

=====

I B I S C O N N E C T O R S P E C I F I C A T I O N

Last Updated: 04-25-2002

- Updated text positioning per Arpad's "diff" file.

ISSUES TO ADDRESS

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\*!!! Manufacturer in Section 7. There could be copyright / legal issues of external companies referencing copyrighted names without permission. I would suggest dropping the "Note:" in [Manufacturer]

\* The [File Rev] keywords require a Text String. Wouldn't it be better to require specific types of field formats, so that this information could be processed automatically?

\* Still need to address "What information needs to stay with the specific interconnect mode. . ." especially if the interconnect model is to be eventually included in a larger file.

\* Dual purpose use of the [Source] keyword. It is used to record the manufacturer's name, and the place and method from whence the model was created. This mixes two pieces of information that are both useful. I would propose another keyword [Part Manufacturer] which can be used to contain the name of the manufacturer of the part. This will make it very easy to search for manufacturers in a database of interconnect models.

[Source] then becomes the source of the information for extraction, which might also be some person or organization other than the interconnect manufacturer. (For example, SiQual or Mentor.)

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Specification Revision level 0.992

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=====  
REVISION HISTORY  
xx-xx-200x, v1.0 Specification  
=====

=====  
1.0 GENERAL INTRODUCTION  
=====

This document contains a general purpose specification for interconnect modeling in an IBIS (I/O Buffer Information Specification) compatible format. It was written to provide means for modeling all electrical interconnect types, including connectors, cables, packages, and printed circuit boards.

This section gives a general overview of the remainder of this document. Sections 2 to 5 contain general information about the IBIS versions and the general rules and guidelines. The remaining sections describe the interconnect keywords and usage rules.

=====

## 2.0 STATEMENT OF INTENT

=====

In order to enable an industry standard method to electronically transport IBIS interconnect modeling data between interconnect design and simulation tools. The intention of this specification is to specify a consistent format that can be parsed by software, allowing simulation vendors to derive models compatible with their own products.

One goal of this template is to represent the current state of IBIS data, while allowing a growth path to more complex models / methods (when deemed appropriate). This would be accomplished by a revision of the base template, and possibly the addition of new keywords or categories.

Another goal of this template is to ensure that model creation is simple enough for interconnect vendors and customers to use, while ensuring that it is rigid enough for simulation vendors to write reliable parsers.

This template is meant to contain a complete description of the elements on an entire interconnect.

This specification is intended to provide a basis for future versions which are expected to be backward compatible with this initial version.

## 3.0 GENERAL SYNTAX RULES AND GUIDELINES

=====

1) Only ASCII characters, as defined in ANSI Standard X3.4-1986, may be used in an IBIS-Interconnect file. The use of characters with codes greater than hexadecimal 07E is not allowed. Also, ASCII control characters (those numerically less than hexadecimal 20) are not allowed, except for TAB characters and line termination sequences.

NOTE: the use of TAB characters is strongly discouraged.

2) Except for keywords (words enclosed by a square bracket []), the content of an Ibis Interconnect Model (ICM) file is case sensitive.

3) Keywords must be enclosed in square brackets, [], and must start in column 1 of the line. No space is allowed immediately after the opening bracket '[' or immediately before the closing bracket ']'. If used, only one space (' ') or underscore ('\_') character separates the parts of a multi-word keyword. Spaces and underscores are equivalent within square bracket. Some keywords may be followed by an argument. Keyword arguments are of three types: either a text string, a file name, or a text block. Text string and file name arguments start on the same line as the keyword and are terminated with a line termination sequence. A text block starts on the same line as the keyword, may extend over multiple lines, and is terminated by the occurrence of the next keyword.

4) Keywords and sub-parameters must begin with a letter, and shall consist only of alphanumeric characters and the underscore (\_). Spaces are not allowed in sub-parameter names.

5) Each IBIS Interconnect data file is divided into sections. Each section is delimited by keywords of the form [Begin "section name"] and [End "section name"]. Within each section only specific keywords are legal (note, however, a keyword may be legal in more than one section). Unless otherwise noted, a

section's keywords can appear in any order.

6) To facilitate portability between operating systems, file names used in the IBIS Interconnect file must only have lower case characters. File names should have a basename followed by a period ('.'), followed by a file name extension of no more than three characters. There is no length restriction on the basename. The basename and extension must use characters from the following set (space, ' ', 0x20 is not included):

```
a b c d e f g h i j k l m n o p q r s t u v w x y z  
0 1 2 3 4 5 6 7 8 9 _ -
```

7) A line of the file may have at most 120 characters, followed by a line termination sequence. The line termination sequence must be one of the following two sequences: a linefeed character, or a carriage return followed by linefeed character.

8) Anything following the comment character is ignored and considered a comment on that line. The default "|" (pipe) character can be changed by the keyword [Comment Char] to any other character. The [Comment Char] keyword can be used throughout the file as desired.

9) Valid scaling factors are:

```
T = tera      k = kilo      n = nano  
G = giga      m = milli     p = pico  
M = mega      u = micro     f = femto
```

When no scaling factors are specified, the appropriate base units are assumed. (These are volts, amperes, ohms, farads, henries, and seconds.) The parser looks at only one alphabetic character after a numerical entry; therefore it is enough to use only the prefixes to scale the parameters. However, for clarity, it is allowed to use full abbreviations for the units, (e.g., pF, nH, mA, mOhm). In addition, scientific notation IS allowed (e.g., 1.2345e-12).

10) All temperatures are represented in degrees Celsius.

11) Multiple definitions of a specific symbol are illegal. Specifically, multiple definitions (either redundant or alternate) of an object type of the same object class are illegal. Refer to section 8 for more information on object classes and object types.

12) All lines that occur before the [Begin Header] keyword or after the [End] keyword shall be treated as comments and ignored by the parser. The intent of this rule is to facilitate the inclusion of HTML tags, revision control headers, etc. at the beginning of the file.

13) The following words are reserved words and must not be used for any other purposes in the document:

```
PWRGND- reserved model name, used with power or ground pins,  
POWER  - reserved model name, used with power supply pins,  
GND    - reserved model name, used with ground pins,  
RET    - reserved word indicating either power or ground used  
        as a high-frequency return path.  
NC     - reserved model name, used with no-connect pins,  
NA     - used where data not available.
```

```
=====  
  
4.0 KEYWORD TREE DIAGRAM  
  
=====
```

```

/-- Start of File
-----
--/--[Begin Header]
|  |--[Comment Char]
|  |--[IBIS ICM Model Ver]
|  |--[File Name]
|  |--[File Rev]
|  |--[Date]
|  |--[Source]
|  |--[Notes]
|  |--[Disclaimer]
|  |--[Copyright]
|  |--[Support]
|  |--[Redistribution]
|  |--[Redistribution Text]
|  \--[End Header]

--/--[Begin ICM Model Family]      | (Chapter 7)
|  |--[Manufacturer]
|  |--[ICM Model Description]
|  |--[ICM Family Description]
|  |--[ICM Model List]

|  --/--[Begin ICM Model]
|  |    ICM_Model_Type
|  |    GSR
|  |    Ref_impedance
|  |--[Tree Path Description]
|  |    Model_PinMap
|  |    Fork, EndFork
|  |    Section
|  |--[Nodal Path Description]
|  |    Model_NodeMap
|  |    N_section
|  |--[ICM Swath Parameters]      | (optional for Swath)
|  |    LeftEdge
|  |    RightEdge
|  |    TopEdge
|  |    BottomEdge
|  |--[ICM Swath Pin Numbers]    | (optional for Swath)
|  \--[End ICM Model]

|  --[ICM Pin Map]                | Pins to Physical
|  |    Pin_order
|  |    Num_of_columns
|  |    Num_of_rows
|  |--[ICM Node Map]              | Nodes to Physical
|  \--[End ICM Model Family]

--/--[Begin ICM Section]          | (Chapter 8) Define Matrices
|  |--[Derivation Method]
|  |--[Resistance Matrix]
|  |    /-- [Bandwidth]
|  |    \-- [Row]
|  |--[Inductance Matrix]
|  |    /-- [Bandwidth]
|  |    \-- [Row]
|  |--[Capacitance Matrix]
|  |    /-- [Bandwidth]

```

```

| | \-- [Row]
| | |--[Conductance Matrix]
| | | /-- [Bandwidth]
| | | \-- [Row]
| |
| | |--[ICM Sparameter]
| | | Pin_order
| | | Num_of_columns
| | | Num_of_rows
| |
| | \--[End ICM Section]
|
|--[End]

```

---

## 5.0 HEADER KEYWORDS

---

**Keyword:** [Begin Header]  
**Required:** Yes  
**Argument:** None  
**Description:** This keyword denotes the beginning of the file header section.  
**Usage Rules:** [Begin Header] must be the first keyword in any ICM file.  
This keyword may be preceded by lines of general text and/or comments which should be treated as comments by the parser.

---

```
[Begin Header]
```

**Keyword:** [IBIS ICM Model Ver]  
**Required:** Yes  
**Argument:** Text String  
**Description:** This keyword allows electronic parsers to immediately determine that this file contains an IBIS interconnect model.  
The version number is used to inform the parser what keywords are valid for this model and to allow backward support as new keywords are added.  
**Usage Rules:** This keyword must appear directly after the [Begin Header] keyword.

---

```
[IBIS ICM Model Ver] 1.0
```

**Keyword:** [File Name]  
**Required:** Yes  
**Argument:** Text String (file name)  
**Description:** Specifies the name of the IBIS Interconnect Model (ICM) file.  
**Usage Rules:** The purpose of this keyword is to document a single filename the file uses even if the file is transferred from one computer to another. The file name must conform to the rules given in section 4, "General Syntax Rules and Guidelines".

---

```
[File Name] iconm_hdi_202.icm
```

---

Keyword: [File Rev]  
Required: Yes  
Argument: Text String  
Description: Tracks the revision level of a particular .icm file.  
Usage Rules: Revision level is set at the discretion of the engineer  
defining the file. The following guidelines are suggested:

- 0.x interconnect and/or file in development
- 1.x pre-manufacturing interconnect and/or model
- 2.x mature interconnect and or model, no more changes

likely

-----  
[File Rev] 1.0 Used for .icm file versions

=====  
Keyword: [Date]  
Required: No  
Argument: Text String (Date)  
Description: Date this file was last modified.  
Usage Rules: This keyword is provided to insure the last changed date for  
this file is not lost if the file is transmitted between  
computer systems. The format is fixed. The pattern to be used  
is "Month Day, Year". Month is fully written out. Day uses two  
digits. Year uses four digits. See example.

-----  
[Date] July 1, 2000 | The latest file revision date

=====  
Keyword: [Source]  
Required: No  
Argument: Text Block  
Description: Records the originating source of model data.  
Usage Rules: Use this keyword to record how the model information was  
obtained (physical measurement of device, simulations, data  
book, etc.). This field contain the name of the company who  
created the model.

NOTE: It is recommended that the argument to the [Source]  
keyword be limited to a maximum of 24 lines of text.

-----  
[Source] Put originator and the source of information here. For example:  
Results from field simulation

=====  
Keyword: [Notes]  
Required: No  
Argument: Text Block  
Description: Optional notes regarding the file.  
Usage Rules: The keyword provides a place for the model maker to record  
important notes about the file or model data that are not  
included elsewhere. Such information may include notes on  
validation level, model limits, usage assumptions, etc.

NOTE: It is recommended that the argument to the [Notes]  
keyword be limited to a maximum of 24 lines of text.

The [Notes] keyword can only be used once.

-----

[Notes] Use this section for any special notes related to the file.

