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Second edition
2008-05-01

Identification cards — Test methods —

Part 7: Vicinity cards

Cartes d'identification — Méthodes d'essai —

Partie 7: Cartes de voisinage

Reference number
ISO/IEC 10373-7:2008(E)

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national 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 and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC 10373-7 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 17, *Cards and personal identification*.

This second edition cancels and replaces the first edition (ISO/IEC 10373-7:2001), Clause 5 and subclause 6.3.5 of which have been technically revised.

ISO/IEC 10373 consists of the following parts, under the general title *Identification cards — Test methods*:

— *Part 1: General characteristics*

— *Part 2: Cards with magnetic stripes*

— *Part 3: Integrated circuit(s) cards with contacts and related interface devices*

— *Part 5: Optical memory cards*

— *Part 6: Proximity cards*

— *Part 7: Vicinity cards*

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Identification cards — Test methods —

Part 7:
Vicinity cards

1 Scope

ISO/IEC 10373 defines test methods for characteristics of identification cards according to the definition given in ISO/IEC 7810. Each test method is cross-referenced to one or more base standards, which may be ISO/IEC 7810 or one or more of the supplementary standards that define the information storage technologies employed in identification card applications.

NOTE 1 Criteria for acceptability do not form part of ISO/IEC 10373, but will be found in the International Standards mentioned above.

NOTE 2 Test methods defined in ISO/IEC 10373 are intended to be performed separately. A given card is not required to pass through all the tests sequentially.

This part of ISO/IEC 10373 deals with test methods, which are specific to contactless integrated circuit card (vicinity card) technology. ISO/IEC 10373-1 deals with test methods which are common to one or more ICC technologies and other parts deal with other technology-specific tests.

Unless otherwise specified, the tests in this part of ISO/IEC 10373 apply exclusively to vicinity cards defined in ISO/IEC 15693-1 and ISO/IEC 15693-2.

2 Normative reference(s)

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/IEC 7810, *Identification cards — Physical characteristics*

ISO/IEC 15693-1, *Identification cards — Contactless integrated circuit(s) cards — Vicinity cards — Part 1: Physical characteristics*

ISO/IEC 15693-2:2006, *Identification cards — Contactless integrated circuit cards — Vicinity cards — Part 2: Air interface and initialization*

ISO/IEC 15693-3, *Identification cards — Contactless integrated circuit(s) cards — Vicinity cards — Part 3: Anticollision and transmission protocol*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) — Part 4-2: Testing and measurement techniques — Electrostatic discharge immunity test*

ISBN 92-67-10188-9, *Guide to the Expression of Uncertainty in Measurement*, ISO, 1993

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3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
base standard
standard which the test method is used to verify conformance to

3.1.2
operate as intended
surviving the action of some potentially destructive influence to the extent that any integrated circuit present in the card continues to operate and show a response[1)] as defined in ISO/IEC 15693-3 which conforms to the base standard

NOTE If other technologies exist on the same card, they will operate as intended in accordance with their respective standard.

3.1.3
test method
method for testing characteristics of identification cards for the purpose of confirming their compliance with International Standards

3.2 Symbols and abbreviated terms

DUT device under test

ESD electrostatic discharge

fc frequency of the operating field

fs1, fs2 frequencies of the subcarriers

H_{max} maximum field strength of the VCD antenna field

H_{min} minimum field strength of the VCD antenna field

VCD vicinity coupling device

VICC vicinity card

4 Default items applicable to the test methods

4.1 Test environment

Unless otherwise specified, testing shall take place in an environment of temperature 23°C ± 3°C (73°F ± 5°F) and of relative humidity 40% to 60%.

1) This International Standard does not define any test to establish the complete functioning of integrated circuit(s) cards. The test methods require only that a minimum functionality be verified. This may, in appropriate circumstances, be supplemented by further, application specific functionality criteria which are not available in the general case.

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4.2 Pre-conditioning

Where pre-conditioning is required by the test method, the identification cards to be tested shall be conditioned to the test environment for a period of 24 h before testing.

4.3 Default tolerance

Unless otherwise specified, a default tolerance of ± 5% shall be applied to the quantity values given to specify the characteristics of the test equipment (e.g. linear dimensions) and the test method procedures (e.g. test equipment adjustments).

4.4 Spurious inductance

Resistors and capacitors should have negligible inductance.

4.5 Total measurement uncertainty

The total measurement uncertainty for each quantity determined by these test methods shall be stated in the test report.

Basic information is given in the “Guide to the Expression of Uncertainty in Measurement”, ISBN 92-67-10188-9, ISO, 1993.

5 Static electricity test

The purpose of this test is to check the behaviour of the VICC in relation to electrostatic discharge (ESD) exposure of the test sample. The VICC under test is exposed to a simulated electrostatic discharge (ESD, human body model) and its basic operation checked following the exposure.

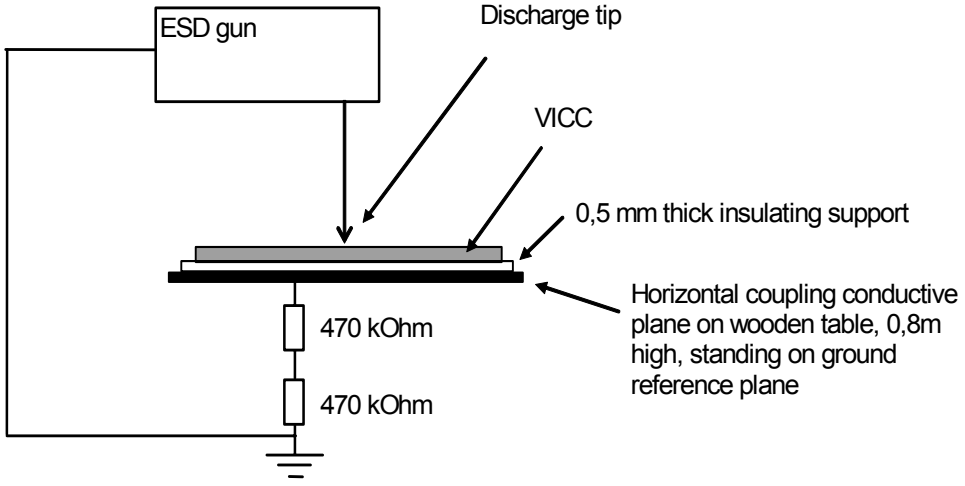


Figure 1 — ESD test circuit

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5.1 Apparatus

Refer to IEC 61000-4-2.

a) Main specifications of the ESD generator:

- energy storage capacitance: 150 pF ± 10%
- discharge resistance: 330 Ohm ± 10%
- charging resistance: between 50 MOhm and 100 MOhm
- rise time: 0,7 to 1 ns

b) Selected specifications from the optional items:

- type of equipment: table top equipment
- discharge method: direct application of air discharge to the equipment under test
- discharge electrodes of the ESD generator: round tip probe of 8 mm diameter

5.2 Procedure

Connect the test apparatus as specified in IEC 61000-4-2.

Apply the discharge successively in normal polarity to each of the 20 test zones shown in Figure 2. Then repeat the same procedure with reversed polarity. Allow a cool-down period between successive pulses of at least 10 s.

WARNING — If the VICC includes contacts, the contacts shall be face up and the zone which includes contacts shall not be exposed to this discharge.

Check that the VICC operates as intended at the end of the test.

