IEC 61967-4

Edition 2.0 2021-03

INTERNATIONAL STANDARD

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Integrated circuits – Measurement of electromagnetic emissions – Part 4: Measurement of conducted emissions – 1 Ω/150 Ω direct coupling method

Circuits intégrés – Mesure des émissions électromagnétiques – Partie 4: Mesure des émissions conduites – Méthode par couplage direct 1 Ω/150 Ω

IEC 61967-4:2021-03(en-fr)

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ICS 31.200

ISBN 978-2-8322-9568-7

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CONTENTS

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INTEGRATED CIRCUITS – MEASUREMENT OF ELECTROMAGNETIC EMISSIONS –

Part 4: Measurement of conducted emissions – 1 Ω/150 Ω direct coupling method

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IEC 61967-4 has been prepared by subcommittee 47A: Integrated circuits, of IEC technical committee 47: Semiconductor devices. It is an International Standard.

This second edition cancels and replaces the first edition published in 2002 and Amendment 1:2006. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) frequency range of 150 kHz to 1 GHz has been deleted from the title;

b) recommended frequency range for 1 Ω method has been reduced to 30 MHz;

c) Annex G with recommendations and guidelines for frequency range extension beyond 1 GHz has been added.

The text of this International Standard is based on the following documents:

Draft	Report on voting
47A/1101/CDV	47A/1107/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts of the IEC 61967 series, under the general title *Integrated circuits – Measurement of electromagnetic emissions* can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

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INTEGRATED CIRCUITS –
MEASUREMENT OF ELECTROMAGNETIC EMISSIONS –

Part 4: Measurement of conducted emissions –
1 Ω/150 Ω direct coupling method

1 Scope

This part of IEC 61967 specifies a method to measure the conducted electromagnetic emission (EME) of integrated circuits by direct radio frequency (RF) current measurement with a 1 Ω resistive probe and RF voltage measurement using a 150 Ω coupling network. These methods ensure a high degree of reproducibility and correlation of EME measurement results.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

IEC 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61967-1, *Integrated circuits – Measurement of electromagnetic emissions – Part 1: General conditions and definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions of IEC 61967-1 apply.

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4 General

4.1 Measurement basics

The maximum tolerated emission level from an integrated circuit (IC) depends on the permitted maximum emission level of the electronic system, which includes the IC, and also on the immunity level of other parts of the electronic system itself (so called inherent EMC). The value of this emission level is dependent on system and application specific (ambient) parameters. To characterise ICs, i.e. to provide typical EME values for a data sheet, a simple measurement procedure and non-resonant measurement setup are required to guarantee a high degree of reproducibility. Subclause 4.1 describes the basis of this test procedure.

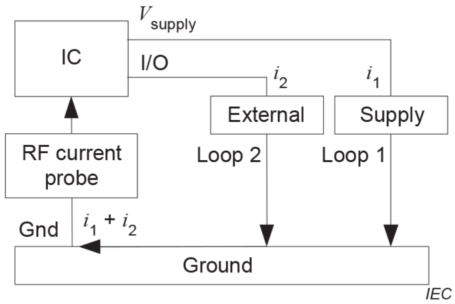

Figure 1 – Example of two emitting loops returning to the IC via common ground

The emission of an IC is generated by sufficiently fast changes of voltages and currents inside the IC. These changes drive RF currents inside and outside the IC. The RF currents cause conducted EME, which is mainly distributed via the IC pins conductor loops in the printed circuit board (PCB) and the cabling. These loops are regarded as the emitting loop antennas. In comparison to the dimension of these loops, the loops in the internal IC structure are considered to be small.

The RF currents that accompany ICs action are different in amplitude, phase and spectral content. Any RF current has its own loop that returns to the IC. All loops return mostly via the ground or supply connection back to the IC. In Figure 1, this is shown for two loops returning via ground. Loop 1 represents the supply wiring harness for the IC while loop 2 represents the routing of an output signal. The common return path via ground is a suitable location to measure the conducted EME as the measurement of the common RF sum current of the ground pin. This test is named the "RF current measurement".

If the IC under test has only one ground pin and all other pins are suspected to contribute essentially to the EME, then the RF sum current is measured between the ground pin of the IC under test and the ground (see $i_1 + i_2$ in Figure 1).

