An ICM Example Using a Semiconductor Device Package

By

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Agenda

- ICM Status
- BGA Package Structure
- Package Modeling in IBIS 4.x
- A 4.x Package Example
- An ICM 1.0 Example Using a BGA Design
- ICM Advantages
- Areas for Improvement
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- Questions and Free Discussion

ICM Status

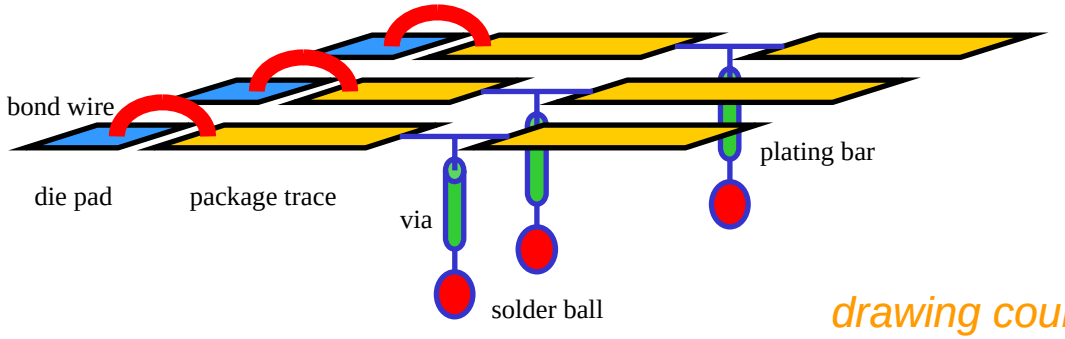
- **ICM = IBIS Interconnect Modeling Specification**
- **Version 1.0 approved September 12, 2003**
- **Final documents posted October 1, 2003:**

  http://www.eda.org/pub/ibis/icm_ver1.0/

- **Development of a parser in progress**
  - **Code about 25% completed**
  - **Alpha test version expected early November**

BGA Package Structure

- **Package modeling: a direct application of ICM…**



drawing courtesy A. Muranyi

- **BGA (Ball Grid Array) Package structure**
  - **Five-part path**
    - **Bond wire (usually gold) – connects die pad to substrate**
    - **Package trace – routing path in substrate**
    - **Via – connects trace to solder ball**
    - **Solder ball – attach point for device to PCB**
    - **Plating par – stub left from separation of packages during manufacturing**

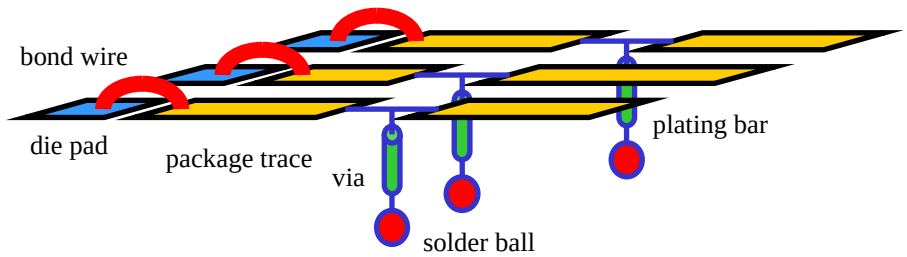
Package modeling in IBIS 4.x

- **[Package] keyword**
  - Required for each component
  - Contains typical (optionally minimum and maximum) values for R_pkg, L_pkg and C_pkg
- **[Pin] keyword**
  - Each pin can have a distinct R_pin, L_pin or C_pin value
  - Overrides the values under the [Package] keyword
  - Only a single value can be used (no corners)
- **[Package Model] keyword**
  - Can reference an external file or [Define Package Model] within the same .IBS file
  - Overrides the values under the [Package] keyword
  - Two methods possible currently
    - *coupled, single-lump RLC matrix description (full, banded, and sparse matrix formats available)*
    - *uncoupled multi-section description using RLC, length*
- **[Alternate Package Model] keyword**

Adapted from A. Muranyi, "Introduction to IBIS Models and IBIS Model Making"

