Interconnect Modeling Update Using IBIS-ISS and Touchstone

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Presented by Bob Ross, Teraspeed Labs

Agenda

- History
- The need for improved interconnect support
- Principles of the Interconnect Proposal
  - Structure
  - Terminals, Models and Sets, and Groups (new)
  - New Keywords
- An example explained
- New or changed features
- Summary

History

- Interconnect Task Group resumed meeting in early 2014
  - Received draft BIRD from Walter Katz (SiSoft) to support IBIS-ISS packages within IBIS
- BIRD189.x uploaded (awaiting approval)
  - http://www.ibis.org/birds/
  - 41 pages with examples
  - Still resolving some issues
  - Comments welcome
- Intended for IBIS Version 7.0
- Brief overview with some key points is given here

Why Update Interconnect Modeling?

- Improve package models with IBIS-ISS (an HSPICE subset) and Touchstone support

- Package modeling in IBIS stable since 2000
  - [Pin], [Package], [Package Model]
  - [Alternate Package Models] selector added
  - Limited support of loss, crosstalk and/or partitioning

- EBD (Electrical Board Description) for boards; No coupling and limited package model application

- IBIS, IBIS-ISS, Touchstone 2.0 and ICM are separate specifications
  - Limited interaction between them for package modeling
  - ICM (Interconnect Model) never adopted by industry

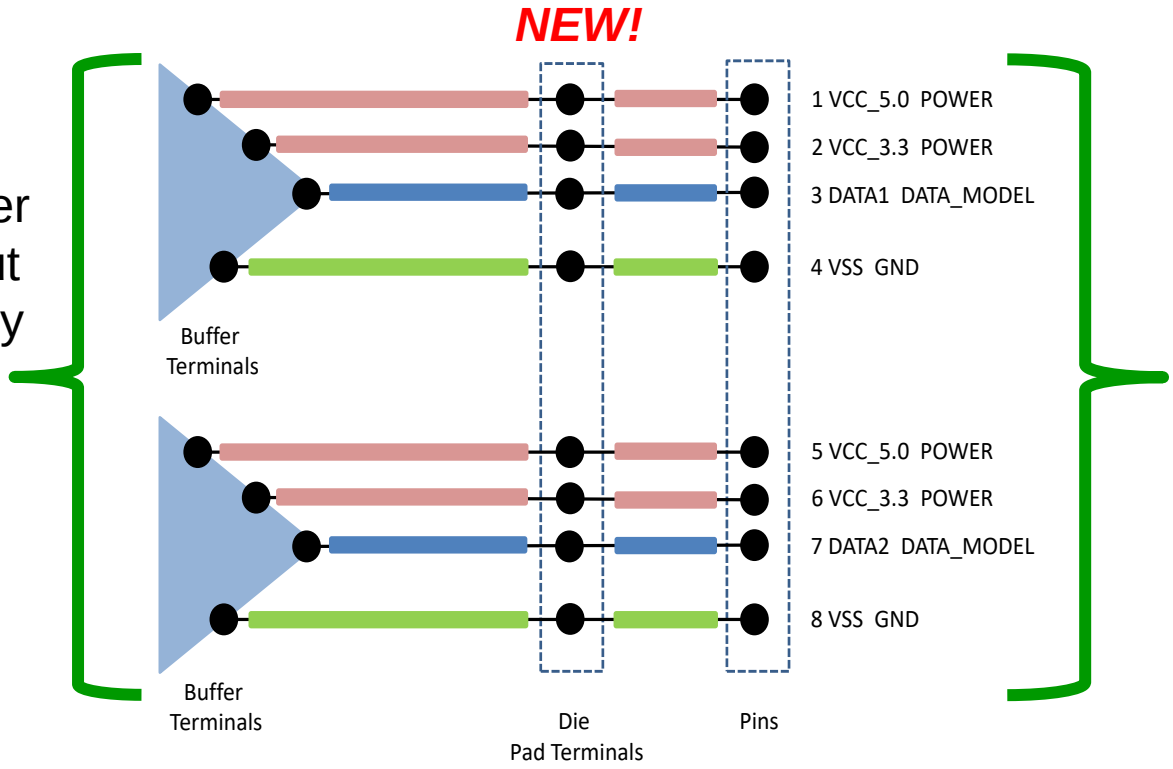
Features of the Interconnect Proposal

- Supports…
  - IBIS-ISS and Touchstone models (common in industry)
  - Both I/O and supply (POWER and GND) connections
  - (New) optional Die pad interface between Pins and Buffers
  - I/O pin_names as terminal qualifiers
    - *May have optional Aggressor_Only designation*
  - POWER and GND terminal qualifiers by pin_name, pad_name, signal_name or [Pin Mapping] bus_label for rail connections with direct or combined terminals
  - Many other features not covered here

