```
================================================================================

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

================================================================================
                    Specification Revision level 0.99901
================================================================================
```

Table of Contents
```
================================================================================
```

===
REVISION HISTORY
Aug-nn-2002, v1.0 Specification: Initial release
===

===

 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 of 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 subparameters must begin with a letter, and shall consist only of alphanumeric characters and the underscore "_". Spaces are not allowed in subparameter 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 a 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) 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.

12) The following words are reserved words and must not be used for
any other purposes in the document:
    POWER - reserved model name, used with power supply pins,
    GND   - reserved model name, used with ground pins,
    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]
| | |--[IBIS ICM Model Ver]
| | |--[Comment Char]
| | |--[File Name]
| | |--[File Rev]
| | |--[Date]
| | |--[Source]
| | |--[Notes]
| | |--[Disclaimer]
| | |--[Copyright]
| | |--[Support]
| | |--[Redistribution]
| | |--[Redistribution Text]
| \--[End Header]
|
|
|--/--[Begin ICM Family] | (Chapter 7)
| | |--[Manufacturer]
| | |--[ICM Family Description]
| | |--[ICM Model List]
| |
| |--/--[Begin ICM Model]
| | | ICM_Model_Type
| | | SGR
| | | Ref_impedance
| | |--[ICM Model Description]
| | |--[Tree Path Description]
| | | Model_PinMap
| | | Fork, End_fork
| | | Section
| | |--[Nodal Path Description]
| | | Model_NodeMap
| | | N_section
| | |--[ICM Swath Parameters] | (optional for Swath)

```
|   |   |      Left_edge
|   |   |      Right_edge
|   |   |      Top_edge
|   |   |      Bottom_edge
|   |   |--[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 Family]
|
|
|--/--[Begin ICM Section]              | (Chapter 8)  Define Matrices
|  |--[Derivation Method]
|  |--[Resistance Matrix]
|  |    /-- [Bandwidth]
|  |    \-- [Row]
|  |--[Inductance Matrix]
|  |    /-- [Bandwidth]
|  |    \-- [Row]
|  |--[Conductance Matrix]
|  |    /-- [Bandwidth]
|  |    \-- [Row]
|  |--[Capacitance Matrix]
|  |    /-- [Bandwidth]
|  |    \-- [Row]
|  |
|  |--[ICM S-parameter]
|  |    Pin_order
|  |    Num_of_columns
|  |    Num_of_rows
|  |
|  \--[End ICM Section]
|
|
\--[End]
```

==

5.0 HEADER KEYWORDS

==

```
    Keyword: [Begin Header]
   Required: Yes
       Uses: [IBIS ICM Model ver], [File Name], [File Rev], [Date], [Source],
             [Notes], [Disclaimer], [Copyright], [Support], [Redistribution],
             [Redistribution Text], [End Header]
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 proceeded 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
      Used By: [Begin Header]
  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)
      Used by: [Begin Header]
  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".

               The [File Name] keyword may appear only once between the [Begin
               Header]/[End Header] keyword pair.
--------------------------------------------------------------------------------
[File Name]     iconm_hdi_202.icm


================================================================================
      Keyword: [File Rev]
     Required: Yes
     Argument: Text String
      Used By: [Begin Header]
  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

               The [File Rev] keyword may appear only once between the [Begin
               Header]/[End Header] keyword pair.

--------------------------------------------------------------------------------
[File Rev]     1.0                      | Used for ICM file versions


================================================================================
      Keyword: [Date]
     Required: No
     Argument: Text String (Date)
      Used By: [Begin Header]
  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.
```

```
                The [Date] keyword may appear only once between the [Begin
                Header]/[End Header] keyword pair.


     --------------------------------------------------------------------------
[Date]          July 01, 2000          | The latest file revision date


=============================================================================
     Keyword: [Source]
    Required: No
    Argument: Text Block
     Used by: [Begin Header]
 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 or
                entity that created the model.

                The [Source] keyword may appear only once between the [Begin
                Header]/[End Header] keyword pair.

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


=============================================================================
     Keyword: [Notes]
    Required: No
    Argument: Text Block
     Used By: [Begin Header]
 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.

                The [Notes] keyword can only be used once.

                The [Notes] keyword may appear only once between the [Begin
                Header]/[End Header] keyword pair.


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


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

                The [Disclaimer] keyword may appear only once between the [Begin
                Header]/[End Header] keyword pair.


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

```
                      guaranteed.


     ================================================================================
           Keyword: [Copyright]
          Required: No
          Argument: Text Block
           Used By: [Begin Header]
       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.

                    The [Copyright] keyword may appear only once between the [Begin
                    Header]/[End Header] keyword pair.


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


     ================================================================================
           Keyword: [Support]
          Required: No
          Argument: Text Block (URL path name)
           Used By: [Begin Header]
       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.

                    The [Support] keyword may appear only once between the [Begin
                    Header]/[End Header] keyword pair.


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


     ================================================================================
           Keyword: [Redistribution]
          Required: Yes
          Argument: Text String (Yes, No, Specific)
           Used By: [Begin Header]
       Description: Indicates to EDA tool companies and model users who may use and
                    redistribute 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.

