Bridge Fault Extraction from LADB

Tessent® Diagnosis Tool

Software Version 2017.2

June 2017

DRAFT 06/02/2017

Beta Release

This software is in pre-production form and is considered to be Beta Code that is subject to the terms of the current Mentor Graphics End-User License Agreement or your signed agreement with Mentor Graphics that contains beta terms, whichever applies.This software is in pre-production form and is considered to be Beta Code that is subject to the terms of the current Mentor Graphics End-User License Agreement or your signed agreement with Mentor Graphics that contains beta terms, whichever applies.

Mentor Graphics Corporation
8005 S.W. Boeckman Road, Wilsonville, Oregon 97070-7777
Telephone: 503.685.7000
Toll-Free Telephone: 800.592.2210
Website: www.mentor.com
SupportNet: supportnet.mentor.com/

Send Feedback on Documentation: supportnet.mentor.com/doc_feedback_form

Table of Contents

Chapter 1
Introduction 9

Critical Area Calculation 10
Critical Area Calculation Formula 12
Alternative Critical Area Calculation Formula 14

Chapter 2
Command Line Options 15

Shell Command Description 15
Command Line Syntax Conventions 15
Command Line Options in Alphabetical Order 16
extract_fault_sites 17
import_dfm 22
set_marker_file_options 24

Chapter 3
How to View Extracted Bridges 25

Highlighting Bridge Faults in Design Layout 27

Chapter 4
How to Import DFM Violations 29

DFM Hotspot Areas and Extracted Bridges 30

Chapter 5
Output Files 33

The UDFM File for Extracted Bridges 33
The Critical Area Based Bridge Distribution 33
The Summary of Extracted Bridges 34
The UDFM Section for DFM-Hotspots 35
The UDFM Section for Power Bridges 35
The Marker File 36

Chapter 6
Critical Area Based Bridge Pattern Generation 37

Four-Way Bridge Model for Static ATPG 37
How to Generate Static Bridge Patterns 38
Four-Way Bridge Model for Delay ATPG 39
How to Generate Delay Bridge Patterns 39
How to report Bridge Coverage Gain Figures 40
Dofile for Critical Area Based Static Bridge Topoff ATPG 40
Dofile for Critical Area Based Delay Bridge Topoff ATPG 41

Details about the Coverage Gain Table 42

Appendix A
Third-Party Information 43

End-User License Agreement

List of Figures

Figure 1-1. Overview 9
Figure 1-2. Probability and critical area 10
Figure 1-3. Bridge area calculation 10
Figure 1-4. Critical area calculation 11
Figure 1-5. High bridge probability 11
Figure 1-6. Low bridge probability 11
Figure 1-7. Critical area calculation formula 12
Figure 1-8. Critical area example - side-to-side bridges 12
Figure 1-9. Critical area example - corner-to-corner bridge 13
Figure 1-10. Alternative critical area calculation formula 14
Figure 2-1. Critical area calculation - method 1 18
Figure 2-2. Critical area calculation - method 2 18
Figure 3-1. GDS view with RVE window 25
Figure 3-2. RVE details view 26
Figure 3-3. Highlighted bridge fault B1 27
Figure 4-1. RDB file example 29
Figure 4-2. DFM hotspot “Viol1” and Bridge B1 30
Figure 4-3. DFM hotspot “Viol2” and Bridges B2, B3, B4 31
Figure 5-1. Marker file example 36
Figure 6-1. Four-way bridge model - static ATPG 37
Figure 6-2. Four-way bridge model - delay ATPG 39
Figure 6-3. Calculating the bridge coverage gain 40
Figure 6-4. FastScan/TestKompress Coverage Gain Table 42

List of Tables

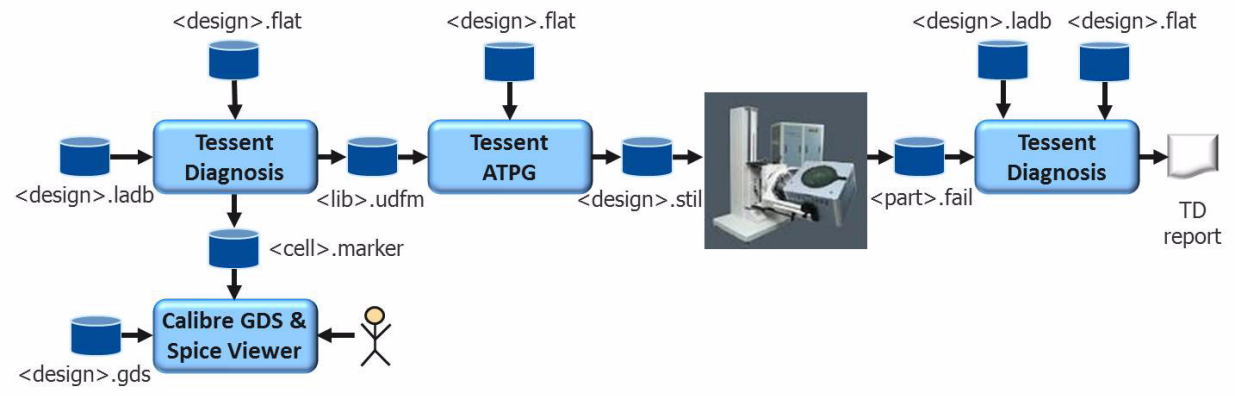
Table 2-1. Conventions for Command Line Syntax 15
Table 2-2. Command Summary 16

Chapter 1
Introduction

Extracting bridges from a chip layout (gds) file is a complex task and requires deep competencies in layout extraction tools such as Calibre.

This bridge layout extraction feature does not require specific layout extraction competencies and enables the extraction of critical area (CA) based bridges. Input to the CA-based bridge extraction feature is not a chip layout (gds) file but the layout database (LADB), which is created anyway for the layout based diagnosis. An overview is shown in Figure 1-1.

Figure 1-1. Overview



From the LADB, static and delay interconnect bridges can be extracted, and for each bridge the critical area will be calculated (see Figure 1-4 on page 11) while considering also the distance of adjacent bridging objects to eliminate those bridges whose distance is too large.

The considered static and delay bridges are written out into UDFM (user-defined fault model) files that are passed on to the Tessent ATPG for the CA-based bridge pattern generation.

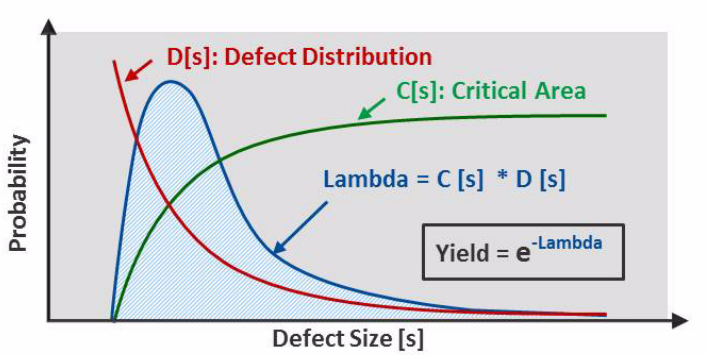
In addition to the UDFM files for ATPG purpose, also a <design>.marker file can be created to back-annotate (highlight) bridges of interest within the chip layout using the Calibre layout viewer.

Critical Area Calculation

The extraction of the bridge fault sites can be influenced by various settings that refer to the defect probability and the critical area calculation.

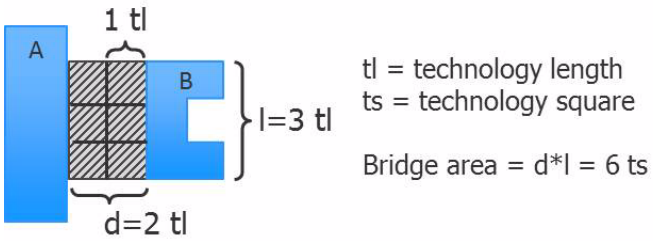
The critical area is calculated based on the relation between the size and density of particles that may cause a bridge fault, and the bridge probability that depends, among others, on the distance between two adjacent objects. The generic relation between the probability, defect size, the critical area, and lambda, which is the multiplication product of defect size and critical area, is shown in Figure 1-2.

Figure 1-2. Probability and critical area



Based on the calculation shown in Figure 1-2, the particle sizes, that most probably will cause a bridge defect, will be taken into account for the bridge area calculation as shown in Figure 1-3, and also for the critical area calculation as explained in Figure 1-4 on page 11. The assumed defect sizes are normalized to the technology length [tl]. That means, a value of 1 tl is equal to the length of the technology node.

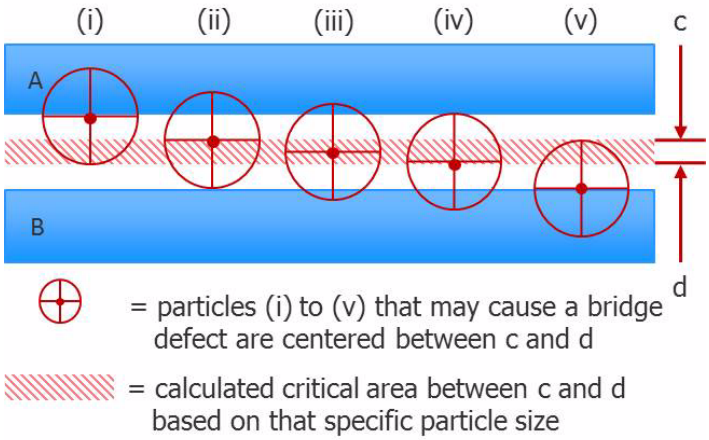
Figure 1-3. Bridge area calculation



In the example shown in Figure 1-3, there are two adjacent objects in the cell layout on the same layer (for example metal2) and the distance of the adjacent objects from each other is 2 technology lengths. The length of the bridging area is 3 technology lengths. As a result, the bridging area is 6 technology squares.

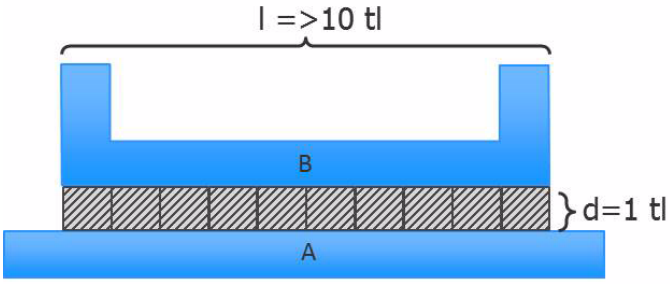
With the information about the maximum defect size that shall be considered, as shown in Figure 1-2 on page 10, the critical area of each defect is calculated; this is illustrated in Figure 1-4.

Figure 1-4. Critical area calculation



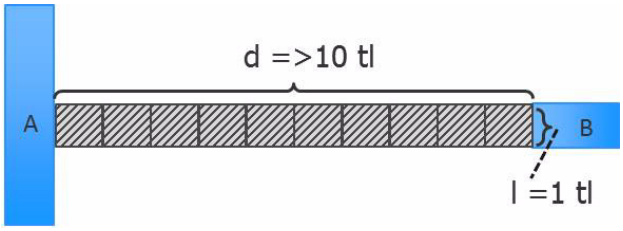
For the probability of each defect, the distance of the adjacent objects and the length of the bridging area are taken into account. A high probability is reached, when the distance of the adjacent objects is for example just 1 technology length and the length of the bridging area is for example 10 or more technology lengths, see the example shown in Figure 1-5.

