



# **HyperLynx<sup>®</sup> 3D EM Designer**

## **Quick Start Guide for Wire Bond Packages**

Release 15.2

---

**© 2009 - 2012 Mentor Graphics Corporation  
All rights reserved.**

This document contains information that is proprietary to Mentor Graphics Corporation. The original recipient of this document may duplicate this document in whole or in part for internal business purposes only, provided that this entire notice appears in all copies. In duplicating any part of this document, the recipient agrees to make every reasonable effort to prevent the unauthorized use and distribution of the proprietary information.

This document is for information and instruction purposes. Mentor Graphics reserves the right to make changes in specifications and other information contained in this publication without prior notice, and the reader should, in all cases, consult Mentor Graphics to determine whether any changes have been made.

The terms and conditions governing the sale and licensing of Mentor Graphics products are set forth in written agreements between Mentor Graphics and its customers. No representation or other affirmation of fact contained in this publication shall be deemed to be a warranty or give rise to any liability of Mentor Graphics whatsoever.

MENTOR GRAPHICS MAKES NO WARRANTY OF ANY KIND WITH REGARD TO THIS MATERIAL INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

MENTOR GRAPHICS SHALL NOT BE LIABLE FOR ANY INCIDENTAL, INDIRECT, SPECIAL, OR CONSEQUENTIAL DAMAGES WHATSOEVER (INCLUDING BUT NOT LIMITED TO LOST PROFITS) ARISING OUT OF OR RELATED TO THIS PUBLICATION OR THE INFORMATION CONTAINED IN IT, EVEN IF MENTOR GRAPHICS CORPORATION HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

#### **RESTRICTED RIGHTS LEGEND 03/97**

U.S. Government Restricted Rights. The SOFTWARE and documentation have been developed entirely at private expense and are commercial computer software provided with restricted rights. Use, duplication or disclosure by the U.S. Government or a U.S. Government subcontractor is subject to the restrictions set forth in the license agreement provided with the software pursuant to DFARS 227.7202-3(a) or as set forth in subparagraph (c)(1) and (2) of the Commercial Computer Software - Restricted Rights clause at FAR 52.227-19, as applicable.

**Contractor/manufacturer is:**

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](http://www.mentor.com)

SupportNet: [supportnet.mentor.com/](http://supportnet.mentor.com/)

Contact Your Technical Writer: [supportnet.mentor.com/doc\\_feedback\\_form](http://supportnet.mentor.com/doc_feedback_form)

**TRADEMARKS:** The trademarks, logos and service marks ("Marks") used herein are the property of Mentor Graphics Corporation or other third parties. No one is permitted to use these Marks without the prior written consent of Mentor Graphics or the respective third-party owner. The use herein of a third-party Mark is not an attempt to indicate Mentor Graphics as a source of a product, but is intended to indicate a product from, or associated with, a particular third party. A current list of Mentor Graphics' trademarks may be viewed at: [www.mentor.com/trademarks](http://www.mentor.com/trademarks).

**End-User License Agreement:** You can print a copy of the End-User License Agreement from: [www.mentor.com/eula](http://www.mentor.com/eula).

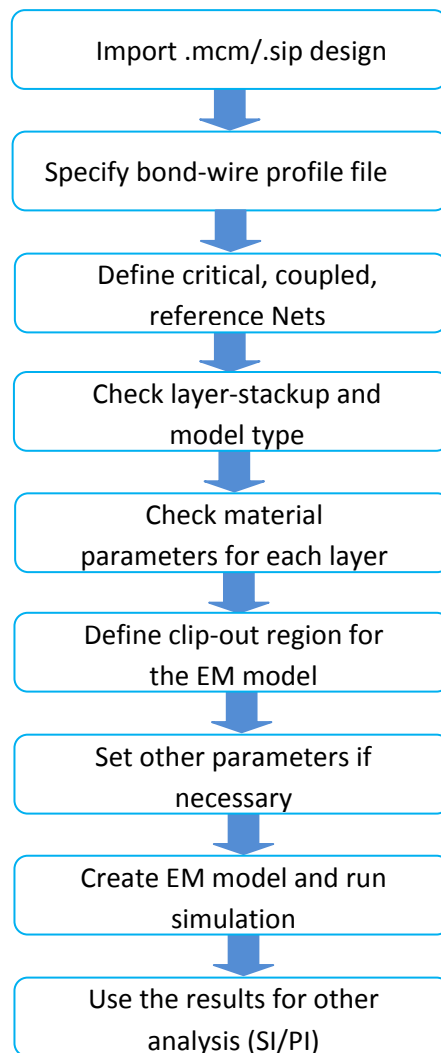
## OBJECTIVE OF GUIDE

The objective of this guide is to demonstrate how to import a bond-wire package database into **HyperLynx 3D EM Designer** for EM model extraction. A typical test case (*bond\_wire\_single\_die.mcm*) will be discussed in the following sections to exemplify the main features of **HyperLynx 3D EM Designer** covering thick model, HALO function, solder balls, bond wires, different types of nets as well as vias and ports.

## WHAT IS HyperLynx 3D EM Designer

**HyperLynx 3D EM Designer** is specially designed to fill the gap between IC packaging designers and circuit/signal integrity engineers. **HyperLynx 3D EM Designer** provides an interface to Cadence's Allegro Package Design and CDNSiP tools to enable a layout-to-EM-model flow. Circuit/IC designers without solid EM background can use **HyperLynx 3D EM Designer** to quickly generate EM models and obtain accurate EM simulation results.

## HyperLynx 3D EM Designer IMPORT FLOW

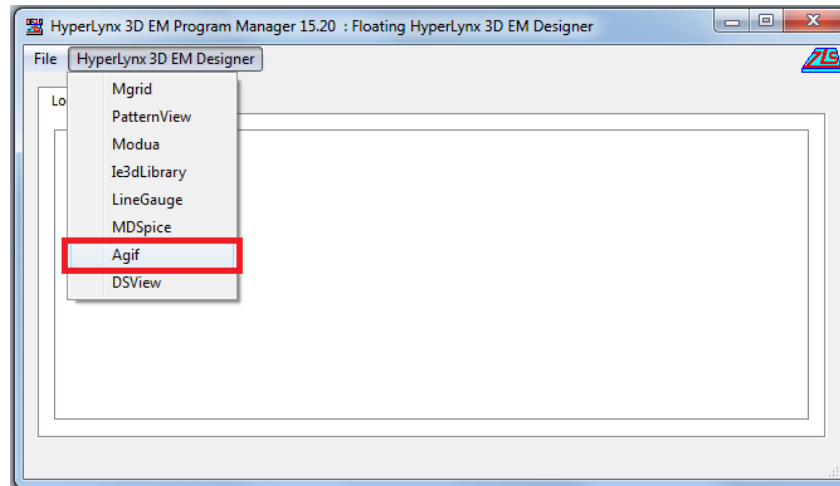


**Fig. 1 Automated Packaging Database to HyperLynx 3D EM Designer Flow**

You may refer to **AGIF\_Integration\_Guide.pdf** to add the **HyperLynx 3D EM Designer** menu item on the Cadence APD main menu

