in parallel with an external capacitance. The value of the capacitance is 100 nF.

5.4.2 Transient Pulse A

Transient Pulse A is illustrated in Figure 14. The characteristics of this transient, which is due to arcing during contact opening, consists of high frequency repetitive pulses with peak positive voltages levels between +100 to +300 volts and peak negative voltage levels between –280 to –500 volts. Duration of individual pulses may vary between 100 nsec to 1 usec. Duration of the full transient event may vary between 100 – 500 usec. The variations in voltage magnitude and pulse/event duration occur between consecutive transient events thus producing the random behavior exemplified by this test method (see 4.8.1)

5.4.3 Transient Pulses B1 and B2

Transient Pulse B1 and B2 is illustrated in Figure 15. The characteristics of these transients, which is due to the external capacitance, are dependent on the actions of the switch contacts.

Pulse B1 is produced when the switch opens and there is no contact arcing. This transient pulse is characterized by a damped sinusoidal transient of approximately 2 kHz. The frequency is the result of the resonant circuit formed between the load inductance “L” and the parallel 100 nF capacitor. The peak positive voltage level is approximately 150 volts and the peak negative voltage level is approximately –250 volts. Associated peak current levels are less than 2 amperes.

Pulse B2 is produced as the result of contact bounce when the switch is closed. This transient pulse is characterized by higher frequency, damped sinusoidal transient of approximately 180 kHz. The frequency is the result of the resonant circuit formed between the wiring inductance "LW_1" and the parallel 100 nF capacitor (see Figure 13). The peak positive voltages level is approximately 150 volts and the peak negative voltage level approximately –200 volts. Associated peak-peak current levels are approximately 30 amperes. Duration of the full transient event may vary between 100 – 500 usec. The variations in voltage magnitude and pulse/event duration occur between consecutive transient events thus producing the random behavior exemplified by this test method (see 4.8.1).

When attempting to measure Pulse B2, with an oscilloscope, it is recommended to trigger on the transient current.

5.4.4 Test Modes for Transient Pulses A, B1 and B2

Generation of transient pulses A, B1 and B2 during CIC testing are facilitated using two different test modes.

- Mode 1: Transient pulses are applied as single events in a pseudo-random timing sequence.
- Mode 2: Transient pulses are applied as using pseudo- random bursts.

Figure 16 illustrates the pulse timing sequence and the resulting transient pulse events. The minimum time "T" shown in the timing sequence is 50 msec. Longer times may be selected in addition to different timing sequences, but shall be agreed between the vehicle manufacturer and the supplier.

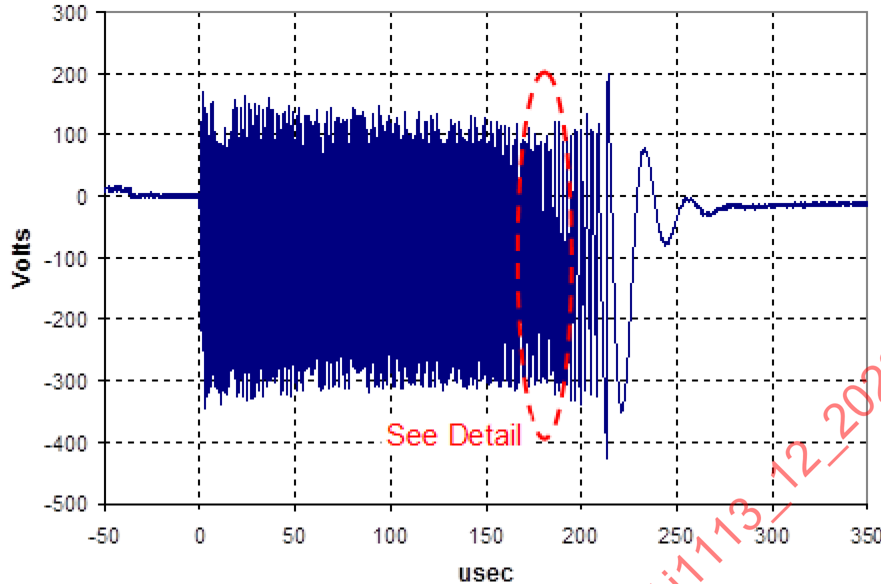
5.4.5 Transient Pulse Generator for Pulse A and B

The generator used to produce transient pulses A, B1 and B2 is illustrated in Appendix C. Information is also provided regarding the configuration settings to produce each waveform in addition to the test mode. Figure C.2 illustrates the generator's electrical circuit. All components shall be packaged in a metal enclosure which is grounded directly to the test bench.