Figure 1-5. High bridge probability



A low probability is present, when the bridging length is for example just 1 technology length and the distance of the 2 adjacent objects is for example 10 times or more the technology length. This is illustrated in Figure 1-6.

Figure 1-6. Low bridge probability



Critical Area Calculation Formula

The formula for calculating the critical area is shown in Figure 1-7.

Figure 1-7. Critical area calculation formula

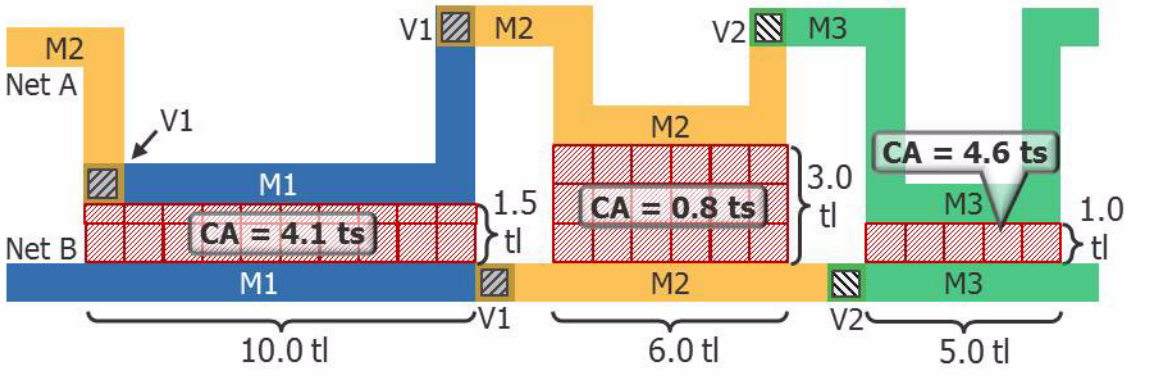
$$\int_{s_{min}}^{s_{max}} \text{Probability}(s) * \text{Area}(s)\, ds \Rightarrow \int_{s_{min}}^{s_{max}} \frac{3 * dist_{min}^{2} * (s + length) * (s - dist)}{s^3}\, ds$$

The definitions for the variables are as follows:

- s = spot size in technology length [tl]
- s_{min} = minimum spot size in [tl], that can create a bridge
- s_{max} = maximum spot size in [tl] to be considered
- $dist_{min}$ = technology dependent minimum distance of objects in [tl]
- length = length of the bridging area in [tl]
- dist = distance of the bridging objects in [tl]

Figure 1-8 shows the result of such a calculation in three examples of side-to-side (S2S) bridges, with critical areas in layer M1, M2, and M3, each with a different distance and a different length.

Figure 1-8. Critical area example - side-to-side bridges



The total critical area (TCA) in technology squares [ts] in the example in Figure 1-8 is:

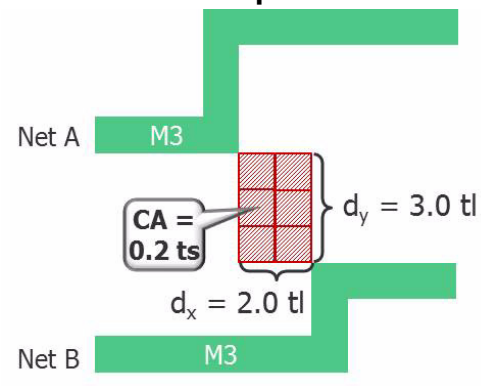
4.1 ts + 0.8 ts + 4.6 ts = 9.5 ts

The minimum spot size s_{min} is different for the three bridge areas, that means for the bridge area in layer M1 in above example it is $s_{min} = 1.5$; for the M2 bridge area it is $s_{min} = 3.0$; and for the M3 bridge area it is $s_{min} = 1.0$.

In all cases, the maximum spot size that is considered is $s_{max} = s_{min} + 2$

Figure 1-9 shows the result of the critical area calculation for a corner-to-corner (C2C) bridge in layer M3.

Figure 1-9. Critical area example - corner-to-corner bridge



The definitions for the variables for calculating the CA for C2C bridges slightly differ from the definitions for S2S bridges:

- length = - (higher value of d_x or d_y) in [tl]
- dist = lower value of d_x or $d_y$in [tl]

Note

Note that in this definition, the “length” is negative since the sides do not overlap. Also, in the example in Figure 1-9, the d_y value is higher than the d_x value. So, “length” is defined to be -3tl, and “dist” is defined to be 2tl.

The critical area for this C2C bridge is 0.2 ts.

Alternative Critical Area Calculation Formula

An alternative method for calculating the critical area is an analytical solution based on a wider range of defects but taking critical area saturation into account as follows:

Figure 1-10. Alternative critical area calculation formula

$$CA = \ln\left(\frac{2d + w}{d}\right) + \left(\frac{l - d}{2}\right) x \left(\frac{1}{d} - \frac{1}{2d + w}\right)$$

The definitions for the variables are as follows:

- d = distance of the bridging objects
- l = length of the bridging area
- w = width of the net

Note that this alternative critical area calculation formula omits the units.

Based on this calculation method, the TCA of the S2S bridges shown in Figure 1-8 is:

2.7 + 1.1 + 2.4 = 6.2

Accordingly, the TCA for the C2C example in Figure 1-9 is 0.3.

Chapter 2
Command Line Options

Shell Command Description

This chapter describes the bridge fault extraction related shell commands within the Tessent Diagnosis tool. The notational conventions are the same as those used in other parts of the manual. Do not enter any of the special notational characters (such as { }, [ ], < > or |) when typing a command.

Command Line Syntax Conventions

This manual uses the following command usage line syntax conventions.

Table 2-1. Conventions for Command Line Syntax

Convention	Example	Usage
[ ]	cellmodelgen [-help]	Square brackets enclose optional arguments. Do not enter the brackets.
Italic	-cell_name <*cell name*>	An italic font indicates a user-supplied argument.
{ }	{ }	Braces enclose arguments to show grouping. Do not enter the braces.
|	on | off	The vertical bar indicates an either/or choice between items. Do not include the bar in the command.
Underline	-data_warnings <u>on</u> | off	An underlined item indicates either the default argument or the default value of an argument.
< >	-extract <extract switches>	Angle brackets indicate command line switches or values which are described in more detail later

Command Line Options in Alphabetical Order

In the following table all bridge fault extraction related commands are listed in alphabetical order. For each command, a link to the appropriate chapter is given.

Table 2-2. Command Summary

Command	Description
extract_fault_sites	A command to extract interconnect bridges from LADB and write them out in UDFM file format
import_dfm	A command to import a Calibre-compatible results database (RDB) file containing DFM rule violations into the layout data base
set_marker_file_options	A command to specify settings for the marker file generated by the extract_fault_sites command

extract_fault_sites

A command to extract interconnect bridges from LADB and write them out in UDFM file format.

Context: patterns -scan_diagnosis

Mode: setup analysis

Usage

```
set_context                 patterns  -scan_diagnosis
    read_flat_model         design.flat.gz
    open_layout             design.ladb
    set_access_code         -code code
        extract_fault_sites -output_file <filename>
            [ -defect_types  all | bridges | power_bridges | dfm_bridges ]
            [ -critical_area_calculation  method1 | method2 ]
            [ -min_tca       <value> ]
            [ -max_tca       <value> ]
            [ -max_distance  <value> ]
            [ -max_bridges   <value> | unlimited ]
            [ -max_power_bridges <value> | unlimited ]
            [ -max_dfm_bridges <value> | unlimited ]
            [ -marker_file   <filename>
            [ -replace ]
```

Description

This command allows to extract the interconnect bridges from the layout database (LADB) and to write them out in UDFM file format. Using this command requires the following prerequisites to be fulfilled:

- Flatten the design to the simulation model
- Open the LADB by using the “open_layout” command
- Request the access code from Mentor Graphics

Note

The -extract_fault_sites command is compatible only with modern layout databases, that is layout databases created with version 2014.4 or later.

Arguments

- ***-output_file <filename>***

  A switch to specify the name of the file to which the interconnect bridges shall be written.

- ***-defect_types all | bridges | power_brigdes | dfm_bridges***

  An optional switch to specify the defect type(s) to be written to the udfm file. Multiple defect types are allowed. In case of using the option "dfm_bridges", the settings for -max_distance, -min_tca, and max_tca are ignored. The default is "bridges".

Note

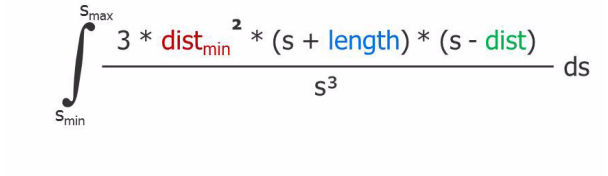
Using this switch with the option "dfm_bridges" requires to previously import a Calibre-compatible results database (RDB) into the LADB, see "import_dfm" on page 22.

- ***-critical_area_calculation method1 | method2***

  There are different methods to calculate the critical area. This optional switch allows to choose which of these methods shall be applied. The default is "method1".

  - ***method1*** is an integral calculation as follows:

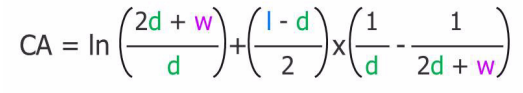
Figure 2-1. Critical area calculation - method 1



The definitions for the variables and some examples are given in Chapter 1, "Critical Area Calculation Formula" on page 12.

  - ***method2*** is an analytical solution based on a wider range of defects but taking critical area saturation into account :

Figure 2-2. Critical area calculation - method 2



The definitions for the variables and some examples are explained in Chapter 1, "Alternative Critical Area Calculation Formula" on page 14.

- ***-min_tca <value>***

  An optional switch to specify the minimum TCA (total critical area) for a bridge to be extracted from the LADB. Valid <*values*> are positive real numbers. All bridges with a minimum TCA greater than or equal to the specified value will be extracted. The default is 0, that means no limitation is set.

- ***-max_tca <value>***

  An optional switch to specify the maximum TCA (total critical area) for a bridge to be extracted from the LADB. Valid <*values*> are positive real numbers. By default no limitation is set.

- ***-max_distance <value>***

  An optional switch to specify the maximum distance between two nets to be accepted as a bridge defect. Valid <*values*> are real numbers, where the specified number is the factor to be multiplied with the technology length to get the real physical distance.

  The default is 3.0; that means that by default only the bridges with a distance between the nets of 3 times the technology length, or less, will be extracted from the LADB.

- ***-max_bridges <value> | unlimited***

  An optional switch to specify the maximum number of bridges to be extracted from the LADB. Valid arguments are either an integer number or “unlimited”, which means that all bridges from the LADB will be extracted (which may increase the output file size as well as the runtime).

  The default is 100000.

- ***-max_power_bridges <value> | unlimited***

  An optional switch to specify the maximum number of power bridges to be extracted from the LADB. Valid arguments are either an integer number or “unlimited”, which means that all power bridges from the LADB will be extracted (which may increase the output file size as well as the runtime).

  The default is 100000.

- ***-max_dfm_bridges <value> | unlimited***

  An optional switch to specify the maximum number of DFM bridges to be extracted from the LADB. Valid arguments are either an integer number or “unlimited”, which means that all DFM bridges from the LADB will be extracted (which may increase the output file size as well as the runtime).

  The default is “unlimited”.

- ***-marker_file <filename>***

  An optional switch to generate a marker file with the defined file name containing the specified interconnect bridges.

