INTERNATIONAL STANDARD

ISO 7637-3

Second edition
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Road vehicles — Electrical disturbances from conduction and coupling —

Part 3:
Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines

Véhicules routiers — Perturbations électriques par conduction et par couplage —

Partie 3: Transmission des perturbations électriques par couplage capacitif ou inductif le long des lignes autres que les lignes d'alimentation

Reference number
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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 7637-3 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

This second edition cancels and replaces the first edition (ISO 7637-3:1995), which has been technically revised. It also incorporates the Technical Corrigendum ISO 7637-3:1995/Cor.1:1995.

ISO 7637 consists of the following parts, under the general title *Road vehicles — Electrical disturbances from conduction and coupling*:

— *Part 1: Definitions and general considerations*

— *Part 2: Electrical transient conduction along supply lines only*

— *Part 3: Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines*

Introduction

Experience collected over a long period of immunity testing of instruments, equipment and devices under test (DUTs) shows that a test simulating transient coupling phenomena is needed for a sufficient coverage of the wide range of electric and electromagnetic interferences. The knowledge of these facts is common among electomagnetic conductivity (EMC) experts, and many companies have developed such coupling tests.

The fast transient test uses bursts composed of a number of fast transients, which are coupled into lines of electronic equipment, in particular input/output (I/O) lines. The fast rise time, the repetition rate and the low energy of the fast transient bursts are significant to the test.

The slow transient test uses a single pulse similar to that used for conducted transient, applied a number of times to the DUT.

During system development, the production wiring harness is not available and the vehicle's electrical noises are not known. The test shall therefore be performed with the worst case situation, which is represented by the capacitive and inductive coupling described in this part of ISO 7637.

Road vehicles — Electrical disturbances from conduction and coupling —

Part 3: Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines

1 Scope

This part of ISO 7637 establishes a bench top test for the evaluation of the immunity of devices under test (DUTs) to transient transmission by coupling via lines other than supply lines. The test transient pulses simulate both fast and slow transient disturbances, such as those caused by the switching of inductive loads and relay contact bounce.

Three test methods are described in this part of ISO 7637:

— the capacitive coupling clamp (CCC) method;

— the direct capacitive coupling (DCC) method; and

— the inductive coupling clamp (ICC) method.

NOTE The applicability of the three test methods is shown in Table 1.

Only one test method need be selected for slow transients and only one method need be selected for fast transients.

This part of ISO 7637 applies to road vehicles fitted with nominal 12 V, 24 V or 42 V electrical systems.

For transient immunity, Annex B provides recommended test severity levels in line with the functional performance status classification (FPSC) principle described in ISO 7637-1.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7637-2, *Road vehicles — Electrical disturbances from conduction and coupling — Part 2: Electrical transient conduction along supply lines only*

3 Test methods

3.1 General

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

The test pulse severity levels should be mutually agreed upon between the vehicle manufacturer and the supplier prior to the test.

The test pulses defined are typical pulses which represent the characteristics of most of the actual transients which may occur in the vehicle.

In special cases, it may be necessary to apply additional test pulses. Some test pulses may be omitted if a device, depending on its function or its configuration, is not influenced by comparable transients in the vehicle. It is part of the vehicle manufacturer's responsibility to define the test pulses needed for specific components.

A test plan shall be written to define

- the test methods to be used,
- the test pulses to be applied,
- the test pulse amplitudes,
- the number of pulses to be applied,
- the DUT operating modes,
- the wiring harness (test versus production),
- the leads to be included in the capacitive coupling clamp, if used,
- the leads 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,
- the leads to be included in the inductive coupling clamp, if used,
- the type of inductive coupling clamp, if the inductive coupling method is used.

Suggested values for the evaluation of immunity of DUTs can be chosen from Tables B.1, B.2, B.3 and B.4.

The applicability of the three different test methods is indicated in Table 1. Only one test method need be selected for slow transients and only one method need be selected for fast transients.

Table 1 — Test method applicability

Transient type	CCC method	DCC method	ICC method
Slow pulses of 4.3.3	Not applicable	Applicable	Applicable
Fast pulses a and b of 4.3.2	Applicable	Applicable	Not applicable

3.2 Standard test conditions

The ambient temperature during the test shall be (23 ± 5) °C.

Unless otherwise defined in this part of ISO 7637, the tolerance on time, resistance and capacitance is ± 10 %.

Unless otherwise defined in this part of ISO 7637, the tolerance on voltage is $\left(\begin{smallmatrix}+10\\0\end{smallmatrix}\right)$ %.

The supply voltage shall be as shown in Table 2 unless other values are agreed upon by the users of this part of ISO 7637, in which case such values shall be documented in the test reports.

Table 2 — Test voltages

Nominal system voltage V	**Test voltage** V
12	13,5 ± 0,5
24	27 ± 1
42	42 ± 1,5

3.3 Ground plane

The ground plane shall be a metallic sheet (e.g. copper, brass or galvanized steel) with a minimum thickness of 1 mm. The minimum size of the ground plane shall be 2 m × 1 m; however, the final size depends on the dimensions of the DUT and the test harness. The ground plane shall be connected to the facility earth ground.

3.4 Test set-up

3.4.1 General

The DUT is arranged and connected according to its requirements. The DUT should be connected to the original operating devices (loads, sensors, etc.) using a test harness or the production wiring harness, as agreed upon 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 separated from the ground plane by an insulating support having a thickness of 0,05 m to 0,1 m, unless the DUT case is connected to the chassis and has its own ground connection.

The DUT shall be connected to the grounding system according to the manufacturer's installation specification; no additional grounding connections are allowed.

Where possible, all loads, sensors, etc. are connected to the ground plane using the shortest possible lead 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 room (with the exception of the ground plane underneath the test set-up), be more than 0,5 m.

