IBIS Package Proposal

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IBIS Summit, Santa Clara
January 31, 2014
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## Decisions Made

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<td>Broadband EBD</td>
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<td>Interposers</td>
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<tr>
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<td>Stacked Memory</td>
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<td>Splits/Joins of Signal (I/O) in Package or Die</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>RDL as separate element</td>
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<td>Yes</td>
</tr>
<tr>
<td>New list of supply (PDN) die pads</td>
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<td>Yes</td>
</tr>
<tr>
<td>Separate package and on-die interconnect model</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Broadband I/O Package Modeling</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Package PDN</td>
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<td>Broadband I/O On-Die Modeling</td>
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<td>Yes</td>
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<td>On-Die PDN</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Interconnect coupling (crosstalk) between I/O and I/O</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Interconnect coupling between I/O and PDN</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Optical Interconnect</td>
<td>No</td>
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</table>
What These Decisions Mean

• For signal (I/O) pins there is a one to one correspondence between Pin Number, Die Pad, and Buffer.
• There is a Few to Many or Many to Few relationship between supply (PDN) pins and supply die pads, and buffer Pullup, Pulldown, Power Clamp and Ground Clamp Reference terminals.
• There MAY be a one to one correspondence between signal (I/O) Pin Numbers and Signal Names (IBIS 6.0 is not clear on this).
Intent of this Proposed Syntax

During 2013 the IBIS Package ad hoc committee had numerous meetings to determine the package and on-die interconnect needs of the IC Vendor and User community.

This is a proposed syntax that satisfies the package and on-die interconnect modeling requirements agreed to in IBIS-ATM meetings as well as alternative methods of associating interconnect models with Model Names and Model Types that satisfy the needs of the IC Vendor and User community expressed in the IBIS Package ad hoc committee.
[Begin Package Models], [End Package Models]

Keyword: [Begin Package Models]/[End Package Models]

Required: No

Description: New Section within [Component] containing IBIS-ISS Package and On-Die interconnect models

Sub-Params: None

Usage Rules: This section within [Component] contains one or more package or on-die interconnect models. [Begin Package Models] is terminated by [End Package Models].

Example:

[Begin Package Models]

...

[End Package Models]
Keyword: [Begin Package Model], <Package Model Name>

Required: No

Description: New Section within [Begin Package Models] that defines an interface to a IBIS-ISS subckt or Touchstone File.

Sub-Params: Language, File, Subckt, Parameter, Ports

Usage Rules: This section within [Begin Package Models] defines an interface to a IBIS-ISS subckt or Touchstone File. The sub-parameters under [Begin Package Model] are terminated with [End Package Model]

Example::

[Begin Package Models]
[Begin Package Model] DQ1
...
[End Package Model]
[Begin Package Model] DQ2
...
[End Package Model]
[End Package Models]
Language

Sub-parameter: Language <language>

Required: Yes

Description: Language is either IBIS-ISS or Touchstone

Usage Rules: This sub-parameter within [Begin Package Model] determines if the model is a IBIS-ISS subckt or a Touchstone file

Examples:

[Begin Package Model] DQ1
Language IBIS-ISS
...
[End Package Model]

[Begin Package Model] DQ2
Language Touchstone
...
[End Package Model]
File

Sub-parameter:    File <format> <file name> {<file name> <file name> }

Required:    Yes
Description:    Defines the file(s) used by this package model

Usage Rules:    <format> is either Value, DelayCorner, XtalkCorner or DelayXtalkCorner.
If <format> is Value, then requires one <file name>. If <format> is DelayCorner or
XtalkCorner, then requires three <file name>s. If <format> is DelayXtalkCorner, then
requires nine <file name>s. If Language is Touchstone then the file(s) shall be a
Touchstone I or II file.

