VOLKSWAGEN

AKTIENGESELLSCHAFT

Group Standard

TL 82466

Issue 2009-06

Class. No.: 8MD50

Descriptors: EMC, ESD, electrostatic discharge

Electromagnetic Compatibility of Automotive Electronic Components

Immunity to Electrostatic Discharge (ESD)

Preface

Additional tests necessary for evaluation and release of electronic components beside the EMC tests are defined and specified in the drawing, Technical Supply Specifications (TL standard), or other documents.

Previous issues

TL 82466: 1998-08, 2000-07, 2005-02, 2007-11

Changes

The following changes have been made as compared to TL 82466: 2007-11:

– Table 1, adaptation of limit values
– Introduction of functional performance status classification (FPSC) acc. to ISO standard

Contents

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1 Scope

This Technical Supply Specification (TL) contains requirements and tests to ensure electromagnetic compatibility (EMC) of electronic assemblies with respect to electrostatic discharges. These apply to discharges during:

– assembly,
– servicing,
– vehicle use

that occur directly on the assembly and to discharges to neighboring objects that can couple into supply and signal lines of the vehicle or into electric assemblies.

2 Terms and definitions

Unless otherwise specified, the definitions of terms set forth in DIN EN 61000-4-2 "Testing of Interference Immunity to Electrostatic Discharge" apply.

Assembly

An assembly is defined as one single component or a combination of components as supplied by the supplier.

Direct discharge

Discharge occurs directly onto the DUT.

FPSC (Function Performance Status Classification)

This standard uses the functional performance status classification (FPSC) as defined in ISO 11452-1 AMD 1, ISO 7637-1 AMD 1 and ISO 10605. A detailed description can be gathered from Appendix A.

Indirect discharge

Discharge occurs onto a coupling structure located in the vicinity of the DUT. It simulates a discharge onto objects located in the vicinity of the DUT or discharges that flow off via lines that are adjacent to lines of the DUT in the wiring harness.

Malfunction

Disturbance of the device's function that is beyond permissible. The malfunction ends after the disturbance subsides.

Contact discharge

Test method characterized by bringing the test generator electrode in contact with the DUT; discharge is then initiated by the generator discharge switch.

Air discharge

Test method characterized by quickly bringing the charged test generator electrode close to the device under test (DUT); the discharge arcs over to the DUT .

Surface

Here the term "surfaces" does not only refer to larger surfaces but also to all gaps and openings (switches, tip switches, transition points, ventilation slots, speaker openings, etc.).

Test step

In the context of this standard, the term test step refers to the specified number of discharges that occur at a discharge point and which have a specific polarity and voltage.

Damage

One or more functions of the device do not perform as designed during and after exposure to the disturbance and the device has to be repaired or replaced or, if there is still functional capability, some parameters do not lie within the specified tolerances.

System

A system is defined as the assembly in conjunction with all components necessary for complete functioning (tip switches, switches, antennas, displays, sensors, actuators, etc.).

3 General requirements

3.1 Underlying standards

TL 82466 is based on DIN EN 61000-4-2 (Testing of Interference Immunity to Electrostatic Discharge) and ISO 10605 (Road vehicles - Test methods for electrical disturbances from electrostatic discharge).

3.2 Protection objectives

There must not be any permanent damage to an assembly caused by electrostatic discharges during installation, after-sales service measures, or vehicle use. In addition, discharges from persons in the vehicle or at the vehicle must not cause malfunctions or function failures.

Design measures must be taken in order to prevent charging of components through air flows or motion.

The semiconductor components connected to the DUT´s terminals must pass this test without additional protective circuitry at the respective pins. If this requirement is not met by semiconductor elements used, the assembly developer must explain how sufficient ESD interference immunity can be achieved using other suitable protection measures.

4 Test scope and test severity

ESD testing must be performed at assembly, system, and vehicle level. Component-specific performance specifications may contain additional tests or deviations as compared to the test scope and/or test severity defined in this TL, specified by the responsible Volkswagen Group EMC engineering department.

All test scopes specified in Table 1 must be performed.

Table 1 – Test scope overview

	A: Assembly (packaging & handling)	**Objective:** no damage **Performed by:** contractor
1	All pins	**Contact discharge (3 discharges per test step):** ± 2 kV, ± 4 kV, ± 6 kV with discharge network R = 330 Ω and C = 150 pF
2	Housing	**A Discharge point, plastic** **Air discharge (10 discharges per test step):** ± 4 kV, ± 8 kV, ± 15 kV with discharge network R = 330 Ω and C = 150 pF
		B Discharge point, metal **Contact discharge (5 discharges per test step):** ± 4 kV, ± 8 kV with discharge network R = 330 Ω and C = 150 pF **Air discharge (10 discharges per test step):** ± 15 kV [a)] with discharge network R = 330 Ω and C = 150 pF
	B: System level (laboratory setup)	**Objective:** no malfunction or damage **Performed by:** contractor
3	Discharge on the coupling structure´s discharge stations (indirect discharge)	**Contact discharge (10 discharges per test step):** ± 4 kV, ± 8 kV, ± 15 kV with discharge network R = 330 Ω and C = 330 pF
4	Discharge on DUT (control units, displays, associated control elements and periphery as well as interfaces that can be used by the customer including fuses etc.) (direct discharge)	**A Discharge point, plastic** **Air discharge (10 discharges per test step):** ± 4 kV, ± 8 kV, ± 15 kV with discharge network R = 330 Ω and C = 330 pF