The [Redistribution] keyword may appear only once between the
[Begin Header]/[End Header] keyword pair.

[Redistribution] Yes

==
     Keyword: [Redistribution Text]
    Required: Yes, ONLY if [Redistribution] value is "Specific", otherwise it
              is optional
    Argument: Text block
     Used By: [Begin Header]
 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.

              The [Redistribution Tesxt] keyword may appear only once between
              the [Begin Header]/[End Header] keyword pair.

[Redistribution Text] Your text goes here.

==
     Keyword: [End Header]
    Required: Yes
     Used By: [Begin Header]
 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:

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

The [Comment Char] keyword can only appear after the
[IBIS ICM Model Ver] keyword. A file may contain multiple
[Comment Char] keywords.

[Comment Char] |_char

==

7.0 INTERCONNECT MODEL FAMILY KEYWORDS

==

     Keyword: [ICM Model Family]
    Required: Yes
    Argument: Text String
        Uses: [Manufacturer], [ICM Family Description], [ICM Model List],
              [ICM Model], [End ICM Family]
 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 Family]/[End ICM Family]
              keyword is allowed per file.

              Interconnect family descriptions are terminated by the
              occurrence of the [End ICM Family] keyword.

[Begin ICM Family] High_Speed_Interconnect

==
     Keyword: [Manufacturer]
    Required: Yes
    Argument: Text String
     Used By: [Begin ICM Family]
 Description: This keyword gives the name of the manufacturer of the
              physical connectors or interconnect being described in this file.
 Usage Rules: Following the keyword is the interconnect manufacturer's name.
              Blank characters are allowed.

              The [Manufacturer] keyword may appear only once between the
              [Begin ICM Family]/[End ICM Family] keyword pair.

[Manufacturer] XYZ Incorporated

==
     Keyword: [ICM Family Description]
    Required: Yes
    Argument: Text Block

```
         Used By: [Begin ICM Family]
     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 Family] and [End ICM Family] keywords.


------------------------------------------------------------------------------
[ICM Family Description]
High Density 0.1 center square pin connector designed for use on IEEE 99999
buses.



==============================================================================
         Keyword: [ICM Model List]
        Required: Yes
         Used By: [Begin ICM Family]
     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: The [ICM Model List] keyword may appear only once between the
                  [Begin ICM Family]/[End ICM Family] keyword pair."

                  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 connector 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 connector half that is
                             attached to a daughter card, cable, edgecard,
                             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_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: [ICM Model]
    Required: Yes
    Argument: Text String (Model name)
    Used By: [Begin ICM Family]
       Uses: [ICM Model Description], [Tree Path Description], [Nodal Path
             Description], [ICM Swath Parameters], [End ICM Model]
 Description: This keyword marks the beginning of each individual
             interconnect model.
  Sub-param: ICM_Model_Type, SGR, 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.  The [Begin ICM Model]
```

keyword must appear after the [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.

The [Begin ICM Family] keyword must appear after the [End
Header] keyword.

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_even_mode", "SLM_odd_mode", "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_even_mode" 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_odd_mode" 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 SGR 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_even_mode" and "SLM_odd_mode" 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_matix may

13

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

SGR

If the ICM_Model_Type subparameter is equal to SLM_general,
then this SGR 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 connector was taken with 6 of the pins grounded, the
signal to ground ratio is 18/6 or 3 to 1. The SGR subparameter
argument would then be listed as 3:1.

This subparameter is only valid when the ICM_Model_Type sub-
parameter has a value of "SLM_general".

If this subparameter is present and the ICM_Model_Type sub-
parameter 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
      Used By: [Begin ICM Model]
  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, if [Nodal Path Description] does not exist
    Sub-param: Model_PinMap, Section, Fork, End_fork
      Used By: [Begin ICM Model]
         Uses: [ICM Pin Map]

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 End_fork
              subparameters allow sections to branch off the main
              interconnect path as a stub or tee.
Usage Rules: A [Tree Path Description] is used when all of the sections in a
              given interconnect have one to one mapping. 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 all cases, all the RLGC matrixes must have the same number of
              diagonal terms, regardless whether they are swath or full
              matrices. Further, all diagonal terms must be in the same order.

              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 "tee" connections are
              indicated by the "Fork" and "End_fork" 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 sub-
              parameter 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 sub-
parameter 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:

                         Mult = value

where "value" must be an integer number.

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

                         Len = 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
"Mult" while others use "Len", if so desired. If "Mult" is
used the [Derivation Method] keyword for the corresponding [ICM
Section] must have a value of "Lumped" else it is an error. If
"Len" 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 "Len" 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 "Len" is not allowed.

"Mult" and "Len" are separate arguments. "Mult" and "Len"
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.

[ICM 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.

Fork, End_fork

The Fork and End_fork subparameters are used if there
are forks or "stubs" in the interconnect being modeled.
Fork marks the beginning of the stub while End_fork
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 End_fork.  If no pin
               map name is placed between an Fork and End_fork block,
               then the fork constitutes a stub.  However, if a pin map name
               is placed at the end of the Fork and End_fork 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
                         End_fork

--------------------------------------------------------------------------------
"ICM Model" Examples
--------------------------------------------------------------------------------
Example 1:  (A simple single line model with one section).