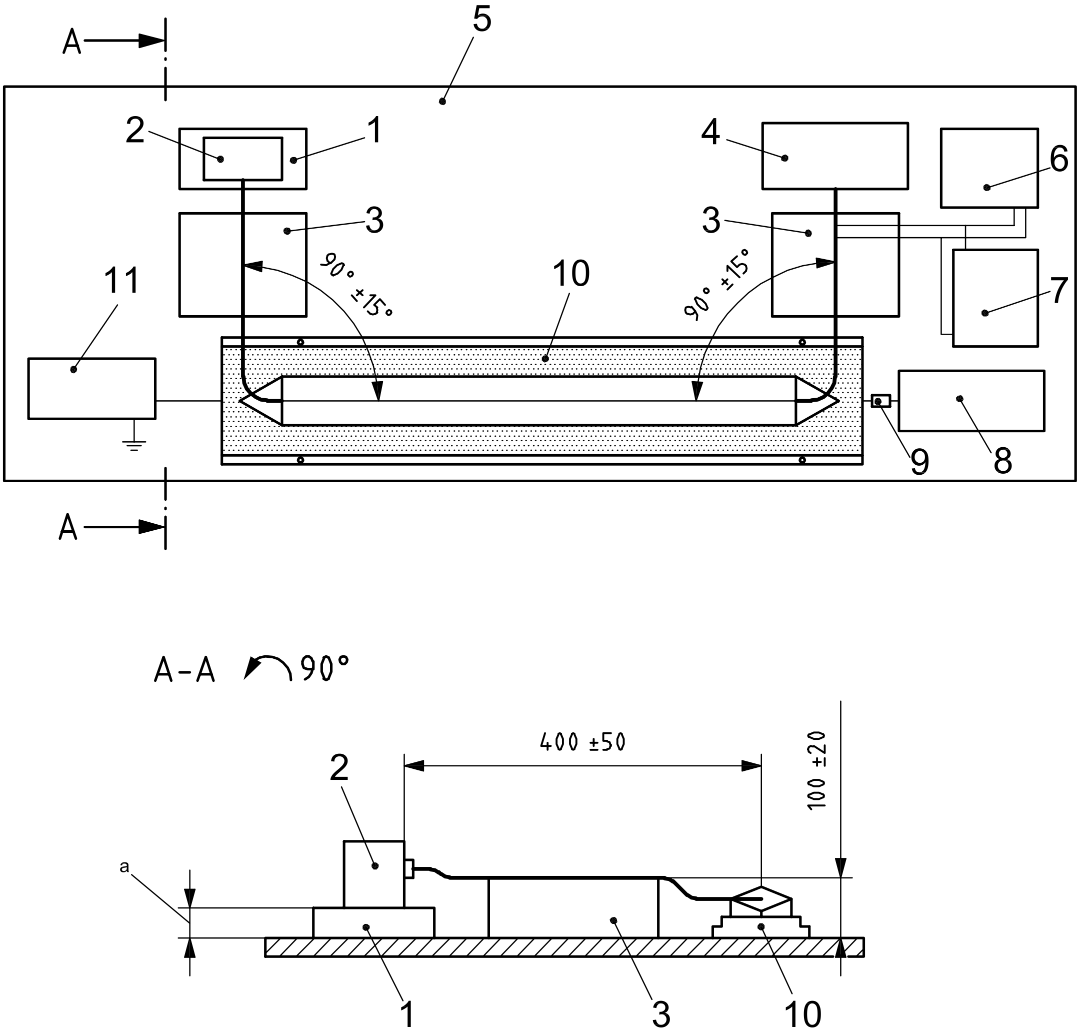
3.4.2 Capacitive coupling clamp (CCC) method

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

The test method using the CCC is shown in Figure 1. The coupling circuit consists of a CCC through which all lines of the DUT are installed as agreed between the vehicle manufacturer and the supplier (excluding or including the supply lines). The coupling length is 1 m.

The test can be performed either as shown in Figure 1 or with a straight harness as implemented in ISO 11452-4.

Dimensions in millimetres



Key

1 insulation support (if DUT is not to be connected to the ground in the vehicle)

2 DUT

3 insulating supports for test harness

4 peripheral (e.g. sensors, load, accessories), mounted as in the vehicle

5 ground plane

6 power supply

7 battery

8 oscilloscope

9 50 Ω attenuator

10 CCC

11 test pulse generator

[a] The selected dimension is specified in the test plan and documented in the test report.

Figure 1 — Test set-up for CCC method

In the case of the use of a test harness, as specified in this part of ISO 7637, the power supply lines routed outside the coupling clamp shall have a length of 1 m. The distance between the DUT and the CCC, and between peripheral devices and the CCC, shall be (400 ± 50) mm. The portions of the lines being tested which are outside the CCC shall be placed at a distance of (100 ± 20) mm above the ground plane and oriented 90° ± 15° to the longitudinal CCC axis.

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.

The DUT shall be placed on the same end of the CCC as the pulse generator.

NOTE It is advisable to limit the length of the harness to 2 m in order to improve the reliability of the results.

If using a production harness with a length exceeding 2 m, the wire length should not be coiled, the wire harness should be positioned as flat as possible and the arrangement shall be specified in the test report. The maximum distance of 0,45 m between DUT and CCC shall be maintained.

3.4.3 Direct capacitor coupling (DCC) method

The DCC method, using the recommended capacitance value, has been shown to couple the same voltage to the DUT lines for the fast transient test pulse.

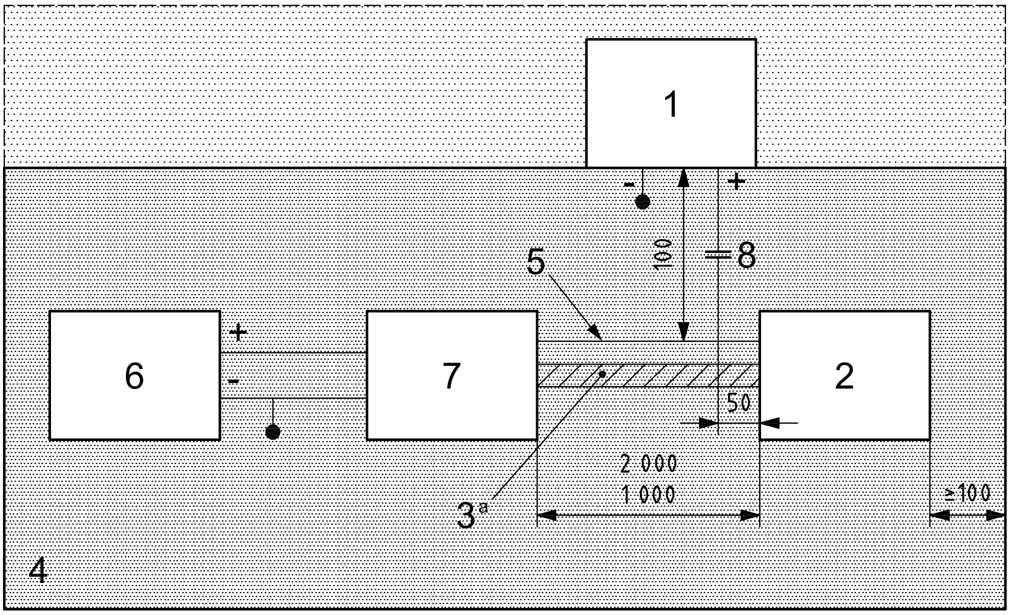
In addition, the DCC method is effective in coupling the slow transient test pulse when the recommended capacitance value is used.