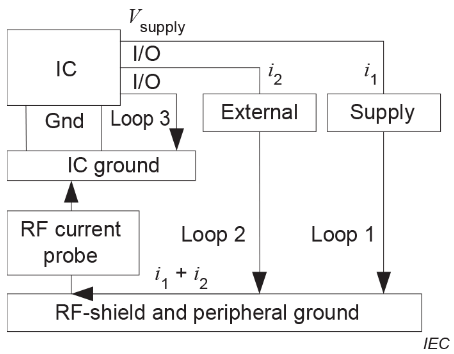

Figure 2 – Example of IC with two ground pins, a small I/O loop and two emitting loops

If the IC under test has more than one ground pin or some of the pins are not suspected to contribute much to the whole EME, then the IC under test gets its own ground plane as shown in Figure 2. This ground plane is named "IC ground". It is kept separately from the other ground, that is named "RF-shield and peripheral ground". The RF current is measured between the IC ground and the peripheral ground.

ICs are often used in different configurations based on the application. For instance, a microcontroller could be used as a single chip controller, with the I/O ports directly connected to the external cabling system. In order to understand the influence of a single I/O pin on the emission level of the IC, an additional measurement procedure, using the same equipment, is provided. This measurement is named "single pin RF voltage measurement at IC pins" (see also 4.3). In addition to the RF sum current measurement, the RF current measurement of a single supply pin can be of interest in the analysis of an IC. This can also be attained with application of the RF current measurement probe. For example, the RF current probe can be applied to any of the multiple ground or supply pins in order to quantify the contribution of the measured pin to the whole emission.

4.2 RF current measurement

In the test procedure, this measurement shall be made by measuring the voltage across the 1 Ω resistance of a RF current probe using a measurement receiver. The measurement shall be made at the location shown in Figure 1 and Figure 2. The construction of the RF current probe is specified in 6.2. The RF voltage level measured by the receiver is the voltage resulting from all of RF currents returning to the IC through the probe impedance. The voltage measurement can be converted to current by dividing the voltage by the probe impedance, if the probe impedance is determined for the applicable frequency range e.g. in a verification report.

NOTE 1 The probe impedance can be frequency dependant, caused by stray inductances of the probe, and thus the usable frequency range can be limited.

NOTE 2 The probe impedance causes, depending on the IC current consumption, a voltage drop that can affect the proper operation of the IC and limit the application of this method.

4.3 RF voltage measurement at IC pins

This measurement is used to identify the contribution of a single pin or a group of pins to the EME of the IC under test. This measurement is only applied to those pins of the IC under test that are intended to be connected directly to long (longer than 10 cm) PCB traces or wiring harnesses (e.g. I/O, supply). These pins are loaded by a typical common mode impedance of 150 Ω, as specified in IEC 61000-4-6. In order to connect the measurement receiver, that has an input-impedance of 50 Ω, the load has to be built as an impedance matching network. This matching network is defined in 6.4.

Other I/O-pins of an IC may be loaded as specified in the general part of IEC 61967-1.

4.4 Assessment of the measurement technique

The above techniques have the following properties:

- high measurement reproducibility, because few parameters influence the result;
- capability to compare different IC configurations (e.g. packages);
- single pin EME measurements of the various I/O pins are dependent on their importance for the emission in a specific application;
- assessment of the EME contribution of the IC using current sum measurement;
- simple verification of the measurement impedance using insertion loss measurement;
- measurement is also possible at very low frequencies.

With these characteristics, it is possible to measure the EME of ICs with a high degree of reproducibility and therefore this technique offers a good method for comparison.

Annex D gives an example of how the measurement techniques can be used for the assessment of ICs.

5 Test conditions

All test conditions required in this document are specified in IEC 61967-1.

6 Test equipment

6.1 RF measuring instrument

The measurement equipment shall fulfil the requirements described in IEC 61967-1.

6.2 RF current probe specification

Figure 3 shows the basic construction of the 1 Ω RF current probe.

