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SURFACE VEHICLE RECOMMENDED PRACTICE

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

RATIONALE

The March 2000 version of this document has been revised to incorporate the latest changes in the International Standard ISO 7637 Part 3 and to revise the chattering relay test.

1. SCOPE

This SAE Standard establishes a common basis for the evaluation of devices and equipment in vehicles against transient transmission by coupling via lines other than the power supply lines. The test 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 – Capacitive Coupling Clamp, Chattering Relay, Direct Capacitor Coupling, and Inductive Coupling Clamp.

1.1 Measurement Philosophy

Years of experience with immunity testing of instruments, devices, and equipment shows the need for tests simulating transient coupling phenomena covering a wide range of electric and electromagnetic disturbances on non-supply leads. The knowledge of these facts is common among EMC experts, and many companies have developed such coupling tests.

1.1.1 Capacitive Coupling Clamp (CCC)

The fast transient test uses bursts composed of a number of fast pulses, which are coupled into all lines other than the supply lines of electronic equipment. The short rise time, the repetition rate, and the low energy of the transients are significant for the test.

Theoretical and practical examinations of capacitive and inductive coupling test procedures for car electrical systems with respect to coupling via lines other than the supply lines have been made. Since in the actual test situation neither the original cable harness nor the possible sources of interference are available, worst case testing must be performed which is represented by capacitive coupling. The coupling clamp can be used to couple these fast transients to the DUT via the test harness.

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1.1.2 Chattering Relay

In an actual vehicle, inductive transients are usually random in occurrence, amplitude, and duration. Other methods of testing using commercial test instruments that create a very repeatable event are much less effective at finding certain types of concerns since they do not create such a random sequence. This randomness is extremely critical for DUTs containing microprocessors since the transients must often line up in time with a certain point in software execution to have an effect. To create such a match using commercial transient generators takes an unreasonable amount of test time. The noise created by this test is designed to provide a continuous series of random transients using a chattering relay.

1.1.3 Direct Capacitor Coupling

The Direct Capacitor Coupling (DCC) method uses a capacitor to directly couple both fast and slow transients depending on the capacitor used. When using the DCC method, care has to be taken to ensure that signals are not unacceptably distorted (e.g. communication on bus systems). For the fast transient test, the disadvantage of the DCC method is that each line is tested individually unlike the Coupling Clamp method.

1.1.4 Inductive Coupling Clamp

The Inductive Coupling Clamp (ICC) method uses the Bulk Current Injection components to apply the test pulses. The method is able to better couple the slow transient test pulses. For DUTs with a moderate or large number of lines to be tested, this method has an advantage over the DCC method.

2. REFERENCES

General information regarding this testing including definitions, artificial loading, and safety considerations is found in SAE J1113-1. Information on test equipment for the Capacitive Coupling Clamp method is in SAE J1113-11. Information on the Inductive Coupling Clamp is in SAE J1113-4.

2.1 Applicable Publications

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

SAE J1113-1 Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle Components (Except Aircraft)

SAE J1113-4 Bulk Current Injection

SAE J1113-11 Immunity to Conducted Transients on Power Leads

2.2 Related Publication

The following publication is provided for information purposes only and is not a required part of this document.

2.2.1 ISO Publication

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 7637-3 Road vehicles—Electrical disturbance by conduction and coupling

3. TEST EQUIPMENT

3.1 Grounding

A ground plane shall be used for this test. The details of its construction are given in SAE J1113-1. The ground plane shall be connected to the test facility grounding system (i.e., the “green” wire of the power distribution system).

3.1.1 DUT Grounding

The DUT shall be placed on a ground plane as follows:

a. Ungrounded—The DUT shall be separated from the ground plane by an insulating support having a thickness of 0.05 to 0.1 m and $\varepsilon_r \leq 1.4$.

b. Grounded—The DUT shall be connected to the ground plane by a short metal strap or conductive fastener at the production ground point.

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

3.1.2 DUT Layout with Respect to the Ground

The DUT is arranged and connected according to its requirements over the ground plane. To minimize extraneous capacitive coupling to the DUT, it is recommended 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 DUT and the coupling clamp) be more than 0.5 m.

3.2 Power Supply and Measurement Instrumentation

Details of the equipment required are found in other parts as follows:

a. Power Supply—See SAE J1113-1

b. Oscilloscope (preferably storage)—See SAE J1113-11

c. Voltage Probe—See SAE J1113-11

d. BCI Clamp—See SAE J1113-4

e. BCI Calibration Fixture—See SAE J1113-4

3.3 Capacitive Coupling Clamp

The clamp provides the means of coupling the test pulses into the circuit under test without any galvanic connection to the terminals of the circuits, or any other part of the DUT.

The clamp coupling efficiency depends on the diameter and the material of the DUT harness.

The coupling clamp, as defined in Figure 1, can be made, for example, of brass, copper or galvanized steel.

At both ends, the line shall be equipped with a coaxial connector for the connection of the test pulse generator and the 50 Ω terminating resistor.

The recommended configuration of the coupling clamp is shown in Figure 1.

