The following recommended clarification changes are based on the [Pulldown], [Pullup], [GND Clamp], [POWER Clamp] keyword section starting on page 53 of ver6\_2\_draft\_rev1.docx. The entire section is given below.

8 Jul 2015 – Mike LaBonte

* Initial draft drawn from Walter Katz email.
* Includes changes as decided in the 8 July ibis-editorial meeting.

July 8 2015 – Bob Ross

* Added "by default GND if not defined" to the [Pulldown] and [GND Clamp] keyword (since GND is a node name for 0.0 V in most systems, and this covers the case where only [Voltage Range] is declared
* Corrected the ECL Pulldown to use Pulldown\_ref, and added (i.e., Pulldown\_ref = Pullup\_ref) to the last sentence to clarify BOTH and added individual equations for both the [Pullup] and [Pulldown] tables because of confusing references
* I now prefer keeping Vtable to keep the notation simple. The meaning has been clear to everyone for the last 22 years, so there is no need to change. Vtable is a good short-cut name as clarified by the addition: "The voltages in the Voltage column of the data tables are derived from the equation " Some figures may become more cluttered and confusing with a longer name. In other areas we use Vtable\_pu and Vtable\_pd, but we have to look at this. The left hand-side term must start with "V " to be sort of consistent with SPICE voltage naming convention and to equating with V(a, b).

July 15 2016 – Editorial Task Group

* Revert to Vtable in LHS of voltage equations.
* Restore equation comments in example, adding two more for complete set.
* Change buffer\_I/O to Buffer\_I/O.

*Keywords:* [Pulldown], [Pullup], [GND Clamp], [POWER Clamp]

*Required:* Yes, if they exist in the model

*Description:* The data points under these keywords define the I-V tables of the pulldown and pullup structures of an output buffer and the I-V tables of the clamping diodes connected to the GND and the POWER pins, respectively. Currents are considered positive when their direction is into the component.

*Usage Rules:* In each of these sections, the first column contains the voltage value, and the three remaining columns hold the typical, minimum, and maximum current values. The four entries, Voltage, I(typ), I(min), and I(max) must be placed on a single line and must be separated by at least one white space.

All four columns are required under these keywords. However, data is only required in the typical column. If minimum and/or maximum current values are not available, the reserved word “NA” must be used. “NA” can be used for currents in the typical column, but numeric values MUST be specified for the first and last voltage points on any I-V table. Each I-V table must have at least 2, but not more than 100, rows.

*Other Notes:* The I-V table of the [Pullup] and the [POWER Clamp] structures are “Pullup\_ref relative”, meaning that the voltage values are referenced to the Pullup\_ref pin. (Note that, under these keywords, all references to “Pullup\_ref” refer to the voltage rail defined by the [Voltage Range], [Pullup Reference], or [POWER Clamp Reference] keywords, as appropriate.) The voltages in the Voltage column of the data tables are derived from the equation:

*Vtable = V(Pullup\_ref, Buffer\_I/O)*

The I-V table of the [POWER Clamp] structures is “Power\_clamp\_ref relative”, meaning that the voltage values are referenced to the Power\_clamp\_ref pin. (Note that, under these keywords, all references to “Power\_clamp\_ref” refer to the voltage rail defined by the [Voltage Range], or [POWER Clamp Reference] keywords, as appropriate.) The voltages in the Voltage column of the data tables are derived from the equation:

*Vtable* = *V(Power\_clamp\_ref, Buffer\_I/O)*

The I-V table of the [Pulldown] structures is “Pulldown\_ref relative”, meaning that the voltage values are referenced to the Pulldown\_ref pin. (Note that, under these keywords, all references to “Pulldown\_ref” refer to the voltage rail by default GND if not defined or defined by the [Pulldown Reference] keyword.) The voltages in the Voltage column of the data tables are derived from the equation:

*Vtable* = *V(Buffer\_I/O, Pulldown\_ref)*

The I-V table of the [GND Clamp] structures is “Gnd\_clamp\_ref relative”, meaning that the voltage values are referenced to the Gnd\_clamp\_ref pin. (Note that, under these keywords, all references to “Gnd\_clamp\_ref” refer to the voltage rail by default GND if not defined or defined by the [GND Clamp Reference] keyword.) The voltages in the Voltage column of the data tables are derived from the equation:

*Vtable* = *V(Buffer\_I/O, Gnd\_clamp\_ref)*

Therefore, for a 5 V model (Vcc=[Voltage Range]=[Pullup Reference]=[POWER Clamp Reference]=5.0V, [Pulldown Reference]=[GND Clamp Reference]=0.0V), -5 V in the table actually means 5 V above Vcc, which is +10 V with respect to ground; and 10 V means 10 V below Vcc, which is -5 V with respect to ground. Vcc-relative data is necessary to model a pullup structure properly, since the output current of a pullup structure depends on the voltage between the output and Vcc pins and not the voltage between the output and ground pins. Note that the [GND Clamp] I-V table can include quiescent input currents, or the currents of a 3-stated output, if so desired.

