**BUFFER ISSUE RESOLUTION DOCUMENT (BIRD)**

**BIRD NUMBER:** TBD draft 29 (December 18, 2019)

**ISSUE TITLE:** *Electrical Descriptions of Modules*

**REQUESTOR:**  Walter Katz, Signal Integrity Software (SiSoft)

**DATE SUBMITTED:**

**DATE REVISED:**

**DATE ACCEPTED:**

**STATEMENT OF THE ISSUE:**

The industry lacks a method to describe modules that consist of one or more integrated circuits or other modules mounted on a printed circuit board, mult-chip module or substrate that connects them to a system through a set of pins. The following BIRD proposes a new type of file called .emd – Electrical Module Description (EMD) -- that addresses this need. This proposal does not encompass an electrical description of connectors and other interconnect devices.

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

This BIRD has resulted from several years of discussion regarding the need for more flexible descriptions of module interconnects in IBIS. It was decided to avoid a keyword-based approach, in favor of a circuit language approach. IBIS-ISS was developed for this purpose, and a means to instantiate IBIS-ISS models from IBIS became the logical next step.

**SOLUTION REQUIREMENTS:**

The IBIS specification must meet these requirements:

Table 1: Solution Requirements

|  |  |
| --- | --- |
| Requirement | Notes |
| * The model maker must be able to provide EMD Models representing modules, using a combination of IBIS-ISS and Touchstone formats.
 |  |
| * Touchstone models without an IBIS-ISS wrapper circuit must be supported.
 |  |
| * An EMD Model may connect one signal\_name or any combination of signal\_names in one [Begin EMD].
 | Coupled electrical paths are supported. |
| * IBIS component pin terminals associated with I/O pins must be assignable to EMD Model terminals directly by pin name.
 |  |
| * EMD pin terminals associated with POWER and GND rail pins must be assignable to EMD Model terminals directly by pin name, or indirectly by [Pin] signal\_name or bus\_label.
 |  |
| * The model maker must be able to provide alternative EMD Models for any given set of pins.
 | For example, for a given pin pair it must be possible to provide both coupled and uncoupled models, high and low bandwidth models, or both IBIS-ISS and Touchstone models. |
| * The EDA tool and model user must be able to locate all EMD Models that include a specified set of pins it must analyze.
 | Simulation netlisting begins with a list of pins that must be simulated. |
| * The EDA tool and model user must be able to determine all the pins that a given EMD Model includes.
 | Once a model is chosen, it may add more pins to the simulation. |
| * The EDA tool and model user must be able to determine how to terminate any terminals of an EMD Model not necessary for an analysis.
 | May need to handle Touchstone and IBIS-ISS models differently. |
| * The model user must have useful information needed to make the choice between alternative EMD Models that differ only in characteristics other than the model format and the set of pins included.
 | For example: coupled/uncoupled, low/high bandwidth. This will be used to choose which alternative model set to use. |
| * The model user must be informed which pins of an EMD Model have been modeled with coupling to other pins, sufficient for the to represent the victim pins and the all the aggressor pins in a crosstalk simulation.
 |  |

**BACKGROUND INFORMATION/HISTORY:**

STATEMENT OF THE RESOLVED SPECIFICATIONS:

**Under Section 3, First Paragraph**

REPLACE

Unless noted otherwise, this section contains general syntax rules and guidelines for IBIS file formats .ibs (Sections 4, 5, 6 and 12), .pkg (Section 7), .ebd (Section 8), .ims (Section 11), and where applicable, .ami (Sections 10.3 through 10.11) and parameter passing files (Section 6.3).

WITH (adding .emd, .ems):

Unless noted otherwise, this section contains general syntax rules and guidelines for IBIS file formats .ibs (Sections 4, 5, 6 and 12), .pkg (Section 7), .ebd (Section 8), .ims (Section 11), .emd (Section 12??), .ems (Section 13??), and where applicable, .ami (Sections 10.3 through 10.11) and parameter passing files (Section 6.3).

**ADD to Section 3.3 Keyword Hierarchy:**

.emd FILE

 ├── File Header Section

 │ ├── **[IBIS Ver]**

 │ ├── **[Comment Char]**

 │ ├── **[File Name]**

 │ ├── **[File Rev]**

 │ ├── **[Date]**

 │ ├── **[Source]**

 │ ├── **[Notes]**

 │ ├── **[Disclaimer]**

 │ └── **[Copyright]**

 │

 ├── **[Begin EMD]**

 │ ├── **[Manufacturer]**

 │ ├── **[Description]**

 │ ├── **[Number of EMD Pins]**

 │ ├── **[EMD Pin List]** signal\_name, signal\_type

 │ │ │bus\_label

 │ │ └── **[End EMD Pin List]**

 │ │

 │ ├── **[EMD Designator Map]**

 │ │ └── **[End EMD Designator Map]**

 │ │

 │ ├── **[Designator Pin List]** signal\_name, signal\_type

 │ │ │ bus\_label

 │ │ └── **[End Designator Pin List]**

 │ │

 │ ├── **[EMD Group]**

 │ │ └── **[End EMD Group]**

 │ │

 │ └── **[End EMD]**

 │

 ├── **[EMD Set]**

 │ ├── **[Manufacturer]**

 │ ├── **[Description]**

 │ ├── **[EMD Model]** Param, File\_TS, File\_IBIS-ISS,

 │ │ │ Unused\_port\_termination,

 │ │ │ Number\_of\_terminals

 │ │ └── **[End EMD Model]**

 │ │

 │ └── **[End EMD Set]**

 │

 └── **[End]**

.ems FILE

 ├── File Header Section

 │ ├── **[IBIS Ver]**

 │ ├── **[Comment Char]**

 │ ├── **[File Name]**

 │ ├── **[File Rev]**

 │ ├── **[Date]**

 │ ├── **[Source]**

 │ ├── **[Notes]**

 │ ├── **[Disclaimer]**

 │ └── **[Copyright]**

 │

 ├── **[EMD Set]**

 │ ├── **[Manufacturer]**

 │ ├── **[Description]**

 │ ├── **[EMD Model]** Param, File\_TS, File\_IBIS-ISS,

 │ │ │ Unused\_port\_termination,

 │ │ │ Number\_of\_terminals

 │ │ └── **[End EMD Model]**

 │ │

 │ └── **[End EMD Set]**

 │

 └── **[End]**

**In Section 4:**

REPLACE

*Keyword:* [File Name]

*Required:* Yes

*Description:* Specifies the file name of the file containing this keyword.