[Begin ICM Model] MyModelExample1
  ICM_Model_Type SLM_general
  SGR 3:1
  Ref_Impedance 50

[Tree Path Description]
  Model_PinMap  Example1_pinmap
  Section Mult=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 Mult=1 SectA
  Section Mult=1 SectB
  Section Mult=1 SectC
  Section Mult=1 SectD
  Section Mult=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
```
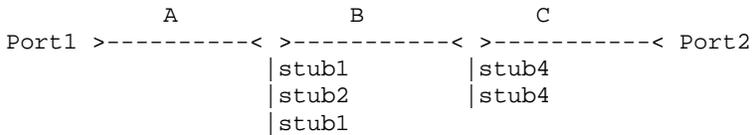
```
[Begin ICM Model] MyModelExample3
  ICM_Model_Type MLM
[Tree Path Description]
  Model_PinMap MyModelPinMapA
  Section Mult=1 SectionA
  Fork
    Section Mult=1 StubSection1
  End_fork
  Section Mult=1 SectionB
  Model_PinMap MyModelPinMapB
  .
  .
  .
[End ICM Model]


----------------------------------------------------------------------------
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 Mult=1 A
  Fork
    Section Mult=1 stub1
    Section Mult=1 stub2
    Section Mult=1 stub1
  End_fork
  Section Mult=1 B
  Fork
    Section Mult=2 stub4
  End_fork
  Section Mult=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 Mult=1 A
  Fork
```
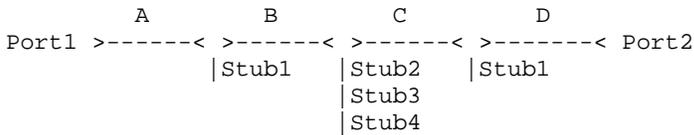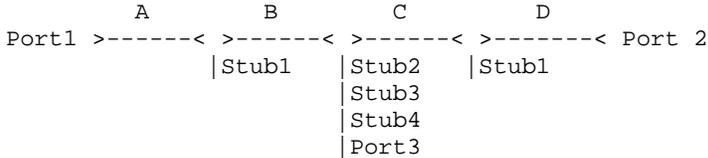
```
      Section Mult=1 Stub1
  End_fork
    Section Mult=1 B
  Fork
    Section Mult=1 Stub2
    Section Mult=1 Stub3
    Section Mult=1 Stub4
  End_fork
    Section Mult=1 C
  Fork
    Section Mult=1 Stub1
  End_fork
    Section Mult=1 D
  Model_PinMap MyModelPinMapB
  .
  .
  .
[End ICM Model]