4	Discharge on DUT (control units, displays, associated control elements and periphery as well as interfaces that can be used by the customer including fuses etc.) (direct discharge)	**B Discharge point, metal** **Contact discharge (10 discharges per test step):** ± 4 kV, ± 8 kV with discharge network R = 330 Ω and C = 330 pF **Air discharge (10 discharges per test step):** ± 15 kV a) with discharge network R = 330 Ω and C = 330 pF
	C: Vehicle level	**Objective: no malfunction or damage** **Performed by: vehicle manufacturer**
5	Components that are only accessible from the vehicle exterior	**Air discharge (10 discharges per test step):** ± 4 kV, ± 8 kV, ± 15 kV with discharge network R = 330 Ω and C = 150 pF
6	All other components not covered by item 5	**Air discharge (10 discharges per test step):** ± 4 kV, ± 8 kV, ± 15 kV with discharge network R = 330 Ω and C = 330 pF

a) Additionally, in order to ensure sparkover resistance (e.g. insulated metallic surfaces).

5 Test equipment and general test requirements

The requirements for test generators as specified in DIN EN 61000-4-2 apply except for the following deviations:

- It must be possible to select an energy storage capacitance between 150 pF and 330 pF.
- The discharge resistance must be 330 Ω.
- It must be possible to select an output voltage of up to and including ± 15 kV for contact and air discharges.
- The test generator properties are to be documented according to ISO 10605.
- Relative humidity must lie between 20% and 60% during the test.

Prior to performing a test, a test plan is to be prepared, which contains all items, operating states and test severities to be tested.

A test starts with the lowest absolute test voltage and ends with the highest absolute test voltage. In this context, either alternating polarities (e.g. +4 kV → -4 kV → … → +15 kV → -15 kV) or separate test runs with positive and negative test voltage (e.g. +4 kV → … → +15 kV → -4 kV → … → -15 kV) are possible.

Unless agreed otherwise with the responsible EMC engineering department in the Volkswagen Group, the function is to be checked and the event log is to be read out after each discharge voltage.

Discharges cause the charge to build up on conducting surfaces or connector pins. These charges must be dissipated before every new discharge.

During discharge, the electrode is to be kept perpendicular to the DUT to the extent possible. If this is not possible, an angle of at least 45° must be maintained.

6 Tests at assembly level (packaging and handling)

6.1 Test setup and test conditions for tests at assembly level

The test setup for testing at assembly level is represented in Figure 1. The requirements set forth in Section 5 apply. The test setup corresponds to the one described in ISO 10605. The DUT must be tested individually, i.e. as delivered by the contractor and without peripheral devices connected to it.

The DUT must always be placed directly onto the ground plate. An insulating base must not be used.

In the case of metallic housings, steps must be taken to ensure a well-conducting contact between DUT and base.

The return line leading from the ESD generator to the ground connection is to be routed without shortening at the greatest possible distance from the ground plate.

