

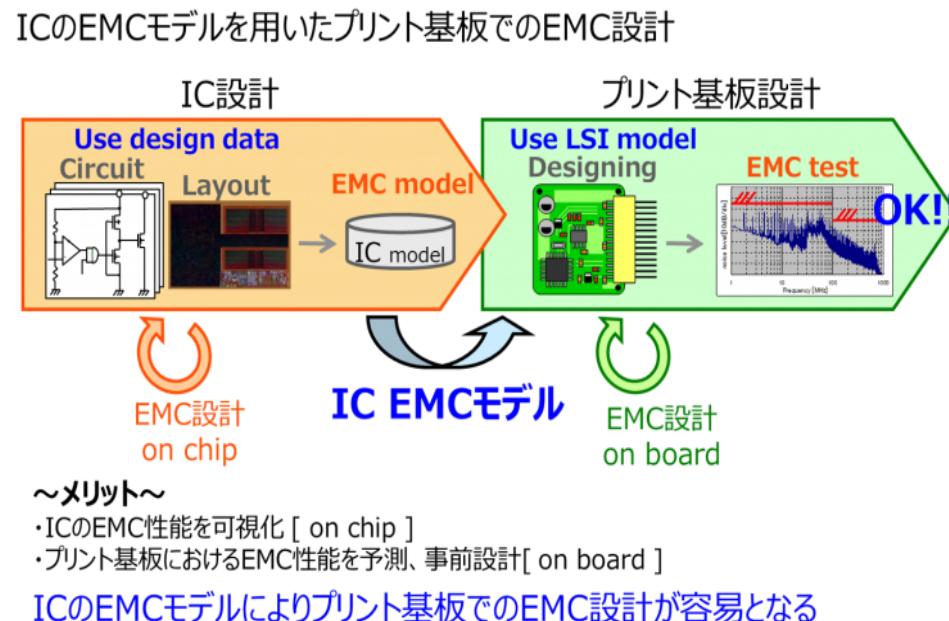
IEC 62433の活用に関するディスカッション
～IEC 62433 関連文献調査
IEC 62433-6について
モデルベースデザイン・システムWG

弘前大学 金本 俊幾



IEC 62433 とは

- 電磁両立性(EMC: Electromagnetic Compatibility)検証に関する
IC (Integrated Circuit) モデリングの国際電気標準会議(IEC)規格



IEC 62433 とは

- 電磁両立性(EMC: Electromagnetic Compatibility)検証に関する
IC (Integrated Circuit) モデリングの国際電気標準会議(IEC)規格
- ICEM(Integrated Circuit Emission Model):
Models of integrated circuits for EMI behavioral simulation
 - ✓他の機器に電磁妨害(EMI : Electro Magnetic Interference)を与えない
- IEC 62433-2 : Conducted Emissions modelling (**ICEM-CE**)
- IEC 62433-3 : Radiated Emissions modelling (**ICEM-RE**)