A few objectives for the Interconnect Modeling proposal

Structure of the Interconnect Proposal

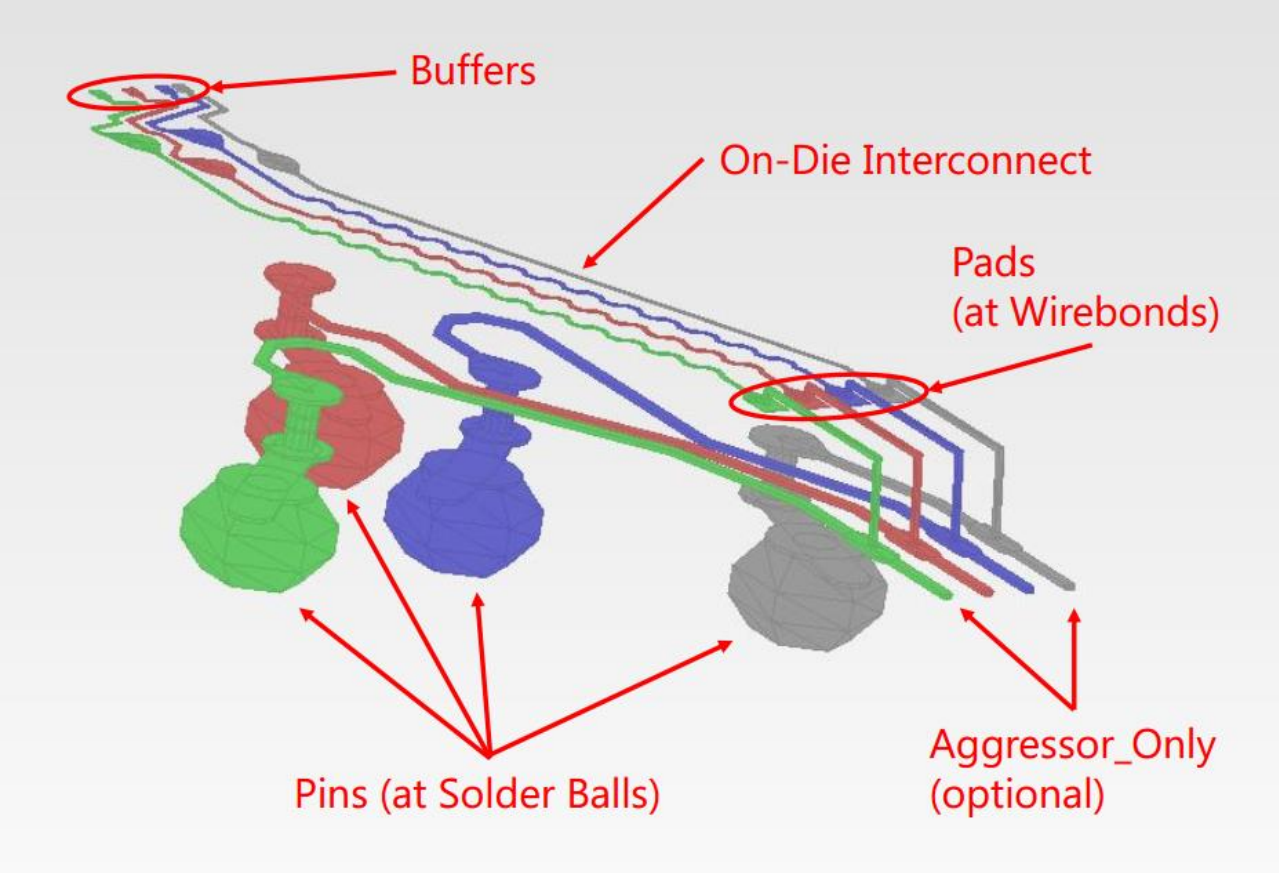
[Model] buffer definition but with explicitly identified terminals