3.3.1 Capacitive Coupling Clamp Characteristics

a. Typical coupling capacitance between cable and clamp[1]—about 100 pF (max. 200 pF)

b. Applicable diameter range of harness—4 mm to 40 mm

c. Pulse voltage insulation strength—≥200 V

d. Characteristic impedance (without inserted lines)—50 Ω ± 10%

3.3.2 Connection Between Coupling Clamp and Test Pulse Generator

A 50 Ω coaxial cable and connectors shall be used. The length shall not exceed 0.5 m.

3.3.3 Test Pulse Generator

The test pulse generator shall be capable of producing the test pulses shown in Figures 2, 3, 4 and 5 and shall be adjustable within the limits given in the figures. The pulse generator of SAE J113-11 shall be used and the wave shapes shall be verified according to SAE J1113-11 Appendix A.

Tolerances for the parameters are:

a. ±10% for time and resistance

b. +10%-0% for voltage

A coaxial connector shall be used for the generator output signal. The internal resistance R_s is defined for each pulse in Figures 2 and 3.

3.3.4 Test Pulses A, B, C, and D

These test pulses are a simulation of transients which occur as a result of switching processes. The characteristics of these transients are influenced by distributed capacitance and inductance of the wiring harness. Only pulses A and B are used on the capacitive coupling clamp.

The pulse shapes and parameters are given in Figures 2, 3, 4, and 5.

3.4 Chattering Relay

3.4.1 Equipment

a. 12 V power supply capable of driving the relay.

b. Test fixture consisting of terminations for the DUT, connections to the power supply, and connections to the loads for the DUT.

c. Wire harness fixture consisting of 1 m nonconductive mounting plate with a movable single wire 1 mm above the DUT wires as shown in Figure 7 and additional 1 m of wire which connects to the DUT and test fixture.

d. 12 V AC normally closed relay capable of continuous chopped operation with no coil suppression. The relay specifications are shown in Figure 7. If another relay is used, it is to be defined in the test report and be capable of producing a minimum of 300 V spikes.

[1] Capacitance value is a function of the wire used, number of circuits, etc., and the clamp construction. As long as the values are in the range given, the test is valid.

3.5 Direct Capacitor Coupling (DCC) Method

The DCC method uses the recommended capacitance values in Table 1.

TABLE 1 - CAPACITOR VALUES FOR THE DCC TEST METHOD

Test Pulse	Capacitor Value
Fast transient test pulses (A and B)	100 pF
Slow transient test pulses (C and D)	0.1 µF

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 1 with a tolerance of ±10 %.

3.6 Inductive coupling clamp (ICC) method

The test set up using the ICC is shown in Figure 12. The coupling circuit consists of an ICC which enfolds all non-ground lines to the DUT. Normally ground lines are excluded from the ICC except when the DUT, as used in the vehicle, has a separate ground line. The configuration of the ground lines shall be stated in the test report.

The test can be performed either as shown in Figure 12 or with a straight harness as implemented in SAE J1113-4.

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

4. TEST SETUP AND PROCEDURES

Unless otherwise specified, the test conditions and tolerances of SAE J1113-1 shall be used.

4.1 Capacitive Coupling Clamp

4.1.1 Test Setup

The test shall be set up as shown in Figure 9. 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 supplier and the car manufacturer. If the original operating devices are not available, they may be simulated by methods outlined in SAE J1113-1.

When using a test harness[2] the following is required:

a. Power supply lines routed outside of the coupling clamp shall have a length of 1 m.

b. The distance between device under test and coupling clamp and between peripheral device and coupling clamp shall be 400 mm ± 50 mm.

c. The portions of the lines being tested, which are outside of the coupling clamp, shall be placed at a distance of 100 mm above the ground plane, and perpendicular (90 degrees ± 15 degrees) to the longitudinal coupling clamp axis.

When using a production harness having a length exceeding 2 m, the excess length shall be coiled into flat loops, each having a diameter of 0.3 m, and placed at a distance of 0.10 m above the ground plane. The maximum distance of 0.45 m between DUT and coupling clamp shall be maintained.

[2] Has to be specified by the users of the standard.

To ensure consistent test results, the hinged lid of the clamp shall be placed as flat as possible to ensure contact with the test harness.

4.1.2 Test Procedures

The test pulse severity levels should be mutually agreed upon between manufacturers and suppliers prior to the test.

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

In special cases, however, it may be necessary to apply additional test pulses that are observed in vehicles.[3]

Verify the pulse generator's operating characteristics according to the appropriate Appendix in SAE J1113-11 prior to performance testing.

Next the test pulse generator shall be connected to the coupling clamp which is terminated in a 50 Ω resistor.

Set the pulse amplitude to the appropriate voltage value selected from Appendix A of this document using an oscilloscope. The output of the coupling clamp shall be loaded to 50 Ω including the oscilloscope and terminating resistor, if necessary. No lines are to be routed through the coupling clamp during the setting of the test level and no adjustment is needed for the wave shape. Set up shown in Figure 6.

After setting the test level, insert the test harness into the clamp, removed the oscilloscope, add the terminating load, if necessary, and begin the test.

The tests shall be performed according to the test plan, which shall specify:

a. Test pulse type

b. Test voltage level

c. Test pulse duration

d. Operating conditions of the DUT

e. The use of a test harness or a production wiring harness

4.2 Chattering Relay

4.2.1 Test Setup

Position the DUT, wire harness, test fixture, and relay as shown in Figure 7. If the DUT normally includes shielded and/or twisted wiring, this shall be included as part of the test harness. However, if this wiring is used, a section shall be included in the middle of the test harness where the shielding is removed and the wiring is untwisted. This is illustrated in Figure 8. If the relay wire is not fixtured to maintain the 1 mm spacing, a dielectric spacer of $\varepsilon_r \leq 1.4$ shall be used. See 3.1.1 for grounding of the DUT.

