**BUFFER ISSUE RESOLUTION DOCUMENT (BIRD)**

**BIRD NUMBER:** 147.2

**ISSUE TITLE:** Back-channel Support

**REQUESTOR:**  Bob Miller, Broadcom, Ltd

Ambrish Varma, Cadence Design Systems, Inc;

Walter Katz, Signal Integrity Software, Inc;

Kumar Keshavan, Cadence Design Systems, Inc;

Ken Willis, Cadence Design Systems, Inc

**DATE SUBMITTED:** October 18, 2011

**DATE REVISED:** September 1, 2016, October 11, 2016

**DATE ACCEPTED:**

**DEFINITION OF THE ISSUE:**

Link training communication is required for PCI Express, IEEE 802.3,USB, Fibre Channel and other emerging serial link standards. This communication ‘provides a mechanism through which the receiver can tune the transmitter equalizer to optimize performance’ [1]. These mechanisms employ a reliable “back-channel” to support administrative link training communication between the transmitter and receiver SerDes.

Broadcom wants the IBIS standard to be able to define standardized Back Channel Interface (BCI) Protocols so that different IC Vendors can write IBIS-AMI models that can communicate with each other, without requiring any support from EDA Vendor tools.

This BIRD defines how link training communications can be standardized in the IBIS specification. This BIRD expressly does not attempt at this time to define specific standard protocols which utilize these definitions.

[1] Section 5, IEEE Std 802.3.**SOLUTION REQUIREMENTS:**

The IBIS specification must meet these requirements:

|  |  |
| --- | --- |
| Requirement | Notes |
| 1. Enable back-channel link training messages between the Tx and Rx executable models to enable the Rx executable model to control the equalization of the Tx during time domain (AMI\_GetWave) simulations. | Back-channel messages are implemented via file I/O in the simulation’s working directory instead of parameter string passing via the EDA tool. |
| 1. Support back-channel messages between the Tx and Rx executable models in channels that have Repeater(s) to enable the Downstream (primary) Rx executable model to control the equalization of the upstream Tx and Rx executable models during time domain (AMI\_GetWave) simulations. | A lightweight communication scheme supports multi-hop channel optimization, the details of which may be defined in specific future protocols. |
| 1. Does not require the EDA tool to make any changes to support these communications. | There are minor changes the EDA tool can make to improve the user experience, but these changes are not required since they can be accommodated in either the .ami files, or some extra setup required by the user. |
| 1. Allow the user and tool to know when link training has ended and normal operation has begun. | EDA support can facilitate user awareness of successful training but is not required. |
| 1. Support both private and published link training protocols. | Protocols might be published within IBIS or elsewhere later. |
| 1. Provide all channel executable model instances with a unique file namespace for back-channel communication. | If the EDA tool does not directly facilitate the namespace selection, the user may select namespaces which are compatible with a specific EDA tool via the models’ ami files. |

**SUMMARY OF PROPOSED CHANGES:**

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

|  |  |  |
| --- | --- | --- |
| Specification Item | New/Modified/Other | Notes |
| New AMI Reserved\_Parameters  BCI\_Protocol  BCI\_State  BCI\_ID  BCI\_GetWave\_Block\_UI  BCI\_Training\_UI | All are new AMI Parameters | All affect the operation of the AMI functions AMI\_Init, AMI\_GetWave |

**PROPOSED CHANGES:**

## Introduction (Section 10.1)

(Insert before

‘This section defines how the components of an algorithmic model are specified in an IBIS file.’)

There are scenarios when a receiver and transmitter circuits do not have prior information of their analog channel. Advanced models can perform link training communication to tune the transmitter equalizer parameters for optimized performance and adapt to the signature of any analog channel. This is done when transmitter tap parameters are re-configurable and receivers help them to be configured. Advanced communication specifications such as PCI express, USB, Fibre Channel, and IEEE 802.3 define link training protocols for transmitters and receivers. If both the transmitter and receiver AMI executable models support the same link training protocol (Back-channel Protocol), the EDA tool will facilitate the communication between the executable models enabling link training. Another name for Link Training in the industry is Auto-Negotiation.