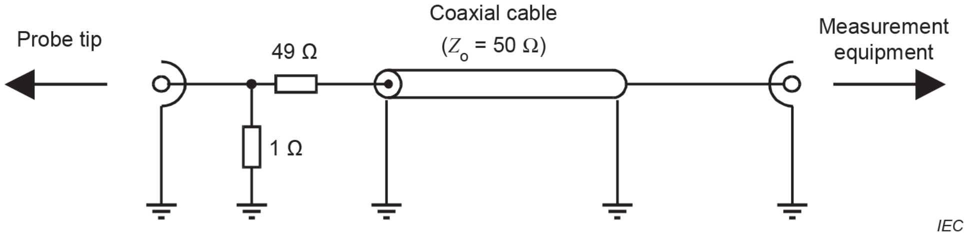

Figure 3 – Construction of the 1 Ω RF current probe

Table 1 presents a detailed specification of the RF current probe.

To prevent the measurement equipment from being damaged by DC voltage, the use of a DC block is recommended. This shall have an attenuation of <0,5 dB at the lowest frequency to be measured.

Table 1 – Specification of the RF current probe

Frequency range	DC to 30 MHz The applicable frequency range of the used probe shall be evaluated e.g. in a S-parameter measurement and documented in the test report. Current probes available on the market have proved to be usable e.g. only up to 30 MHz. Therefore bandwidth and impedance over frequency of the used probe shall be verified and documented in a diagram. The same applies to on-board probes with SMD components. In future, for enhanced RF probes, the usable frequency range may change.
Measurement resistor	RF resistor (low inductance)[a)] 1 Ω (±1 %). The measurement resistor can also consist of resistors in parallel, which increases the maximum permissible current through the probe (e.g. 2 Ω//2 Ω) and reduce the stray inductance.
Matching resistor	49 Ω (±1 %)
Maximum current	< 0,5 A
Output impedance Z_o	40 Ω to 60 Ω
Insertion loss in verification circuit	34 dB ± 2 dB
Decoupling in verification circuit	See Figure A.1 and Figure A.5.
Cable connection	Flexible, double shielded coaxial cable with 50 Ω ± 2 Ω line impedance. The RF connector shall be mounted with low reflection. The insertion loss includes the cable and the probe. Changes to the cable length will result in additional attenuation to be considered with the measurement results.
Construction	Coaxial probe or comparable construction, which can be connected to a 4 mm coaxial socket. The measurement resistor shall be as close as possible to the probe tip. It shall be built in such a way that no mechanical damage is possible. The connection of the probe cable shall be coaxial; the probe tips should be replaceable, but nevertheless firmly connected to the cable.

a) The series impedance caused by the parasitic inductance should be lower than the resistor in the used measurement range.

6.3 Test of the RF current probe capability

The current probe shall be functionally verified in a test circuit shown and described in detail in Annex A.

6.4 Matching network specification

Based on IEC 61000-4-6, a cabling network can be represented in most cases by an antenna with an impedance of about 150 Ω. In order to get accurate measurement results over the full frequency range, a termination network of 145 Ω ± 20 Ω shall be used. Usual measurement equipment provides an input impedance of 50 Ω so that the matching network shall match the signal line impedance to the equipment impedance. The circuitry is shown in Figure 4, and the characteristics of the impedance matching network used are shown in Table 2. Additional information of matching networks for differential pin measurements are provided in Annex F and recommendations.

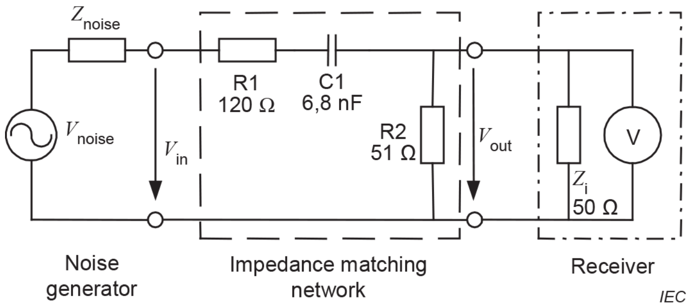

Figure 4 – Impedance matching network corresponding with IEC 61000-4-6

Table 2 – Characteristics of the impedance matching network

Frequency range	150 kHz – 1 GHz
Input impedance with 50 Ω termination Z_i	145 Ω ± 20 Ω
Insertion loss within a 50 Ω system	0,258 6 (−11,75 dB ± 2 dB)
Voltage ratio V_{out} / V_{in}	0,173 8 (−15,20 dB ± 2 dB)

7 Test setup

7.1 General test configuration

A general test configuration is shown in Figure 5. This general test configuration can be built up in the form of a special test configuration (an example is described in Clause E.2) or in any other configuration, e.g. also in a real application.