IEC 62433 とは

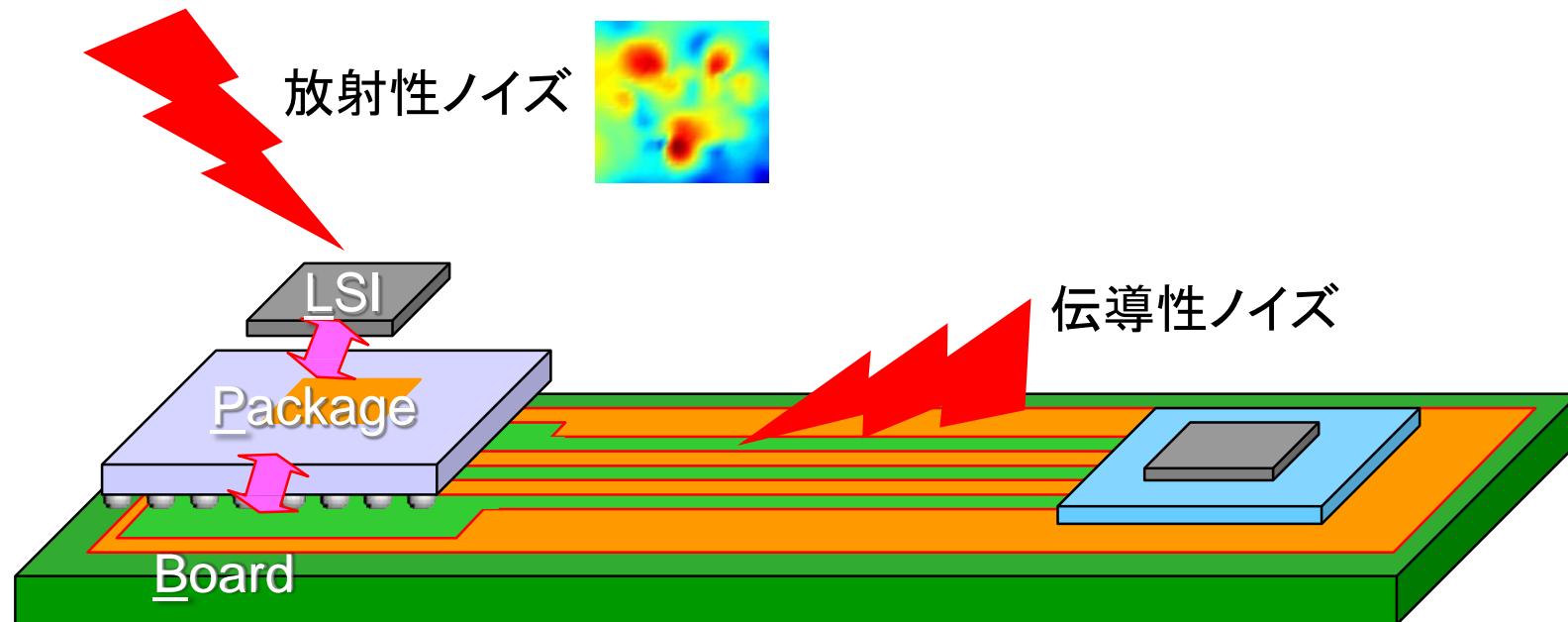
- 電磁両立性(EMC: Electromagnetic Compatibility) 検証に関する
IC (Integrated Circuit) モデリングの国際電気標準会議(IEC)規格
- ICIM(Integrated Circuit Immunity Model):
Models of integrated circuits for RF immunity behavioral simulation
- ✓ 電磁妨害を受けても正常動作(EMS : Electro Magnetic Susceptibility)
IEC 62433-4 : Conducted Immunity modelling (**ICIM-CI**)
IEC 62433-5 : Radiated Immunity modelling (**ICIM-RI**) →未提案

IEC 62433 とは

- 電磁両立性(EMC: Electromagnetic Compatibility) 検証に関する
IC (Integrated Circuit) モデリングの国際電気標準会議(IEC)規格
- ICIM(Integrated Circuit Immunity Model):
Models of integrated circuits for RF immunity behavioral simulation
- ✓ 電磁妨害を受けても正常動作(EMS : Electro Magnetic Susceptibility)
IEC 62433-6 : Conducted Pulse Immunity modelling (ICIM-CPI)

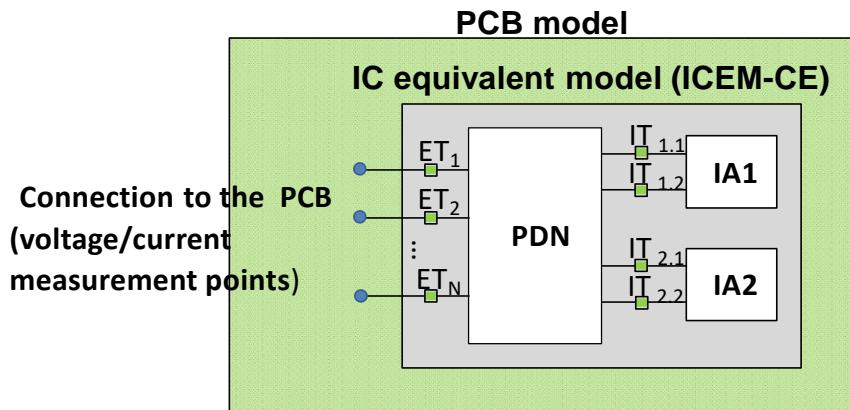
ICEM Models of integrated circuits for EMI behavioral simulation