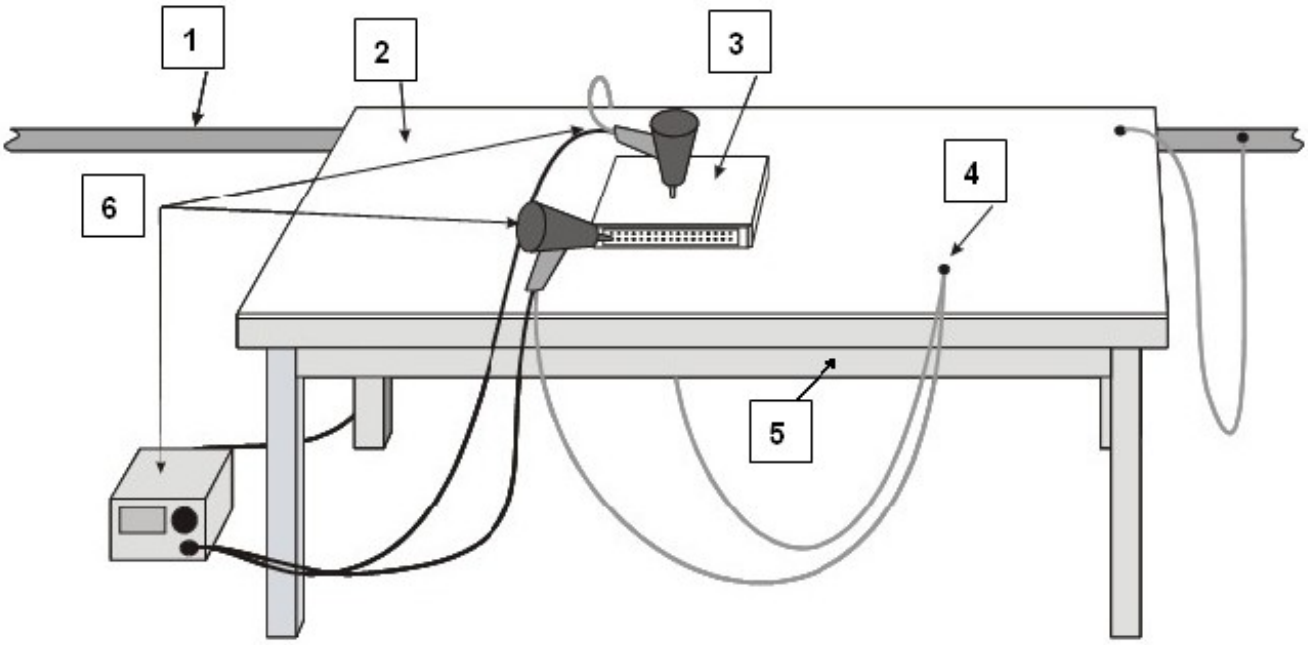

Figure 1 – Exemplary test setup for testing on assembly level

Legend

1 Ground bus
2 Ground plate
3 DUT
4 Ground point
5 Wooden table
6 ESD generator

6.2 Procedure for tests at assembly level

Testing at assembly level is to be performed by the contractor in accordance with ISO 10605, observing the specified amendments and changes.

The test requirements can be gathered from Table 1.

The tests must always be performed on three samples.

At least 3 or 5 discharges per discharge point for contact discharges, and 10 discharges for air discharge must be carried out for each discharge voltage and each polarity. Details can be found in Table 1.

The contact discharges onto pins must be carried out in a defined manner on each individual pin (also for coaxial systems). If necessary, the pins must be extended using a piece of cable.

In order to detect premature damage, the DUTs are to be included in the life test after conclusion of the ESD tests.

The test at assembly level (packaging and handling) is regarded to have been passed if all of the following items are fulfilled:

– The tested assemblies pass a complete functional test after this ESD test. Permanent damage must not occur.
– Stored data must not have been changed or erased.
– After the ESD test, the bus nodes attain sleep mode, maintain bus sleep, can be woken up, and do not transmit faulty data (e.g. error frames, syntax errors).
– The closed-circuit current after the test must correspond to that determined before the test. Deviations of more than 5% are to be regarded as an error.
– The EMC protective circuitry (e.g. input capacitors for the purpose of ensuring interference immunity or interference emission) must still be effective after ESD exposure.
– Complete documentation acc. to Section 9 is available.

7 Tests at system level

Testing at system level involves two different tests: direct discharge and indirect discharge.

– Direct discharge via air or contact discharge onto all areas (surfaces, tip switches, switches, antennas, displays, etc.) according to the definition given in Table 1 (test setup see Figure 2).
– Indirect discharge to a coupling structure via contact discharge (test setup see Figure 3)

Before a test is performed by the contractor, a test plan must be prepared that describes all discharge points, operating states, and test severity levels to be tested. This test plan must be coordinated with the responsible Volkswagen Group EMC engineering department.

One complete test must be performed for each operating state specified in the test plan.

The DUT must be monitored during the test. The system to be tested must be operated periodically to ensure that it functions as required during and after an ESD exposure.

Testing on one sample is sufficient for tests carried out at system level.

7.1 Test setup and test conditions for tests at system level

The test setup for the test at system level is represented in Appendix B, Figure B.1. The requirements set forth in Section 5 apply.

The test arrangement for tests with direct discharge is shown in Figure 2. The test arrangement for tests with indirect discharge is shown in Figure 3. The following description also refers to the numbering in the figures.

For testing, the assembly is to be connected to all peripheral devices necessary for a functional test as well as to all controls, sensors, and actuators.

If controls or assemblies that are connected in the vehicle and that can be touched are not available for testing, it is always to be assumed that a dielectric breakdown on the connecting lines is possible. As a consequence, direct discharge into the corresponding lines is required. This also includes supply lines with fuses that can be changed by the customer without the use of tools.

If antenna amplifiers connected in the vehicle are not available, a totally passive antenna is to be assumed and direct discharge must be carried out on the corresponding lines (for coaxial systems, the inner conductor must be extended for this purpose).

The return conductor of the ESD generator to the ground connection must remain unshortened and is to be routed at the greatest possible distance from the ground plate. It must be connected to point 3 (Figure 2 and Figure 3) on the side of the coupling structure.

The ground connection of the DUT for the system test must be implemented based on the subsequent configuration in the vehicle:

– for local (short) ground connection, direct connection to point 3 (Figure 2 and Figure 3) and
– for long ground connection, connection via point 10 (Figure 2 and Figure 3).

If the DUT comprises an electrically conductive housing with a direct conductive connection to the vehicle body, it must be connected directly to the ground via the coupling structure or via point 3 for the test.

In this case, the supply battery is located on the test table and is connected directly to the ground plate via point 10 (Figure 2 or Figure 3). The risk of battery explosion is to be taken into consideration. Appropriate protective measures must be taken.