-------------------------------------------------------------------------------
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 Mult=1 A
  Fork
    Section Mult=1 Stub1
  End_fork
  Section Mult=1 B
  Fork
    Section Mult=1 Stub2
    Section Mult=1 Stub3
    Section Mult=1 Stub4
    Model_PinMap MyModelPinMapC
  End_fork
  Section Mult=1 C
  Fork
    Section Mult=1 Stub1
  End_fork
  Section Mult=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
```
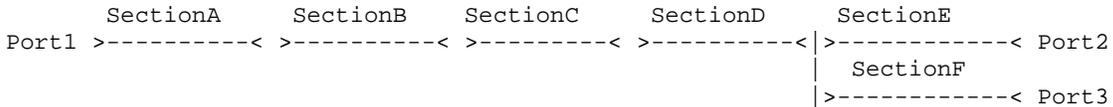
```
[Begin ICM Model] MyModelExample7
  ICM_Model_Type SLM_quiescent
[Tree Path Description]
  Model_PinMap = MyModelPinMapA
  Section Mult=1 SectionA
  Section Mult=1 SectionB
  Section Mult=1 SectionC
  Section Mult=1 SectionD
  Fork
    Section Mult=1 SectionF
    Model_PinMap MyModelPinMapB
  End_fork
  Section Mult=1 SectionE
  Model_PinMap MyModelPinMapC
  .
  .
  .
[End ICM Model]
```

==
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_sections 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 node 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:

                    Mult = value

where "value" must be an integer number.

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

                    Len = value

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

"Mult" and "Len" are separate arguments.   "Mult" and "Len" are not allowed to be used in the same section.

Some sections within a particular path description can use M while others use "Len", if so desired. If "Mult" is used the [Derivation Method] keyword for the corresponding [ICM Section] must have a value of "Lumped" else it is an error. If "Len" 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 "Len" 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 "Len" 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.
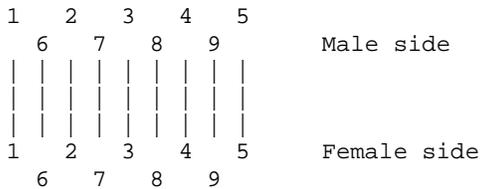
The Model_NodeMap subparameter is followed by one argument,

which the name of a node map. The argument must match the
                    name of a node map defined by a subsequent [ICM 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
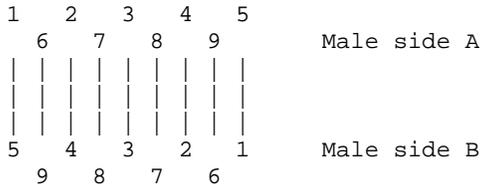   Description] keyword due to its regularity and the one to one mapping.

      1   2   3   4   5
        6   7   8   9   Male side
      | | | | | | | | |
      | | | | | | | | |
      | | | | | | | | |
      1   2   3   4   5   Female side
        6   7   8   9

    [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) Mult=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.

      1   2   3   4   5
        6   7   8   9   Male side A
      | | | | | | | | |
      | | | | | | | | |
      | | | | | | | | |
      5   4   3   2   1   Male side B
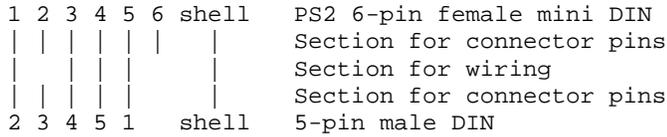   9   8   7   6

    [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) Mult=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

    1 2 3 4 5 6 shell   PS2 6-pin female mini DIN
    | | | | | |   |       Section for connector pins
    |   | | |     |       Section for wiring
    | | | | |     |       Section for connector pins
    2 3 4 5 1   shell   5-pin male DIN

[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) Mult=1 RLGC_matrix_7x7
  N_section ( n11       n13  n14  n15       n17
             n21       n23  n24  n25       n27) Mult=1 RLGC_matrix_5x5
  N_section ( n21  n22  n23  n24  n25       n27
            DIN2 DIN3 DIN4 DIN5 DIN1      DIN7) Mult=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/ps2keyboardygateway.html

    1 2  3   4  5 6 shell       6-pin male mini DIN (computer)
    | | +-+ +-+ | |   +---+
    | | | | | | | |   |   |     Section
    2 | 3 | 4 | 6 | shell |     6-pin female DIN (keyboard)
      2   3   4   6     shell   6-pin female DIN (mouse)

[Begin ICM Model] PS2_splitter
  ICM_Model_Type MLM
[Nodal Path Description]
  Model_NodeMap PS2_splitter_Computer_side
  N_section (C1 C3 C4 C5 Cs C2 C3 C4 C6 Cs
            K2 K3 K4 K6 Ks M2 M3 M4 M6 Ms) Mult=1 RLGC_matrix_10x10
  Model_NodeMap PS2_splitter_Keyboard_side
  Model_NodeMap PS2_splitter_Mouse_side
[End ICM Model]


-------------------------------------------------------------------------------
Example 5:

2 ports per pin, 5 sections straight through.  Note that this interconnect
could have been also described by the [Tree Path Description] keyword due to
its
regularity and the one to one mapping.

          SectA      SectB      SectC      SectD      SectE
Port_A >-------< >-------< >-------< >-------< >-------< Port_B

[Begin ICM Model] MyModelExample5
  ICM_Model_Type SLM_quiescent
[Nodal Path Description]
```
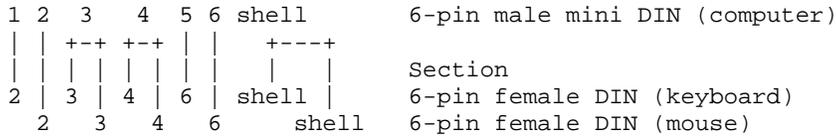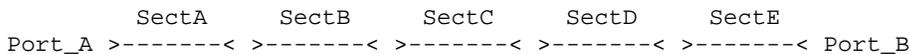
```
   Model_NodeMap Port_A
  N_section (A1 A2 A3 A4  11 12 13 14) Len=1.0 SectA
  N_section (11 12 13 14  21 22 23 24) Len=1.0 SectB
  N_section (21 22 23 24  31 32 33 34) Len=1.0 SectC
  N_section (31 32 33 34  41 42 43 44) Len=1.0 SectD
  N_section (41 42 43 44  B1 B2 B3 B4) Len=1.0 SectE
   Model_NodeMap Port_B
[End ICM Model]


------------------------------------------------------------------------
Example 6:


2 ports per pin, 2 series sections with one stub that taps into line_2 and
line_4.

            SectionA           SectionB
Port_A1 >----------<----->----------< Port_B1
Port_A2 >----------<---o->----------< Port_B2
Port_A3 >----------<---+->----------< Port_B3
Port_A4 >----------<-o-+->----------< Port_B4
Port_A5 >----------<-+-+->----------< Port_B5
                     | |
                     | |
               StubSection1


[Begin ICM Model] MyModelExample6
  ICM_Model_Type MLM
[Nodal Path Description]
  N_section   (A1 A2 A3 A4 A5  11 12 13 14 15) Len=1.0 SectionA
    N_section (   12    14        x2    x4   ) Len=1.0 StubSection1
  N_section   (11 12 13 14 15  B1 B2 B3 B4 B5) Len=1.0 SectionB
[End ICM Model]


------------------------------------------------------------------------
Example 7:


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

             A             B             C
Port_A >---------< >---------< >---------< Port_B
                  |stub1       |stub4
                  |stub2       |stub4
                  |stub1
                  |Port_C

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


========================================================================
     Keyword: [ICM Swath Parameters]
    Required: No, unless an interconnect is described by a swath.
  Sub-param: Left_edge, Right_edge, Top_edge, Bottom_edge
```

```
     Used By: [Begin ICM Model]
        Uses: [ICM Swath Pin Numbers]
 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
             connector.  The edges of the matrix represent the same edge
             effects that exists in the full size connector.  The center
             area of the matrix represents the same effects as the center
             of the full size connector.

             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 connector that is 2x100.

 Usage Rules: Only rectangular interconnects without missing conductor 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.  This keyword is only required when
             using only a part of the matrix or when expanding the matrix.


             MUST be followed by 4 required subparameters:

               1) Left_edge:   Columns in the swath matrix used to represent
                               left edge
               2) Right_edge:  Columns in the swath matrix used to represent
                               right edge
               3) Top_edge:    Rows in the swath matrix used to represent
                               top edge
               4) Bottom_edge: 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.

         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 connector represent the electrical coupling:

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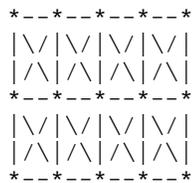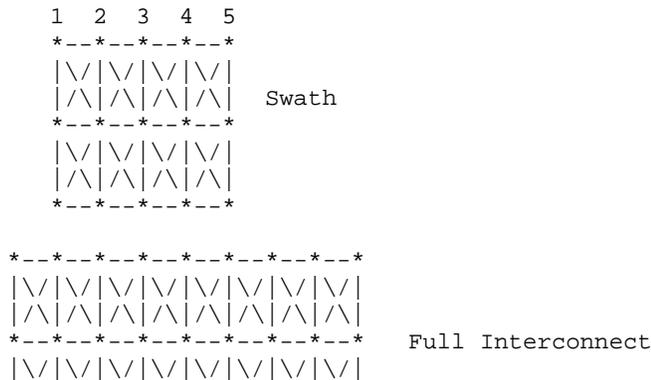
Notice that columns 2, 3, and 4 have the maximum amount of
coupling from each side. In this case the edge effect
columns 1 and 5 do not have coupling from both sides.

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