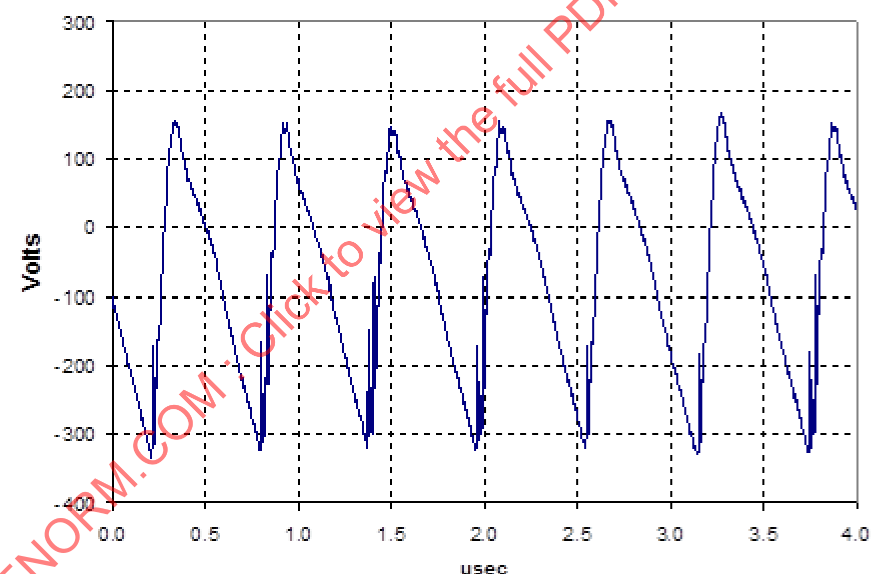
50 Ω coaxial cables (RG 225 or equivalent) less than 1 meter in length shall be used to connect the generator to the coupling fixture. An external arbitrary signal generator is used to generate the pseudo- random timing sequence.

5.4.6 Transient Pulse Generator Modifications for Higher Voltage Systems

The transient pulse generator design shown in Appendix C is limited to testing of 12 volt systems. Modification of the generator for higher voltage systems (e.g., 24, 42 volt) is possible but requires modification or resistor R2 so as to yield the same steady state current as for the 12-volt system. More critical, is knowledge of the mechanical/electromechanical switch technology used because that can have a significant impact on transient voltage characteristics. Peak voltage magnitudes may be two to three times greater depending on the switch technology used.

