Notes on Corners in IBIS (BIRD 140)

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The original thinking

From IBIS v1.1:

```
|                        NOTES ON DATA DERIVATION METHOD                        |
|                                                                               |
| This section explains how data values are derived.  The intention here is to  |
| avoid over-guardbanding, enabling simulation results that are meaningful and  |
| useful.  This is accomplished by having each silicon vendor base their data   |
| on typical process data, and then derate by voltage and temperature, and a    |
| proprietary "X%" factor.  This methodology also has the nice feature that     |
| the data can be derived either from vendor-proprietary silicon models, or     |
| typical device measurement over temperature/voltage.
```

- **Note that the data for all corners was supposed to be extracted and derived from typical models or silicon**
  - in the days this was written, skewed silicon was not available (to us, SI guys at Intel) for lab measurements
  - ffff/ssss SPICE models were made with 6-sigma variation, way too much for realistic system design, so we used typical models with derating factors
- **The concept of exporting the extracted data into IBIS files "as measured" was not present in our thinking**

IBIS v2.1 “relaxed” the rules

These words in Section 9 (pg. 174) were in the spec since v2.1:

New in v2.1

From v1.1

```
| The required "typ" column for all data represents typical operating
| conditions. For most [Model] keyword data, the "min" column describes slow,
| weak performance, and the "max" column describes the fast, strong
| performance. It is permissible to use slow, weak components or models to
| derive the data for the "min" column, and to use fast, strong components or
| models to derive the data in the "max" columns under the corresponding
| voltage and temperature derating conditions for these columns. It is also
| permissible to use typical components or models derated by voltage and
| temperature and optionally apply proprietary "X%" and "Y%" factors described
| later for further derating. This methodology has the nice feature that the
| data can be derived either from semiconductor vendor proprietary models, or
| typical component measurement over temperature/voltage.
```

- **“slow weak components”**
  - refers to skewed silicon, actual chips, representing process variations
- **“or *[slow weak]* models”**
  - refers to ffff/ssss SPICE models, representing process variations
- **“voltage and temperature derating” conditions**
  - refers to environmental conditions in which the device is operated having a “derating” effect on the normal device characteristics
- **Note the heavy use of “derate”**
  - the usage of skewed silicon and/or ffff/ssss SPICE models was now allowed
  - but derating was still needed and emphasized because neither skewed silicon nor SPICE models had the right amount of skew we wanted for the IBIS models

Regarding: "For most [Model] keyword data"

Note towards the bottom of pg. 174:

```
| The "min" and "max" columns for all remaining keywords and subparameters
| will contain the smallest and largest magnitude values.
```

List of keywords and subparameters above that statement:

I-V [Pulldown], [Pullup], [GND Clamp], and [POWER Clamp]
all [Ramp] subparameters dV/dt_r and dV/dt_f

V-t all waveform table keywords and subparameters [Rising Waveform], [Falling Waveform], V_fixture, V_fixture_min, and V_fixture_max

Supply [Voltage Range], [Pulldown Reference], [Pullup Reference], [GND Clamp Reference], and [POWER Clamp Reference]

Temp. [Temperature Range]

- **The above list contains the I-V and V-t tables, [Ramp] and their associated voltage reference and temperature keywords**
- **Keep in mind, that this statement is also originated from the v2.1 specification**
- **Consider the number of keywords which have been added to the specification since v2.1…**

C_comp

Quote from the bottom of pg. 174:

| The "min" and "max" columns for all remaining keywords and subparameters
| will contain the smallest and largest magnitude values. **This applies to the**
| **[Model] subparameter C_comp as well even if the correlation to the voltage,**
| **temperature, and process variations are known because information about such**
| **correlation is not available in all cases.**
|
| C_comp is considered an independent variable. This is because C_comp
| includes bonding pad capacitance, which does not necessarily track
| fabrication process variations. **The conservative approach to using IBIS**
| **data will associate large C_comp values with slow, weak models, and the**
| **small C_comp values with fast, strong models.**

- **Notice that "even if the correlation … are known", C_comp should be treated as an independent variable**
- **The "conservative approach" clause allows us to use that as a default (see Arpad's proposal later)**

Expectations and reasons

- **This is not stated in the IBIS specification, but the expectation was that the model's user will simulate all possible combinations of the independent variables in their design (including model and board parameters) to find the best and worst case corners of the design**

- **A given parameter value could result in best or worst timing under different circumstances**
  - a small C_comp can result in faster edge rates and reduce time delays, but it can also result in more overshoot and ringing which tend to increase settling time and consequently the timing delays
  - so is the min value in C_comp the fast or slow corner?

- **For these reasons, giving best/worst or fast/slow meaning to the model data was consciously avoided in IBIS**

The AMI Format Corner parameter

```
| Corner <typ value> <slow value> <fast value>
...
...
...
| Note that in the context of Algorithmic Model for type 'Corner', <slow
| value> and <fast value> align implicitly to slow and fast corners, and
| <slow value> does not have to be less than <fast value>.
```

The specification is not clear on what we are aligning to and how.
This is one way an AMI parameter of Format Corner might work:

```
|** (My_param  (Usage Info) (Type Integer) (Corner 0 1 2) )
|**
|** When the IBIS corner is "Typ", My_param = 0
|** When the IBIS corner is "Min", My_param = 1
|** When the IBIS corner is "Max", My_param = 2
```

Questions:

Does IBIS min = AMI slow and IBIS max = AMI fast, or is it the other way around?