The distance between the ESD test setup and other conductive structures such as shielded walls or the like must be at least 0,5 m. The test setup must be grounded via a ground line, into which two high-voltage-proof 470-kΩ resistors are inserted (one of which at point 3 (Figure 2 or Figure 3) and the other at the opposite connection point of the ground line).

The coupling structure must project from the DUT by at least 10 mm on every side. The distance between the peripherals required for the test and the coupling structure must be at least 200 mm. The ground plate must project from the test setup by at least 100 mm on all sides.

The waiting time between the individual discharges must be more than 1 s. The discharge of the ESD generator must also be ensured.

7.2 Procedure for testing at system level – direct discharge

All surfaces of the DUT and of the connected peripherals such as controls, displays, lines, plug-in connections to mobile peripherals (e.g. Aux IN, USB port) etc. must be subjected to discharges. If neither charging caused by air flow, motion or by neighboring components nor sparkover from adjacent metal structures can be ruled out, surfaces that are not accessible during normal vehicle operation must also be tested. A connection must be agreed upon in the test plan. The location of the package in a potential successor vehicle must also be included in the decision.

Refer to Table 1 for the test voltages to be used and the discharge network.

Ten discharges must be carried out per discharge point for each test voltage and polarity. The ESD simulator must be brought close to the discharge point as quickly as possible until the discharge occurs or until the discharge tip contacts the discharge point. As far as discharges on insulated metal surfaces are concerned, the residual charge must be discharged after each ESD pulse (e.g. by means of a high-impedance resistor).

The test at system level (direct discharge) is regarded to have been passed if all of the following items are fulfilled:

- The tested assemblies maintain the required FPSC as defined in Table 2 and Table 3 during the ESD test.
- Stored data must not have been changed or erased.
- After the ESD test, the bus nodes attain sleep mode, maintain bus sleep, can be woken up, and do not transmit faulty data (e.g. error frames, syntax errors).
- The closed-circuit current after the test must correspond to that determined before the test. Deviations of more than 5% are to be regarded as an error.
- The ESD test must not result in the generation of error log entries.
- Complete documentation acc. to Section 9 is available.

Table 2 – FPSC air discharge, system test, direct discharge

Test severity	Category 1	Category 2	Category 3
L2	± 15 kV	± 15 kV	not specified
L1	± 4 kV	± 8 kV	± 15 kV

Table 3 – FPSC contact discharge, system test, direct discharge

Test severity	Category 1	Category 2	Category 3
L2	± 8 kV	± 8 kV	not specified
L1	± 4 kV	± 4 kV	± 8 kV