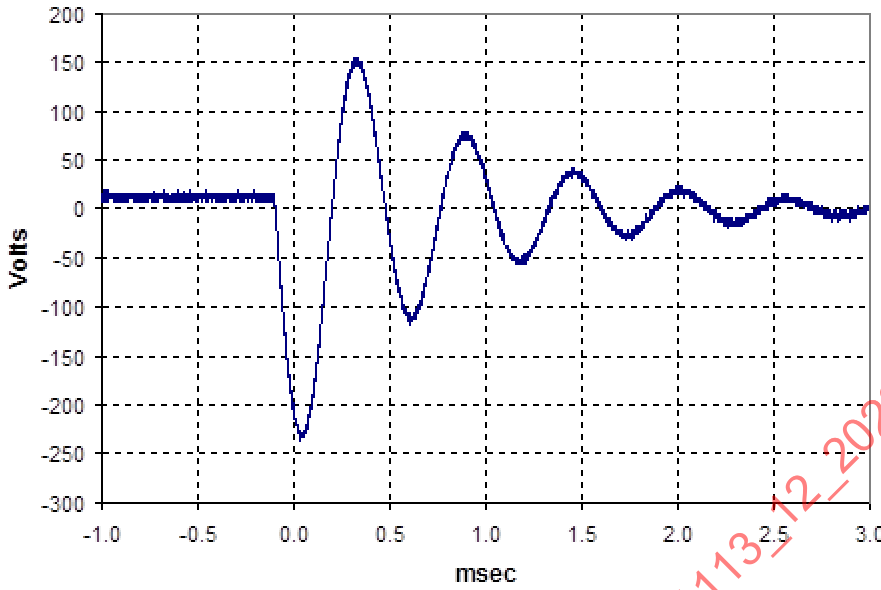


Pulse A

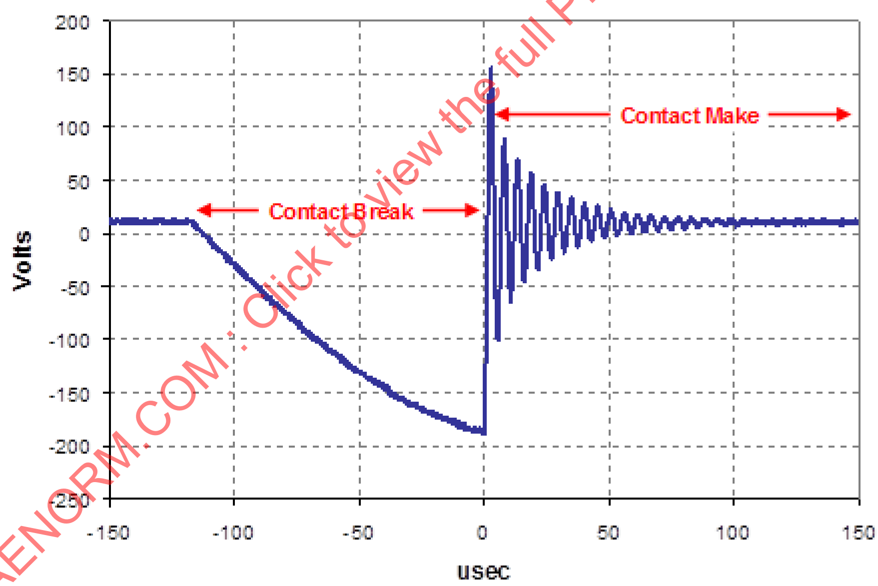


Pulse A (Detail)