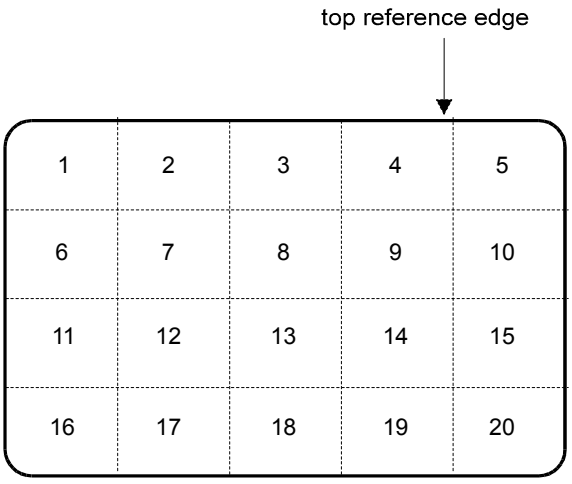


Figure 2 — Test zones on VICC for ESD test

5.3 Test report

The test report shall state whether or not the VICC operates as intended.

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6 Test apparatus and test circuits

This clause defines the test apparatus and test circuits for verifying the operation of a VICC or a VCD according to ISO/IEC 15693-2. The test apparatus includes:

— calibration coil (see 6.1),

— test VCD assembly (see 6.2),

— reference VICC (see 6.3),

— digital sampling oscilloscope (see 6.4).

6.1 Calibration coil

This subclause defines the size, thickness and characteristics of the calibration coil.

6.1.1 Size of the calibration coil card

The calibration coil card consists of an area, which has the height and width defined in ISO/IEC 7810 for ID-1 type containing a single turn coil concentric with the card outline.

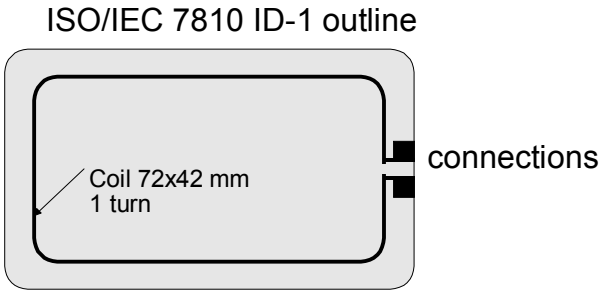


Figure 3 — Calibration coil

6.1.2 Thickness and material of the calibration coil card

The thickness of the calibration coil card shall be 0,76 mm ±10%. It shall be constructed of a suitable insulating material.

6.1.3 Coil characteristics

The coil on the calibration coil card shall have one turn. The outer size of the coil shall be 72 mm (± 2%) × 42 mm (± 2%) with corner radius 5 mm.

NOTE 1 The area over which the field is integrated is approximately 3000 mm^2.

The coil is made as a printed coil on PCB plated with 35 µm copper. Track width shall be 500 µm ± 20%. The size of the connection pads shall be 1,5 mm × 1,5 mm.

NOTE 2 At 13,56 MHz the approximate inductance is 200 nH and the approximate resistance is 0,25 Ohm.

A high impedance oscilloscope probe (e.g. >1MOhm, <14pF) shall be used to measure the (open circuit) voltage in the coil. The resonance frequency of the whole set (calibration coil, connecting leads and probe) shall be above 60 MHz.

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NOTE 3 A parasitic capacitance of the probe assembly of less than 35 pF normally ensures a resonant frequency for the whole set of greater than 60 MHz.

The open circuit calibration factor for this coil is 0,32 V (rms) per A/m (rms) [Equivalent to 900 mV (peak-to-peak) per A/m (rms)].

6.2 Test VCD assembly

The test VCD assembly for load modulation consists of a 150 mm diameter VCD antenna and two parallel sense coils: sense coil a and sense coil b. The test set-up is shown in Figure 4. The sense coils are connected such that the signal from one coil is in opposite phase to the other. The 10 Ohm potentiometer P1 serves to fine adjust the balance point when the sense coils are not loaded by a VICC or any magnetically coupled circuit. The capacitive load of the probe including its parasitic capacitance shall be less than 14 pF.

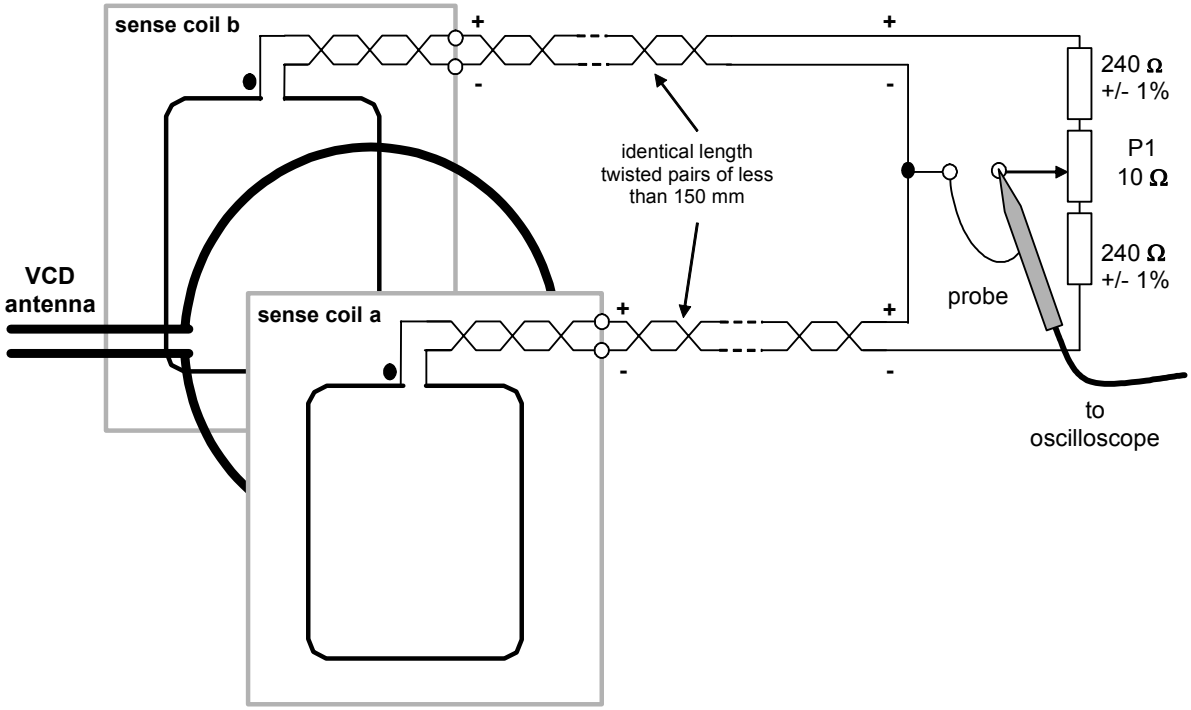


Figure 4 — Test set-up

The maximum length of 150 mm of the twisted pairs takes the wider spacing of the sense coils in comparison to the set-up in ISO/IEC 10373-6 into account.

In order to avoid any unintended misalignment in case of an unsymmetrical set-up the tuning range of the potentiometer P1 is only 10 Ω. If the set-up cannot be compensated by the 10 Ω potentiometer P1 the overall symmetry of the set-up should be checked.

The capacitance of the connections and oscilloscope probe should be kept to a minimum for reproducibility.

The high impedance oscilloscope probe ground connection should be as short as possible, less than 20 mm or coaxial connection.

6.2.1 Test VCD antenna

The Test VCD antenna shall have a diameter of 150 mm and its construction shall conform to the drawings in Annex A. The tuning of the antenna may be accomplished with the procedure given in Annex B.