*Usage Rules:* The file name shall conform to the rules in item 3 of Section **Error! Reference source not found.**.2, "SYNTAX RULES". In addition, the file name shall use the extension “ibs”, “pkg”, “ebd”, or “ims”. The file name shall be the actual name of the file.

*Example:*

[File Name] ver6\_1.ibs

*Keyword:* [File Rev]

*Required:* Yes

*Description:* Tracks the revision level of a particular .ibs, .pkg, .ebd, or .ims file.

*Usage Rules:* Revision level is set at the discretion of the engineer defining the file. The following guidelines are recommended:

0.x silicon and file in development

1.x pre-silicon file data from silicon model only

2.x file correlated to actual silicon measurements

3.x mature product, no more changes likely

*Example:*

[File Rev] 1.0 | Used for .ibs file variations

WITH (adding .emd, .ems)

*Keyword:* [File Name]

*Required:* Yes

*Description:* Specifies the file name of the file containing this keyword.

*Usage Rules:* The file name shall conform to the rules in item 3 of Section **Error! Reference source not found.**.2, "SYNTAX RULES". In addition, the file name shall use the extension “ibs”, “pkg”, “ebd”, “ims”, “emd”, or “ems”. The file name shall be the actual name of the file.

*Example:*

[File Name] ver7\_1.ibs

*Keyword:* [File Rev]

*Required:* Yes

*Description:* Tracks the revision level of a particular .ibs, .pkg, .ebd, .ims, .emd, or .ems file.

*Usage Rules:* Revision level is set at the discretion of the engineer defining the file. The following guidelines are recommended:

0.x silicon and file in development

1.x pre-silicon file data from silicon model only

2.x file correlated to actual silicon measurements

3.x mature product, no more changes likely

*Example:*

[File Rev] 1.0 | Used for IBIS file variations

**In Section 6.3.6 :**

REPLACE

file formats except .ami (e.g., .ibs, .pkg, .ebd and .ims)

WITH (pages 118, 119, 139, 140)

file formats except .ami (e.g., .ibs, .pkg, .ebd, .ims, .emd, and .ems)

**Move Section 12 to Section 14 and Add a New Section 12?:**

**<# TBD> ELECTRICAL MODULE DESCRIPTION (EMD)**

**INTRODUCTION**

 “Module” is a generic term describing a printed circuit board (PCB), multi-chip module (MCM), stacked die component, interposer, or substrate which can contain components or other modules, and which can connect to another board or module through a set of user-visible pins. The electrical connectivity of such a board or module-level component is described through an “Electrical Module Description”.

For the purposes of the rest of this section, “module” shall mean PCB, MCM, stacked die, interposer, substrate or similar structure connecting EMD Models.

For example, a DIMM module is a module level component that is used to attach several DRAM components on the PCB to another module through edge connector pins. An Electrical Module Description file (a .emd file) is defined to describe the connections of a module level component between the module pins and its components on the module.

Pins in the EMD Pin List and the Designator Pin List that have the same signal\_name are connected. It will be common for EMD files to be generated automatically from CAD layout databases. Each pin in a CAD database has a CAD net, and when two pins have the same CAD net, they are connected. Normally the signal\_name of EMD pins and designator pins will be the same as their CAD net in the layout database. An exception to this is when there are series terminations and parallel terminations. In this case the model maker can choose to either:

1. Combine two CAD nets into an extended net. All the pins in the two CAD nets will use the extended net name as their signal\_name in the EMD file. The termination resistor or capacitor would be included in the interconnect model for this extended net. An extended net is defined as the list of EMD and designator pins that are connected with an interconnect model.
2. Create separate interconnect models for each CAD net. There will need to be a designator for the termination component.

One of the requirements of an EMD file is to enable the EDA tool to generate all the extended nets.

What is and is not included in an EMD Model is defined by its boundaries. For the definition of the boundaries, see the description section under the [EMD Model] keyword.

Usage Rules:

A .emd file is intended to be a stand-alone file, not referenced by or included in any .ibs, .ebd, or .pkg file. Electrical Module Descriptions are stored in a file whose name is <stem>.emd, where <stem> must conform to the naming rules given in Section **Error! Reference source not found.** of this specification. The emd extension is mandatory.

Contents:

A .emd file is structured like a standard .ibs file. It must contain the following keywords, as defined in IBIS: [IBIS Ver], [File Name], [File Rev], and [End]. It may also contain the following optional keywords: [Comment Char], [Date], [Source], [Notes], [Disclaimer], and [Copyright].

The actual module description is contained between the keywords [Begin EMD] and [End EMD], and includes the keywords listed below:

.emd file keywords

[Begin EMD]

[Manufacturer]

[Description]

 [Number Of EMD Pins]

[EMD Pin List]

[End EMD Pin List]

      [EMD Designator Map]

[End EMD Designator Map]

 [Designator Pin List]

[End Designator Pin List]

[EMD Group]

[End EMD Group]

[End EMD]

[EMD Set] [EMD Set] keywords permitted within a .emd file and covered later

[Manufacturer]

[Description]

      [EMD Model]

      [End EMD Model]

[End EMD Set]

.ems file Keywords

[EMD Set]

[Manufacturer]

[Description]

      [EMD Model]

      [End EMD Model]

[End EMD Set]

Only one [Begin EMD]/[End EMD] keyword pair is allowed in a .emd file.

**KEYWORD DEFINITIONS**

*Keyword:* [Manufacturer]

*Required:* Yes

*Description:* Declares the manufacturer of the module that uses this .emd file.

*Usage Rules:* Following the keyword is the manufacturer’s name. It must not exceed 40 characters and can include blank characters. Each manufacturer must use a consistent name in all .emd files.

*Example:*

[Manufacturer] Quality SIMM Corp.

*Keyword:* [Description]

*Required:* No

*Description:* Provides a concise yet easily human-readable description of what kind of interconnect the [EMD Set] represents.

*Usage Rules:* The description shall fit on a single line and may contain spaces.