Figure 14 - Transient pulse A characteristics



b) Pulse B1



b) Pulse B2

Figure 15 - Transient pulse B1 and B2 characteristics

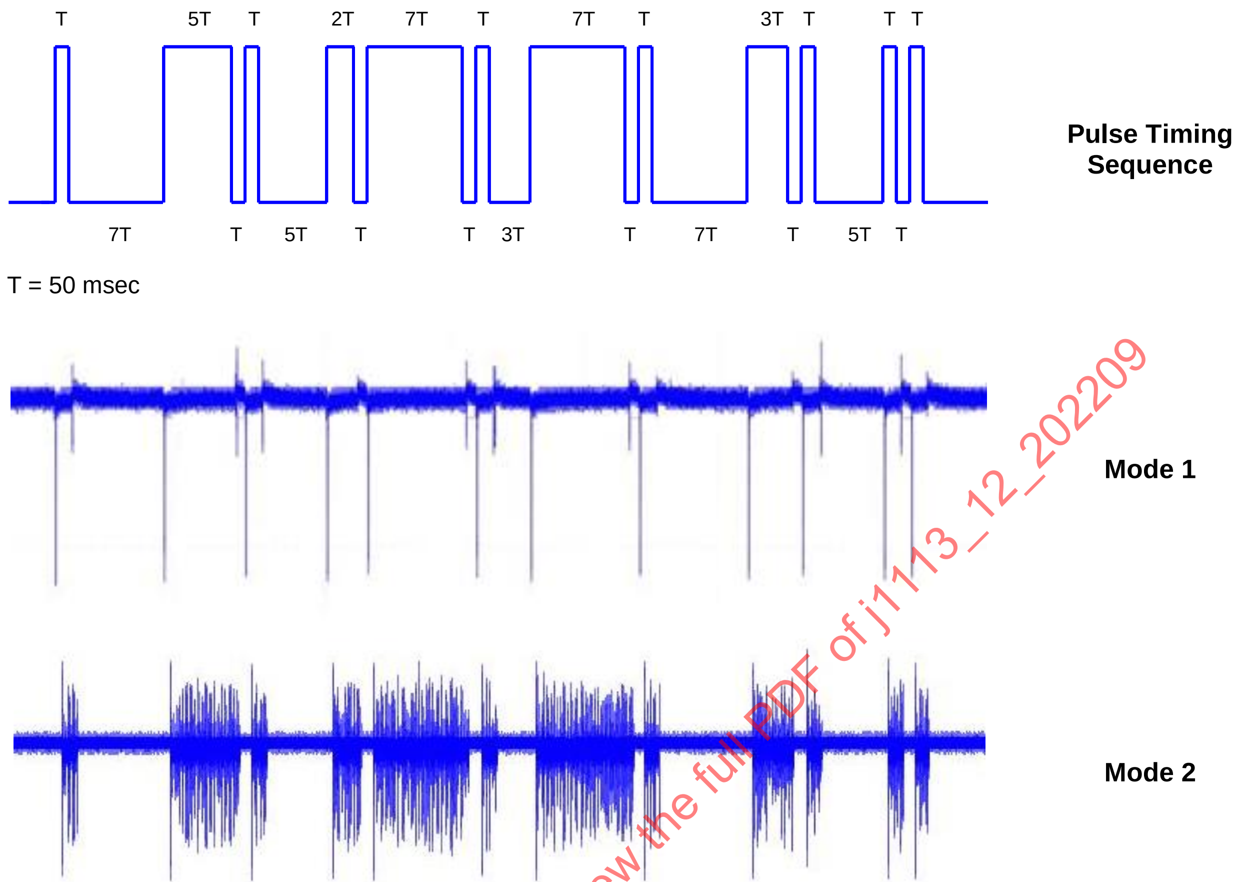


Figure 16 -Test mode characteristics

5.5 CCC Fixture

The CCC, as defined in Appendix A, can be made, for example, of brass, copper or galvanized steel. The characteristics of the CCC are as follows:

- typical coupling capacitance between cable and clamp is around 100 pF;
- applicable diameter range of harness: 4 mm to 40 mm;
- transient pulse voltage insulation strength: ≥ 200 V;
- characteristic impedance (without wires in the clamp): (50 ± 5) Ω.

5.6 DCC Fixture

The DCC fixture is a non-polarized capacitor with characteristics defined in Table 2 subclause 4.6.1.

5.7 ICC Fixture

The ICC is a bulk current injection (BCI) probe which is suitable for this test. It provides the means of coupling the transient pulses into the circuit under test without any galvanic connection to the DUT, wiring harness and/or auxiliary equipment.