When tabulating data for ECL models, the data in the [Pulldown] table is measured with the output in the “logic low” state. In other words, the data in the table represents the I-V characteristics of the output when the output is at the most negative of its two logic levels. Likewise, the data in the [Pullup] table is measured with the output in the “logic one” state and represents the I-V characteristics when the output is at the most positive logic level. Note that in BOTH of these cases, the data is referenced to the same supply voltage (i.e., Pulldown\_ref = Pullup\_ref), using the equations:

Logic high state [Pullup] table

*Vtable* = *V(Pullup\_ref, Buffer\_I/O)*

Logic low state [Pulldown] table

*Vtable* = *V(Pulldown\_ref, Buffer\_I/O)*

Monotonicity Requirements:

To be monotonic, the I-V table data must meet any one of the following 8 criteria:

1- The CURRENT axis either increases or remains constant as the voltage axis is increased.

2- The CURRENT axis either increases or remains constant as the voltage axis is decreased.

3- The CURRENT axis either decreases or remains constant as the voltage axis is increased.

4- The CURRENT axis either decreases or remains constant as the voltage axis is decreased.

5- The VOLTAGE axis either increases or remains constant as the current axis is increased.

6- The VOLTAGE axis either increases or remains constant as the current axis is decreased.

7- The VOLTAGE axis either decreases or remains constant as the current axis is increased.

8- The VOLTAGE axis either decreases or remains constant as the current axis is decreased.

An IBIS syntax checking program shall test for non-monotonic data and provide a maximum of one warning per I-V table if non-monotonic data is found. For example:

“Warning: Line 300, Pulldown I-V table for model DC040403 is non-monotonic! Most EDA tools will filter this data to remove the non-monotonic data.”

It is also recognized that the data may be monotonic if currents from both the output stage and the clamp diode are added together as most EDA tools do. To limit the complexity of the IBIS syntax checking programs, such programs will conduct monotonicity testing only on one I-V table at a time.

It is intended that the [POWER Clamp] and [GND Clamp] tables are summed together and then added to the appropriate [Pullup] or [Pulldown] table when a buffer is driving high or low, respectively.

From this assumption and the nature of 3-statable buffers, it follows that the data in the clamping table sections are handled as constantly present tables and the [Pullup] and [Pulldown] tables are used only when needed in the simulation.

The clamp tables of an Input or I/O buffer can be measured directly with a curve tracer, with the I/O buffer 3-stated. However, sweeping enabled buffers results in tables that are the sum of the clamping tables and the output structures. Based on the assumption outlined above, the [Pullup] and [Pulldown] tables of an IBIS model must represent the difference of the 3-stated and the enabled buffer’s tables. (Note that the resulting difference table can demonstrate a non-monotonic shape.) This requirement enables the EDA tool to sum the tables, without the danger of double counting, and arrive at an accurate model in both the 3-stated and enabled conditions.

Since in the case of a non 3-statable buffer, this difference table cannot be generated through lab measurements (because the clamping tables cannot be measured alone), the [Pullup] and [Pulldown] tables of an IBIS model can contain the sum of the clamping characteristics and the output structure. In this case, the clamping tables must contain all zeroes, or the keywords must be omitted.

*Example:*

[Pulldown] | Note: Vtable = V(Buffer\_I/O, Pulldown\_ref)

|

| Voltage I(typ) I(min) I(max)

|

 -5.0V -40.0m -34.0m -45.0m

 -4.0V -39.0m -33.0m -43.0m

| .

 0.0V 0.0m 0.0m 0.0m

| .

 5.0V 40.0m 34.0m 45.0m

 10.0V 45.0m 40.0m 49.0m

|

[Pullup] | Note: Vtable = V(Pullup\_ref, Buffer\_I/O)

|

| Voltage I(typ) I(min) I(max)

|

 -5.0V 32.0m 30.0m 35.0m

 -4.0V 31.0m 29.0m 33.0m

| .

 0.0V 0.0m 0.0m 0.0m

| .

 5.0V -32.0m -30.0m -35.0m

 10.0V -38.0m -35.0m -40.0m

|

[GND Clamp] | Note: Vtable = V(Buffer\_I/O, Gnd\_clamp\_ref)

|

| Voltage I(typ) I(min) I(max)

|

 -5.0V -3900.0m -3800.0m -4000.0m

 -0.7V -80.0m -75.0m -85.0m

 -0.6V -22.0m -20.0m -25.0m

 -0.5V -2.4m -2.0m -2.9m

 -0.4V 0.0m 0.0m 0.0m

 5.0V 0.0m 0.0m 0.0m

|

[POWER Clamp] | Note: Vtable = V(Power\_clamp\_ref, Buffer\_I/O)

|

| Voltage I(typ) I(min) I(max)

|

 -5.0V 4450.0m NA NA

 -0.7V 95.0m NA NA

 -0.6V 23.0m NA NA

 -0.5V 2.4m NA NA

 -0.4V 0.0m NA NA

 0.0V 0.0m NA NA