=====  
Keyword: [Disclaimer]  
Required: No  
Argument: Text Block  
Description: Legal disclaimer and copyright information  
Usage Rules: This keyword provides a place for the user to add a legal disclaimer.

NOTE: It is recommended that the argument to the [Disclaimer] keyword be limited to a maximum of 96 lines of text.

-----  
[Disclaimer] This information is for modeling purposes only, and is not guaranteed.

=====  
Keyword: [Copyright]  
Required: No  
Argument: Text Block  
Description: Legal copyright information  
Usage Rules: Because model writers may consider the information in these keywords essential to users, and sometimes legally required, design automation tools should make this information available. Any text following the [Copyright] keyword must be included in any derivative models verbatim.

NOTE: It is recommended that the arguments to the [Copyright] keywords be limited to a maximum of 96 lines of text.

-----  
[Copyright] Copyright 2000, XYZ Corp., All Rights Reserved

=====  
Keyword: [Support]  
Required: No  
Argument: Text Block (URL path name)  
Description: Specifies a web site that can be visited to get the latest version of the file.  
Usage Rules: Following the [Support] keyword is the URL of a web site the user may visit for more information on the model or model(s). The entire link, including any file extension, is required. The [Support] keyword may appear only once between the [Begin Header]/[End Header] keyword pair.

NOTE: It is recommended that a separate IBIS model web site (not page) be maintained to prevent accidental changes of page name from breaking this link.

-----  
[Support] <http://www.VendorNameIbisModels.com> |example ibis web site root

=====  
Keyword: [Redistribution]  
Required: Yes  
Argument: Text String (Yes, No, Specific)  
Description: Indicates to EDA tool companies and model users who may use and redistributed this file.



Usage Rules: Following the [Redistribution] keyword is one of three arguments: "Yes", "No" and "Specific".

An argument value of "Yes" means that a EDA tool vendor or end user may freely distribute the model as long as no fee is charged. A fee may be charged if authorized by the model creator.

An argument value of "No" means that the model may not be redistributed or retransmitted in any form.

An argument value of "Specific" means that specific license information is contained in the [Redistribution Text] field.

Use of the "Specific" or "No" argument prevents automated redistribution.

-----  
[Redistribution] Yes

=====  
Keyword: [Redistribution Text]

Required: Yes, ONLY if [Redistribution] value is "Specific", otherwise it is optional

Argument: Text block

Description: Allows model creator to supply specific redistribution information.

Usage Rules: If the argument to the [Redistribution] keyword is 'Specific', then the user must include additional information on licensing details, or where to find them. Any text following the [Redistribution Text] keyword must be included in any derivative models verbatim.

Note: It is recommended that the argument to the [Redistribution Text] keyword be limited to a maximum of 24 lines of text.

-----  
[Redistribution Text] Your text goes here.

=====  
Keyword: [End Header]

Required: Yes

Argument: None

Description: Marks the end of an IBIS Interconnect header section.

Usage Rules: [End Header] must be the last keyword in any IBIS Interconnect header section.

-----  
[End Header]

=====  
**6.0 GLOBAL KEYWORDS**  
=====

Keyword: [Comment Char]

Required: No

Argument: Text String  
 Description: Defines a new comment character to replace the default  
 "|" (pipe) character, if desired.  
 Usage Rules: The new comment character to be defined must be followed by  
 the underscore character and the letters "char". For example:  
 "|\_char" redundantly redefines the comment character to be  
 the pipe character. The new comment character is in effect  
 only following the [Comment Char] keyword. The following  
 characters MAY be used:

! " # \$ % & ' ( ) \* , : ; < > ? @ \ ^ ` { | } ~

If used, the [Comment Char] keyword can only appear after the  
 [Begin Header] and [IBIS-X Ver] keywords. A file may contain  
 multiple [Comment Char] keywords

-----  
 [Comment Char] |\_char

=====  
**7.0 INTERCONNECT MODEL FAMILY KEYWORDS**  
 =====

The Interconnect Model Family keywords in this section documents several ways  
 that interconnect models will be formatted. Some keywords work with or  
 require only certain other keywords. The hierarchical scope and intent of  
 certain groups of keywords are as follows:

[Begin ICM Model Family] Contains all electrical information in the file.

[Manufacturer] Informational documentation.

[ICM Family Description] Informational documentation.

[ICM Model List] Describes each interconnect that is in the file:

Model\_name This names the model described by [Begin ICM Model]  
 below. A unique name is required for each  
 electrical variation, even if it is for the same  
 physical interconnect.

Mated (for through path model) or  
 Unmated\_\* (disconnected electrical termination).

Min\_slew\_time Documents the electrical simulation limit of the  
 model. EDA tools are expected to issue a Warning  
 if this value is exceeded during simulation. The  
 same interconnect may have models with different  
 Min\_slew\_time values for user selection.

Image Supplemental and optional physical support  
 documentation supplied by the interconnect  
 manufacturer.

[Begin ICM Model] Each Model\_name requires a separate block.

Description subparameters:

ICM\_Model\_Type Specifies certain model types: MLM, SLM\_General,  
 SLM\_Quiescent, SLM\_Even, SLM\_Odd.

GSR Other electrical descriptive information that  
 Ref\_Impedance may be used for checking.

```

[Tree Path Description] Specific electrical path.
    Model_PinMap Pin Map naming information, if applicable.
    Section Multiple occurrences of Section provides names
    Section for electrical descriptions. Each unique name
    requires a separate [Begin ICM Section] keyword
    block below.
    ....
[ICM Pin Map] Describes a pin map, if applicable referred to
    by Model_PinMap. Each Model_PinMap name requires
    [ICM Pin Map] keyword.

[Nodal Path Description] Specific electrical path using nodal syntax.
    Model_NodeMap Pin or signal name to node name map information
    N_Section Multiple occurrences of N_Section provides names
    N_Section for electrical descriptions. Each unique name
    requires a separate [Begin ICM Section] keyword
    block below.
    ....
[ICM Node Map] Describes a Node map, referred to by Model_NodeMap.
    Each Model_NodeMap name requires [ICM Node Map]
    keyword.
    ....
[End ICM Model]

[Begin ICM Section] Each Section named under [Tree Path Description]
    .... is documented in this block, as discussed in
[End ICM Section] Matrix Keywords section.

[End ICM Model Family] End of technical information.

```

Two distinct modes are available to provide interconnect information under each [Begin ICM Model] keyword. They are defined and briefly described below followed by the related keywords.

A. Full Pinout, Full Matrix:

All interconnect Pins are listed, and the Section matrices document ALL pins.

A restriction exists that SLM\_Quiescent, SLM\_Even, and SLM\_Odd require fixed, predetermined return paths and are only meaningful for this mode.

This is the only mode supporting non-rectangular pin arrangements such as those with a different number of pins in each row.

B. Full Pinout, Partial Matrix:

All interconnect Pins are listed, but the Section matrices document just a "Swath" or rectangular portion of the pins.

This is a common format when interconnects can contain hundreds of pins, but the accurate electrical information for Sections is often limited to a smaller rectangular block of pins within the interconnect.

The list of keywords in this section that are required, optional or prohibited for each mode are listed below for an overall summary.

A. Full Pinout, Full Matrix:

(to be filled in)

B. Full Pinout, Partial Matrix:

(to be filled in)

Each keyword described in this section also documents to which mode or mode it applies. Keyword descriptions follow:

```
=====  
Keyword: [Begin ICM Model Family]  
Required: Yes  
Argument: Text String  
Description: This keyword marks the beginning of the interconnect family  
description section. An interconnect "family" consists of one  
or more similar interconnects. Note that each individual  
interconnect in a family will have a separate interconnect  
model.  
Usage Rules: Following the keyword is the name of the interconnect family.  
Only one [Begin ICM Model Family]/[End ICM Model Family]  
keyword is allowed per file.  
  
Interconnect family descriptions are terminated by the  
occurrence of the [End ICM Model Family] keyword.
```

```
-----  
[Begin ICM Model Family] High_Speed_Interconnect
```

```
=====  
Keyword: [Manufacturer]  
Required: Yes  
Argument: Text String  
Description: This keyword gives the name of the manufacturer of the  
interconnect family being described in this file.  
Usage Rules: Following the keyword is the manufacturer's name. Blank  
characters are allowed.
```

```
-----  
[Manufacturer] XYZ Incorporated
```

```
=====  
Keyword: [ICM Family Description]  
Required: Yes  
Argument: Text Block  
Description: Provides a human-readable description of this interconnect  
family.  
Usage Rules: Only a single occurrence of [ICM Family Description] is allowed  
in the file, and this keyword must be placed between the  
[Begin ICM Model Family] and [End ICM Model Family] keywords.  
  
Note: It is recommended that the family description be limited  
to a maximum of 4 lines.
```

```
-----  
[ICM Family Description]  
High Density 0.1 center square pin connector designed for use on IEEE 9999  
buses.
```

```
=====  
Keyword: [ICM Model List]  
Required: Yes
```

Argument: None  
Description: This keyword lists the model name, mating conditions, minimum slew time and picture link for each individual interconnect model described in this file.  
Usage Rules: Following the keyword are four columns of data, as shown in the example below (the column headings are shown as comments and are not required). The "Name", "Mating" and "Min\_Slew\_Time" columns are required, and all columns must be in the left to right order shown.

The "name" column lists the model name for each interconnect model contained in the file. The model name must match one of the model names given as an argument to the [Begin ICM Model] keyword(s).

The "mating" column specifies the mating condition under which each model's data is valid. Valid mating choices are "Mated", "Unmated\_Side\_A" and "Unmated\_Side\_B". These choices are defined as follows:

Mated: Both halves of a two piece interconnect are mated together for the model.

UnMated\_Side\_A: A model of non-mated interconnect. Typically, this would be the interconnect half that is attached to a baseboard, or the socket which holds the socket of an IC.

UnMated\_Side\_B: A model of non-mated interconnect. Typically, this would be the interconnect half that is attached to a daughter card, cable, edgcard, or package of an IC.

Note that using two unmated models in series DOES NOT provide a correct model of a mated interconnect. Also, if the interconnect model describes a package, one should always make it "mated" since unmated packages don't have any practical use.

The Min\_Slew\_Time column specifies the minimum slew time (i.e. fastest edge rate) for which each model is valid. Slew time is defined as the time it takes a signal to transition from 20% to 80% of its final value. This term does not indicate the bandwidth of the actual interconnect. Rather, this term is used to define a usage limit of each model.

Note: It is strongly recommended that an EDA tool issue a warning if a signal with a lesser slew time (i.e. faster edge rate) is applied to the model during a simulation.

The optional image column specifies an associated file that contains an image of each interconnect. The image file shall be either a .jpg or .txt (ASCII) formatted picture. The interconnect model MUST be considered valid by EDA tools even if an image file is specified but is missing.

If present, images should be maintained in the same directory as the interconnect model file or stored in the same compressed file with the interconnect to ensure that the files remain paired.

The same image file may be repeated for all model types if desired.

Note: it is suggested that EDA tools provide a viewer for the

.jpg format and that model builders provide at least one picture for an interconnect.