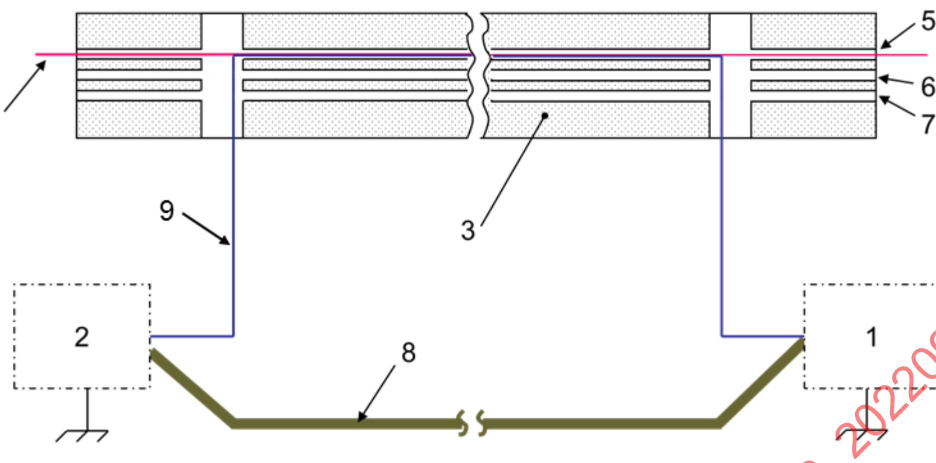
5.8 CIC Fixture

The CIC method uses a special coupling fixture that facilitates both capacitive and inductive coupling of transient pulses dependent on the impedance of the DUT and its attached peripheral electrical loads. Although the intended usage of the fixture is to test individual DUT circuit wires, the fixture will also facilitate testing of wire pairs, twisted wire pairs and shielded wiring in addition to 3-wire circuits (e.g., sensors). Figure 17 illustrates how this fixture may be used.

The source wire, located in Slot A, is connected to the transient pulse generator detailed in Appendix C. Normally each DUT circuit wire is placed in Slot A for testing. However, Slots B and C may be selected to reduce the coupling to the source wire. This approach may be desirable if the DUT wiring spacing is controlled within the actual vehicle cable harness. Selection of which test slot to use shall be agreed between the vehicle manufacturer and the supplier.

Slots A, B and C are also enough to accommodate tapped wire pairs or twisted wire pairs as long as the maximum diameter is not greater than 6 millimeters. Wire pairs that are not taped or twisted may be individually located in Slots A and B. Slot C is available to testing 3-wire DUTs (e.g., sensors).

Details concerning the physical construction of the CIC test fixture are found in Appendix D.



Key

1.DUT
2.Load Simulator (see section 4.3)
3.CIC Test Fixture
4.CIC Test Fixture: source wire
5.CIC Test Fixture: Slot A
6.CIC Test Fixture: Slot B
7.CIC Test Fixture: Slot C
8.DUT Test Harness (wiring not being tested)
9.DUT Wire under test