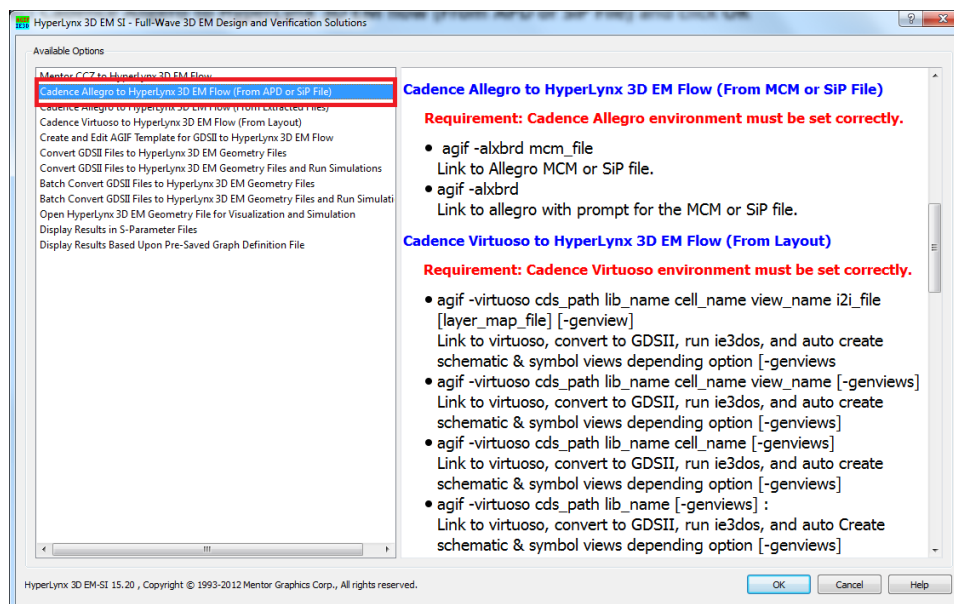
If your Cadence APD is on the same computer where **HyperLynx 3D EM Designer** is installed, please follow the steps below:

1. Navigate to **AGIF** on **HyperLynx 3D EM Designer Program Manager** as shown in the following picture:



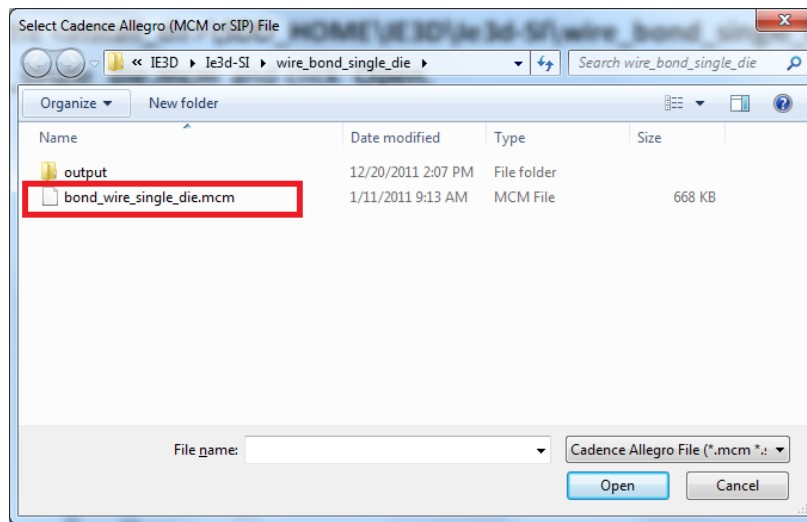
**Fig. 2 HyperLynx 3D EM Designer Program Manager**

2. Select **Cadence Allegro to HyperLynx 3D EM flow (From APD or SiP File)** and click **OK**



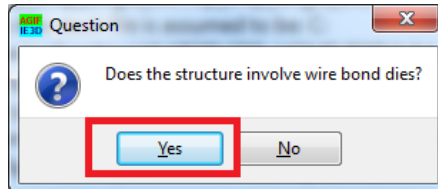
**Fig. 3 AGIF Main Menu**

3. Browse to the **<install\_dir>\SDD\_HOME\IE3D\ie3d-SI\wire\_bond\_single\_die\** directory and select **bond\_wire\_single\_die.mcm** and click **Open**.



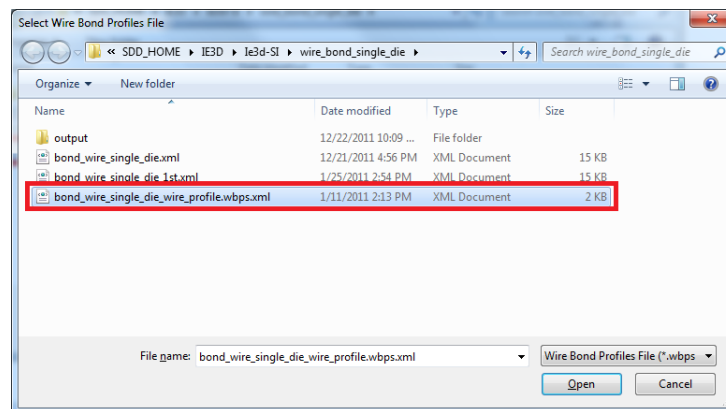
**Fig. 4 Select Package Data File**

- The following window appears asking if there are bond wires in the design:



**Fig. 5 Question about Bond Wire Information**

- Click Yes button to proceed since there are bond wires in the example, the program will prompt for the bond wire profile:



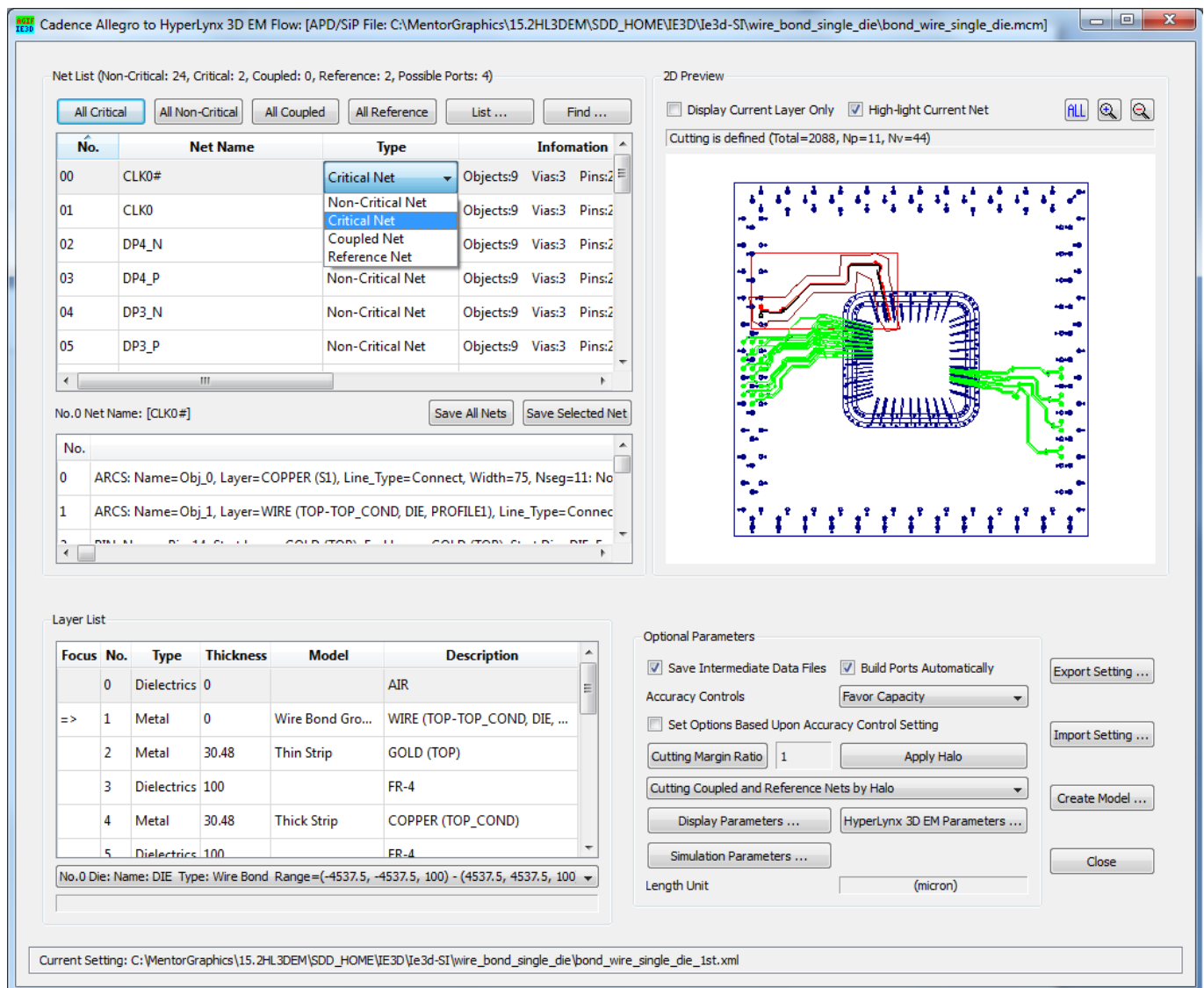
**Fig. 6 Bond Wire Profile File**

Note that the bond wire profile can be exported from APD and saved as a .xml file. Go to Cadence *APD main menu->Route->Wire Bond->Settings*, and click *View/Edit wire profiles* button, and then click *Save* button to save the profile in an appropriate location. For our case, the wire bond profile is the:

**wire\_bond\_single\_die\_wire\_profile.wbps.xml**

Select this file and click *Open* button

6. The following window will show up after the entire database has been successfully read into AGIF:



**Fig. 7 Imported Package Design with Bond Wires**

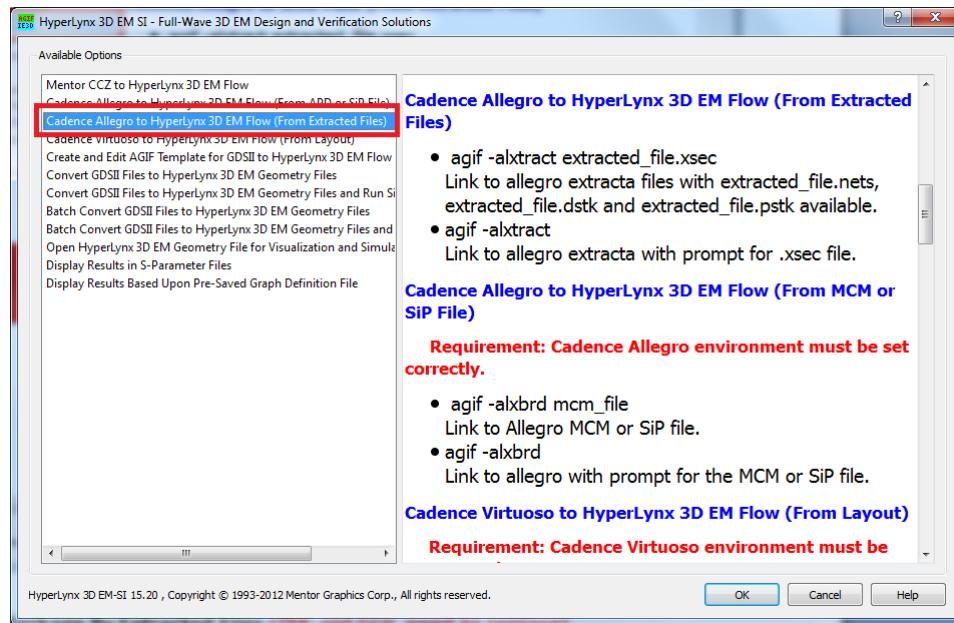
If your Cadence APD is not installed on the same computer where *HyperLynx 3D EM Designer* is installed, you can follow the steps below to import your Cadence .mcm/.sip design:

1. Extract necessary files by using Cadence EXTRACTA. The EXTRACTA normally is in \Cadence\SPB\_16.3\tools\pcb\bin\ . Open a Windows command line window, and use the following command to extract all necessary files:

```
extracta -c -q -r "X: \bond_wire_single_die.mcm" "X: \bond_wire_single_die.txt" "X: \bond_wire_single_die.xsec" "X: \bond_wire_single_die.nets" "X: \bond_wire_single_die.dstk" "X: \bond_wire_single_die.pstk"
```

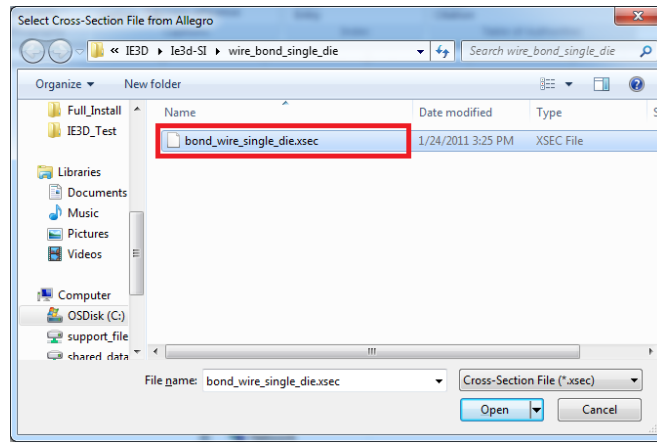
Totally four files will be generated with .xsec, .nets, .dstk and .psk extensions respectively. These four files will be used for importing the .mcm design in AGIF. Please remember the wire bond profile file should also be generated separately from Cadence APD as shown above.

2. Select **Cadence Allegro to HyperLynx 3D EM flow (From Extracted Files)** and click **OK**:



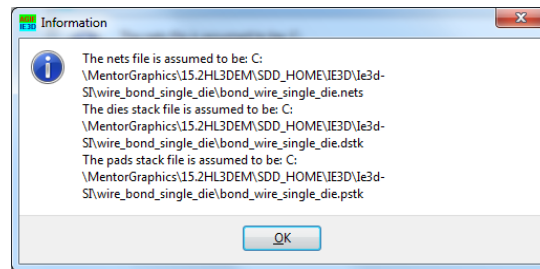
**Fig. 8 Import Package By Extracted Files**

3. Select .xsec file and click **OK**:



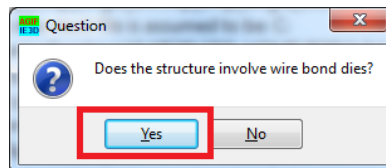
**Fig. 9 Select the .xsec file**

4. The program shows that all other three files are automatically used for importing data:



**Fig. 10 Information for Other Files**

5. Again, the program will ask if there are any bond wires in the design:



**Fig. 11 Query on Bond Wires**

6. Click Yes to proceed.
7. Select the bond wire profile as shown in Fig 6.
8. The imported structure should be showing up as shown in Fig. 7.