- ***-replace***

  An optional switch to allow to overwrite an existing file. This switch applies to both the UDFM file and the marker file.

Example 1

```
extract_fault_sites
   -output_file         interconnect_bridges.udfm
      -defect_types     bridges
      -marker_file      interconnect_bridges.marker
```

In this example, signal interconnect bridges will be extracted with all influencing parameters set to their default values. The generated UDFM file “interconnect_bridges.udfm” will contain the 100000 most important bridges, that means the bridges with the highest total critical area. Distances up to 3 times the technology length are considered, due to the -max_distance default value of 3.0.

Example 2

```
extract_fault_sites
   -output_file         interconnect_bridges.udfm
      -marker_file      interconnect_bridges.marker
      -max_distance     4.0
      -min_tca          100.0
```

In this example, signal interconnect bridges will be extracted up to a defect size of 4 times the technology length. In addition, only those bridges are written out that have TCA value greater than or equal to 100. The generated UDFM file is named “interconnect_bridges.udfm”, and the generated marker file is named “interconnect_bridges.marker”.

Example 3

```
extract_fault_sites
   -output_file         tca_100_or_greater.udfm
      -marker_file      tca_100_or_greater.marker
      -min_tca          100.0

extract_fault_sites
   -output_file         tca_100_1000.udfm
      -marker_file      tca_100_1000.marker
      -min_tca          100.0
      -max_tca          1000.0

extract_fault_sites
   -output_file         tca_100_500.udfm
      -marker_file      tca_100_500.marker
      -max_tca          500.0
      -min_tca          100.0
```

In this example, three UDFM files and their corresponding marker files are created. The first extract_fault_sites command will create a UDFM file for the bridges with the total critical area equal or greater than 100.0. The second extract_fault_sites command will create a UDFM file for the bridges that have a TCA in the range of a value equal or greater than 100.0 up to 1000.0. The third extract_fault_sites command will create a UDFM file for the bridges with a TCA in the range of a value equal or greater than100.0 up to 500.0. That means, all bridges with a TCA less than 100 or greater than 500 are not written out.

Example 4

```
extract_fault_sites
   -output_file         dfm_bridges.udfm
      -marker_file      dfm_bridges.marker
      -defect_types     {dfm_bridges bridges}
      -max_distance     2.5
      -max_dfm_bridges  10
```

In this example, signal interconnect bridges will be extracted up to a distance of 2.5 times the technology length. In addition, DFM bridges will be extracted, where the number of DFM bridges is limited to 10. For the DFM bridges, the setting for -max_distance is ignored (but not for the regular bridges).

import_dfm

A command to import a Calibre-compatible results database (RDB) file containing DFM rule violations into the layout database. It is required, when using the "extract_fault_sites" command with the option "-defect_types" set to "dfm_bridges".

This description therefore refers to the specific usage in combination with the extract_fault_sites command.

Context: patterns -scan_diagnosis

Mode: analysis

Usage

import_dfm
-rdb ***<rdb_filename>***
-layer ***<layer name>***
-type **bridge**
[-replace]

Description

This command allows to import a Calibre-compatible results database (RDB) file containing DFM rule violations into the layout database. It verifies that the DFM rule violations match the layout geometries in the LADB.

This command is required, when using the "extract_fault_sites" command, when you want dfm-hotspots interconnect bridges to be written to a UDFM file.

Note

Using this switch requires to previously open the corrsponding layout database of your design, using the "open_layout <*layout_database*>" command. Make sure you have write permission to write into the layout database.

For further details on this command see the Tessent Shell Reference Manual.

Arguments

- ***-rdb <rdb_filename>***

  A required switch to define the name of the RDB file to be imported.

- ***-layer <layer name>***

  A required switch that specifies the layer at which the polygons in the RDB file shall be stored in the layout database. The layer name must match one of the layers that appear in the corresponding layout.

- ***-type bridge***

  A required switch to specify the type of DFM violation to be analyzed.

Note

The current version of the extract_fault_sites command only supports **bridge** defects. When other defect types are specified, a warning message will be issued.

- ***-replace***

  An optional switch to replace existing DFM violations with the same rule name and layer with the new information.

Example

```
open_layout mydesign.ladb

import_dfm -rdb dfm_violation_M1.rdb -layer M1 -type bridge -replace
import_dfm -rdb dfm_violation_M2.rdb -layer M2 -type bridge -replace
```

In this example, the specified RDB files “dfm_violation_M1.rdb” and “dfm_violation_M2.rdb” are imported into the layout database. Bridge violations in layer M1 and in layer M2 will be imported.

As a result, when using the extract_fault_sites command with the -defect_types switch including dfm_bridges, bridges in layer M1 and also in layer M2 will be extracted in the area of the identified DFM violations.

Note

An example of an RDB file with two DFM hotspot areas is given in Chapter 4, “How to Import DFM Violations” on page 29.

set_marker_file_options

A command to specify settings for the marker file generated by the extract_fault_sites command.

Context: patterns -scan_diagnosis

Mode: analysis

Usage

set_marker_file_options
[-max_bridges ***<value>*** **| unlimited**
[-top_name ***<name>*** **]**

Description

This command allows defining settings for the marker file generated by the extract_fault_sites command.

Arguments

- ***-max_bridges <value> | unlimited***

  An optional switch to specify the maximum number of bridges to be included in the marker file. The entries in the generated marker file are sorted. For example when specifying -max_bridges 20, then first the 10 bridges with the largest total critical area and then the 10 bridges with the smallest total critical area are written out to the marker file.

  The default is 1000.

- ***-top_name <name>***

  An optional switch to specify the design name of the top module for the marker file.

Example

```
set_marker_file_options
   -max_bridges         100
   -top_name            my_chip
```

In this example, 100 bridges will be written to the marker file, that is, first the 50 bridges with the largest total critical area and then the 50 bridges with the smallest total critical area. The top module name that is written to the marker file is “my_chip”.

Chapter 3
How to View Extracted Bridges

When you have executed the extract_fault_sites command using the -marker_file switch, you can use the GDS viewer of Calibre to get a detailed view of the extracted interconnect bridges within the layout of the design. For this, you need, in addition to the generated marker file, the <*design*>.gds file and optionally the layer properties file. To open the design layout with the Calibre GDS viewer, type the following:

calibredrv -m <*design*>.gds -rve <*filename*>.marker [-l <*layer.info*>]

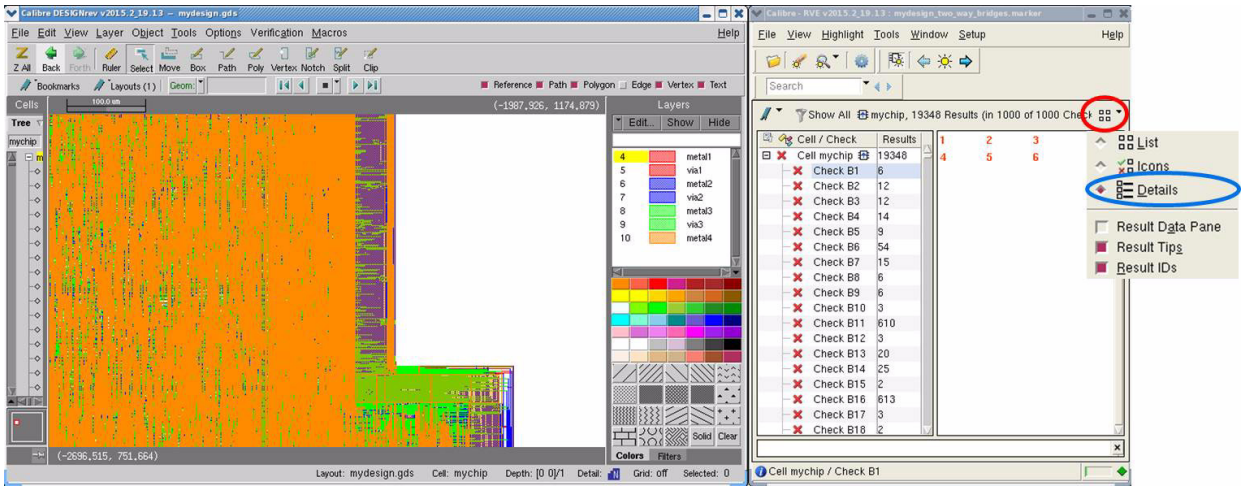
This will open Calibre showing the layout of your design, and the RVE window containing the list of all extracted interconnect bridges. If you have no layer properties file for your design, you can omit the -l option and start Calibre by typing:

calibredrv -m <*design*>.gds -rve <*filename*>.marker

The design layout will then be opened containing all layers being shown with Calibre defined properties.

A zoomed-in view of an example design with the RVE window is shown in Figure 3-1.

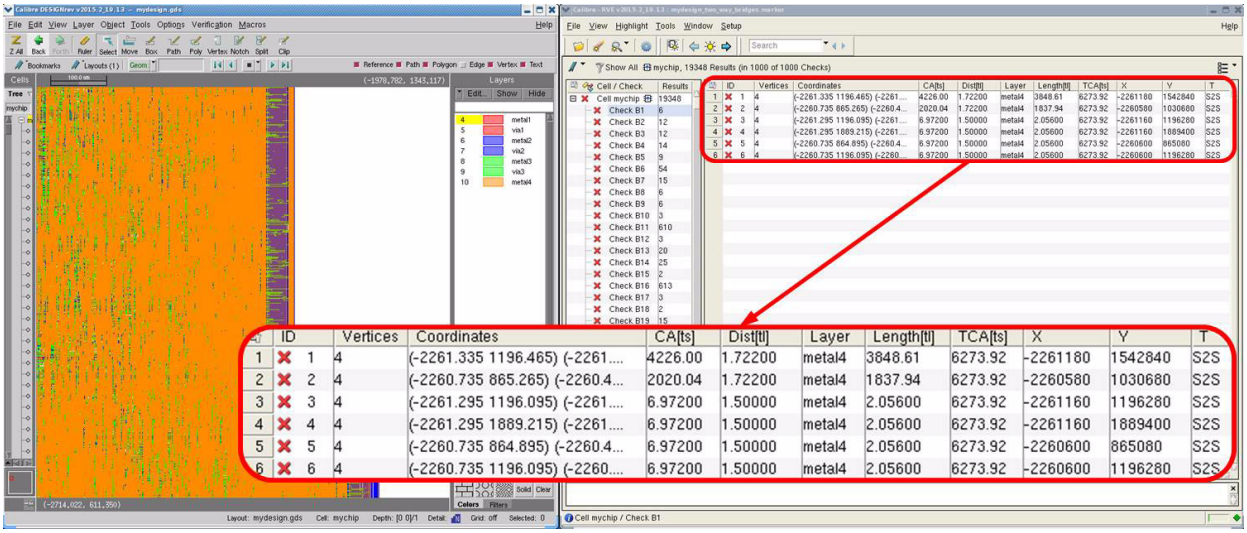
Figure 3-1. GDS view with RVE window



In the RVE window on the right side of Figure 3-1, you see the list of all extracted interconnect bridges. You can change the view of the result window to not only see the Calibre internal ID(s) of the selected bridge objects (in this example the bridge areas of bridge B1, numbered from 1 to 6), but also detailed information on the selected bridges. For this, click on the red circled button shown in Figure 3-1, then select “Details”, see the blue shape.

When having selected the details view as explained on page 25, the RVE window displays detailed information on the selected bridge fault as shown in Figure 3-2.