The DCC method is shown schematically in Figure 2. The length of the harness shall be between 1 000 mm and 2 000 mm.

When using the DCC method, care shall be taken to ensure that signals are not unacceptably distorted (e.g. communication on bus systems). The DCC method should not be used on symmetrical lines (e.g. twisted-pair lines) unless care has been taken to excite all lines identically at the same time (see Figure 3).

For the fast transient test, the disadvantage of the DCC method is that each line is tested individually.

Dimensions in millimetres



Key

1 test pulse generator

2 DUT

3 harness

4 ground plane

5 I/O line under test

6 power supply

7 DUT exerciser

8 high-voltage (200 V minimum) ceramic leaded capacitor

NOTE For the value of the capacitor, see Table 3.

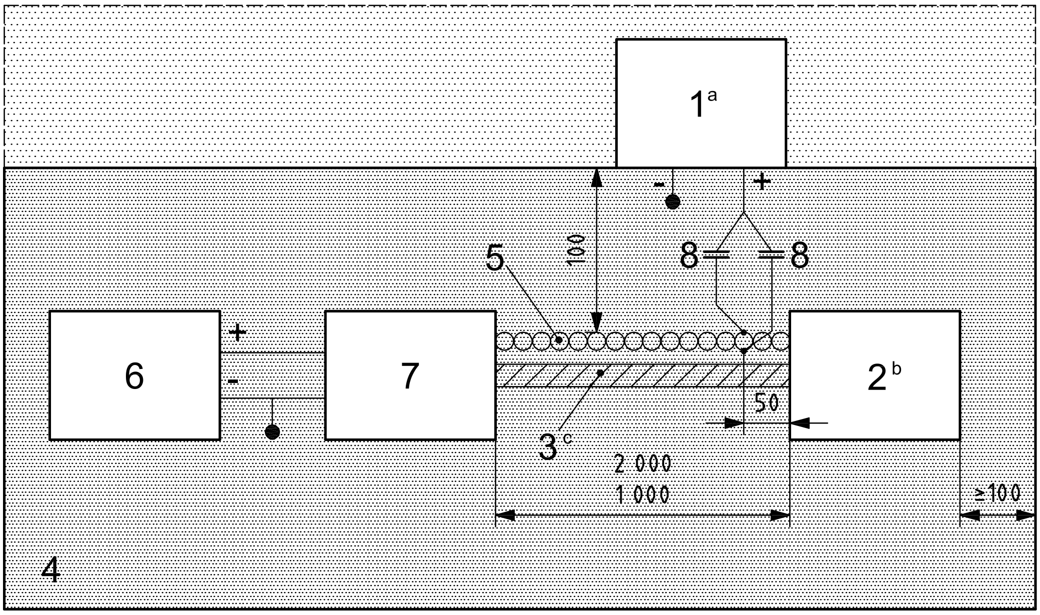
[a] All harnesses are (50 ± 5) mm above ground plane.

Figure 2 — Test set-up for DCC method

Table 3 — Capacitor values for DCC test method

Test pulse	Capacitor value
Fast transient test pulse	100 pF
Slow transient test pulse	0,1 μF

Dimensions in millimetres



Key

1 test pulse generator
2 DUT
3 harness
4 ground plane
5 CAN BUS lines
6 power supply
7 DUT exerciser
8 high-voltage (200 V minimum) ceramic leaded capacitor

[a] For fast transient test pulse, the recommended capacitor value is 100 pF; and for slow transient test pulse, the recommended capacitor value is 470 pF.

[b] The capacitor values are selected to ensure that the communication signals are not disturbed and that the pulses can still be coupled to these lines.

[c] All harnesses are (50 ± 5) mm above ground plane.

Figure 3 — Example of DCC test set-up for CAN BUS

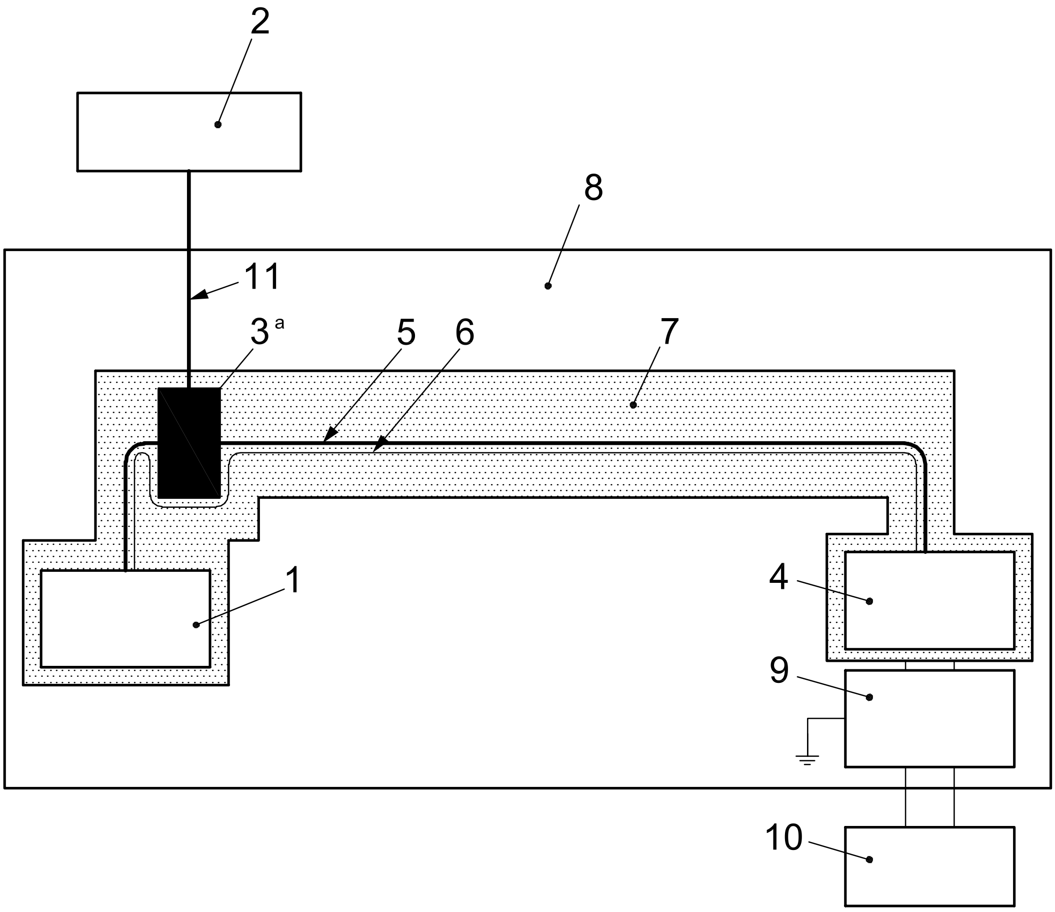
3.4.4 Inductive coupling clamp (ICC) method

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

The test method using the ICC is shown in Figure 4. The coupling circuit consists of an ICC which enfolds all signal lines. The DUT 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 4 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.