## **AGIF PARAMETER SETTINGS**

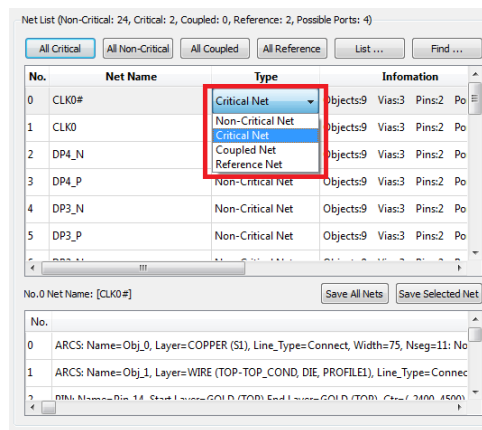
After the structure has been successfully imported into AGIF, some parameter settings need to be taken care of in order to get correct EM model:



- Define Critical/Coupled/Reference nets in the net list window
- Define layer type for each metal layer. Change material parameters if necessary
- Define other parameters, such as clip-out region by using HALO, simulation parameters etc.
- Define other geometry-handling parameters
- Create EM model

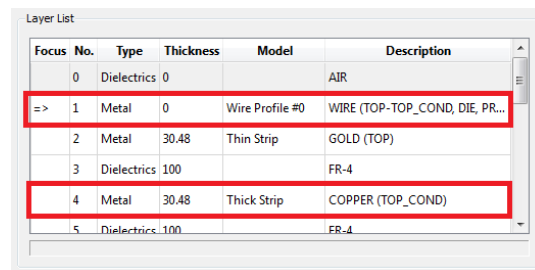
The Cadence APD/SiP to HyperLynx 3D EM flow has been further automated on version 15.2 to make the flow much easier and less confusing when extracting the EM model. The following paragraphs show how to define these parameters for the single-die bond wire example:

- Under *Netlist* section, select No.0 net “CLK0#” and No.1 net “CLK0” as **critical nets**, and No. 26<sup>th</sup> net “VSS” and No. 27<sup>th</sup> net “VDD” as **Reference Net** respectively. You may click “List...” button to get the complete list of the defined nets, or “Find...” button to search for a specific net by name.



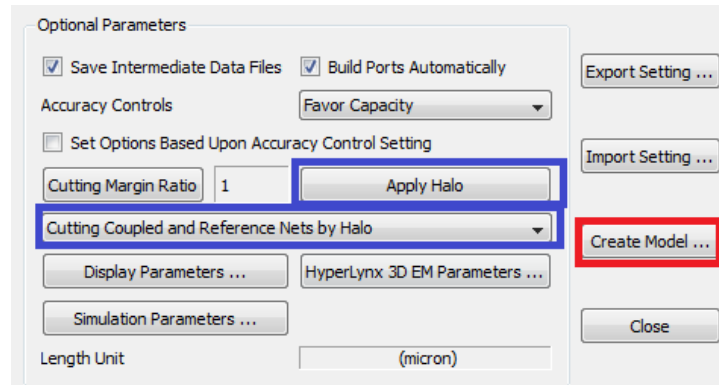
**Fig. 12 Define Net Types**

- In the *Layer List* window, click the combo box in *Type* column to define model type of each metal layer. As can be seen in Fig. 14, No. 1 layer has been automatically defined as bond wire layer. Metal layers can be either *Thin* or *Thick* type. If a metal layer is not intended to be included in the EM model, define it as *Void*. To change the material parameters of a metal or substrate layer, double click the layer and change the parameters in the material window. For this example, Layer 4, 6 and 14 should all be defined as *Thick* model since the thickness should be applied to traces to preserve high simulation accuracy:



**Fig. 13 Define Layer Type**

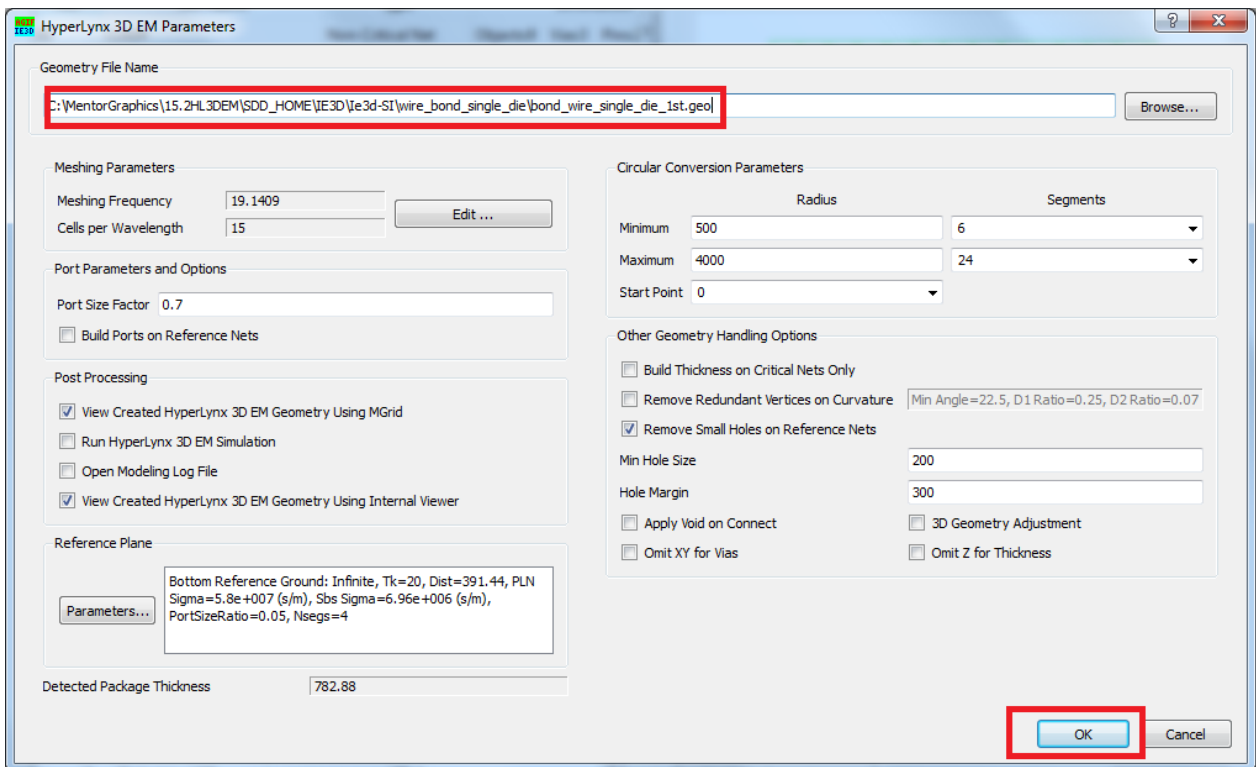
3. Define other parameters in the *Optional Parameters* region:



**Fig. 14 Optional Parameters**

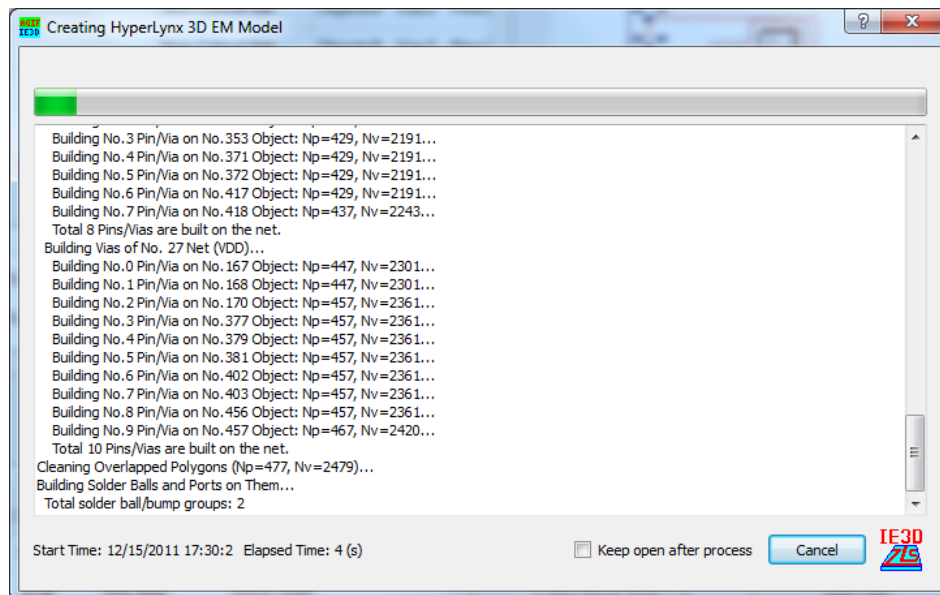
Optional parameters include *Display Parameters*, *HyperLynx 3D EM Designer Parameters*, *Simulation Parameters*, and EM model boundary parameters. Normally the default values/settings serve well for most structures. One useful function is the *HALO* function that automatically define the closest boundary surrounding the defined nets for optimal EM simulation region. User have options to define either rectangular clip-out region, or optimized region using *HALO* function. Please refer to *AGIF User Manual* for more details on these parameters.