pin_names, signal_names, and model_names from the [Pin] keyword

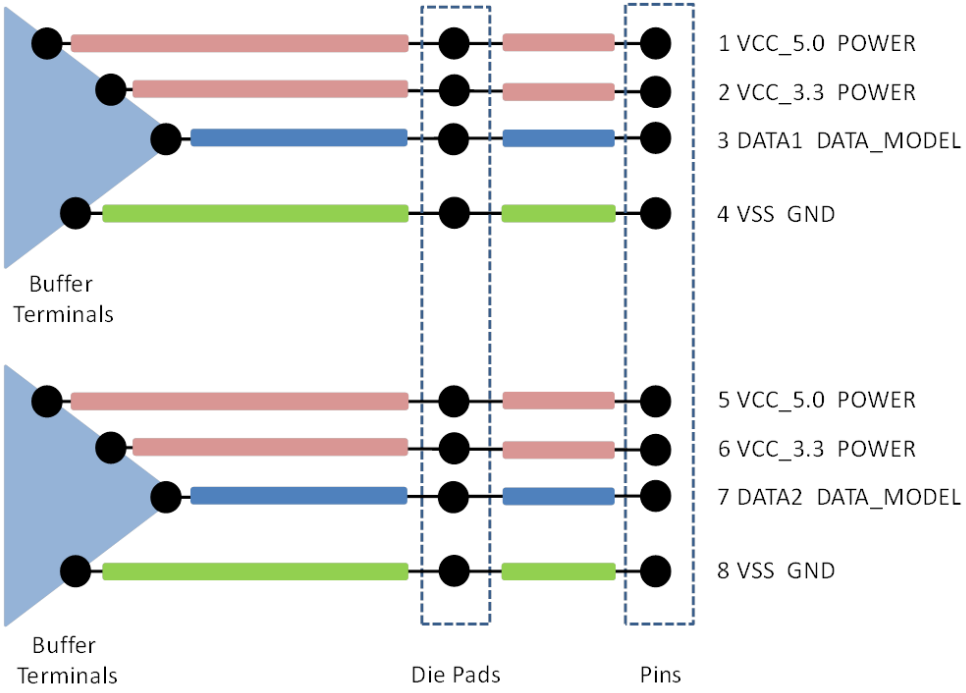
Introduces optional Die pad interface for terminals separate from Buffer and Pin interface terminals

Relates to Physical Structures



One-to-one path connection; Die pad interface optional; Aggressor_Only designation optional

Terminals at Buffer, Die Pad and Pin Interfaces



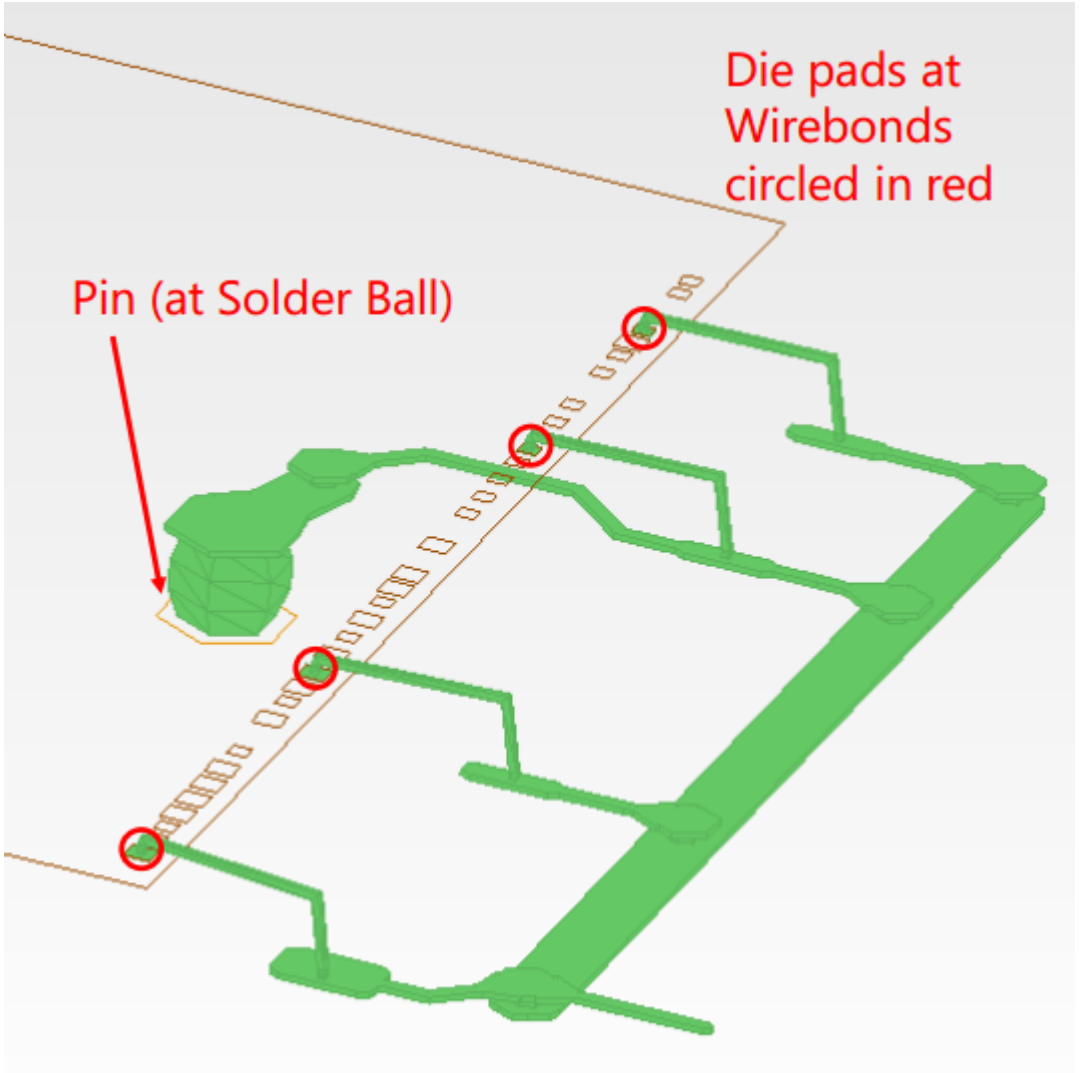
Original IBIS (4.0 and earlier)