Examples:

[Begin Package Model] DQ2
Language IBIS-ISS
File Value DQ2_.iss
...
[End Package Model]

[Begin Package Model] DQ3
Language Touchstone
File DelayCorner DQ3_Typ.s2p DQ3_Slow.s2p DQ3_Fast.s2p
Parameter FBASE Value 100Meg
Parameter FMAX Value 10G
...
[End Package Model]
Subckt

Sub-parameter: Subckt <format> <subckt name> {< subckt name> < subckt name> }

Required: Yes, if Language IBIS-ISS

Description: Defines the subckts (s) used by this IBIS-ISS package file

Usage Rules: <format> is either Value, DelayCorner, XtalkCorder or DelayXtalkCorder. If <format> is Value, then requires one <subckt name>. If <format> is DelayCorner or XtalkCorder, then requires three <subckt name>s. If <format> is DelayXtalkCorder, then requires nine <subckt name>s.

Examples:

[Begin Package Model] DQ1
Language IBIS-ISS
File Value DQ1.iss
Subckt DelayCorner DQ1_Typ DQ1_Slow DQ1_Fast
...
[End Package Model]

[Begin Package Model] DQ2
Language IBIS-ISS
File Corner DQ2_Typ.iss DQ2_Slow.iss DQ2_Fast.iss
Subckt Value DQ2
...
[End Package Model]
Parameter

Sub-parameter: Parameter <parameter name> <format> <value> < value > …

Required: No

Description: Defines a parameter passed to an IBIS-ISS subckt instance

Sub-Params: None

Usage Rules: <parameter name> is the name of a parameter passed to an IBIS-ISS subckt instance. Language must be IBIS-ISS. <format> is either Value, DelayCorner, XtalkCorder or DelayXtalkCorder. If <format> is Value, then requires one < parameter name>. If <format> is DelayCorner or XtalkCorder, then requires three < parameter name>s. If <format> is DelayXtalkCorder, then requires nine < parameter name>s. There may be none, one, or any number of Parameter keywords within a [Begin Package Model]

Examples:
[Begin Package Model] DQ1
Language IBIS-ISS
File Value DQ1.iss
Subckt Value DQ1
Parameter Length Value 1.3
Parameter Wline DelayCorner ‘wline_typ’ ‘wline_fast’ ‘wline_slow’ …

[End Package Model]
Corner Formats

- **DelayCorner**
  - Typ Min Max
  - Typ Typical Delay
  - Min Min Delay (Fastest)
  - Max Max Delay (Slowest)

- **XtalkCorner**
  - Typ Min Max
  - Typ Typical Delay
  - Min Min Crosstalk Coupling
  - Max Max Crosstalk Coupling

- **DelayXtalkCorner**
  - TypTyp TypMin TypMax MinTyp MinMin MinMax MaxTyp MaxMin MaxMax
  - MinMax Min Delay Max Crosstalk Coupling
Enhanced Parameter Formats

Other possible <formats> that can be considered are:

- **Gaussian** `<mean> <sigma>`
- **IntegerRange** `<min> <max>`
- **RealRange** `<min> <max>`
- **PDF** `<value> <probability> <value> <prob.> <value> <prob.> ...`
- **List** `<value> <value> <value> <value> <value> ...`

Each <format> requires a definition of “Typ”

- **Corner** `<typ>`
- **Gaussian** `<mean>`
- **IntegerRange** `(<min>+<max>)/2.` (round down)
- **RealRange** `(<min>+<max>)/2.`
- **PDF** Mean|Median|Mode
- **List** FirstValue | MiddleValue

Three types of Parameter Value Selection

1. All Parameters are Typ
   This is the current IBIS Package Modeling capability
2. Corner Parameter are Typ|Slow|Fast (rest are Typ)
   Compatible with rest of IBIS using (Typ Min Max)
3. User/EDA tool can select any allowed value for each Parameter
   “AMI Flexibility” to support more than 3 corners, DOE, …
Ports

Sub-parameter: Ports <port> <port> <port> <port> <port> <port> …

Required: No

Description: Defines the node names associated with the Ports (Terminals) of an IBIS-ISS subckt or a Touchstone file.

Usage Rules: Ports must be allowed <port> names that correspond to either a Component Pin, Component Die Pad, or Buffer Terminal. The order of the <ports> shall be the order of the Terminals of the IBIS-ISS subckt or Touchstone file. There may be more than one Ports keyword in a [Begin Package Model]. If there are more than one Ports record in a [Begin Package Model], then subsequent Ports records after the first Port record shall be considered continuation lines, and the <ports> shall be concatenated.