Figure 3-2. RVE details view



Looking for example at bridge fault B1, you see that the bridge consists of 6 bridge areas, numbered in the “ID” column from 1 to 6. The column “Coordinates” contains the X/Y coordinates of each of the four vertices of each bridge area. These are not important because there is also an “X” and a “Y” column. The column “CA[ts]” displays the calculated critical area per bridge area in technology squares (ts). The column “Dist[tl]” contains the distance between the bridging objects per bridge area in technology length (tl). The “Layer” column displays the layer on which the bridge is detected. The “Length[tl]” column contains the length of each bridge area in technology length [tl]. The column “TCA[ts]” displays the calculated total critical area in technology squares (ts), that is the sum of all calculated critical areas for that bridge fault. The “X” and “Y” columns contain the X and Y coordinates pointing to the center of each bridge area. The “T” column displays the bridge type, which can be either S2S (side-to-side) or C2C (corner-to corner).

Highlighting Bridge Faults in Design Layout

From the RVE window you can select any bridge fault to be highlighted in the design layout. Select one item from the list, click the right mouse button and select “Highlight” or simply press the “H” button on your keyboard. You can also highlight dedicated single bridge areas from the details window. An example for highlighting bridge fault B1 and two of the bridge areas is shown in Figure 3-3.

Figure 3-3. Highlighted bridge fault B1

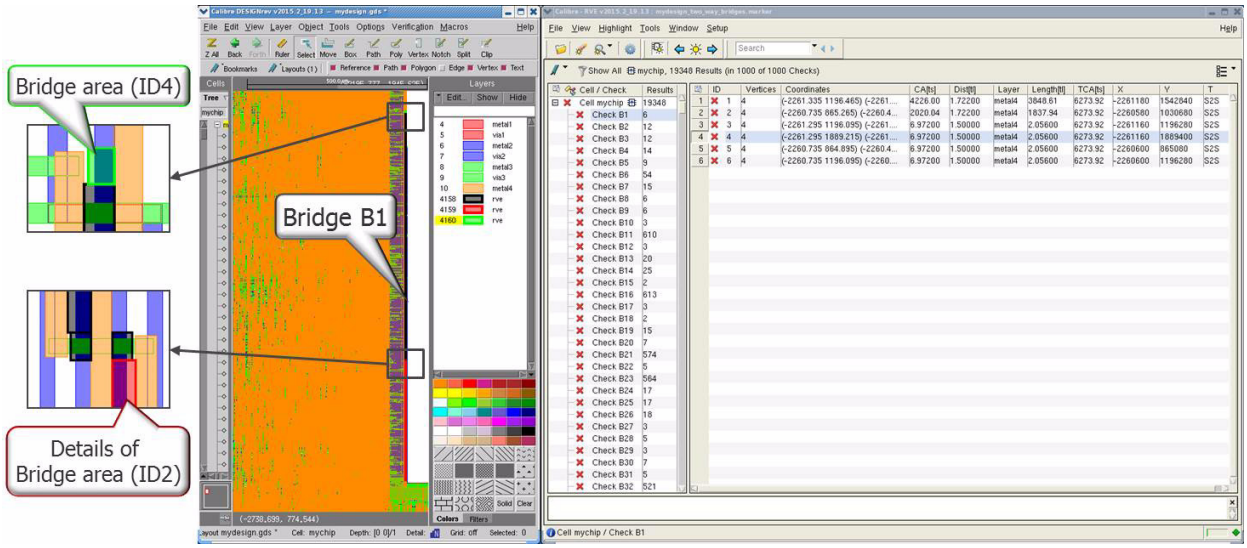


Figure 3-3 shows the bridge fault B1 as a black line on the right side of the layout window, beginning on top with a green dot for bridge area 4 (see “ID” column) and ending at the bottom with the red line for bridge area 2. On the left side of Figure 3-3 you see the enlarged picture details of bridge area 4 and bridge area 2.

To clear the highlights, click “Highlight” in the menu bar of the RVE window, then select “Clear Highlights”, or simply press the “F4” button on your keyboard.

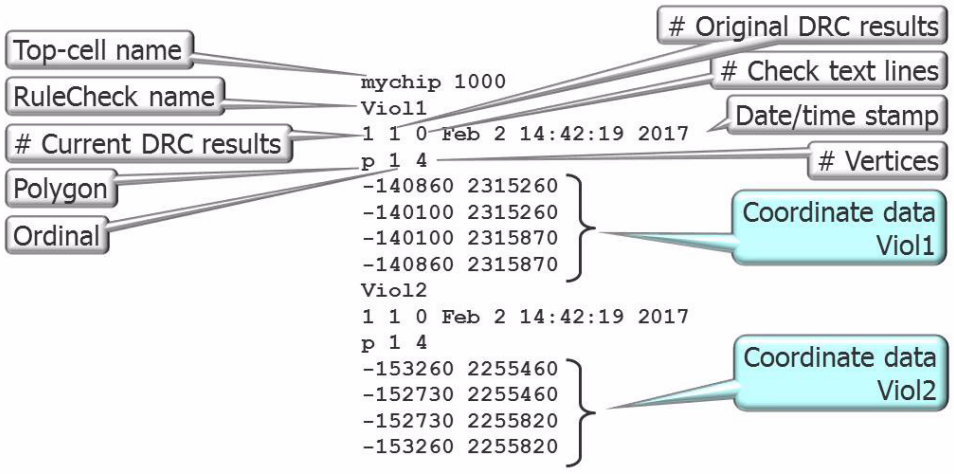
Chapter 4
How to Import DFM Violations

If you want to generate a UDFM file containing DFM hotspot interconnect bridges, you need first to import a Calibre-compatible results database (RDB) file, containing DFM rule violations, into the layout database by using the import_dfm command. For details on the usage of this command, see Chapter 2, "import_dfm" on page 22. To import bridge violations in layer metal3, for example, type:

```
import_dfm -rdb dfm_violation_M3.rdb -layer metal3 -type bridge -replace
```

Figure 4-1 shows an example of an RDB file, containing two DFM hotspot areas Viol1 and Viol2.

Figure 4-1. RDB file example



After that you need to execute the extract_fault_sites command setting the -defect_types switch to "dfm_bridges". To view the design layout with a GDS viewer, also the -marker_file switch is required. For example, type:

```
extract_fault_sites -defect_types dfm_bridges -output_file dfm.udfm -marker_file
dfm_extract.marker -replace
```

This will create a UDFM file named dfm.udfm and a marker file named dfm_extract.marker, by replacing existing files with the same name. The contents of these files are further explained in Chapter 5, "The UDFM File for Extracted Bridges" on page 33 and "The Marker File" on page 36.

DFM Hotspot Areas and Extracted Bridges

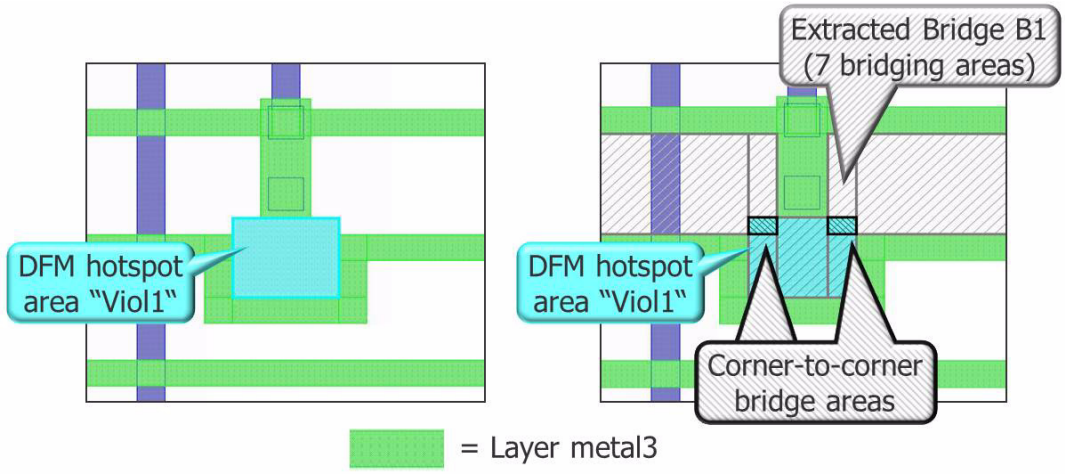
You can now open the GDS viewer Calibre typing the follwing command:

calibredrv -m <design>.gds -rve dfm_extract.marker -l <layer_properties_file>

The marker file in this example contains four bridges B1 to B4. When you want to view also the DFM hotspot areas given in the imported RDB file, you can click “File” in the RVE window of the layout viewer, then “Open database...” and select the corresponding .rdb file. This should then contain the coordinates for the DFM violations “Viol1” and “Viol” as shown in Figure 4-1 on page 29.

Figure 4-2 shows the DFM hotspot area defined as “Viol1” on the left side, and the extracted bridge B1 on the right side.

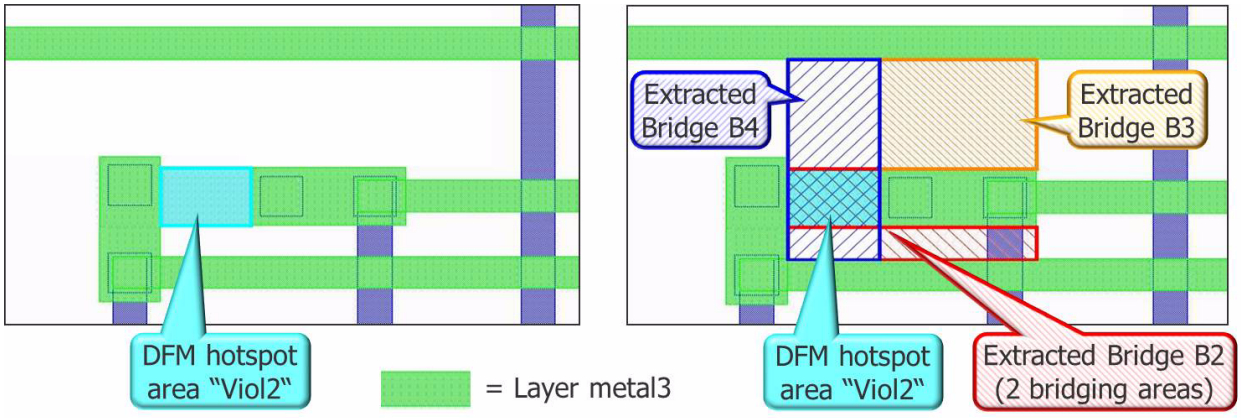
Figure 4-2. DFM hotspot “Viol1” and Bridge B1



The bridge B1 consists of seven bridge areas, each having at least one coordinate in common with the “Viol1” coordinates given in the RDB file.

In Figure 4-3 you see the DFM hotspot area defined as “Viol2” on the left side, and the extracted bridges B2, B3, and B4 on the right side.

Figure 4-3. DFM hotspot “Viol2” and Bridges B2, B3, B4



All bridges have at least one coordinate in common with the “Viol2” coordinates given in the RDB file, where bridge B2 consists of two bridge areas.

Chapter 5
Output Files

The UDFM File for Extracted Bridges

When running the extract_fault_sites command, an encrypted UDFM file will be generated. The contents are further explained in below sections.