```
        1  2  3  4  5
        *--*--*--*--*
        |\/|\/|\/|\/|
        |/\|/\|/\|/\|   Swath
        *--*--*--*--*
        |\/|\/|\/|\/|
        |/\|/\|/\|/\|
        *--*--*--*--*


     *--*--*--*--*--*--*--*
     |\/|\/|\/|\/|\/|\/|\/|\/|
     |/\|/\|/\|/\|/\|/\|/\|/\|
     *--*--*--*--*--*--*--*   Full Interconnect
     |\/|\/|\/|\/|\/|\/|\/|\/|
```

```
|/\|/\|/\|/\|/\|/\|/\|/\|
*--*--*--*--*--*--*--*--*
1  2  3  4  5  6  7  8  9
```

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 similar to 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

```
        1  2  3  4  5
        *--*--*--*--*
        |\/|\/|\/|\/|
        |/\|/\|/\|/\|    Swath
        *--*--*--*--*
        |\/|\/|\/|\/|
        |/\|/\|/\|/\|
        *--*--*--*--*


        *--*--*--*--*--*--*--*
        |\/|\/|\/|\/|\/|\/|\/|
        |/\|/\|/\|/\|/\|/\|/\|
        *--*--*--*--*--*--*--*    Full Interconnect
        |\/|\/|\/|\/|\/|\/|\/|
        |/\|/\|/\|/\|/\|/\|/\|
```

```
*--*--*--*--*--*--*--*--*
1  2  3  4  5  6  7  8  9
```

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

(b) Repeat the center pattern,

```
1  2  3  4  5
*--*--*--*--*
|\/|\/|\/|\/|
|/\|/\|/\|/\|     Swath
*--*--*--*--*
|\/|\/|\/|\/|
|/\|/\|/\|/\|
*--*--*--*--*


*--*--*--*--*--*--*--*--*
|\/|\/|\/|\/|\/|\/|\/|\/|
|/\|/\|/\|/\|/\|/\|/\|/\|
*--*--*--*--*--*--*--*--*     Full Interconnect
|\/|\/|\/|\/|\/|\/|\/|\/|
|/\|/\|/\|/\|/\|/\|/\|/\|
*--*--*--*--*--*--*--*--*
1  2  3  4  5  6  7  8  9
```

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

```
        1  2  3  4  5
        *--*--*--*--*
        |\/|\/|\/|\/|
        |/\|/\|/\|/\|     Swath
        *--*--*--*--*
        |\/|\/|\/|\/|
        |/\|/\|/\|/\|
        *--*--*--*--*