A Link Training algorithm can either emulate what the silicon is actually doing, or it can use channel analysis methods to determine the optimal Tx equalization settings. This ability will also allow Rx AMI models to determine the Tx equalizations settings for channels that do not have automatic link training capabilities.

Channels with Repeaters will require that the Downstream Rx be able to control all upstream equalization.

Communications between the Rx and Tx executable models are in messages that both the Rx and Tx executable models understand, and the EDA tool does not need to understand. These agreed upon messages are called a Back-channel Protocol. This specification does not describe the details of the Back-channel Protocol but only a method to make the communication work.

This specification describes an underlying mechanism for the AMI .ami file and the executable model to allow information to be transferred from the Tx to the Rx and from the Rx to the Tx without requiring the EDA tool to understand the content of this information, or even for the EDA tool to know that back-channel communications is occurring.

With the information provided in this specification, IC Vendors can develop models that support Back Channel Training in current IBIS AMI EDA tools.

**ADD A SECTION 10.8 after Section 10.7 AND (RENUMBER LATER SECTIONS AS NECESSARY)**

## 10.8 AMI Reserved Parameter DEFINITIONs For Link training Communications

In this section, the parameters BCI\_Protocol, BCI\_State, BCI\_ID, BCI\_GetWave\_Block\_UI and BCI\_Training\_UI are documented to enable link training communication. These Reserved Parameters are in the AMI file and positioned under the Reserved\_Parameters branch.

*Parameter:* **BCI\_Protocol**

*Required:* No, and illegal before AMI\_Version 7.0

*Direction:* Rx, Tx

*Descriptors*:

Usage: In

Type: String

Format: Value, List

Default: <string literal>

Description:<string>

*Definition:* This parameter contains the name (or names) of Back-channel Protocol(s) that the model supports. This parameter tells the model which Back-channel Protocol is being used for the training process. The BCI\_Protocol defines the back-channel message files and BCI data contained therein that is read and/or generated by each call to each executable model.

*Usage Rules:* Both the transmitter and receiver for a given channel must have identical settings for the BCI\_Protocol parameter for link training to be enabled. Both the transmitter and receiver for a given channel must have GetWave\_Exists = True for link training to be enabled.

BCI\_Protocol must be present if the model supports any BCI protocol

*Other Notes:* A BCI\_Protocol may be private, published, or approved by the IBIS Open Forum. This approval process is explicitly not stated in this specification, and left to the IBIS Open Forum to decide.

BCI\_Protocol names beginning with “IBIS” are reserved for future protocols adopted and published. Names for private and independently-specified published protocols should contain character strings sufficiently unique to avoid conflicts with other independently-named protocols.

*Example:*

(BCI\_Protocol (Usage In)(Type String)(Value "Company\_xyz")

(Description "This Device supports Back-channel Protocol Company\_xyz. For private protocols, we suggest that the name should begin with a company name to help keep private protocol names unique. Protocols officially adopted by the IBIS Open Forum would begin with IBIS."))

*Parameter:*    **BCI\_ID**

*Required:* No, and illegal before AMI\_Version 7.0

*Direction:*Rx, Tx

*Descriptors*:

Usage:                   In

Type:                     String

Format:                  Value

Default:                 <string literal>

Description:<string>

*Definition:* The EDA tool is responsible for recognizing this parameter name and replacing the value declared in the .ami file with a string that contains a unique alphanumeric identifier, optionally pre-pended with a “path string”. The algorithmic model is responsible for using BCI\_ID as the base name and path for any data files that the model creates, either for use as temporary storage or for recording output data in accordance with the BCI\_Protocol.  All model instances in a channel between and including the upstream Tx and downstream Rx shall share a unique BCI\_ID. Each concurrent channel (as in a crosstalk simulation) has its own BCI\_ID. The use of BCI\_ID helps guarantee that multiple channels do not mix up data as a result of collisions between temporary or permanent file names.