The Critical Area Based Bridge Distribution

The UDFM file starts with a summary of the applied command line options followed by a distribution graph, displaying the number of bridges in relation to the total critical area (TCA).

```
//                Copyright 2011-2017 Mentor Graphics Corporation
//
//                           All Rights Reserved.
//
//    THIS WORK CONTAINS TRADE SECRET AND PROPRIETARY INFORMATION WHICH
//  IS THE PROPERTY OF MENTOR GRAPHICS CORPORATION OR ITS LICENSORS AND IS
//                         SUBJECT TO LICENSE TERMS.
//
//
//  tool_name : Tessent Shell
//  tool_version : 2017.2
//  created_date : Thu Jun 01 13:35:29 GMT 2017
//  max_distance : 3
//  min_tca : 0
//  max_tca : unlimited
//  defect_types : bridges
//  max_bridges : 100000
//  critical_area_calculation_method : method1
//  Command line :
//  extract_fault_sites -output_file bridges.udfm -defect_types bridges -replace
```

The following shows an example of a distribution graph for bridges:

```
//                    |                              # Bridges
//       TCA[ts]      |          10       100      1000     10000    100000   1000000
//                    |           |         |         |         |         |         |
//  -----------------  -  ------------------------------------------------------------
//  >100.0 -- 125.9    |  ****************************************** 16513
//  >125.9 -- 158.5    |  ********************************************** 23578
//  >158.5 -- 199.5    |  ******************************************* 17104
//  >199.5 -- 251.2    |  ************************************** 12984
//  >251.2 -- 316.2    |  ***************************************** 10298
//  >316.2 -- 398.1    |  ************************************ 6844
//  >398.1 -- 501.2    |  ************************************* 4600
//  >501.2 -- 631.0     |  ************************** 3246
//  >631.0 -- 794.3     |  ********************************* 2073
//  >794.3 -- 1000.0    |  ******************************* 1260
//  >1000.0 -- 1258.9   |  ***************************** 802
//  >1258.9 -- 1584.9   |  ************************ 384
//  >1584.9 -- 1995.3   |  ********************** 156
//  >1995.3 -- 2511.9   |  ****************** 85
//  >2511.9 -- 3162.3   |  ***************** 45
//  >3162.3 -- 3981.1   |  ************ 18
//  >3981.1 -- 5011.9   |  ******** 7
//  >5011.9 -- 6309.6   |  ***** 3
```

In this example, there are 16,513 bridges with a total critical area between >100.0 and 125.9 ts. In contrast, there are only 3 bridges with a total critical area between >5011.9 and 6309.6 ts.

This part is followed by the summary of extracted bridges which is explained in below example.

The Summary of Extracted Bridges

```
UDFM {
 Version : 3;
 EncryptedLocationAliases {
  "zIYEAAAAAAAABqEAAAAAAGQOMQHm2zPeHPtI8RYLEBpudnJEyNtSP...3jQ4P71IS";
 }
 UdfmType("interconnect_bridges") {
  Instance("/") {
      Bridge("B1") {Type:S2S;TCA:4147.131;Layer:"M6";Net1:$N2;Net2:$N4;CA:4117.096;
        Distance:3.500;Length:1757.667;X:2262.960;Y:2683.830;XL:0.420;YL:210.920;}
      Bridge("B2") {Type:S2S;TCA:3033.123;Layer:"M5";Net1:$N6;Net2:$N7;CA:2804.613;
        Distance:2.333;Length:3201.667;X:2227.260;Y:2813.230;XL:384.200;YL:0.280;}
        .
        .
        .
      Bridge("B19") {Type:C2C;TCA:1676.722;Layer:"M5";Net1:$N20;Net2:$N35;CA:1628.613;
        Distance:2.333;X:2261.700;Y:2828.350;XL:222.920;YL:0.280;}
      Bridge("B20") {Type:S2S;TCA:1666.703;Layer:"M5";Net1:$N21;Net2:$N43;CA:1395.863;
        Distance:2.333;Length:1591.667;X:2249.940;Y:2829.190;XL:191.000;YL:0.280;}
  }
 }
}
```

The top lines show the bridge faults with the highest defect probability reflected by the “TCA” value; the bottom lines show the bridges with the lowest probability.

Each fault is summarized in one line containing the following information:

- Bridge ID: This is the defect id, for example B1
- Type: This is the bridge type of the largest bridge area, which can be a side-to-side (S2S), a corner-to-corner (C2C) bridge, a bridge-to-ground (B2G), or a bridge-to-power (B2P).
- TCA: This is the calculated total critical area, which is the sum of all critical areas for that bridge fault
- Layer: This is the layer, where the bridge fault is detected, for example M5
- Net1, Net2: These are the corresponding location aliases for the net names at which the bridge fault is located. In case of a power bridge (B2P), or a bridge-to-ground (B2G) Net2 is not specified.
- CA: This is the calculated critical area for the largest bridge area of that bridge fault
- Distance: This is the distance between the bridging objects of the largest bridge area, defined in technology length [tl]
- Length: This is the length of the largest bridge area, defined in technology length [tl]. In case of a corner-to-corner (C2C) bridge, the length is excluded.

- X, Y: These are the X/Y coordinates in microns, pointing to the center of the largest bridge area
- XL, YL: These are the width and length values of the largest bridge area, defined in microns

The UDFM Section for DFM-Hotspots

When using the "-defect_types dfm_bridges" switch, an additional section will be written to the UDFM file. In the following, the UDFM section for dfm-hotspot interconnect bridges is shown exemplarily:

```
UdfmType("dfm_interconnect_bridges") {
  Instance("/") {
      Bridge("B1") {Type:S2S;TCA:34.303;Layer:"metal1";Net1:$N61;Net2:$N63;CA:13.653;
        Distance:0.944;Length:4.833;X:450.190;Y:-2081.890;XL:0.170;YL:0.870;}
      Bridge("B2") {Type:S2S;TCA:26.455;Layer:"metal1";Net1:$N61;Net2:$N64;CA:13.653;
        Distance:0.944;Length:4.833;X:449.230;Y:-2077.070;XL:0.170;YL:0.870;}
      Bridge("B3") {Type:S2S;TCA:25.525;Layer:"metal1";Net1:$N61;Net2:$N65;CA:13.653;
        Distance:0.944;Length:4.833;X:449.650;Y:-2081.890;XL:0.170;YL:0.870;}
      Bridge("B4") {Type:S2S;TCA:14.892;Layer:"metal1";Net1:$N66;Net2:$N61;CA:9.241;
        Distance:1.278;Length:5.333;X:451.120;Y:-2077.615;XL:0.230;YL:0.960;}
      Bridge("B5") {Type:B2G;TCA:8.605;Layer:"metal1";Net1:$N61;CA:2.180;Distance:2.861;
        Length:4.833;X:450.170;Y:-2079.202;XL:0.870;YL:0.515;}
      Bridge("B6") {Type:B2P;TCA:5.281;Layer:"metal1";Net1:$N61;CA:1.853;Distance:2.139;
        Length:0.833;X:449.440;Y:-2075.853;XL:0.150;YL:0.385;}
      Bridge("B7") {Type:S2S;TCA:1.211;Layer:"metal1";Net1:$N61;Net2:$N67;CA:0.354;
        Distance:6.611;Length:2.556;X:448.720;Y:-2076.405;XL:1.190;YL:0.460;}
  }
```

The UDFM Section for Power Bridges

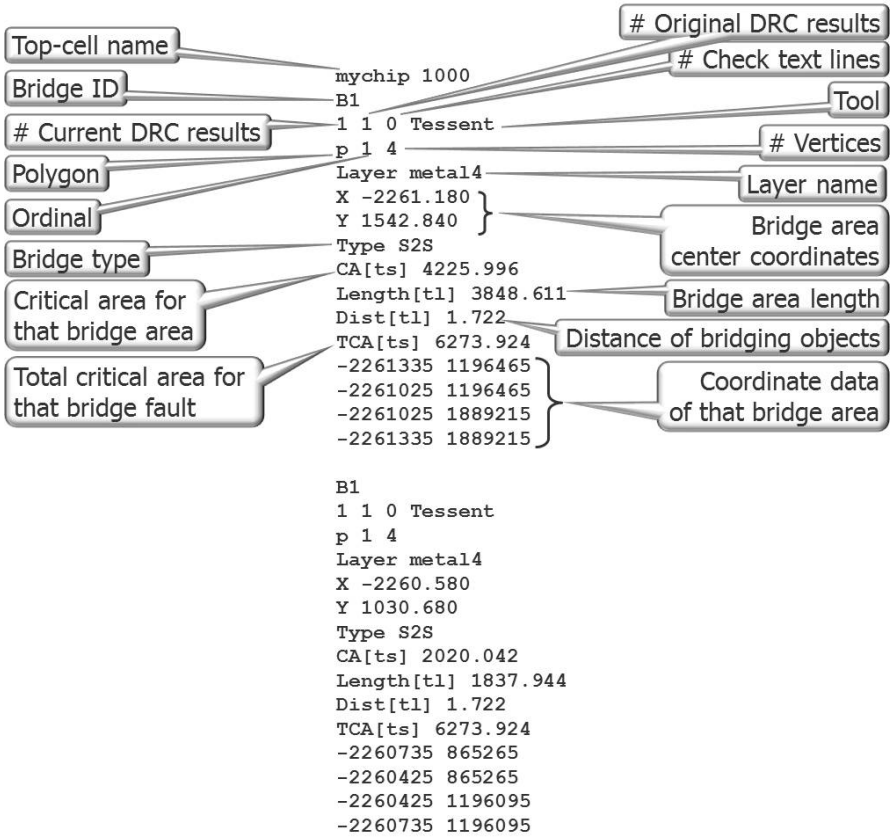
When using the "-defect_types power_bridges" switch, an additional section will be written to the UDFM file. In the following, the UDFM section for power bridges is shown exemplarily:

```
UdfmType("power_bridges") {
  Instance("/") {
      Bridge("P1") {Type:B2G;TCA:32.186;Layer:"metal1";Net1:$N2;CA:11.513;
        Distance:0.833;Length:2.889;X:-1941.605;Y:-1535.400;XL:0.150;YL:0.520;}
      Bridge("P2") {Type:B2G;TCA:23.026;Layer:"metal1";Net1:$N4;CA:11.513;
        Distance:0.833;Length:2.889;X:-1942.085;Y:-852.840;XL:0.150;YL:0.520;}
        .
        .
        .
      Bridge("P40") {Type:B2G;TCA:5.629;Layer:"metal3";Net1:$N58;CA:2.815;
        Distance:0.983;X:1536.475;Y:2421.400;XL:0.130;YL:0.120;}
      Bridge("P41") {Type:B2G;TCA:5.629;Layer:"metal3";Net1:$N59;CA:2.815;
        Distance:0.983;X:1536.475;Y:2404.120;XL:0.130;YL:0.120;}
  }
```

The Marker File

When running the extract_fault_sites command by using the -marker_file switch, also a marker file will be generated, containing layout information for all specified interconnect bridges. Figure 5-1 shows a part of such a marker file.