Key

1 DUT
2 test pulse generator
3 ICC
4 peripheral
5 test harness (length ⩽ 2 m)
6 ground line
7 insulation [(50 ± 10) mm]
8 ground plane
9 battery
10 d.c. power supply
11 50 Ω coaxial cable (⩽ 0,5 m)

[a] The ICC is placed 150 mm from the DUT.

Figure 4 —Test set-up for ICC method

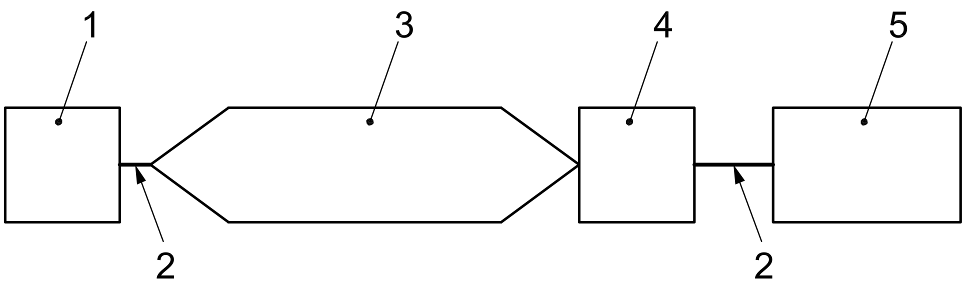
3.5 Application of transient test pulses

3.5.1 CCC method

Using a 50 Ω coaxial cable, the test pulse generator shall be connected to the CCC terminated in a 50 Ω resistor. The coaxial cable shall be no longer than 1 m.

The test pulse generator shall be calibrated prior to performance of the test (see Figure 5). The pulse amplitude is calibrated with an oscilloscope connected to the coupling clamp which is terminated in a 50 Ω attenuator and 50 Ω oscilloscope. No lines are permitted to route through the coupling clamp during calibration.

The voltage measurement is made by a 50 Ω oscilloscope connected to a 50 Ω attenuator by a 50 Ω coaxial cable. The attenuator is used instead of the CCC termination resistor.



Key

1 test pulse generator

2 50 Ω coaxial cable

3 CCC

4 50 Ω attenuator

5 oscilloscope (50 Ω input)

Figure 5 — Set-up for calibration of the test pulse amplitude — CCC method

3.5.2 DCC method

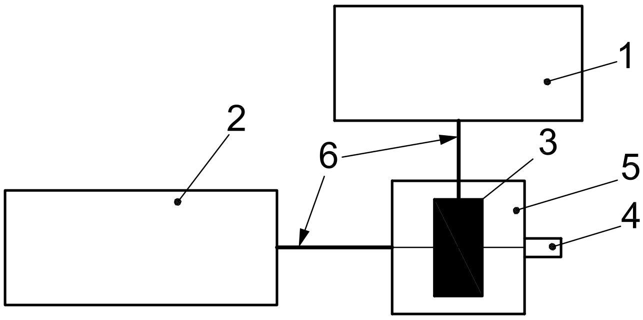
For the DCC method, the characteristics of the pulse generator shall be verified by measuring the open circuit voltage, followed by measurement of the pulse voltage with the generator terminated in the impedance appropriate for the pulse as defined in ISO 7637-2.

The output of the generator is connected in series through the coupling capacitor. A high-impedance oscilloscope should be used to measure the open circuit peak voltage at the output end of the capacitor. The generator output shall be adjusted to achieve the test level.

3.5.3 ICC method

The test pulse generator shall be connected to the inductive coupling clamp with a cable or cables no longer than 0,5 m.

In contrast to the CCC and DCC methods, the ICC method does not use the open circuit voltage of the pulse generator to specify the test level. Rather, the ICC method specifies the test level as the output voltage measured with the calibration test set-up defined in Figure 6. The coupled pulse shall fulfil the requirements of 4.6. See Annex C for information on the process used for estimating the inductive coupling factor.



Key

1 test pulse generator
2 oscilloscope (1 MΩ input)
3 ICC
4 short circuit
5 calibration fixture
6 50 Ω coaxial cable

NOTE See Annex A for an example of the calibration fixture used for the ICC test method.

Figure 6 — Test set-up for ICC calibration

4 Test instrument description and specification

4.1 Power supply

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

4.2 Oscilloscope

The oscilloscope and probes defined in ISO 7637-2 shall be used for these tests.

4.3 Test pulse generator

4.3.1 General

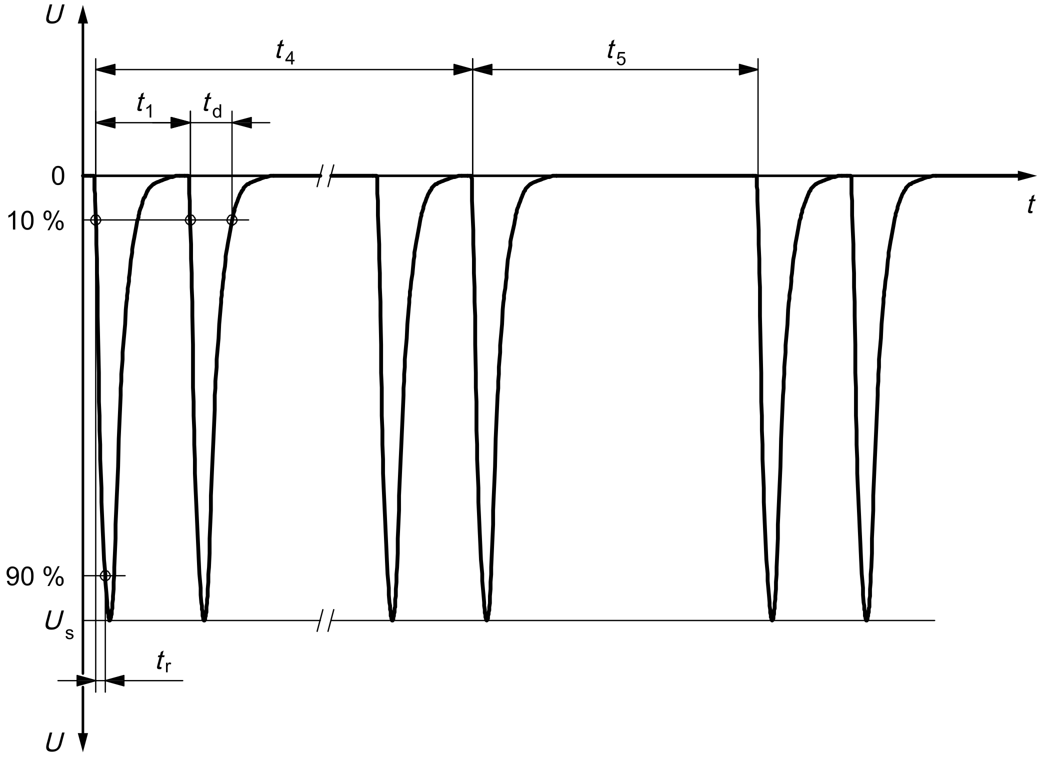
The test pulse generator shall be capable of producing the test pulses shown in Figures 7, 8, 9, and 10 and shall be adjustable within the limits given in the figures.

