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# INTERNATIONAL STANDARD

colour inside

## EMC IC modelling –
## Part 1: General modelling framework



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# EMC IC MODELLING –

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## FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 62433-1 has been prepared by subcommittee 47A: Integrated circuits, of IEC technical committee 47: Semiconductor devices.

IEC 62433-1 cancels and replaces IEC TS 62433-1 published in 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC TS 62433 1:2011:

Incorporation of a data exchange format for an integrated circuit's model representation.

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

| CDV | Report on voting |
|---|---|
| 47A/1042/CDV | 47A/1055/RVC |

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 62433 series, under the general title *EMC IC modelling*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.



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# EMC IC MODELLING –

# Part 1: General modelling framework

## 1 Scope

This part of IEC 62433 specifies the framework and methodology for EMC IC macro-modelling. Terms that are commonly used in IEC 62433 (all parts), different modelling approaches, requirements and data-exchange format for each model category that is standardized in this series are defined in this document.

## 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 62433 (all parts), *EMC IC modelling*



ISO 8879, *Information processing – Text and office systems – Standard Generalized Markup Language (SGML)*



ANSI INCITS 4:1986, *Information Systems – Coded Character Sets – 7-Bit American National Standard Code for Information Interchange (7-Bit ASCII)*



## 3 Terms, definitions, abbreviated terms and conventions

### 3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

**3.1.1**
**ICEM-CE**
Integrated Circuit Emission Model – Conducted Emissions
macro-model of an integrated circuit (IC) to simulate the conducted electromagnetic emissions

Note 1 to entry: An ICEM-CE macro-model can be used for modelling an IC-die, a functional block and an Intellectual Property (IP) block.

**3.1.2**
**ICEM-RE**
Integrated Circuit Emission Model – Radiated Emissions
macro-model of an integrated circuit (IC) to simulate the radiated electromagnetic emissions

**3.1.3**
**ICIM-CI**
Integrated Circuit Immunity Model – Conducted Immunity
macro-model of an integrated circuit (IC) to simulate the susceptibility levels of the IC to conducted disturbances applied on the IC pins

**3.1.4**
**ICIM-RI**
Integrated Circuit Immunity Model – Radiated Immunity
macro-model of an integrated circuit (IC) to simulate the susceptibility levels of the IC to external radiated disturbances

**3.1.5**
**ICIM-CPI**
Integrated Circuit Immunity Model – Conducted Pulse Immunity
macro-model of an integrated circuit (IC) to simulate the susceptibility levels of the IC to conducted pulse disturbances applied on the IC pins

**3.1.6**
**IA**
Internal Activity
component of an IC model represented by a current or voltage source, which originates in activity of active devices in an IC or in a portion of the IC

Note 1 to entry: The component is applicable for both analogue and digital circuitry.



**3.1.7**
**IB**
Immunity Behaviour
block that describes the internal immunity behaviour of the IC



**3.1.8**
**FB**
Failure Behaviour
block that describes the internal failure behaviour of the IC

**3.1.9**
**PDN**
Passive Distribution Network
component of an IC model that represents the characteristics of propagation path of electromagnetic noises such as power distribution network

Note 1 to entry: The propagation path can be represented either as an electrical network or as an equivalent network of electromagnetic sources such as electric and magnetic dipoles.

**3.1.10**
**NLB**
Non-Linear Block
component of the IC model that represents the non-linear characteristics of the propagation path of the electromagnetic noises such as power distribution network

EXAMPLE ESD diodes, clamping diodes, back-to-back diodes.

**3.1.11**
**IBC**
Inter-Block Coupling
network of passive elements that presents a coupling effect between circuit blocks within an IC

**3.1.12**
**DI**
Disturbance Input
input terminal for the injection of RF and transient disturbances

Note 1 to entry: It could be any pin of IC, an input, supply or an output.

**3.1.13**
**DO**
Disturbance Output
terminal whose load influences the impedance of DI terminal, and/or the transfer characteristics of PDN, and that outputs a part of the disturbance received on the DI terminals

**3.1.14**
**OO**
Observable Output
output terminal where the immunity criteria are monitored during the test

**3.1.15**
**section**
XML element placed one level below the root element or within another section and that contains one or more XML elements, but no value

**3.1.16**
**parent**
keyword which is one level above another keyword



**3.1.17**
**child**
keyword which is one level below another keyword



**3.1.18**
**parser**
tool for syntactic analysis of data that is encoded in a specified format

**3.1.19**
**S-parameter**
scattering parameter
$S_{ij}$
element of the S-matrix expressing the transmission and reflection coefficients of a device

Note 1 to entry: As most commonly used, each S-parameter relates the complex electric field strength of a reflected or transmitted wave to that of an incident wave; the subscripts of a typical S-parameter $S_{ij}$ refer to the output and input ports related by the S-parameter, which may vary with frequency.