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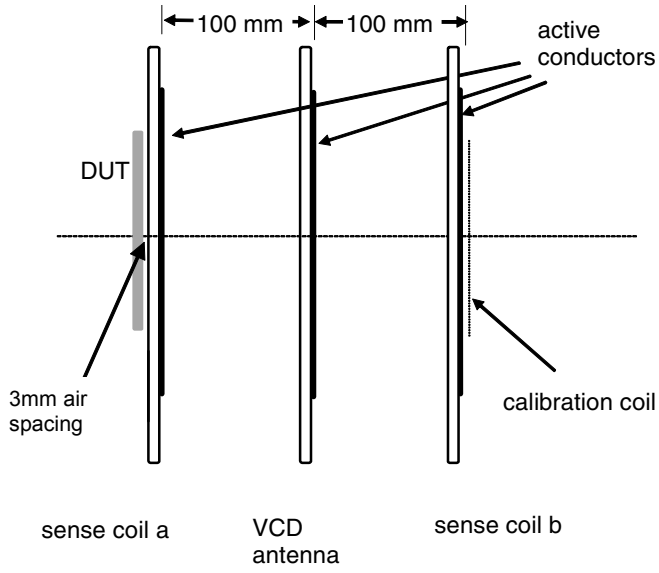
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6.2.2 Sense coils

The size of the sense coils is 100 x 70 mm. The sense coil construction shall conform to the drawings in Annex C.

6.2.3 Assembly of test VCD

The sense coils and test VCD antenna are assembled parallel and with the sense and antenna coils coaxial and such that the distance between the active conductors is 100 mm as in Figure 5. The distance between the coil in the DUT and the calibration coil shall be equal with respect to the coil of the test VCD antenna.



NOTE The distance of 100 mm reflects larger read distance and 3mm air spacing avoids parasitic effects such as detuning by closer spacing or ambiguous results due to noise and other environmental effects.

Figure 5 — Test VCD assembly

6.3 Reference VICCs

Reference VICCs are defined

— to test H_{min} and H_{max} produced by a VCD (under conditions of loading by a VICC),

— to test the ability of a VCD to power a VICC,

— to detect the minimum load modulation signal from the VICC.

6.3.1 Reference VICC for VCD power

The schematic for the power test is shown in Annex D. Power dissipation can be set by the resistor R1 or R2 respectively in order to measure H_{max} and H_{min} as defined in 8.1.2. The resonant frequency can be adjusted with C2.

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6.3.2 Reference VICC for load modulation test

A suggested schematic for the load modulation test is shown in Annex E. The load modulation can be chosen to be resistive or reactive.

This reference VICC is calibrated by using the Test VCD assembly as follows:

The reference VICC is placed in the position of the DUT. The load modulation signal amplitude is measured as described in 7.2. This amplitude should correspond to the minimum amplitude at all values of field strength required by the base standard.

6.3.3 Dimensions of the reference VICCs

The reference VICCs consist of an area containing the coils which has the height and width defined in ISO/IEC 7810 for ID-1 type. An area external to this, containing the circuitry which emulates the required VICC functions, is appended in a way as to allow insertion into the test set-ups described below and so as to cause no interference to the tests. The dimensions shall be as in Figure 6.

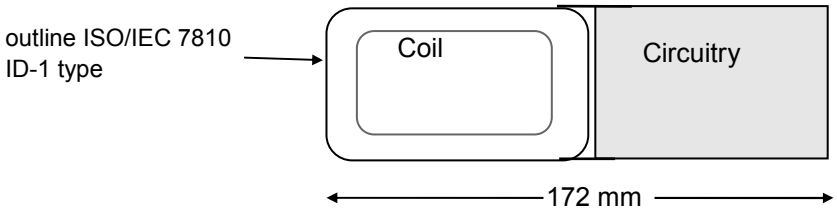


Figure 6 — Reference VICC dimensions

6.3.4 Thickness of the reference VICC board

The thickness of the reference VICC active area shall be 0,76 mm ±10%.

6.3.5 Coil characteristics

The coil in the active area of the reference VICC shall have 4 turns and shall be concentric with the area outline.

The outer size of the coils shall be 72 mm ± 2% x 42 mm ± 2%.

The coil is printed on PCB plated with 35 µm copper.

Track width and spacing shall be 500 µm ± 20%.

NOTE At 13,56 MHz the nominal inductance is 3,5 µH and the nominal resistance is 1 Ohm.

6.4 Digital sampling oscilloscope

The digital sampling oscilloscope shall be capable of sampling at a rate of at least 100 million samples per second with a resolution of at least 8 bits at optimum scaling. The oscilloscope should have the capability to output the sampled data as a text file to facilitate mathematical and other operations such as windowing on the sampled data using external software programmes (Annex F).

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7 Functional test — VICC

7.1 Purpose

The purpose of this test is to determine the amplitude of the VICC load modulation signal within the operating field range [H_{min}, H_{max}] as specified in 6.2 of the base standard and the functionality of the VICC with the modulation under emitted fields as defined in Figure 1 and Figure 2 of ISO/IEC 15693-2:2006, of the base standard.

7.2 Test procedure

Step 1: The load modulation test circuit of Figure 4 and the test VCD assembly of Figure 5 are used.

The RF power delivered by the signal generator to the test VCD antenna shall be adjusted to the required field strength and modulation waveforms as measured by the calibration coil without any VICC. The output of the load modulation test circuit of Figure 4 is connected to a digital sampling oscilloscope. The 10 Ohm potentiometer P1 shall be trimmed to minimise the residual carrier. This signal shall be at least 40 dB lower than the signal obtained by shorting one sense coil.

Step 2: The VICC under test shall be placed in the DUT position, concentric with sense coil a. The RF drive into the test VCD antenna shall be re-adjusted to the required field strength.

NOTE Care should be taken to apply a proper synchronization method for low amplitude load modulation.

Exactly two subcarrier cycles of the sampled modulation waveform shall be Fourier transformed. A discrete Fourier transformation with a scaling such that a pure sinusoidal signal results in its peak magnitude shall be used. To minimize transient effects, a subcarrier cycle immediately following a non-modulating period must be avoided. In case of two subcarrier frequencies this procedure shall be repeated for the second subcarrier frequency.

The resulting amplitudes of the two upper sidebands at *fc+fs1* and *fc+fs2* and the two lower sidebands at *fc-fs1* and *fc-fs2*, respectively, shall be above the value defined in 8.1 of the base standard.

An appropriate command sequence as defined in ISO/IEC 15693-3 shall be sent by the reference VCD to obtain a signal or load modulation response from the VICC.

7.3 Test report

The test report shall give the measured amplitudes of the upper sidebands at *fc+fs1* and *fc+fs2* and the lower sidebands at *fc-fs1* and *fc-fs2* and the applied fields and modulations.

8 Functional test — VCD

8.1 VCD field strength and power transfer

8.1.1 Purpose

This test measures the field strength produced by a VCD with its specified antenna in its operating volume as defined in accordance with the base standard. The test procedure of clause 8.1.2 is also used to determine that the VCD with its specified antenna generates a field not higher than the value specified in ISO/IEC 15693-1.

This test uses a reference VICC as defined in Annex D to determine that a specific VCD to be tested is able to supply a certain power to a VICC placed anywhere within the defined operating volume.

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8.1.2 Test procedure

Procedure for H_{max} test:

1. Set Jumper J1 to position 'a' to activate R1.

2. Tune the reference VICC to 13,56 MHz.

NOTE The resonance frequency of the reference VICC is measured by using an impedance analyser or a LCR-meter connected to a calibration coil. The coil of the reference VICC should be placed on the calibration coil with 3 mm (± 10 %) spacing, with the axes of the two coils being congruent. The resonance frequency is that frequency at which the reactive part of the measured complex impedance is at maximum.