Note that the <port> names are used to associate nodes in the package model subckt instance, and are not the names of the nodes within the subckt itself. If we want to allow these names to be the node names inside of the subckt, then the syntax for <port> will need to be revised to be IBIS-ISS node name compliant.

Example::

Ports Pin.A7 Buf.A7
Sparse_Ports

Sub-parameter: Sparse_Ports <port #> <port> <port #> <port> …

Required: No

Description: Defines the node names associated with the Ports (Terminals) of an IBIS-ISS subckt or a Touchtone file

Usage Rules: Sparse_Ports must be followed by port number and port names pairs. The port number must be a positive integer numerically less than or equal to the number of ports in the subckt, or Touchstone file. A port number may appear only once in the list of pairs. The port name must correspond to either a Component Pin, Component Die Pad, or Buffer Terminal. There may be more than one Sparse_Ports keyword in a [Begin Package Model]. If there are more than one Sparse_Ports record in a [Begin Package Model], then subsequent Sparse_Ports records after the first Port record shall be considered continuation lines.

Example::

Sparse_Ports 27 Pin.A7 54 Buf.A7
Ports is Ports

- Package and On-Die interconnect models are between component pins, die pads and/or buffer model terminals.
- There is a 1:1 relationship between signal (I/O) Pins, Die Pads and Buffer signal terminals.
- Proposed Port naming convention uses strings Pin, Pad, Buf to indicated if component pin, die pad or buffer terminal respectively.
- Buffer models also have supply and control terminals.
- In general, there are a different number of supply (PDN) pins, supply die pads, and buffer supply terminals.
Signal (I/O) Port Naming Rules

**Pin I/O**
- Pin.<pin_number>
- Pin_Mod.<model_name>.<n>
- Pin_Mod+.<model_name>.<n>
- Pin_Mod-.<model_name>.<n>

**Die Pad I/O**
- Pad.<pin_number>:
- Pad_Mod.<model_name>.<n>
- Pad_Mod+.<model_name>.<n>
- Pad_Mod-.<model_name>.<n>

**Buffer Terminal I/O**
- Buf.<pin_number>
- Buf_Mod.<model_name>.<n>
- Buf_Mod+.<model_name>.<n>
- Buf_Mod-.<model_name>.<n>

**Notes:** +/- indicate non-inverting/inverting side of differential pairs
Ports with same <n> are connected
Model Type Package Models

Pin I/O
Pin_Type.<type>.<n>
Pin_Type+.<type>.<n>
Pin_Type-.<type>.<n>

Pad I/O
Pad_Type.<type>.<n>
Pad_Type+.<type>.<n>
Pad_Type-.<type>.<n>

Buf I/O
Buf_Type.<type>.<n>
Buf_Type+.<type>.<n>
Buf_Type-.<type>.<n>

• Notes
  – <type>
    • I Buffers that can be Input
    • O Buffers that can be Output
    • IO Buffers that can be either Input or Output
  – Ports with same <n> are connected
  – All Ports with same <n> must have same <type>
Package Precedence Rules

1. Match by Pin, Pad, and Buf Ports
2. Match by Pin_Mod, Pad_Mod, Buf_Mod Ports
3. Match exactly by I, O, IO Ports
   - I Input
   - O Output
   - IO I/O
4. Match by I, O, IO Ports
   - I Input or I/O
   - O Output or I/O
   - IO Input, Output, I/O
Example Default Model

[Begin Package Models]

[Begin Package Model] Single_Ended
Language Touchstone
File DelayCorner SE_Typ.s2p SE_Fast.s2p SE_Slow.s2p
Ports Pin.IO.1 Buf.IO.1
[End Package Model]

[Begin Package Model] Differential
Language Touchstone
File DelayCorner Diff_Typ.s4p Diff_Fast.s4p Diff_Slow.s4p
Ports Pin.IO+.1 Pin.IO-.1 Buf.IO+.1 Buf.IO-.1
[End Package Model]