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

4.3.2 Fast transient test pulses a and b

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

The pulse shapes and parameters are given in Figures 7 and 8.



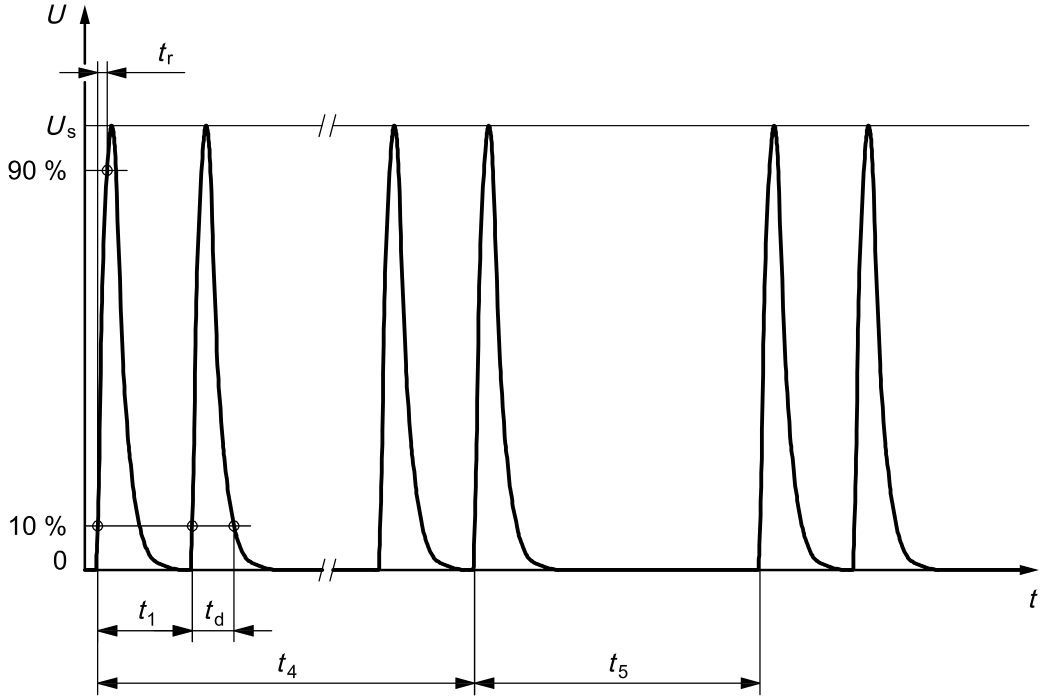
Key

t time

U tension, in volts

Parameters	12 V system	24 V system	42 V system
U_s in V	See Table B.1	See Table B.2	See Table B.3
t_r in ns	5	5	5
t_d in µs	0,1	0,1	0,1
t_1 in µs	100	100	100
t_4 in ms	10	10	10
t_5 in ms	90	90	90
R_i in Ω	50	50	50

Figure 7 — Fast transient test pulse a



Key

t time

U tension, in volts

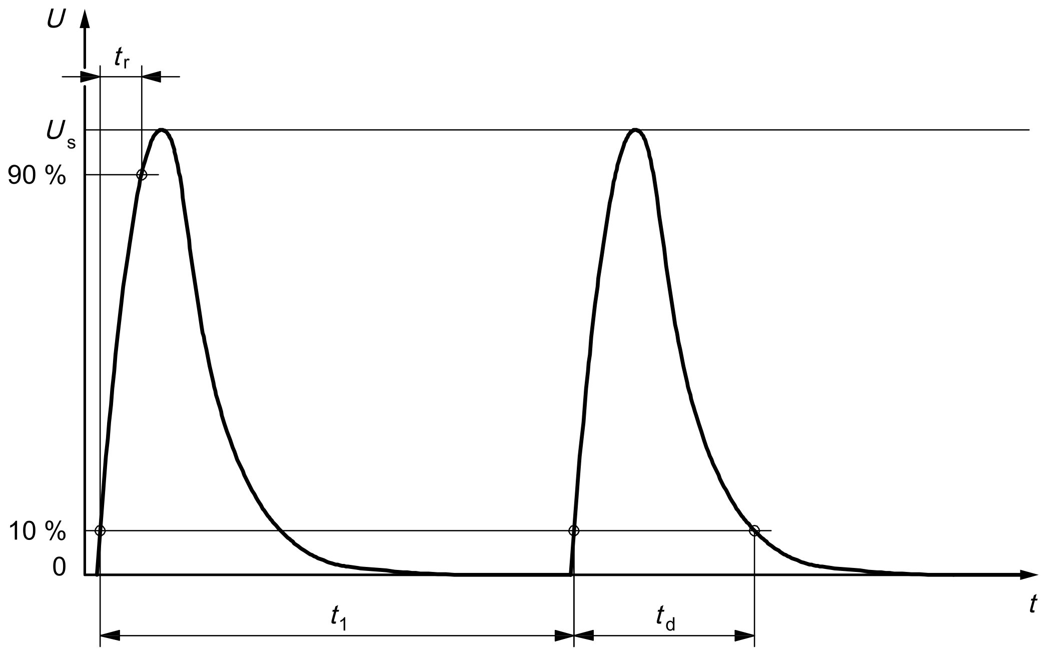
Parameters	12 V system	24 V system	42 V system
U_s in V	See Table B.1	See Table B.2	See Table B.3
t_r in ns	5	5	5
t_d in µs	0,1	0,1	0,1
t_1 in µs	100	100	100
t_4 in ms	10	10	10
t_5 in ms	90	90	90
R_i in Ω	50	50	50

Figure 8 — Fast transient test pulse b

4.3.3 Slow transient test pulses

The slow transient test pulses are a simulation of transients 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 pulse shapes and parameters are given in Figures 9 and 10.