3. Set Jumper J1 to position “b” to activate R2.

4. Calibrate the Reference VICC in the Test VCD Assembly set to produce H_{max} operating condition for an output voltage of V_{DC} = 3 V by adjusting R2.

5. Position the reference VICC within the defined operating volume of VCD under test.

6. The DC voltage (V_{DC}) across resistor R3 (Annex D) is measured with a high impedance voltmeter and shall not exceed 3 V.

Procedure for H_{min} test:

1. Set Jumper J1 to position “a” to activate R1.

2. Tune the reference VICC to 13,56 MHz.

3. Calibrate the reference VICC in the test VCD assembly set to produce H_{min} operating condition for an output voltage of V_{DC} = 3 V by adjusting R1.

4. Position the reference VICC within the defined operating volume of the VCD under test.

5. The DC voltage (V_{DC}) across resistor R3 is measured with a high impedance voltmeter and shall exceed 3 V.

8.1.3 Test report

The test report shall give the measured values for V_{DC} at H_{min} and H_{max} under the defined conditions.

8.2 Modulation index and waveform

8.2.1 Purpose

This test is used to determine the index of modulation of the VCD field as well as the rise and fall times and the overshoot values as defined in Figure 1 and Figure 2 of ISO/IEC 15693-2:2006 within the defined operating volume.

8.2.2 Test procedure

The calibration coil is positioned anywhere within the defined operating volume, and the modulation index and waveform characteristics are determined from the induced voltage on the coil displayed on a suitable oscilloscope.

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8.2.3 Test report

The test report shall give the measured modulation index of the VCD field, the rise and fall times and the overshoot values as defined in Figure 1 and Figure 2 of ISO/IEC 15693-2:2006 within the defined volume.

8.3 Load modulation reception

This test may be used to verify that a VCD correctly detects the load modulation of a VICC which conforms to the base standard. It is supposed that the VCD has means to indicate correct reception of the subcarrier(s) produced by a test VICC.

Annex E shows a circuit which can be used in conjunction with the test apparatus to determine the sensitivity of a VCD to load modulation within the defined operating volume.

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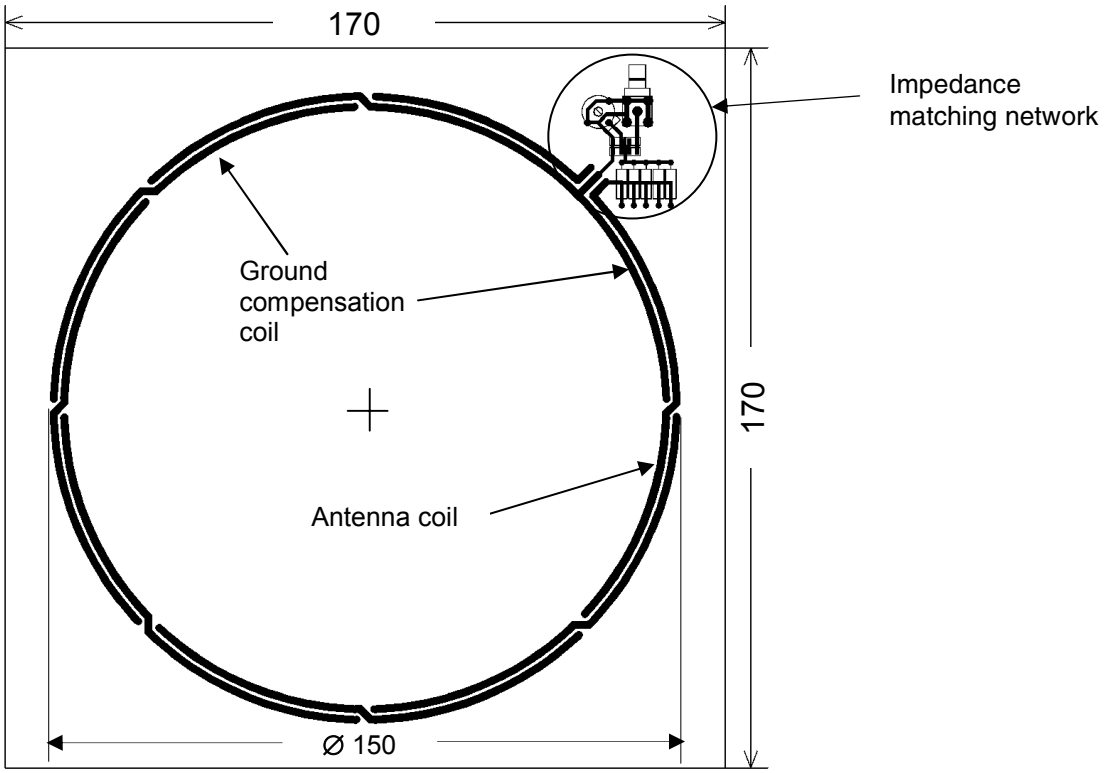
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Annex A
(normative)

Test VCD antenna

A.1 Test VCD antenna layout including impedance matching network



Dimensions in millimeters (drawings are not to scale).
The antenna coil track width is 1,8 mm (except for through-plated holes).
Starting from the impedance matching network there are crossovers every 45°.
PCB: FR4 material thickness 1,6 mm, double sided with 35 µm copper.

Figure A.1 — Test VCD antenna layout including impedance matching network (view from front)

NOTE The layout of the impedance matching network may take another form.

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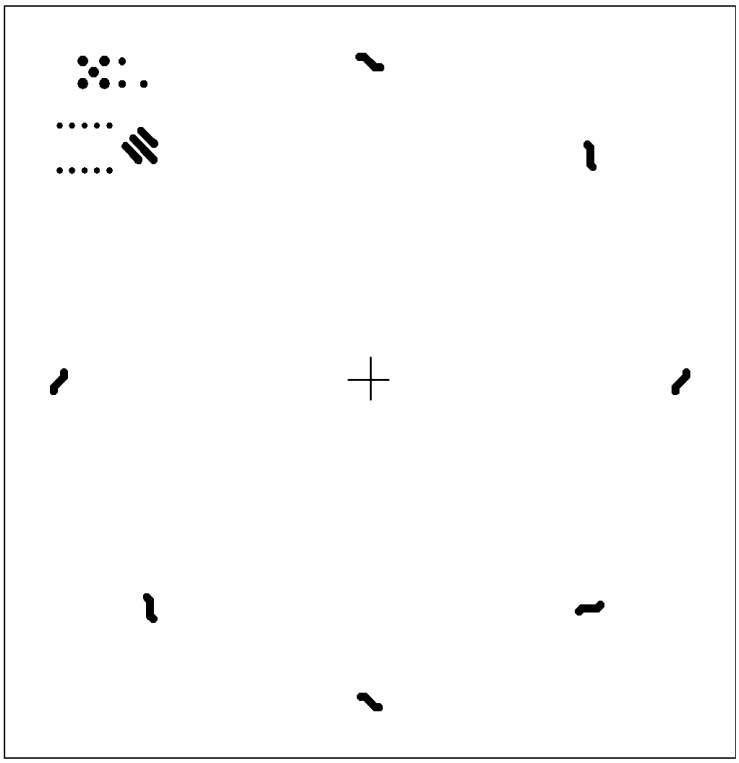


Figure A.2 — VCD antenna layout (view from back)

NOTE PCBs and/or Layout may be made available by:

arsenal research
RFID Testlab
Giefinggasse 2
A-1210 Vienna
Austria
Phone: +43 50 550-6272
Fax: +43 50 550-6439
www.arsenal.ac.at/rfid
email: mci@arsenal.ac.at