*Example:*

[Description] 6-Pin Quad Ceramic Flat Pack

*Keyword:* [Begin EMD]

*Required:* Yes

*Description:* Marks the beginning of an Electrical Module Description

*Usage Rules:* The keyword is followed by the name of the module level component. The length of the component name must not exceed 40 characters in length, and blank characters are allowed. There must be a matching [End EMD] keyword.

*Example:*

[Begin EMD] 16X8\_SIMM

*Keyword:* [Number Of EMD Pins]

*Required:* Yes

*Description:* Tells the parser the number of EMD pins to expect. EMD pins are any externally accessible electrical connection to the module.

*Usage Rules:* The field must be a positive integer. The [Number Of EMD Pins] keyword must be positioned before the [EMD Pin List] keyword. This does not include the number of designator pins.

*Example:*

[Number Of EMD Pins] 128

*Keyword:* [EMD Pin List]

*Required:* Yes

*Description:* Tells the parser the pin names of the user accessible pins. It also informs the parser which pins are connected to power and ground.

*Sub-Params:* signal\_name, signal\_type, bus\_label

*Usage Rules:* Following the [EMD Pin List] keyword are four columns. The first column lists the pin name (in the data book this can also be called pin number). The second column lists the data book name of the signal connected to that pin. The third column is required if the pin is a rail pin or a no connect pin. The allowed values for this third column are:

POWER This pin is connected to a power signal

GND This pin is connected to a ground signal

NC This pin is not connected to any signal

The fourth column (bus\_label) is optional for rail pins (signal\_type POWER or GND). The bus\_label is a name given to a subset of the pins on a rails signal\_name. All pins that have the same bus\_label must have the same signal\_name. If the bus\_label column is not specified for signal\_type POWER or GND, then the bus\_label shall be assumed to be the signal\_name.

The [EMD Pin List] keyword shall be followed by the strings “signal\_name”, “signal\_type”, and “bus\_label” as column headings.

There must be as many pin\_name/signal\_name/bus\_label rows as there are pins given by the preceding [Number Of EMD Pins] keyword. Pin names must be the alphanumeric external pin names of the module. The pin names cannot exceed eight characters in length. As described in Section 3.2 the reserved words “GND”, “POWER”, and “NC” are case-insensitive.

All non-rail pins (generically referred to as I/O pins) are required to be listed and have only a signal\_name entry. No signal\_type or bus\_label entry is permitted. The signal\_name entry may be used to signify the primary connection to other I/O pins (necessary for Aggressor\_Only described later).

Two pins in either the EMD Pin List or the Designator Pin List are connected if they have the same signal name. There is a low resistance assumed to exist between two connected points. There is a special case exception when a blocking cap is used in an I/O connection. In this special case, the two points are connected with a low impedance at the Nyquist rate (twice the maximum target signaling rate of the connections).

It is often convenient to merge multiple rail pins into a single interconnect model terminal. This may include all of the rail pins with the same signal name, all of the rail pins with the same signal\_name in a specific designator, or all of the rail pins of a bus\_label in a designator. In this case, all of the pins that are merged together into a single terminal are “shorted”.

*Example:*

| A SIMM Module Example:

|

[Begin EMD] 16X8\_SIMM

[Manufacturer] Quality SIMM Corp.

[Number Of Pins] 6

[EMD Pin List] signal\_name signal\_type bus\_label

A1 GND GND

A2 DQ1 | I/O pin

A3 DQ2 | I/O pin

A4 POWER5 POWER Power5x

A5 RFU NC

A6 POWER3.3 POWER

[End EMD Pin List]

*Keyword:* [**End EMD Pin List**]

*Required:* Yes

*Description:* Indicates the end of the data after [EMD Pin List].*Example:*

[End EMD Pin List]

*Keyword:* [EMD Designator Map]

*Required:* Yes, if an [EMD Model] lists an EMD designator

*Description:* Maps an EMD designator to an IBIS component or EMD module.

*Usage Rules:* The [EMD Designator Map] keyword must be followed by a list of all the EMD designators. Each EMD designator is followed by the file reference of a .ibs [Component] name or .emd [Begin EMD] name.

For the context in this **<# TBD>** Electrical Module Description section, a “designator” shall be one line in the data following [EMD Designator Map].

A designator that is an .emd file, can itself reference an EMD module. This shall be limited to 6 hierarchy levels of nested .emd files.

An EMD file may not reference itself directly or indirectly.

The EMD designator, file reference, and component/module name terms are separated by white space.

The reference designator is limited to ten characters.

*Example:*

[EMD Designator Map]

|

| External Part References:

|

| Designator File reference Component

u23 pp100.ibs Processor

u24 simm.emd 16X8\_SIMM

u25 ls244.ibs NoName\_74LS244a

u26 r10K.ibs My\_10K\_Pullup

[End EMD Designator Map]

*Keyword:* [**End EMD** Designator Map]

*Required:* Yes

*Description:* Indicates the end of the data after [EMD Designator Map].

*Example:*

[End EMD Designator Map]

*Keyword:* [Designator Pin List]

*Required:* Yes

*Description:* Tells the parser the pin names of the designator pins. It also informs the parser which designator pins are connected to power and ground. Designators are defined in the [EMD Designator Map] section and can be instances of either an .ibs [Component] or an .emd [Begin EMD].*Sub-Params:* signal\_name, signal\_type, bus\_label

*Usage Rules:* Following the [Designator Pin List] keyword are three columns. The first column lists the pin name (in data book this can also be called pin number). The second column lists the name of the signal associated with the pin\_name.

This signal\_name is the name that is assigned by the top-level EMD and may be reassigned from the signal\_names of the designator .ibs [Component] or of the designator .emd [Begin EMD]. This allows attached components or attached electrical model descriptions with standardized pin\_name positions but with different manufacturer terminology to be interchanged.

The third column is required if the pin is a rail pin or a no connect pin.

The allowed values for this third column are:

POWER This pin is connected to a power signal

GND This pin is connected to a ground signal

NC This pin is not connected to any signal

The fourth column, bus\_label, is optional for rail pins (signal\_type POWER or GND). The bus\_label entry is a name assigned to a subset of the pins with a rail signal\_name.

The optional bus\_label entry provides a way to describe some routing groupings such as left-hand and right-hand rail paths. If the bus\_label column is not specified for signal\_type POWER or GND, then the bus\_label shall be assumed to be the signal\_name.