- Pins are explicit
- Buffer terminals implicit in [Model]
- Die pad terminals same as buffer terminals
- Packages defined connections between pins and buffers

Current Proposal

- Die pad terminals are now explicit
- Buffer terminals are now explicit
- [Pin]s are…. still pins
- Separate interconnect definitions can be created between …
  - Pin-to-Die pad terminals,
  - Die pad-to-Buffer terminals,
  - Pin-to-Buffer terminals (still) supported

Physical Rails (Can be Merged)



New Keywords and Subparameters (Limited Discussion Here)

- [Bus Labels] | bus_label
- [Die Supply Pads] | pad_name, optional bus_label
- [Interconnect Model]/[End Interconnect Model]
  - Unused_port_termination <Open | Ref.> | Unused port ref. Z
  - Param | parameter passing
  - File_IBIS-ISS | names IBIS-ISS file
  - File_TS, File_TS0 | names Tstone file
  - Number_of_terminals=<value> | number of terminals
  - <terminal lines> | described later
- [Interconnect Model Set]/[End Interconnect Model Set]
- [Interconnect Model Set Group]/[End Interconnect Model Set Group] (New and changed from “Selector”)

[Interconnect Model]

- [Interconnect Model] <interconnect_model_name>
  - Connections between terminals with IBIS-ISS or Touchstone files
  - Terminal connection points at Buffer, Die pad, or Pin interfaces
  - Identifies rail or I/O terminals
  - Allows pin_name, signal_name, pad_name, or bus_label terminal qualifiers for rails (and pin_name for I/O terminals)
  - Identifies whether a coupled signal is only an aggressor or also "experiences" coupling from other sources

How package and on-die electrical information is generated and delivered today

[Interconnect Model Set]s [Interconnect Model Set Group]s (New)

- [Interconnect Model Set] <set_name>
  - Encapsulates one or more Interconnect Models
- [Interconnect Model Set Group] <group_name>
  - References one or more Interconnect Model Sets to be used together
  - Should be used to establish a complete path for selected buffers
  - <group_name> helps in identify the buffers that are selected for simulation
- Some Example Groupings and Applications
  - Separate groups: one per interface (e.g., memory, network)
  - Separate groups for coupled vs. single-line simulations
  - Different sets for different power delivery network complexities
    - *POWER connected at single pin, single buffer terminal*
    - *POWER connected through multiple pins, rails to individual buffer terminals*

<Terminal lines> Syntax

- All column entries on one line:

  <Terminal_number> <Terminal_type>
  <Terminal_type_qualifier> <Qualifier_entry>
  [Aggressor_Only]

