

BUFFER ISSUE RESOLUTION DOCUMENT (BIRD)

BIRD NUMBER: (for administrative use)
ISSUE TITLE: C_comp Model Using IBIS-ISS or Touchstone
REQUESTOR: Walter Katz, Signal Integrity Software, Inc.
 Randy Wolff, Micron Technology, Inc.
DATE SUBMITTED: (for administrative use)
DATE REVISED: (for administrative use)
DATE ACCEPTED: (for administrative use)

DEFINITION OF THE ISSUE:

The current C_comp model is either a single capacitance or optionally up to four capacitors attached to a [Model]'s power and ground reference terminals. This simple C_comp model is not accurate enough for high speed buffers. This BIRD enhances IBIS to allow an alternative C_comp model using an IBIS-ISS subcircuit or Touchstone file. An enhanced C_comp model would allow modeling of effects such as frequency and voltage dependencies.

SOLUTION REQUIREMENTS:

The IBIS specification must meet these requirements:

Table 1: Solution Requirements

Requirement	Notes
1. Allow an IBIS-ISS subcircuit or Touchstone file to be used as a C_comp model.	
2. Allow up to three models to be declared and define how they align with typ/min/max corners.	
3. Define the terminals of the C_comp model including references, signal (both internal and external to allow a series resistance between buffer and pad) and a receiver terminal for probing the input buffer.	A receiver terminal would allow for modeling series element filtering between the pad and the input buffer. EDA software could support plotting of the waveform at this terminal and measurement of signal switching thresholds at this terminal.
4. Support single-ended as well as pseudo/true differential models.	
5. Explain handling of the reference for Touchstone files.	

6. Define how parameters can be instantiated and passed into the IBIS-ISS subcircuits for each of the typ/min/max corners.	Parameters should be single values that can be passed into either the typ, min or max corner subcircuit. Parameters are not meant to define ranges or allow sweeps.
7. Explain hierarchy of the new C_comp model with existing keywords including [C Comp Corner] or any other C_comp* models.	The new C_comp model should override other C_comp models. May need to explain how a simulator could use traditional C_comp* values for K-T curve generation. Recommended use of [C Comp Corner] for this.

SUMMARY OF PROPOSED CHANGES:

For review purposes, the proposed changes are summarized as follows:

Table 2: IBIS Keywords, Subparameters, AMI Reserved_Parameters, and AMI functions Affected

Specification Item	New/Modified/Other	Notes
[C_comp Model]	New	Positioned after [C Comp Corner]
[C Comp Corner]	Modified	Required when using [C_comp Model]
[Component]	Modified	Si_location & Timing_location sub-params

PROPOSED CHANGES:

A new keyword [C_comp Model] shall be positioned after [C Comp Corner]. In the tree diagram under [Model] and after [C Comp Corner], add:



The [C Comp Corner] keyword requires a modification to the “Required” description as noted below:

Keyword: [C Comp Corner]
Required: Yes, if the [C_comp Model] keyword is present

The [Component] keyword requires a modification to the “Usage Rules” description as noted below:

Si_location and Timing_location are optional and specify where the Signal Integrity and Timing measurements are made for the component. Allowed values for either subparameter are “Buf”, “Die” or “Pin”. The default location is at the “Pin”. The “Die” location is also commonly referred to as the Pad location. The “Buf” location refers to the Buf_rx* terminal(s) of a [C_comp Model].

After the keyword [C Comp Corner] add:

Keyword: [C_comp Model], [End C_comp Model]

Required: No

Description: Defines an enhanced C_comp model referenced in an external file using either the Touchstone or IBIS-ISS languages. The [C_comp Model] has terminals compatible with the [Model] keyword or has terminals compatible with the [Model] keyword plus additional terminals connecting between the [Model] and the pad and/or at the input buffer.

Sub-Params: Param, File_TS, File_IBIS-ISS, Number_of_Terminals, Terminal

Usage Rules: If [C_comp Model] is present, it overrides [C Comp Corner] or any other C_comp* representations. If [C_comp Model] is present, [C Comp Corner] is required. EDA software may use the [C Comp Corner] values in K-T table function generation during Device-In-Action simulation.