The [Designator Pin List] keyword shall be followed by the strings “signal\_name”, “signal\_type”, and “bus\_label” as column headings.

Pin names must be the alphanumeric external pin\_names of the designator. The pin names cannot exceed eight characters in length. In addition, NC is a legal signal type and indicates that the pin is a “no connect”. As described in Section 3.2 the reserved words “GND”, “POWER”, and “NC” are case-insensitive.

Note that all EMD Pins and designator Pins that have the same signal\_name (or subset bus\_label) are “connected”. Connection details between the EMD Pins and any Designator Pins are described by the electrical models under the [EMD Model]

All non-rail pin\_name (generically referred to as I/O pins) are required to be listed and have only a signal\_name entry. No signal\_type or bus\_label entry is permitted. The signal\_name entry may be assigned to designate I/O pins on .ibs [Component]s or .emd [Define EMD] that are associated with corresponding [EMD Pin List] I/O pins. In other words, the [EMD Pin List] pin\_names may be different than the corresponding pin\_names of the designator component, but the EMD level assigned signal\_name entries are used for the association. This association will be useful when describing Aggressor\_Only terminals discussed later.

*Example:*

| A SIMM Module Example:

|

[Begin EMD] 16X8\_SIMM

[Manufacturer] Quality SIMM Corp.

[Number Of EMD Pins] 6

[EMD Pin List] signal\_name signal\_type bus\_label

A1 VSS GND

A2 DQ1 | I/O pin

A3 DQ2 | | I/O pin

A4 VDD POWER VDD1

A5 VDD POWER VDD2

A6 VDDQ POWER

[End EMD Pin List]

[Designator Pin List] signal\_name signal\_type bus\_label

U1.11 VSS GND

U1.12 DQ1 | I/O pin

U1.13 DQ2 | I/O pin

U1.14 VDD POWER VDD1

U2.21 VDD POWER VDD2

U2.22 DQ1 | I/O pin

U2.23 DQ2 | I/O pin

U2.24 VDDQ POWER

[End Designator Pin List]

*Keyword:* [**End Designator Pin List**]

*Required:* Yes

*Description:* Indicates the end of the data after [Designator Pin List].

*Example:*

[End Designator Pin List]

*Keyword:* [EMD Group]

*Required:* Yes

*Description:*  [EMD Group] has a single argument, which is the name of the associated EMD Group. The length of the EMD Group name shall not exceed 40 characters in length. Blank characters are not allowed. The [EMD Group]/[End EMD Group] keyword pair is hierarchically scoped by the [Begin EMD]keyword. The [EMD Group] keyword is used to define a list of [EMD Set]s by name that shall be used together to define EMD Models to be used in a simulation. A simulation may contain EMD Models from the EMD Sets listed in only one Group.

*Usage Rules:* [Begin EMD] must contain one or more [EMD Group] keywords (identified by a name). Each [EMD Group] must contain at least one [EMD Set] name. EMD Sets contain EMD Models used to describe EMD pin, or IBIS designator pin connections to IBIS-ISS subcircuit terminals or Touchstone terminals.

EMD Sets that exist for the module shall be listed in one or more EMD Groups. An EMD Group is required even if it references only one EMD Set.

The section under the [EMD Group] keyword shall have two entries per line, with each line identifying one EMD Set associated with the module. The entries shall be separated by at least one white space. The first entry lists the EMD Set name (up to 40 characters long). The second entry is the file reference of the file containing the EMD Set and shall have the extension “ems”. This file reference shall conform to the rules given in Section 3, ‘GENERAL SYNTAX RULES AND GUIDELINES’. If the EMD Set is in the same IBIS file as [Begin EMD], then the second entry shall be “NA”.

The files containing the EMD Sets with the ems extension shall be located in the same directory as the .emd file or in a specified directory under the .emd file as determined by the directory path according to the file name rules given in Section 3, ’GENERAL SYNTAX RULES AND GUIDELINES’ (i.e., a file reference containing a relative path to a directory below that of the referencing .emd file is permitted). An EMD Set with matching name shall be found in the stated location for each EMD Set named in the [EMD Group] keyword.

Each EMD Set name and its file\_reference may only appear once under each [EMD Group] keyword for a given designator.

As discussed in Section XXX, two interface locations exist: EMD pin and designator pin. These interfaces are identified in the terminal lines under the [EMD Model] keyword and by their Terminal\_type column entries (shown in Table 41) as follows:

pin: Pin\_I/O, Pin\_Rail, A\_gnd

A\_gnd is the simulator global reference node of the EMD Model.

Identifiers associated with these Terminal\_type Pin\_I/Os are pin\_name entries. EMD pin\_names shall be present in the [EMD Pin List] section. Designator Pins shall be the pin\_name preceded by the reference designator with a “.” inserted between the reference designator and the pin\_name (e.g. U2.DQ1). In addition, some Pin\_I/O terminals may have the optional Aggressor\_Only column. If any \*\_I/O pin is marked as Aggressor\_Only, then all I/O pins with the same signal\_name are Aggressor\_Only (really the signal\_name connection is Aggressor\_Only). Any \*\_I/O Terminal\_type without the Aggressor\_Only column may be considered as an aggressor or a victim.

The remaining terminals are used for POWER or GND and are referred to as “rails”. The rail identifiers are pin\_name, signal\_name and bus\_label.

An EMD Group contains a list of EMD Sets which in turn contains a list of EMD Models. There are several rules that apply to this combined list of EMD Models in an EMD Group.

A terminal line that contains pins at the EMD interface shall be called an EMD terminal. A terminal line contains pins at a designator interface shall be called a designator terminal. An EMD terminal shall consist of either one EMD I/O pin or one or more EMD rail pins shorted together. A designator terminal shall consist of either one designator I/O pin or one or more designator rail pins from one designator shorted together.