A 4.x Package Example

```
|*****************************************
|
[Define Package Model] BGA example
[Manufacturer]         Noname Corp.
[OEM]                  Noname Corp.
[Description]          BGA
[Number Of Sections]   5
[Number Of Pins]       3
[Pin Numbers]
|
A1 Len=0 R=0.160 L=5.0n /      | bond wire
Len=4.00 L=0.170n C=0.250p /   | package trace
Fork
  Len=0.80 L=0.200n C=0.100p / | plating bar
  Endfork
Len=0.010 L=0.010n C=0.020p /  | via
Len=0 C=2.0p /                 | Ball 1
|
A2 Len=0 R=0.160 L=5.0n /      | bond wire
Len=2.50 L=0.170n C=0.250p /   | package trace
Fork
  Len=0.80 L=0.200n C=0.100p / | plating bar
  Endfork
Len=0.010 L=0.010n C=0.020p /  | via
Len=0 C=2.0p /                 | Ball 2
|
A3 Len=0 R=0.160 L=5.0n /      | bond wire
Len=4.00 L=0.170n C=0.250p /   | package trace
Fork
  Len=0.80 L=0.200n C=0.100p / | plating bar
  Endfork
Len=0.010 L=0.010n C=0.020p /  | via
Len=0 C=2.0p /                 | Ball 3
```




```
| The resistance matrix for this
package has
| no coupling
|
[Resistance Matrix]     Banded_matrix
[Bandwidth]             0
[Row]   1
10.0
[Row]   2
15.0
[Row]   3
15.0
|
[Inductance Matrix]     Full_matrix
[Row]   1
3.04859e-07      4.73185e-08
1.3428e-08
[Row]   2
3.04859e-07      4.73185e-08
[Row]   3
3.04859e-07
|
|
[Capacitance Matrix]    Sparse_matrix
[Row]   1
```

An ICM 1.0 Example

- **Assumptions:**
  - **BGA device package, five-part path**
  - **Differential interface, 90 Ω diff. impedance**
  - **RLGC nodal structure**
- **Other details**
  - **Package designed using Cadence* tools (MCM format)**
  - **Electrical data extracted using Ansoft* tools into lumped matrix and distributed HSPICE* W-element format (not tabular frequency)**
  - **Sections extracted as pairs or pair-of-pairs**

An ICM 1.0 Example

```
|*************************************************************************
| The following example corresponds to a BGA wirebond package
|*************************************************************************
[Begin Header]
[ICM Ver]    1.0
[File Rev]   1.1
[File Name]  bga_example.icm
[Date]       10/15/2003
[Source]     From SPICE model data
[Notes]      This is an example wirebond BGA package model.
[Disclaimer] This model is provided as an example only.
[Copyright]  ---
[Support]    http://www.yourcompanyhere.com
[Redistribution] Yes
[End Header]
|
|*************************************************************************
|
[Begin ICM Family]  Wirebond_Package
[Manufacturer]      Noname
[ICM Family Description] A wirebond BGA package design
|
|*************************************************************************
|
[ICM Model List]
| Name                    Mating         Min_Slew_Time    Image
|-------------------------------------------------------------------------
diff-two-pair-short-TRL   Mated          1000ps
diff-two-pair-mid-TRL     Mated          1000ps
diff-two-pair-long-TRL    Mated          1000ps
|
|          wirebond   TRL   via     ball
|Die_side >--------< >---< >---< >--------< Ball_side
|                              |
|                              |platingbar
```

An ICM 1.0 Example

```
|*************************************************************************
|Units below assumed to be meters
|
[Begin ICM Model] diff-two-pair-short-TRL
ICM_model_type MLM
[Nodal Path Description]
Model_nodemap Die_side
N_section (A1 A2 A3 A4  11 12 13 14 ) Mult=1     wirebond
N_section (11 12 13 14  21 22 23 24 ) Len=1.0e-3 TRL
N_section (21 22        31 32       ) Mult=1     via
N_section (      23 24        33 34 ) Mult=1     via
N_section (31 32        x1 x2       ) Len=1.0e-3 platingbar
N_section (      33 34        x3 x4 ) Len=1.0e-3 platingbar
N_section (31 32        B1 B2       ) Mult=1     ball
N_section (      33 34        B3 B4 ) Mult=1     ball
Model_nodemap Ball_side
[End ICM Model]
|
[Begin ICM Model] diff-two-pair-mid-TRL
ICM_model_type MLM
[Nodal Path Description]
Model_nodemap Die_side
N_section (A1 A2 A3 A4  11 12 13 14 ) Mult=1     wirebond
N_section (11 12 13 14  21 22 23 24 ) Len=2.5e-3 TRL
N_section (21 22        31 32       ) Mult=1     via
N_section (      23 24        33 34 ) Mult=1     via
N_section (31 32        x1 x2       ) Len=1.0e-3 platingbar
N_section (      33 34        x3 x4 ) Len=1.0e-3 platingbar
N_section (31 32        B1 B2       ) Mult=1     ball
N_section (      33 34        B3 B4 ) Mult=1     ball
Model_nodemap Ball_side
[End ICM Model]
|
```