Suggested .jpg image attributes:

size = 160 horizontal by 120 vertical (pixels)  
color = 24 bit  
Image quality = 85%

Larger or smaller images may be used but are not recommended. A standard image size will allow EDA tools to provide uniform look and feel for images from all vendors. The size was chosen to be a small disk file size and be useful as either a thumb-nail in a model selection window or scaled up to give a larger picture. The 160x120 was chosen as a perfect 4:1 scale in both axis of a 640x480 picture.

```
-----  
|  
| [Begin ICM Model List]  
|-----  
| Name           Mating       Min_Slew_Time  Image  
|-----  
HDI_TEST_202           Mated           100ps          HDI_TEST_202_Mated.jpg  
HDI_TEST_202_UnMatedA  UnMated_Side_A 100ps          HDI_TEST_202_UnMatedA.jpg  
HDI_TEST_202_UnMatedB  UnMated_Side_B 100ps          HDI_TEST_202_UnMatedB.jpg  
HDI_TEST_202_ThruHole_to_Cable Mated           25ps          HDI_TEST_202_Mated.jpg  
HDI_TEST_202_SMT_to_Cable Mated           25ps          HDI_TEST_202_Mated.jpg  
HDI_TEST_202_SMT_to_ThruHole Mated           25ps          HDI_TEST_202_Mated.jpg  
-----
```

```
=====  
Keyword: [Begin ICM Model]  
Required: Yes  
Argument: Text String (Model name)  
Description: This keyword marks the beginning of each individual  
interconnect model.  
Sub-params: ICM_Model_Type, GSR, Ref_impedance  
Usage Rules: Following the keyword is a single argument specifying the  
name of this particular interconnect model. The name must be  
one of the model names listed under the "model name" column of  
the preceding [ICM Model List] keyword. Note that for every  
model name listed by the [ICM Model List] keyword there must  
be a corresponding model as defined by a [Begin ICM Model]/  
[End ICM Model] keyword pair.
```

Subparameters:

ICM\_Model\_Type

Following the keyword line is a required subparameter ICM\_Model\_Type. This subparameter defines the type of the data (RLGC or S-parameter), and the conditions under which the RLGC data was gathered.

The legal values for this subparameter are "SLM\_General", "SLM\_Quiescent", "SLM\_EvenMode", "SLM\_OddMode", "MLM", and "S-parameter".

The subparameter and its value are separated by a single whitespace. Only one ICM\_Model\_Type is allowed per interconnect model.

An ICM\_Model\_Type subparameter value of "SLM\_Quiescent" indicates that the model data was gathered with all other neighboring conductors non-switching and terminated by a reference impedance as given by the optional Ref\_Impedance subparameter.

A value of "SLM\_EvenMode" indicates that all other neighboring conductors are transitioning at the same time and in the same direction as the conductor being modeled (i.e. under even mode switching conditions). A value of "SLM\_OddMode" indicates that all other neighboring conductors are transitioning at the same time but in the opposite direction as the conductor being modeled (i.e. under odd mode switching conditions).

A value of "SLM\_General" indicates that the model data was gathered with all other neighboring conductors non-switching and the ground to signal ratio is specified by GSR and the return path is unknown.

Note that the use of an SLM\_\* value indicates that this is a "single line model" (SLM) and no electrical data is supplied to model the coupling between pins. Specifically, the corresponding RLGC matrix must contain only a single diagonal term. SLMs can be used to evaluate for Prop Delay, bandwidth, and impedance where ideal ground can be assumed. SLMs should not be used when lossy return paths contributions are required for simulations.

"SLM\_Quiescent", "SLM\_EvenMode" and "SLM\_OddMode" have a defined reference or return path. SLM\_General does not have specified Return Path given in the matrix.

An ICM\_Model\_Type value of "MLM" indicates that this model is a "multi line model" and the electrical data suitable for modeling pin to pin coupling is supplied. Any combination of Diagonal\_matrix, Sparse\_matrix, Banded\_matrix or Full\_matrix may be used in an MLM model. In general, MLMs should not be used in simulations with perfect ground planes on both sides of the interconnect model.

An ICM\_Model\_Type value of "S-parameter" indicates that this model is a "multi line model" and the electrical data suitable for modeling pin to pin coupling is supplied in a frequency domain format. Specifically, the model is a secondary file in "Touchstone" format.

Example: ICM\_Model\_type SLM\_Quiescent

#### GSR

If the ICM\_Model\_Type subparameter is equal to SLM\_General, then this GSR subparameter is required. This subparameter specifies the signal to ground ratio used when generating the SLM\_General model. The signal to ground ratio is indicated as "number of signal pins per ground pin", followed by a colon (:), followed by the number one (1). For example, if the data for an 18 pin interconnect was taken with 6 of the pins grounded, the signal to ground ratio is 18/6 or 3 to 1. The GSR subparameter argument would then be listed as 3:1.

This subparameter is only valid when the ICM\_Model\_Type subparameter has a value of "SLM\_General".

If this subparameter is present and the ICM\_Model\_Type subparameter is NOT "SLM\_General" a warning should be issued.

#### Ref\_impedance

An optional subparameter that can be used to specify the impedance of the system used to extract SLM values. If not given the Ref\_Impedance value is assumed to be 50 ohms. The reference impedance for an "S-parameter" model is located in the model file.

=====

Keyword: [ICM Model Description]

Required: No

Argument: Text Block

Description: Provides a concise yet easily human-readable description of this interconnect model

Usage Rules: This keyword may appear multiple times in the file however it may appear only once between each pair of [Begin\_ICM\_Model]/[End\_ICM\_Model] keywords.

-----

[Begin ICM Model Description]

High Density 0.1 center square pin with PCB effects

=====

Keyword: [Tree Path Description]

Required: Yes

Argument: None

Description: This keyword describes the connection path between the pin or pins on one side of the interconnect and the corresponding set of pins on the other side. This pin to pin interconnect is divided into one or more "sections", where each section consists of RLGC and/or S-parameter data. Sections are generally cascaded in series, but the Fork and EndFork subparameters allow sections to branch off the main interconnect path as a stub or tee. A [Tree Path Description] is used when all of the sections in a given interconnect are connected straight through. These straight through connections are relative to the matrices. This description is useful when all of the matrices used in each section can be connected in a conductor by conductor fashion. In this case all the matrices must be of the same size and diagonal terms must be in the same order.

Sub-params: Model\_PinMap, Section, Fork, EndFork

Usage Rules: There must be one and only one path description keyword between a [Begin ICM Model] and [End ICM Model] keyword pair. The [Nodal Path Description] and [Tree Path Description] keywords are mutually exclusive and only one of them can be used between a [Begin ICM Model] and [End ICM Model] keyword pair. However, these keywords may appear more than once and may be used together within one file.

A path description begins with the subparameter Model\_PinMap, which points to the [ICM Pin Map] used for one end of the interconnect. This is followed by one or more Section subparameters. The electrical properties of an interconnect are contained in the [ICM Section] matrix(s) pointed to by the



Section subparameter. Branches or "T" connections are indicated by the "Fork" and "EndFork" subparameters. Finally, a path description is terminated by a Model\_PinMap subparameter.

These subparameters are described in detail below.

#### Model\_PinMap

A path description begins with the required subparameter Model\_PinMap. This subparameter is followed by the name of a "pin map" which names the pins on that end of the interconnect. A second Model\_PinMap is used at the end of the path description to reference the pin map used for the other end of the interconnect. The Model\_PinMap subparameter is also used to reference a pin map for the pins at the end of any Fork. Note that the pin map name given as an argument to a Model\_PinMap subparameter must match the name of a pin map defined by a subsequent [ICM Pin Map] keyword.

The argument to the Model\_PinMap subparameter and the subparameter itself are separated by whitespace. There can be as many Model\_PinMap subparameters as required to represent an interconnect, but each must be on a single line.

In general, an interconnect will have a single pin map that is referenced at the beginning and end of a path description. However, two different pin maps will be used if the interconnect contains cross over pins.

#### Section

Following the opening Model\_PinMap subparameter is one or more instances of the required subparameter Section. This subparameter defines which [ICM Section] matrix is part of this interconnect model. Matrix sections are serially interconnected and may be re-used to form a complete interconnect model.

Arguments "multiplier" and "section name" must follow the Section parameter.

The "multiplier" argument contains a single numeric value which allows a matrix section to be re-used as a scaled value. This argument can either be a multiplier factor determining how many times the section should be repeated in series (cascaded), or defines what its length is. The value of the second argument may be any positive value greater than zero. If a section is intended to be repeated (cascaded) a certain amount of times, the syntax of this argument is:

$$M = \text{value}$$

where "value" must be an integer number.

If this argument contains the length of a section, its syntax is:

$$L = \text{value}$$

where "value" is a floating point decimal real number. (Note

that spaces around the "=" sign are not required).

Some sections within a particular path description can use M while others use L, if so desired. If "M=" is used the [Derivation Method] keyword for the corresponding [ICM Section] must have a value of "Lumped" else it is an error. If "L=" is used the [Derivation Method] keyword for the corresponding [ICM Section] must have a value of "Distributed" else it is an error.

The scale factor "L" is applied to each parameter of all matrices of a section resulting in scaled RLGC matrices. When S-parameters are used to describe a section, the usage of scale factor "L" is not allowed.

M or L are separate arguments. M and L are not allowed to be used in the same section.

The "section name" is the name of the section as specified under the [Begin ICM Section] keyword.

Section may be used as many times as required to describe the interconnect. Each scale factor and section name MUST be separated by at least one space.

Section must appear after the keyword [Begin ICM Model] and before the keyword [End ICM Model].

Fork, EndFork

The Fork and EndFork subparameters are used if there are forks or "stubs" in the interconnect being modeled. Fork marks the beginning of the stub while EndFork marks the end of the stub. These subparameters do not have any arguments.

At a fork, a "tee" section is created. Matrix sections are connected to the previous section and interconnected to zero or more sections between Fork and EndFork. If no pin map name is placed between an Fork and EndFork block, then the fork constitutes a stub. However, if a pin map name is placed at the end of the Fork and EndFork block, an externally available port is created on the interconnect.

Any number of Fork subparameters may be used per path description, however only one subparameter is allowed per line.

Example: Fork  
          EndFork

-----  
"ICM Model" Examples  
-----

Example 1: (A simple single line model with one section).

```
[Begin ICM Model] MyModelExample1
  ICM_Model_Type SLM_General
  GSR 3:1
  Ref_Impedance 50
```

```
[Tree Path Description]
```

```

Model_PinMap Example1_pinmap
Section M=1 Diagonal_matrix1
Model_PinMap Example1_pinmap
.
.
.
[End ICM Model]

```

-----

Example 2: (2 ports per pin, 5 sections straight through).

```

          SectA      SectB      SectC      SectD      SectE
Port1 >-----< >-----< >-----< >-----< >-----< Port2
[Begin ICM Model] MyModelExample2
  ICM_Model_Type SLM_Quiescent

[Tree Path Description]
  Model_PinMap MyModelPinMapA
  Section M=1 SectA
  Section M=1 SectB
  Section M=1 SectC
  Section M=1 SectD
  Section M=1 SectE
  Model_PinMap MyModelPinMapB
.
.
.
[End ICM Model]

```

-----

Example 3: (2 ports per pin, 2 series sections with one stub).

```

          SectionA      SectionB
Port1 >-----< >-----< Port2
          |
          StubSection1

[Begin ICM Model] MyModelExample3
  ICM_Model_Type MLM
[Tree Path Description]
  Model_PinMap MyModelPinMapA
  Section M=1 SectionA
  Fork
    Section M=1 StubSection1
  EndFork
  Section M=1 SectionB
  Model_PinMap MyModelPinMapB
.
.
.
[End ICM Model]

```

-----

Example 4: (2 ports per pin, 2 stub sections, one stub matrix is re-used,  
and another stub is repeated).

```

          A      B      C
Port1 >-----< >-----< >-----< Port2
          |      |      |
          |stub1  |stub4
          |stub2  |stub4
          |stub1

```

[Begin ICM Model] MyModelExample4

```

ICM_Model_Type MLM
[Tree Path Description]
Model_PinMap MyModelPinMapA
Section M=1 A
Fork
  Section M=1 stub1
  Section M=1 stub2
  Section M=1 stub1
EndFork
Section M=1 B
Fork
  Section M=2 stub4
EndFork
Section M=1 C
Model_PinMap MyModelPinMapB
.
.
.
[End ICM Model]