The “path string” portion of the BCI\_ID string is constructed and interpreted according to the following rules (similar to those of the Reserved\_Parameter “DLL\_Path”):

The contents of the “path string” concatenated into BCI\_ID can either be an absolute path, or a path relative to the current working directory of the process running the executable model. In this string, the path separator is the forward slash "/". Back slashes “\” are not allowed. The model is responsible for making any OS-specific adjustments (for example, replacing forward slashes "/" with backslashes "\") if necessary. The last character of the “path string” shall be a forward slash “/”.

*Usage Rules:*To access a supporting file using BCI\_ID, the executable model should create a file name by creating a string consisting of the value of BCI\_ID, convert forward slashes “/” to backslashes “\” on operating systems that require a backslash “\” as a path separator, and then appending additional characters as specified in BCI\_Protocol to create the name of the file. If the EDA tool chooses to make the current working directory the directory where files are created and accessed under the BCI\_Protocol, then the “path string” portion of BCI\_ID can be “./”, the absolute path to this directory, or omitted entirely. If the EDA tool uses BCI\_ID to specify a directory other than the current working directory, the directory must exist and be read/write accessible to the executable models.

BCI\_ID must be present if BCI\_Protocol is present. BCI\_ID must be absent if BCI\_Protocol is absent.

*Other Notes:*  A BCI\_Protocol may define one, two (e.g. one per direction) or any number of BCI message files with the same BCI\_ID prefix to be used by the channel Tx and Rx executable models to support the required back-channel optimization.

If the EDA tool does not modify/uniquify BCI\_ID, the user must select and insert an appropriate matching string in the ami files of each executable model participating in the channel’s BCI\_Protocol to manually provide a functioning file namespace.

*Example:*

(BCI\_ID (Usage In) (Type String) (Value "../dll\_scratch\_dir/channel1")

(Description "Models may create/read/write/delete files in ‘../dll\_scratch\_dir’ with names beginning with ‘channel1’"))

*Parameter:* **BCI\_State**

*Required:* No, and illegal before AMI\_Version 7.0

*Direction:* Rx, Tx

*Descriptors*:

Usage: InOut

Type: String

Format: List (“Off” ”Training” “Converged” “Failed” “Error”)

Default: <string\_literal>

Description:<string>

*Definition:* The user sets the value of BCI\_State to either “Off” or ”Training” on the calls to the Tx and Rx AMI\_Init. The values of BCI\_State sent to the Tx and Rx executable models shall be the same for both the Tx and Rx AMI\_Init.

*Usage Rules:* If the BCI\_State is “Off” on the calls to Tx and Rx AMI\_Init, both the Tx and Rx executable models will not read or generate files in the BCI\_ID namespace. The values of BCI\_Protocol, BCI\_GetWave\_Block\_UI or BCI\_Training\_UI shall be ignored by the executable models. Executable models receiving BCI\_State “Off” and subsequently returning BCI\_State shall return BCI\_State “Off”.

If the BCI\_State is “Training” on the calls to Tx and Rx AMI\_Init, both the Tx and Rx executable models will read and/or write files in the BCI\_ID namespace per the BCI\_Protocol. The values of BCI\_Protocol, BCI\_ID, BCI\_GetWave\_Block\_UI and BCI\_Training\_UI are required. The Rx AMI\_GetWave calls shall return a value in BCI\_State of either “Training”, “Converged”, ”Failed” or “Error”. If theTx AMI\_GetWave returns a value in BCI\_State, it shall also be either “Training”, “Converged”, ”Failed” or “Error”; “Training”, “Converged” , and “Failed” should reflect the Rx state per the BCI\_Protocol.

The EDA tool shall consider the value of BCI\_State returned by the terminating Rx executable model to be the definitive BCI\_Protocol training state. However, any executable model in the channel, upon returning a BCI\_State value of “Error”, may thereby signal that a BCI\_Protocol has failed due to a mis-communication under the BCI\_Protocol.

If the returned value is “Training”, then the Tx and Rx AMI\_GetWave will continue to read and/or modify BCI\_ID files per the BCI\_Protocol.

If the returned value is “Converged”, then the Tx and Rx AMI\_GetWave may continue to read and/or modify the BCI\_ID files per the BCI\_Protocol. However, it is implied that no further adaptation is performed under the BCI\_Protocol and the EDA tool may complete the simulation/analysis starting with this waveform.