- 目的: ICの伝導性および放射性ノイズ放出をモデル化すること
→他の機器に電磁妨害を与えない(許容範囲)ことを検証



IEC 62433-2 (ICEM-CE)

- 目的: ICの伝導性ノイズ放出をモデル化すること
- 概要: ICを以下の要素で表現
 - ✓ IA(Internal Activity): ICの内部動作。時間・周波数領域の電流・電圧源
 - ✓ PDN(Passive Distribution Network): 集中定数、分布定数、Sパラメータ等
 - ✓ IBC(Internal Block Coupling): 異電源間の結合等を表すマクロモデル



Chaimae Ghfiri, André Durier, Alexandre Boyer, Sonia Ben Dhia, Christian Marot.
“Construction of an Integrated Circuit Emission Model of a FPGA.” APEMC, May 2016,
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IEC 62433-2 (ICEM-CE) ~引用文献

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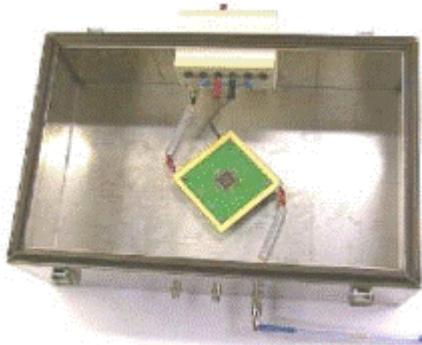
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- [2] T. Quarles, A.R.Newton, D.O.Pederson, A.Sangiovanni-Vincentelli, SPICE3 Version 3f3 User's Manual, Department Electrical Engineering Computer Sciences University of California, 1994 回路シミュレーション
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- [5] POZAR, David M, Microwave engineering, 4th ed, ISBN 978-0-470-63155-3, Wiley, 2011 伝送線路
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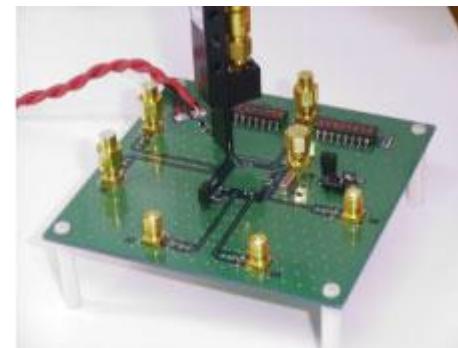
Technical Report

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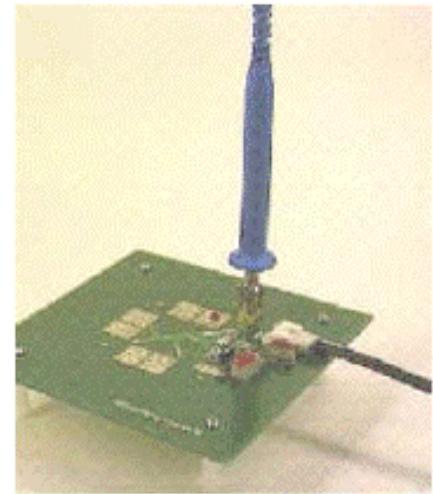
- IEC 61967 (all parts), Integrated Circuits – Measurement of electromagnetic emissions EMI評価方法
IEC 61967-4 Measurement of conducted emissions $1\Omega/150\Omega$ (VDE)法
IEC 61967-5 Measurement of conducted emissions ワークベンチ・ファラデーケージ法
IEC 61967-6 Measurement of conducted emissions マグネティックプローブ法