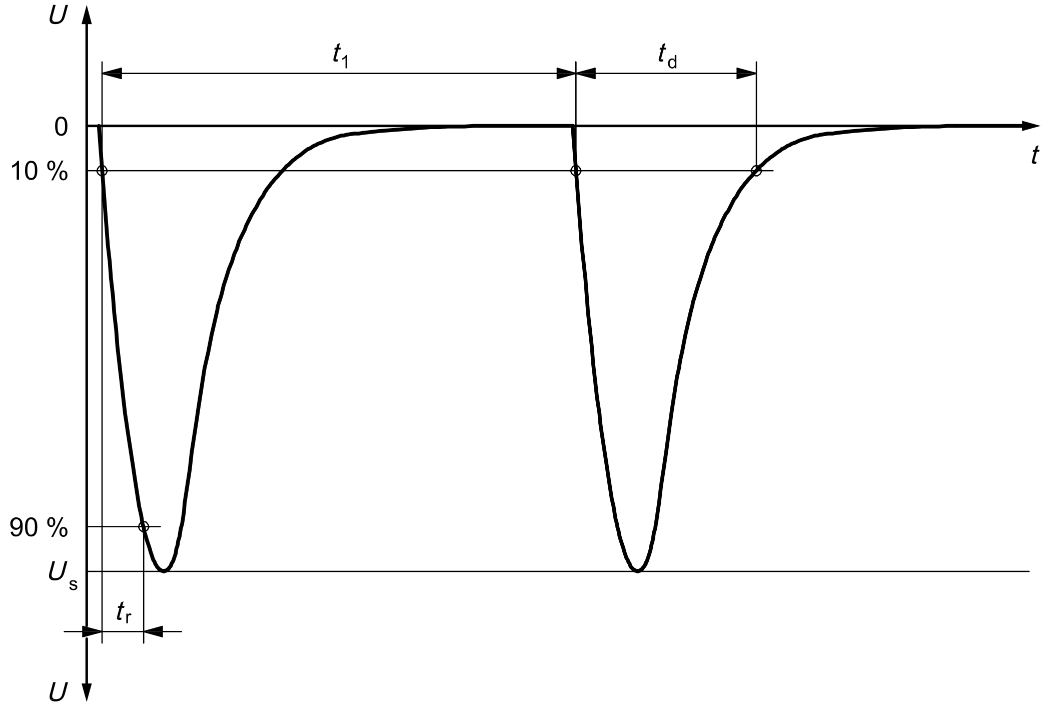
Key

t time

U tension, in volts

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

Figure 9 — Slow transient test pulse — Positive



Key

t time

U tension, in volts

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

Figure 10 — Slow transient test pulse — Negative

4.4 Capacitive coupling clamp

The CCC provides the means of coupling the test pulses into the circuit under test without any galvanic connection to the DUT, wiring harness and/or auxiliary equipment.

The CCC coupling efficiency depends on the diameter and the material of the cables.

The CCC, as defined in Figure 11, can be made, for example, of brass, copper or galvanized steel.

Both ends of the CCC shall be equipped with a 50 Ω coaxial connector.

The recommended test set-up using the CCC is shown in Figure 1.

The characteristics of the CCC are as follows:

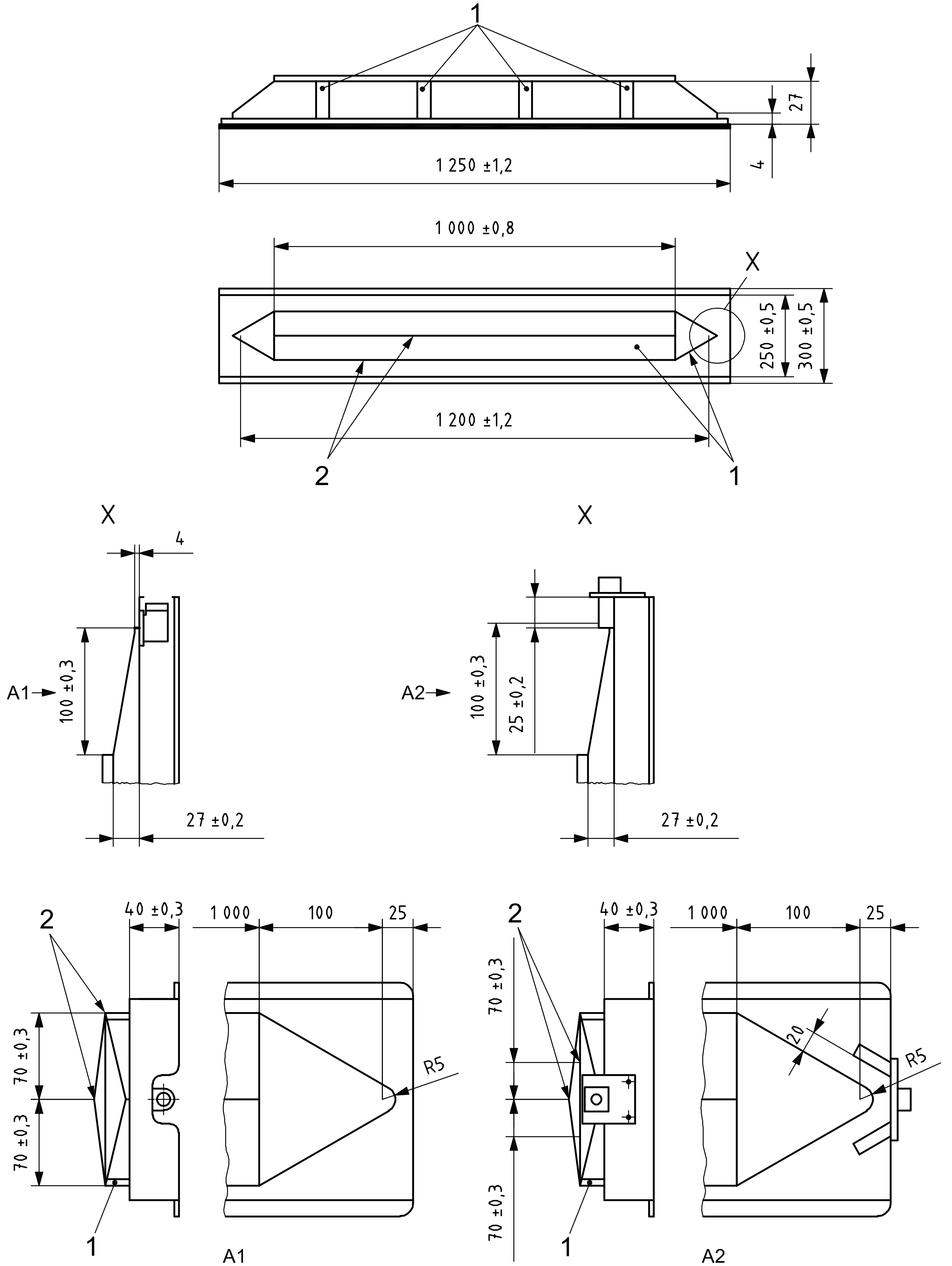
— typical coupling capacitance between cable and clamp: about 100 pF (200 pF maximum);