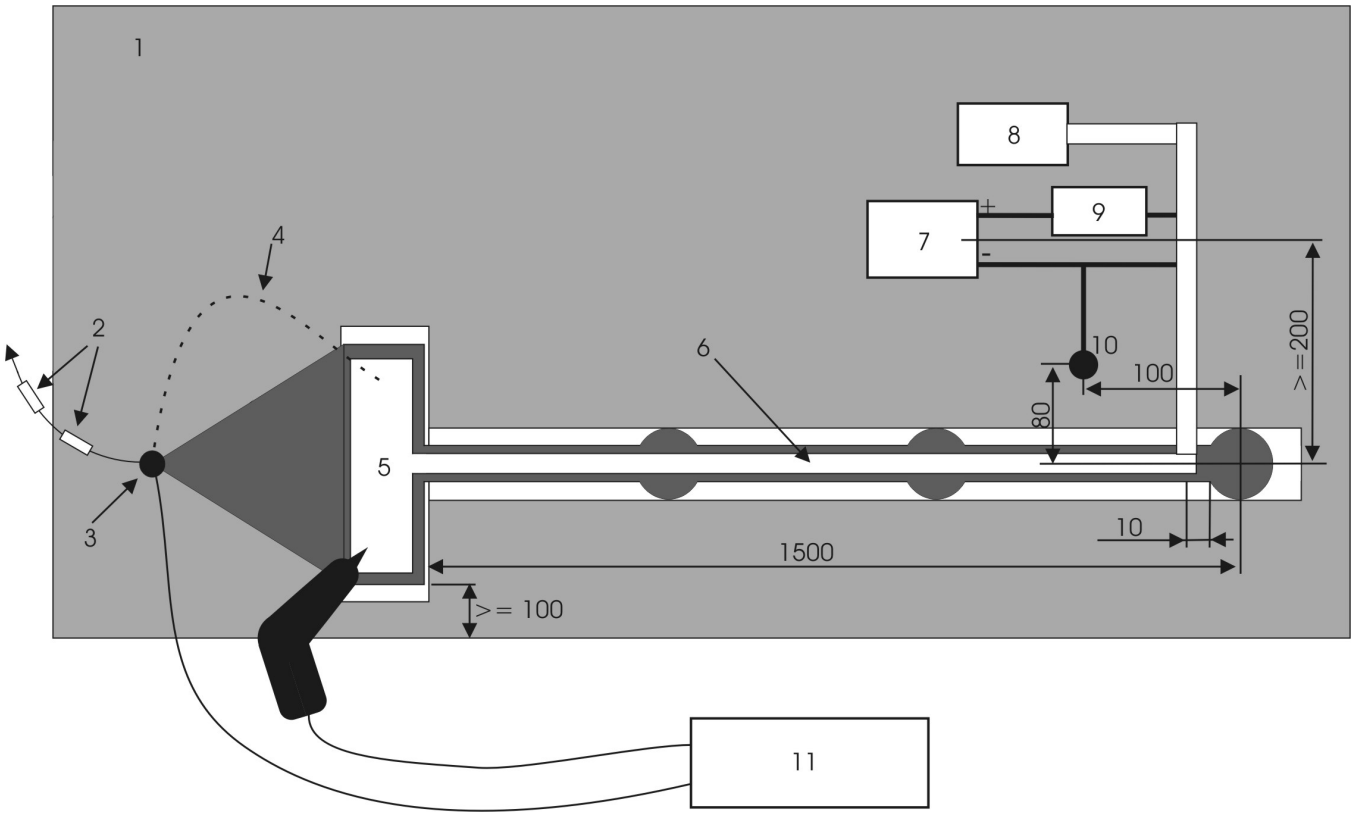

Figure 2 – Direct discharge at system level

Legend

1	Ground plate
2	High-voltage-proof 470-kΩ resistors for grounding/protective ground
3	Ground reference point for coupling structure, ESD generator
4	Local grounding of the DUT (if necessary)
5	DUT
6	Test wiring harness
7	Supply battery
8	Peripherals, controls
9	Artificial network (if required)
10	Ground reference point for supply battery and peripherals
11	ESD generator

Dimensions in mm ± 5%

7.3 Procedure for testing at system level – indirect discharge

Refer to Table 1 for the test voltages to be used and the discharge network.

For each test voltage and polarity, ten contact discharges must be carried out for each of the three discharge stations in an open area of the discharge station not covered by the test wiring harness.

In the case of cable bundles containing more than 40 cables, the cable bundle must be rotated 180° around the longitudinal axis and the test must be repeated.