ワークベンチ・ファラデーケージ法



マグネティックプローブ法



$1\Omega/150\Omega$ (VDE)法

- IEC 62014-1, Electronic design automation libraries – Part 1: Input/output buffer information specifications (IBIS version 3.2)
IEC/TS 62433-1, EMC IC modelling – Part 1: General modelling framework1
IEC/TS 62404, Logic digital integrated circuits – Specification for I/O Interface Model for Integrated Circuit (IMIC version 1.3)

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Ghfiri, A. Durier, A. Boyer and S. Ben Dhia, “A new methodology to extract the ICEM-CE internal activity block of a FPGA,” 2017 International Symposium on Electromagnetic Compatibility – EMC EUROPE, Angers, 2017, pp. 1–6. IAの抽出手法

A. Ramanujan, E. Sicard, A. Boyer, J. Levant, C. Marot and F. Lafon, “Developing a universal exchange format for Integrated Circuit Emission Model – Conducted Emissions,” 2015 10th International Workshop on the Electromagnetic Compatibility of Integrated Circuits (EMC Compo), Edinburgh, 2015, pp. 252–257.

C. Ghfiri, A. Durier, C. Marot, A. Boyer and S. Ben Dhia, “Modeling the internal activity of an FPGA for conducted emission prediction purpose,” 2018 IEEE International Symposium on Electromagnetic Compatibility and 2018 IEEE Asia-Pacific Symposium on Electromagnetic Compatibility (EMC/APEMC), Singapore, 2018, pp. 309–314. IAのモデリング手法

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M. MOIGN, J. LECA, N. Froidevaux, Y. LEDUC and G. JACQUEMOD, “Effect of SSN on signal and power integrity on 32-bit microcontroller : Modeling and correlation,” 2019 15th Conference on Ph.D Research in Microelectronics and Electronics (PRIME), Lausanne, Switzerland, 2019, pp. 193–196.

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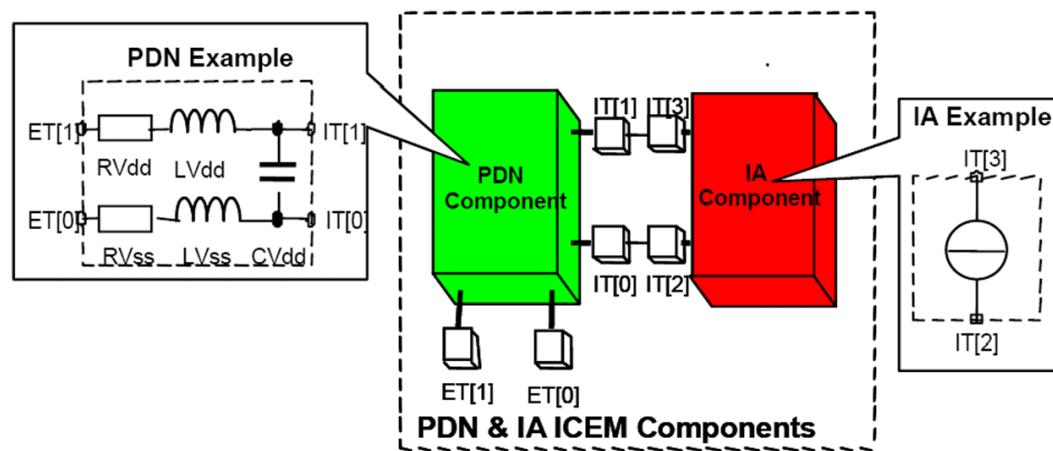
C. Ghfiri, A. Boyer, A. Bensoussan, A. Durier and S. Ben Dhia, “A New Methodology for EMC Prediction of Integrated Circuits After Aging,” in IEEE Transactions on Electromagnetic Compatibility, vol. 61, no. 2, pp. 572–581, April 2019. 経時変化を考慮したモデリング

C. Ghfiri, A. Durier, A. Boyer and S. B. Dhia, “Methodology of modelling of the internal activity of a FPGA for conducted emission prediction purpose,” 2017 11th International Workshop on the Electromagnetic Compatibility of Integrated Circuits (EMCCompo), St. Petersburg, 2017, pp. 21–26. IAのモデリング手法

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IEC 62433-3 (ICEM-RE)