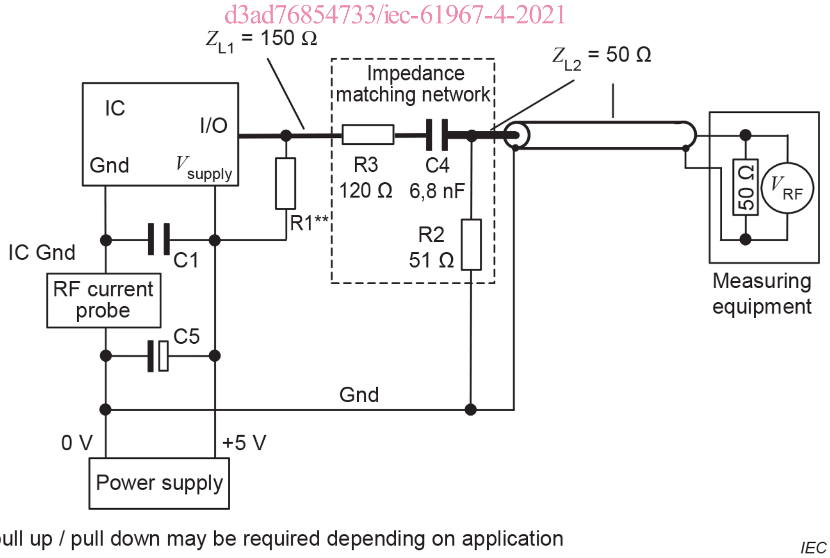

Figure 5 – General test configuration

7.2 Printed circuit test board layout

In order to obtain a high degree of reproducibility of measurement results and be able to make a valid comparison between different printed circuit test boards, the following guidance is given.

The test board should be built using PCB material of epoxy type (thickness 0,6 mm to 3 mm, dielectric constant about 4,7). The top side and the bottom side are covered with a minimal 35 µm copper layer.

The bottom layer should be used as ground plane.

If peripheral ground and IC ground are used for the 1 Ω method, these two grounds are isolated by an isolation gap. This isolation gap should be between 0,5 mm and 0,6 mm. If needed, the IC ground shall be located underneath the DUT. The maximum size of this area should not exceed the size of the package minimum footprint by more than 3 mm on each side.

To obtain the necessary accuracy for higher frequencies, parasitic coupling capacitance between IC ground and peripheral ground shall be controlled. This parasitic coupling capacitance between IC ground and peripheral ground shall be lower than 30 pF.

The IC ground is solely connected to the peripheral ground via the 1 Ω probe. In case of external RF current probe, a socket should be used. The shield of the RF current probe tip should be connected to the RF peripheral ground by the socket, while the IC ground or the IC ground pin is connected to the current probe tip. The connection between the IC ground and the probe tip shall be as short as possible. In any case, the trace length shall not exceed 15 mm. The trace should be connected to the IC ground at the shortest distance to the centre point of the DUT.

If the above-mentioned guidelines are not applicable, the transfer characteristic of modified design shall be determined and documented in the test report.

The DUT and all components needed to operate the DUT should be mounted onto the top side of the test board. As much wiring as possible should be routed in the top layer. The DUT should be placed in the centre of the PCB, while the needed matching networks should be placed around this centre. The wiring between the IC pins and the matching network should be designed to have a line impedance of 150 Ω. In case the 150 Ω line impedance is difficult to implement, the line shall be of the maximum reasonable impedance but short enough, in order to comply with the requirements of Table 2.

The wiring of the outputs of the matching networks should be designed to have a line impedance of 50 Ω. An example of a PCB layout can be found in Annex E.

The supply shall be connected with a single wire directly to the capacitor C5. C5 could be a surface mount device, of electrolytic type and having a value of at least 10 µF. The capacitor C5 shall be positioned near the probe socket.

The test board may have any rectangular or circular shape.

Additional information and guidelines for extended frequency applications are described in Annex G.

8 Test procedure

The requirements for the test procedure are described in IEC 61967-1.

9 Test report

The requirements for the test report are described in IEC 61967-1.

Emission measurement results may be presented using classification or reference levels. An example of a classification scheme for emission levels is presented in Annex B. In addition, Annex C shows how this classification scheme may be applied to set up reference levels for ICs used in the automotive industry.