Other Notes:

IBIS-ISS interconnect models allow for on-die interconnect circuits between the Buffer I/O Terminal and the Die Pad. A [C_comp Model] may also contain series elements modeling on-die interconnect between the Buffer Terminal and the Die Pad. Use of a [C_comp Model] with series elements in the signal path shall assume that V-T curves are measured at the Buf_I/O terminal of the [Model]. If there is no on-die interconnect model, then this is the “Pad” in legacy IBIS models. The effect of series elements in a [C_comp Model] may need to be de-embedded from I-V table data in the [Model].

The following subparameters are defined:

Param

File_IBIS-ISS

File_TS

Number_of_terminals = <value>

In addition to these subparameters, the [C_comp Model]/[End C_comp Model] section may contain lines describing terminals and their connections. No specific subparameter name, token, or other string is used to identify terminal lines.

Unless noted below, no C_comp Model subparameter requires the presence of any other subparameter.

Param rules:

The subparameter Param is optional and only legal with the File_IBIS-ISS subparameter documented below. Param is illegal with the File_TS subparameter documented below. Param shall be followed by several arguments: an unquoted string argument giving the name of the parameter to be passed into the IBIS-ISS subcircuit, a reserved word for the parameter format, and other arguments based on the parameter format to be passed into the IBIS-ISS subcircuit. Valid entries for format are:

Value – A single numerical value or string value.

Corner – Three numerical values or three string values (surrounded by double quotes) located in the typ, min and max columns. A typ value is required. Either or both the min and max entries may be NA, in which cases the typ entry is used. The typ, min and max parameters are associated with the corner_name Typ, Min and Max files and their corresponding circuit_names respectively.

Several Param lines are permitted as long as each of the parameter names is unique within the [C_comp Model]/[End C_comp Model] section. The Param values shall all be numerical or all string values (or NA).

The numerical value rules follow the scaling conventions in Section 3, “GENERAL SYNTAX RULES AND GUIDELINES”. The EDA tool is responsible for translating IBIS specified parameters into IBIS-ISS parameters. For example, 1 megaohm, would be represented as 1M in Param value according to the Section 3 rules, but would be converted by the EDA tool to case-insensitive 1meg (1X is not recommended) or 1E6 for IBIS-ISS use. Quoted string parameters in IBIS are converted to the string parameter syntax in IBIS-ISS subcircuits. For example, the Param value “typ.s1p” would be converted to str(‘typ.s1p’) in IBIS-ISS subcircuits.

Examples:

Param	param_name	format	typ	min	max
Param	R_esr	Corner	4.0	6.0	2.0
Param	C_123	Value	425f		
Param	ts_file	Corner	“typ.s1p”	“min.s1p”	“max.s1p”

File_IBIS-ISS rules:

Either File_IBIS-ISS or File_TS is required for a [C_comp Model]/[End C_comp Model] section. The File_IBIS-ISS subparameter is followed by three unquoted string arguments consisting of corner_name, file_name, and circuit_name (.subckt name) for an IBIS-ISS file. The referenced file under file_name shall be located in the same directory as the .ibs file. The corner_name shall be Typ, Min or Max. File_IBIS-ISS for the Typ corner_name is required, and File_IBIS-ISS for the Min and Max corner_names are optional. If present, each File_IBIS-ISS shall have a unique corner_name. If File_IBIS-ISS for either the Min or Max corner_name is missing, the File_IBIS-ISS for the Typ corner_name shall be used to describe the missing corner_name file reference. The Min and Max file_names should represent minimum (slow) and maximum (fast) model conditions respectively.

Examples:

file_type	corner_name	file_name	circuit_name (.subckt name)
File_IBIS-ISS	Typ	c_comp.iss	c_comp_typ
File_IBIS-ISS	Min	c_comp.iss	c_comp_min in same file Typ
File_IBIS-ISS	Max	c_comp_max.iss	c_comp_max in separate file

File_TS rules:

Either File_TS or File_IBIS-ISS is required for a [C_comp Model]/[End C_comp Model] section. File_TS is followed by three unquoted string arguments for typ, min, and max file names. The typ entry is required and shall point to a Touchstone file located in the same directory as the .ibs file and representing typical conditions. The min and max entries may point to the same file or other files representing minimum (slow) and maximum (fast) models or contain NA. If the entry is NA, the typical file entry shall be used.