4. Click *Create Full Model* button, and the *HyperLynx 3D EM Parameters* window will show up to let user double check if *HyperLynx 3D EM* parameters have been defined correctly. Click *OK* to proceed:



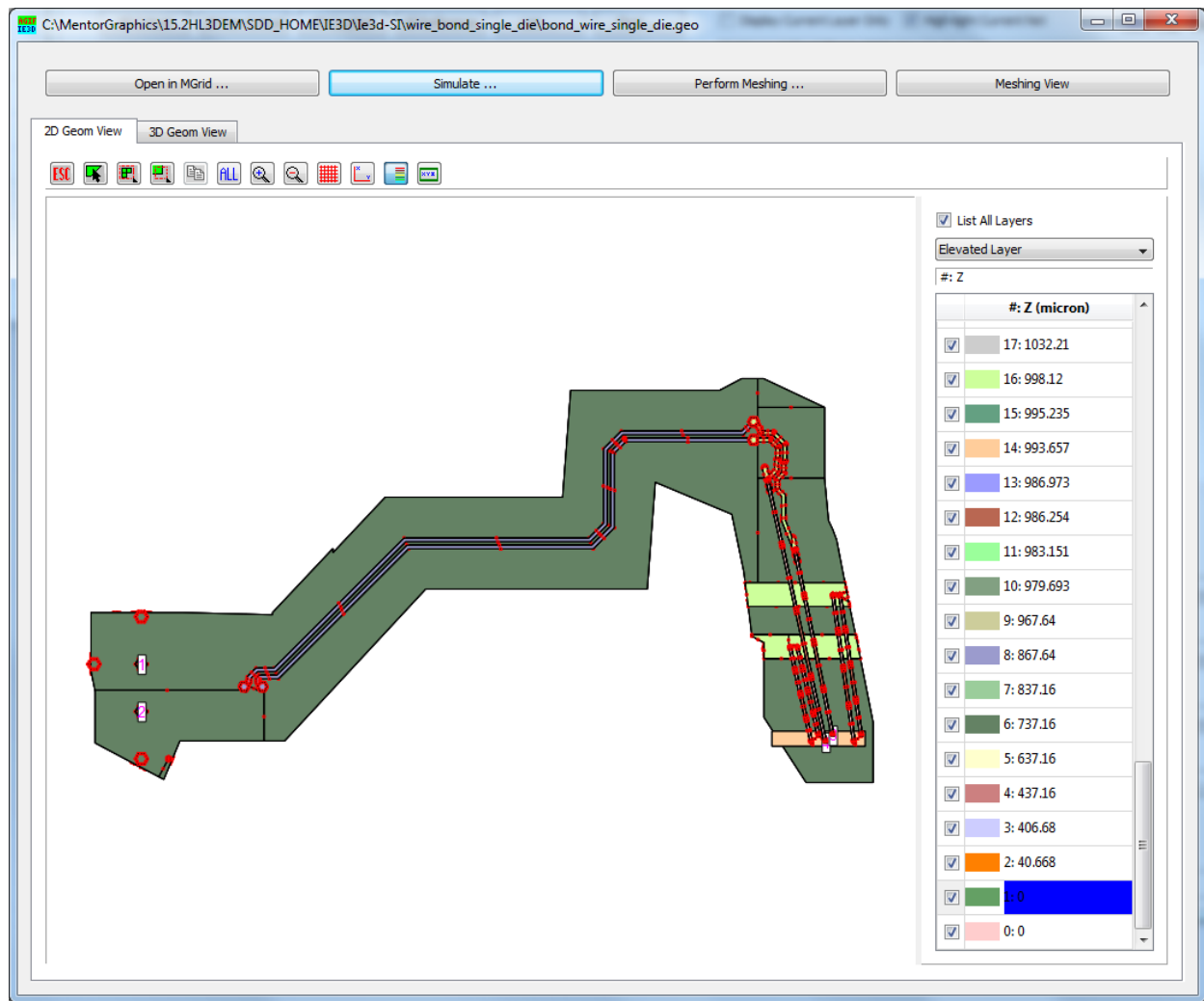
**Fig. 15 HyperLynx 3D EM Parameters**

5. A progress window will show up as follows:



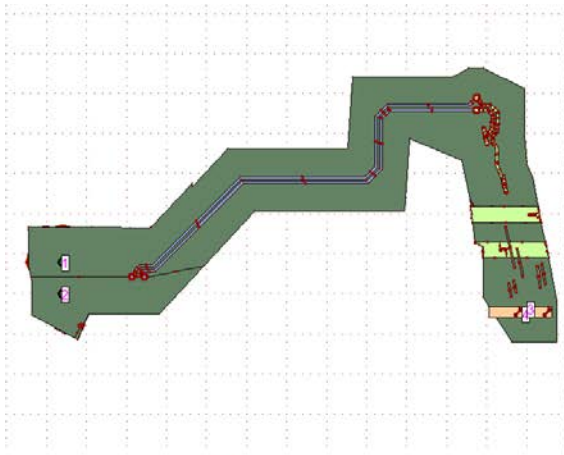
**Fig. 16 Progress of Model Creation**

After the whole process is completed, the created EM model will be automatically shown:

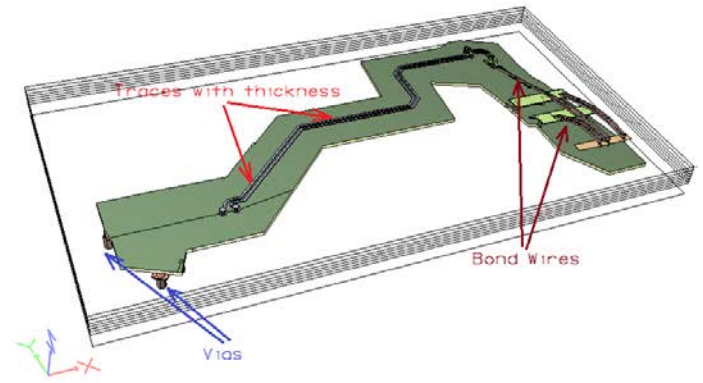


**Fig. 17 Created EM Model on QT Interface**

On Windows OS, the created EM model will also be automatically sent to MGrid for further modification if necessary. Users can launch simulations either from the interface shown in Fig. 17, i.e. QT interface, or from MGrid. The created model in MGrid is shown below:



2D Top View



3D View

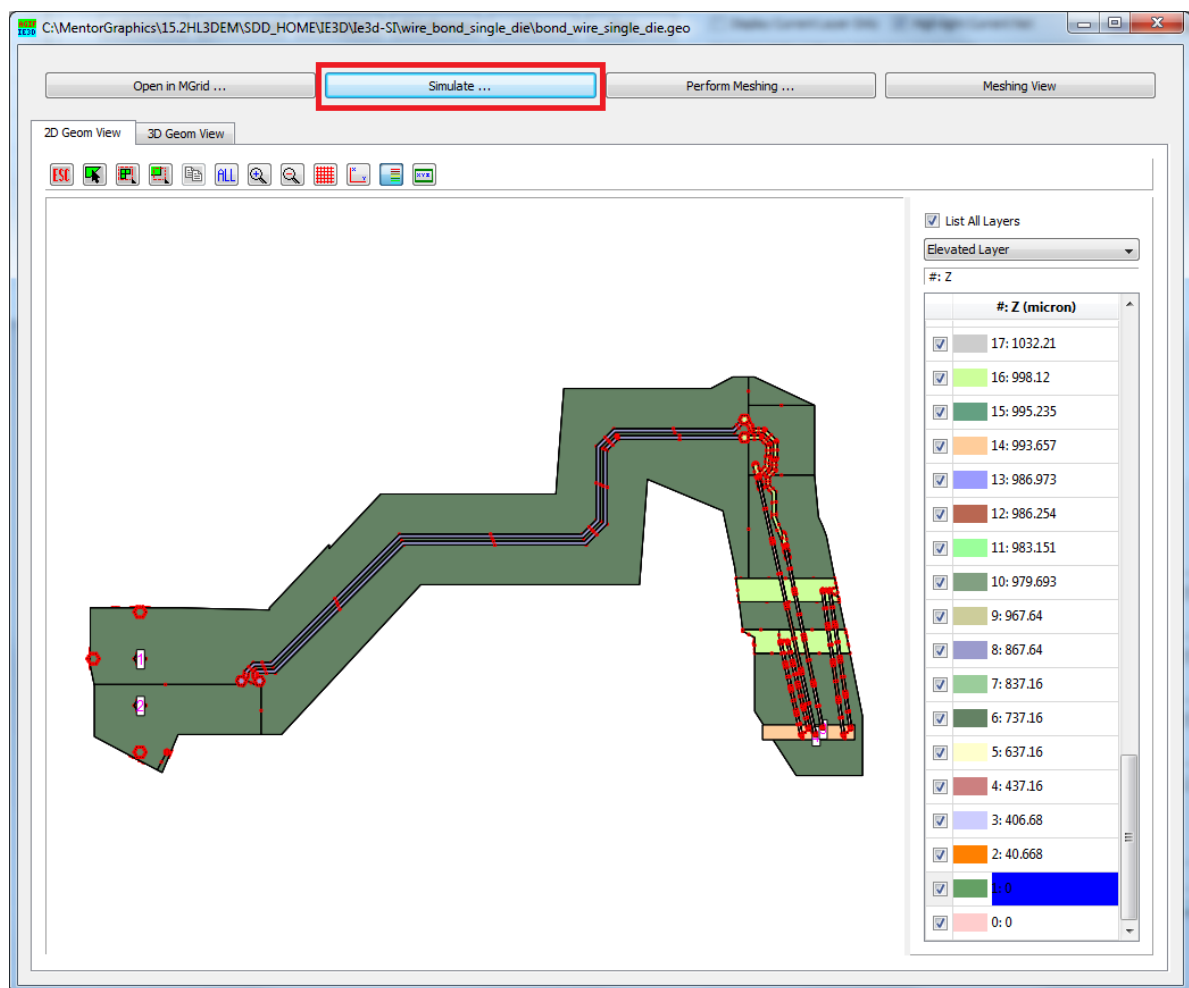
**Fig. 18 2D and 3D View of the Created EM Model**

As can be seen in the 3D view, the entire EM model has been automatically set up including 3D objects. The ports are also automatically created. The added reference plane, where bond wires land, representing the die layer in the original design is automatically created for terminating port 3 and port 4. The created structure can also be further edited in case, for example, some parts in the EM model are irrelevant and can be removed, or some necessary objects need to be added to the EM model.

## **HYPERLYNX 3D EM FULL-WAVE EM SIMULATION**

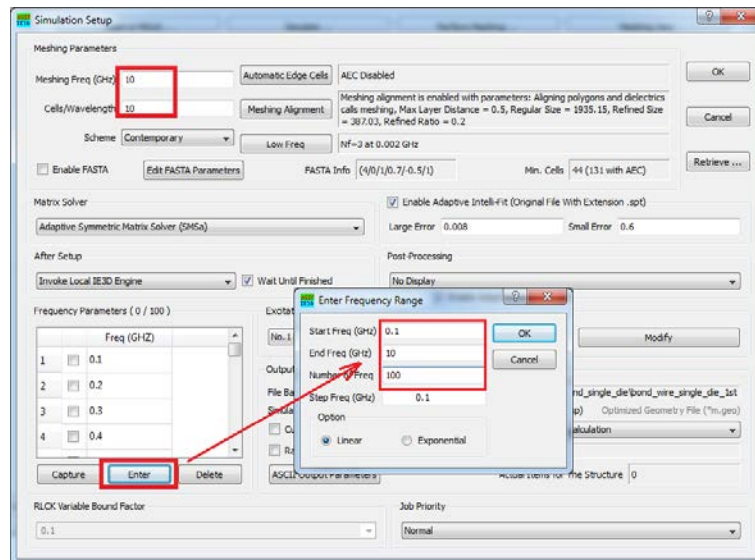
After the EM model has been successfully created, we are ready to simulate the structure. Basically the structure can be simulated through two interfaces: one is shown in Fig 17, the other is MGrid. The following paragraphs show the procedure of simulation via both interfaces:

### 1. QT Interface



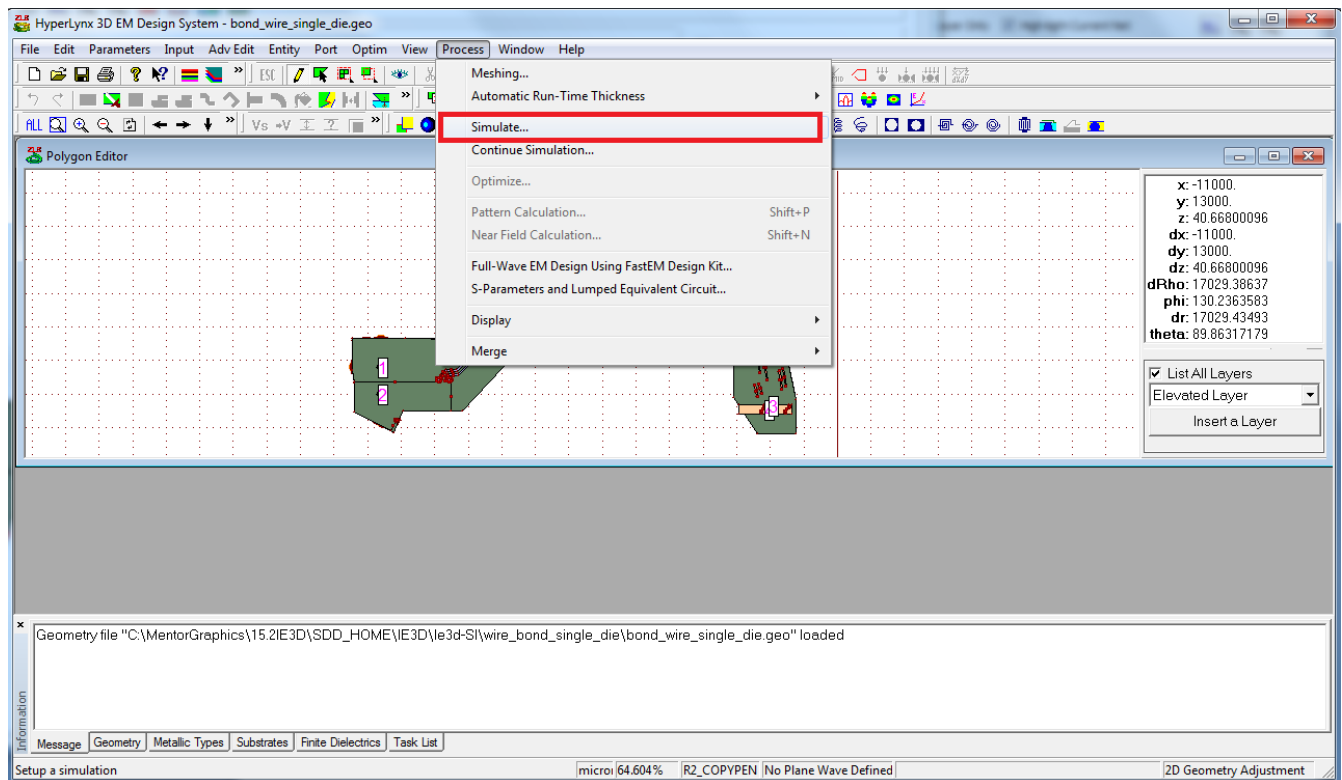
**Fig. 19 QT Interface**

Click the *Simulate* button on QT interface, and the *Simulation Setup* window will show up as shown below:



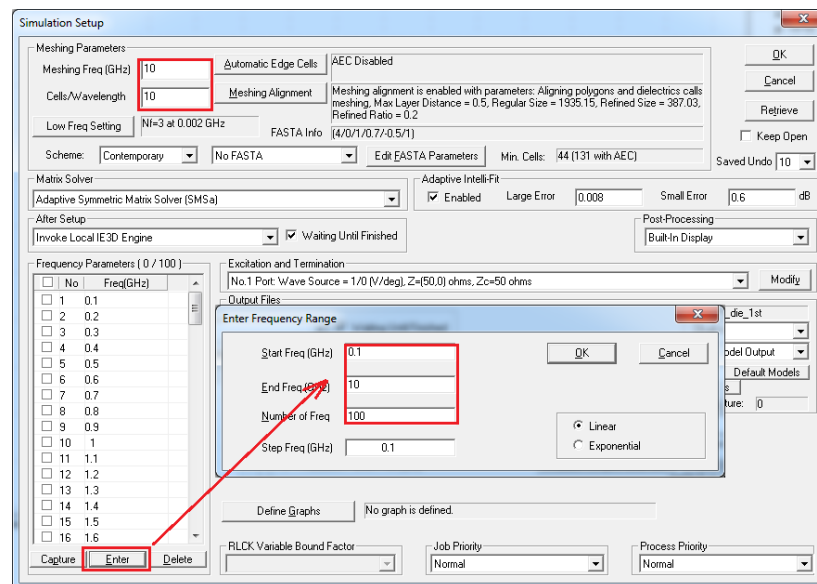
Enter **10** for both *Meshing Frequency* and *Cell/Wavelength*, which define how the structure will be meshed; then define the frequency range and number of frequencies in *Frequency Parameters* list box. Click the *Delete* button to delete all or some of the predefined frequency points, and click *Enter* button to redefine the frequency range and number in case that the predefined frequency range and number are not correct. For this case, we define the frequency range is from 0.1GHz to 10GHz, and 100 frequency points. Finally hit the *OK* button to start the simulation.

MGrid provides more sophisticated functions than the QT interface where the automatically created EM model can be edited and modified.



**Fig. 21 EM Model in MGrid**

Fig. 22 shows the EM model in MGrid. Go to *Process* and then *Simulate...*, a similar *Simulation Setup* window will show up as shown below:



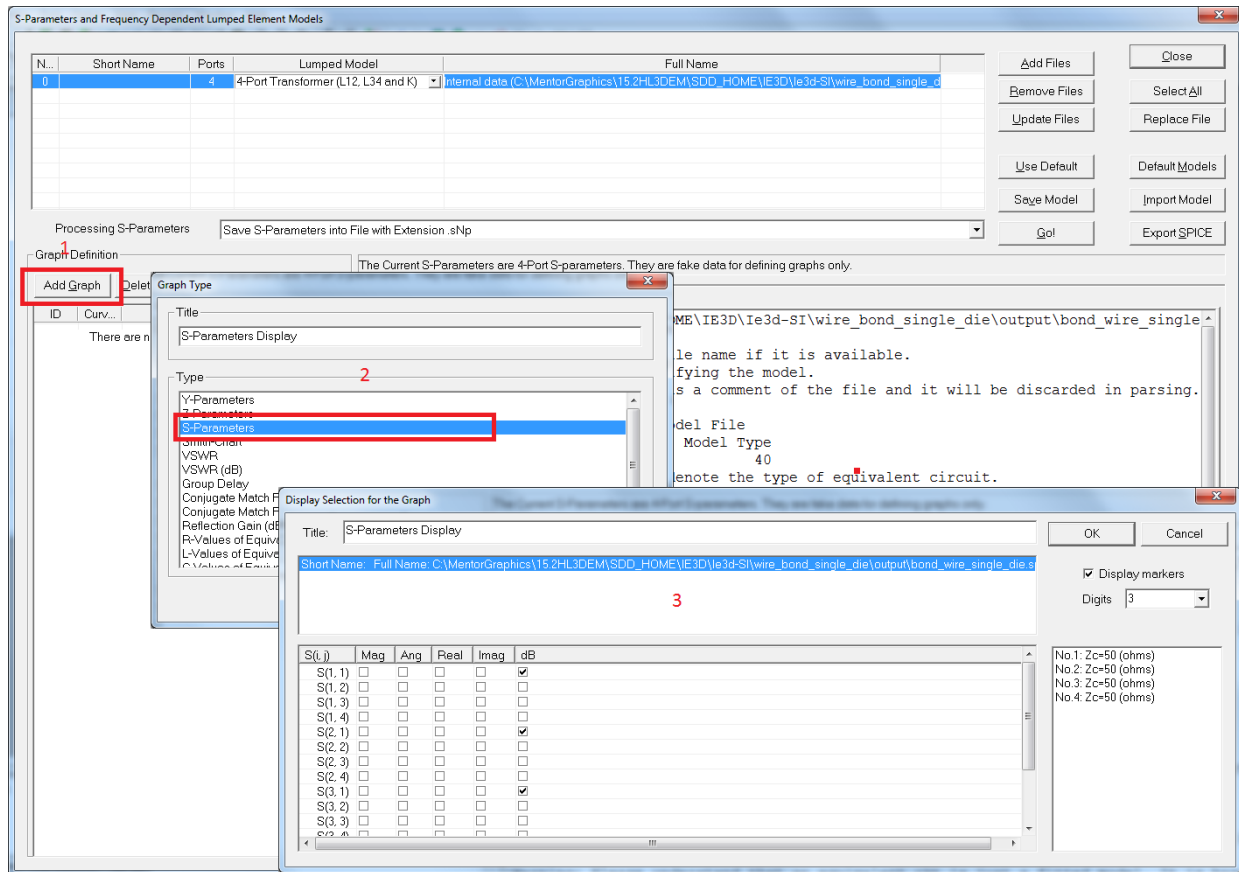
**Fig. 22 Simulation Setup Window in MGrid**

Use the same parameters as those shown in the QT simulation setup window to start the simulation.