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[3] The coupling clamp is only suitable for pulses which have a rise time of 100 ns or less. The magnitude of the test pulse is reduced by 50% (to account for coupling clamp termination assuming a 50 Ω generator and the clamp coupling coefficient) from the value measured at the pulse source. It is part of the user's responsibility to define the test pulse needed for certain instruments, devices, and equipment.

4.2.2 Test Procedures

a. Activate the relay and verify that the transients generated across the relay coil are at least 300 peak V at the beginning of the test.

b. Move the relay wire over the entire width of the 1 m section of the wire harness fixture exposing each wire in the fixture to the noise for 5 to 10 s.

c. Monitor the DUT for proper operation during the exposure to the noise.

NOTE: Since this is a statistical test, the magnitude of the transients do vary with time. Verifying the transient levels at the beginning and end of the test is sufficient to ensure that the intent of the test is met.

4.3 DCC Method

The output of the generator is connected in series through the coupling capacitor as shown in Figure 10. A high impedance oscilloscope should be used to measure the open circuit peak voltage at the output end of the capacitor. The generator shall be adjusted to achieve the test level.

4.4 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 as shown in Figure 12. In contrast to the CCC and DCC methods, the ICC method doesn't 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 setup defined in Figure 11. The coupled pulses (C and D) measured in the calibration test set-up (see Figure 11) shall fulfill the requirements stated in Table 2. See Appendix B for information on the process for estimation of the inductive coupling factor.

TABLE 2 - 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

5. TEST PULSE SEVERITY LEVELS AND EVALUATION OF RESULTS

A full description and discussion of the Function Performance Status Classification is given in SAE J1113-1 and SAE J1812. Please review it prior to using the Test Severity Levels presented in Appendix A.

6. TEST DOCUMENTATION

When required in the test plan, a test report shall be submitted detailing the test performed, the test equipment used, systems tested, pulses used or deviations from the recommended relay, system interactions, and any other relevant information regarding the test such as deviations, if any, from the original test plan and an explanation of why they occurred.

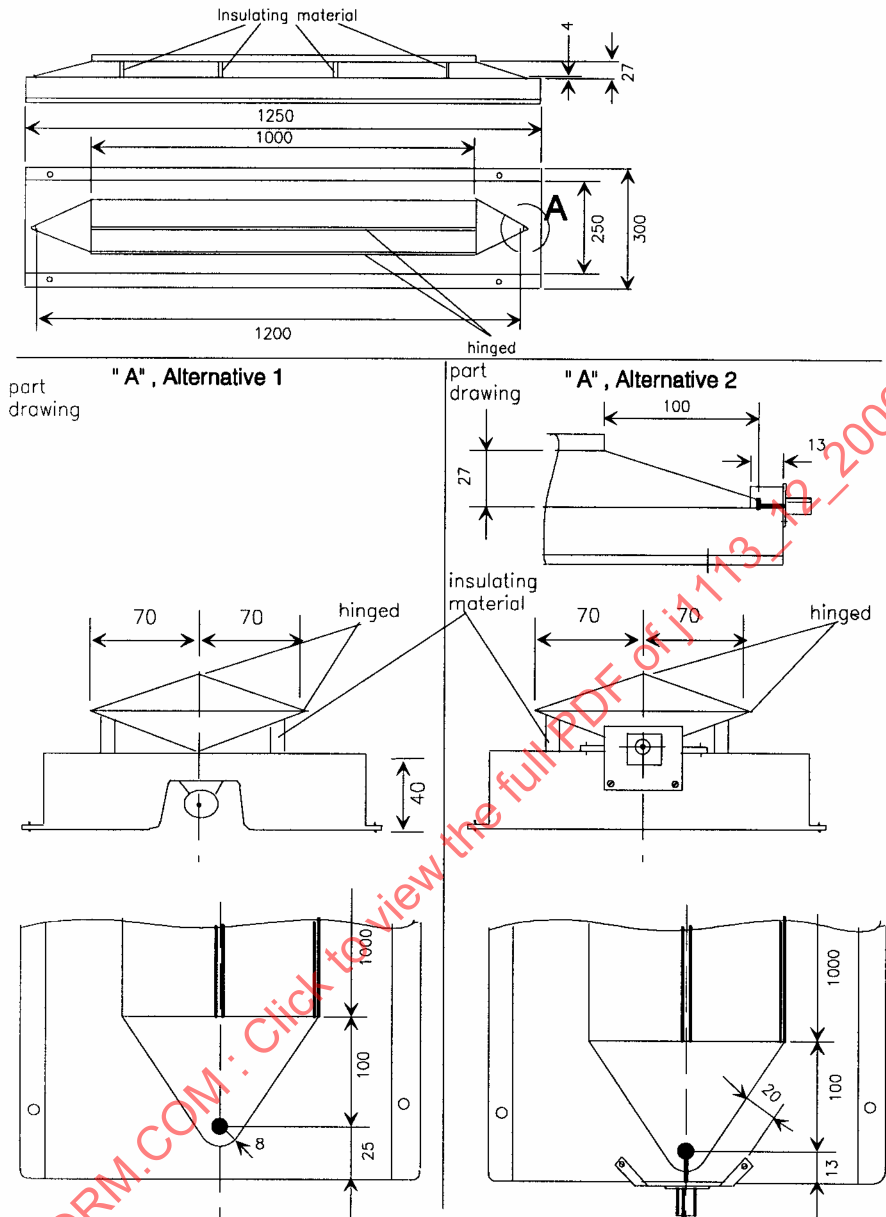
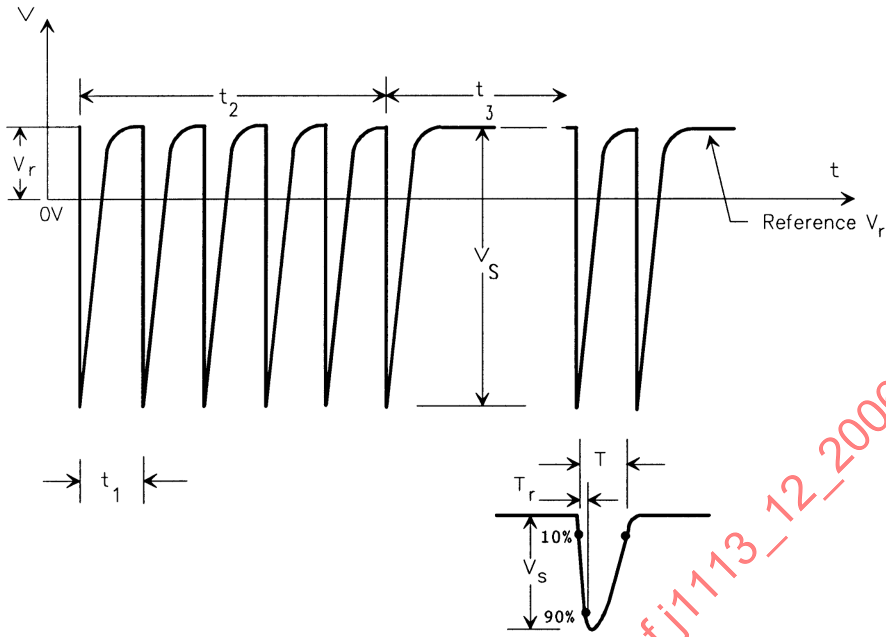