```

-----

Example 5: (2 ports per pin, 3 stubs).

```

          A          B          C          D
Port1 >-----< >-----< >-----< >-----< Port2
          |Stub1    |Stub2    |Stub1
          |          |Stub3
          |          |Stub4

```

```

[Begin ICM Model] MyModel4
  ICM_Model_Type MLM
[Tree Path Description]
Model_PinMap MyModelPinMapA
Section M=1 A
Fork
  Section M=1 Stub1
EndFork
Section M=1 B
Fork
  Section M=1 Stub2
  Section M=1 Stub3
  Section M=1 Stub4
EndFork
Section M=1 C
Fork
  Section M=1 Stub1
EndFork
Section M=1 D
Model_PinMap MyModelPinMapB
.
.
.
[End ICM Model]

```

-----

Example 6: (3 ports per pin, 2 stubs).

```

          A          B          C          D
Port1 >-----< >-----< >-----< >-----< Port 2
          |Stub1    |Stub2    |Stub1
          |          |Stub3
          |          |Stub4

```

|Port3

```
[Begin ICM Model] MyModelExample6
ICM_Model_Type MLM
[Tree Path Description]
  Model_PinMap MyModelPinMapA
  Section M=1 A
  Fork
    Section M=1 Stub1
  EndFork
  Section M=1 B
  Fork
    Section M=1 Stub2
    Section M=1 Stub3
    Section M=1 Stub4
  Model_PinMap MyModelPinMapC
  EndFork
  Section M=1 C
  Fork
    Section M=1 Stub1
  EndFork
  Section M=1 D
  Model_PinMap MyModelPinMapB
  .
  .
  .
[End ICM Model]
```

-----  
Example 7: (3 ports per pin, 5 sections straight through).

```
          SectionA      SectionB      SectionC      SectionD      SectionE
Port1 >-----< >-----< >-----< >-----< |>-----< Port2
                                     |
                                     SectionF
                                     |>-----< Port3
```

```
[Begin ICM Model] MyModelExample7
ICM_Model_Type SLM_Quiescent
[Tree Path Description]
  Model_PinMap = MyModelPinMapA
  Section M=1 SectionA
  Section M=1 SectionB
  Section M=1 SectionC
  Section M=1 SectionD
  Fork
    Section M=1 SectionF
    Model_PinMap MyModelPinMapB
  EndFork
  Section M=1 SectionE
  Model_PinMap MyModelPinMapC
  .
  .
  .
[End ICM Model]
```

=====  
Keyword: [Nodal Path Description]  
Required: Yes  
Argument: None  
Sub-params: N\_section, Model\_NodeMap  
Description: This keyword marks the beginning of a nodal path description.  
It contains the information on how two or more nodes are

connected. The nodal description style allows for any arbitrary topologies to be described.

Nodes define the connection points where the conductors of two or more sections are joined together, or where the path is interfaced to the outside world. Please note that single connections (dangling ends) at nodes are also permitted. Thus nodes can represent any connection points, including pins (on either side of connectors, packages, or sockets), pads and bumps of a die (where the connections to the package or printed circuit board are made), or the ends of either side of interconnect sections of printed circuit boards.

An interconnect path may have one or more sections where each section is described by RLGC, or S-parameter matrices. Multiple sections within a path description may be connected in any arbitrary manner by using the usual node naming techniques. Please note that the swath features cannot be used with this keyword.

Usage Rules: There must be one and only one path description keyword between a [Begin ICM Model] and [End ICM Model] keyword pair. The [Nodal Path Description] and [Tree Path Description] keywords are mutually exclusive and only one of them can be used between a [Begin ICM Model] and [End ICM Model] keyword pair. However, these keywords may appear more than once and may be used together within one file.

Following the [Nodal Path Description] keyword line are the subparameters that describe the topology and electrical characteristics of the pin to pin connections through the interconnect.

Path description sections are terminated by the occurrence of the next keyword.

The [Nodal Path Description] keyword line is followed by at least one Model\_NodeMap and one N\_section subparameters which describe the pin to node mapping, and the topology of the interconnect. The order in which the Model\_NodeMap and N\_section subparameters are listed in a path description is irrelevant. However, for visual clarity it is a good practice to follow the physical layout of the interconnect with the order in which they are listed. The electrical properties of an interconnect section are described in the matrices under the [Begin ICM Section] keyword which are referenced by the N\_section subparameter(s), discussed below.

Connections between the nodes of the various N\_sections, branching or T-ing are achieved using the usual node naming techniques.

Detailed descriptions of these subparameters follow below.

#### N\_section

The N\_section subparameter is used to describe the connectivity and electrical characteristics of an interconnect segment in the path description.

A path description must have at least one occurrence of the required subparameter N\_section, but can have as many

N\_section as needed to adequately describe an interconnect. Each N\_section subparameter must start on a separate line and must end on the line on which the closing parentheses are found. (This allows long node lists to span over multiple lines without causing parsing problems).

The subparameter name N\_section is followed by three arguments, separated by at least one white space.

The first argument is a list of nodes and must be enclosed in parentheses. The length of each node name cannot exceed 20 characters. The node names within the parentheses are separated by at least one white space. The allowable characters for node names are a-z, A-Z, 0-9, and the underscore character "\_".

There must be an even number of nodes in a node list when using an RLGC matrix to describe a section. There will be half as many rows in an RLGC matrix as there are nodes. When an N\_section is described by S-parameter matrices an odd number of nodes is allowed in the node list.

The order of the nodes names in the first half of the node list must match the order of the rows in the corresponding RLGC matrix data, or the order of the node names in the node list must be the same as the order of the rows in the corresponding S-parameter matrix.

A port for the S-parameter data is defined between a node and the ideal ground.

Matching node names inside a path description section are assumed to be connected with an ideal short. Nodes having the same names in different [Nodal Path Description]s are assumed to be not connected.

The second argument contains a single numeric value which allows a matrix section to be re-used as a scaled value. This argument can either be a multiplier factor determining how many times the section should be repeated in series (cascaded), or defines what its length is. The value of the second argument may be any positive value greater than zero. If a section is intended to be repeated (cascaded) a certain amount of times, the syntax of this argument is:

$$M = \text{value}$$

where "value" must be an integer number.

If this argument contains the length of a section, its syntax is:

$$L = \text{value}$$

where "value" is a floating point decimal real number. (Note that spaces around the "=" sign are not required).

Some sections within a particular path description can use M while others use L, if so desired. If "M=" is used the [Derivation Method] keyword for the corresponding [ICM Section] must have a value of "Lumped" else it is an error. If "L=" is used the [Derivation Method] keyword for the corresponding [ICM Section] must have a value of "Distributed"

else it is an error.

The scale factor "L" is applied to each parameter of all matrices of a section resulting in scaled RLGC matrices. When S-parameters are used to describe a section, the usage of scale factor "L" is not allowed.

The third argument contains the name of the N\_section which must match the name of a subsequent [Begin ICM Section] keyword. The electrical characteristics of sections are described in the form of RLGC or S-parameter matrices under the [Begin ICM Section] keyword(s). A [Begin ICM Section] keyword may be referenced by more than one N\_section subparameter even if they are in different path descriptions.

#### Model\_NodeMap

The required subparameter Model\_NodeMap is used to reference the [Node Map] keyword which provides a mapping between the actual data book pin (or signal) names and the node names used in the path description.

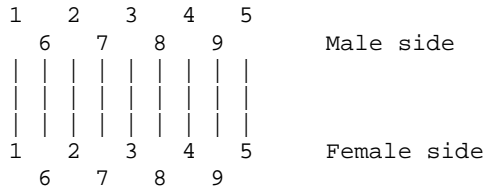
A path description must have at least one occurrence of the required subparameter Model\_NodeMap, but can have as many Model\_NodeMap subparameters as needed to adequately describe the interconnect. The number of Model\_NodeMap subparameters used in a path description would be typically the same as the number of ends or sides in a connector or interconnect. Each Model\_NodeMap subparameter must be on a single line.

The Model\_NodeMap subparameter is followed by one argument, which is the name of a node map. The argument must match the name of a node map defined by a subsequent [Node Map] keyword. The argument and the subparameter must be separated by at least one white space.

-----  
Please note that the following examples can be easily applied to connectors as well as cable assemblies, packages and printed circuit boards.  
-----

#### Example 1:

A simple model for a DB9 male to female adapter with a straight through wiring modeled as one section. The pin numbering increases left to right when facing the male side, and right to left when facing the female side. Note that this connector could have been also described by the [Path Description] keyword due to its regularity and the one to one mapping.



```
[Begin ICM Model] DB9M_F
  ICM_Model_Type MLM
[Nodal Path Description]
  Model_NodeMap DB9_Male_side
  N_section (M1 M2 M3 M4 M5 M6 M7 M8 M9
            F1 F2 F3 F4 F5 F6 F7 F8 F9) M=1 RLGC_matrix_9x9
```



```

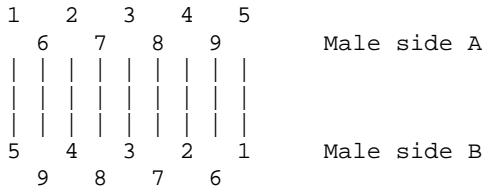
Model_NodeMap DB9_Female_side
[End ICM Model]

```

-----

Example 2:

This is a model of the same adapter as in example 1, except that both sides are male which results in a crossed pinout. Note that this connector could have been also described by the [Tree Path Description] keyword due to its regularity and the one to one mapping.



```

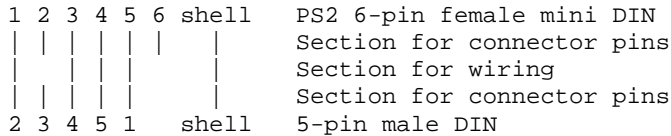
[Begin ICM Model] DB9M_M
  ICM_Model_Type MLM
[Nodal Path Description]
  Model_NodeMap DB9_side_A
  N_section (A1 A2 A3 A4 A5 A6 A7 A8 A9
            B5 B4 B3 B2 B1 B9 B8 B7 B6) M=1 RLGC_matrix_9x9
  Model_NodeMap DB9_side_B
[End ICM Model]

```

-----

Example 3:

This is a model of a PS2 6-pin female mini DIN to 5-pin male DIN adapter. The model consist of three sections to provide a more detailed model. The drawing of this adapter was found on the following web site:  
<http://www.grand-tek.com/SPEC-7/GM06F-R05MM0-04.pdf>



```

[Begin ICM Model] PS2_6_DIN_5
  ICM_Model_Type MLM
[Nodal Path Description]
  Model_NodeMap PS2_6_DIN_5_PS2_side
  N_section ( PS1 PS2 PS3 PS4 PS5 PS6 PS7
            n11 n12 n13 n14 n15 n16 n17) M=1 RLGC_matrix_7x7
  N_section ( n11          n13 n14 n15          n17
            n21          n23 n24 n25          n27) M=1 RLGC_matrix_5x5
  N_section ( n21 n22 n23 n24 n25
            DIN2 DIN3 DIN4 DIN5 DIN1          DIN7) M=1 RLGC_matrix_6x6
  Model_NodeMap PS2_6_DIN_5_DIN_side
[End ICM Model]

```

-----

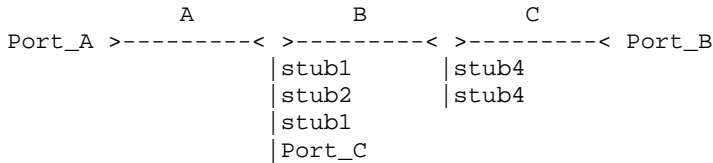
Example 4:

This is a model of a PS2 keyboard Mouse Y-splitter adapter. The model consist of only one section for simplicity, but includes connections between the shells (not shown on the drawing of the web site). The specifications for this adapter were found on the following web site:  
<http://www.hardwarebook.net/adapter/userinput/ps2keyboardgateway.html>



-----  
Example 7:

2 ports per pin, 2 stub sections, one stub matrix is re-used, and another stub is repeated.



```
[Begin ICM Model] MyModelExample7
  ICM_Model_Type MLM
[Nodal Path Description]
  N_section (A1 A2 A3 A4 A5 11 12 13 14 15) L=1.0 A
  N_section (11 12 13 14 15 s1 s2 s3 s4 s5) L=1.0 stub1
  N_section (s1 s2 s3 s4 s5 t1 t2 t3 t4 t5) L=1.0 stub2
  N_section (t1 t2 t3 t4 t5 C1 C2 C3 C4 C5) L=1.0 stub1
  N_section (11 12 13 14 15 21 22 23 24 25) L=1.0 B
  N_section (21 22 23 24 25 x1 x2 x3 x4 x5) M=2 stub4
  N_section (21 22 23 24 25 B1 B2 B3 B4 B5) L=1.0 C
[End_ICM_Model]
```

=====

**Keyword:** [ICM Swath Parameters]

**Required:** No, unless an interconnect is described by a swath.

**Argument:** None

**Sub-Params:** LeftEdge, RightEdge, TopEdge, BottomEdge

**Description:** Describes a smaller matrix which can be used to represent interconnects of equal or larger size. To visualize this, consider the swath matrix being a smaller version of a interconnect. The edges of the matrix represent the same edge effects that exists in the full size interconnect. The center area of the matrix represents the same effects as the center of the full size interconnect.

It is the responsibility of the EDA tool to use the matrix and the required keyword information as a "mini" interconnect that is centered about the electrical paths of interest and/or to expand this information into a larger sized swath up to the full sized interconnect itself. For example a 2x8 matrix might be expanded to represent a interconnect that is 2x100.

**Usage Rules:** Only rectangular interconnects without missing pins may be represented by a swath matrix. If the interconnect is non-rectangular or the pin field has missing pins then the matrix must describe the full interconnect and this keyword cannot be used. This keyword **MUST** be present if the number of rows in the matrix does not equal the number of pin names as given by the [ICM Pin Map] keyword used for this model.

This keyword must appear between the [Begin ICM Model]/[End ICM Model] keyword pair.

**MUST** be followed by 4 required subparameters:

- 1) LeftEdge: Columns in the swath matrix used to represent left edge
- 2) RightEdge: Columns in the swath matrix used to represent

- right edge
- 3) TopEdge: Rows in the swath matrix used to represent top edge
- 4) BottomEdge: Rows in the swath matrix used to represent bottom edge

These subparameters use the physical representation of the pins to define the minimum coupling bandwidth. This keyword is only required when using only a part of the matrix or when expanding the matrix.

The model maker decides on the minimum number of columns (for a column swath) or rows (for a row swath) that should be used to define the banded matrix, then assigns values to the appropriate subparameter that will, by subtraction of the columns or rows, create the appropriate maximum matrix size for the swath.

The basic goal is to define how far the edge effects extend into the coupling fields.

None of the values of these numbers may exceed the number of rows or column of pins that are defined by the matrices of a given model. The swath is applicable to any model supported by the specification

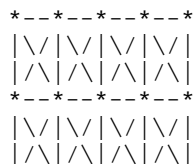
At this time, there must be at least two subparameters with a value not equal to zero.

Please see the example below to see how these are used with the keyword

The edge effects describe the edge rows or columns that do not contain all of the coupling effects (from both sides) that the centermost rows or columns. This information is useful for "swath expansion" when determining what larger size to use.

When the swath represents a SLM or else documents all of the pins in a physical interconnect, the off diagonal entries are 0 by convention. If the swath describes a section with fewer columns, but the same number of rows as the physical interconnect, then the row edge effects are 0 by convention. Similarly, if the swath describes a section with fewer rows, but the same number of columns as the physical interconnect, then the column edge effects are 0 by convention.

In a fully coupled swath where all pins couple to all others, all of the rows or columns except for the one designated as the centermost row or column can have edge simplification. So the number of rows or columns can extend to all but the center row or column. On the other hand, a coupling pattern that extends over a few columns may result in a smaller number of edges designated. Below is an example of a 3 row by 5 column swath, where the lines in a rectangular interconnect represent the electrical coupling:



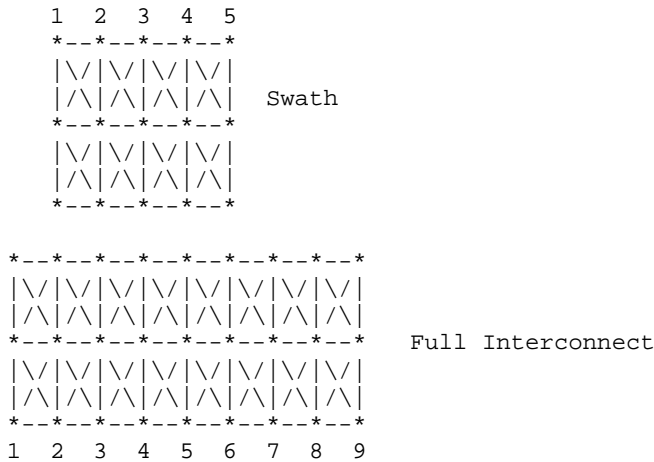
\*--\*--\*--\*--\*

Notice that columns 2, 3, and 4 have the maximum amount of coupling from each side. In this case the edge effect columns 1 and 5 do not have coupling from both sides.

Application of Swath Matrices:

For the purposes of this discussion a 3 row by 5 column swath is used and the full sized interconnect is 3 rows by 9 columns. The swath matrix data can be organized by [ICM Swath Parameters]. Three methods can be used to apply the Swath matrix information:

(1) Centering the Swath around the pins of interest



The Swath above is centered about column 4. The paths of interest including those of columns 3 and 5 are also described by swath matrix data that has coupling from both sides. However, because of edge effects, columns 2 and 6 are less accurately approximated.

Centering is a way to map the swath matrix pins directly into the corresponding pins of the actual interconnect.

When the signals of interest are at the left or right edges, the swath would normally be positioned just to the edges. For example, column 1 of the swath matrix would line up with column 1 of the interconnect.

(2) Expansion and Centering: Expanding the Swath matrix into a larger sized Swath matrix and centering it about the paths of interest.

This approach is the same as centering. However, the signal pins of interest might have more columns than the non-edge section of the swath. One solution is to expand the swath to a larger swath and then use the larger swath for centering. This is a subset of expanding the swath into the full sized interconnect.

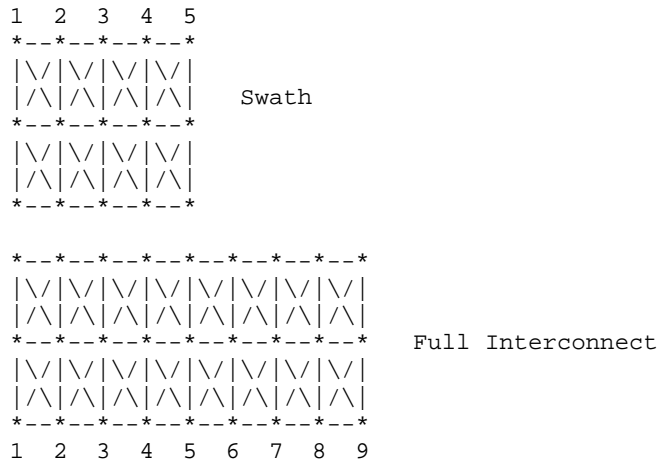
A larger swath might be constructed to span the number of

columns of interest plus the edge effect columns to assure that the most accurate coupling information from both sides is used for the columns of interest.

- (3) Expansion to Full Sized Interconnect: Expanding the swath matrix to the full sized interconnect matrix.

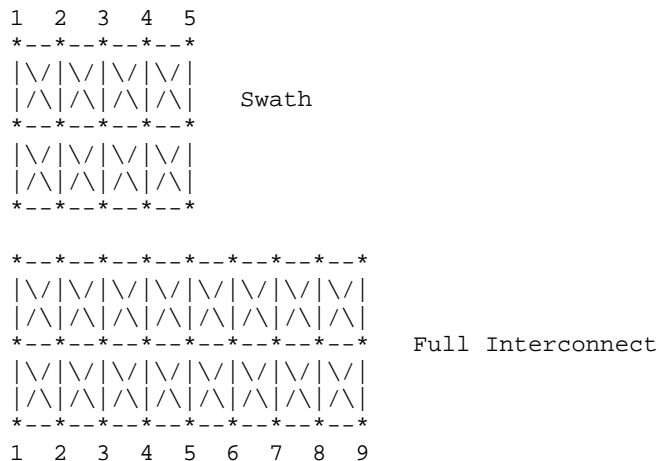
There are three steps to this procedure (a, b, and c below). This is illustrated using the 3 row, 5 column swath and showing how it is expanded into a 3 row, 9 column full sized interconnect.

- (a) Copy the left column pattern



The matrix data for swath columns 1 and 2 (including forward references) copied into the new full interconnect matrix.

- (b) Repeat the center pattern,



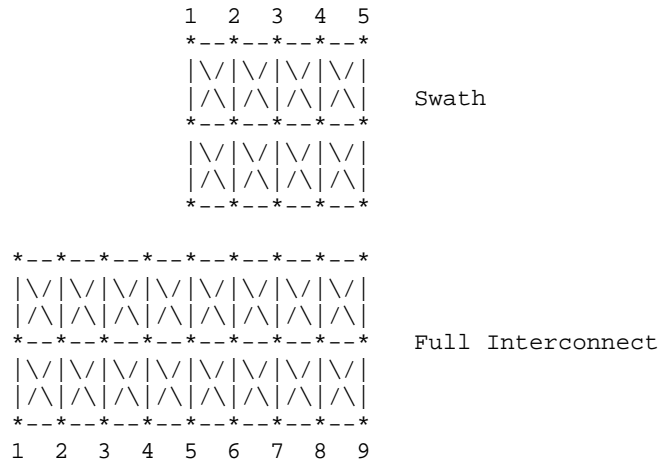
Starting at the center of the swath, the coupling pattern of just the center column (column 3 in this example) is copied for the interconnect matrix. In this case, the coupling pattern extends forward to the next column. The

column

pattern is copied by mapping the swath pin numbers into the interconnect pin numbers and copying the center

forward referenced data. In this example, the operation starts at the full interconnect column 3 and ends upon completion at the full interconnect column 7.

(c) Copy the right column patterns



using  
positioned  
patterns  
columns

The final step is similar to Step (a), but concluded the right side of the swath. When the swath is against the right edge as shown, then the coupling for the swath columns are duplicated for the final of the full sized interconnect. So the patterns of swath columns 4 and then 5 are duplicated for the full sized interconnect columns 8 and 9.

A similar process could be created for expanding the number of rows. Some details are left to the EDA tool to implement. For example, if the swath contains an even number of columns, then either the left of center or the right of center column may be used for center section expansion.

```

-----
[ICM Swath Parameters]
  LeftEdge = 1
  RightEdge = 1
  TopEdge = 0
  BottomEdge = 0

```

```

=====
  Keyword: [ICM Swath Pin Numbers]
  Required: Yes, if [ICM Swath Parameters] is present, else it must not be
            used.
  Arguments: None
  Description: Lists the pins of the matrix in the exact order that the
              swath matrix rows are entered and gives the corresponding
              physical location of the pin.

