**BUFFER ISSUE RESOLUTION DOCUMENT (BIRD)**

**BIRD NUMBER:** 158.6\_ draft9

**ISSUE TITLE:** *AMI Ts4file Analog Buffer Models*

**REQUESTOR:**  *Walter Katz, Signal Integrity Software, Inc.*

*Todd Westerhoff, Signal Integrity Software, Inc.*

*Fangyi Rao, Keysight Technologies, Inc.*

*Radek Biernacki, Keysight Technologies, Inc.*

**DATE SUBMITTED:** February 20, 2013; May 15, 2013; May 17, 2013; May 24, 2013;

 April 18, 2017; April 27, 2017

**DATE ACCEPTED:**

**ANALYSIS PATH/DATA THAT LED TO SPECIFICATION:**

The IBIS 5.1 specification provided limited capability for describing the frequency-dependent behavior of SerDes transmitter analog output networks or receiver analog input networks. This made it difficult to model device’s insertion and return losses accurately, both of which are key factors in determining Inter-Symbol Interference (ISI) and overall signal quality. The IBIS 6.0 specification addressed those issues via IBIS-ISS modeling within [External Model] and [External Circuit] buffer descriptions, though the approach was not as simple and straightforward as proposed here. This BIRD assumes that the Tx analog output and Rx analog input networks are described using linear 4-port network data and that the data is developed in a manner consistent with the subcircuits and parameters defined below. The subcircuits used to instantiate the transmitter and receiver on-die 4-port parameters are shown on the following pages. These subcircuits are treated as standard templates that are used whenever the AMI parameters defined in this document are used in the .ami file. This BIRD defines the following new AMI reserved parameters: Ts4file, Ts4file\_Boundary, Tx\_V, Tx\_R, and Rx\_R.

**ANY OTHER BACKGROUND INFORMATION:**

BIRD158: (From the original ANALYSIS PATH/DATA THAT LED TO SPECIFICATION)

The IBIS 5.1 specification provides limited capability for describing the frequency-dependent behavior of a Serdes transmitter’s analog output driver or receiver’s analog input termination network. This makes it difficult to model a device’s insertion and return loss accurately, both of which are key factors in determining Inter-Symbol Interference (ISI) and overall signal quality. This BIRD assumes that the Tx analog output and Rx termination network are described using 4 port S-parameter data and that the .s4p data is developed in a manner consistent with the subcircuits and parameters defined below. The subcircuits used to instantiate the transmitter and receiver on-die S-parameters are shown on the following pages. These subcircuits are treated as standard templates that are used whenever the AMI parameters defined in this document are used in the .ami file. It is assumed that the value for the transmitter parameter Tx\_V will be the I/O driver’s supply voltage in volts.

BIRD158.1:

1. Missing Transmitter Analog Circuit figure in the ANALYSIS PATH/DATA THAT LED TO SPECIFICATION Section:

BIRD158.2:

1. ANY OTHER BACKGROUND INFORMATION below was added:

The IBIS AMI flow requires that the EDA tool generate an Impulse Response of the channel. This Impulse Response includes the Tx analog buffer model, the Tx package model, the interconnect between the Tx component pin and the Rx component pin the Rx package model and the Rx analog buffer model. The Touchstone file defined in this BIRD is to be used for either the Tx analog buffer and/or the Rx analog buffer model. Note that when the Reserved Parameters Tstonefile is defined in the AMI model the Touchstone file is to be used in lieu of the analog buffer model in the [Model] section. The [Model] may also have IV and VT curves and may also have an [External Model] defined, however they are not used when the Reserved Parameter Tstonefile is defined in the .ami file. For a Tx buffer, this Touchstone file defines the analog buffer model between the zero impedance stimulus input voltage source and the die side of the package model. For an Rx buffer, this Touchstone file defines the analog buffer model between the die side of the package model and a high impedance probe at the input to the Rx Algorithmic model. Note that this Touchstone analog model only represent the on-die model between the die pad and buffer interface to the algorithmic model, and therefore the EDA tool must include a package model between the die pad and the component pin. Given that the Touchstone buffer model, package interconnect model and interconnect between the Tx and Rx component pin is LTI there are many methods of generating an Impulse Response of the channel to be used in AMI modeling that will give the identical result within numerical accuracy of the technique chosen. One technique such method commonly used in SPICE simulation is to generate a Step Response simulation by applying a step response voltage source that transitions from 0.0V to Tx\_V to the port 3 of the Tx Touchstone file and a simultaneously a step response voltage source that transitions from Tx\_V to 0.0V at the port 1 of the Tx Touchstone file. The rise time of the step response voltage source should be as close to 0 within the practical limits of SPICE simulations. The Step Response of the channel is measured with a high impedance differential probe between ports 2 and 4 of the Rx Touchstone file. The Impulse Response of the channel to be used as the input to the Tx AMI\_Init function is the time derivative of this Step Response.

1. Some editorial corrections regarding terminology for parameter definition *Descriptors*: *Default* and *Description* line entries were corrected to be consistent with the AMI sections in IBIS.
2. .S4P changed to .s4p.