FIGURE 1 - CAPACITIVE COUPLING CLAMP
(All dimensions are in mm)



For 12V Systems

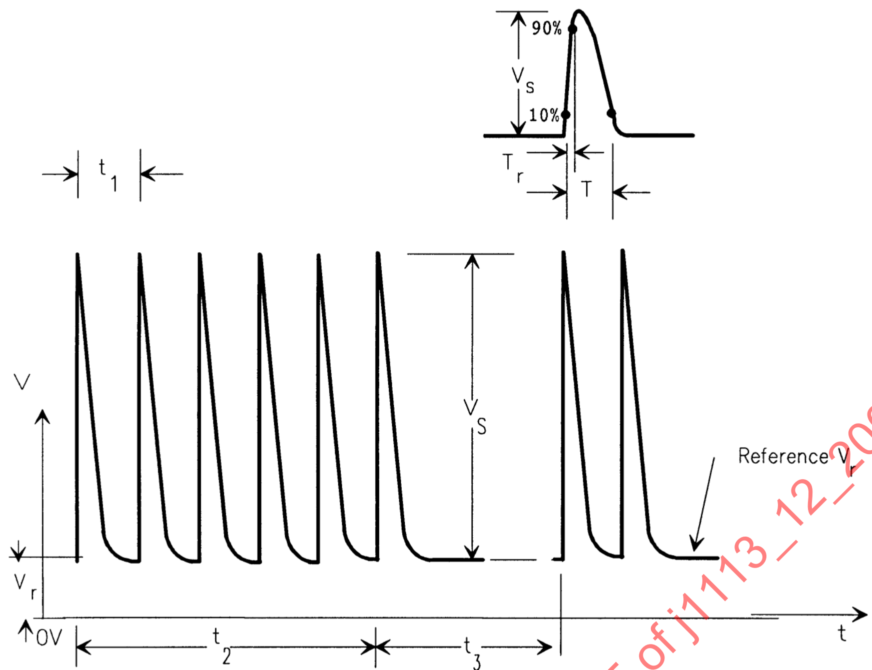
V_S = 0 to −60 V
Rs_1 = 50 Ω

For 24V Systems

V_S = 0 to −80 V
Rs_1 = 50 Ω

T = 0.1 μs +100/−0%
T_r = 5 ns ± 50%
t_1 = 100 μs
t_2 = 10 ms
t_3 ≥ 90 ms

FIGURE 2 - TEST PULSE A



For 12V Systems

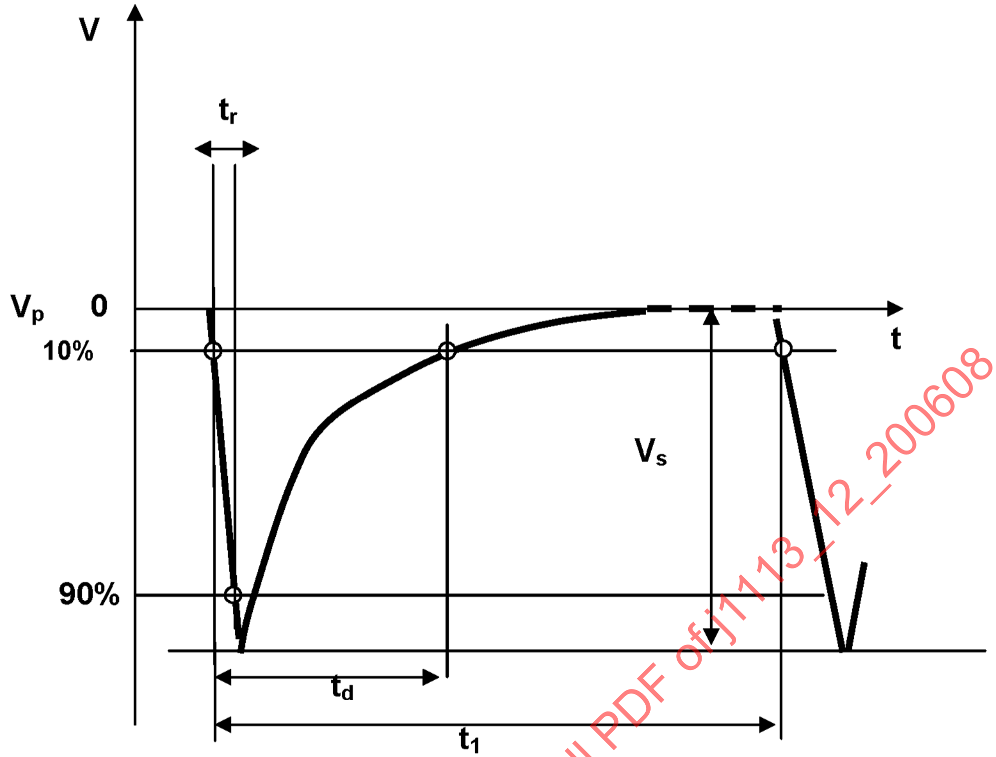
Vs = 0 to +40 V
R_1 = 50 Ω

For 24V Systems

Vs = 0 to +80 V
R_1 = 50 Ω

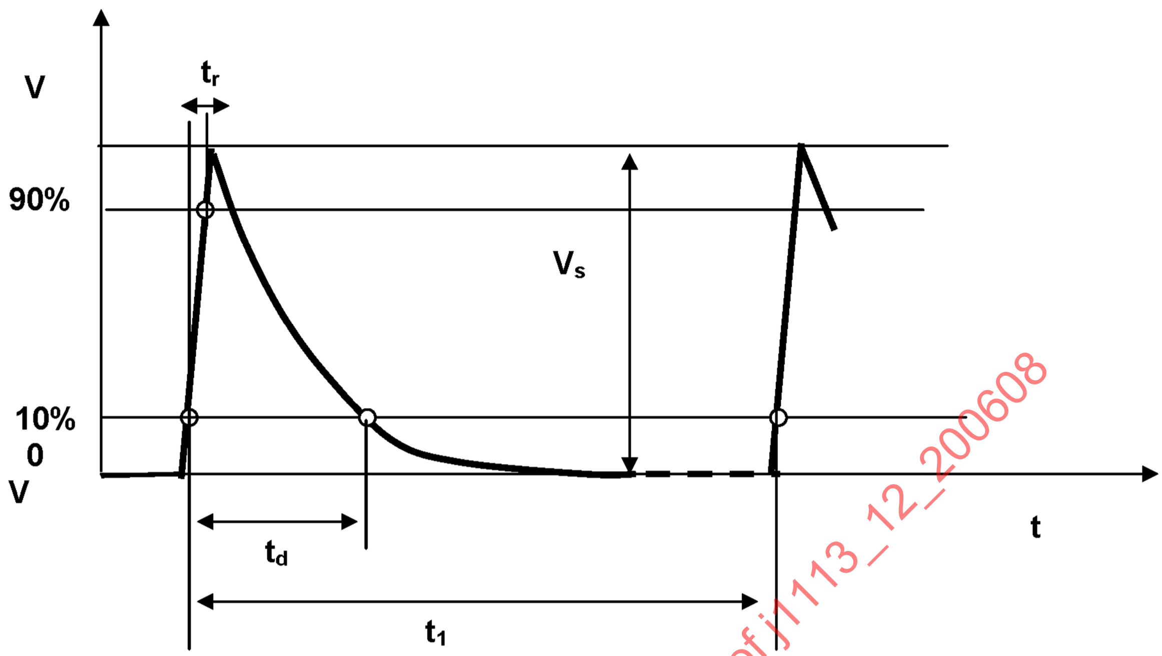
T = 0.1 μs +100/−0%
T_r = 5 ns ± 50%
t_1 = 100 μs
t_2 = 10 ms
t_3 ≥ 90 ms