- <Terminal_number> is IBIS-ISS node position or Touchstone port number

- Allowable <Terminal_type> names and associations next

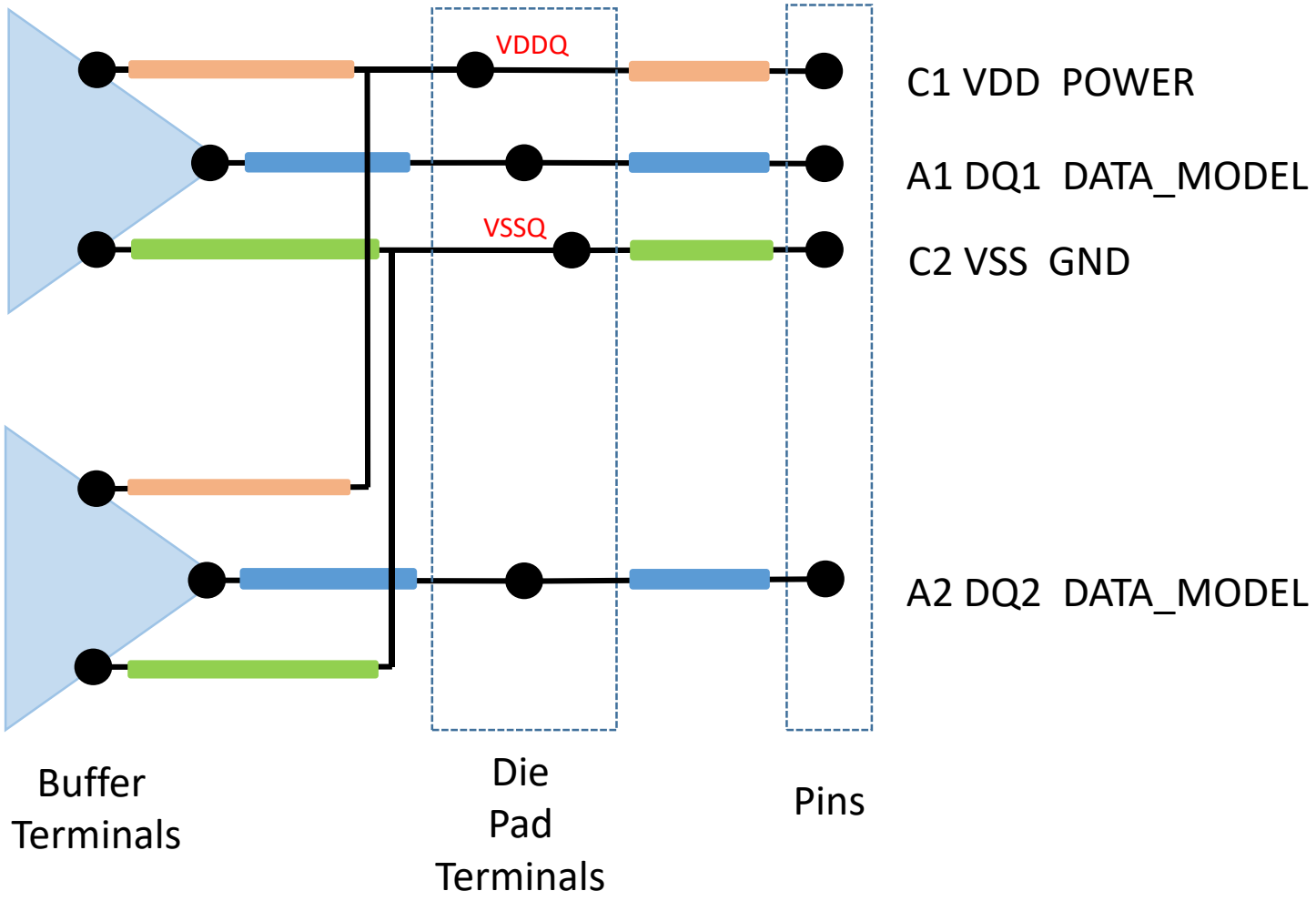
Allowable <Terminal_type> Associations

<Terminal_number> <Terminal_type> <Terminal_type_qualifier> <Qualifier_entry> [Aggressor_Only]

Terminal_type	Terminal_type_qualifier				Aggressor_Only
	pin_name	signal_name	bus_label	pad_name	
Pin_I/O	X				A
Pad_I/O	X				A
Buffer_I/O	X				A
Pin_Rail	Y	Y	Y		
Pad_Rail		Y	Y	Z	
Buffer_Rail		Y	Y		
Pullup_ref	X				
Pulldown_ref	X				
Power_clamp_ref	X				
Gnd_clamp_ref	X				
Ext_ref	X				

<Qualifier_entry>: ”X” I/O pin_name; “Y,” or “Z”: POWER or GND name. Optional “A”: “Aggressor_Only”