[SOURCE: CISPR 17:2011, 3.1.13, modified – The example has been removed.]

**3.1.20**
**IC_EMCML**
Integrated Circuit ElectroMagnetic Compatibility Markup Language
data exchange format for EMC IC model description

**3.1.21**
**CEML**
Conducted Emissions Markup Language
data exchange format for conducted emissions macro-model

**3.1.22**
**REML**
Radiated Emissions Markup Language
data exchange format for radiated emissions macro-model

**3.1.23**
**CIML**
Conducted Immunity Markup Language
data exchange format for conducted immunity macro-model

**3.1.24**
**RIML**
Radiated Immunity Markup Language
data exchange format for radiated immunity emissions macro-model

**3.1.25**
**CPIML**
Conducted Pulse Immunity Markup Language
data exchange format for conducted pulse immunity macro-model

**3.1.26**
**CEMLBase**
Conducted Emissions Markup Language Base
abstract type from which all CEML model components are directly or indirectly derived in the conducted emissions macro-model definition



**3.1.27**
**REMLBase**
Radiated Emissions Markup Language Base
abstract type from which all REML model components are directly or indirectly derived in the radiated emissions macro-model definition



**3.1.28**
**CIMLBase**
Conducted Immunity Markup Language Base
abstract type from which all CIML model components are directly or indirectly derived in the conducted immunity macro-model definition

**3.1.29**
**RIMLBase**
Radiated Immunity Markup Language Base
abstract type from which all RIML model components are directly or indirectly derived in the radiated immunity macro-model definition

**3.1.30**
**CPIMLBase**
Conducted Pulse Immunity Markup Language Base
abstract type from which all CPIML model components are directly or indirectly derived in the conducted pulse immunity macro-model definition

## 3.2 Abbreviated terms

**3.2.1**
**XML**
eXtensible Markup Language
markup language that defines a set of rules for encoding data or files in a format that is both human-readable and machine-readable

**3.2.2**
**SPICE**
Simulation Program with Integrated Circuit Emphasis
general purpose analogue and mixed signal circuit simulator

### 3.3 Conventions

For the sake of clarity, but with some exceptions, the writing conventions of XML have been used within the text and tables. The following print types are used throughout this standard:

– XML keywords are defined in *Italics*

– The symbol "μ" is used in the text part to define micro = 1e-6. The symbol "u" is used in the XML parts to define the micro = 1e-6.

## 4 Definition of models

### 4.1 General

Different categories of EMC IC models are defined in IEC 62433 (all parts). IC models that are built in conformity with these guidelines can be applied to simulations for EMC. The models can be used for EMI (Electromagnetic Interference) and/or EMS (Electromagnetic Susceptibility) evaluation of electronic systems.

Each model is presented in a separate part of the IEC 62433 series and classified in one of the following categories (see 4.2 to 4.6 included).



### 4.2 Conducted emission model

A conducted emission (CE) model is a macro-model which describes an Integrated Circuit (IC) or multiple dies in a package or module (System in Package, SiP) as a source of conducted RF disturbances.



A CE model shall be described as a multi-terminal or a multi-port circuit which can be linear or nonlinear. Each CE model consists of internal activities (IAs) as noise sources and passive distribution networks (PDNs) which express characteristics of internal circuits in the form of a black box and/or an equivalent circuit. The model can also include sub-models of inter-block coupling (IBC).

The model describes RF disturbances at external terminals of an IC as voltage and/or current which are generated by its internal operations.

The model is described in CEML format.

### 4.3 Radiated emission model

A radiated emission (RE) model is a macro-model which describes radiated RF disturbances generated by an integrated circuit (IC) or multiple dies in a package or module (System in Package, SiP).

A RE model shall be described as equivalent sources of electric or magnetic fields, which cause near-field coupling or far-field radiation, or an equivalent circuit which express electric or magnetic coupling between the IC or dies and external circuits or enclosures. Each RE model consists of internal activities (IAs) as noise sources and passive distribution network (PDNs) that define the radiating elements (as equivalent antennas) of the internal circuits in the form of a black box.

The model is described in REML format.

### 4.4 Conducted immunity model

A conducted immunity (CI) model is a macro-model which describes an Integrated Circuit (IC) or multiple dies in a package or module (System in Package, SiP) as a victim of conducted RF disturbances applied from outside.