```

Usage Rules: The [ICM Swath Pin Numbers] keyword is followed by a list of entries that apply for all of the sections for which the [Tree Path Description] references.

The number of entries in the list is equal to the product of the rows and columns of the [ICM Swath Pin Numbers] keyword.

Each line must contain three columns documenting the row names and physical row and column locations for each entry of the matrices under the corresponding [Begin ICM Section] keyword. The entries consist of [Row] name designated row\_name, physical row number designated physical\_row, and physical column number designated physical\_column. All three columns are required and must be separated by at least one white space.

The physical row number consists of an integer value from 1 to the number of rows documented in the [ICM Swath Pin Numbers] keyword. Similarly, the physical column number consists of an integer value from 1 the number of columns documented in the [ICM Swath Pin Numbers] keyword.

These physical row and column numbers give the relative physical location of each of the swath matrix elements as if they were the pin numbers of the interconnect itself. Only one unique physical row and physical column number pair are allowed in the list. In other words, no two or more row\_name entries shall refer to the same physical\_row, physical\_column pair.

Other Notes: It is required that all of the sections that are referenced by the [Begin ICM Section] keyword have swath matrix entries that are ordered in the same manner. This would be expected from the field solver working on a single interconnect swath, but issuing its results as separate sections.

The EDA tool that processes this keyword has enough information to reorder the swath matrix, if needed, to position its electrical contents among the pins of interest in the actual interconnect.

-----  
Consider a 2 row by 3 column Swath matrix that was extracted for the pins as shown below:

```
A B C
D E F
```

The field extractor may have produced matrices ordered: C E B F A D

```
[Swath Pin Numbers]
| row_name      physical_row  physical_column
| C             1             3
| E             2             2
| B             1             2
| F             2             3
| A             1             1
| D             2             1
```

=====  
Keyword: [ICM Pin Map]  
Required: No, unless the [Tree Path Description] keyword exists.



Argument: Text String (Model\_PinMap name)  
Sub-params: Pin\_order, Num\_of\_columns, Num\_of\_rows  
Description: This keyword gives the names of the pins on one side of an interconnect, then defines a pin ordering such that pins can be associated with rows in the RLGC or S-parameter section matrixes. This keyword also defines if the pins are listed in column ordered or row ordered fashion.

Usage Rules: Following the keyword is the name of this pin map. The pin map name must match the pin map name used as an argument to one of the Model\_PinMap subparameters in a model's [Tree Path Description] keyword.

Following the [ICM Pin Map] line are three subparameters: Pin\_order, Num\_of\_rows, Num\_of\_columns. Each subparameter is placed on a separate line, and when used they must appear in the above order. Following the subparameters is a list of pin names that are covered by this pin map.

Subparameters and the pin list are described in detail below.

#### Pin\_order

The Pin\_order subparameter is required. Legal arguments to the Pin\_order subparameter are Row\_ordered, Column\_ordered or Un-ordered. The subparameter name and its argument are separated by one or more white spaces.

Row\_ordered and Column\_ordered refers to the order in which the pins in the accompanying pin list are listed. Row\_ordered means that all the pins in the top row of an interconnect are listed in order, then the second row of pins is listed, and so on. Likewise, Column\_ordered means that all the pins in the first column of an interconnect are listed, then the second column, and so forth.

If the Row\_ordered or Column\_ordered argument is specified then the Num\_of\_rows and Num\_of\_columns subparameters are also required.

If the Un-ordered argument is specified, the pins are not listed in row or column order and the Num\_of\_rows and Num\_of\_columns subparameters must not be used. Un-ordered also implies that the interconnect is not swathable.

#### Num\_of\_columns

This optional subparameter specifies the number of columns that are in the physical interconnect. The subparameter name is followed by a single positive integer.

#### Num\_of\_rows

This optional subparameter specifies the number of rows that are in the physical interconnect. The subparameter name is followed by a single positive integer.

Note that the pin order and number information are required in order for EDA software to properly position and expand a swath matrix around a given pin.

## Pin List

Following the subparameters is a list of the pin names covered by this pin map. The pin list is required. Each pin name is listed on a separate line on the file. The pin names must be organized as specified by the Pin\_order subparameter.

**IMPORTANT NOTE:** The intent of the [ICM Pin Map] keyword pin order information is to give an EDA tool enough information to map pin names to the rows of an interconnect's section matrix. In the case of a full-matrix/full-pinout description of an interconnect, it is required that the rows of a section matrix appear in the same row or column order as the pin names. For example, suppose the pins names of a six pin connector were listed as follows:

```
A1
A2
A3
B1
B2
B3
```

A six pin connector can be described by a 6x6 matrix. It is required that the first row of the matrix contain the data for pin A1, the second row contain the data for pin A2, and so on.

Other Notes: More than one [ICM Pin Map] keyword is allowed in a file.

This keyword must occur outside the [Begin ICM Model]/[End ICM Model] keyword pair. This is to allow a [ICM Pin Map] to be referenced by multiple interconnect models.

The examples below use the connector represented by:

```
A1 A2 A3 A4
B1 B2 B3 B4
```

```
-----
[ICM Pin Map] Baseboard_side
Pin_order = row_ordered
Num_of_columns = 4
Num_of_rows = 2
|Pin
  A1
  A2
  A3
  A4
  B1
  B2
  B3
  B4
```

```
[ICM Pin Map] Baseboard_side2
Pin_order = column_ordered
Num_of_columns = 4
Num_of_rows = 2
|Pin
  A1
```

B1  
A2  
B2  
A3  
B3  
A4  
B4

[ICM Pin Map] Daughtecard\_side

Pin\_order = Un\_ordered

|Pin  
A1  
A2  
A3  
A4  
B1  
B2  
B3  
B4

=====

**Keyword:** [ICM Node Map]

**Required:** No, unless the [Nodal Path Description] keyword exists.

**Argument:** Text String (Model\_NodeMap name)

**Description:** This keyword is used to provide a mapping between the actual data book pin names and the node names used in the path description. This may be useful, for example, when the data book pin names are identical on either side of a interconnect, or when only a signal name is available for a conductor on package or BCP, because the node names on the two ends of these interconnects must be unique in the path description (to prevent shorting the pins of the two sides). Typically there would be as many Model\_NodeMap subparameters in a path description as there are many ends or sides in the interconnect.

**Usage Rules:** Following the keyword is the name of this node map. The node map name must match the node map name used as an argument to one of the Model\_NodeMap subparameters in a model's [Nodal Path Description] keyword.

The [ICM Node Map] line is followed by a two-column table. The first column contains the list of pin or signal names and the second column contains the corresponding node names. The node names listed here must match the node names by the N\_section subparameter(s) under the [Nodal Path Description] keyword to make a connection.

Note that the first columns (i.e. the pin or signal names) of different [ICM Node Map] keywords may be identical in certain situations. This does not result in an electrical short between those pins or signals even if these [ICM Node Map] keywords are called by the Model\_NodeMap subparameters of the same [Nodal Path Description] keyword, because it is the associated node names which make the electrical connections. Also, the node names defined in the [ICM Node Map] keyword are not required to be nodes having a single connection only in the path description.

**Other Notes:** More than one [ICM Node Map] keyword is allowed in a file.

This keyword must occur outside the [Begin ICM Model] / [End ICM Model] keyword pair. This is to allow a [ICM Node Map] to

be referenced by multiple interconnect models.

[ICM Node Map] sections are terminated by the occurrence of the next keyword.

-----  
The following examples are to be used with the examples following the description of the [Nodal Path Description] keyword.  
-----

Example 1:

```
[ICM Node Map] DB9_Male_side
| pin  node
  1    M1
  2    M2
  3    M3
  4    M4
  5    M5
  6    M6
  7    M7
  8    M8
  9    M9
[ICM Node Map] DB9_Female_side
| pin  node
  1    F1
  2    F2
  3    F3
  4    F4
  5    F5
  6    F6
  7    F7
  8    F8
  9    F9
```

-----  
Example 2:

```
[ICM Node Map] DB9_side_A
| pin  node
  1    A1
  2    A2
  3    A3
  4    A4
  5    A5
  6    A6
  7    A7
  8    A8
  9    A9
[ICM Node Map] DB9_side_B
| pin  node
  1    B1
  2    B2
  3    B3
  4    B4
  5    B5
  6    B6
  7    B7
  8    B8
  9    B9
```

-----  
Example 3:

```

[ICM Node Map] PS2_6_DIN_5_PS2_side
| pin    node
  1     PS1
  2     PS2
  3     PS3
  4     PS4
  5     PS5
  6     PS6
  shell PS7
[ICM Node Map] PS2_6_DIN_5_DIN_side
| pin    node
  1     DIN1
  2     DIN2
  3     DIN3
  4     DIN4
  5     DIN5
  shell DIN7

```

-----

Example 4:

```

[ICM Node Map] PS2_splitter_Computer_side
| pin    node
  1     C1
  2     C2
  3     C3
  4     C4
  5     C5
  6     C6
  shell Cs
[ICM Node Map] PS2_splitter_Keyboard_side
| pin    node
  2     K2
  3     K3
  4     K4
  6     K6
  shell Ks
[ICM Node Map] PS2_splitter_Mouse_side
| pin    node
  2     M2
  3     M3
  4     M4
  6     M6
  shell Ms

```

-----

Example 5:

```

[ICM Node Map] Port_A
| pin    node
  Port_A1  A1
  Port_A2  A2
  Port_A3  A3
  Port_A4  A4
[ICM Node Map] Port_B
| pin    node
  Port_B1  B1
  Port_B2  B2
  Port_B3  B3
  Port_B4  B4

```

-----

Example 6:

```

[ICM Node Map] Port_A
| pin      node
  Port_A1  A1
  Port_A2  A2
  Port_A3  A3
  Port_A4  A4
  Port_A5  A5
[ICM Node Map] Port_B
| pin      node
  Port_B1  B1
  Port_B2  B2
  Port_B3  B3
  Port_B4  B4
  Port_B5  B5

```

-----

Example 7:

```

[ICM Node Map] Port_A
| pin      node
  Port_A1  A1
  Port_A2  A2
  Port_A3  A3
  Port_A4  A4
  Port_A5  A5
[ICM Node Map] Port_B
| pin      node
  Port_B1  B1
  Port_B2  B2
  Port_B3  B3
  Port_B4  B4
  Port_B5  B5
[ICM Node Map] Port_C
| pin      node
  Port_C1  C1
  Port_C2  C2
  Port_C3  C3
  Port_C4  C4
  Port_C5  C5

```

```

=====
Keyword: [End ICM Model]
Required: Yes
Argument: None
Description: Defines the end of the interconnect models for the
interconnect family.

```

-----

[End ICM Model]

```

=====
Keyword: [End ICM Model Family]
Required: Yes
Argument: None
Description: Defines the end of the interconnect model family.
Usage Rules: These commands wrap the entire model in this file.

```

-----

[End ICM Model Family]

=====

## 8.0 MATRIX KEYWORDS

=====

**Keyword:** [Begin ICM Section]  
**Required:** Yes  
**Argument:** Text String  
**Description:** Indicates the beginning and the name of a set of RLGC matrix data.  
**Usage Rules:** This keyword is followed by the name of a section. The section must be used in one of the models in the document.

When using [Tree Path Description], every matrix used for given interconnect model MUST have exactly the same number of diagonal traces.

If the swath method is used the matrix may have fewer conductors than the interconnect model.

When the swath method is not used, the matrix MUST have exactly the same number of diagonal terms as the interconnect has conductors.

The matrices used for the RLGC description can be defined using any of the matrix description methods allowed in the specification. The matrix description methods can also be mixed within a given section. For example the resistance matrix might use the Diagonal\_matrix and the inductance matrix might use a Full matrix.