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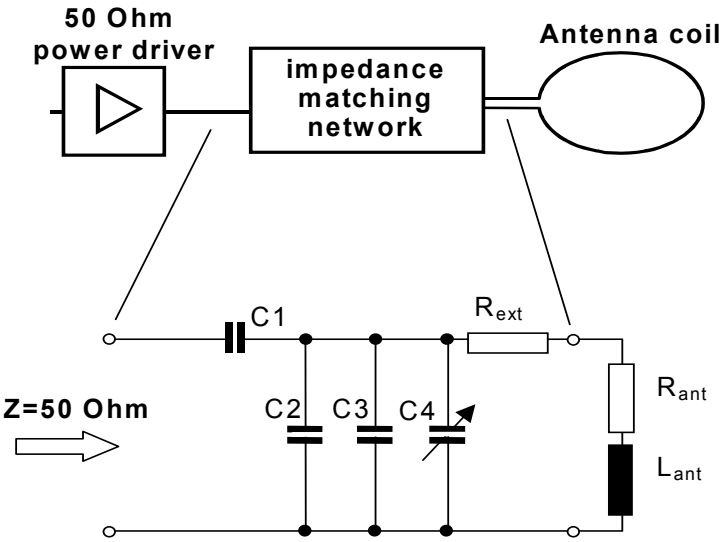
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A.2 Impedance matching network

The antenna impedance (R_{ant}, L_{ant}) is adapted to the function generator output impedance (Z=50 Ohm) by a matching circuit (see below). The capacitors C1, C2 and C3 have fixed values. The input impedance phase can be adjusted with the variable capacitor C4.

NOTE 1 Care has to be taken to keep maximum voltages and maximum power dissipation within the specified limits of the individual components.

The linear low distortion variable output 50 Ohm power driver should be capable of emitting appropriate signal sequences. The modulation index should be adjustable in the ranges of 10 % - 30 % and 95 % - 100 %. The output power should be adjustable to deliver H fields in the range of 150 mA/m – 12 A/m. Care should be taken with the duration of fields above the upper operating range of 5 A/m.



Component Table:

	Value	Unit
C1	47	pF
C2	180	pF
C3	33	pF
C4	2-27	pF
Rext	5x4.7 (parallel)	Ohm

Figure A.3 — Impedance matching network

C4 shall be adjusted for an input impedance of (50 ± 5) Ohms with phase angle of (0 ± 5) degrees.

NOTE 2 The component table gives typical values which may have to be modified slightly to give more precise adjustment.

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Annex B
(informative)

Test VCD antenna tuning

The figures below show the two steps of a simple phase tuning procedure to match the impedance of the antenna to that of the driving generator. After the two steps of the tuning procedure the signal generator shall be directly connected to the antenna output for the tests.

Step 1:

A high precision resistor of 50 Ohm ± 1% (e.g. 50 Ohm BNC resistor) is inserted in the signal line between the signal generator output and an antenna connector. The two probes of the oscilloscope are connected to both sides of the serial reference resistor. The oscilloscope displays a Lissajous figure when it is set in Y to X presentation. The signal generator is set to:

— Wave form: Sinusoidal

— Frequency: 13,56 MHz

— Amplitude: 2V (rms) - 5V (rms)

The output is terminated with a second high precision resistor of 50 Ohm ± 1% (e.g. 50 Ohm BNC terminating resistor). The probe, which is in parallel to the output connector has a small parasitic capacitance C_{probe}. A calibration capacitance C_{cal} in parallel to the reference resistor compensates this probe capacitor if $C_{cal} = C_{probe}$. The probe capacitor is compensated when the Lissajous figure is completely closed.

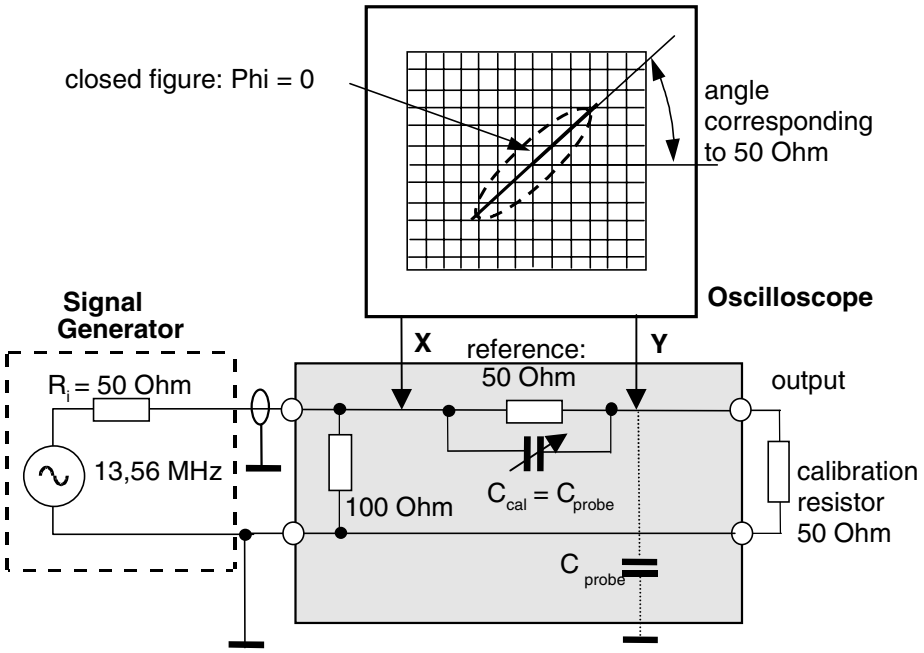


Figure B.1 — Calibration set-up (Step 1)

NOTE The ground cable has to be run close to the probe to avoid induced voltages caused by the magnetic field.

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Step 2:

Using the same values as set for step 1, in the second step the matching circuitry is connected to the antenna output. The capacitor C4 on the antenna board is used to tune the phase to zero.