Examples:

file_type	typ	min	max
File_TS	c_comp_typ.s5p	c_comp_min.s5p	c_comp_max.s5p

file_type	typ	min	max
File_TS	c_comp_typ.s4p	c_comp_min.s4p	NA

Number_of_terminals rules:

The Number_of_terminals subparameter is required and defines the number of Terminals associated with the C_comp Model. The subparameter name shall be followed by a single integer argument equal to or greater than two on the same line. The argument shall be separated from the subparameter name by the “=” character. The subparameter name, “=” character, and argument may optionally be separated by whitespace. Only one Number_of_terminals subparameter may appear for a given [C_comp Model] keyword. The Number_of_terminals subparameter shall appear before any Terminal lines and after all other subparameters for a given C_comp Model.

Terminal line rules:

Terminal lines shall appear after the Number_of_terminals subparameter and before the [End C_comp Model] keyword. No token or reserved word identifies Terminal lines. Each Terminal line contains information on a Terminal of an IBIS-ISS subcircuit (or Touchstone file). Two or more Terminal lines may appear under a given [C_comp Model] keyword. At least one signal and one reference Terminal line is required.

Terminal lines are of the form

<Terminal_number> <Terminal_type>

Terminal_number

Terminal_number is an identifier for a specific Terminal. Terminal_number shall be a positive non-zero integer less than or equal to the value of the Number_of_terminals argument, and which also matches the number of terminals used in a corresponding IBIS-ISS subcircuit, or the number of ports plus 1 used in a corresponding Touchstone file. The same Terminal_number shall not appear more than once for a given C_comp Model. All Terminals must be present for a given C_comp Model.

The Terminal_number entry shall match the IBIS_ISS terminal (node) position or the Touchstone file terminal (line) position, plus an undeclared reference line. The

Terminal_number entries may be listed in any order as long as there are no duplicate entries.

Terminal_type

Terminal_type shall be one of the following: Buf_I/O, Buf_O, Buf_I/O_pos, Buf_O_pos, Buf_I/O_neg, Buf_O_neg, Buf_I, Buf_I_pos, Buf_I_neg, Pullup_ref, Pulldown_ref, Power_clamp_ref, Gnd_clamp_ref or Ext_ref. Terminal_type entries are described in Table 1.

Table 1 – Terminal_type Definitions

Terminal_type	Definition
Buf_I/O	Connects to the [Model]'s signal terminal. This is the location that is either at the Die Pad, or there may optionally be on-die interconnect between this terminal and the Die Pad.
Buf_O	Internal node connecting between a [Model] and the Buf_I/O terminal when there is a series component to the C_comp Model.
Buf_I/O_pos	Connects to the positive (non-inverting) side of a differential [Model]'s signal terminal. This is the location that is either at the Die Pad, or there may optionally be on-die interconnect between this terminal and the Die Pad.
Buf_O_pos	Internal node connecting between a [Model] and the Buf_I/O_pos terminal when there is a series component to the differential C_comp Model.
Buf_I/O_neg	Connects to the complementary (inverting) side of a differential [Model]'s signal terminal. This is the location that is either at the Die Pad, or there may optionally be on-die interconnect between this terminal and the Die Pad.
Buf_O_neg	Internal node connecting between a [Model] and the Buf_I/O_neg terminal when there is a series component to the differential C_comp Model.
Buf_I	Available when there is a series element between the Buf_I/O terminal and the input buffer, where Signal Integrity and/or Timing measurements could be made for the component. This location may be referenced as a Si_location and/or Timing_location by [Component].
Buf_I_pos	Available when there is a series element between the Buf_I/O_pos terminal and the differential input buffer, where Signal Integrity and/or Timing measurements could be made for the component. This location may be referenced as a Si_location and/or Timing_location by [Component].
Buf_I_neg	Available when there is a series element between the Buf_I/O_neg terminal and the differential input buffer, where Signal Integrity and/or Timing measurements could be made for the component. This location may be referenced as a Si_location and/or Timing_location by [Component].
Pullup_ref	Connects to the [Model]'s pullup reference.