BIRD158.3:

1. Tx\_Voh and Tx\_Vol defined to replace Tx\_V
2. The TRANSMIT ANALOG DRIVER CIRCUIT and RECEIVER ANALOG TERMINATION CIRCUIT titles and figures were moved out of the ANY OTHER BACKGROUND INFORMATION section and into the body of the BIRD158.3 change
3. However the above section is in between the figure and the Reserved Parameter Definitions

BIRD158.4:

1. Title changed from “AMI Touchstonefile ® Analog Buffer Models” to “AMI Ts4file Analog Buffer Model”
2. Parameter Touchstonefile changed to Ts4file because Touchstonefile has a more general meaning in IBIS-ISS. Its usage in BIRD158.4 is restricted to a four-port Touchstone format of fixed port order and no reference terminal. This would allow for fixed n-port definitions in the future’
3. Tx\_Vol and Tx\_Voh changed back to Tx\_V
4. Ts4File\_Includes is defined to support buffer, pad, or pin boundaries
5. Reference figures for Transmit and Receive show Buffer Terminals
6. Entire Analog Circuit figure from Tx to Rx shown
7. Various editorial changes related to the above changes

BIRD158.5:

1. The name of reserved parameter “Ts4file\_Includes” is changed to “Ts4file\_Boundary”
2. The example following that parameter is updated to illustrate just that parameter.
3. Various straightforward editorial changes.

BIRD158.6:

1. The reserved parameter Ts4file is described using the “file reference” terminology, introduced in BIRD 186.3.
2. Parameter Ts4file\_Boundary removed and the “buffer” terminal boundary was selected. The Pad boundary was considered, but for many applications the Buffer and Pad boundaries are the same. BIRD158.6 provides a shortcut replacement for a [Model] keyword that does not include the pad boundary.
3. Section title “10.x ALTERNATIVE AMI ANALOG BUFFER MODELING” added to position the technical content of this BIRD158.6
4. Figure section titles reduced to “TRANSMITTER ANALOG CIRCUIT” and “RECEIVER ANALOG CIRCUIT”
5. Figure titles added
6. Box in Entire Analog Circuit from Package-Channel-Package removed
7. Related editorial changes and definition of the reference terminal

The following text is to be added as a new sub-section 10.x within the section “10 ALGORITHMIC MODELING”.

**10.x ALTERNATIVE AMI ANALOG BUFFER MODELING**

This section discusses an alternative analog buffer modeling technique, specifically designed for AMI applications. The approach uses 4-port analog circuit data provided in a Touchstone file specified by the AMI parameter named Ts4file. (Note: Ts4file implies a restricted Touchstone format, where the number of ports is four and the port numbering is predefined.)

**Transmitter Analog Circuit**

Fig xxx Transmitter Analog Circuit

For logic level 1 Vp=Tx\_V / 2 and Vn=-Tx\_V / 2 where Tx\_V is a reserved parameter (defined below). For logic level 0 Vp=-Tx\_V / 2 and Vn=Tx\_V / 2. The ideal step stimulus is a differential voltage waveform Vp - Vn when the logic level is switched from 0 to 1. This may be used to determine the impulse response needed for the AMI flow. For Tx models that have the reserved parameter Ts4file, the reserved parameter Tx\_V is required and the reserved parameter Tx\_R is optional (default is 0.0 Ohms). For a Tx buffer, the transmitter circuit defines the analog buffer model between the zero-impedance stimulus input voltage source and the buffer terminals.

Ports 1, 2, 3 and 4 of the 4-port network are between the nodes 1, 2, 3 and 4 and the common reference node Ref, respectively. Ports 1 and 3 are at the stimulus source side, and ports 2 and 4 are the transmitter analog buffer model’s output. Furthermore, ports 1 and 2 correspond to the non-inverting signal path and ports 3 and 4 to the inverting signal path.

Note: The triangle ground symbols in the Tx, Rx and channel circuits represent the same node. This node would typically be the global ground, such as node 0 in IBIS-ISS.

# Receiver Analog Circuit



Fig xxx Receiver Analog Circuit

Ports 1, 2, 3 and 4 of the 4-port network are between the nodes 1, 2, 3 and 4 and the common reference node Ref, respectively. Ports 1 and 3 are the receiver analog buffer model’s input, and the waveforms at ports 2 and 4 are the differential input of the Rx algorithmic model. Furthermore, ports 1 and 2 correspond to the non-inverting signal path and ports 3 and 4 to the inverting signal path. For Rx models that have the reserved parameter Ts4file, the reserved parameter Rx\_R is optional (default is open circuit). For an Rx buffer, the receiver circuit defines the analog buffer model between the buffer terminals and the high impedance input of the Rx Algorithmic model.

Note: The triangle ground symbols in the Tx, Rx and channel circuits represent the same node. This node would typically be the global ground, such as node 0 in IBIS-ISS.