*--*--*--*--*--*--*--*--*
|\/|\/|\/|\/|\/|\/|\/|\/|
|/\|/\|/\|/\|/\|/\|/\|/\|
*--*--*--*--*--*--*--*--*     Full Interconnect
|\/|\/|\/|\/|\/|\/|\/|\/|
|/\|/\|/\|/\|/\|/\|/\|/\|
*--*--*--*--*--*--*--*--*
1  2  3  4  5  6  7  8  9
```

The final step is similar to Step (a), but concluded using the right side of the swath. When the swath is positioned against the right edge as shown, then the

```
                    coupling patterns for the swath columns are duplicated
                    for the final columns 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]
    Left_edge = 1
    Right_edge = 1
    Top_edge = 0
    Bottom_edge = 0



===========================================================================
      Keyword: [ICM Swath Pin Numbers]
     Required: Yes, if [ICM Swath Parameters] is present, else it must not be
              used.
      Used By: [ICM Swath Parameters]
  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 as referenced by the
              [Tree Path Description] keyword.

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


              The [ICM Swath Pin Numbers] keyword must appear only once
              between the [Begin ICM Model]/[End ICM Model] keyword pair.

              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: [End ICM Model]
    Required: Yes
     Used By: [Begin ICM Model]
 Description: Defines the end of the interconnect models for the
              interconnect family

[End ICM Model]

==
     Keyword: [ICM Pin Map]
    Required: No, unless the [Tree Path Description] keyword exists.
    Argument: Text String (Model_PinMap name)
   Sub-param: Pin_order, Num_of_columns, Num_of_rows
     Used By: [Tree Path Description]
 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 whether 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.

              This key word should be between the [Begin ICM Family] and
              [End ICM Family] keywords.

              Following the [ICM Pin Map] line are three subparameters:
              Pin_order, Num_of_rows, Num_of_columns. Each subparameter is
              placed on a seperate 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 seperated
by one or more white spaces.

Row_ordered and Column_ordered refers to the order in which
the pins in the accompanyng 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. There is a
second column which contains a name for the pin

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  SIG
A2  SIG
A3  SIG
B1  SIG
B2  SIG
B3  GND
```

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.

"GND" is a reserved word. The use of "GND" is required for models designated as "SLM_quiescent", "SLM_even_mode" and "SLM_odd_mode". For SLM_general and MLMs "GND" cannot be used. "GND" is optional for model type s-parameter.

All diagonal values in any of the parametric matrix positions that are referenced as "GND" must contain the value of "0". See the "Matrix Description" section of this document for further information.

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  Type
  A1  SIG
  A2  SIG
  A3  SIG
  A4  SIG
  B1  SIG
  B2  SIG
  B3  SIG
  B4  SIG

[ICM Pin Map] Baseboard_side2
Pin_order = column_ordered
Num_of_columns = 4
Num_of_rows = 2
|Pin
  A1 SIG
  B1 SIG
  A2 SIG
  B2 SIG
  A3 SIG
  B3 SIG
  A4 SIG
```

```
  B4 SIG


[ICM Pin Map] Daughtecard_side
Pin_order = Un_ordered
|Pin
  A1 SIG
  A2 SIG
  A3 SIG
  A4 SIG
  B1 SIG
  B2 SIG
  B3 SIG
  B4 SIG
```

```
==========================================================================
       Keyword: [ICM Node Map]
      Required: No, unless the [Nodal Path Description] keyword exists.
      Argument: Text String (Model_NodeMap name)
      Used By: [Nodal Path Description]
   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 connector, 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 ends or sides.

   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.

                This key word should be between the [Begin ICM Family] and
                [End ICM Family] keywords.

                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.

                There is a third column, which contains a name for the pin.

                "GND" is a reserved word.  The use of "GND" is required for
                models designated as "SLM_quiescent", "SLM_even_mode" and
                "SLM_odd_mode".  For SLM_general and MLMs "GND" cannot be used.
                "GND" is optional for model type s-parameter.
```

All diagonal values in any of the parametric matrix positions
that are referenced as "GND" must contain the value of "0". See
the "Matrix Description" section of this document for further
information.

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

Example 2:

```
[ICM Node Map] DB9_side_A
|  pin     node
    1       A1      SIG
    2       A2      SIG
    3       A3      SIG
    4       A4      SIG
    5       A5      SIG
    6       A6      SIG
    7       A7      SIG
    8       A8      SIG
    9       A9      SIG
[ICM Node Map] DB9_side_B
|  pin     node
    1       B1      SIG
    2       B2      SIG
```

```
   3       B3      SIG
   4       B4      SIG
   5       B5      SIG
   6       B6      SIG
   7       B7      SIG
   8       B8      SIG
   9       B9      SIG


--------------------------------------------------------------------------------
Example 3:

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


--------------------------------------------------------------------------------
Example 4:

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


--------------------------------------------------------------------------------
Example 5:

[ICM Node Map] Port_A
|  pin         node
   Port_A1     A1      SIG
   Port_A2     A2      SIG
```

```
      Port_A3      A3     SIG
      Port_A4      A4     SIG
[ICM Node Map] Port_B
|    pin          node
      Port_B1      B1     SIG
      Port_B2      B2     SIG
      Port_B3      B3     SIG
      Port_B4      B4     SIG


--------------------------------------------------------------------------------
Example 6:

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


--------------------------------------------------------------------------------
Example 7:

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




================================================================================
     Keyword: [End ICM Family]
    Required: Yes
     Used By: [Begin ICM Family]
 Description: Defines the end of the interconnect model family
 Usage Rules: These commands wrap the entire model in this file.


--------------------------------------------------------------------------------
```