An ICM 1.0 Example

```
[Begin ICM Model] diff-two-pair-long-TRL
ICM_model_type MLM
[Nodal Path Description]
Model_nodemap Die_side
N_section (A1 A2 A3 A4  11 12 13 14 ) Mult=1     wirebond
N_section (11 12 13 14  21 22 23 24 ) Len=4.0e-3 TRL
N_section (21 22        31 32       ) Mult=1     via
N_section (      23 24        33 34 ) Mult=1     via
N_section (31 32        x1 x2       ) Len=1.0e-3 platingbar
N_section (      33 34        x3 x4 ) Len=1.0e-3 platingbar
N_section (31 32        B1 B2       ) Mult=1     ball
N_section (      33 34        B3 B4 ) Mult=1     ball
Model_nodemap Ball_side
[End ICM Model]
|
|*************************************************************************
|
[ICM Node Map] Die_side
| pin node name
1 A1 Die_Pair1_P
2 A2 Die_Pair1_N
3 A3 Die_Pair2_P
4 A4 Die_Pair2_N

[ICM Node Map] Ball_side
| pin node name
1 B1 Ball_Pair1_P
2 B2 Ball_Pair1_N
3 B3 Ball_Pair2_P
4 B4 Ball_Pair2_N

[End ICM Family]
|
```

An ICM 1.0 Example

```
|*************************************************************************
[Begin ICM Section] TRL
[Derivation Method] Distributed
| Note - resistance and conductance data taken at DC
[Resistance Matrix] Full_matrix
[Row] 1
12.88360411759953 0.1122120358629589 0.1122120358629535 0.1122120358629596
[Row] 2
12.88360411759959 0.1122120358629578 0.1122120358629697
[Row] 3
12.88360411759938 0.1122120358630265
[Row] 4
12.88360411759949

[Inductance Matrix] Full_matrix
[Row] 1
  4.762471117800315e-007  1.574556825167307e-007  4.166419413304077e-008  2.533102103479589e-008
[Row] 2
  4.746270568634125e-007  7.829217743956544e-008  4.167732136295897e-008
[Row] 3
   4.74695722999582e-007  1.575422041099422e-007
[Row] 4
  4.764080626393532e-007

[Capacitance Matrix] Full_matrix
[Row] 1
1.13724568263412e-010 -3.699327364720182e-011  -3.195922952611326e-012  -1.703330485507162e-012
[Row] 2
1.161253452991748e-010  -1.420237001727346e-011 -3.194945464961537e-012
[Row] 3
1.160998680089507e-010 -3.698488552069936e-011
[Row] 4
1.135869774794572e-010
[Conductance Matrix] Diagonal_matrix
0
0
0
0
[End ICM Section] TRL
```

An ICM 1.0 Example

```
|*************************************************************************
[Begin ICM Section] platingbar
[Derivation Method] Distributed
| Note - resistance and conductance data taken at DC
[Resistance Matrix] Full_matrix
[Row] 1
6.447272395548234 0.06157635467979937
[Row] 2
6.447272395547882

[Inductance Matrix] Full_matrix
[Row] 1
3.875774956956585e-007   1.453875900301228e-007
[Row] 2
3.876372566358464e-007

[Capacitance Matrix] Full_matrix
[Row] 1
1.228751177567252e-010 -4.55112340759e-011
[Row] 2
1.228294743230235e-010

[Conductance Matrix] Diagonal_matrix
0
0
[End ICM Section] platingbar
```