A CI model shall be described as a multi-terminal or a multi-port circuit in a form of a black box and/or an equivalent circuit which can be linear or nonlinear. Each CI model consists of immunity behavior (IBs) blocks that define the susceptibility of the IC and passive distribution networks (PDNs) that define the characteristics of the noise propagation path. The model can also include sub-models of inter-block coupling (IBC).

A CI model provides measures or criteria of malfunctions caused by RF disturbances injected at external terminals as voltage, current, or RF power.

The model is described in CIML format.

### 4.5 Radiated immunity model

A radiated immunity (RI) model is a macro-model which describes an Integrated Circuit (IC) or multiple dies in a package or module (System in Package, SiP) as a victim of radiated RF disturbances from outside.

An RI model provides measures or criteria of malfunctions caused by RF disturbances applied as electric or magnetic fields in near-field or electromagnetic field.



An RI model is described as equivalent circuits which can express electric or magnetic coupling between the IC or dies and external circuits or enclosures caused due to external field coupling. A description of the different components of the model will be elaborated in the future.



The model is described in RIML format.

### 4.6 Conducted pulse immunity model

A conducted pulse immunity (CPI) model is a macro-model which describes an Integrated Circuit (IC) or multiple dies in a package or module (System in Package, SiP) as a victim of conducted pulse or transient disturbances from outside.

A CPI model provides measures or criteria of malfunctions caused by pulse or transient disturbances applied on IC pins. Each CPI model consists of failure behavior (FBs) blocks that define the susceptibility of the IC and pulse propagation networks (PPNs) that define the characteristics of the noise propagation path. The PPNs consist of the linear passive distribution networks (PDNs) and the non-linear blocks (NLBs). The model can also include sub-models of inter-block coupling (IBC).

The model is described in CPIML format.

## 5 Modelling approaches

### 5.1 General

Description of an EMC IC model, such as equivalent circuit parameters, can be derived from design data of the device, or extracted from data obtained by measurement. Each of the models shall contain information of an internal integrated circuit (IC) or multiple dies as well as that of a package.

A conducted emission (CE) or conducted immunity (CI) or conducted pulse immunity (CPI) model can be expressed in either a form of a black box model, or an equivalent circuit model. A model shall be expressed with a circuit concept including terminals and/or nodes.

A radiated emission (RE) or radiated immunity (RI) model can be expressed with either an electromagnetic model or an equivalent circuit model. An electromagnetic RE model expresses near field or far field which causes electromagnetic interference (EMI). An electromagnetic RI model expresses electromagnetic coupling induced in the device. An equivalent circuit model for RE/RI describes electric or magnetic coupling with capacitive or inductive circuit elements. The equivalent circuit model for RE/RI can include a black box model as a sub-model.

Clauses 5.2 to 5.4 describe modelling approaches for each possible expression of a model. Some of the expressions can be combined and used in one model.

### 5.2 Black box modelling approach

The expression of a black box model is essentially an *N*-port circuit, whose characteristics are expressed in a matrix form or with some circuit equations. When a black box model is used to express a CE or RE model, some voltage and/or current sources are connected to the black box as noise sources to express the internal activity (IA). The following expressions are possible for black box models.

For a linear circuit, or a circuit which can be approximated as linear, the following parameters can be used; these parameters are expressed as functions of frequency, and time-variant or non-linear elements are not considered.



- impedance (Z) parameter;
- admittance (Y) parameter;
- fundamental (F) parameter;
- scattering (S) parameter.

Elements of a matrix can be expressed with formulas with some parameters, or tables which express frequency characteristics of the circuit.

In the definition of a model, internal terminals/ports and external terminals/ports shall be distinguished and defined clearly in the matrix expression.

Characteristics of a distributed constant circuit, such as transmission lines, can be expressed with a scattering (S) matrix as a multi-port circuit. For these circuits, definition of ports and their locations shall be described with port impedance for each. Particularly when a differential port is used, it is desirable to define a common-mode port as a counterpart of a differential signal port.

### 5.3 Equivalent circuit modelling approach

Equivalent circuit models, both lumped element circuits and distributed constant circuits, can be used to express electrical characteristics of CE/CI and RE/RI models. In the circuit expression, non-linear circuits can be included as well as linear circuits.

A linear circuit which is described with a black box model, or a matrix model, may be converted to an equivalent circuit model. Particularly when a model is constructed by measurement, characteristics of the circuit are first expressed in a matrix form, and then converted to an equivalent circuit.

Some of non-linear characteristics of a device can be obtained by measurement and can be included in an equivalent circuit model. Additionally, model simplification is possible using a complex circuit model and generating information of the circuit by simulation.