— applicable diameter range of harness: 4 mm to 40 mm;

— pulse voltage insulation strength: ⩾ 200 V;

— impedance (without wires in the clamp): (50 ± 5) Ω.

Dimensions in millimetres



Key

1 insulating material
2 hinge

Figure 11 — Capacitive coupling clamp

4.5 Direct coupling capacitor

A non-polarized capacitor with a voltage rating of at least twice the maximum applied voltage shall be used. The value of the capacitance shall be as shown in Table 2 with a tolerance of ± 10 %.

4.6 Inductive coupling clamp

The ICC is a bulk current injection (BCI) probe with special characteristics. It provides the means of coupling the test pulses into the circuit under test without any galvanic connection to the DUT, wiring harness and/or auxiliary equipment. The pulses, as described in Figures 9 and 10, applied to the injection probe and then measured in the calibration test set-up (see Figure 6) shall fulfill the requirements stated in Table 4.

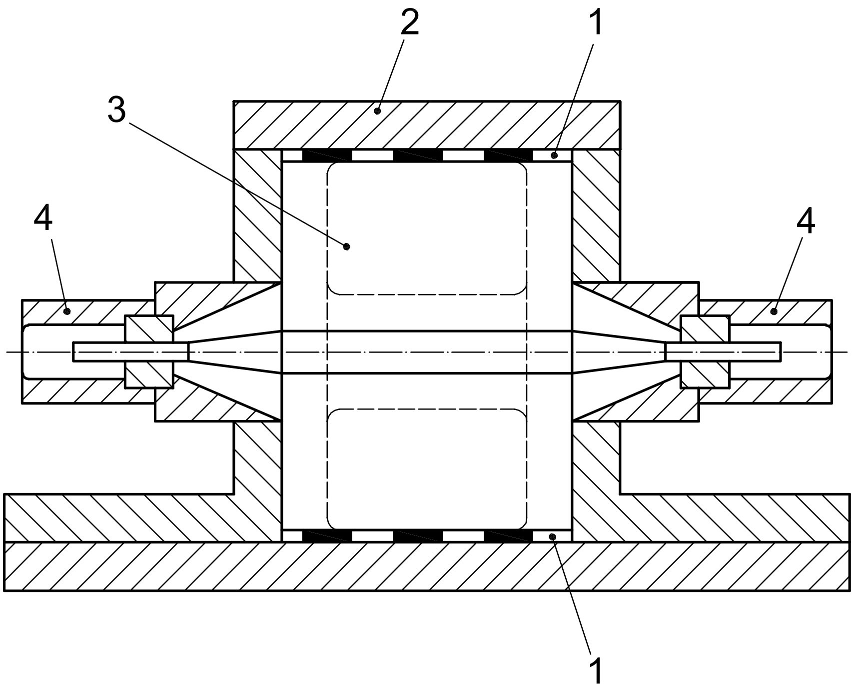
Table 4 — ICC — Characteristics of the coupled pulses

Parameters	12 V system	24 V system	42 V system
t_d in µs	(7 ± 30) %	(7 ± 30) %	(7 ± 30) %
t_r in µs	⩽ 1,2	⩽ 1,2	⩽ 1,2

Annex A
(normative)

Calibration fixture used for the ICC test method

Figure A.1 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

3 current injection probe

4 coaxial connector

Figure A.1 — Example of calibration fixture (jig)

Annex B
(informative)

Example of test severity levels associated with functional performance status classification

B.1 General

This annex provides examples of test severity levels which should be used in line with the principle of functional performance status classification (FPSC) described in ISO 7637-1.

B.2 Classification of test pulse severity level

The values given for all three methods for 12 V systems and for fast transient for 24 V systems are based on considerable experience. The values given for 42 V system are extrapolated from very limited experience. As experience is accumulated with 24 V and 42 V systems, the tables concerned will be updated.

The suggested minimum and maximum severity levels are given in columns I and IV of Tables B.1 to B.3.

A test level and test time at or in between these values may be selected according to the agreement between vehicle manufacturer and supplier. In cases where no specific values are defined, it is recommended to use levels selected from columns I to IV in Tables B.1 to B.3.

The recommended test severity levels for a 12 V electrical system are given in Table B.1.

Table B.1 — Recommended test severity levels for a 12 V electrical system

Test pulse [a]	Selected test level [b]	Test levels U_s [c] V				Test time min
		I min.	II	III	IV max.	
Fast a (DCC and CCC)		− 10	− 20	− 40	− 60	10
Fast b (DCC and CCC)		+ 10	+ 20	+ 30	+ 40	10
DCC slow +		+ 8	+15	+ 23	+ 30	5
DCC slow −		− 8	− 15	− 23	− 30	5
ICC slow +		+ 3	+ 4	+ 5	+ 6	5
ICC slow −		− 3	− 4	− 5	− 6	5

[a] Test pulses as in 4.3.

[b] Values agreed to between vehicle manufacturer and supplier.

[c] The amplitudes in the table are the values of U_s, as defined for each test pulse in 4.3. U_s is referenced at the output of the CCC for the CCC method, or at the output of the open circuit generator for the DCC method.

The recommended test severity levels for a 24 V electrical system are given in Table B.2.

Table B.2 — Recommended test severity levels for a 24 V electrical system

Test pulse [a]	Selected test level [b]	Test levels U_s [c] V I min.	 II	 III	 IV max.	Test time min
Fast a (DCC and CCC)		− 14	− 28	− 56	− 80	10
Fast b (DCC and CCC)		+ 14	+ 28	+ 56	+ 80	10
DCC slow +		+ 15	+25	+ 35	+ 45	5
DCC slow −		− 15	− 25	− 35	− 45	5
ICC slow +		+ 4	+ 6	+ 8	+ 10	5
ICC slow −		− 4	− 6	− 8	− 10	5

[a] Test pulses as in 4.3.