* I/O pin\_name rules
	+ I/O terminals use pin\_name identifiers
	+ All Pin\_I/O pin\_names may omit the Aggressor\_Only column (may be aggressors or victims)
	+ No connection in an EMD Model may appear as a Pin\_I/O terminal without the Aggressor\_Only column in more than one EMD Model in the EMD Group.
	+ At the EMD pin interface, a terminal whose Terminal\_type is Pin\_Rail can be identified by a pin\_name, signal\_name, or bus\_label. A pin\_name maps directly into a Pin\_Rail pin\_name. These terminals are EMD terminals.
	+ At the designator pin interface, a terminal whose Terminal\_type is Pin\_Rail can be identified by a pin\_name, signal\_name, or bus\_label. A pin\_name maps directly into a Pin\_Rail pin\_name. These terminals are designator terminals.
	+ A Power Delivery Network (PDN) has one or more connections of rail terminals between EMD terminals and Designator terminals.
	+ An EMD Model with only rail terminals and two interfaces (no I/O terminals) can be used for a PDN.
	+ An EMD Model with only rail terminals (no I/O terminals) and only one interface is permitted for applications such as for modeling rail decoupling circuits.
	+ A PDN structure can also exist in an EMD Model with I/O terminals.
	+ Also, rail terminals or A\_gnd can be used in EMD Models to provide a reference node for the electrical interconnections associated with \*\_I/O terminals.
* Rail terminal rules
	+ At the pin interface, a rail pin\_name may appear on a terminal line whose Terminal\_type is Pin\_Rail in multiple EMD Models in the EMD Group.
	+ A rail terminal in EMD Models can represent a list of EMD pins shorted together or a list of designator pins from one designator shorted together.

Note that these rules apply to the complete list of EMD Models that are included in each EMD Group, regardless of which EMD Sets contain the EMD Models.

All EMD Models with only rail terminals are available for power delivery simulations.

*Examples:*

| Example 1

|

[EMD Group] Full\_ISS\_PDN\_1

| EMD Set file\_reference

Full\_ISS\_PDN\_1 NA | The [EMD Set] is

 | present in the .emd file for

 | all pins

[End EMD Group]

|

| Example 2

|

[EMD Group] Full\_ISS\_PDN\_sn\_2

| EMD Set file\_reference

Full\_ISS\_PDN\_sn\_2 NA | The [EMD Set] is

 | present in the .emd file for

 | all I/O pins and PDN

[End EMD Group]

*Keyword:* [**End EMD Group**]

*Required:* Yes, for each instance of the [EMD Group] keyword

*Description:* Indicates the end of the data for one [EMD Group].

*Example:*

[End EMD Group]

*Keyword:* [End EMD]

*Required:* Yes

*Description:* Marks the end of a module.

*Usage Rules:* This keyword must come at the end of each complete module description.

*Example:*

[End EMD]

**ADD a New Section 13?:**

**<# TBD> EMD SET DESCRIPTION**

*Keyword:* [EMD Set]

*Required:* No

*Description:* Used to contain EMD Models

*Usage Rules:* [EMD Set] has a single argument, which is the name of the EMD Set. The length of the EMD Set name shall not exceed 40 characters in length. Blank characters are not allowed. The [EMD Set]/[End EMD Set] keyword pair is hierarchically equivalent in scope to [Begin EMD].

The section under the [EMD Set] keyword may contain a [Manufacturer] keyword section and [Description] keyword section and shall contain one or more EMD Models. See the section [EMD Model] for a description of the content of each EMD Model.

An [EMD Set] contains a list of [EMD Model]s that have a logical association such as:

* All signals in a bus (e.g. DDR4, or PCIeG3)
* Full PDN structures from EMD pins to designator pins.
* Full PDN structures from EMD pins to EMD pins
* All I/O structures between EMD pins and designator pins
* I/O structures from designator pins to designator pins.
* Combinations of I/O and PDN structures
* Coupled models
* Touchstone electrical models
* Decoupling capacitor models
* IBIS-ISS electrical models

*Example:*

[EMD Set] Signal\_Integrity

[Manufacturer] Acme Packaging, Inc.

[Description] This set contains one model for each I/O buffer

[EMD Model] DQ1

…

[End EMD Model]

[EMD Model] DQ2

…

[End EMD Model]

[EMD Model] DQS

…

[End EMD Model]

[End EMD Set]

*Keyword:* [Manufacturer]

*Required:* Yes

*Description:* Declares the manufacturer of the module that uses this .emd file.

*Usage Rules:* Following the keyword is the manufacturer’s name. It must not exceed 40 characters and can include blank characters. Each manufacturer must use a consistent name in all .emd files.

*Example:*

[Manufacturer] Quality SIMM Corp.

*Keyword:* [Description]

*Required:* No

*Description:* Provides a concise yet easily human-readable description of what kind of interconnect the [EMD Set] represents.

*Usage Rules:* The description shall fit on a single line and may contain spaces.

*Example:*

[Description] 6-Pin Quad Ceramic Flat Pack

*Keyword:* [**End EMD Set**]

*Required:* Yes, for each instance of the [EMD Set] keyword.

*Description:* Indicates the end of the EMD Set data.

*Example:*

[End EMD Set]

**12.2 GENERAL EMD MODEL SYNTAX REQUIREMENTS**

Terminal lines under the [EMD Model] keyword describe connections.

Pin\_name in this context is either the pin\_name in the [EMD Pin List], or designator.pin\_name in the [Designator Pin List] for designator pins.

I/O terminals shall be connected using only the pin\_name qualifier:

Rail terminal connections have more options to support direct connections to terminals or to groups of terminals using signal\_name or pin\_name, signal\_name, or bus\_label. The rail terminal can connect to:

* a specific designator or [EMD Pin List] rail pin\_name
* all the designator pins of a rail signal\_name within a designator
* all designator pins of a rail bus\_label within a designator
* all the [EMD Pin List rail pins of a rail bus\_label

One or more EMD Sets may be included in a separate EMD Set file, using a file name with the extension “ems”, or within the .emd file~~.~~ The [EMD Set] keyword can contain the optional [Manufacturer] and [Description] keywords and one or more [EMD Model] keywords and the [EMD Model] associated subparameters, as listed in Table 40.