Example Showing Connections



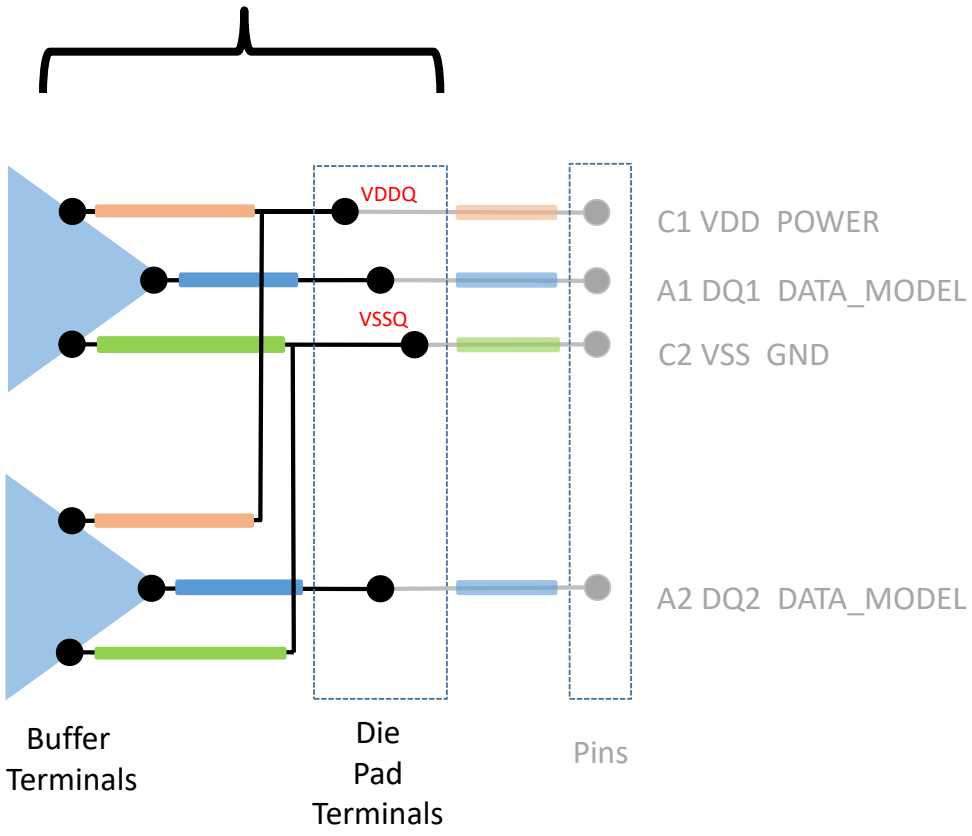
[Die Supply Pads] for pad_names Shown in Example

The [Die Supply Pads] keyword establishes pad_name <Qualifier_entries> for rails, and associates them with signal_name (and optionally with bus_label entries)

```
[Die Supply Pads] signal_name bus_label
| pad_name
VDDQ                VDD
VSSQ                VSS
```

[Interconnect Model] for Buffer-to-Die Pad Side

```
[Interconnect Model Set] Full_ISS_PDN
|
[Interconnect Model] Partial_ISS_buf_pad
|
File_IBIS-ISS        buf_pad.iss  buf_pad_2_typ
Number_of_terminals = 10
|
1  Pad_I/O        pin_name     A1 |  DQ1 (DQ signal)
2  Pad_I/O        pin_name     A2 |  DQ2 (DQ signal)
|
| POWER and GND terminals with pad_names and pin_names
3  Pullup_ref     pin_name     A1 |  VDD (POWER connection)
4  Pulldown_ref   pin_name     A1 |  VSS (GND connection)
5  Buffer_I/O     pin_name     A1 |  DQ1 (DQ signal)
6  Pullup_ref     pin_name     A2 |  VDD (POWER connection)
7  Pulldown_ref   pin_name     A2 |  VSS (GND connection)
8  Buffer_I/O     pin_name     A2 |  DQ2 (DQ signal)
|
| POWER and GND terminals with signal_names
9  Pad_Rail       pad_name   VDDQ |  VDD  POWER
10 Pad_Rail       pad_name   VSSQ |  VSS  GND
|
[End Interconnect Model]
```



[Interconnect Model] for Buffer-to-Die Pad Side (Expanded)