- 目的: ICの放射性ノイズ放出をモデル化すること
- 概要: ICを以下の要素で表現
 - ✓ IA(Internal Activity): 放射のパワー(振幅と位相)を規定。
 - ✓ PDN(Passive Distribution Network): (主にパッケージの)LCで表現したダイポールアンテナの配置



→ 実測 or IEC 63422-2 ベースの抽出

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- [3] F. De-Daran , F. Lafon, and O. Maurice, “Prediction of the Field Radiated at One Meter from PCB's and Microprocessors from Near EM Field Cartography”, in Proc. ICONIC 2003, France, June 2003 同上
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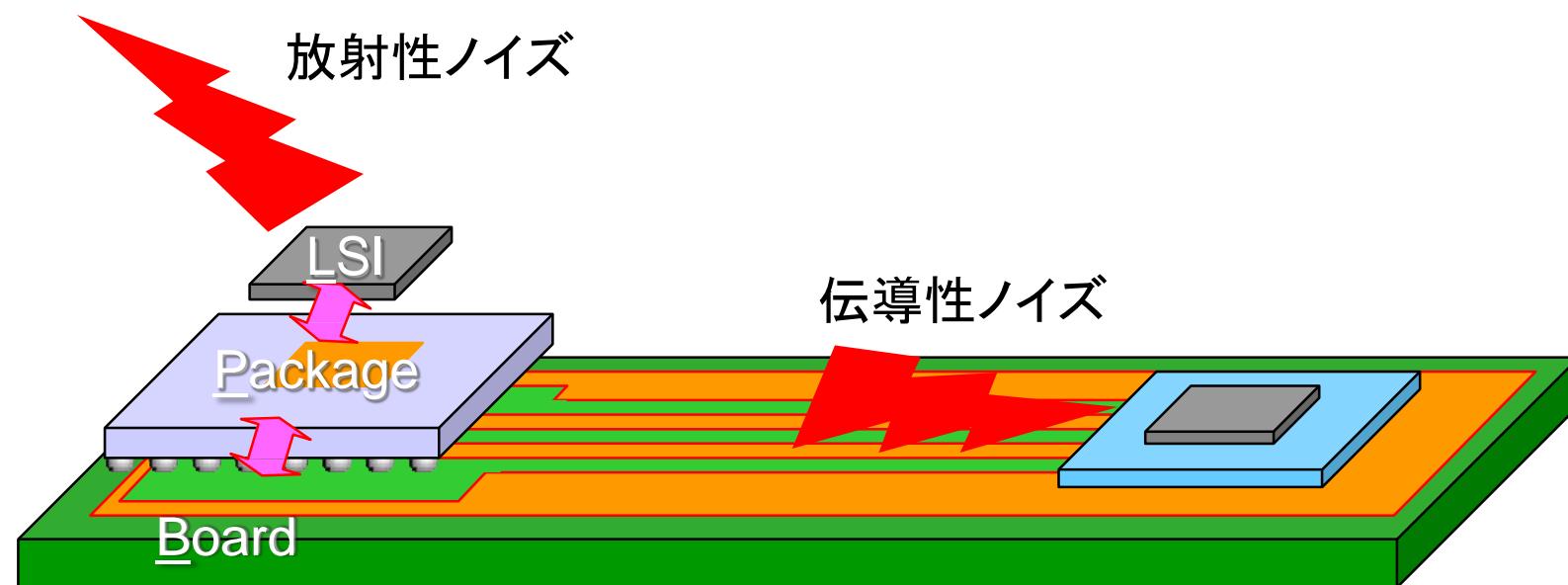
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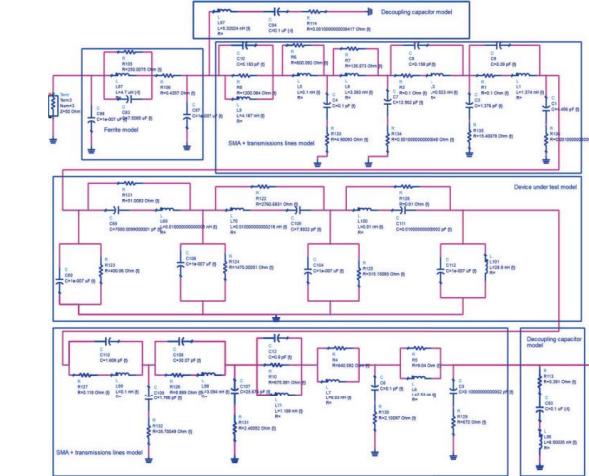
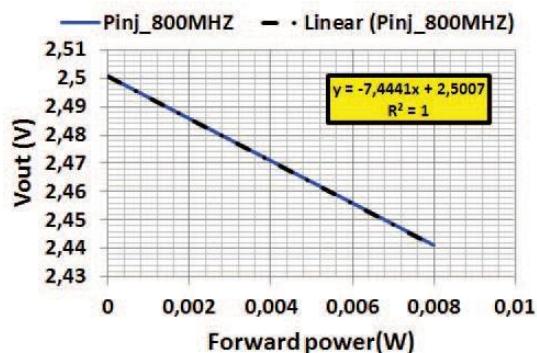
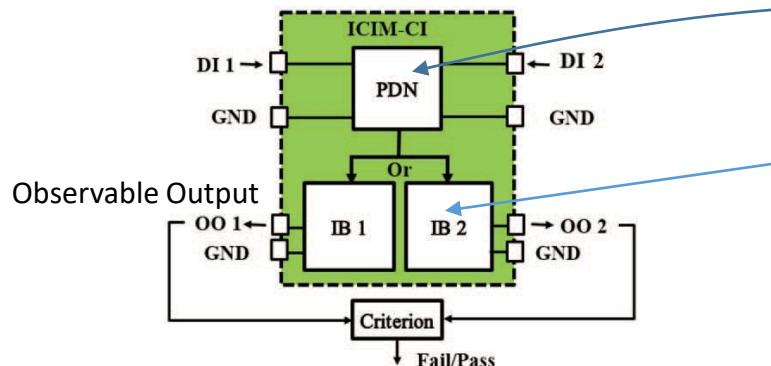
ICIM Models of Integrated Circuits for RF Immunity behavioral simulation

