Model Connection Protocol
extensions for Mixed Signal SiP

Taranjit Kukal (kukal@cadence.com)
Dr. Wenliang Dai (wldai@cadence.com)
Brad Brim (bradb@sigrity.com)
assisted by Eiji Fujine Fujitsu VLSI Limited

Presented by: Dr. Wenliang Dai - Cadence
Agenda

- Why Model Connection Protocol
- Model Connection Protocol overview
- Extensions required for Mixed Signal SiP
- MCP Applications
- Summary
Why Model Connection Protocol
- IC/Pkg/Board PDN Co-design

- Design low impedance path: supply to chip

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Why Model Connection Protocol - IC/Pkg/Board PDN Co-design

Chip PDN models can vary from 2-node to N-nodes, where N is the number of physical pins.

There can be 1 to M current sources, where M may be much larger than N.
Why Model Connection Protocol
- IC/Pkg/Board PDN Co-design

- Chip/Package/Board have many physical connections
  - Chip-Package Boundary: 100-6000
  - Package-Board Boundary: 100-3000

- Not all electrical nodes can have per-pin resolution
  - Models may become too large for computation, simulation

- Need way to group pins and auto-connect models across IC/Pkg/Board
MCP Overview

- Establish mapping

Pin grouping and mapping

- physical pin (of layout) to electrical node (of model) per Net
- Mapping to connecting structure using physical location

Example of VDD net across chip-pkg-board
Example of VDD net across chip-pkg-board

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MCP Extensions for Mixed Signal SiP

- Analyze power-delivery to ICs when Package rails supply power to
  - different ICs that could be digital and/or analog
  - RF-modules and Passive/Active SMDs

- Need Schematic driven Mixed Signal Simulations to process IR-drop at power-rails
MCP Extensions for Mixed Signal SiP
-Current MCP scope

Board → Package ← DIE-Digital
MCP Extensions for Mixed Signal SiP

Diagram:
- Board
- Package
- DIE-Analog
- DIE-Digital
- Module (Example RFmodule, SMDs)

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MCP Extensions for Mixed Signal SiP
- Mixed Signal IR-drop Task Flow

Schematic driven Analog

SiP & Circuit Design
Schematic Capture

Pre- & Post-Layout Simulation

Analog IR-drop
(schematic simulation driven)

SiP Layout

Power-RAIL extract

Analog IC Layout

Power-Net Extract

Digital IR-drop

HDL

Digital IC layout

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MCP Extensions for Mixed Signal SiP
- Electrical connectivity of models with disparate pin grouping

- Support for mapping of different electrical port-groups across different structures
  - As an example
    - a package model with 2-by-2 grid-based pin grouping
    - a chip model with 3-by-3 grid-based pin grouping
  - desired is an electrical circuit to interface between an 8 node circuit and an 18 node circuit
MCP Extensions for Mixed Signal SiP

- Optional Column for mapping of electrical nodes across structures

Package: .Subckt bp1 dp1

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Examine the nodes of the each net

- for overlapping pin group domains, the corresponding nodes are shorted together
  - (1,1) node shorts together {(1,1), (1,2), (2,1), (2,2)} nodes
  - (1,2) node shorts together {(1,2), (1,3), (2,2), (2,3)} nodes
  - (2,1) node shorts together {(2,1), (2,2), (3,1), (3,2)} nodes
  - (2,2) node shorts together {(2,2), (2,3), (3,2), (3,3)} nodes

alternately
  - (2,2) node shorts together {(1,1), (1,2), (2,1), (2,2)} nodes

- all nodes are shorted together, reducing to per-net connectivity
  - instead of 8 or 18 node electrical connectivity it is actually 2 node connectivity

Recommendation

- Connecting two disparately pin-grouped models is possible by choosing to short together electrical nodes that have overlapping pin domains
  - but it can reduce the effective resolution of the model at the chip/package interface
  - Useful in case of early debugging and quick connectivity
Extensions over existing MCP

- Support for Modules as connect type structures

- Mixed Signal SiPs would have elements other that ICs like
  - RFmodules
  - Metal Passive structures
  - SMD components
  - Silicon Interposers

- These structure draw power impacting PDN loading and hence we need to support [Module] category besides IC, Package and Board
Extensions over existing MCP
- Support for Modules as connect type structures
In order to connect to structures that are SMD or metal-passive structures on SiP – usually a case for Mixed Signal SiP, it becomes difficult to connect by X-Y locations.

Early analysis may require quick way of stitching the models across structures and minor placement or resolution changes can cause X-Y mapping to fail.

Optional column showing connection by REFDES makes easy mapping for Mixed-Signal modules and early trials

Examples of connecting interfaces could be
- IO-cellname (DIE IO)
- R1:1 (pin 1 of R1)
- CONN:1 (pin1 of PCB connector)
- my_model_opamp:3 (port-3 of opamp subcircuit)
Extensions over existing MCP
- Connection by Refdes besides X-Y location

- Simulating Analog DIE in package schematics with loading from passive structures connected to DIE
- The simulation data is post-processed to obtain IR-drop at power-rails

```
[connection type MODULE]
Pin1  dp1  VDD  5 4
Pin2  dp1  VDD  6 4
Pin3  dp1  VDD  7 4
```

```vdd
varistor1:2 //Reference_design:pin//
varistor2:2
```
MCP applications: Digital DIE IR-drop
- Digital DIE in context of package model

Simulation results of Vdd rail: Dynamic IR-Drop

Without package effects
worst-case IR drop: 147.5mV

With package effects
worst-case IR drop: 179.3mV

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MCP applications: Analog DIE IR-drop
-Analog DIE in context of package model & Digital DIE-models

- Analog DIE test-bench with power-rail model
- Digital DIE model connected to represent loading of power-rail
- Analog DIE IR-drop post simulations

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Summary: MCP format updated in context of Mixed Signal contents

```plaintext
* [MCP Begin]
* [MCP Ver] 1.1
* [Structure Type] {DIE|PKG|PCB}
* [MCP Source] source text
* [Coordinate Unit] unit
* [Connection] connectionName {partName, numberPhysicalPins
* [Connection Type] {DIE|PKG|PCB}
* [Power Nets]
  pinName modelName netName x y
  ...
  pinName modelName netName x y
* [Ground Nets]
  pinName modelName netName x y
  ...
  pinName modelName netName x y
* [Signal Nets]
  pinName modelName netName x y
  ...
  pinName modelName netName x y
* [MCP End]
```

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