If the returned value is “Failed” the Rx AMI\_GetWave function indicates a condition that it was not able to converge in its search algorithm. Then the Tx and Rx AMI\_GetWave may continue to read and/or modify the BCI\_ID files per the BCI\_Protocol. However, it is implied that no further adaptation is performed under the BCI\_Protocol and the EDA tool may complete the simulation/analysis starting with this waveform.

If the returned Tx or Rx value is “Error”, the executable model indicating “Error” is unable to understand the messages according to the BCI\_Protocol. The Tx and/or Rx AMI\_GetWave will stop reading and/or modifying the BCI\_ID files. The EDA tool may communicate a protocol error to the user and complete the simulation/analysis starting with this waveform.

BCI\_State must be present if BCI\_Protocol is present. BCI\_State must be absent if BCI\_Protocol is absent.

*Other Notes:* Training and co-optimization is done by Rx models using one or more Tx equalization exploration algorithms. The Rx model may have Model Specific parameters that allow the user to choose which exploration algorithm to use.

During “Training”, the EDA tool may supply a “training” stimulus pattern defined by the user. While not required, the Back Channel Protocol will likely specify the pattern that should be used.

*Example:*

(BCI\_State (Usage InOut)(Type String)

(List“Off” ”Training” “Converged” “Failed” “Error”))

*Parameter:* **BCI\_GetWave\_Block\_UI**

*Required:* No, and illegal before AMI\_Version 7.0

*Direction:* Rx

*Descriptors*:

Usage: Info

Type: UI

Format: Value

Default: <numeric\_literal>

Description:<string >

*Definition:* This Rx parameter tells the EDA tool the recommended number of UI in each AMI\_GetWave call to be used in Time Domain simulations.

*Usage Rules:* The wave\_size passed to AMI\_GetWave would be the value of BCI\_GetWave\_Block\_UI\*bit\_time/sample\_interval.

BCI\_GetWave\_Block\_UI must be present if BCI\_Protocol is present. BCI\_GetWave\_Block\_UI must be absent if BCI\_Protocol is absent.

*Other Notes:* This parameter allows a BCI\_Protocol to define the number of training bits (“dwell time”) between BCI messages, which necessarily must occur at most once per AMI\_GetWave call. This may be necessary in some protocols or rigorous channel simulations to enforce bit-by-bit emulation.

*Example:*

(BCI\_GetWave\_Block\_UI(Usage Info) (Type UI) (Value 2000)

(Description "AMI\_GetWave blocks should contain 2000 UI”))

*Parameter:* **BCI\_Training\_UI**

*Required:* No, and illegal before AMI\_Version 7.0

*Direction:* Rx

*Descriptors*:

Usage: In

Type: UI

Format: Value

Default: <numeric\_literal>

Description:<string>

*Definition:* Tells the EDA tool how long the time variant model may take to complete training.

*Usage Rules:* This parameter is meant for Rx models that support BCI Training. The value in this field tells the EDA tool and the Rx AMI\_GetWave function how many bits of the AMI\_GetWave output should be used for training.

BCI\_Training\_UI must be present if BCI\_Protocol is present. BCI\_Training\_UI must be absent if BCI\_Protocol is absent.

*Other Notes:* If an EDA tool does not use BCI\_Training\_UI or BCI\_State to determine when it can start analysis of the optimized waveform generated by the Rx AMI\_GetWave, the user (or .ami file) should set Ignore\_Bits to the same value as BCI\_Training\_UI.

