References in IBIS

Bob Ross, Teraspeed Labs
bob@teraspeedlabs.com

DesignCon IBIS Summit
Santa Clara, California
January 22, 2016

Copyright 2016 Teraspeed Labs
Goals and Contents

• Overview of existing IBIS handling of voltages
• Local reference node of “ground” is implicitly assumed throughout IBIS
  o Evolution of IBIS leads to this interpretation
  o A few exceptions exist
• Clarifying references is IBIS Version 6.1 is a current task
• Simple definition: a voltage (or potential difference) is measured between TWO points (sometimes called nodes) in a system
• A single-valued node voltage entry usually assumes that the other node is “ground”
History

• IBIS 1.0, 1.1 had only [Voltage Range]
  o Focused only on CMOS and bipolar (e.g., TTL) technologies with the negative node connected to “ground”

• [Voltage Range] meant to be a voltage span
  o Later clarified as a fixed voltage with respect to “ground”
  o Necessary interpretation for simulation model extraction

• Other specific references added in Version 2.0
  o [Pulldown Reference], [Pullup Reference], [GND Clamp Reference], [Power Clamp Reference]
  o Covers general configurations (e.g., RS-232) and other technologies, i.e., ECL and PECL
  o Could override [Voltage Range], regardless of its entry
[Model] Voltages and Voltage References

• Keywords give single-valued voltage entries relative to a “ground” node, NOT with respect to any other reference
  ○ [Voltage Range] 3.3 3.0 3.6
  ○ [Pullup Reference] 3.3 3.0 3.6

• Determines actual voltages for the 0.0 V position in the corresponding I-V tables
  ○ [Pullup], [Pulldown], [POWER Clamp], [GND Clamp]
Other Notes: Power Supplies: It is intended that standard TTL and CMOS models be specified using only the [Voltage Range] keyword. However, in cases where the output characteristics of a model depend on more than a single supply and ground, or a [Pullup], [Pulldown], [POWER Clamp], or [GND Clamp] table is referenced to something other than the default supplies, use the additional “reference” keywords.
Terminal Names

- **[Component]/[Pin Mapping]**
  - Terminals associated with [Model] reference voltages
  - `pulldown_ref` for [Pulldown Reference], `pullup_ref` for [Pullup Reference], etc.
  - `ext_ref` for buffer terminal, if it exists

- **[External Model] (also [External Circuit])**
  - `A_puref`, `A_pdref`, `A_extref`, etc.
  - Also, `A_gnd` was added to allow connecting to SPICE node 0 in a subcircuit

- **[External Reference] special application**
  - Externally set or internally derived (such as from a voltage divider)
  - Another threshold voltage
Specification Voltages and Capacitances

• Also relative to a “ground” node
  o Voltage values may shift with the [* Reference] voltages

• Single values, relative to “ground”, e.g.,
  o Vinh = 3.5 V
  o Vinl = 1.5 V

• [Model Spec] single-valued typ/min/max voltage entries usually relative to “ground”

• [Model Spec] Cref*, Vref* connected to an external “ground”

• Two node exceptions: e.g., vdiff, Cref_diff
Timing Test Load
External “ground” Example
Specification Voltage Example

- Values can shift with [* Reference] supplies
- Entries with respect to “ground” even though thresholds relative to Vcc

<table>
<thead>
<tr>
<th>[Model Spec]</th>
<th>10% supply variations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>typ</td>
</tr>
<tr>
<td>ECL (Vcc = 0.0 V, Vee = -5.2 V)</td>
<td>Vinh: -1.165</td>
</tr>
<tr>
<td></td>
<td>Vinl: -1.365</td>
</tr>
<tr>
<td>PECL (Vcc = 5.0 V, Vee = 0.0 V)</td>
<td>Vinh: 3.835</td>
</tr>
<tr>
<td></td>
<td>Vinl: 3.525</td>
</tr>
<tr>
<td>PECL (Vcc 2.0 V, Vee = -3.2 V)</td>
<td>Vinh: 0.835</td>
</tr>
<tr>
<td></td>
<td>Vinl: 0.525</td>
</tr>
</tbody>
</table>

|                | referenced to Vcc | no internal “ground” node |
©Copyright 2016 Teraspeed Labs
Package References

- Also relative to “ground”
- [Package] C_pkg
- [Pin] C_pin
- [Define Package Model]
  - [Capacitance Matrix]
  - C
- EBD
  - C
C_comp

- Historically assumed a “ground” node reference
- For simulation model extraction, any fixed node reference produces the same simulation model
- Power-aware simulation
  - C_comp node connections critical
  - Global or local “ground” reference is not accurate
  - However, using C_comp* subparameters allow connecting C_comp to *_ref terminals to increase simulation accuracy
- C_comp improvements to be resolved
Terminator Model “ground” in IBIS 5.0 and 6.1

*Note: More advanced package parameters are available within this standard, including more detailed power and ground net descriptions.*
Notes on Data Derivation Method

• Ranges listed ambiguously in terms of model names GND and POWER as voltages
• E.g., For [Pulldown] table
  ○ GND-POWER to POWER+POWER (using typ value only)
• Rule incorrectly uses model names POWER and GND as voltages
• Must INFER the intended rule if the reference voltages are shifted
• Better rule statement needs to be developed
[Test Load], EMI Section

- [Test Load]
  - Capacitances relative to external “ground” node
  - Td, Zo – ideal transmission line relative to external “ground”

- EMI also has several capacitor subparameters
  - C_Heatsink_float – no reference
  - C_Heatsink_gnd – “ground” reference
  - Cpd – power dissipation capacitance used in a formula per a device specification, and is not connected
[Receiver Thresholds] Specification Exception

- **[Receiver Thresholds]**
- **Reference_supply** subparameter uses reserved arguments to name which reference voltage to use:

  Sub-Params: Vth, Vth_min, Vth_max, Vinh_ac, Vinh_dc, Vinl_ac, Vinl_dc, Threshold_sensitivity, Reference_supply, Vcross_low, Vcross_high, Vdiff_ac, Vdiff_dc, Tslew_ac, Tdiffslew_ac

  Reference_supply indicates which supply voltage Vth tracks; i.e., it indicates which supply voltage change causes a change in input threshold. The legal arguments to this subparameter are as follows:

  - **Power_clamp_ref** The supply voltage defined by the [POWER Clamp Reference] keyword
  - **Gnd_clamp_ref** The supply voltage defined by the [GND Clamp Reference] keyword
  - **Pullup_ref** The supply voltage defined by the [Pullup reference] keyword
  - **Pulldown_ref** The supply voltage defined by the [Pulldown reference] keyword
  - **Ext_ref** The supply voltage defined by the [External Reference] keyword
Advice to Fix

• Understand and apply to all areas of IBIS
• Note, that references are stated in many ways or are just assumed to be “ground” or external “ground”
• So page-by-page scrub is needed based on understanding