[End ICM Family]

===

8.0 MATRIX KEYWORDS

===

      Keyword: [Begin ICM Section]
     Required: Yes
     Argument: Text String
      Used By: [Tree Path Description] or [Nodal Path Description]
         Uses: [Derivation Method], [Resistance Matrix], [Inductance Matrix],
               [Conductance Matrix], [Capacitance Matrix], [ICM S-parameter],
               [End ICM Section]
  Description: Indicates the beginning and the name of a set of RLGC
               or S-parameter 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.

               This keyword should be after the [End ICM Family]
               keyword.

               When using [Tree Path Description], every matrix used for given
               interconnect model MUST have exactly the same number of diagonal
               terms. When using a [Nodal Path Description], the number of
               diagonal terms in the matrices may vary.

               If the swath method is used the matrix may have fewer
               conductors then 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 Family] and [End ICM Model Familay] as sections
               may be reused by more than one interconnect model.

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

===
      Keyword: [Derivation Method]
     Required: Yes
     Argument: Text String (Lumped or Distributed)
      Used By: [Begin ICM Section]
  Description: This keyword 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: [Resistance Matrix], [Inductance Matrix],
[Conductance Matrix], and [Capacitance 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 matrices within the same section must share the same
derivation method.

For any SLM lumped model, Resistance and Inductance are series
components, Capacitance and Conductance are shunted to the
return path.

The assumed circuit topology is RLGC for any derivation method.
If a different circuit topology is desired (for example, CLRG)
then start the model by creating a section that has only the
capacitance element, then follow this by a standard LRG section.

[Derivation Method] Lumped

==
     Keyword: [Resistance Matrix], [Inductance Matrix], [Conductance Matrix],
              [Capacitance Matrix]
    Required: Yes, at least one
    Argument: Text String (Matrix Type)
     Used By: [Begin ICM Section]
 Description: Each keyword marks the beginning of its respective matrix data
              set and also specifies how the matrix data is formatted.
 Usage Rules: Following each matrix keyword, one of the following arguments is
              required: Diagonal_matrix, Banded_matrix, Sparse_matrix, or
              Full_matrix. No more than one of each matrix type
              is allowed per section. If model type is SLM only a diagonal
              matrix is allowed.

              Each [Resistance Matrix], [Inductance Matrix], [Conductance
              Matrix], and [Capacitance Matrix] keyword must appear between the
              [Begin ICM Section]/[End ICM Section] keyword pair."

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

              If the location in the matrix is defined as a return path ("GND")
              in the [ICM Pin Map] or [ICM Node Map], the values associated
              with the "GND" designation in the matrix diagonal must be 0 for
              any of the matrices.

              Arguments:
              Diagonal_matrix, Banded_matrix, Sparse_matrix, or Full_matrix

Diagonal_matrix

The Diagonal_matrix is used to specify uncoupled models.

This subparameter 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. Mark each row with the [Row] keyword.

Banded_matrix

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 bandwith 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.

Symmetry is exploited to reduce the amount of data by eliminating, from the matrix, any entries below the main diagonal.

Sparse_matrix

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.

An NxN 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.

Symmetry is exploited to reduce the amount of data by eliminating, from the matrix, any entries below the main diagonal.

Full_matrix

Description: When the Full_matrix format is used, the coupling 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.
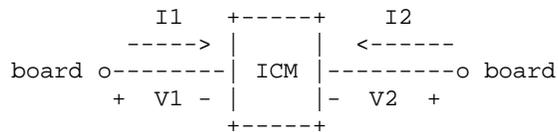
Symmetry is exploited to reduce the amount of data by eliminating, from the matrix, any entries below the main diagonal.

See example "Matrix Example" lower in this document.

Matrix Descriptions

This insert provides additional information regarding the [Resistance Matrix], [Inductance Matrix], [Conductance Matrix], and [Capacitance Matrix] keywords. These will be referred to as "RLGC" matricies.

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.

```
              I1    +-----+    I2
             ----->  |     |  <------
     board o--------|  ICM |---------o board
            +  V1 - |      |-  V2  +
                    +-----+
```

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:

The resistance matrix represents the total DC resistance in ohms between the two ends of this section of the interconnect.

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.

When the [ICM Section] or N_section subparameters use the "Mult" variable then DO NOT USE ohms/meter as this is the total value and includes the length of this section.

When the [ICM Section] or N_section subparameters use the "Len" variable then USE ohms/meter.