FIGURE 3 - TEST PULSE B



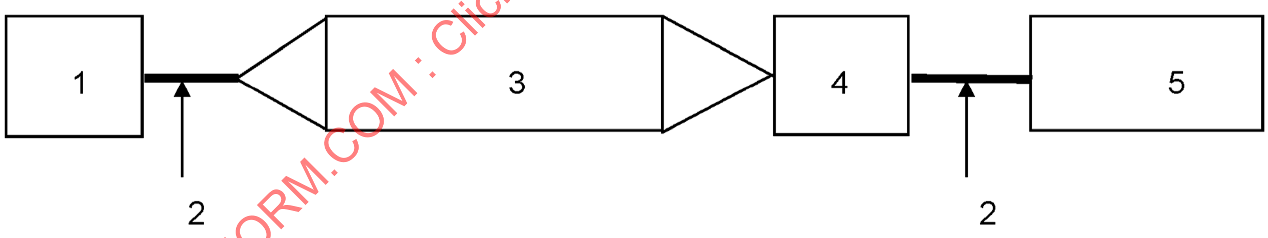
Parameters
V_S: To be defined in the test plan
$R_i = 2\ \Omega$
t_1 = 0,5 s to 5 s
t_d = 0,05 ms
$t_r \leq 1\ \mu s$

FIGURE 4 - TEST PULSE C



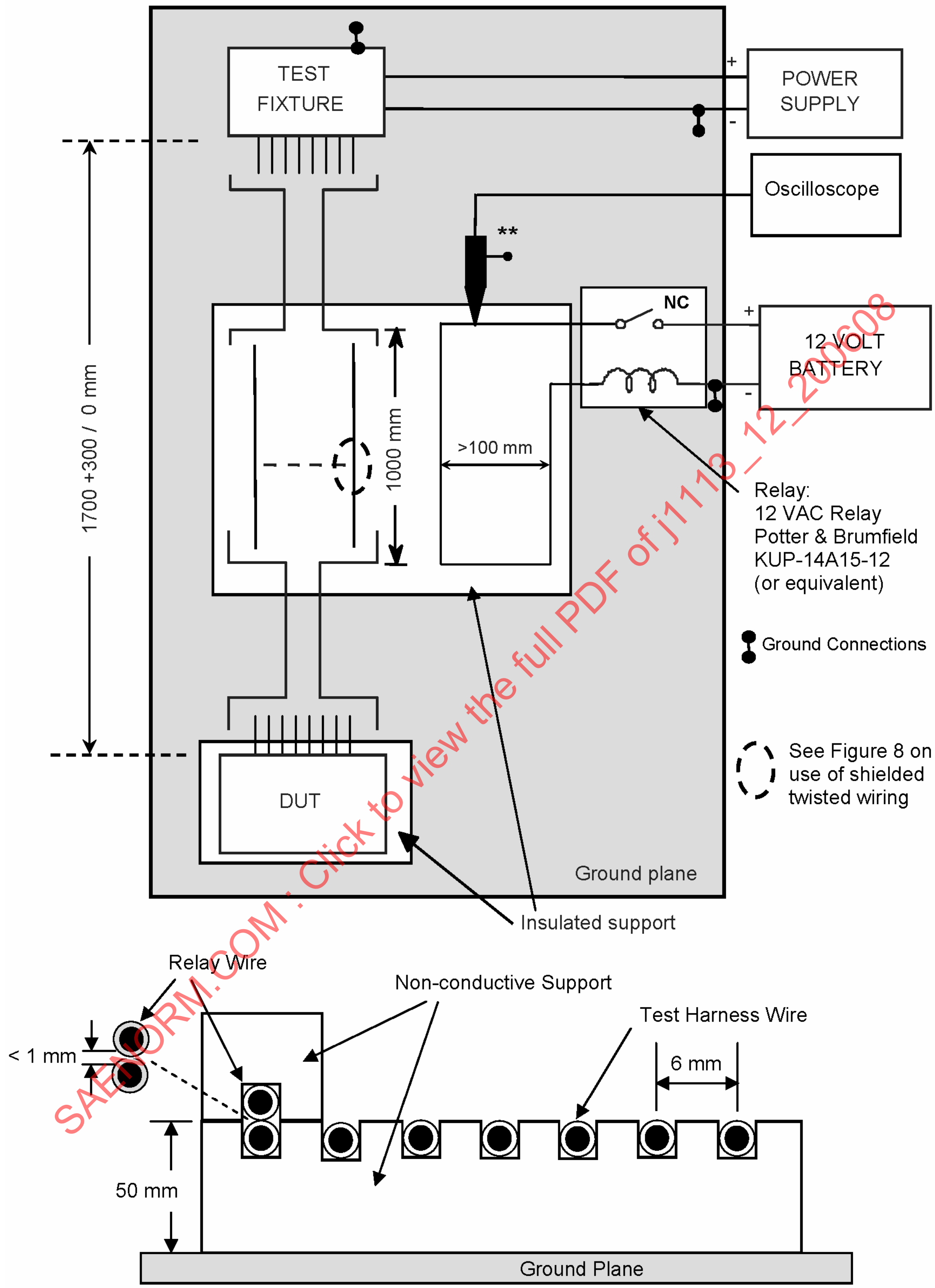
Parameters
V_S: To be defined in the test plan
R_I = 2 Ohms
t_1 = 0,5 s to 5 s
t_d = 0,05 ms
$t_r \leq 1$ µs

FIGURE 5 - TEST PULSE D



Key
1 Test pulse generator
2 50 Ω coaxial cable
3 CCC
4 50 Ω attenuator
5 Oscilloscope

FIGURE 6 - SET-UP FOR CALIBRATION OF THE TEST PULSE AMPLITUDE - CCC METHOD



Non-Conductive Support should be constructed using High Density Polyethylene or Delrin. All dimensions are in mm.