Pulldown_ref	Connects to the [Model]'s pulldown reference.
Power_clamp_ref	Connects to the [Model]'s power clamp reference.
Gnd_clamp_ref	Connects to the [Model]'s ground clamp reference.
Ext_ref	Connects to the [Model]'s external reference.

A C_comp Model can either replace C_comp by connecting a single terminal of the C_comp Model at the same location that the [Model]'s C_comp connects (see Figure X), or it can replace C_comp with a model containing series elements (see Figure Y). In this case, the C_comp Model will require a terminal at the output of the buffer (Buf_O) and a terminal at an internal buffer node (Buf_I).

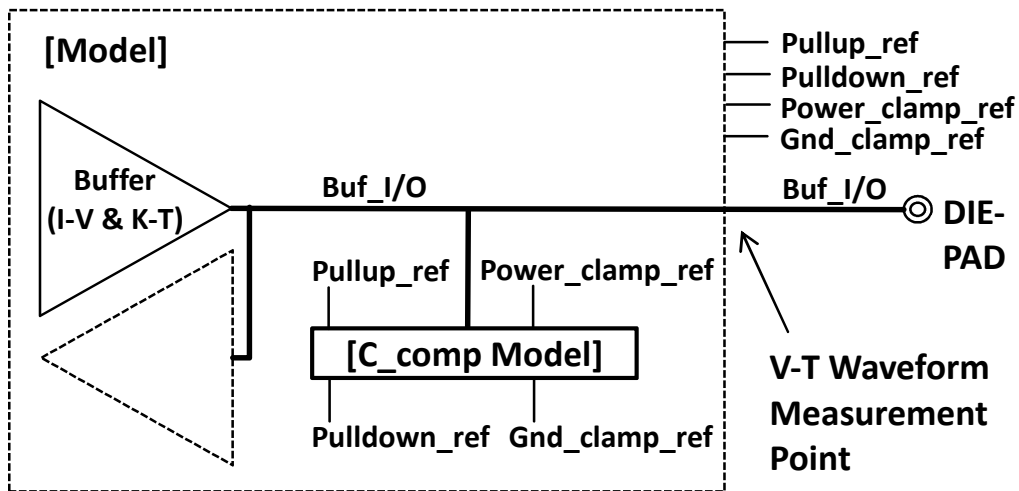


Figure X

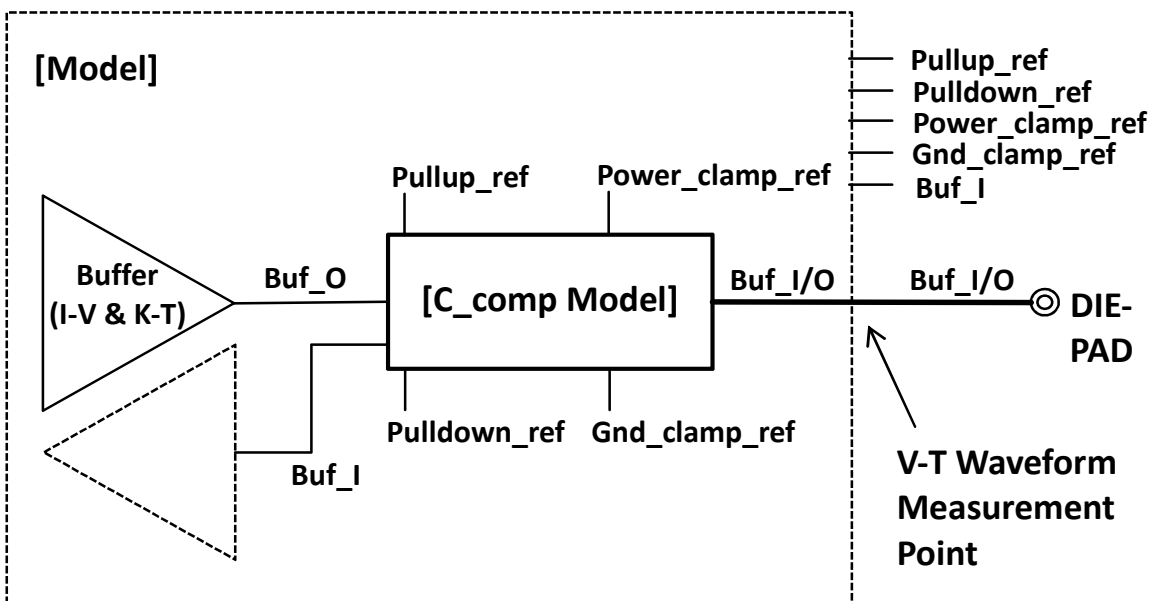


Figure Y

Some Input and/or I/O buffers contain series elements between the Die Pad and the input buffer circuit that may provide isolation or filtering. If it is desired to view the analog input waveform at the input buffer, the C_comp Model can contain the terminal Buf_I as seen in Figure Y. Buf_I may be referenced as a Si_location and/or Timing_location by [Component]. The terminal Buf_I is analogous to the terminal my_receive of an [External Model] as seen in Figure 24. If the buffer is differential, then terminals Buf_*_pos and Buf_I*_neg can be used as seen in Figure Z.