Figure 17 - CIC coupling fixture

6. NOTES

6.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

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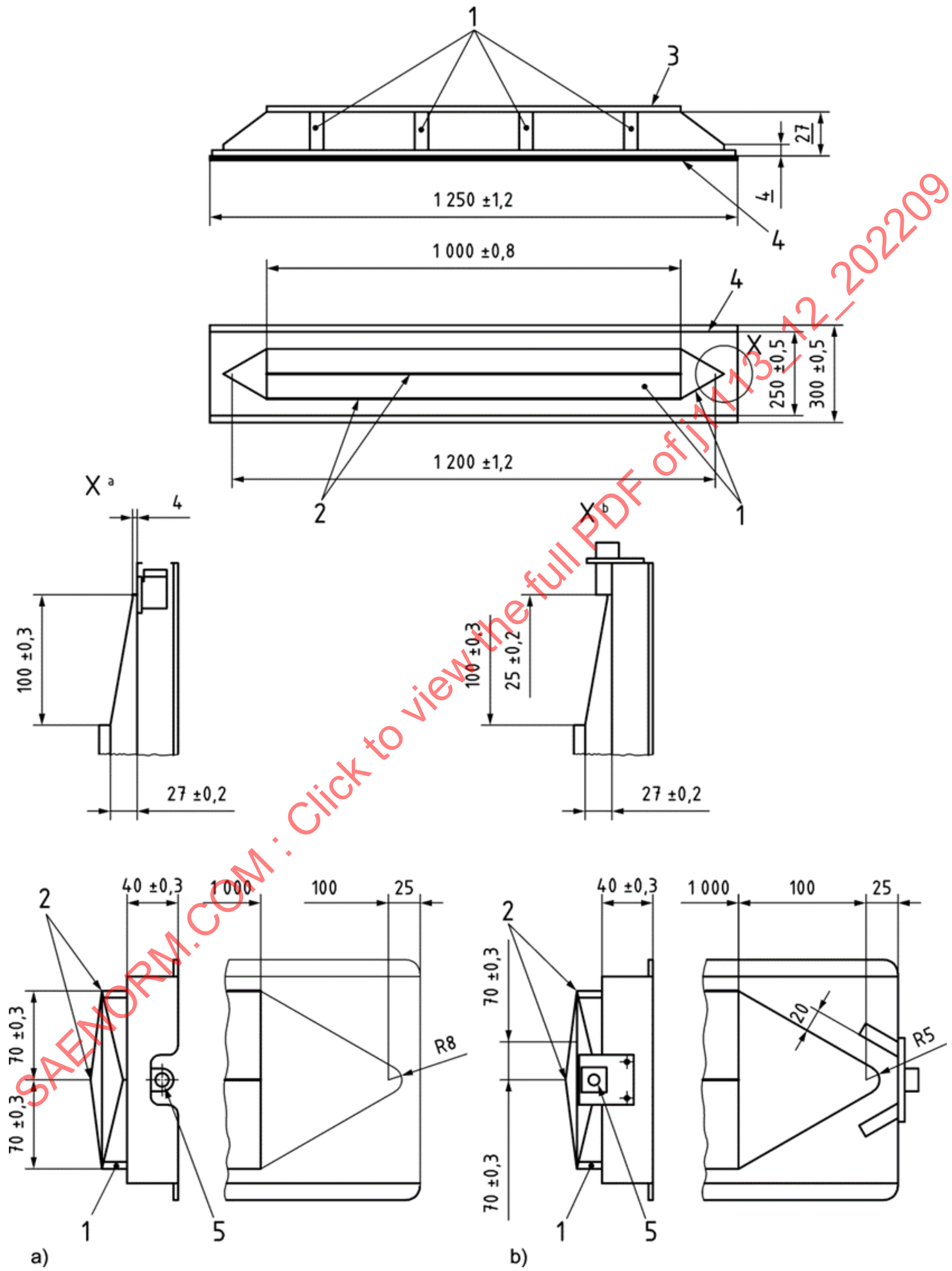
APPENDIX A

(normative)

CCC Test Fixture



Key

1.Insulating material
2.Hinge
3.Coupling plate
4.Ground plane
5.Coaxial connector

NOTE The input and output of CCC structure are selectable as shown in a) and b).

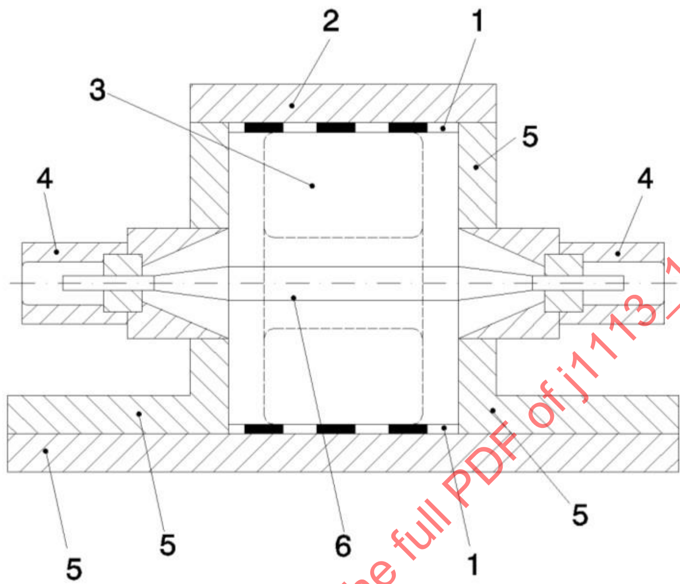
Figure A1 - Capacitive coupling clamp

APPENDIX B

(normative)

B.1 CALIBRATION FIXTURE USED FOR THE ICC TEST METHOD

Figure A1 shows an example of a calibration fixture used for the ICC test method. The physical size of the calibration fixture shall be compatible with the injection probe to be calibrated.