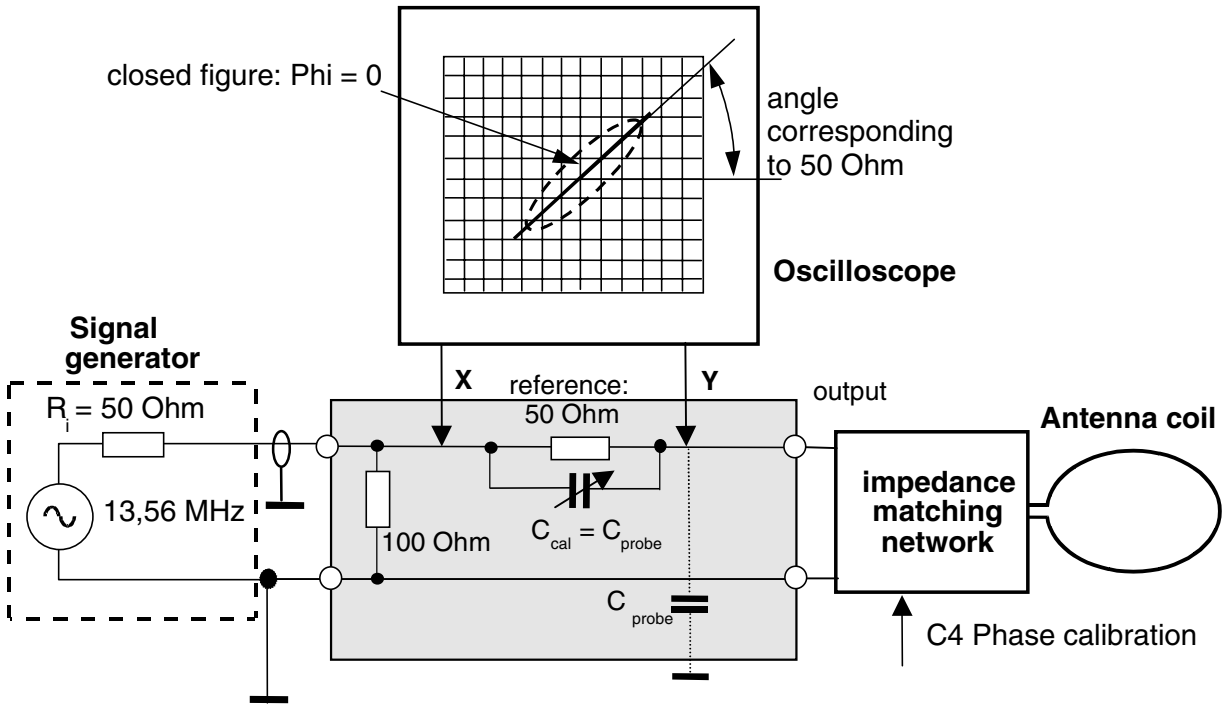


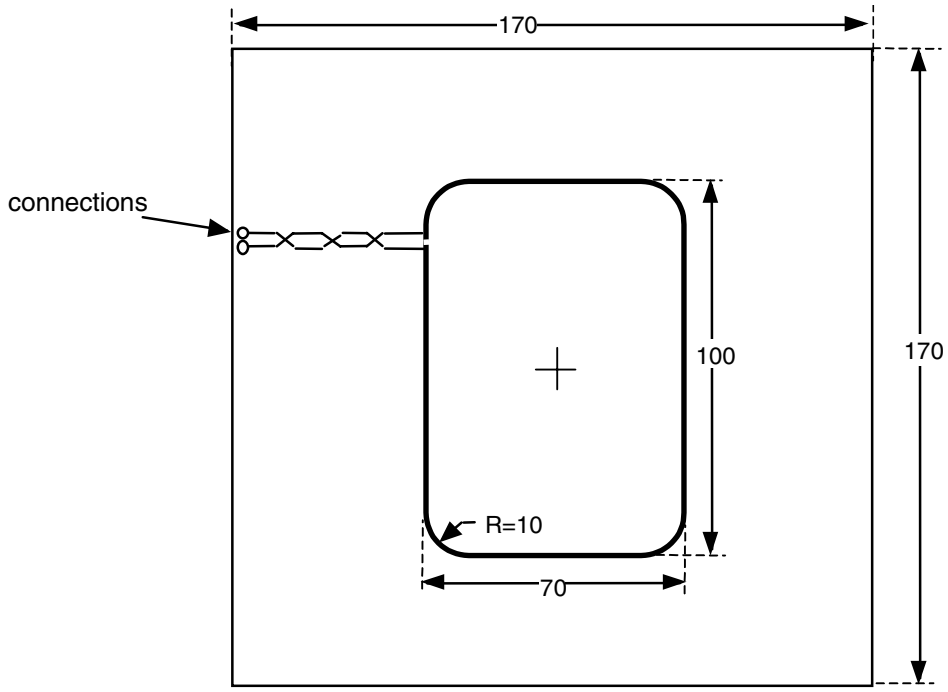
Figure B.2 — Calibration set-up (Step 2)

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Annex C
(normative)

Sense coil

C.1 Sense coil layout



Dimensions in millimeters (Drawings are not to scale).

The sense coils track width is 0,5 mm with relative tolerance ±20% (except for through-plated holes). Sizes of the coils refer to the outer dimensions.

PCB: FR4 material thickness 1,6 mm, double sided with 35 µm copper.

Figure C.1 — Layout for sense coils a and b

NOTE PCBs and/or Layout may be made available by:

arsenal research
RFID Testlab
Giefinggasse 2
A-1210 Vienna
Austria
Phone: +43 50 550-6272
Fax: +43 50 550-6439
www.arsenal.ac.at/rfid
email: mci@arsenal.ac.at

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C.2 Sense coil assembly

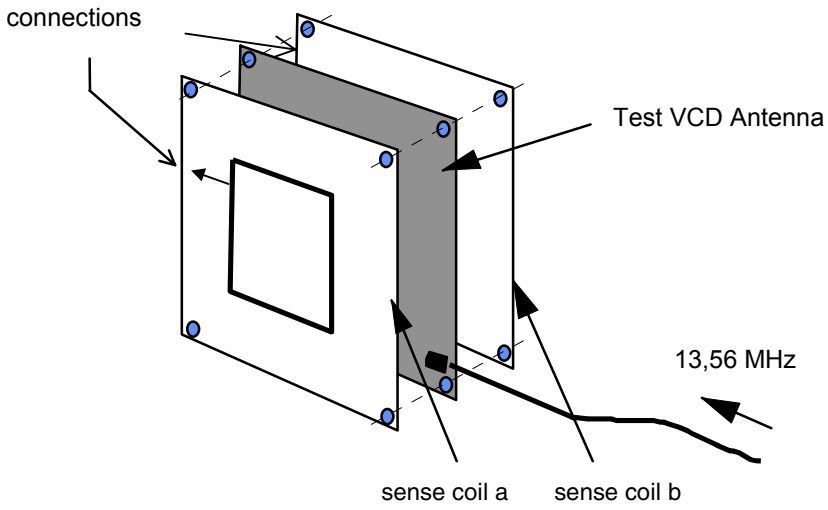
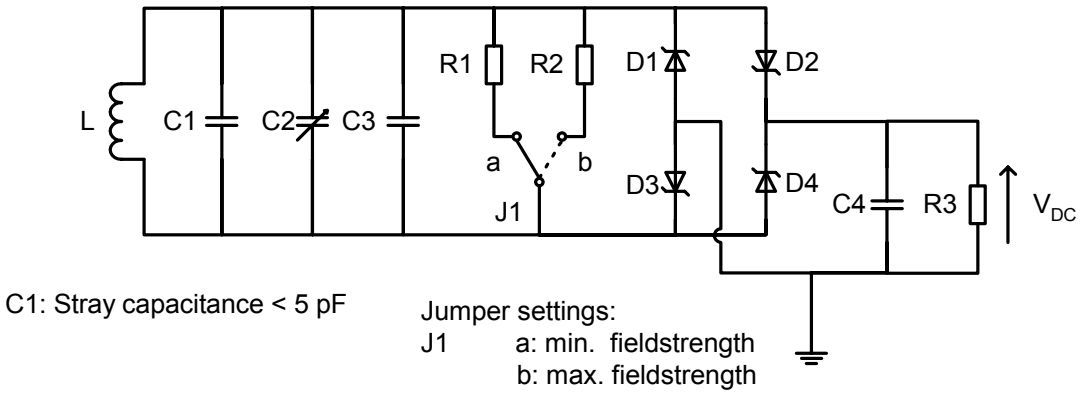


Figure C.2 — Sense coil assembly

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Annex D
(normative)

Reference VICC for VCD power test



C1: Stray capacitance < 5 pF

Jumper settings:
J1 a: min. fieldstrength
b: max. fieldstrength

Component list:

Component	Value
L (coil)	see clause 6.3.5
C1	Stray capacitance < 5pF
C2	2 … 10 pF
C3	27 pF
C4	10 nF
D1, D2, D3, D4	see characteristics in table D.1 (BAR 43 or equivalent)
R1	11 kOhm
R2	91 Ohm
R3	100 kOhm

Figure D.1 — Circuit diagram for Reference VICC

NOTE The component table gives typical values for R1 and R2 which may have to be modified slightly to give more precise adjustment (see 8.1.2).