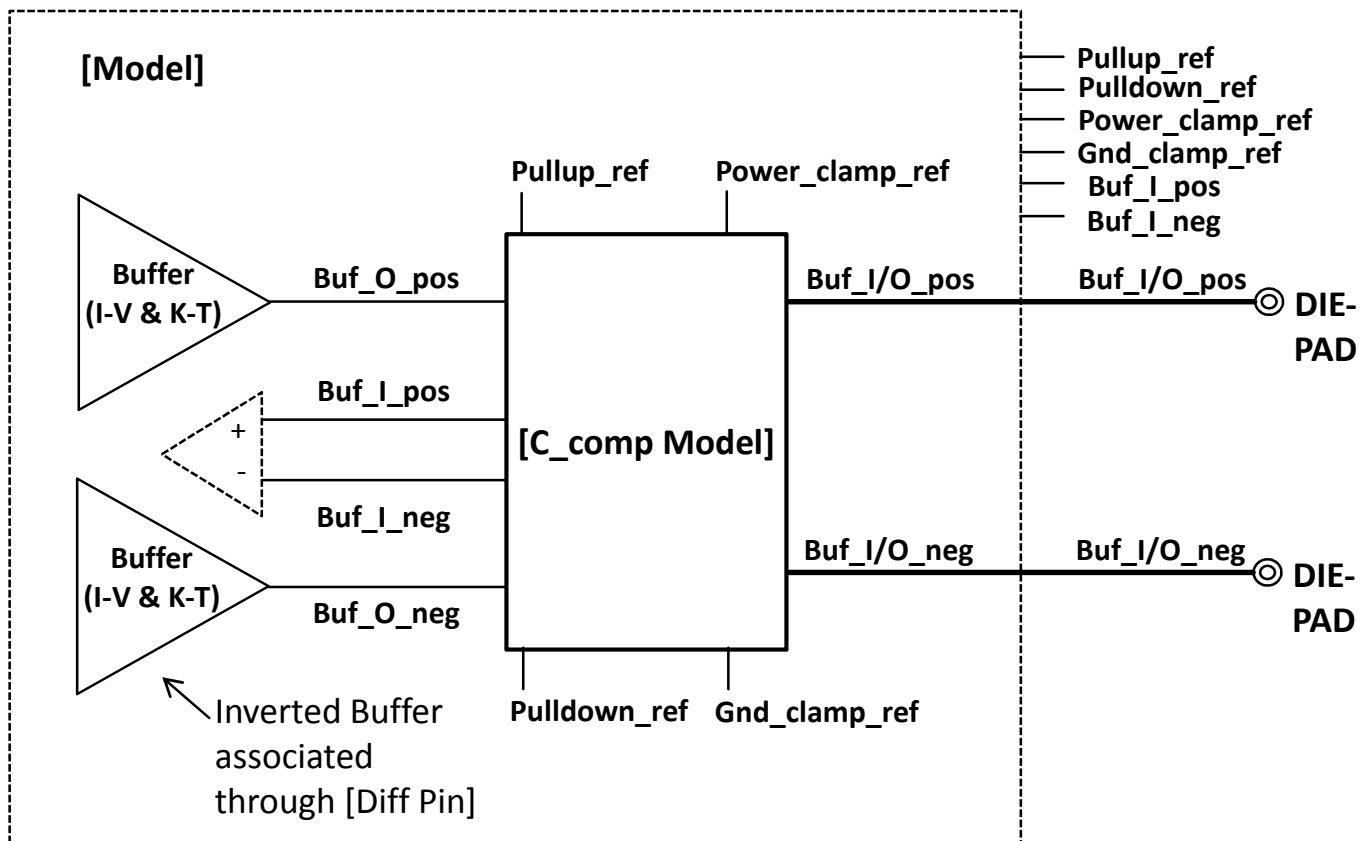


Figure Z

Other Notes:

Touchstone Files

For a C_comp Model using File_TS with N ports, N shall match the number of ports present in the data of the associated Touchstone 1.x file, or the value associated with the [Number of Ports] keyword in the associated Touchstone 2 file. The Number_of_terminals entry in the C_comp Model shall be an integer equal to N+1. Terminal rules are described below:

- The EDA tool shall use the Terminal “N+1” entry as the reference node for each of the N ports. For a C_comp Model with N ports, the Terminals and Ports are associated as follows:

- | ○ <u>Terminal</u> | <u>Port</u> |
|-------------------|-------------|
| ○ 1 | 1 |
| ○ 2 | 2 |
| ○ ... | |
| ○ N | N |
| ○ N+1 | reference |
- If a Terminal with number less than or equal to N is not connected, then it shall be terminated by the EDA tool with a resistor to the node on Terminal N+1. The value of this resistance shall be the value associated with the Port Reference Impedance subparameter.
 - Terminal N+1 shall be connected to a Buffer Terminal which is in turn connected to a Pin with a signal_name of POWER or GND.

Examples:

```
[C_comp Model]
File_IBIS-ISS Typ A.iss A
Param C Corner 1pF 2pF 0.5pF
Number_of_Terminals 2
1 Buf_I/O
2 Gnd_clamp_ref
[End C_comp Model]
```

```
[C_comp Model]
File_TS C_typ.s2p C_min.s2p C_max.s2p