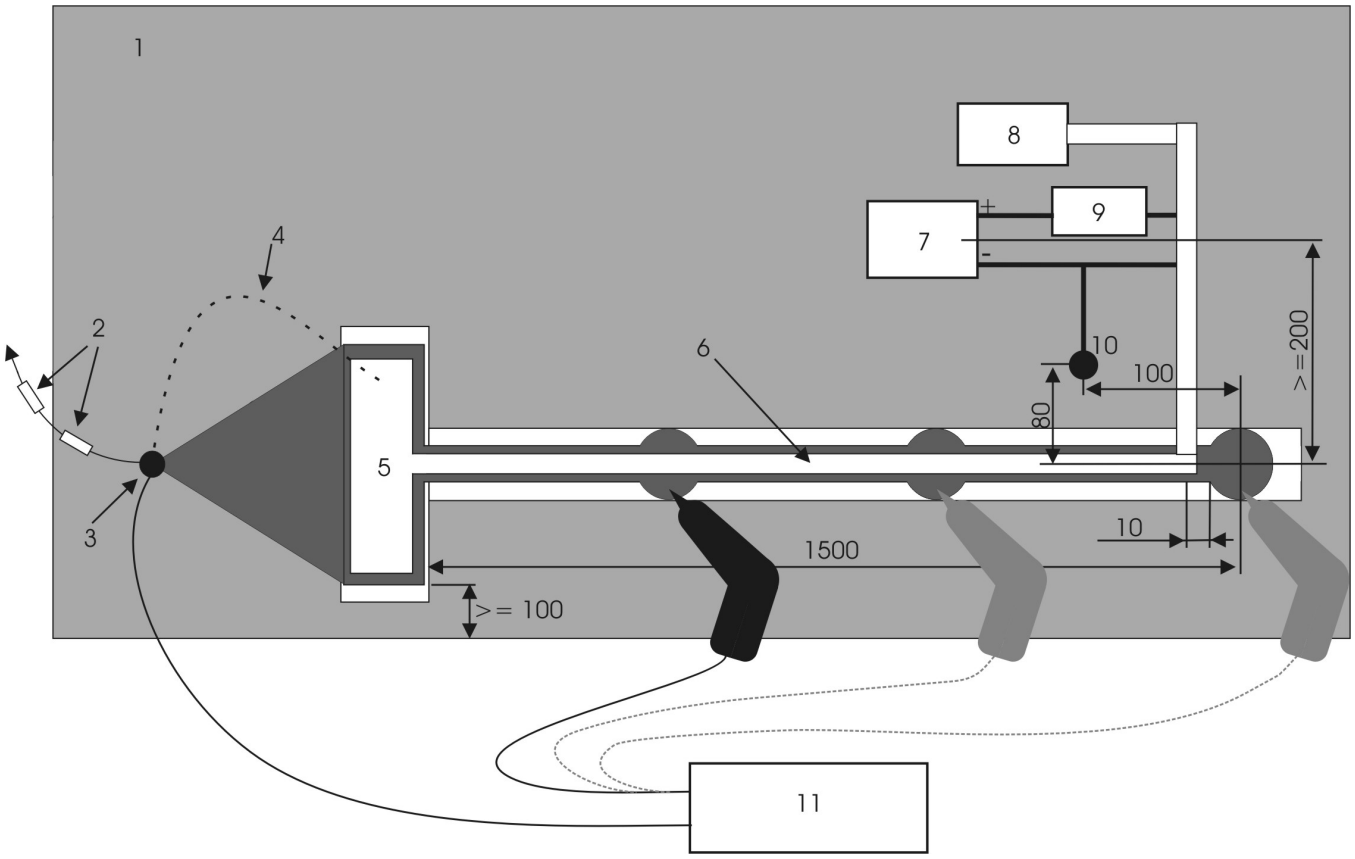

Figure 3 – Indirect discharge at system level

Legend

1	Ground plate
2	High-voltage-proof 470-kΩ resistors for grounding/protective ground
3	Ground reference point for coupling structure, ESD generator
4	Local grounding of the DUT (if necessary)
5	DUT
6	Test wiring harness
7	Supply battery
8	Peripherals, controls
9	Artificial network (if required)
10	Ground reference point for supply battery and peripherals
11	ESD generator

Dimensions in mm ± 5%

The test at assembly level (indirect discharge) is regarded to have been passed if all of the following items are fulfilled:

– The tested assemblies maintain the required FPSC as defined in Table 4 during the ESD test.
– Stored data must not have been changed or erased.
– After the ESD test, the bus nodes attain sleep mode, maintain bus sleep, can be woken up, and do not transmit faulty data (e.g. error frames, syntax errors).

- The closed-circuit current after the test must correspond to that determined before the test. Deviations of more than 5% are to be regarded as an error.
- The ESD test must not result in the generation of error log entries.
- Complete documentation acc. to Section 9 is available.

Table 4 – FPSC for contact discharge, indirect discharge

Test severity	Category 1	Category 2	Category 3
L2	± 15 kV	± 15 kV	not specified
L1	± 4 kV	± 8 kV	± 15 kV

8 Test at vehicle level

ISO 10605 serves as the basis for vehicle testing.

8.1 Test setup and test conditions for tests at vehicle level

As a rule, the test at vehicle level is performed by the responsible EMC engineering department of the Volkswagen Group. The requirements set forth in Section 5 apply.

During testing, the vehicle is operated with the engine running. Testing is performed on and in the vehicle by means of air discharges onto all areas that can be accessed by the vehicle user (tip switches, switches, displays, surfaces, steering lock, controls, antennas, etc.) as well as onto locations where charging due to air flows or other moving components cannot be ruled out.

The return line in the ESD generator´s discharge circuit must be directly connected to the vehicle body. For tests in the passenger compartment, the seat rail or the seat belt latch may be used for this purpose. In this context, attention must be paid to ensure that the resistance between the ESD generator ground and the vehicle ground does not exceed 2 Ω.

The return line of the ESD generator to the ground connection must remain unshortened and is to be routed at the greatest possible distance from the body.

8.2 Procedure for tests at vehicle level

Refer to Table 1 for the test scopes to be used, while taking the following into account:

- Ten air discharges must be delivered to all points to be tested for each required charging voltage and polarity. The waiting time between the individual discharges must be more than 1 s. As far as discharges on insulated metal surfaces are concerned, the residual charge must be discharged after each ESD pulse (e.g. by means of a high-impedance resistor). The discharge of the ESD generator must also be ensured.
- During the test, all systems are to be operated periodically in order to ensure that they function as required during and after an ESD exposure.
- Before and after the test, the following parameters must be checked and documented for the installed systems or for the whole vehicle: Error log entries, going into sleep mode, maintenance of bus sleep, measurement of closed-circuit current, ability to be woken up, and errors during data transmission.
- Testing on one sample is sufficient for all components at the vehicle level.

Representative points in the vehicle (engine compartment, vehicle interior, trunk) which may be touched by persons when entering/leaving/driving/loading the vehicle or which may be touched by

the customer when servicing the vehicle, are to be chosen as discharge points. These include for example:

- all switches and controls,
- displays,
- accessible electric/electronic components,
- door handles,
- metallic structures in the entry/exit area (e.g. A-pillar, door),
- components containing automotive fuses.

The ESD full vehicle test is considered to have been passed if all of the following items are fulfilled:

- The tested assemblies maintain the required FPSC as defined in Table 5 during the ESD test.
- The tested assemblies pass a complete functional test after the completion of the entire ESD vehicle test. There must not be any permanent damage.
- Stored data must not have been changed or erased.
- After the ESD vehicle test, all bus nodes attain sleep mode, maintain bus sleep, can be woken up, and do not transmit faulty data (e.g. error frames, syntax errors).
- The closed-circuit current after the ESD full vehicle test must correspond to that determined before the test. Deviations of more than 5% are to be regarded as an error.
- The ESD test must not result in the generation of error log entries.
- Complete documentation of the ESD vehicle test acc. to items 1, 2 and 7 specified in Section 9, in which these criteria are confirmed, is available.