Figure 5-1. Marker file example



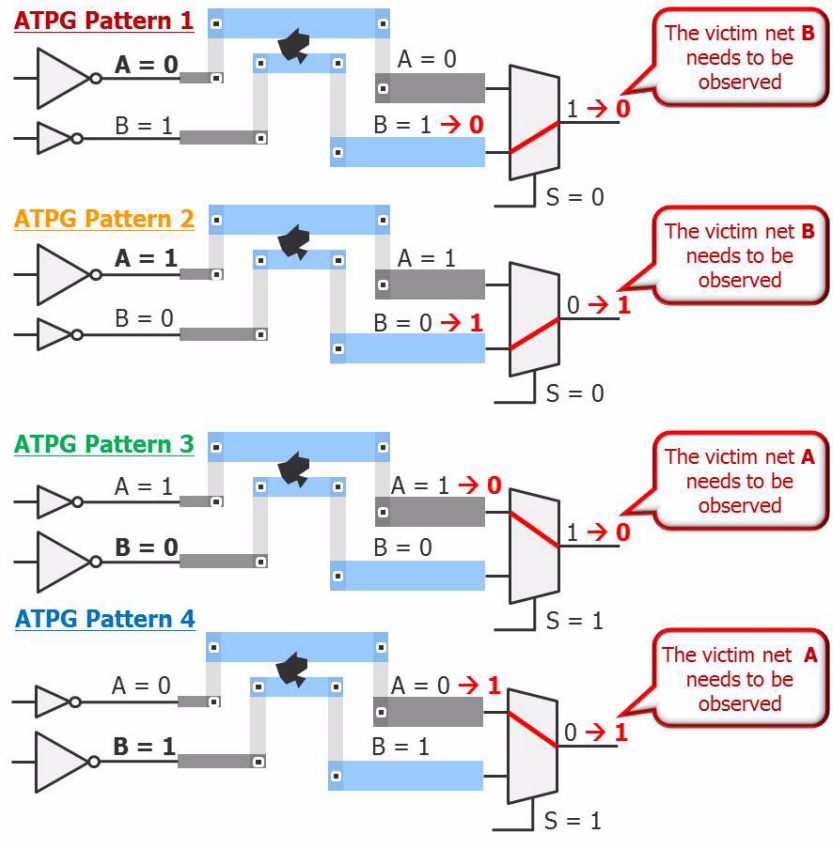
Each bridge fault consists of a number of bridge areas. For example, bridge B1 consists of 2 bridge areas, and for each bridge area, the details are listed separately.

Chapter 6
Critical Area Based Bridge Pattern Generation

Four-Way Bridge Model for Static ATPG

The ATPG is forced to generate in total four static patterns, two patterns assuming net A is the aggressor, and net B is the victim, and two additional patterns assuming net B is the aggressor, and net A is the victim, which is illustrated in Figure 6-1. In case that both nets can be observed concurrently, it is possible that only two patterns are generated.

Figure 6-1. Four-way bridge model - static ATPG



How to Generate Static Bridge Patterns

After extracting the bridges using the "extract_fault_sites" command as explained in Chapter 2, "extract_fault_sites" on page 17, the created UDFM file can be used within Tessent Shell to generate critical area based bridge patterns. An example for the corresponding dofile for static pattern generation is shown below:

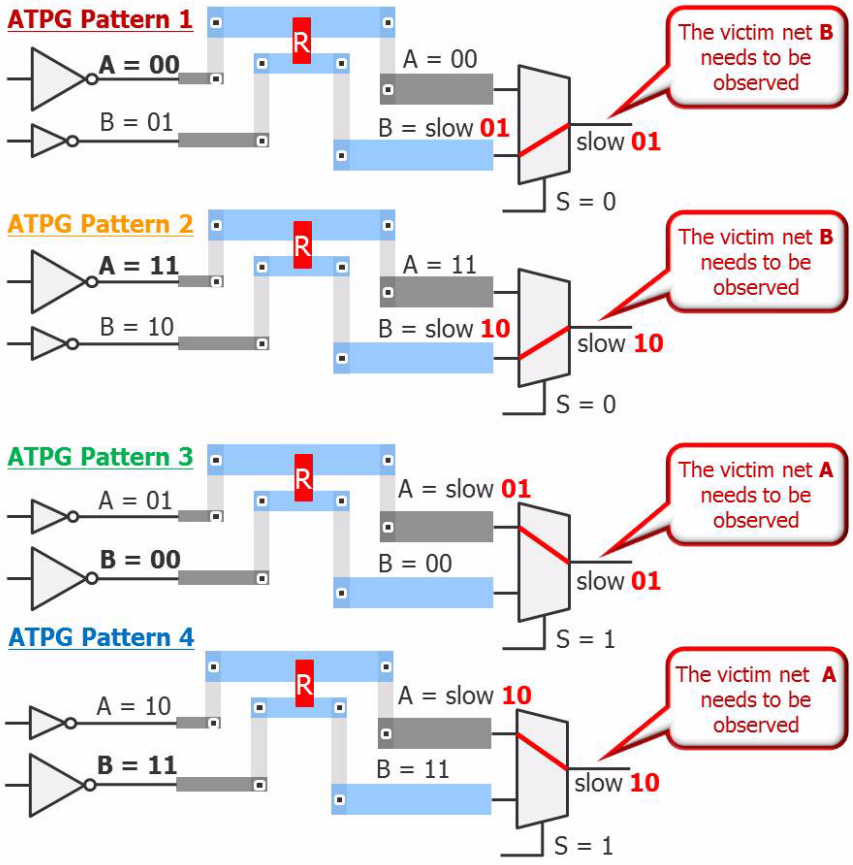
```
set_context patterns -scan
read_flat_model my_design.flat_model.gz
set_system_mode analysis
set_fault_type udfm -static_fault
read_fault_sites my_design_bridges.udfm
add_faults -all
create_patterns
report_statistics
write_patterns my_design_static_bridges.stil.gz -stil -replace
report_resources
```

The "add_faults -all" will add the bridge faults as defined in the UDFM. You may specify the -verbose option to the add_faults command to get a reporting of netnames that could not be matched to netnames of the design.

Four-Way Bridge Model for Delay ATPG

The ATPG is forced to generate in total four delay patterns, two patterns assuming net A is the aggressor with a constant state, and net B is the victim with a rising and a falling edge, and two additional patterns assuming net B is the aggressor with a constant state, and net A is the victim with a rising and a falling edge. This is illustrated in Figure 6-2.

Figure 6-2. Four-way bridge model - delay ATPG



How to Generate Delay Bridge Patterns

An example for the corresponding dofile for delay pattern generation is shown below:

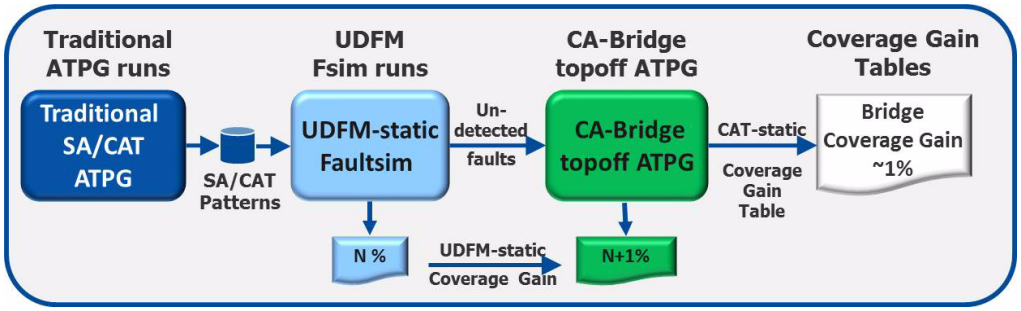
```
set_context patterns -scan
read_flat_model my_design.flat_model.gz
set_system_mode analysis
set_fault_type udfm -delay_fault
read_fault_sites my_design_bridges.udfm
add_faults -all
create_patterns
report_statistics
write_patterns my_design_delay_bridges.stil.gz -stil -replace
report_resources
```

How to report Bridge Coverage Gain Figures

For reporting bridge coverage gain figures, the ATPG flow can be executed, where bridge topoff patterns are generated on top of stuck-at (SA) or cell-aware test (CAT) patterns.

The flow is shown in Figure 6-3.

Figure 6-3. Calculating the bridge coverage gain



For reporting the bridge coverage gain, first traditional SA or CAT-static patterns are generated and saved in a pattern file. As second step, these static patterns are fault simulated using the UDFM ("-fault_type udfm -static") fault model. The achieved detections are reported and saved in memory by using the ATPG command "-report_udfm_statistics -set_baseline". The undetected faults are then targeted by a bridge topoff ATPG run. A second "-report_udfm_statistics" is issued at the end which will report the bridge coverage gain.

Dofile for Critical Area Based Static Bridge Topoff ATPG

The following is an example of a dofile for the critical area based static bridge topoff ATPG, that might need to be adjusted for your design.

```
set_context patterns -scan
read_flat_model my_design.flat_model.gz
set_system_mode analysis
set_fault_type udfm -static_fault
read_fault_sites my_design_bridges.udfm
add_faults -all

read_patterns apt1_SA_atpg.pat.gz
simulate_patterns -source external
report_udfm_statistics  -set_baseline

set_pattern_source internal
create_patterns
report_udfm_statistics

report_statistics
write_patterns my_design_static_bridges.stil.gz -stil -replace
report_resources
```

Dofile for Critical Area Based Delay Bridge Topoff ATPG

The following is an example of a dofile for the critical area based delay bridge topoff ATPG, that might need to be adjusted for your design.

```
set_context patterns -scan
read_flat_model my_design.flat_model.gz
set_system_mode analysis
set_fault_type udfm -delay_fault
read_fault_sites my_design_bridges.udfm
add_faults -all

read_patterns apt1_SA_atpg.pat.gz
simulate_patterns -source external
report_udfm_statistics  -set_baseline

set_pattern_source internal
create_patterns
report_udfm_statistics

report_statistics
write_patterns my_design_delay_bridges.stil.gz -stil -replace
report_resources
```

Details about the Coverage Gain Table

In Figure 6-4 , an example of a coverage gain table is shown.

The related report command was:

report_udfm_statistics

Figure 6-4. FastScan/TestKompress Coverage Gain Table

```
//  Type                Block     Name   Instances  Port-Insts  Faults  DS[%]  FC[%]  TC[%]  Add-DT  GN[%]
//  ------------------  --------  -----  ---------  ----------  ------  -----  -----  -----  ------  -----
//  interconnect_bridges  Instance  /             1           0  400000  74.89  75.13  76.61    1866   0.48
//                                Total           1           0  400000  74.89  75.13  76.61    1866   0.48
```

As can bee seen in Figure 6-4, the table contains only one row and one “Total” line at the end which is the coverage gain for the whole design. Each line contains the coverage data per type. The Add-DT column contains the number of additional detected defects (faults) per type. The last column is the coverage gain (GN[%]) in percent per type. This percentage is the relative coverage gain of the type. So, the relative coverage gain is defined as:

$$GN = \frac{\text{Additional bridge defects}}{\text{\# of bridge faults} \times 100\%}$$

The content of the various columns is as follows:

Column 6 “Faults”: This column indicates the number of faults related to all instances of the corresponding cell type.

Column 7 “DS[%]”: This column indicates the percentage of faults detected by simulation, that means faults that are detected by test patterns.

Column 8 “FC[%]”: This column indicates the percentage of the achieved fault coverage.

Column 9 “TC[%]”: This column indicates the percentage of the achieved test coverage.

Column 10 “Add-DT”: This column indicates the absolute number of additional detected faults in relation to the status when the “report_udfm_statistics -set_baseline” command was issued previously.

Column 11 “GN[%]”: This column indicates the relative percentage of the coverage gain for the corresponding cell type.