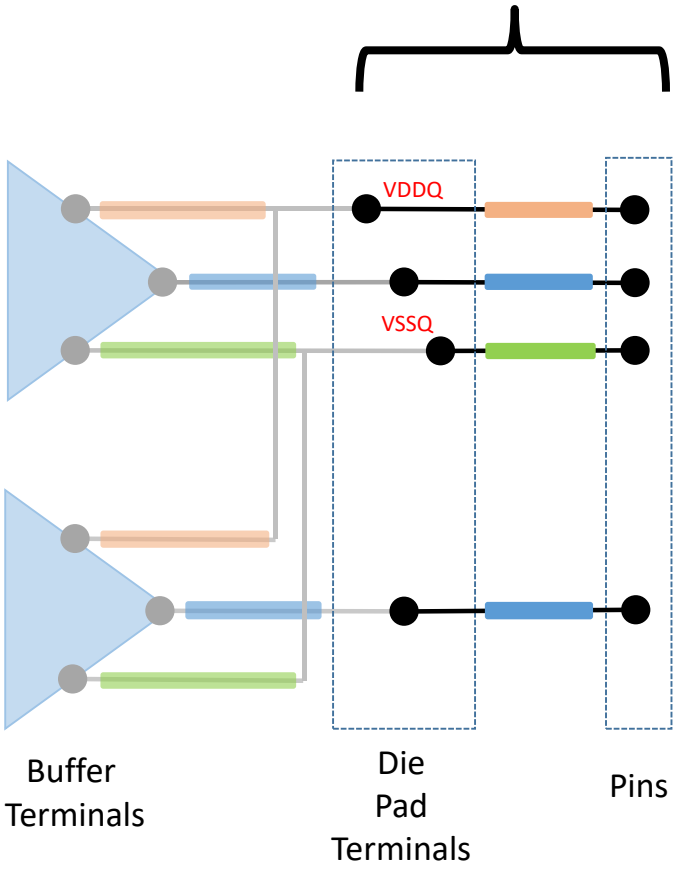
```
[Interconnect Model Set] Full_ISS_PDN
|
[Interconnect Model] Partial_ISS_buf_pad
|
File_IBIS-ISS        buf_pad.iss  buf_pad_2_typ
Number_of_terminals = 10
|
1  Pad_I/O        pin_name     A1 |  DQ1 (DQ signal)
2  Pad_I/O        pin_name     A2 |  DQ2 (DQ signal)
|
| POWER and GND terminals with pad_names and pin_names
3  Pullup_ref     pin_name     A1 |  VDD (POWER connection)
4  Pulldown_ref   pin_name     A1 |  VSS (GND connection)
5  Buffer_I/O     pin_name     A1 |  DQ1 (DQ signal)
6  Pullup_ref     pin_name     A2 |  VDD (POWER connection)
7  Pulldown_ref   pin_name     A2 |  VSS (GND connection)
8  Buffer_I/O     pin_name     A2 |  DQ2 (DQ signal)
|
| POWER and GND terminals with signal_names
9  Pad_Rail       pad_name    VDDQ |  VDD  POWER
10 Pad_Rail       pad_name    VSSQ |  VSS  GND
|
[End Interconnect Model]
```

[Interconnect Model]

File and subcircuit

<Terminal lines> for connecting the subcircuit nodes (by position) to the interconnect structure

[Interconnect Model] for Die Pad-to-Pin Side



C1 VDD POWER

A1 DQ1 DATA_MODEL

C2 VSS GND

A2 DQ2 DATA_MODEL

```
[Interconnect Model] Partial_ISS_pad_pin_2
|
File_IBIS-ISS        pad_pin.iss  pad_pin_2_typ
Number_of_terminals = 8
|
1  Pin_I/O    pin_name      A1 | DQ1 (DQ signal)
2  Pin_I/O    pin_name      A2 | DQ2 (DQ signal)
|
| POWER and GND terminals with signal_names
3  Pin_Rail   signal_name  VDD | VDD (POWER connection)
4  Pin_Rail   signal_name  VSS | VSS (GND connection)
5  Pad_I/O    pin_name      A1 | DQ1  (DQ signal)
6  Pad_I/O    pin_name      A2 | DQ2  (DQ signal)
|
| POWER and GND terminals with pad_names
7  Pad_Rail   pad_name    VDDQ | pad_name with VDD
8  Pad_Rail   pad_name    VSSQ | pad_name with VSS
|
[End Interconnect Model]
|
[End Interconnect Model Set]
```

[Interconnect Model] for Die Pad-to-Pin Side (Expanded)

[Interconnect Model]