The IBIS AMI flow requires that the EDA tool generates the impulse response of the entire analog circuitry between the Tx and Rx algorithmic models, including the Tx and Rx analog buffer models. Typically, the Touchstone file data specified here will be used to describe only the analog behavior of the buffer itself including the on-die interconnect, but excluding the effects of the package, as illustrated in the following figure.



Fig xxx Entire Analog Circuit

The Tx or Rx analog circuits specified in the AMI file by means of the parameter Ts4file shall be used as a direct replacement of the corresponding analog model described by the [Model] keyword.

Note: The triangle ground symbols in the Tx, Rx and channel circuits represent the same node. This node would typically be the global ground, such as node 0 in IBIS-ISS.

By definition, the placement of the Ts4file information within .ami files makes the Ts4file data exclusively limited to AMI applications. If the same electrical behavior is desired for non-AMI applications of the same IBIS model (the one referencing the Algorithmic Model) the model maker can optionally provide an equivalent description using the [External Model] keyword. However, the latter is not needed if the model is intended for AMI applications only.

## Reserved Parameter DEFINITIONs

*Parameter:* **Ts4file**

*Required:* No

*Direction:* Tx, Rx

*Descriptors*:

Usage: Info, Dep

Type: String

Format: Value, List, Corner

Default: <string literal>

Description:<string>

*Definition:* This parameter provides the file reference for a 4-port Touchstone file to be used in the Analog Circuit. See the Analog Circuit definitions above for the port order associated with the Touchstone file data.

*Example:*

(Ts4file (Usage Info)(Type String)(Corner “typ.s4p” “min.s4p” “max.s4p”))

*Parameter:* **Tx\_V**

*Required:* Yes, if the .ami file is defined for the Tx direction and **Ts4file** parameter is defined. Illegal otherwise.

*Direction:* Tx

*Descriptors*:

Usage: Info, Dep

Type: Float

Format: Value, List, Corner, Range, Increment, Steps

Default: <numeric\_literal>

Description:<string>

*Definition:* This parameter defines the voltage swing of the stimulus input to the transmitter circuit.

*Example:*

(Tx\_V (Usage Info)(Type Float)(Range 1.0 0.5 1.0))

*Parameter:* **Tx\_R**

*Required:* No, illegal if parameter **Ts4file** is not defined.

*Direction:* Tx

*Descriptors*:

Usage: Info, Dep

Type: Float

Format: Value, List, Corner, Range, Increment, Steps

Default: <numeric\_literal>

Description:<string>

*Definition:* This parameter is optional and defines the value Tx\_R in ohms of the series resistors shown in the Fig. XX. It can only be present if the .ami file is defined for the Tx direction. If this parameter is not present in the .ami file, the value of Tx\_R defaults to zero.

*Example:*

(Tx\_R (Usage Info)(Type Float)(Value 0.0))

*Parameter:* **Rx\_R**

*Required:* No, illegal if parameter **Ts4file** is not defined.

*Direction:* Rx

*Descriptors*:

Usage: Info, Dep

Type: Float

Format: Value, List, Corner, Range, Increment, Steps

Default: <numeric\_literal>

Description:<string>

*Definition:* This parameter is optional and defines the value of Rx\_R in ohms of the resistors shown in Fig. XX. It can only be present if the .ami file is defined for the Rx direction. If this parameter is not present in the .ami file, the value of Rx\_R defaults to infinity, or a reasonable approximation thereof.

*Example:*

(Rx\_R (Usage Info)(Type Float)(Value 1.0e6))

The following three tables need to be added and renumbered appropriately.

Table 1 – General Rules and Allowable Usage for General Reserved Parameters

| **Reserved Parameter** | **General Rules** | **Allowable Usage** |
| --- | --- | --- |
| **Required** | **Default** | **Info** | **In** | **Out** | **Dep1** | **InOut** |
| Ts4file | No | -- | X |  |  | X |  |
| Tx\_V | Yes/No | -- | X |  |  | X |  |
| Tx\_R | No | 0 | X |  |  | X |  |
| Rx\_R | No | Infinity | X |  |  | X |  |

Table 2 – Allowable Data Types for General Reserved Parameters

| **Reserved Parameter** | **Data Type** |
| --- | --- |
| **Float** | **UI** | **Integer** | **String** | **Boolean** |
| Ts4file |  |  |  | X |  |
| Tx\_V | X |  |  |  |  |
| Tx\_R | X |  |  |  |  |
| Rx\_R | X |  |  |  |  |

Table 3 – Allowable Data Formats for General Reserved Parameters

| **Reserved Parameter** | **Data Format** |
| --- | --- |
| **Value** | **Range** | **Corner** | **List** | **Increment** | **Steps** | **Gaussian** | **Dual-Dirac** | **DjRj** | **Table** |
| Ts4file | X |  | X | X |  |  |  |  |  |  |
| Tx\_V | X |  |  |  |  |  |  |  |  |  |
| Tx\_R | X |  |  |  |  |  |  |  |  |  |
| Rx\_R | X |  |  |  |  |  |  |  |  |  |