Number_of_Terminals 3
1 Buf_O
2 Buf_I/O
3 Gnd_clamp_ref
[End C_comp Model]
```

```
[C_comp Model]
File_IBIS-ISS Typ B.iss B
Number_of_Terminals 7
1 Buf_O
2 Buf_I/O
3 Pullup_ref
4 Pulldown_ref
5 Power_clamp_ref
6 Gnd_clamp_ref
7 Buf_I
[End C_comp Model]
```

```
[C_comp Model]
File_TS C_typ.s4p NA NA
Number_of_Terminals 5
1 Buf_O_pos
2 Buf_O_neg
3 Buf_I/O_pos
4 Buf_I/O_neg
5 Gnd_clamp_ref
[End C_comp Model]
```

The following section should be appended to the end of the IBIS document.

RULES OF PRECEDENCE

The EDA tool shall either use C_comp* or [C_comp Model], but not both. The user and EDA tool may assume that [C_comp Model] is more accurate than C_comp*. EDA software may use the [C Comp Corner] values in K-T table function generation during Device-In-Action simulation.

BACKGROUND INFORMATION/HISTORY:

Several drafts of the BIRD document were shared with the IBIS ATM task group in late 2014 and early 2015. Draft 6 from April 7, 2015 is found here:

http://www.ibis.org/macromodel_wip/archive/20150407/randywolff/C_comp%20Model%20Using%20IBIS-ISS%20BIRD%20draft%206/. Draft 6 was used as a starting point for this BIRD with the documented updated for the new BIRD template.

Notes on a discussion of the requirements section were captured in the IBIS ATM meeting minutes of May 31, 2016, http://www.ibis.org/macromodel_wip/minutes/20160531/.