File and subcircuit

<Terminal lines> for connecting the subcircuit nodes (by position) to the interconnect structure

```
[Interconnect Model] Partial_ISS_pad_pin_2
|
File_IBIS-ISS        pad_pin.iss  pad_pin_2_typ
Number_of_terminals = 8
|
1  Pin_I/O    pin_name      A1 | DQ1 (DQ signal)
2  Pin_I/O    pin_name      A2 | DQ2 (DQ signal)
|
| POWER and GND terminals with signal_names
3  Pin_Rail   signal_name  VDD | VDD (POWER connection)
4  Pin_Rail   signal_name  VSS | VSS (GND connection)
5  Pad_I/O    pin_name      A1 | DQ1  (DQ signal)
6  Pad_I/O    pin_name      A2 | DQ2  (DQ signal)
|
| POWER and GND terminals with pad_names
7  Pad_Rail   pad_name    VDDQ | pad_name with VDD
8  Pad_Rail   pad_name    VSSQ | pad_name with VSS
|
[End Interconnect Model]
|
[End Interconnect Model Set]
```

Complete [Interconnect Model Set] With Both [Interconnect Model]s

[Interconnect Model Set]

[Interconnect Model]s

```
[Interconnect Model Set] Full_ISS_PDN
|
[Interconnect Model] Partial_ISS_buf_pad
|
File_IBIS-ISS        buf_pad.iss  buf_pad_2_typ
Number_of_terminals = 10
|
1  Pad_I/O        pin_name     A1 |  DQ1 (DQ signal)
2  Pad_I/O        pin_name     A2 |  DQ2 (DQ signal)
|
| POWER and GND terminals with pad_names and pin_names
3  Pullup_ref     pin_name     A1 |  VDD (POWER connection)
4  Pulldown_ref   pin_name     A1 |  VSS (GND connection)
5  Buffer_I/O     pin_name     A1 |  DQ1 (DQ signal)
6  Pullup_ref     pin_name     A2 |  VDD (POWER connection)
7  Pulldown_ref   pin_name     A2 |  VSS (GND connection)
8  Buffer_I/O     pin_name     A2 |  DQ2 (DQ signal)
|
| POWER and GND terminals with signal_names
9  Pad_Rail       pad_name   VDDQ |  VDD  POWER
10 Pad_Rail       pad_name   VSSQ |  VSS  GND
|
[End Interconnect Model]
```

```
[Interconnect Model] Partial_ISS_pad_pin_2
|
File_IBIS-ISS        pad_pin.iss  pad_pin_2_typ
Number_of_terminals = 8
|
1  Pin_I/O    pin_name      A1 | DQ1 (DQ signal)
2  Pin_I/O    pin_name      A2 | DQ2 (DQ signal)
|
| POWER and GND terminals with signal_names
3  Pin_Rail   signal_name  VDD | VDD (POWER connection)
4  Pin_Rail   signal_name  VSS | VSS (GND connection)
5  Pad_I/O    pin_name      A1 | DQ1  (DQ signal)
6  Pad_I/O    pin_name      A2 | DQ2  (DQ signal)
|
| POWER and GND terminals with pad_names
7  Pad_Rail   pad_name    VDDQ | VDD is signal name
8  Pad_Rail   pad_name    VSSQ | VSS is signal name
|
[End Interconnect Model]
|
[End Interconnect Model Set]
```

[End Interconnect Model Set]

[Interconnect Model Set Group] (New) for a Selected Group

```
[Interconnect Model Set Group]     A1_A2_PDN
|
| Interconnect Model Set Name      File_reference
Full_ISS_PDN                       NA
|
[End Interconnect Model Set Group]
```

[Interconnect Model Set Group] is at same level as [Package Model] for selected group of Buffer_IO pin(s)

Name should be descriptive for easy selection (e.g., A1-A2_PDN)

Can contain several references to [Interconnect Model Set]s

Sets can be in the .ibs file (NA) or in a separate directories

[Interconnect Model]s within a Group must be connected

File_TS, File_TS0 (New) Issue

- Touchstone files can now be documented with a single reference (File_TS) or ground “Node 0” reference (File_TS0)
  - Offering both choices eliminates issue about which is better
  - File_TS0 would not be used for power-aware simulations
- File_IBIS-ISS with S model can be used for more references, if needed

Touchstone Unused Port Termination

- Not an issue with IBIS-ISS – all terminal connection are required
- For Touchstone files
  - Unused_port_termination <Open | Reference>
  - Reference: reference impedance reduces the number of Touchstone ports through matrix reduction
  - Open: represents the physically disconnected port
  - EDA tools might still provide an interface to override the choices
- Other options still being discussed

Summary

- BIRD189.x improves IBIS package modeling
- Links IBIS, IBIS-ISS and Touchstone for package models
  - Adds flexible support for package loss, crosstalk and partitioning
- Formalizes and separates Die pads and Buffers
- Other extensions (not covered here) included

New advanced Interconnect format for IBIS Version 7.0!