*Examples:*

(BCI\_Training\_UI (Usage In) (Type UI) (Value 100000)

(Description "BCI training may require 100000 UI")

**Table YY1 – General Rules and Allowable Usage for General Reserved Parameters**

| **Reserved Parameter** | **General Rules** | | **Allowable Usage** | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Required** | **Default** | **Info** | **In** | **Out** | **Dep1** | **InOut** |
| BCI\_GetWave\_Block\_UI | No, Yes if BCI\_Protocol is present | -- | X |  |  |  |  |
| BCI\_ID | No, Yes if BCI\_Protocol is present | -- |  | X |  |  |  |
| BCI\_Protocol | No, Yes to support BCI protocol | -- |  | X |  |  |  |
| BCI\_State | No, Yes if BCI\_Protocol is present | -- |  |  |  |  | X |
| BCI\_Training\_UI | No, Yes if BCI\_Protocol is present | -- |  | X |  |  |  |

1. Illegal for AMI\_Version 6.0 and earlier

**Table YY2 – Allowable Data Types for General Reserved Parameters**

| **Reserved Parameter** | **Data Type** | | | | |
| --- | --- | --- | --- | --- | --- |
| **Float** | **UI** | **Integer** | **String** | **Boolean** |
| BCI\_GetWave\_Block\_UI |  | X |  |  |  |
| BCI\_ID |  |  |  | X |  |
| BCI\_Protocol |  |  |  | X |  |
| BCI\_State |  |  |  | X |  |
| BCI\_Training\_UI |  | X |  |  |  |

**Table YY3 – Allowable Data Formats for General Reserved Parameters**

| **Reserved Parameter** | **Data Format** | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Value** | **Range** | **Corner** | **List** | **Increment** | **Steps** | **Gaussian** | **Dual-Dirac** | **DjRj** | **Table** |
| BCI\_GetWave\_Block\_UI | X |  |  |  |  |  |  |  |  |  |
| BCI\_ID | X |  |  |  |  |  |  |  |  |  |
| BCI\_Protocol | X |  |  | X |  |  |  |  |  |  |
| BCI\_State |  |  |  | X |  |  |  |  |  |  |
| BCI\_Training\_UI | X |  |  |  |  |  |  |  |  |  |

**Training/Analysis Flow for Channels with No Repeater**

The EDA tool shall make the following calls to the Tx and Rx AMI\_Init, AMI\_Init and AMI\_GetWave functions:

1. Tx AMI\_Init is called with
   1. (BCI\_State “Training”) (BCI\_Protocol “<name>“) (BCI\_ID “<my\_ ID> “)
   2. If the Tx executable model does not implement the BCI\_Protocol, it returns “Error” in BCI\_State.
   3. The Tx may write a message file in the BCI\_ID namespace under BCI\_Protocol.
2. Rx AMI\_Init is called with
   1. (BCI\_State “Training”) (BCI\_Protocol “<name>“) (BCI\_ID “<my\_ID> “) (BCI\_Training\_UI <# Training Bits>)
   2. If the Rx executable model does not implement BCI\_Protocol, it returns “Error” in BCI\_State.
   3. The Rx may read, write, modify and/or delete message files in the BCI\_ID namespace under BCI\_Protocol.
3. Tx AMI\_GetWave is called with the stimulus pattern. The Tx may read, write, modify and/or delete message files in BCI\_namespace under BCI\_Protocol.
4. Rx AMI\_GetWave is called with the waveform output of Tx AMI\_GetWave convolved with the IR of the channel. The Rx may read, write, modify and/or delete message files under BCI\_Protocol.
5. Steps 3 and 4 are repeated until the EDA tool stops the simulation.
   1. The EDA tool should start processing the output of Rx AMI\_GetWave after Ignore\_Bits and either:

after BCI\_Training\_UI, or

when the Rx AMI\_GetWave function returns BCI\_State “Converged” or “Failed” or either the Tx or Rx executable model returns “Error”.

Note that the EDA tool does not need to perform any operations specifically assisting the BCI communication between the Tx and the Rx executable models beyond passing the BCI parameters to both executable models on AMI\_Init.