- 目的: ICの伝導性および放射性ノイズ耐性をモデル化すること
→電磁妨害を受けても正常動作することを検証



IEC 62433-4 (ICIM-CI)

- 目的: ICの伝導性ノイズ耐性をモデル化すること
- 概要: ICを以下の要素で表現
 - ✓ IB(Immunity Behaviour): ノイズ印加に対する出力の応答を表す関数
 - ✓ PDN(Passive Distribution Network): 集中定数、分布定数、Sパラメータ等
 - ✓ IBC(Internal Block Coupling): 異電源間の結合等を表すマクロモデル



S. H. Airieau, T. Dubois, G. Duchamp and A. Durier,
"Multiport ICIM-CI modeling approach applied to a
bandgap voltage reference," 2016 International
Symposium on Electromagnetic Compatibility – EMC
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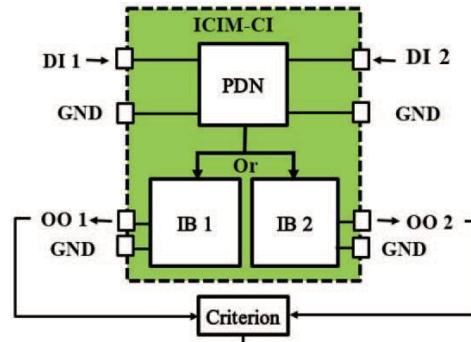