TableError! Reference source not found. 40 – EMD Set and EMD Model Keywords and Subparameters

| **Keyword or Subparameter** | **Notes** |
| --- | --- |
| [EMD Set] |  |
| [Manufacturer] | (note 1) |
| [Description] | (note 1) |
| [EMD Model] | (note 2) |
| Param |  |
| File\_TS | (note 3) |
| File\_IBIS-ISS | (note 3) |
| Unused\_port\_termination | (note 4) |
| Number\_of\_terminals | (note 5) |
| <terminal line> | (note 6) |
| [End EMD Model] | (note 7) |
| [End EMD Set] | (note 8) |
| Note 1 [Manufacturer] and [Description] are each optional keywords within any [EMD Set].Note 2 At least one [EMD Model] is required for each [EMD Set].Note 3 One of either the File\_TS or File\_IBIS-ISS subparameters is required.Note 4 This subparameter shall be followed by the “=” character and a numeric value (integers and reals are acceptable), with both optionally surrounded by whitespace.Note 5 This subparameter shall be followed by the “=” character and an integer value, with both optionally surrounded by whitespace.Note 6 See text below.Note 7 Required when the [EMD Model] keyword is used.Note 8 Required when the [EMD Set] keyword is used. |

When EMD Set definitions occur within a .emd file, their scope is “local”— they are known only within that .emd file and no other .emd file.

Usage Rules for the .ems file:

EMD Models are stored in a file whose file name uses the format:

<stem>.ems

The <stem> provided shall adhere to the rules given for the [File Name] keyword. Use the “ems” extension to identify files containing EMD Models. The .ems file shall contain the [IBIS Ver], [File Name], [File Rev], and the [End] keywords. Optional elements include the [Date], [Source], [Notes], [Disclaimer], [Copyright], and [Comment Char] keywords. All these keywords and associated subparameters follow the same rules as those for a normal .ibs file.

Note that the [Begin EMD] and [Model] keywords are not allowed in the .ems file. The .ems file is for EMD Models only.

*Keyword:* [EMD Model]

*Required:* Yes

*Description:* Marks the beginning of an Electrical Module Description that is used to define the interfaces to IBIS-ISS subcircuit or Touchstone files.

*Sub-Params:* Unused\_port\_termination, Param, File\_TS, File\_IBIS-ISS, Number\_of\_terminals

*Usage Rules:* [EMD Model] has a single argument, which is the name of the associated EMD Model. The length of the EMD Model name shall not exceed 40 characters in length. Blank characters are not allowed. The [EMD Model]/[End EMD Model] keyword pair is hierarchically scoped by the [EMD Set]/[End EMD Set] keywords.

The [EMD Model]/[End EMD Model] section defines both the association between a Touchstone file or IBIS-ISS subcircuit and an EMD Model, as well as defining the terminals and terminal usage for the EMD Model in the context of the given [Begin EMD].

An [EMD Model] may contain any combination of designator pins and [EMD Pin List] pins.

An [EMD Model] may contain:

* only power rail terminals
* one or more I/O signal terminals
* both power rail terminals and one or more I/O signal terminals
* EMD terminal rails only
* designator terminal rails only

The following subparameters are defined:

Param

File\_IBIS-ISS

File\_TS

Unused\_port\_termination

Number\_of\_terminals = <value>

In addition to these subparameters, the [EMD Model]/[End EMD 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 EMD 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 three 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 one numerical value or one string value (surrounded by double quotes) for the parameter value to be passed into the IBIS-ISS subcircuit.

The numerical value rules follow the scaling conventions in Section 3.2, “SYNTAX RULES”. 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.s2p" would be converted to str('typ.s2p') in IBIS-ISS subcircuits.

*Examples:*

| Param name format value

Param abc Value 2m | 2E-3 in IBIS

Param def Value 4k | 4E3 in IBIS

Param ts\_file Value "typ.s2p" | file name string passed

 | into IBIS-ISS

File\_IBIS-ISS rules:

Either File\_IBIS-ISS or File\_TS is required for a [EMD Model]/[End EMD Model] group*.* The File\_IBIS-ISS subparameter is followed by two unquoted string arguments consisting of the file\_reference and circuit\_name (.subckt name) for an IBIS-ISS file. The IBIS-ISS file under file\_reference shall be located in the same directory as the referencing .emd file or .ems file or in a specified directory under the referencing file as determined by the directory path (i.e., a file reference containing a relative path to a directory below that of the referencing .emd or .ems file is permitted).

*Example:*

| file\_type file\_reference circuit\_name(.subckt name)

File\_IBIS-ISS net.iss netlist\_typ

File\_TS rules:

Either File\_TS or File\_IBIS-ISS is required for a [EMD Model]/[End EMD Model] group.File\_TS is followed by one unquoted string argument, which is the file\_reference for a Touchstone file. The Touchstone file under file\_reference shall be located in the same directory as the referencing .emd file or .ems file or in a specified directory under the referencing file as determined by the directory path (i.e., a file reference containing a relative path to a directory below that of the referencing .emd or .ems file is permitted).

*Example:*

| file\_type file\_reference

File\_TS typ.s8p

Unused\_port\_termination rules:

The Unused\_port\_termination subparameter is required under this condition:

File\_TS is used and the number of terminal lines (described below) is less than N+1 (where N is the number of ports in the Touchstone file)

Unused\_port\_termination is illegal under these conditions:

File\_IBIS-ISS is used.

File\_TS is used and the number of terminal lines is N+1

If required, only one Unused\_port\_termination subparameter may appear for a given [EMD Model] keyword.

The Unused\_port\_termination subparameter is followed by white space and one of these arguments:

Open

Reference

Resistance

“Open” declares that the unused ports remain unterminated (open-circuited).

“Reference” declares that the EDA tool terminates all unused ports with resistors whose resistance values are equal to the reference impedances provided in the Touchstone file for the respective unused ports, and all connected to the model’s reference terminal.

“Resistance” declares that the EDA tool terminates all unused ports with resistors, all having the same value, and all connected to the model’s reference terminal. The “Resistance” entry is followed by a third column entry with the (non-negative) numerical resistance value.

*Examples:*

Unused\_port\_termination Open

Unused\_port\_termination Reference

Unused\_port\_termination Resistance 43.5

Number\_of\_terminals rules:

The Number\_of\_terminals subparameter is required and defines the number of terminals associated with the EMD Model. The subparameter name shall be followed by a single integer argument 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 [EMD Model] keyword. The Number\_of\_terminals subparameter shall appear before any terminal lines and after all other subparameters for a given EMD Model.