Key

1. insulation
2. removable metal cover (test fixture outer conductor)
3. current injection probe
4. coaxial connector
5. test fixture outer conductor
6. test fixture inner conductor

Figure B1 - Example of calibration fixture (jig)

APPENDIX C

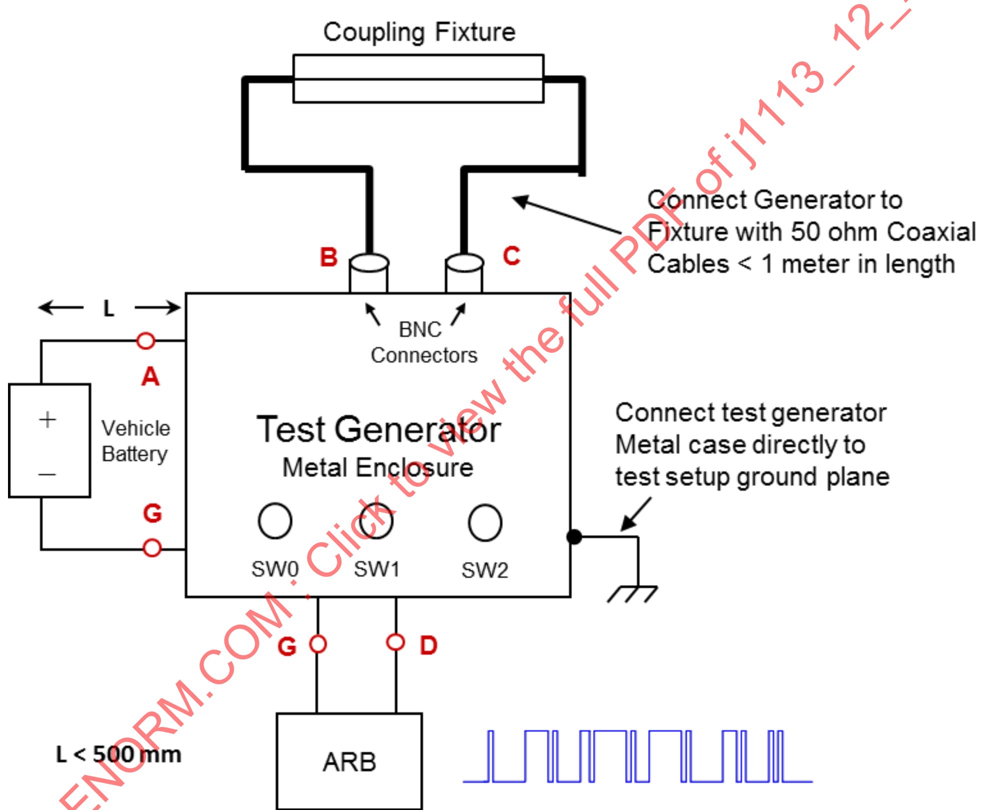
(normative)

C.1 TRANSIENT PULSE GENERATOR FOR CIC TEST METHOD

The transient pulse generator used to produce test pulses for the CIC test method is shown in Figure C1. The transient pulse generator is comprised of the test generator and attached arbitrary waveform generator. Also shown are the switch configuration settings to select pulses A, B1 or B2 in addition to the test mode. Figure C2 illustrates the generator's electrical circuit. All components shall be packaged in a metal enclosure which is grounded directly to the test bench.

50 Ω coaxial cables less than 1 meter in length shall be used to connect the generator to the coupling fixture. An external arbitrary signal generator is used to generate the pseudo- random timing sequence.

The transient pulse generator design is limited to testing of 12 volt systems. [(1)]



ARB: Arbitrary Signal Generator

Pulse	Mode	SW1	SW2
Pulse A	1	Closed	Open
	2	Open	Open
Pulses B1 and B2	1	Closed	Closed
	2	Open	Closed

* SW0 is used to activate or deactivate the transient pulse generator operation

Figure C1 - CIC transient pulse generator