Fig. 1. ICIM - CI model

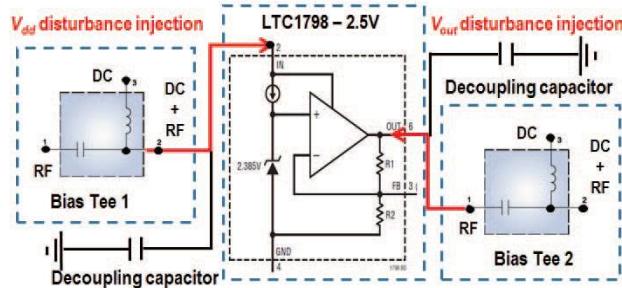
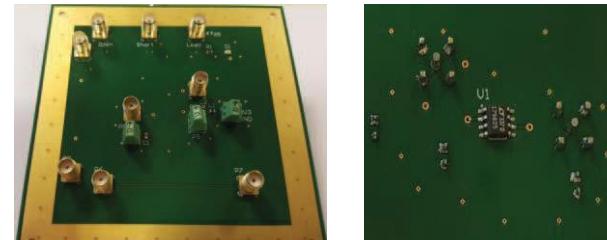


Fig. 3. LTC1798-2.5V block diagram + bias tees



a) Bottom side b) Top side
Fig. 2. ELECIS-V demonstrator

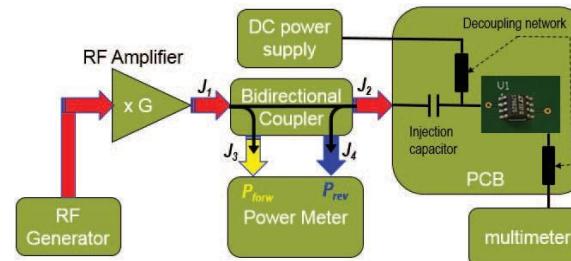


Fig. 4. Illustration of the DPI setup

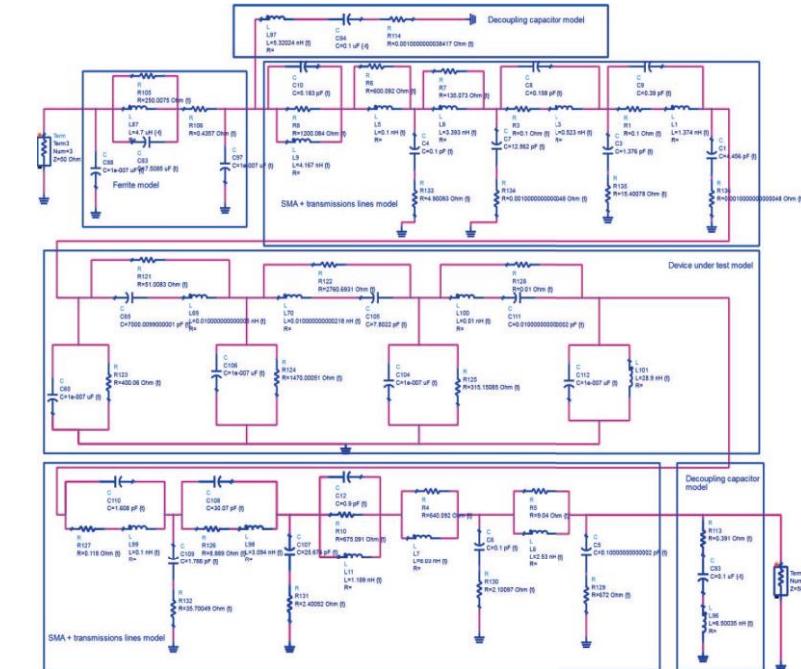


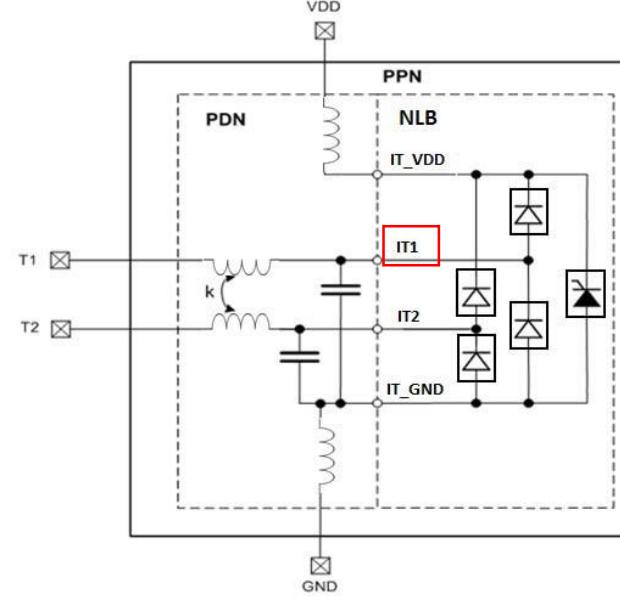
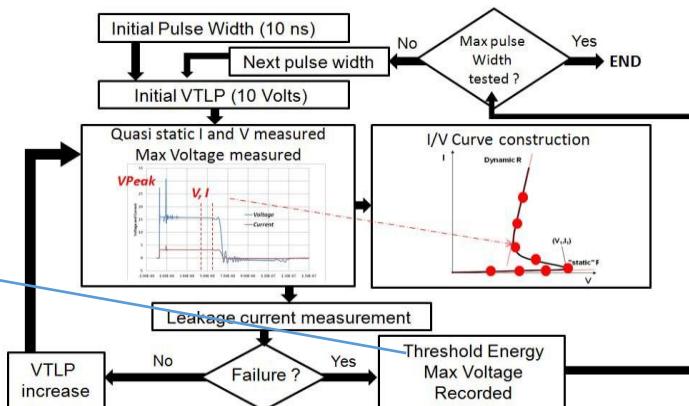
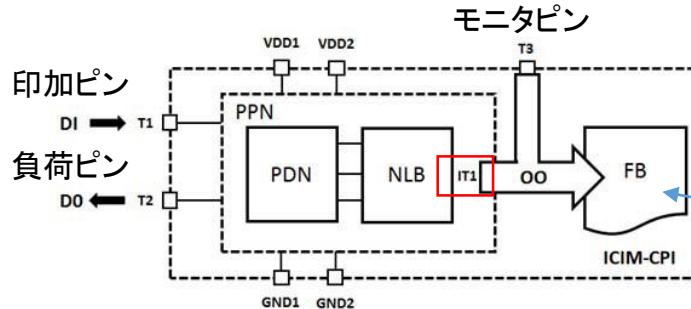
Fig. 11. PDN electrical schematic

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IEC 62433-6 (ICIM-CPI)

- 目的: ICの伝導パルス性ノイズ耐性をモデル化
- 概要: ICを以下の要素で表現 (\uparrow ESD耐性)
 - ✓ FB(Failure Behaviour): ESD印加に対する挙動
 - ✓ PDN(Passive Distribution Network): 集中定数、分布定数、Sパラメータ等
 - ✓ NLB(Nonlinear Block): ESD保護ダイオードなどの非線形形素子回路



PPN: Pulse Propagation Network

A. Durier, JL. Levant, P. Fernandez-Lopez, C. Marot,
 "ICIM-CPI : Integrated circuits immunity model :
 Conducted pulse immunity Description, extraction and
 example" in the 2018 Joint IEEE International Symposium
 on Electromagnetic Compatibility & Asia-Pacific
 Symposium on Electromagnetic Compatibility, Singapore
 May 2018

IEC 62433-6 (ICIM-CPI)

- 目的: ICの伝導パルス性ノイズ耐性をモデル化
- 概要: ICを以下の要素で表現 (\uparrow ESD耐性)
 - ✓ FB(Failure Behaviour): ESD印加に対する挙動
故障のクライテリア
 - Class EIC: 完全故障(ブレークダウン破壊) ← オンチップESD設計の視点
 - Class D1IC: 一時故障。人手介入により復帰
 - Class D2IC: 一時故障。電源再投入により復帰
 - Class CIC: 一時故障。自己復帰

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ICIM-CPI のマイコン事例

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C. M. Somashekaraiah, “Overview of ESD impacts over industry yield: Technical consideration to control ESD during prototype development and production, advanced inspection techniques for ESD failure analysis,” 2016 International Conference on ElectroMagnetic Interference & Compatibility (INCEMIC), Bangalore, 2016, pp. 1–4. ICIM-CPI 相当のマイコン事例