An ICM 1.0 Example

```
|*************************************************************************
[Begin ICM Section] ball
[Derivation Method] Lumped
| Note - resistance and conductance data taken at DC
[Resistance Matrix] Full_matrix
[Row] 1
0.00122974     5.92605e-005
[Row] 2
0.00121302

[Inductance Matrix] Full_matrix
[Row] 1
3.91849e-011     4.81629e-012
[Row] 2
4.0174e-011

[Capacitance Matrix] Full_matrix
[Row] 1
3.99986e-014    -5.64816e-015
[Row] 2
3.84177e-014

[Conductance Matrix] Diagonal_matrix
0
0
[End ICM Section] ball
```

An ICM 1.0 Example

```
|*************************************************************************
[Begin ICM Section] wirebond
[Derivation Method] Lumped
| Note - resistance and conductance data taken at DC
[Resistance Matrix] Full_matrix
[Row] 1
0.357348   0.0153167 0.000203431 0.0
[Row] 2
0.360486  0.00520121 0.000603478
[Row] 3
0.358009   0.0157098
[Row] 4
0.356194

[Inductance Matrix] Full_matrix
[Row] 1
3.12277e-009     1.01577e-009     3.05886e-010     2.22836e-010
[Row] 2
3.02065e-009     4.47214e-010     2.93897e-010
[Row] 3
2.99636e-009     9.45824e-010
[Row] 4
3.01787e-009

[Capacitance Matrix] Full_matrix
[Row] 1
4.03601e-013    -1.28769e-013    -1.50353e-014    -8.75617e-015
[Row] 2
4.19554e-013    -3.78802e-014    -1.42581e-014
[Row] 3
4.16062e-013    -1.22606e-013
[Row] 4
4.06634e-013

[Conductance Matrix] Diagonal_matrix
0
0
0
0
[End ICM Section] wirebond
```

An ICM 1.0 Example

```
|*************************************************************************
[Begin ICM Section] via
[Derivation Method] Lumped
| Note - resistance and conductance data taken at DC
[Resistance Matrix] Full_matrix
[Row] 1
0.00301846 0.000640491
[Row] 2
0.00304867

[Inductance Matrix] Full_matrix
[Row] 1
6.42506e-011     2.56352e-011
[Row] 2
5.96354e-011

[Capacitance Matrix] Full_matrix
[Row] 1
4.81705e-013    -8.01111e-014
[Row] 2
4.89624e-013

[Conductance Matrix] Diagonal_matrix
0
0
[End ICM Section] via
|*************************************************************************
|
[End]
```

ICM 1.0 Advantages

- **Each section can be independently modeled**
  - **If nodal scheme used, the number of paths in each section does not need to match that of any other section**
- **Coupling can be represented directly per section**
  - **Per-section coupling missing in IBIS PKG**
  - **ICM is a major enhancement**
- **Conductance is added as a parameter**
  - **IBIS PKG RLC -> ICM RLGC**
- **ICM data format very cleanly converts other matrix data formats**
  - **Conversion can be scripted**
  - **Lower- vs. upper-half matrix format the only irritant**

Areas for Improvement

- **Frequency Dependence**
  - At present, all values taken at DC conditions
  - Additional values and equations can only be included using comments
- **Frequency dependence using an additional subparameter would enable ICM to use tabular-frequency data**
  - Example: Matrix parameters for 1 MHz, 100 MHz, etc.
- **Using ICM with IBIS models**
  - Assumed now that ICM<->IBIS link handled by tool
  - BIRD to [Alternate Package Model] and/or [Package Model] keywords could add link to ICM
  - Requires additional subparameters to map ICM node/pin maps to IBIS [Pin] keyword data

Data Issues

- **ICM cookbook has been proposed**
  - **Data format, scripting, extraction advice**
- **Cookbook may also need data checking recommendations**
  - **“Optimum” frequency for data extraction appropriate to the interface?**
  - **S-parameters: appropriate bandwidth for extracted data?**
  - **S-parameters: passivity may be an issue for data being used for transient simulations**
- **These checks are inappropriate to the golden syntax parser**

Questions and Free Discussion