Appendix A
Third-Party Information

For information about third-party software included with this beta release of Tessent products, refer to the *Third-Party Software for Tessent Products*:

http://supportnet.mentor.com/docs/201211028/docs/pdfdocs/third_party.pdf

End-User License Agreement

The latest version of the End-User License Agreement is available on-line at:
www.mentor.com/eula

IMPORTANT INFORMATION

USE OF ALL SOFTWARE IS SUBJECT TO LICENSE RESTRICTIONS. CAREFULLY READ THIS LICENSE AGREEMENT BEFORE USING THE PRODUCTS. USE OF SOFTWARE INDICATES CUSTOMER'S COMPLETE AND UNCONDITIONAL ACCEPTANCE OF THE TERMS AND CONDITIONS SET FORTH IN THIS AGREEMENT. ANY ADDITIONAL OR DIFFERENT PURCHASE ORDER TERMS AND CONDITIONS SHALL NOT APPLY.

END-USER LICENSE AGREEMENT ("Agreement")

This is a legal agreement concerning the use of Software (as defined in Section 2) and hardware (collectively "Products") between the company acquiring the Products ("Customer"), and the Mentor Graphics entity that issued the corresponding quotation or, if no quotation was issued, the applicable local Mentor Graphics entity ("Mentor Graphics"). Except for license agreements related to the subject matter of this license agreement which are physically signed by Customer and an authorized representative of Mentor Graphics, this Agreement and the applicable quotation contain the parties' entire understanding relating to the subject matter and supersede all prior or contemporaneous agreements. If Customer does not agree to these terms and conditions, promptly return or, in the case of Software received electronically, certify destruction of Software and all accompanying items within five days after receipt of Software and receive a full refund of any license fee paid.

1. **ORDERS, FEES AND PAYMENT.**

   1.1. To the extent Customer (or if agreed by Mentor Graphics, Customer's appointed third party buying agent) places and Mentor Graphics accepts purchase orders pursuant to this Agreement ("Order(s)"), each Order will constitute a contract between Customer and Mentor Graphics, which shall be governed solely and exclusively by the terms and conditions of this Agreement, any applicable addenda and the applicable quotation, whether or not these documents are referenced on the Order. Any additional or conflicting terms and conditions appearing on an Order will not be effective unless agreed in writing by an authorized representative of Customer and Mentor Graphics.

   1.2. Amounts invoiced will be paid, in the currency specified on the applicable invoice, within 30 days from the date of such invoice. Any past due invoices will be subject to the imposition of interest charges in the amount of one and one-half percent per month or the applicable legal rate currently in effect, whichever is lower. Prices do not include freight, insurance, customs duties, taxes or other similar charges, which Mentor Graphics will state separately in the applicable invoice(s). Unless timely provided with a valid certificate of exemption or other evidence that items are not taxable, Mentor Graphics will invoice Customer for all applicable taxes including, but not limited to, VAT, GST, sales tax and service tax. Customer will make all payments free and clear of, and without reduction for, any withholding or other taxes; any such taxes imposed on payments by Customer hereunder will be Customer's sole responsibility. If Customer appoints a third party to place purchase orders and/or make payments on Customer's behalf, Customer shall be liable for payment under Orders placed by such third party in the event of default.

   1.3. All Products are delivered FCA factory (Incoterms 2000), freight prepaid and invoiced to Customer, except Software delivered electronically, which shall be deemed delivered when made available to Customer for download. Mentor Graphics retains a security interest in all Products delivered under this Agreement, to secure payment of the purchase price of such Products, and Customer agrees to sign any documents that Mentor Graphics determines to be necessary or convenient for use in filing or perfecting such security interest. Mentor Graphics' delivery of Software by electronic means is subject to Customer's provision of both a primary and an alternate e-mail address.

2. **GRANT OF LICENSE.** The software installed, downloaded, or otherwise acquired by Customer under this Agreement, including any updates, modifications, revisions, copies, documentation and design data ("Software") are copyrighted, trade secret and confidential information of Mentor Graphics or its licensors, who maintain exclusive title to all Software and retain all rights not expressly granted by this Agreement. Mentor Graphics grants to Customer, subject to payment of applicable license fees, a nontransferable, nonexclusive license to use Software solely: (a) in machine-readable, object-code form (except as provided in Subsection 5.2); (b) for Customer's internal business purposes; (c) for the term of the license; and (d) on the computer hardware and at the site authorized by Mentor Graphics. A site is restricted to a one-half mile (800 meter) radius. Customer may have Software temporarily used by an employee for telecommuting purposes from locations other than a Customer office, such as the employee's residence, an airport or hotel, provided that such employee's primary place of employment is the site where the Software is authorized for use. Mentor Graphics' standard policies and programs, which vary depending on Software, license fees paid or services purchased, apply to the following: (a) relocation of Software; (b) use of Software, which may be limited, for example, to execution of a single session by a single user on the authorized hardware or for a restricted period of time (such limitations may be technically implemented through the use of authorization codes or similar devices); and (c) support services provided, including eligibility to receive telephone support, updates, modifications, and revisions. For the avoidance of doubt, if Customer requests any change or enhancement to Software, whether in the course of receiving support or consulting services, evaluating Software, performing beta testing or otherwise, any inventions, product

improvements, modifications or developments made by Mentor Graphics (at Mentor Graphics' sole discretion) will be the exclusive property of Mentor Graphics.

3. **ESC SOFTWARE.** If Customer purchases a license to use development or prototyping tools of Mentor Graphics' Embedded Software Channel ("ESC"), Mentor Graphics grants to Customer a nontransferable, nonexclusive license to reproduce and distribute executable files created using ESC compilers, including the ESC run-time libraries distributed with ESC C and C++ compiler Software that are linked into a composite program as an integral part of Customer's compiled computer program, provided that Customer distributes these files only in conjunction with Customer's compiled computer program. Mentor Graphics does NOT grant Customer any right to duplicate, incorporate or embed copies of Mentor Graphics' real-time operating systems or other embedded software products into Customer's products or applications without first signing or otherwise agreeing to a separate agreement with Mentor Graphics for such purpose.

4. **BETA CODE.**

   4.1. Portions or all of certain Software may contain code for experimental testing and evaluation ("Beta Code"), which may not be used without Mentor Graphics' explicit authorization. Upon Mentor Graphics' authorization, Mentor Graphics grants to Customer a temporary, nontransferable, nonexclusive license for experimental use to test and evaluate the Beta Code without charge for a limited period of time specified by Mentor Graphics. This grant and Customer's use of the Beta Code shall not be construed as marketing or offering to sell a license to the Beta Code, which Mentor Graphics may choose not to release commercially in any form.

   4.2. If Mentor Graphics authorizes Customer to use the Beta Code, Customer agrees to evaluate and test the Beta Code under normal conditions as directed by Mentor Graphics. Customer will contact Mentor Graphics periodically during Customer's use of the Beta Code to discuss any malfunctions or suggested improvements. Upon completion of Customer's evaluation and testing, Customer will send to Mentor Graphics a written evaluation of the Beta Code, including its strengths, weaknesses and recommended improvements.

   4.3. Customer agrees to maintain Beta Code in confidence and shall restrict access to the Beta Code, including the methods and concepts utilized therein, solely to those employees and Customer location(s) authorized by Mentor Graphics to perform beta testing. Customer agrees that any written evaluations and all inventions, product improvements, modifications or developments that Mentor Graphics conceived or made during or subsequent to this Agreement, including those based partly or wholly on Customer's feedback, will be the exclusive property of Mentor Graphics. Mentor Graphics will have exclusive rights, title and interest in all such property. The provisions of this Subsection 4.3 shall survive termination of this Agreement.

5. **RESTRICTIONS ON USE.**

   5.1. Customer may copy Software only as reasonably necessary to support the authorized use. Each copy must include all notices and legends embedded in Software and affixed to its medium and container as received from Mentor Graphics. All copies shall remain the property of Mentor Graphics or its licensors. Customer shall maintain a record of the number and primary location of all copies of Software, including copies merged with other software, and shall make those records available to Mentor Graphics upon request. Customer shall not make Products available in any form to any person other than Customer's employees and on-site contractors, excluding Mentor Graphics competitors, whose job performance requires access and who are under obligations of confidentiality. Customer shall take appropriate action to protect the confidentiality of Products and ensure that any person permitted access does not disclose or use it except as permitted by this Agreement. Customer shall give Mentor Graphics written notice of any unauthorized disclosure or use of the Products as soon as Customer learns or becomes aware of such unauthorized disclosure or use. Except as otherwise permitted for purposes of interoperability as specified by applicable and mandatory local law, Customer shall not reverse-assemble, reverse-compile, reverse-engineer or in any way derive any source code from Software. Log files, data files, rule files and script files generated by or for the Software (collectively "Files"), including without limitation files containing Standard Verification Rule Format ("SVRF") and Tcl Verification Format ("TVF") which are Mentor Graphics' proprietary syntaxes for expressing process rules, constitute or include confidential information of Mentor Graphics. Customer may share Files with third parties, excluding Mentor Graphics competitors, provided that the confidentiality of such Files is protected by written agreement at least as well as Customer protects other information of a similar nature or importance, but in any case with at least reasonable care. Customer may use Files containing SVRF or TVF only with Mentor Graphics products. Under no circumstances shall Customer use Software or Files or allow their use for the purpose of developing, enhancing or marketing any product that is in any way competitive with Software, or disclose to any third party the results of, or information pertaining to, any benchmark.

   5.2. If any Software or portions thereof are provided in source code form, Customer will use the source code only to correct software errors and enhance or modify the Software for the authorized use. Customer shall not disclose or permit disclosure of source code, in whole or in part, including any of its methods or concepts, to anyone except Customer's employees or contractors, excluding Mentor Graphics competitors, with a need to know. Customer shall not copy or compile source code in any manner except to support this authorized use.

   5.3. Customer may not assign this Agreement or the rights and duties under it, or relocate, sublicense or otherwise transfer the Products, whether by operation of law or otherwise ("Attempted Transfer"), without Mentor Graphics' prior written consent and payment of Mentor Graphics' then-current applicable relocation and/or transfer fees. Any Attempted Transfer without Mentor Graphics' prior written consent shall be a material breach of this Agreement and may, at Mentor Graphics' option, result in the immediate termination of the Agreement and/or the licenses granted under this Agreement. The terms of this Agreement, including without limitation the licensing and assignment provisions, shall be binding upon Customer's permitted successors in interest and assigns.

5.4. The provisions of this Section 5 shall survive the termination of this Agreement.

6. **SUPPORT SERVICES.** To the extent Customer purchases support services, Mentor Graphics will provide Customer updates and technical support for the Products, at the Customer site(s) for which support is purchased, in accordance with Mentor Graphics' then current End-User Support Terms located at http://supportnet.mentor.com/about/legal/.

7. **AUTOMATIC CHECK FOR UPDATES; PRIVACY.** Technological measures in Software may communicate with servers of Mentor Graphics or its contractors for the purpose of checking for and notifying the user of updates and to ensure that the Software in use is licensed in compliance with this Agreement. Mentor Graphics will not collect any personally identifiable data in this process and will not disclose any data collected to any third party without the prior written consent of Customer, except to Mentor Graphics' outside attorneys or as may be required by a court of competent jurisdiction.