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Table D.1 — Specification of basic characteristics of D1, D2, D3, D4

Symbol	Test Condition at Tj=25 °C	Typ.	Max.	Unit
V_F	I_F=2mA		0,33	V
C	V_R=1V, F=1 MHz	7		pF
t_{rr}	I_F=10mA, I_R=10mA, I_{rr}=1mA		5	ns

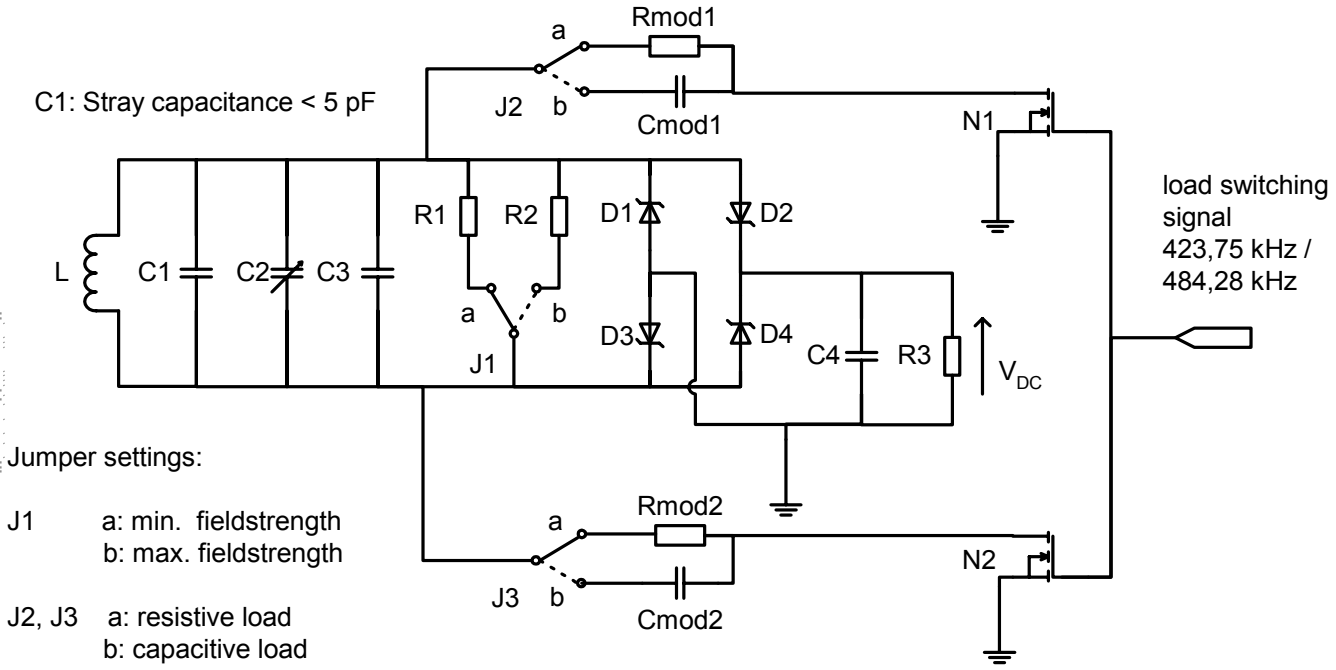
V_F Forward voltage drop
V_R Reverse voltage
I_F Forward current
I_R Reverse current
t_{rr} Reverse recovery time
I_{rr} Reverse recovery current
Tj Junction temperature
F Frequency
C Junction capacitance

--`,,```,,,,````-`-`,,`,,`,`,,`---

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Annex E
(informative)

Reference VICC for load modulation test



Adjust following components for required emulation:

Component	Function	Value
C2	adjust resonance	between 2 pF and 10 pF
Cmod1, Cmod2	capacitive modulation	between 3,0 pF and 120 pF
Rmod1, Rmod2	resistive modulation	between 100 Ohm and 2,7 kOhm

Components list:

Component	Value
R1	11 kOhm
R2	91 Ohm
R3	100 kOhm
D1, D2, D3, D4	as defined in Annex D, Table D.1
L	see clause 6.3.5
C1	Stray capacitance < 5 pF
C3	27 pF
C4	10 nF
N1, N2	N-MOS Transistor with low parasitic capacitance

Figure E.1 — Circuit diagram for Reference VICC for load modulation test

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Annex F
(informative)

Program for evaluation of the spectrum

The following program written in C language gives an example for the calculation of the magnitude of the spectrum from the VICC.

```
/*************************************************************/
/***  This program calculates the fourier coefficients     ***/
/***  of load modulated voltage of a VICC according        ***/
/***  the ISO/IEC 10373-7 Test methods.                    ***/
/***  The coefficient are calculated for the frequency     ***/
/***    Carrier:           13.5600 MHz                     ***/
/***    Subcarrier:        423.75 kHz  / 484.286 kHz       ***/
/***    see #define N_FSUB:   32            28             ***/
/***    Upper sideband:    13.9838 MHz / 14.0443 MHz       ***/
/***    Lower sideband:    13.1363 MHz / 13.0757 MHz       ***/
/*************************************************************/
/*** Input:                                                ***/
/***  File in CSV Format containing a table of two         ***/
/***  columns (time and test VCD output voltage vd, clause 7)***/
/***                                                       ***/
/***  data format of input-file:                           ***/
/***  -------------------------                            ***/
/***  - one data-point per line:                           ***/
/***     {time[seconds], sense-coil-voltage[volts])        ***/
/***  - contents in ASCII, no headers                      ***/
/***  - data-points shall be equidistant time              ***/
/***  - minimum sampling rate: 100 MSamples/second         ***/
/***  - modulation waveform centred                        ***/
/***      (max. tolerance: half of subcarrier cycle)       ***/
/***                                                       ***/
/***    "screen-shot of centred modulation-waveform        ***/
/***     with 8 subcarrier cycles":                        ***/
/***                                                       ***/
/***   XXXXXXXXXX  xx  xx  xx  xx  xx  xx  xx  xxXXXXXXXXXX  ***/
/***   XXXXXXXXXX  xx  xx  xx  xx  xx  xx  xx  xxXXXXXXXXXX  ***/
/***   XXXXXXXXXXxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxXXXXXXXXXX  ***/
/***   XXXXXXXXXXxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxXXXXXXXXXX  ***/
/***   XXXXXXXXXXxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxXXXXXXXXXX  ***/
/***   XXXXXXXXXXxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxXXXXXXXXXX  ***/
/***   XXXXXXXXXX  xx  xx  xx  xx  xx  xx  xx  xxXXXXXXXXXX  ***/
/***   XXXXXXXXXX  xx  xx  xx  xx  xx  xx  xx  xxXXXXXXXXXX  ***/
/***    |-----------------------cc-----------------------|   ***/
/***  example for spreadsheet file (start in next line):   ***/
/***   (time)      (voltage)                               ***/
/***  3.00000e-06 , 1.00                                   ***/
/***  3.00200e-06 , 1.01                                   ***/
/***  .....                                                ***/
/*************************************************************/
/*** RUN: Modtst7 [filename1[.csv] ... filename[.csv] ]    ***/
/*************************************************************/
#include <stdio.h>
#include <conio.h>
#include <string.h>
#include <math.h>
#define MAX_SAMPLES 5000
#define N_FSUB 32.0F    /* sidebands: 13.9838 MHz / 13.1363 MHz */
/* #define N_FSUB 28.0F /* sidebands: 14.0443 MHz / 13.0757 MHz */
float  pi;   /* pi=3.14.... */

/* Array for time and sense coil voltage vd*/
float vtime[MAX_SAMPLES]; /* time array  */
float vd[MAX_SAMPLES];    /* Array for different coil voltage */
```