For File\_IBIS-ISS, the Number\_of\_terminals value shall be equal to the number of subcircuit terminals for an IBIS-ISS subcircuit. Because an IBIS-ISS subcircuit requires at least one terminal the Number\_of\_terminals value shall be 1 or greater. The IBIS-ISS subcircuit terminals shall not contain an ideal reference node (SPICE node 0 or its synonyms).

For File\_TS, the Number\_of\_terminals value shall be a value equal to N+1 (where N is the number of ports in the Touchstone file). Because a Touchstone file requires at least one port, the Number\_of\_terminals value shall be 2 or greater.

*Example:*

Number\_of\_terminals = 3

Terminal line rules:

The terminal lines shall appear after the Number\_of\_terminals subparameter and before the [End EMD Model] keyword.

Terminal lines are of the following form, with each identifier separated by whitespace:

 <Terminal\_number> <Terminal\_type> <Terminal\_type\_qualifier> <Qualifier\_entry> [Aggressor\_Only]

Terminal\_number

The Terminal\_number is the identifier for a specific terminal. The value shall be 1 or greater and less than or equal to the Number\_of\_terminals. The same Terminal\_number shall not appear more than once for a given EMD Model.

For File\_IBIS-ISS, the Terminal\_number entry shall match the IBIS-ISS terminal (node) position. The Terminal\_number entries may be listed in any order as long as there are no duplicate entries. Each IBIS-ISS terminal shall have a terminal line entry.

For File\_TS, the Terminal\_number entry shall match the Touchstone file port number or reference terminal line, as shown below. The Terminal\_number entries may be listed in any order as long as there are no duplicate entries. The terminal line for Terminal\_number N+1 is required as a reference terminal for each port and shall be connected to a rail terminal or A\_gnd in the EMD Model. At least one other terminal line entry is required.

* Terminal\_number Port
* 1                     1
* 2                          2
* …
* N                        N
* N+1 Reference terminal for the Touchstone file

For Touchstone files, each unused port and its corresponding Terminal\_number shall be terminated in simulation with a resistor whose value corresponds to the Unused\_port\_termination subparameter entry. The resistor is connected to the model’s reference terminal.

Terminal\_type
The Terminal\_type is a string that identifies whether the terminal is a reference, supply or I/O terminal and whether the terminal is connected to a EMD pin or designator pin. (Note that “I/O” in this context is a synonym for “signal”, as opposed to “supply” or “rail”; it is not intended to imply model type as used in the “Model\_type” subparameter).

Terminal\_type A\_gnd defines a connection to the simulator global reference node.  The A\_gnd node can be used at any interface.

Terminal\_type A\_gnd is not required under File\_TS or File\_IBIS-ISS.

If present under File\_TS, Terminal\_type A\_gnd may be used only once on the N+1th terminal line.

If present under File\_IBIS-ISS, Terminal\_type A\_gnd may be used any number of times on any of the terminal lines.

Furthermore, if the terminal is connected to a buffer supply rail, the Terminal\_type identifies to which specific buffer rail the terminal is connected. The Terminal\_type shall be one of the following:

* Pin\_I/O
* Pin\_Rail
* A\_gnd

Terminal\_type\_qualifier
Terminal\_type\_qualifier is a string that identifies the association between a terminal and a specific pin\_name, signal\_name or bus\_label in the [EMD Pin List], or specific pin\_name, signal\_name or bus\_label in the [Designator Pin List].

Qualifier\_entry
The <Qualifier\_entry>, shown in angle brackets, is the name required for the following Terminal\_type\_qualifiers:

pin\_name <pin\_name\_entry>

signal\_name <signal\_name\_entry>

bus\_label <bus\_label\_entry>

Terminal\_type A\_gnd defines a connection to the simulator global reference node. The A\_gnd node can be used at any interface.

Terminal\_type A\_gnd is not required under File\_TS or File\_IBIS-ISS.

If present under File\_TS, Terminal\_type A\_gnd may be used only once on the N+1th terminal line.

If present under File\_IBIS-ISS, Terminal\_type A\_gnd may be used any number of times on any of the terminal lines.

Terminal\_type\_qualifier
The Terminal\_type\_qualifier is a string that identifies the association between a terminal and a specific pin\_name, signal\_name or bus\_label.

Aggressor\_OnlyThe Aggressor\_Only entry is optional and is indicated by the string “Aggressor\_Only” without the quotation marks. Assigning Aggressor\_Only to a pin assigns the Aggressor\_Only properties to all pins of the same signal\_name listed in the [EMD Pin List] and [Designator Pin List] keywords.

Multi-line EMD Models may describe only a subset of a coupled structure (e.g., a 64-line bus may be described by a four-line EMD Model). As a result, while the interconnects at the edges of the EMD Model may induce crosstalk onto other interconnects nearby, being on the edge of the EMD Model, they may not themselves experience the full crosstalk impact that the corresponding interconnect experiences in the real, full structure.

Connecting EMD and Designator Pins

Terminal lines describe the IBIS-ISS node or Touchstone port that each terminal should be connected to. Terminals may be at EMD or designator pin interface. The arrangement of the terminal line entries (columns) is described below.

* The first column, Terminal\_number, contains an integer between 1 and the Number\_of\_terminals that describes the ordinal (positional) number of the IBIS-ISS node in the EMD Model subcircuit or Touchstone file port. The second column is Terminal\_type, the third column is Terminal\_type\_qualifier, the fourth column is Qualifier\_entry, and there is an optional fifth column “Aggressor\_Only”
* The second column, Terminal\_type is:
	+ For I/O connections
		- Terminal\_type must be Pin\_I/O.
		- Terminal\_type\_qualifier shall be pin\_name.
			* EMD Pins shall be a pin\_name in the [EMD Pin List] list
			* Designator Pins shall be in the form from the [Designator Pin List]:
				+ <designator>.< pin\_name>.
	+ For rail connections
		- Terminal\_type shall be Pin\_Rail
		- Terminal\_type\_qualifier shall be one of the following:
			* pin\_name
				+ Qualifier\_entry shall be a rail pin\_name in the [EMD Pin List] or [Designator Pin List] and with signal\_type POWER or GND.
			* signal\_name
				+ Qualifier\_entry shall be a rail signal\_name in the [EMD Pin List] or [Designator Pin List]
				+ For the [EMD Pin List] entry, the signal\_name should match the data book entry
				+ For [Designator Pin List] entries, the signal\_name values can be assigned so that they can be associated with the same signal\_name entries on the [EMD Pin List]. The signal\_name entries do not have to be the same as those in the [Designator Pin Map] [Component] or [Define EMD} entries.
			* bus\_label
				+ Qualifier\_entry shall be a rail bus\_label in the [EMD Pin List] or [Designator Pin List]
				+ Pin\_Rail bus\_label U7.VDD …
				+ The bus\_label entry can be assigned to both the [EMD Pin List] and [Designator Pin List] entries to support a subset of connections that might be associated with a common signal\_name. For example, left-side routing and right-side routing might be isolated from each other.
		- At any interface
			* Terminal\_type A\_gnd is available at any interface and without any Terminal\_type qualifier