[b] Values agreed to between vehicle manufacturer and supplier.

[c] The amplitudes in the table are the values of U_s, as defined for each test pulse in 4.3. U_s is referenced at the output of the CCC for the CCC method, or at the output of the open circuit generator for the DCC method.

The recommended test severity levels for a 42 V electrical system are given in Table B.3.

Table B.3 — Recommended test severity levels for a 42 V electrical system

Test pulse [a]	Selected test level [b]	Test levels U_s [c] V I min.	 II	 III	 IV max.	Test time min
Fast a (DCC and CCC)		− 10 (− 20)	− 20 (− 40)	− 40 (− 80)	− 60 (− 120)	10
Fast b (DCC and CCC)		+ 10 (+ 20)	+ 20 (+ 40)	+ 30 (+ 60)	+ 40 (+ 80)	10
DCC slow +		+ 8	+15	+ 23	+ 30	5
DCC slow −		− 8	−15	− 23	− 30	5
ICC slow +		+ 3	+ 4	+ 5	+ 6	5
ICC slow −		− 3	− 4	− 5	− 6	5

[a] Test pulses as in 4.3.

[b] Values agreed to between vehicle manufacturer and supplier.

[c] The amplitudes in the table are the values of U_s, as defined for each test pulse in 4.3. U_s is referenced at the output of the CCC for the CCC method, or at the output of the open circuit generator for the DCC method.

NOTE In testing the device to increasing test pulse severity, care would need to be taken to avoid possible cumulative effects from the previous test.

B.3 Example of FPSC application using test pulse severity levels

An example of severity levels is given in Table B.4. The values can vary depending on the kind of pulse and the type of electrical system, 12 V, 24 V or 42 V (see levels from Tables B.1 to B.3).

Table B.4 — Example of FPSC application using test pulse severity levels

	Category 1	**Category 2**	**Category 3**
L_{4i}	Level II	Level III	Level IV
L_{3i}	Level II	Level III	Level III
L_{2i}	Level II	Level II	Level III
L_{1i}	Level I	Level I	Level II

Annex C
(informative)

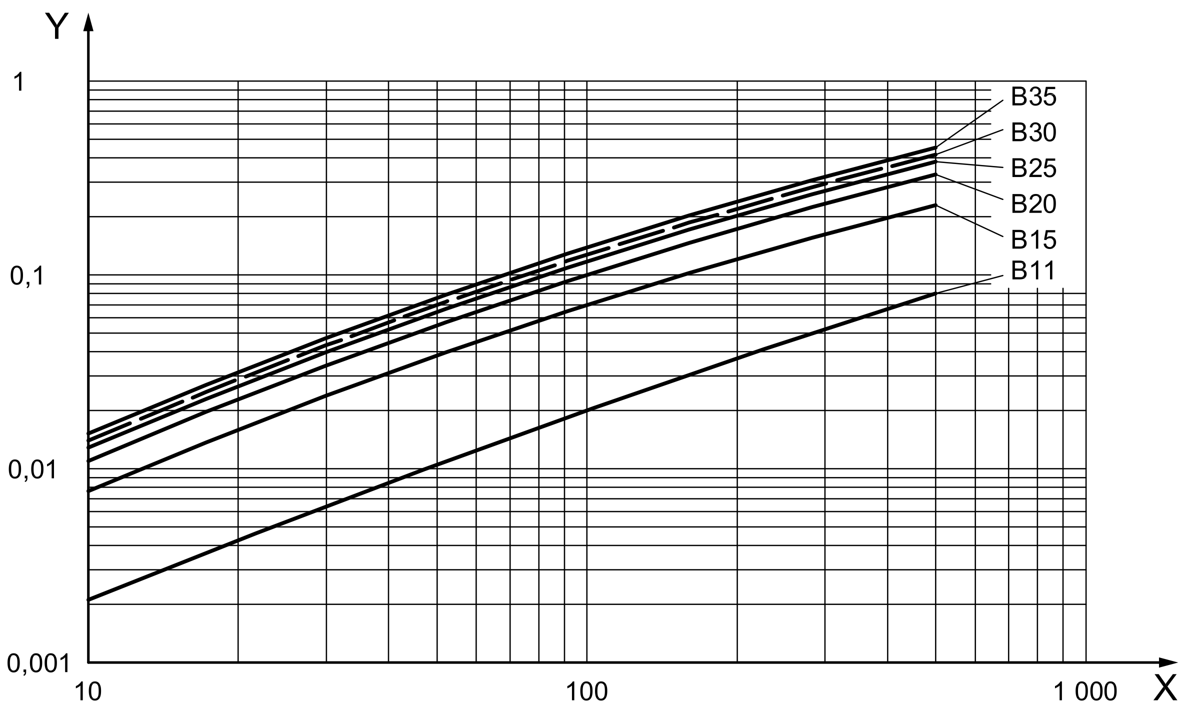
Estimation of the inductive coupling factor

The estimation of inductive coupling factor, k, requires the use of the wire harness classification in Table C.1.

Table C.1 — Wire harness classification used in Figure C.1

Wire harness diameter, d mm	**Set**
$d \leqslant 11$	B11
$11 < d \leqslant 15$	B15
$15 < d \leqslant 20$	B20
$20 < d \leqslant 25$	B25
$25 < d \leqslant 30$	B30
$30 < d \leqslant 35$	B35

The common path of lines within a wire harness defines the coupling network. The coupling factor, k, depends on the parameter of the wire harness diameter (see Figure C.1).



Key

X coupling network length, in centimetres

Y inductive coupling factor, k

Figure C.1 — Dependence between the inductive coupling factor, k, the coupling network length and the diameter of the wire harness in the case of slow transient test pulses

The peak interference voltage (test voltage), U_{test}, is defined in the following equation:

$$U_{\text{test}} = k \times U_{\text{switchoff}}$$

where

k is the inductive coupling factor as shown in Figure C.1;

$U_{\text{switchoff}}$ is the peak voltage produced by a switch-off event.

The peak interference voltage, U_{test}, can be used as an estimated test severity level needed for a special configuration. Using the procedure described in 3.5.3, the generator output voltage (open circuit voltage) can be derived from it.

Bibliography

[1] ISO 7637-1, *Road vehicles — Electrical disturbances from conduction and coupling — Part 1: Definitions and general considerations*

[2] ISO 11452-4, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Bulk current injection (BCI)*

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