Table 5 – FPSC for air discharge, vehicle

Test severity	Category 1	Category 2	Category 3
L2	± 15 kV	± 15 kV	not specified
L1	± 4 kV	± 8 kV	± 15 kV

9 Documentation

In order to furnish proof that an assembly fulfills the ESD requirements, the EMC engineering department must be provided with documentation of ESD immunity containing the following items:

1. Test plan
2. System designation
3. System description with photographs of both the DUT and the test setup, as well as with marking of the discharge points.
4. Hardware version with circuit diagram, layout, and description of the essential EMC measures relevant for ESD (e.g. filter and protective circuitry for inputs and outputs, internal reset lines, as well as supply lines, shielding measures).
5. Software version with description of the essential EMC measures (e.g. filtering of signals implemented in software, temporary deactivation of individual circuit components, emergency operation features).
6. Report with test conditions (including, among other things, climatic and operating conditions, etc.) and description of the test setup for testing at assembly and system level according to Section 6 and Section 7; if applicable, justifications for why requirements could not be met as well as a specification of alternative measures to be taken in order to ensure ESD resistance must also be included.
7. If applicable, a report containing test conditions of vehicle tests carried out according to Section 8. For vehicle testing, all test items or test areas must be documented.
8. ESD evaluation of the packaging materials used for transport and storage

10 Referenced documents

The following documents cited in this standard are necessary for application.

In this Section terminological inconsistencies may occur as the original titles are used.

Standards with the titles given in German are either only available in German or may be procured in other languages from the institution issuing the standard.

DIN EN 61000-4-2	Testing of Interference Immunity to Electrostatic Discharge
ISO 10605	Road vehicles - Test methods for electrical disturbances from electrostatic discharge
ISO 11452-1	Road vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 1: General principles and terminology
ISO 7637-1	Road vehicles - Electrical disturbances from conduction and coupling - Part 1: Definitions and general considerations

Appendix A (normative) Description of the functional performance status classification (FPSC)

This standard uses the functional performance status classification (FPSC) as defined in ISO 11452-1 AMD 1, ISO 7637-1 AMD 1 and ISO 10605.

The following status definitions as specified in ISO 11452-1 AMD 1 are used:

Status I: The function behaves as specified prior to, during and after the test.

Status II: The function does not behave as specified during the test, but returns to normal operation automatically after completion of the test.

The following definitions from ISO 11452-1 AMD 1 are used to determine which status (I or II) must be complied with up to which level (voltage).

L1: Voltage up to which status I must be complied with.

L2: Voltage up to which at least status II must be complied with (status I is permissible as well).

Deviating from the examples given in ISO 11452-1 AMD 1, it is not the different functions of a DUT that are categorized, but the effects or functional deviations of a DUT occurring during an interference immunity test. Based on the effect on the customer, a differentiation is made between three categories of effects:

Category 1: Minor effects or negligible malfunctions of the DUT.

Category 2: Effects or malfunctions of the DUT which impair comfort.

Category 3: All significant and all other effects and malfunctions of the DUT that do not fall into category 1 or category 2.

The vehicle manufacturer alone is responsible for the categorization of the effects that ocurred during testing. If a malfunction has not been assigned a category, that particular malfunction must always be assigned to category 3.

The functional performance status classification is represented graphically as shown in Figure A.1.

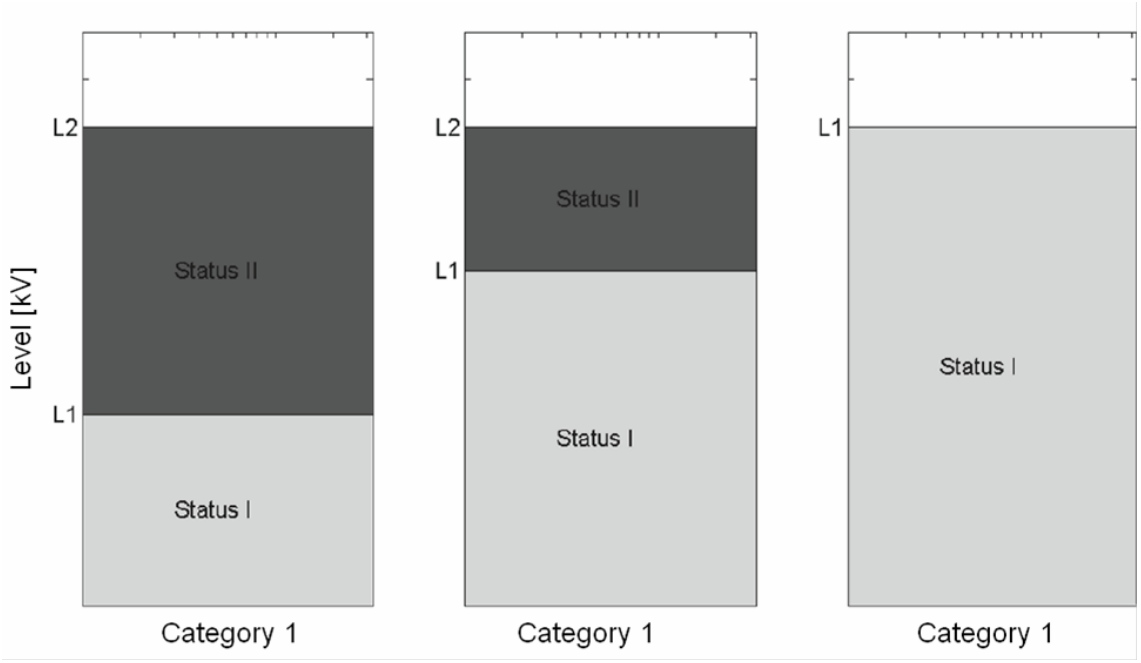

Figure A.1 – Graphical representation of the functional performance status classification (FPSC)