FIGURE 7 - TEST SETUP WITH CHATTERING RELAY

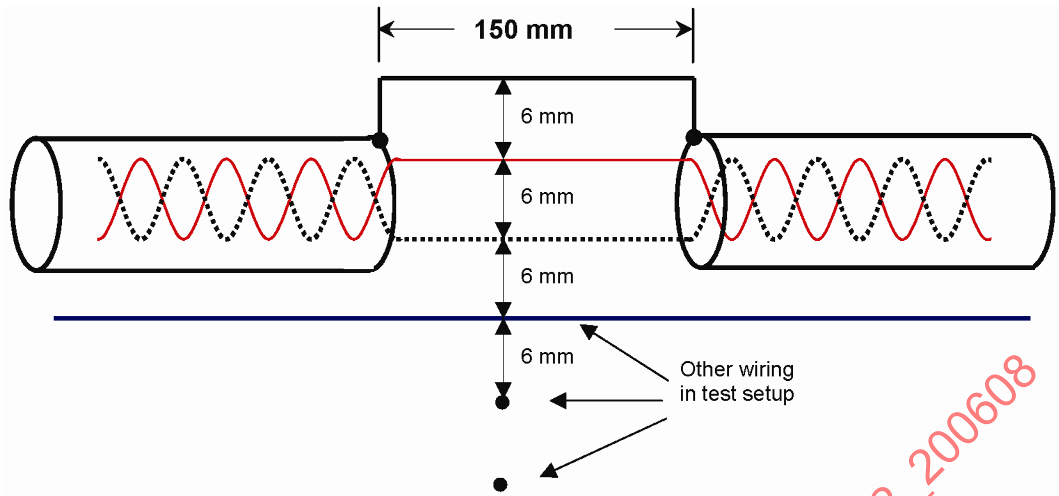


FIGURE 8 - SHIELDED WIRE AND TWISTED WIRE TEST CONFIGURATION
(All dimensions are in mm)

