IMMUNITY MODELING OF INTEGRATED CIRCUITS - REVIEW AND APPLICATION USAGE

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OUTLINE

- Introduction
- ICIM-CI Model structure and its extraction
- Immunity analysis on a Capacitive sensor application
- Conclusion and perspectives
INTRODUCTION
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- During immunity testing, the disturbance propagates and a portion finally reaches the IC.

- This level can be enough to produce malfunction / disturbance effects.

- Based on a complete simulation toolbox (including the modeling of the test method / PCB / filters / IC...), one can predict the EMC performance of its application and interact with the design efficiently.
ICIM-CI MODEL STRUCTURE AND ITS EXTRACTION
**ICIM-CI MODEL STRUCTURE AND ITS EXTRACTION – 62433-4**

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**PDN** – Based on S matrix representation –
- Extraction using VNA
- Linearity assumption

**IB** - Transmitted Power criteria on each access.
- Transmitted power evaluation
- Assumption on transmitted power criteria

*PDN : Passive Distribution Network*

*IB: Internal Behavioural model*
ICIM-CI MODEL STRUCTURE AND ITS EXTRACTION

- Failure criteria definition (based on system level requirements)
- DPI characterization (For each pins considered significant for immunity evaluation and accessible in the system)
- S-parameters extraction (With a VNA, port power lower than the lowest DPI result by 10 dB min)

→ Generic test board usage
  - Component functional supply
  - Functional signal extraction
  - DPI characterization
  - S parameters measurement

DPI: Direct Power Injection

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ICIM-CI MODEL STRUCTURE AND ITS EXTRACTION

- **DPI characterization**
  (For each pins considered significant for immunity evaluation and accessible in the system)

- **Failure criteria definition**
  (based on system level requirements)

- **S-parameters extraction**
  (With a VNA, port power lower than the lowest DPI result by 10 dB min)

- **Validation of transfer function validity**
  (with high power injection to confirm the linearity hypothesis)

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**74HCT14 Example**

- Spice modeling of the DPI test set-up
  (IC Modeling from S parameter transformed into a Spice model by IdeM, simulation of transfer functions)

- **Measurement Simulation**

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- **S21 (dB)**

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*Image of circuit diagram and graph with measurement and simulation data.*

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*References and further details on the process are not provided in the image.*
ICIM-CI MODEL STRUCTURE AND ITS EXTRACTION

- Failure criteria definition (based on system level requirements)
- DPI characterization (For each pins considered significant for immunity evaluation and accessible in the system)
- S-parameters extraction (With a VNA, port power lower than the lowest DPI result by 10 dB min)
- Validation of transfer function validity (with high power injection to confirm the linearity hypothesis)
- Transmitted Power extraction And Validation

**Transmitted Power Threshold**

**Add 10 nF**

**Add 100 pF**

**DPI Result**

**Max Experiment Power**

**Simulation**

**Measure**

**Simulation**

**Measure**
ICIM-CI MODEL STRUCTURE AND ITS EXTRACTION

- An interesting simple example

PARAMETERS:

« Expected » Good impact Of the capacitor

Negative impact Of the capacitor !!!
IMMUNITY ANALYSIS ON A CAPACITIVE SENSOR APPLICATION
INTRODUCTION OF THE APPLICATION – BASED ON CAPACITIVE SENSOR FUNCTION

**Interior Lighting**
- Ambient lighting
- Intuitive lighting
- Power outlets & Cigar lighters
IMMUNITY ANALYSIS ON A CAPACITIVE SENSOR APPLICATION

System architecture & functioning

1. User Request
2. µC Detection
3. µC Request
4. Light Activation
IMMUNITY ANALYSIS ON A CAPACITIVE SENSOR APPLICATION

Schematic

Capacitive detection

μC command
Failure in BCI test results

Right Sample - ON mode - 15cm injection

26 to 39Mhz
IMMUNITY ANALYSIS ON A CAPACITIVE SENSOR APPLICATION

DPI Test results and post processing to generate the ICIM-CI Model

Criteria 1: when injected power is increased and then switched ON/OFF
Criteria 2: when during constant application of the disturbance

Evaluation of maximum Voltage at The IC input producing a defect And related to the DPI injection level
EMC Pspice Simulation:

- Injected current and common mode voltage (Efield)
EMC Pspice Simulation:

Common mode voltage is maximum at 35 MHz. At this frequency Efield is maximum and directly couple on the electrode = E field sensor

The coupling efficiency depends on the electrode
IMMUNITY ANALYSIS ON A CAPACITIVE SENSOR APPLICATION

Initial configuration

With a 10 pF cap as solution
IMMUNITY ANALYSIS ON A CAPACITIVE SENSOR APPLICATION

BCI final results with implemented solution

**Right Sample - ON mode - 15cm injection**

<table>
<thead>
<tr>
<th>15cm</th>
<th>45cm</th>
<th>75cm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ON</strong></td>
<td><strong>OFF</strong></td>
<td><strong>ON</strong></td>
</tr>
<tr>
<td>Ref</td>
<td>C1 KO</td>
<td>C1 KO</td>
</tr>
<tr>
<td>Modif</td>
<td>C2</td>
<td>C2</td>
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</tbody>
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CONCLUSIONS AND PERSPECTIVES
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- ICIM-CI is now a standardized model (62433-4)

- It can be efficiently used to:
  - Investigate and give orientation during debug / testing
  - Anticipate risks and interact with the design of a product

- Commonly used in Valeo with a large number of application and use cases
  (More than 100 models developed and successfully used)

- Next steps:
  - Model is extracted currently up to 2 / 3 GHz – Extension of the frequency range is a need:
    - Identification of efficient immunity techniques (DPI)
    - S parameters measurements techniques to be defined