Table 41 summarizes the rules described above and applies to terminals associated with the [EMD Pin List] keyword and with the [Designator Pin List] keyword.

Table 41 – Allowed Terminal\_type Associations1

| **Terminal\_type** | **Terminal\_type\_qualifier** | **Aggressor\_Only** |
| --- | --- | --- |
| **pin\_name** | **signal\_name** | **bus\_label** |
| Pin\_I/O | X |  |  | A |
| Pin\_Rail | Y | Y | Y |  |
| A\_gnd |  |  |  |  |

Notes

1. In the table, “X” refers to I/O pin names. “Y” are POWER and GND terminals. The letter “A” designates "Aggressor\_Only".

Pins may be terminals of the EMD Model that connect directly to a PCB or other type of system connection to an IBIS designator. Pins can be signal pins (Pin\_I/O), or supply pins (Pin\_Rail). An EMD Model can connect supply pins in one of two ways:

1. By specifying terminals for some or all the supply pins.
2. By assuming that all supply pins connected to a supply signal\_name are shorted together. This is done by specifying a unique terminal (of Terminal\_type Pin\_Rail) for all pins that are connected to a specific signal\_name on at least one supply pin.
3. By assuming that all supply pins connected to a supply signal\_name on a specific designator are shorted together. This is done by specifying a unique terminal (of Terminal\_type Pin\_Rail) for one or more designator.pin\_names in one or more than one component.
4. By assuming that all supply pins connected to a bus\_label\_name are shorted together. This is done by specifying a unique terminal (of Terminal\_type Pin\_Rail) for all pins that are connected to a specific bus\_label on at least one supply pin.
5. By assuming that all supply pins connected to a supply bus\_label on a specific designator are shorted together. This is done by specifying a unique terminal (of Terminal\_type Pin\_Rail) for one or more designator.pin\_names in one or more than one component.
6. Any one pin shall not be included in more than one terminal of an EMD Model.

*Examples:*

[Begin EMD] DIMM

[Number of EMD Pins] 9

[EMD Pin List] signal\_name signal\_type bus\_label

A1    DQ1

A2    DQ2

A3    DQ3

D1    DQS+

D2    DQS-

P1    VDD         POWER VDD1

P2    VDD         POWER

G1    VSS         GND

[End EMD Pin List]

[EMD Designator Map]

U1 mem.ibs Memory

U2 mem.ibs Memory

[End EMD Designator Map]

[Designator Pin List] signal\_name signal\_type bus\_label

U1.1 VDD POWER VDD1

U1.2 VDD POWER

U1.3 VSS GND

U1.4 VSS GND

U1.5 DQ1

U1.6 DQ2

U1.7 DQ3

U1.8 DQS+

U1.9 DQS-

|

U2.1 VDD POWER VDD1

U2.2 VDD POWER

U2.3 VSS GND

U2.4 VSS GND

U2.5 DQ1

U2.6 DQ2

U2.7 DQ3

U2.8 DQS+

U2.9 DQS-

[End Designator Pin List]

[EMD Group] Just\_One

SomeDQ NA

[End EMD Group]

[End EMD]

[EMD Set] SomeDQ

[EMD Model] DQ1

File\_IBIS-ISS DQ1.iss DQ1

Number\_of\_terminals = 8

1  Pin\_I/O      pin\_name A1

2  Pin\_I/O      pin\_name U1.5

3  Pin\_I/O      pin\_name U2.5

4 Pin\_Rail bus\_label VDD1

5 Pin\_Rail signal\_name VSS

6 Pin\_Rail pin\_name U1.1

7 Pin\_Rail pin\_name U1.3

8 Pin\_Rail pin\_name U2.1

[End EMD Model]

[EMD Model] VDD\_bus\_label

File\_IBIS-ISS VDD\_bus\_label.iss VDD\_bus\_label

Number\_of\_terminals = 6

1 Pin\_Rail bus\_label VDD | EMD Pins P2

2 Pin\_Rail bus\_label VDD1 | EMD Pins P1

3 Pin\_Rail bus\_label U1.VDD | U1 Pins 2

4 Pin\_Rail bus\_label U1.VDD1 | U1 Pins 1

5 Pin\_Rail bus\_label U2.VDD | U2 Pins 2

6 Pin\_Rail bus\_label U2.VDD1 | U2 Pins 1

[End EMD Model]

[EMD Model] VDD\_signal\_name

File\_IBIS-ISS VDD\_signal\_name.iss VDD\_signal\_name

Number\_of\_terminals = 3

1 Pin\_Rail signal\_name VDD | EMD Pins P1 P1

2 Pin\_Rail signal\_name U1.VDD | U1 Pins 1 2

3 Pin\_Rail signal\_name U2.VDD | U2 Pins 1 2

 [End EMD Model]

[EMD Model] VDD\_signal\_name\_merged\_pin

File\_IBIS-ISS VDD\_signal\_name.iss VDD\_signal\_name

Number\_of\_terminals = 3

1 Pin\_Rail signal\_name VDD | EMD Pins P1 P1

2 Pin\_Rail signal\_name U1.VDD | U1 Pins 1 2

3 Pin\_Rail bus\_label U2.VDD1 | U2 Pins 1

[End EMD Model]

[End EMD Set]

*Keyword:* [End EMD Model]

*Required:* Yes

*Description:* Marks the end of an EMD Model.

*Usage Rules:* This keyword must come at the end of each complete electrical EMD Model.

*Example:*

[End EMD Model]