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```
/*************************************************************/
/***    Read CSV File  Function                            ***/
/***                                                       ***/
/***    Description:                                       ***/
/***    This function reads the table of time and sense coil ***/
/***    voltage from a File in CSV Format                  ***/
/***                                                       ***/
/***    Input: filename                                    ***/
/***                                                       ***/
/***    Return: Number of samples  (sample Count)          ***/
/***            0  if an error occurred                    ***/
/***                                                       ***/
/***    Displays Statistics:                               ***/
/***                                                       ***/
/***    Filename, SampleCount, Sample rate, Max/Min Voltage  ***/
/*************************************************************/
int readcsv(char* fname)
{
   float a,b;
   float max_vd,min_vd;
   int i;
   FILE     *sample_file;

   /************ Open File **********************************/
   if (!strchr(fname, '.'))   strcat(fname, ".csv");

   if ((sample_file = fopen(fname, "r")) == NULL)
      {
      printf("Cannot open input file %s.\n",fname);
      return 0;
      }
   /*************************************************************/
   /* Read CSV File                                             */
   /*************************************************************/
   max_vd=-1e-9F;
   min_vd=-max_vd;
   i=0;

   while (!feof(sample_file))
      {
      if (i>=MAX_SAMPLES)
      {
          printf("Warning: File truncated !!!\n");
          printf("To much samples in file %s\b\n",fname);
          break;
      }
      fscanf(sample_file,"%f,%f\n", &a, &b);
      vtime[i] = a;
      vd[i] = b;
      if (vd[i]>max_vd) max_vd=vd[i];
      if (vd[i]<min_vd) min_vd=vd[i];
      i++;
      }
   fclose(sample_file);

   /************ Displays Statistics  ***********************/
   printf("\n*********************************************\n");
   printf("\nStatistics: \n");
   printf(" Filename    : %s\n",fname);
   printf(" Sample count: %d\n",i);
   printf(" Sample rate : %1.0f MHz\n",1e-6/(vtime[1]-vtime[0]));
   printf(" Max(vd)     : %4.0f mV\n",max_vd*1000);
   printf(" Min(vd)     : %4.0f mV\n",min_vd*1000);

   return i;
}/*************** End ReadCsv **************/
```

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```
/*************************************************************/
/***    DFT : Discrete Fourier Transform                   ***/
/*************************************************************/
/***    Description:                                       ***/
/***    This function calculate the Fourier coefficient    ***/
/***                                                       ***/
/***    Input: Number of samples                           ***/
/***    Global Variables:                                  ***/
/***                                                       ***/
/***    Displays Results:                                  ***/
/***                                                       ***/
/***     Carrier coefficient                               ***/
/***     Upper sideband coefficient                        ***/
/***     Lower sideband coefficient                        ***/
/***                                                       ***/
/*************************************************************/

void dft(int count)
{
   float c0_real,c0_imag,c0_abs,c0_phase;
   float c1_real,c1_imag,c1_abs,c1_phase;
   float c2_real,c2_imag,c2_abs,c2_phase;
   int   N_data,center,start,end;
   float w0,wu,wl;

   int i;

   w0=(float)(13.56e6*2.0)*pi;  /* carrier        13.56 MHz */
   wu=(float)(1.0+1.0/N_FSUB)*w0; /* upper sideband 13.98 MHz */
   wl=(float)(1.0-1.0/N_FSUB)*w0; /* lower sideband 13.14 MHz */

   c0_real=0;  /* real part of the carrier fourier coefficient */
   c0_imag=0;  /* imag part of the carrier fourier coefficient */
   c1_real=0;  /* real part of the up. sideband fourier coefficient */
   c1_imag=0;  /* imag part of the up. sideband fourier coefficient */
   c2_real=0;  /* real part of the lo. sideband fourier coefficient */
   c2_imag=0;  /* imag part of the lo. sideband fourier coefficient */

   center=(count+1)/2; /*  center address */

   /********** signal selection  ****************************/

   /*   Number of samples for two subcarrier periods  */

   N_data=(int)(0.5+2.0*N_FSUB/(vtime[2]-vtime[1])/13.56e6F);
          /* Note: (vtime[2]-vtime[1]) are the scope sample rate */

   start=center-(int)(N_data/2.0+0.5);
   end=start+N_data-1;

   /*******************    DFT ********************************/
   for( i=start;i<=end;i++)
      {
      c0_real=c0_real+vd[i]*(float)cos(w0*vtime[i]);
      c0_imag=c0_imag+vd[i]*(float)sin(w0*vtime[i]);
      c1_real=c1_real+vd[i]*(float)cos(wu*vtime[i]);
      c1_imag=c1_imag+vd[i]*(float)sin(wu*vtime[i]);
      c2_real=c2_real+vd[i]*(float)cos(wl*vtime[i]);
      c2_imag=c2_imag+vd[i]*(float)sin(wl*vtime[i]);
      }

   /*******************    DFT scale ***************************/
   c0_real=2.0F*c0_real/(float)(N_data);
   c0_imag=2.0F*c0_imag/(float)(N_data);
   c1_real=2.0F*c1_real/(float)(N_data);
   c1_imag=2.0F*c1_imag/(float)(N_data);
   c2_real=2.0F*c2_real/(float)(N_data);
   c2_imag=2.0F*c2_imag/(float)(N_data);
```


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```
   /*************** absolute fourier coefficient     **********/
   c0_abs=(float)sqrt(c0_real*c0_real + c0_imag*c0_imag);
   c1_abs=(float)sqrt(c1_real*c1_real + c1_imag*c1_imag);
   c2_abs=(float)sqrt(c2_real*c2_real+c2_imag*c2_imag);

   /**************    Phase of fourier coefficient    **********/
   c0_phase=(float)atan2(c0_imag,c0_real);
   c1_phase=(float)atan2(c1_imag,c1_real);
   c2_phase=(float)atan2(c2_imag,c2_real);

   /**************  Result Display    *************************/
   printf("\n\nResults: \n");

   printf("Carrier        ");
   printf("Abs: %7.3fmV  ",1000*c0_abs);
   printf("Phase: %3.0fdeg\n",c0_phase/pi*180);

   printf("Upper sideband ");
   printf("Abs: %7.3fmV  ",1000*c1_abs);
   printf("Phase: %3.0fdeg\n",c1_phase/pi*180);

   printf("Lower sideband ");
   printf("Abs: %7.3fmV  ",1000*c2_abs);
   printf("Phase: %3.0fdeg\n\n",c2_phase/pi*180);
   printf("\n*********************************************\n");
   return;
}/*************** End DFT **************/


/************************************************************/
/***    MAIN  LOOP                                        ***/
/************************************************************/
int main(unsigned short paramCount,char *paramList[])
{
   char fname[256];
   unsigned int  i,sample_count;
   pi = (float)atan(1)*4; /* calculate pi */

   printf("\n*********************************************\n");
   printf("\n****  ISO/IEC 10373-7 VICC Test-Program    ****\n");
   printf("\n****  Version: 1.1     JUL 2000            ****\n");
   printf("\n*********************************************\n");

   /************* No Input Parameter           ****************/
   if (paramCount==1)
      {
      printf("\nCSV File name :");
      scanf("%s",fname);
      if (!strchr(fname, '.'))   strcat(fname, ".csv");
      if (!(sample_count=readcsv(fname))) return;

      dft(sample_count);
      }
   else
      {
      /************* Input Parameter Loop     ****************/
      for (i=1;i<paramCount;i++)
         {
         strcpy(fname,paramList[i]);

         if (!strchr(fname, '.'))   strcat(fname, ".csv");
         if (!(sample_count=readcsv(fname))) break;
         dft(sample_count);
         }
      }
   return;
}/********************** End Main  *************************/
```

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