Appendix B (normative) Geometric setup of the coupling structure for indirect discharge at system level

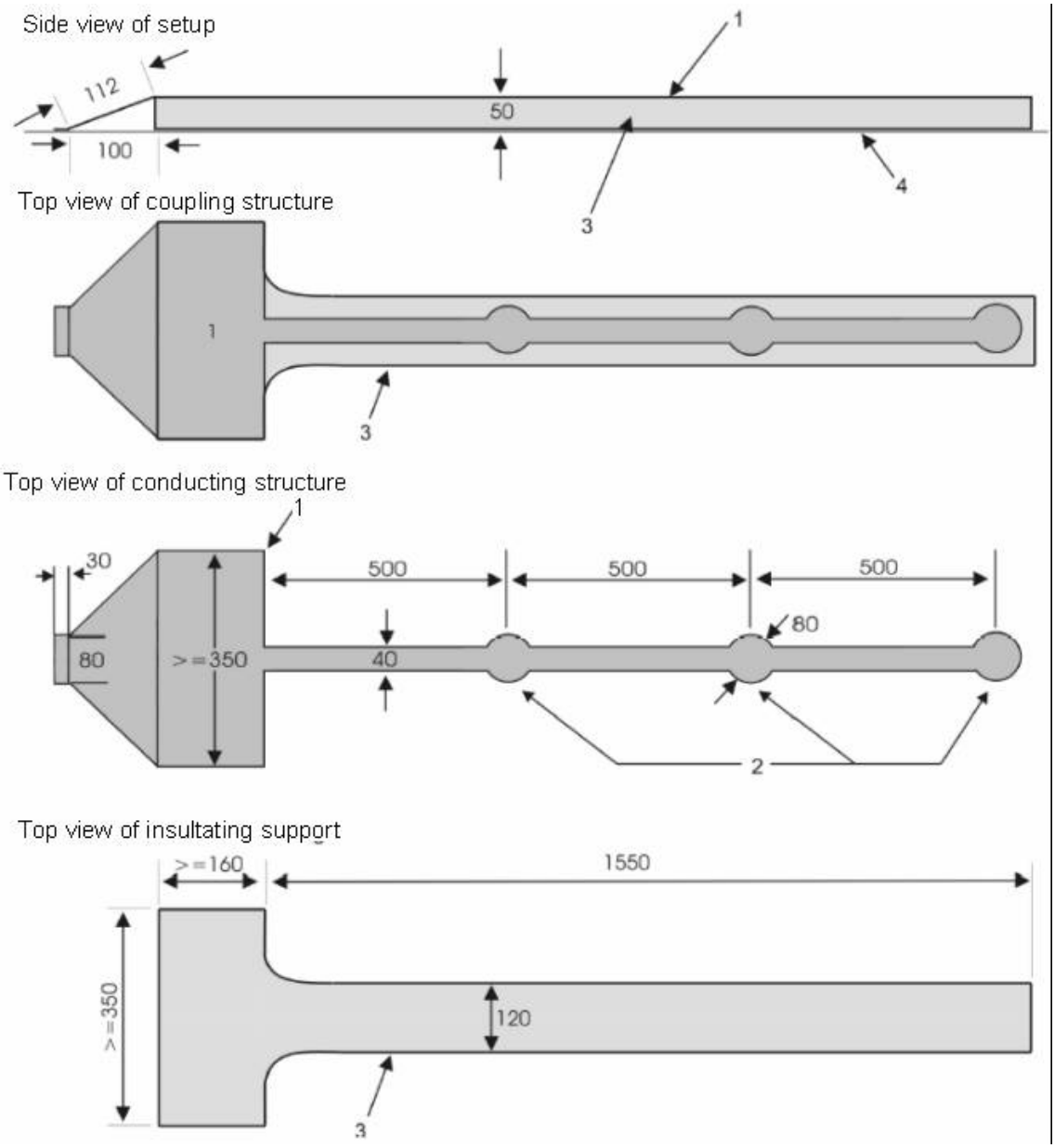

Figure B.1 – Setup of the coupling structure used for indirect discharge

Legend

1	Coupling structure: The area of the coupling structure used to hold the DUT must project from the DUT by at least 10 mm on all sides (minimum dimensions 160 x 350 mm), material: copper or brass, 0,5 to 2 mm thick
2	ESD discharge stations: Connected to the coupling plate in an electrically conductive manner, diameter 80 mm, material: copper or brass, 0,5 to 2 mm thick
3	Insulating base: non-conductive material with ε_r < 2,5, height 50 mm
4	Ground plate: material: copper or brass, 0,5 to 2 mm thick

Dimensions in mm ± 5%