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:

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

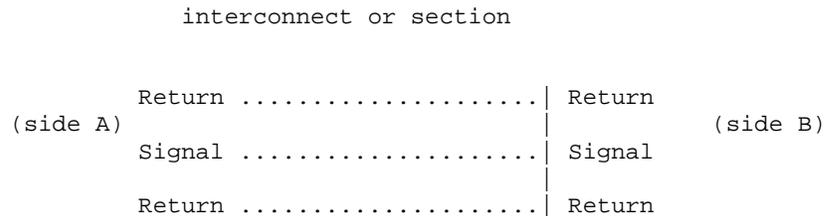If ModelType is SLM then all sections must use loop-inductance.

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

When the [ICM Section] or N_section subparameters use the "Mult"
variable then DO NOT USE henries/meter as this is the total
value and includes the length of this section.

When the [ICM Section] or N_section subparameters use the "Len"
variable then USE henries/meter

Loop-Inductance Matrix Description (SLMs ONLY):

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


         Return ....................| Return
(side A)                            |              (side B)
         Signal ....................| Signal
                                    |
         Return ....................| Return
```

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 given a specific return path.

The loop inductance 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 SGR 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.

Typical uses for SLM_general model might include:
        a 2x17 header connector where the bottom row is all
        grounded. The SGR would be specified in this case
        as 1:1. A model would be developed with these
        assumptions made. Then all pins could 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 if the indicated 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
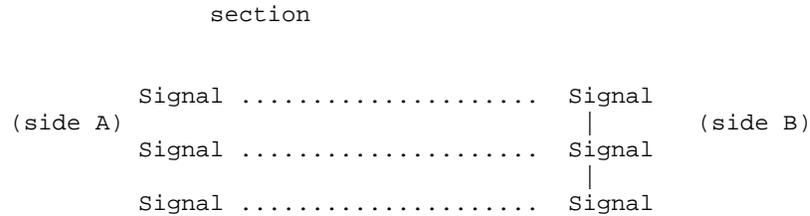corresponding to the ground or power pins.

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):

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 can be calculated. In this way, the self and

mutual inductances of any section 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.

```
             section


        Signal ....................  Signal
(side A)                                  |        (side B)
        Signal ...................   Signal
                                          |
        Signal ...................   Signal
```

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 partial inductance values are required.

Capacitance Matrix 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.

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 Line Capacitance Matrix.

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]=[Cm][V] Where [Cm] 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.

Maxwell Capacitance Matrix Description

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.

When the [ICM Section] or N_section subparameters use the "Mult"
variable then DO NOT USE farads/meter as this is the total
value and includes the length of this section.

When the [ICM Section] or N_section subparameters use the "Len"
variable then USE farads/meter

Conductance Matrix Description:

The Conductance maxtrix 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.

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

When the [ICM Section] or N_section subparameters use the "Mult"
variable then DO NOT USE siemens/meter as this is the total
value and includes the length of this section.

When the [ICM Section] or N_section subparameters use the "Len"
variable then USE siemens/meter

Loss Matrix Description:

The [ICM S-parameter] keyword introduced later provides a format
for describing losses that vary with frequency.

==
     Keyword: [Bandwidth]
    Required: Yes, if a Banded_matrix matrix is being defined.
    Argument: Numeric Value
     Used By: [Resistance Matrix], [Inductance Matrix], [Conductance Matrix],
              [Capacitance Matrix]
 Description: This keyword 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: The bandwidth field must be a non-negative integer. This keyword
              must occur after the [Resistance Matrix], etc., keywords, and
              before the matrix data is given.

              See example "Matrix Example" lower in this document.

```
==============================================================================
     Keyword: [Row]
    Required: Yes
    Argument: Row Number
     Used By: [Resistance Matrix], [Inductance Matrix], [Conductance Matrix],
              [Capacitance Matrix]
 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.  It is allowed to break the data up with new-line
              characters so that the line length 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.

              The [Row] keyword is placed directly after the [Bandwidth]
              keyword.  Following the keyword, on the next line, is the actual
              data for that row.

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


==============================================================================
     Keyword: [ICM S-parameter]
    Required: No, unless ICM_Model_Type subparameter of [Begin ICM Model] is
              equal to "S-parameter".
   Sub-param: File_name, Port_map
     Used By: [Begin ICM Section]
 Description: Indicates a reference to an external S-parameter file
 Usage Rules: An S-parameter matrix can be used in place of an RLGC matrix.
              One [ICM S-parameter] keywords is allowed for each [Begin ICM
              Section] / [End ICM Section].

              The [ICM S-parameter] keywords is allowed between [Begin ICM
              Section] / [End ICM Section] keywords.

              File_name

              File_name is to reference the name of the Touchstone
              file.  It is required that the ICM and the referenced file be in
              the same directory.

              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] or [ICM
Node Map]. 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 Pin Map] or
[ICM Node Map] 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 S-parameter]
File_name anyname.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
     Used By: [Begin ICM Section]
 Description: Indicates the end of [Begin ICM Section]. This keyword is after
the [Derivation Method], [Resistance Matrix], [Inductance Matrix], [Conductance
Matrix], [Capacitance Matrix], [Bandwidth], [Row], [ICM S-parameter].

 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
  Description: Specifies end of file.  Any text after the [End] keyword is
               ignored.
-------------------------------------------------------------------------------
[End]
```