**Training/Analysis Flow for Channels with One Repeater**

The EDA tool shall make the following calls to the Upstream Tx, Repeater Rx, Repeater Tx, Downstream Rx AMI\_Init, AMI\_Init and AMI\_GetWave functions:

1. Upstream Tx AMI\_Init is called with
   1. (BCI\_State “Training”) (BCI\_Protocol “<name>“) (BCI\_ “<my\_ID>“)
   2. If the executable model does not implement the BCI\_Protocol, it returns “Error” in BCI\_State
   3. The executable model may write a message file in the BCI\_ID namespace under BCI\_Protocol.
2. Repeater Rx AMI\_Init is called with
   1. (BCI\_State “Training”) (BCI\_Protocol “<name>“) (BCI\_ID “<my\_ID>“)
   2. If the executable model does not implement the BCI\_Protocol, it returns “Error” in BCI\_State
   3. The executable model may read, write, modify and/or delete message files in the BCI\_ID namespace under BCI\_Protocol.
3. Repeater Tx AMI\_Init is called with
   1. (BCI\_State “Training”) (BCI\_Protocol “<name>“) (BCI\_ID “<my\_ID>“)
   2. If the executable model does not implement the BCI\_Protocol, it returns “Error” in BCI\_State
   3. The executable model may read, write, modify and/or delete message files in the BCI\_ID namespace under BCI\_Protocol.
4. Downstream Rx AMI\_Init is called with
   1. (BCI\_State “Training”) (BCI\_Protocol “<name>“) (BCI\_ID “<my\_ID>“) (BCI\_Training\_UI <# Training Bits>)
   2. If the executable model does not implement the BCI\_Protocol, it returns “Error” in BCI\_State
   3. The executable model may read, write, modify and/or delete message files in the BCI\_ID namespace under BCI\_Protocol.
5. Upstream Tx AMI\_GetWave is called with the stimulus pattern. The executable model may read, write, modify and/or delete message files in the BCI\_ID namespace under BCI\_Protocol.
6. Repeater Rx AMI\_GetWave is called with the waveform output of the Upstream Tx AMI\_GetWave modified by the Upstream Channel Impulse Response. The executable model may read, write, modify and/or delete message files in the BCI\_ID namespace under BCI\_Protocol.
7. Repeater Tx AMI\_GetWave is called with the waveform output of the Repeater Rx AMI\_GetWave. The executable model may read, write, modify and/or delete message files in the BCI\_ID namespace under BCI\_Protocol.
8. Downstream Rx AMI\_GetWave is called with the waveform output of the Repeater Tx AMI\_GetWave modified by the Downstream Channel Impulse Response. The executable model may read, write, modify and/or delete message files in the BCI\_ID namespace under BCI\_Protocol
9. Steps 5 through 8 are repeated until the EDA tool stops the simulation.
   1. The EDA tool should start processing the output of Rx AMI\_GetWave after Ignore\_Bits and either:

after BCI\_Training\_UI, or

when the downstream Rx AMI\_GetWave function returns BCI\_State “Converged” or “Failed” or any executable model in the channel returns “Error”.

Note that it is the responsibility of the BCI \_Protocol to define the BCI message files and contents therein so that each executable model in the channel can determine its role/position in the channel optimization.

**BACKGROUND INFORMATION/HISTORY:**

Link training capability was initially developed by Sigrity (now Cadence Design Systems) and Snowbush (IP division of Gennum). It was deemed desirable to bring this capability to the IBIS standard in order to encourage other SerDes IP suppliers to enable link training functionality for their IP as well.

BIRD 147 has been discussed extensively in the Advanced Technology Modeling Task Group, with a number of updated draft versions posted in the group’s work archive. The changes made for BIRD 147.1 are substantial.

BIRD147.2 based on ATM meeting discussion and subsequent email discussion, this version changes the requirement rules and clarifies that BCI\_Protocol is required to support BCI. All four other BCI\_\* parameters are required. The default of 1000 for BCI\_GetWave\_Block\_UI has been removed. Also, a rule is added that it is not illegal to have any BCI\_\* parameter without the others. This makes the rule and its checking simple and removes a default that the EDA tool may not necessarily implement. The Table YYI Required entries are modified to show the Required dependence on BCI\_Protocol, as stated for each of the other BCI\_\* parameters.

The BCI\_Protocol parameter Other Notes and Example were modified to state that IBIS Specification would not list the approved IBIS protocols, but that we still suggest names of official IBIS protocols start with IBIS, and private protocols start with the company name. A future mechanism where the parser checks for names listed in a file under [www.ibis.org](http://www.ibis.org) could be used to test if an IBIS\_XXX protocol name is official.