MUST be placed outside the context of keywords [Begin ICM Model] and [End ICM Model] as sections may be reused by more than one interconnect model.

MUST be placed outside the context of the [Begin ICM Model Family] and End ICM Model Family

For an example of [Begin ICM Section] see matrix examples that follow.

-----

=====

**Keyword:** [Derivation Method]  
**Required:** Yes  
**Argument:** Text String (Lumped or Distributed)  
**Description:** Describes how the data in the RLGC or S-parameter matrixes should be interpreted. This keyword also places rules on what individual matrixes must be present in a section.  
**Usage Rules:** Following the keyword is one of two arguments: "Lumped" or "Distributed".

If 'Lumped' is specified then the RLGC matrix data represents discrete values suitable for creating a circuit of interconnected inductor, capacitor and resistor elements. A section may be replicated, but the values in each matrix are fixed. For sections described using lumped data any single, any pair, or all of the following keywords could be used to describe a section:  
[Inductance Matrix], [Capacitance Matrix], [Conductance Matrix] and [Resistance Matrix]

If 'Distributed' is specified then the RLGC matrix data

represents per-unit-length values suitable for creating a transmission line representation of the section. A multiplier value representing the physical length of a section may be applied to the data in the RLGC matrixes. For sections described using distributed data both the [Inductance Matrix] and [Capacitance Matrix] keywords are required. The [Conductance Matrix] and [Resistance Matrix] keywords are optional.

For a section described using S-parameter data the argument to the [Derivation Method] keyword shall be 'lumped'.

All matrixes within the same section must share the same derivation method.

-----  
[Derivation Method] Lumped

=====  
Keyword: [Resistance Matrix], [Inductance Matrix], [Capacitance Matrix], [Conductance Matrix]

Required: Yes, If a simple single line model is defined then the following matrixes are required:

case 1: [Resistance Matrix] only (Not to be used with distributed models

OR

case 2: [Inductance Matrix] and [Capacitance Matrix] only for which the [Resistance Matrix] is assumed to be zero ohms

OR

case 3: [Resistance Matrix] and [Inductance Matrix] and [Conductance Matrix] and [Capacitance Matrix]

NOTE: In case 1,2,3 the matrixes must be Diagonal\_matrix.

If a coupled model is defined then the following matrixes are required:

case 4: [Inductance Matrix] and [Capacitance Matrix] only for which the [Resistance Matrix] is assumed to be zero ohms

OR

case 5: [Resistance Matrix] and [Inductance Matrix] and [Capacitance Matrix]

case 6: [Resistance Matrix] and [Inductance Matrix] and [Capacitance Matrix] and [Conductance Matrix]

NOTE: In case 4,5, and 6 the matrixes shall be any combination of matrix types (Diagonal, Banded, Sparse, Full).

Argument: Matrix Type

Description: The sub-parameters mark the beginning of a matrix, and specify how the matrix data is formatted.

Usage Rules: For each matrix keyword, only one of the sub-parameter of each type is allowed (i.e. one inductance, one capacitance, one conductance, and one resistance matrix is allowed per section.)

After each of these sub-parameters, insert the matrix data in the appropriate format. (These formats are described in detail below.)



MUST BE USED between keywords [Begin ICM Section] and [End ICM Section].

If the model type in SLM, then only the diagonal matrix is allowed.

Matrix Type Options:

[Diagonal\\_matrix](#), [Banded\\_matrix](#), [Sparse\\_matrix](#), or [Full\\_matrix](#)

#### [Diagonal\\_matrix](#)

Required: No

Argument: None

Description: The [Diagonal\\_matrix](#) is used to specify uncoupled models.

This sub-parameter is exactly the same as using the [Banded\\_matrix](#) described below with a `Bandwidth=0`. It has the added benefit of requiring half as many lines.

A [Diagonal\\_matrix](#) is one whose entries are guaranteed to be zero if they are not on the main diagonal.

Specify the [Diagonal\\_matrix](#) one row at a time, starting with row 1 and working up to higher rows. Diagonal elements are entered one per line. MUST be used between keywords [Begin ICM Section] and [End ICM Section].

#### [Banded\\_matrix](#)

Required: No

Argument: None

Description: The [Banded\\_matrix](#) is used to specify the coupling effects up to "X" pins on either side for a given pin.

A [Banded\\_matrix](#) is one whose entries are guaranteed to be zero if they are farther away from the main diagonal than a certain distance, known as the "bandwidth."

The bandwidth for a [Banded\\_matrix](#) must be specified using the [Bandwidth] keyword.

Specify the banded matrix one row at a time, starting with row 1 and working up to higher rows. Mark each row with the [Row] keyword.

#### [Sparse\\_matrix](#)

Required: No

Argument: None

Description: A [Sparse\\_matrix](#) is expected to consist mostly of zero-valued entries, except for a few nonzero. Unlike the [Banded\\_matrix](#), there is no restriction on where the nonzero entries can occur.

Symmetry can be exploited to reduce the amount of data by eliminating from the matrix any

entries below the main diagonal.

An N x N Sparse\_matrix is specified one row at a time, starting with row 1 and continuing down to row N. Each new row is marked with [Row] keyword, as in the other matrix formats.

#### Full\_matrix

Required: No

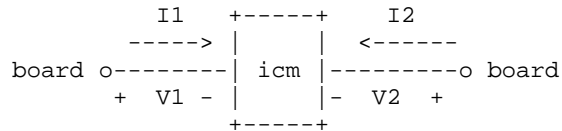
Argument: None

Description: When the Full\_matrix format is used, the couplings between every Pair of elements is specified explicitly. Assume that the Matrix has N rows and N columns.

The Full\_matrix is specified one row at a time, starting with Row 1 and continuing down to Row N. Each new row is identified with the [Row] keyword.

#### Matrix Descriptions

The resistance, inductance, conductance, and capacitance matrices may also be referred to as "RLGC matrices" within this specification. When measuring the entries of the RLGC matrices, either with laboratory equipment or field-solver software, currents are defined as ENTERING the pins of the package from the board. The corresponding voltage drops are to be measured with the current pointing "in" to the "+" sign and "out" of the "-" sign.



It is important to observe this convention in order to get the correct signs for the mutual inductance and resistances.

For each [Resistance Matrix], [Inductance Matrix], [Conductance Matrix] or [Capacitance Matrix] a different matrix type can be used for the data.

#### Resistance Matrix Description

=====

UNITS: OHMS

DESCRIPTION: The resistance matrix represents the total DC resistance between the two ends of this section of the interconnect.

#### NOTES:

The resistance matrix is optional. Simulation tools shall use 0.0 ohms for all diagonal entries and "infinite" for all off diagonal entries if this matrix is not present.

DO NOT USE ohms/meter as this is the total value and includes the length of this section.

Values should all appear in the diagonal terms of the matrix. For example: value 1,1 is the resistance for pin 1

and value 2,2 is the resistance for pin 2.

A "Diagonal\_matrix" matrix type is the best choice for describing the resistance matrix. Diagonal elements may be dominant. Comparably, the off diagonal elements may be negligible thus leading to off diagonal element values of zero leading to the [Diagonal\_matrix] format

Inductance Matrix Description

=====

UNITS: HENRIES

DESCRIPTION: Two inductance matrix methods are supported:  
Loop-Inductance Matrix for SLMs ONLY (non-coupled)  
Partial-Inductance Matrix for MLMs ONLY (coupled)

If ModelType is SLM then all sections must use loop-inductance and capacitance matrices.

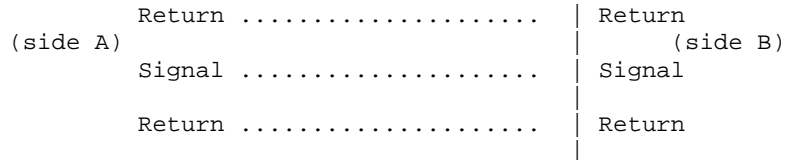
If ModelType is MLM then all sections must use partial-inductance and capacitance matrices.

Loop-Inductance Matrix Description (SLMs ONLY):

=====

DESCRIPTION: To define inductance requires a loop. The loop consists of a closed path including a signal and all possible return paths. The inductance is a coefficient between the emf induced in the loop and the change of magnetic flux through the loop.

interconnect or section



The return path must include all pins that are power or ground. In a loop inductance matrix, the diagonal terms represent the loop inductance of a specific pin with return currents with the assumption that return currents are returned through all pins defined to be power or ground.

NOTES: (Single-Line Loop-Inductance Matrix):  
This method must be used if the ModelType is SLM.

Loop inductance can be experimentally measured.

Loop inductance matrices can be created using field solvers.

An GSR value is normally specified for an SLM model that indicates the ratio of signal pins to return path pins (i.e. power or ground) pins.

SLM models make have zero values for power or ground RLCG values which prevents there use in analyzing interconnect ground bounce effects.

Typical uses for SLM model might include for example a 2x17 header connector where the bottom row is all

grounded. The GSR would be specified in this case as 1:1. A model would be developed with these assumptions made. Then all pins would be filled with average values. To further expand this example see the figure below:

Pin out:

```
1 ..... 17
18 ..... 34
```

Measurement or Field solver connection:

```
Sig Sig Sig ... Sig Sig
Gnd Gnd Gnd ... Gnd Gnd
```

Measured or Computed values:

```
3nH 4nH 4nH ... 4nH 3nH
```

Matrix data:

```
3nH 4nH 4nH ... 4nH 3nH
3nH 4nH 4nH ... 4nH 3nH
```

This allows the user to specify any of the following power/ground connections and still use this model:

Simulator Connection A:

```
Sig Sig Sig ... Sig Sig
Gnd Gnd Gnd ... Gnd Gnd
```

Simulator Connection B:

```
Gnd Gnd Gnd ... Gnd Gnd
Sig Sig Sig ... Sig Sig
```

Simulator Connection C:

```
Sig +5V Sig ... Gnd Sig
Gnd Sig Gnd ... Sig +5V
```

Given the following connection a simulation should generate a warning to the user indicate the ground-signal-ratio has been violated.

Simulator Connection D:

```
Sig Sig Sig ... Sig Sig
Gnd Sig Sig ... Sig Sig
```

All interconnect conductors must be specified with non-zero L and C values in at least one of the sections. The simulator will zero out portions of all sections corresponding to the ground or power pins.

SLM models are most useful where coupling analysis is not critical and where the rise time of the signal is long compared to the electrical delay through the interconnect.

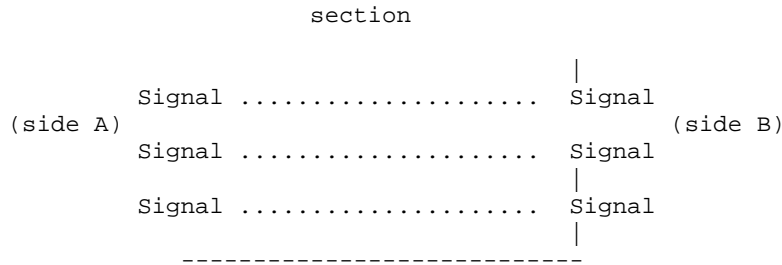
**Partial Self Inductance Matrix Description (MLMs ONLY):**

=====

DESCRIPTION: A partial self inductance is an approximation of the loop inductance in situations where the current return path cannot be explicitly stated in the field extraction stages. Partial self inductance can be numerically calculated by introducing a current in a circuit element that originates on one end and terminates on the other end. There is no physical

loop per se, instead charges will build up on each side of the circuit element. In practice, this situation cannot exist more than instantaneously. For the purposes of simulation the condition does not affect the resultant loop inductance values. Then from the currents found the magnetic fields and inductance's can be calculated. In this way, the self and mutual inductances of any section of a closed circuit can be calculated.