[End Package Models]
Supply (PDN) Port Naming Rules

Pin PDN
Pin.<pin_number>
Pin_Sig.<signal_name>

Die Pad PDN
Pad.<die_supply_pad_name>
Pad_Sig.<signal_name> | Supply (Power/Ground) Signal Name

Buffer Terminal Supply (PDN)
Buf_PUR.<pin_number> | Pullup Reference
Buf_PDR.<pin_number> | Pulldown Reference
Buf_PCR.<pin_number> | Power Clamp Reference
Buf_GCR.<pin_number> | Power Clamp Reference
Buf_EXTREF.<pin_number> | External reference voltage port
Buf_Sig.<signal_name> | Supply (Power/Ground) Signal Name
Unconnected Port Naming Rules

Several Options

R.<value>

Connect this node to GND with a resistance of <value>
[value] can be either
Non-negative IBIS number
Treated as Resistance in Ohms
Blank
Can only be used when Language Touchstone Simulator shall use the Tstonefile reference resistance of the port in ohms.

S.<file>.<subckt>

<subckt> shall be a single Port sub-circuit in IBIS-ISS <file>

0 (Zero)

If Language is IBIS-ISS Equivalent to R.1Meg
If Language Touchstone Tstonefile reference resistance of the port in ohms.

For Sparse_Ports, will need an additional parameter:
Unused_Port_Termination 0 | R.<value> | S.<file>.<subckt>
Miscellaneous Port Rules

The model creator is responsible for the data in each package model (Language, File, Subckt, Parameter, and Ports) are consistent and follow the following rules:

- Package Models may have the following combinations of Ports:
  - Pins and Pads (Package only models)
  - Pads and Buffer (On-Die only Models)
  - Pins and Buffer (combined package and on-die models)
  - Pins, Pads and Buffer

- There may be independent signal (I/O) and supply (PDN) package models.

- Coupled (crosstalk) package models may contain some channels (signals) that ports are specified by pin number (e.g. Pin.A7), and other channels (signals) are specified by Model Name or Model Type (e.g. Pin_Mod.DQ.2, Pin_IO.IO.3)
Crosstalk Victims/Aggressors

- Coupled crosstalk interconnect models have some channels that are strongly coupled to many channels, while some channels are strongly coupled to few channels.
- EDA tool will need to know which channels do have full crosstalk, and which channels should be treated as aggressors.
- This is supported in this proposed syntax by inserting the letter “V_” at the beginning of each port name that should be treated as a Victim.
  - E.g.
While we are at it

• Allow all Pin Names (aka Pin number) in IBIS Component and EBD to be more than 8 characters.
  – Pin_names in [Pin List] cannot exceed 8 characters
  – Pin names in [Pin] cannot exceed 5 characters
• Allow upper and lower case file names
• Allow lines longer that 120 characters, e.g.,
  – 256 characters
  – 512 characters
  – 1000 characters
  – 4000 characters
Functionality Supported in this Proposal

- Default Component Broadband Package Models
  - Single Ended with and without crosstalk
  - Differential with and without crosstalk
- Delay and crosstalk corners
- Model Name and Model Type Package Models
- Uncoupled and Crosstalk Models
- Ability to have separate or combined package and on-die models
- Ability to have separate or combined PDN and I/O models
- Enhanced parameter formats to support DOE
- Direct support for Touchstone data
- Support for different number of Supply (PDN) Pins and Die Pads
- Models are fully supported in all major EDA simulators
- NEXT and FEXT crosstalk models
Next Steps

1. Alternative Proposals
   1. BIRD 125/145 (being withdrawn)
   2. BIRDS 163, 164, 165 (replaces 125/145)

2. Evaluation of this proposal with alternatives
   1. Which proposals solves the IC Vendor, and User problems?
      1. Functionality
      2. Ease of writing models and IBIS files
      3. Ease of parsing IBIS files and using models
   2. IC Vendors and Users need to define package model scenarios, and proponents should implement IBIS files for these scenarios to demonstrate the feasibility of each of the proposals.

3. Next steps
   1. Review Syntax
   2. Make EMD Syntax similar