Can one rule of association be applied to "all remaining" parameters?

(C_comp is not the only questionable parameter in this problem…)

Proposals

- **BIRD 133** ***Model Corner C_comp***
  - add new keyword `[C Comp Corner]` to override the original C_comp
  - the typ/min/max entries are associated with the corner of the device

    AMI_slow corresponds to [C Comp Corner] - min
    AMI_fast corresponds to [C Comp Corner] - max

- **Walter's response to BIRD 140:**
  - min/max of the I-V and V-t tables are already defined as slow/fast
  - let EDA tool decide how to deal with C_comp until BIRD 133 is approved
  - after BIRD 133 is approved (IBIS v5.1?), use the new [C Comp Corner] keyword for the AMI slow/fast associations

- **Problems:**
  - the `[C Comp Corner]` keyword is optional, and there is no definition for the IBIS min/max – AMI slow/fast association when it is absent
  - C_comp is not the only "independent" parameter in IBIS, what do we do with all the rest?
  - what if BIRD 133 doesn't make it into IBIS v5.1?

Additional keywords of interest

```
[Diff Pin]
      tdelay_typ  tdelay_min  tdelay_max

[Rgnd],  [Rpower],  [Rac],  [Cac]

[R Series],  [L Series],  [Rl Series],  [C Series],  [Lc Series],  [Rc Series]

[Series Current],  [Series MOSFET]

[External Model],  [External Circuit]
      | Corner  corner_name  file_name  circuit_name (.subckt name)
      Corner  Typ  buffer_typ.spi  buffer_io_typ
      Corner  Min  buffer_min.spi  buffer_io_min
      Corner  Max  buffer_max.spi  buffer_io_max

      | D_to_A  d_port  port1  port2  vlow  vhigh  trise  tfall  corner_name
      D_to_A  D_drive  my_drive  my_ref  0.0  3.3  0.5n  0.3n  Typ
```

Arpad's proposal

- **Extend IBIS to five (5) corners**
  - add two new optional corners to each keyword or subparameter which currently has typ/min/max
  - the new corner names shall be "Slow" and "Fast"

    AMI_slow corresponds to IBIS_slow
    AMI_fast corresponds to IBIS_fast

- **So that we wouldn't have to rewrite the entire IBIS specification all at once, define a "default" mechanism:**
  - if slow/fast corner values are not present, associate

    AMI_slow with IBIS_min
    AMI_fast with IBIS_max

    in general, and define a different association on a case by case bases for those keywords or subparameters which must have different defaults

Examples

The specification would have a general statement somewhere:

"If not specified otherwise, when data is not provided for the "Slow" and "Fast" corners, the "Min" data shall be treated as the "Slow" corner and the "Max" data as the "Fast" corner."

For exceptions, such as C_comp, we could state in the description of the keyword or subparameter:

"If the "Fast" and "Slow" data values are not present, the value in the "Min" location shall be treated as the "Fast" corner and the value in the "Max" location shall be treated as the "Slow" corner case."

```
| variable  typ    min    max    slow    fast
C_comp      7.0pF  5.0pF  9.0pF  9.0pF   5.0pF

| Corner corner_name  file_name       circuit_name (.subckt name)
Corner   Typ          buffer_typ.spi  buffer_io_typ
Corner   Min          buffer_min.spi  buffer_io_min
Corner   Max          buffer_max.spi  buffer_io_max
Corner   Slow         buffer_min.spi  buffer_io_min
Corner   Fast         buffer_max.spi  buffer_io_max
```

and

```
| variable  typ    min    max
C_comp      7.0pF  5.0pF  9.0pF

| Corner corner_name  file_name       circuit_name (.subckt name)
Corner   Typ          buffer_typ.spi  buffer_io_typ
Corner   Min          buffer_min.spi  buffer_io_min
Corner   Max          buffer_max.spi  buffer_io_max
```

are thus equivalent

Which default is better?

- **Since most parameters are capacitors and resistors, for which large value tends to correspond to slow behavior and small value tends to correspond to fast behavior, we may want to consider the opposite default associations:**
  - if slow/fast corner values are not present, associate

    AMI_fast with IBIS_min

    AMI_slow with IBIS_max

    in general, and define the opposite association on a case by case bases for those keywords or subparameters which deviate from this rule
- **Problem: if slow/fast data is not present in the I-V and V-t tables, this would contradict Section 9 and would require "exception text" to be added to the I-V and V-t keywords**

Another suggestion

- **Extend IBIS to five (6) corners**
  - add three new optional corners to each keyword or subparameter which currently has typ/min/max
  - the new corner names shall be “Typ_performance”, “Slow_performance” and “Fast_performance”, where

AMI_typ	corresponds to	IBIS_typ_performance
AMI_slow	corresponds to	IBIS_slow_performance
AMI_fast	corresponds to	IBIS_fast_performance

- **This addresses the situation when “Typ_performace” is not between “Min/Max_performance”**
- **Same rules would apply as in the five corner proposal**

Summary

- **The IBIS specification describes the concept of fast/slow corners for I-V and V-t curve data only, the rest of the parameters are considered independent**
- **BIRD 133 approach addresses C_comp only, but since it is optional, undefined min/max – slow/fast associations still exist**
- **The five or six corner proposals provide a solution for all keywords or subparameters and eliminate all ambiguities because defaults are defined**