This representation of inductance in terms of partial self and mutual inductance allows the analysis of any combination of current paths. The signal and return current paths can be defined in circuit after the model is established. Assuming that the self inductance is included in the return path, the circuit under simulation can account for the impact on signal-integrity, cross-talk and ground-bounce from currents passing through any combination of pins.



There are many ways to create this information using either 2D or 3D field solvers. It may also be possible to create this information using other methods which are left to the model developer.

For an MLM model it is required that at least one section include partial inductance and capacitance matrices.

Capacitance Matrix Description

=====

UNITS: FARAD

DESCRIPTION: A capacitance is an approximation of the capacitance in situations where the return path cannot be explicitly stated in the field extraction stages.

See "Multi-Line Capacitance Matrix" section above for more information on Multi-Line Matrices.

USAGE RULES: Two capacitance matrix methods are supported:

- SLM, Single-Line, Capacitance Matrix (non-coupled)
- MLM, Multi-Line, Maxwell Capacitance Matrix (coupled)

If ModelType is SLM then all sections must only contain a single capacitance value per line.

If ModelType is MLM then all sections must use a Maxwell Capacitance as stated below.

Single-Line Capacitance Matrix Description:

-----

To define capacitance requires conductors separated by a dielectric. The conductors are those found in a loop consisting of a closed path including a signal and all possible return paths. The Maxwell Capacitance matrix relates the total charges on the conductors to the voltages applied to them.  $[Q]=[C_m][V]$  Where  $[C_m]$  is the Maxwell matrix,  $[Q]$  is the vector of total conductor charges, and  $[V]$  is a vector of applied voltages. The negative values of the off-diagonal entries can be explained on physical grounds: if you put +1 Volt on a single conductor and 0 Volts on the others, then you induce negative charges on those other conductors to terminate the field lines emanating from the conductor at 1 Volt.

In the Maxwell Capacitance matrix, the diagonal term is the maximum capacitance that the conductor encounters, meaning the capacitance to ground plus the capacitances to all the other conductors.

In the Maxwell Capacitance matrix, the OFF-diagonal term is the capacitance that the conductor encounters relative to a second conductor. This capacitance value is affected by other nearby conductors during the field extraction phase. It should not normally be used by itself to determine the capacitance of a random pair of conductors in a given structure.

#### Conductance Matrix Description

=====

Units: Siemens (mhos)

Description: The Conductance matrix represents the energy transfer between the conductor and its surroundings, including the return path. Conductance includes dielectric and radiation losses, as well as any DC conductance.

Notes: The conductance matrix is optional. Simulation tools shall use 0.0 Siemens for all entries if this matrix is not present.

Do NOT use Siemens/meter as this is the total value and includes the length of this section.

#### Loss Matrix Description

=====

This release supports S-Parameters for frequency dependent loss.

#### Uncoupled Models:

=====

Single-Line-Models or SLM models are used for un-coupled models. These models are useful for most simulations where coupled effects can be ignored safely. These models are most accurate if closely spaced ground pins or a ground plane is present.

A "Diagonal\_matrix" matrix type is the best choice for describing all matrices R, L, G, and C for SLM models. (see matrix descriptions below).

Several methods can be used:

Field solvers with return path pins defined. Only the diagonal matrix data is used. The coupling information is ignored. The RLG matrices should represent the electrical parameters for a specific section.

2D field solver with a specific return path or ground. Only the diagonal matrix data is needed. No coupling data is present in the final matrix

Closed form round wire inductance equation.

Experimental lab data may be obtained from TDR, VNA or other Means.

#### Coupled Models:

=====

Multi-Line-Models or MLM models are used for coupled models.

A "Full\_matrix" matrix type is the best choice for describing all matrices R, L, G, and C for MLMs. (see matrix descriptions below)

Several methods can be used:

3D field solver can be used to create partial inductance and capacitance matrices that allow accurate simulations without the need to pre-define the ground pins.

Field solvers without specific return path pins. A return plane May be specified as a reference only and is placed far field.

Experimental lab data may be obtained from multichannel measurements that incorporate TDR, VNAs or other means as long as the resulting inductance matrix contains partial inductance values.

#### Common to Coupled and Uncoupled Models

=====

One common aspect of all the different formats is that they exploit the symmetry of the matrices they describe. This means that the entries below the main diagonal of the matrix are identical to the corresponding entries above the main diagonal. Therefore, only roughly one-half of the matrix needs to be described. By convention, the main diagonal and the UPPER half of the matrix are provided.

In the following text, we use the notation [I, J] to refer to the entry in row I and column J of the matrix. Note that I and J are allowed to be alphanumeric strings as well as integers.

The ordering of these strings is determined by the row/column ordering convention given by the [ICM Row Swath] or [ICM Column Swath] convention, or else matches exactly the [ICM Pin Map] order when the pin map contains the same number of pins as the Swath.

In the following text, "Row 1", means the row corresponding to the first pin.

Also note that the numeric entries of the RLGC matrices are standard IBIS floating point numbers. As such, it is permissible to use metric "suffix" notation. Thus, an entry of the C matrix could be given as 1.23e-12 or as 1.23p or 1.23pF.

Each new row is identified with the Row keyword.

=====  
**Keyword:** [Bandwidth]  
**Required:** Yes, if a Banded\_matrix matrix is being defined.  
**Argument:** Numeric Value  
**Description:** Indicates the size of the width of the coupling matrix.  
This does not have anything in common with electrical bandwidth.  
The bandwidth field must be a nonnegative integer. This is the  
number of off-diagonal matrix rows for which data is provided.  
**Usage Rules:** MUST be used between keywords [Begin ICM Section] and  
[End ICM Section].  
  
MUST follow any usage of one of the following keyword:  
Banded\_matrix

-----  
See example "Matrix Example" lower in this document.

=====  
**Keyword:** [Row]  
**Required:** Yes if a matrix is being defined.  
**Argument:** None  
**Description:** Indicates the beginning of a new row of the matrix.  
**Usage Rules:** The argument must be a sequential number beginning at 1  
and continuing to the last row for the matrix

Following a [Row] keyword is a block of numbers that represent  
the entries for that row. Suppose that the current row is  
number M. Then the first number listed is the diagonal entry,  
[M,M]. Following this number are the entries of the upper half  
of the matrix that belong to row M: [M, M+1], [M, M+2], ... up  
to [M,N].

For even a modest-sized matrix, this data will not all fit on  
one line. You can break the data up with new-line characters so  
that this limit is observed.

Example: Suppose the matrix has 40 conductors and that we are  
currently working on Row 19. There is 1 diagonal entry, plus  
40 - 19 = 21 entries in the upper half of the matrix to be  
specified, for 22 entries total.

Row 1 always has the most entries, and that each successive row  
has one fewer entry than the last; the last row always has just  
a single entry.

**Usage Context:**  
MUST be used between keywords [Begin ICM Section] and  
[End ICM Section].

MUST follow any usage of one of the following keywords:  
Banded\_matrix, Sparse\_matrix, Full\_matrix

-----  
See example "Matrix Example" lower in this document.

---

**Keyword:** [ICM Sparameter]  
**Required:** No, unless ICM\_Model\_Type sub-parameter of [Begin ICM Model] is  
equal to "S-parameter".  
**Sub-Params:** file\_type, file\_name, port\_map  
**Description:** Indicates a reference to an external S-parameter file  
**Usage Rules:** Can be used in addition to or in place of place of LRCG matrix.



file\_type: Touchstone

file\_name

file\_name is to reference the name of the CITI or Touchstone file. It is required that the icm and the referenced file be in the same directory. One [ICM Sparameter] keywords is allowed for each [Begin ICM Section] / [End ICM Section].

port\_map

"port\_map" is to be used to relate the ports in the S-parameter file to the "fixed" pin map in the icm file. It is important that the "port\_map" uses the pin names from [ICM PinMap]. No more or no less entries in the table are allowed.

There are three columns used in the port\_map. The first column is a reference to a "Pin Name" as defined in the [ICM PinMap] keyword. The second column should reference the input port name as defined in the Touchstone file that is related to the "Pin Name". The third column should reference the output port name as defined in the Touchstone file that is related to the "Pin Name".

Example:

```
-----  
[ICM Sparameter]  
file_type touchstone  
file_name anyone.any_extension  
port_map  
|Pin    Port A  Port B  
|A1     1       2  
|A2     3       4  
|A3     5       6  
|A4     7       8  
|B1     9       10  
|B2    11      12  
|B3    13      14  
|B4    15      16
```

```
=====  
Keyword:  [End ICM Section]  
Required: Yes  
Argument: Text String  
Description: Indicates the end of [Begin ICM Section]
```

#### Matrix Examples

```
=====  
The resistance matrix for this package does not have coupling
```

```
[Begin ICM Section]      ExampleMatrix00  
[Derivation Method]     Distributed  
[Resistance Matrix]     Diagonal_matrix  
10.0  
15.0  
15.0  
10.0  
10.0
```

```

15.0
15.0
10.0
[End ICM Section] ExampleMatrix00

```

```
[Begin ICM Section] ExampleMatrix01
```

The resistance matrix for this package does not have coupling and is exactly the same as the Diagonal\_matrix shown above and is described using a trivial version of the Banded\_matrix as an example only. The Diagonal\_matrix should be used for this example to conserve file size.

```

[Resistance Matrix] Banded_matrix
[Bandwidth] 0
[Row] 1
10.0
[Row] 2
15.0
[Row] 3
15.0
[Row] 4
10.0
[Row] 5
10.0
[Row] 6
15.0
[Row] 7
15.0
[Row] 8
10.0

```

The inductance matrix has coupling between pins

```

[Inductance Matrix] Full_matrix
[Row] 1
3.04859e-07 4.73185e-08 1.3428e-08 6.12191e-09
1.74022e-07 7.35469e-08 2.73201e-08 1.33807e-08
[Row] 2
3.04859e-07 4.73185e-08 1.3428e-08 7.35469e-08
1.74022e-07 7.35469e-08 2.73201e-08
[Row] 3
3.04859e-07 4.73185e-08 2.73201e-08 7.35469e-08
1.74022e-07 7.35469e-08
[Row] 4
3.04859e-07 1.33807e-08 2.73201e-08 7.35469e-08
1.74022e-07
[Row] 5
4.70049e-07 1.43791e-07 5.75805e-08 2.95088e-08
[Row] 6
4.70049e-07 1.43791e-07 5.75805e-08
[Row] 7
4.70049e-07 1.43791e-07
[Row] 8
4.70049e-07

```

The capacitance matrix has sparse coupling

```

[Capacitance Matrix] Sparse_matrix
[Row] 1
1 2.48227e-10
2 -1.56651e-11
5 -9.54158e-11

```

```
6      -7.15684e-12
[Row]  2
2      2.51798e-10
3      -1.56552e-11
5      -6.85199e-12
6      -9.0486e-11
7      -6.82003e-12
[Row]  3
3      2.51798e-10
4      -1.56651e-11
6      -6.82003e-12
7      -9.0486e-11
8      -6.85199e-12
[Row]  4
4      2.48227e-10
7      -7.15684e-12
8      -9.54158e-11
[Row]  5
5      1.73542e-10
6      -3.38247e-11
[Row]  6
6      1.86833e-10
7      -3.27226e-11
[Row]  7
7      1.86833e-10
8      -3.38247e-11
[Row]  8
8      1.73542e-10
```

[End ICM Section] ExampleMatrix01

---

## 9.0 End Keyword

---

Keyword: [End]  
Required: Yes  
Argument: None  
Description: Specifies end of file

---

[End]