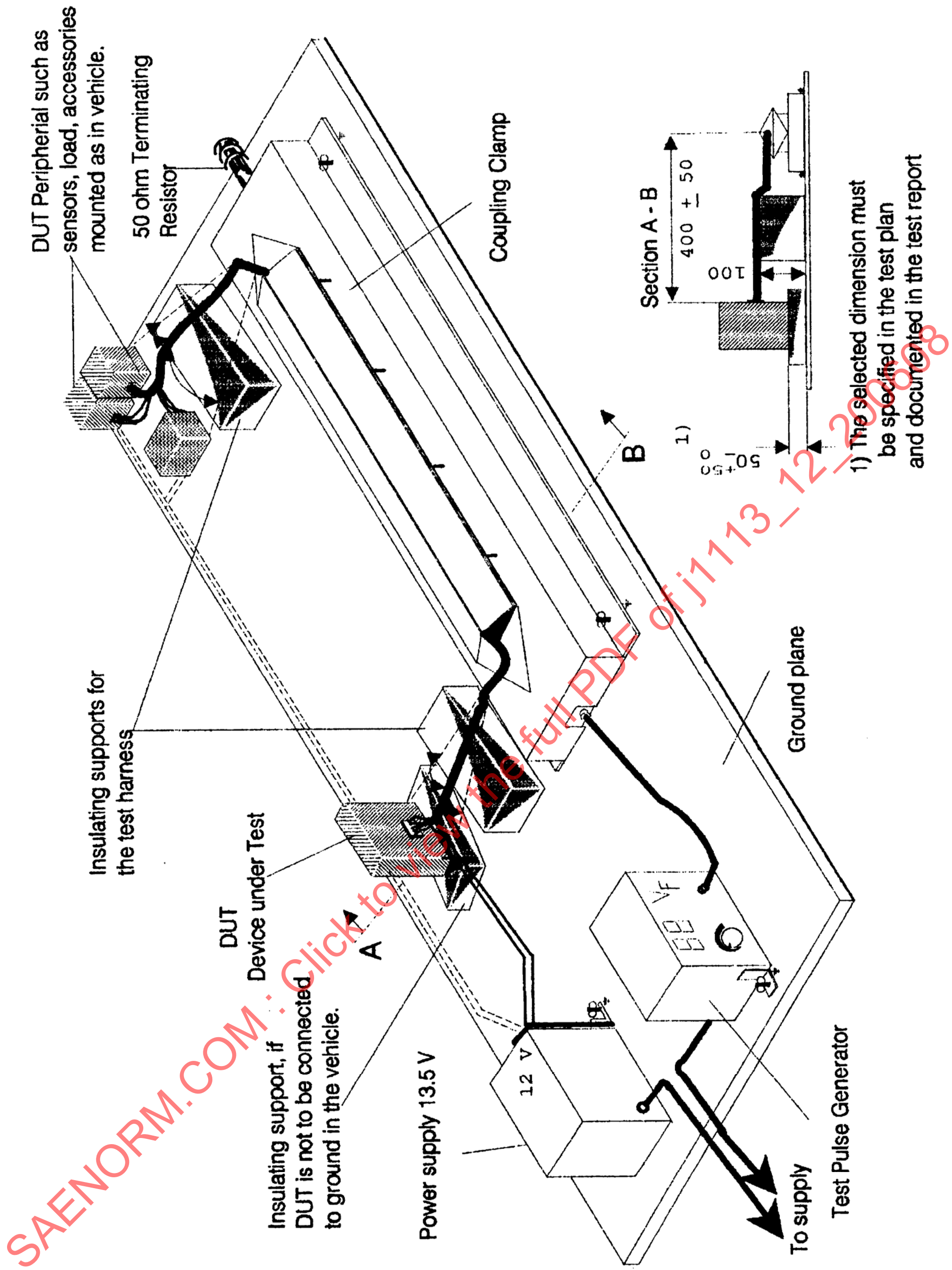
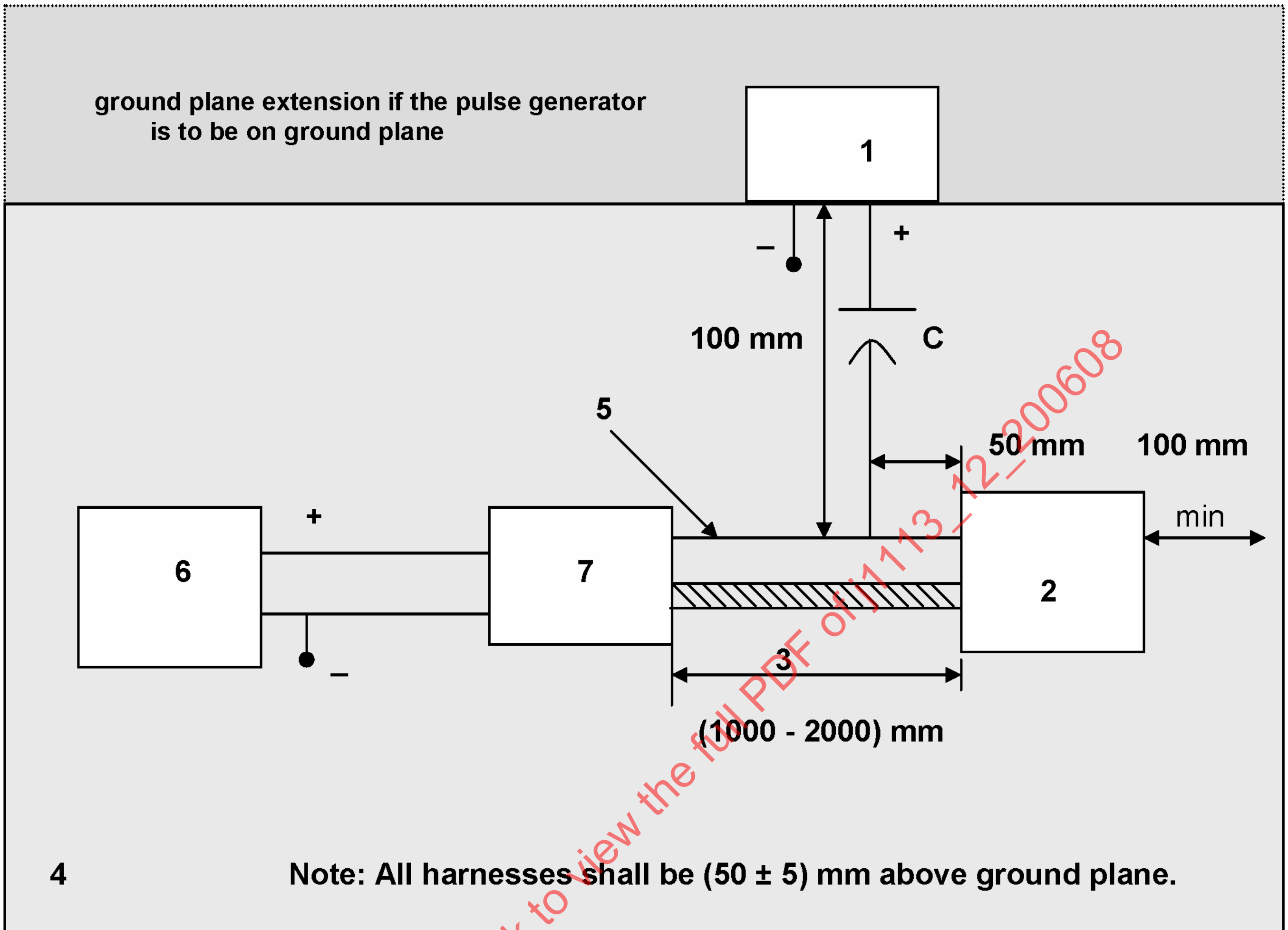


FIGURE 9 - TEST SETUP WITH CAPACITIVE COUPLING CLAMP
(All dimensions are in mm)



Key:

1 Test Pulse Generator
2 DUT
3 Harness
4 Ground Plane
5 I/O Line under test
6 Power Supply
7 DUT Exerciser
C High voltage (200 V minimum) ceramic leaded capacitor (For value of the capacitor, see Table 1.)

FIGURE 10 - TEST SET-UP FOR DCC METHOD