8. **LIMITED WARRANTY.**

8.1. Mentor Graphics warrants that during the warranty period its standard, generally supported Products, when properly installed, will substantially conform to the functional specifications set forth in the applicable user manual. Mentor Graphics does not warrant that Products will meet Customer's requirements or that operation of Products will be uninterrupted or error free. The warranty period is 90 days starting on the 15th day after delivery or upon installation, whichever first occurs. Customer must notify Mentor Graphics in writing of any nonconformity within the warranty period. For the avoidance of doubt, this warranty applies only to the initial shipment of Software under an Order and does not renew or reset, for example, with the delivery of (a) Software updates or (b) authorization codes or alternate Software under a transaction involving Software re-mix. This warranty shall not be valid if Products have been subject to misuse, unauthorized modification or improper installation. MENTOR GRAPHICS' ENTIRE LIABILITY AND CUSTOMER'S EXCLUSIVE REMEDY SHALL BE, AT MENTOR GRAPHICS' OPTION, EITHER (A) REFUND OF THE PRICE PAID UPON RETURN OF THE PRODUCTS TO MENTOR GRAPHICS OR (B) MODIFICATION OR REPLACEMENT OF THE PRODUCTS THAT DO NOT MEET THIS LIMITED WARRANTY, PROVIDED CUSTOMER HAS OTHERWISE COMPLIED WITH THIS AGREEMENT. MENTOR GRAPHICS MAKES NO WARRANTIES WITH RESPECT TO: (A) SERVICES; (B) PRODUCTS PROVIDED AT NO CHARGE; OR (C) BETA CODE; ALL OF WHICH ARE PROVIDED "AS IS."

8.2. THE WARRANTIES SET FORTH IN THIS SECTION 8 ARE EXCLUSIVE. NEITHER MENTOR GRAPHICS NOR ITS LICENSORS MAKE ANY OTHER WARRANTIES EXPRESS, IMPLIED OR STATUTORY, WITH RESPECT TO PRODUCTS PROVIDED UNDER THIS AGREEMENT. MENTOR GRAPHICS AND ITS LICENSORS SPECIFICALLY DISCLAIM ALL IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NON-INFRINGEMENT OF INTELLECTUAL PROPERTY.

9. **LIMITATION OF LIABILITY.** EXCEPT WHERE THIS EXCLUSION OR RESTRICTION OF LIABILITY WOULD BE VOID OR INEFFECTIVE UNDER APPLICABLE LAW, IN NO EVENT SHALL MENTOR GRAPHICS OR ITS LICENSORS BE LIABLE FOR INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES (INCLUDING LOST PROFITS OR SAVINGS) WHETHER BASED ON CONTRACT, TORT OR ANY OTHER LEGAL THEORY, EVEN IF MENTOR GRAPHICS OR ITS LICENSORS HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN NO EVENT SHALL MENTOR GRAPHICS' OR ITS LICENSORS' LIABILITY UNDER THIS AGREEMENT EXCEED THE AMOUNT RECEIVED FROM CUSTOMER FOR THE HARDWARE, SOFTWARE LICENSE OR SERVICE GIVING RISE TO THE CLAIM. IN THE CASE WHERE NO AMOUNT WAS PAID, MENTOR GRAPHICS AND ITS LICENSORS SHALL HAVE NO LIABILITY FOR ANY DAMAGES WHATSOEVER. THE PROVISIONS OF THIS SECTION 9 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

10. **HAZARDOUS APPLICATIONS.** CUSTOMER ACKNOWLEDGES IT IS SOLELY RESPONSIBLE FOR TESTING ITS PRODUCTS USED IN APPLICATIONS WHERE THE FAILURE OR INACCURACY OF ITS PRODUCTS MIGHT RESULT IN DEATH OR PERSONAL INJURY ("HAZARDOUS APPLICATIONS"). NEITHER MENTOR GRAPHICS NOR ITS LICENSORS SHALL BE LIABLE FOR ANY DAMAGES RESULTING FROM OR IN CONNECTION WITH THE USE OF MENTOR GRAPHICS PRODUCTS IN OR FOR HAZARDOUS APPLICATIONS. THE PROVISIONS OF THIS SECTION 10 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

11. **INDEMNIFICATION.** CUSTOMER AGREES TO INDEMNIFY AND HOLD HARMLESS MENTOR GRAPHICS AND ITS LICENSORS FROM ANY CLAIMS, LOSS, COST, DAMAGE, EXPENSE OR LIABILITY, INCLUDING ATTORNEYS' FEES, ARISING OUT OF OR IN CONNECTION WITH THE USE OF PRODUCTS AS DESCRIBED IN SECTION 10. THE PROVISIONS OF THIS SECTION 11 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

12. **INFRINGEMENT.**

12.1. Mentor Graphics will defend or settle, at its option and expense, any action brought against Customer in the United States, Canada, Japan, or member state of the European Union which alleges that any standard, generally supported Product acquired by Customer hereunder infringes a patent or copyright or misappropriates a trade secret in such jurisdiction. Mentor Graphics will pay costs and damages finally awarded against Customer that are attributable to the action. Customer understands and agrees that as conditions to Mentor Graphics' obligations under this section Customer must: (a) notify Mentor Graphics promptly in writing of the action; (b) provide Mentor Graphics all reasonable information and assistance to settle or defend the action; and (c) grant Mentor Graphics sole authority and control of the defense or settlement of the action.

12.2. If a claim is made under Subsection 12.1 Mentor Graphics may, at its option and expense, (a) replace or modify the Product so that it becomes noninfringing; (b) procure for Customer the right to continue using the Product; or (c) require the return of the Product and refund to Customer any purchase price or license fee paid, less a reasonable allowance for use.

12.3. Mentor Graphics has no liability to Customer if the action is based upon: (a) the combination of Software or hardware with any product not furnished by Mentor Graphics; (b) the modification of the Product other than by Mentor Graphics; (c) the use of other than a current unaltered release of Software; (d) the use of the Product as part of an infringing process; (e) a product that Customer makes, uses, or sells; (f) any Beta Code or Product provided at no charge; (g) any software provided by Mentor Graphics' licensors who do not provide such indemnification to Mentor Graphics' customers; or (h) infringement by Customer that is deemed willful. In the case of (h), Customer shall reimburse Mentor Graphics for its reasonable attorney fees and other costs related to the action.

12.4. THIS SECTION 12 IS SUBJECT TO SECTION 9 ABOVE AND STATES THE ENTIRE LIABILITY OF MENTOR GRAPHICS AND ITS LICENSORS FOR DEFENSE, SETTLEMENT AND DAMAGES, AND CUSTOMER'S SOLE AND EXCLUSIVE REMEDY, WITH RESPECT TO ANY ALLEGED PATENT OR COPYRIGHT INFRINGEMENT OR TRADE SECRET MISAPPROPRIATION BY ANY PRODUCT PROVIDED UNDER THIS AGREEMENT.

13. **TERMINATION AND EFFECT OF TERMINATION.** If a Software license was provided for limited term use, such license will automatically terminate at the end of the authorized term.

13.1. Mentor Graphics may terminate this Agreement and/or any license granted under this Agreement immediately upon written notice if Customer: (a) exceeds the scope of the license or otherwise fails to comply with the licensing or confidentiality provisions of this Agreement, or (b) becomes insolvent, files a bankruptcy petition, institutes proceedings for liquidation or winding up or enters into an agreement to assign its assets for the benefit of creditors. For any other material breach of any provision of this Agreement, Mentor Graphics may terminate this Agreement and/or any license granted under this Agreement upon 30 days written notice if Customer fails to cure the breach within the 30 day notice period. Termination of this Agreement or any license granted hereunder will not affect Customer's obligation to pay for Products shipped or licenses granted prior to the termination, which amounts shall be payable immediately upon the date of termination.

13.2. Upon termination of this Agreement, the rights and obligations of the parties shall cease except as expressly set forth in this Agreement. Upon termination, Customer shall ensure that all use of the affected Products ceases, and shall return hardware and either return to Mentor Graphics or destroy Software in Customer's possession, including all copies and documentation, and certify in writing to Mentor Graphics within ten business days of the termination date that Customer no longer possesses any of the affected Products or copies of Software in any form.

14. **EXPORT.** The Products provided hereunder are subject to regulation by local laws and United States government agencies, which prohibit export or diversion of certain products and information about the products to certain countries and certain persons. Customer agrees that it will not export Products in any manner without first obtaining all necessary approval from appropriate local and United States government agencies.

15. **U.S. GOVERNMENT LICENSE RIGHTS.** Software was developed entirely at private expense. All Software is commercial computer software within the meaning of the applicable acquisition regulations. Accordingly, pursuant to US FAR 48 CFR 12.212 and DFAR 48 CFR 227.7202, use, duplication and disclosure of the Software by or for the U.S. Government or a U.S. Government subcontractor is subject solely to the terms and conditions set forth in this Agreement, except for provisions which are contrary to applicable mandatory federal laws.

16. **THIRD PARTY BENEFICIARY.** Mentor Graphics Corporation, Mentor Graphics (Ireland) Limited, Microsoft Corporation and other licensors may be third party beneficiaries of this Agreement with the right to enforce the obligations set forth herein.

17. **REVIEW OF LICENSE USAGE.** Customer will monitor the access to and use of Software. With prior written notice and during Customer's normal business hours, Mentor Graphics may engage an internationally recognized accounting firm to review Customer's software monitoring system and records deemed relevant by the internationally recognized accounting firm to confirm Customer's compliance with the terms of this Agreement or U.S. or other local export laws. Such review may include FLEXlm or FLEXnet (or successor product) report log files that Customer shall capture and provide at Mentor Graphics' request. Customer shall make records available in electronic format and shall fully cooperate with data gathering to support the license review. Mentor Graphics shall bear the expense of any such review unless a material non-compliance is revealed. Mentor Graphics shall treat as confidential information all information gained as a result of any request or review and shall only use or disclose such information as required by law or to enforce its rights under this Agreement. The provisions of this Section 17 shall survive the termination of this Agreement.

18. **CONTROLLING LAW, JURISDICTION AND DISPUTE RESOLUTION.** The owners of certain Mentor Graphics intellectual property licensed under this Agreement are located in Ireland and the United States. To promote consistency around the world, disputes shall be resolved as follows: excluding conflict of laws rules, this Agreement shall be governed by and construed under the laws of the State of Oregon, USA, if Customer is located in North or South America, and the laws of Ireland if Customer is located outside of North or South America. All disputes arising out of or in relation to this Agreement shall be submitted to the exclusive jurisdiction of the courts of Portland, Oregon when the laws of Oregon apply, or Dublin, Ireland when the laws of Ireland apply. Notwithstanding the foregoing, all disputes in Asia arising out of or in relation to this Agreement shall be resolved by arbitration in Singapore before a single arbitrator to be appointed by the chairman of the Singapore International Arbitration Centre ("SIAC") to be conducted in the English language, in accordance with the Arbitration Rules of the SIAC in effect at the time of the dispute, which rules are deemed to be incorporated by reference in this section. This section shall not

restrict Mentor Graphics' right to bring an action against Customer in the jurisdiction where Customer's place of business is located. The United Nations Convention on Contracts for the International Sale of Goods does not apply to this Agreement.

19. **SEVERABILITY.** If any provision of this Agreement is held by a court of competent jurisdiction to be void, invalid, unenforceable or illegal, such provision shall be severed from this Agreement and the remaining provisions will remain in full force and effect.

20. **MISCELLANEOUS.** This Agreement contains the parties' entire understanding relating to its subject matter and supersedes all prior or contemporaneous agreements, including but not limited to any purchase order terms and conditions. Some Software may contain code distributed under a third party license agreement that may provide additional rights to Customer. Please see the applicable Software documentation for details. This Agreement may only be modified in writing by authorized representatives of the parties. Waiver of terms or excuse of breach must be in writing and shall not constitute subsequent consent, waiver or excuse.

Rev. 100615, Part No. 246066