**BUFFER ISSUE RESOLUTION DOCUMENT (BIRD)**

**BIRD NUMBER:** 158.6

**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.*

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**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:**

BIRD 158.6 was updated as agreed in review meetings:

1. The reserved parameter Ts4File is described using the “file reference” terminology, introduced in BIRD 186.3.
2. Additional text relating to the package and on-die interconnect modeling has been added to eliminate potential confusion and to clarify the intent.
3. The use of the term “step response” is avoided as it is not used in the current specification.
4. Various straightforward editorial changes.

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 alternative analog buffer modeling devised specifically for AMI applictions. 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



The voltages of the voltage sources correspond to V=Tx\_V for logic level 1, and V=-Tx\_V for logic level 0. The step stimulus is a differential voltage waveform between the nodes SRC\_pos and SRC\_neg when both voltage sources are synchronously switched from a logic level 0 to a logic level 1. This may be used to determine the impulse response needed for the AMI flow, as described later.

Transition time in switching between the logic levels in the two ideal voltage sources is zero.

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 connected to the buffer terminals. Furthermore, ports 1 and 2 correspond to the non-inverting signal path and ports 3 and 4 to the inverting signal path.

# 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 connected to the buffer terminals, and ports 2 and 4 serve as the differential input to 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.

The IBIS AMI flow requires that the EDA tool generates the impulse response of the entire analog circuitry from Tx to Rx algorithmic models. Typically, the Touchstone file data specified here is to be used for either the Tx analog buffer excluding the Tx package model and/or the Rx analog buffer model excluding the Rx package model. In the preceding sentence the term “package” may mean just the package or the package together with the on-die interconnect. The following figure illustrates the corresponding entire setup when both Tx and Rx use the Ts4file parameter.



Please note that the package data is added to the channel by the user using user’s own data or using some other vendor’s data. This means that the Tx or the Rx analog circuits specified in the AMI file are to be used in lieu of the analog buffer model. This can be modified by another new reserved AMI parameter Ts4file\_Boundary. In any case the package and possibly the on-die interconnect data associated with the IBIS model pointing to this AMI file via the [Algorithmic Model] keyword shall not be automatically incorporated into the above schematic by the EDA tool.

For Tx models that have the reserved parameter Ts4file, the reserved parameter Tx\_V is required and the reserved parameter Tx\_R is optional. For Rx models that have the reserved parameter Ts4file, the reserved parameter Rx\_R is optional. In other words, for a Tx buffer, the transmitter circuit defines the analog buffer model between the zero impedance stimulus input voltage source and the buffer terminals. For an Rx buffer, the receiver circuit defines the analog buffer model between the buffer terminals and a high impedance probe at the input to the Rx Algorithmic model.

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.

Given that the Touchstone 4-port model is LTI there are many methods of generating the impulse response to be used in AMI modeling that will give the identical result within numerical accuracy of the technique chosen. One technique commonly used in EDA tool simulation is to generate the impulse response by applying a step stimulus and calculating the time derivative of the response. When both Tx and Rx Ts4file parameters are present the impulse response is measured between the SRC\_pos/SRC\_neg input and a high impedance differential probe between ports 2 and 4 of the Rx 4-port network. When only one of Tx or Rx .ami files has the Ts4file parameter present then the other component’s contribution to the impulse response comes from the model details provided under the [Model] keyword referencing the .ami file without the Ts4file parameter.

## 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. If the file contains 4-port S-parameters, they can be measured at any reference impedance. See the Analog Circuit definitions above for the port order associated with the Touchstone file data.

*Examples:*

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

*Parameter:* **Ts4file\_Boundary**

*Required:* No, illegal when the parameter **Ts4file** is not present.

*Direction:* Tx, Rx

*Descriptors*:

Usage: Info, Dep

Type: String

Format: Value

Default: <string literal>

Description:<string >

*Definition:* This parameter provides the information about what the 4-port Touchstone file data represents. The data may extend to the buffer terminals, to the pad terminals, or to pin terminals. The value can be one of the following three strings: “buffer”, “pad”, or “pin”. If this parameter is not specified, the default is equivalent to “pad”. The schematics above corresponds to the “buffer” case with package block defined by the user setup covering the entire buffer to pin interconnect and package. The other options would correspond to the schematics modified accordingly, but not shown here.

*Examples:*

(Ts4file\_Boundary (Usage Info)(Type String)(Value “pad”))

*Parameter:* **Tx\_V**

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

*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.

*Examples:*

(Tx\_V (Usage Info)(Type Float)(Range 1. .5 1.))

*Parameter:* **Tx\_R**

*Required:* No

*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.

*Examples:*

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

*Parameter:* **Rx\_R**

*Required:* No

*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.

*Examples:*

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

The following three tables need to be augmented as shown below.

Table 18 – 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 |  |
| Ts4file\_Boundary | No | -- | X |  |  | X |  |
| Tx\_V | Yes/No | -- | X |  |  | X |  |
| Tx\_R | No | 0 | X |  |  | X |  |
| Rx\_R | No | Infinity | X |  |  | X |  |

Table 19 – Allowable Data Types for General Reserved Parameters

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

Table 20 – Allowable Data Formats for General Reserved Parameters

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