## SIMULATION RESULTS POST-PROCESSING

Depending on the size of the problem and the computer hardware used for simulation, the total simulation time ranges from several minutes to hours. After the simulation is completed, the result window will automatically show up and wait for user's data post-processing:



**Fig. 23 How to Display Results**

**HyperLynx 3D EM Designer** provides a wide range of simulation results from a single simulation, for example, S-parameters, Z-parameters, Y-parameters, RLGC values of the equivalent circuit etc. Fig. 25 illustrates how to get the S-parameters of port 1:

- Click *Add Graph* button
- Highlight *S-parameters*
- Check  $S_{11}$ ,  $S_{21}$ ,  $S_{31}$ ,  $S_{41}$  in *dB* column
- Click *OK*
- Click *plot\_0* tab to see the S-parameters of port 1

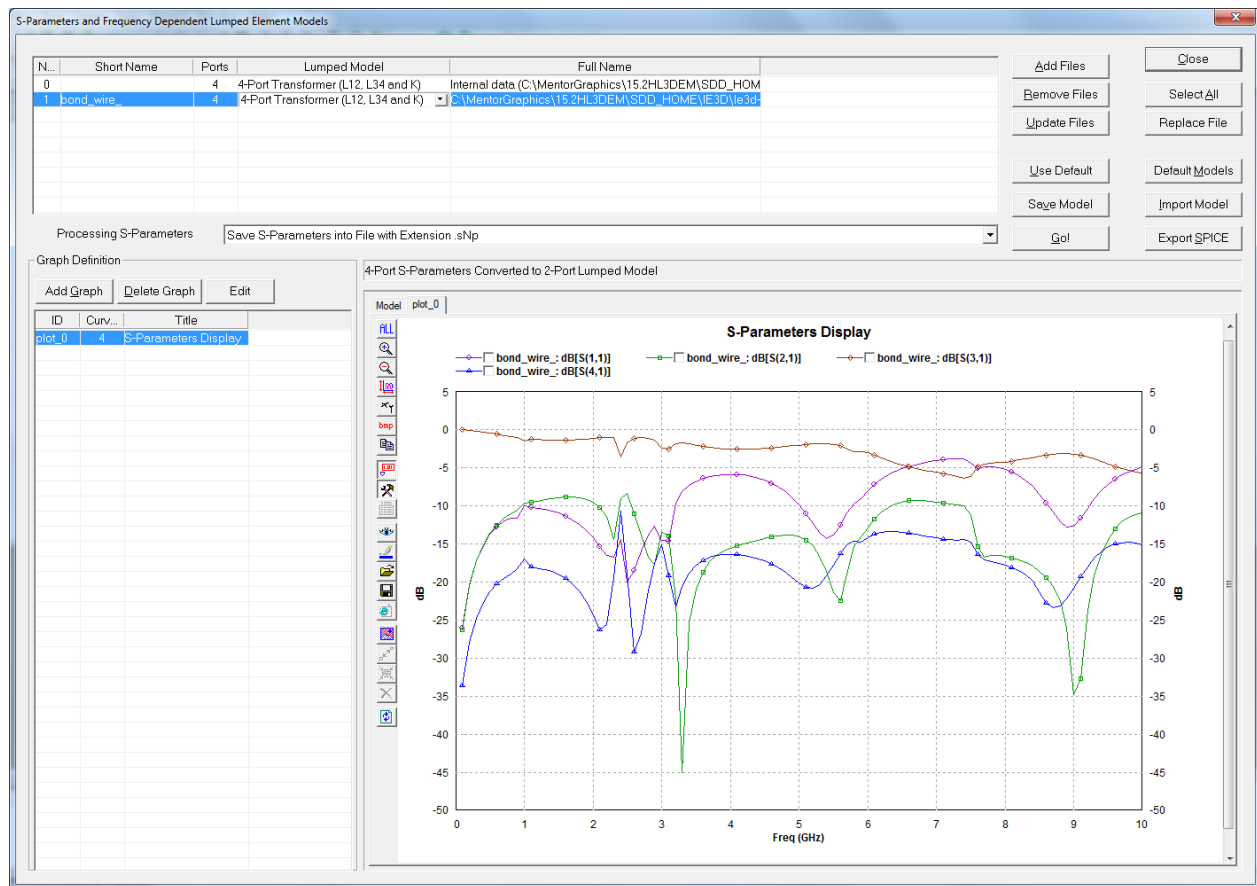
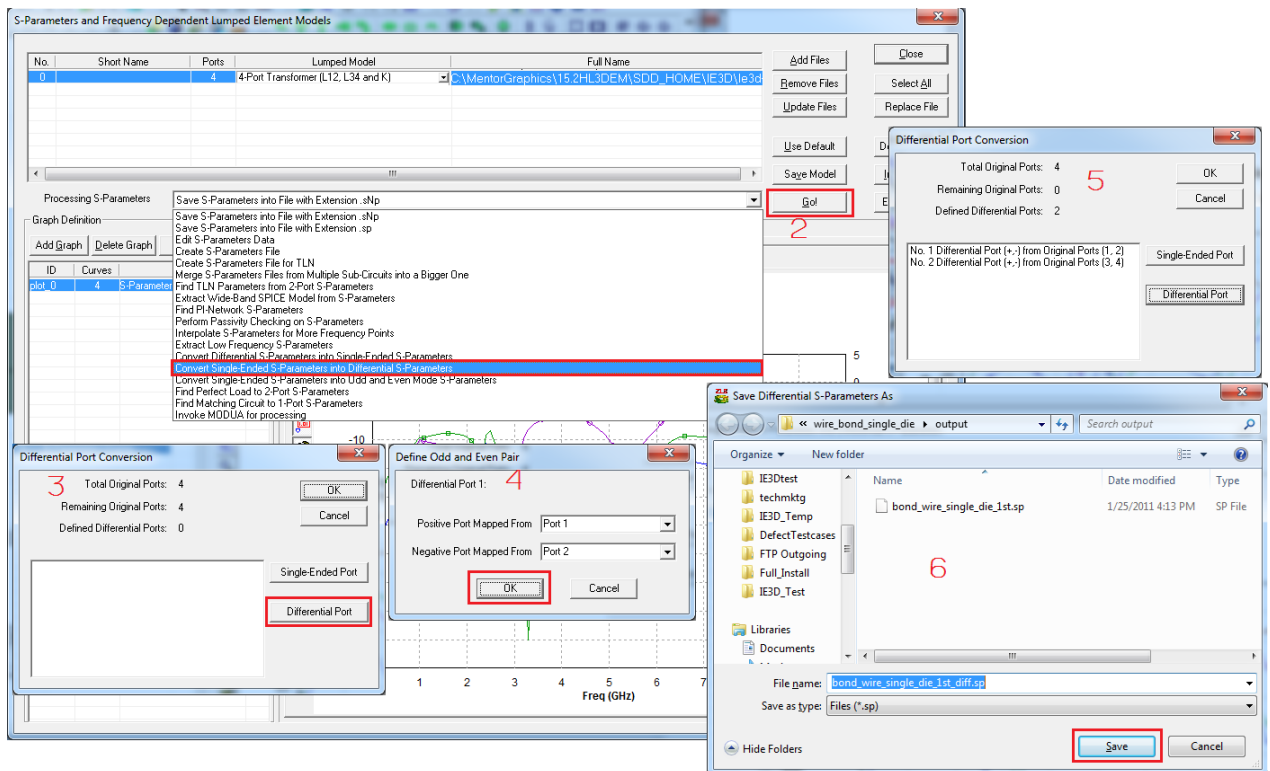


Fig. 24 S-parameters Display

### Single-ended Ports to Differential Ports Conversion

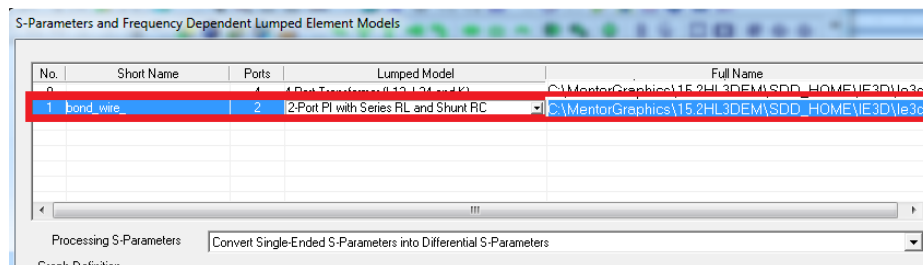
**HyperLynx 3D EM Designer** also provides a wide range of data processing functions, for example, single-ended to differential-pair conversion, SPICE model generation etc. These functions can be found in *S-parameter Processing* combo box:



**Fig. 25 Single-ended to Differential-pair Conversion**

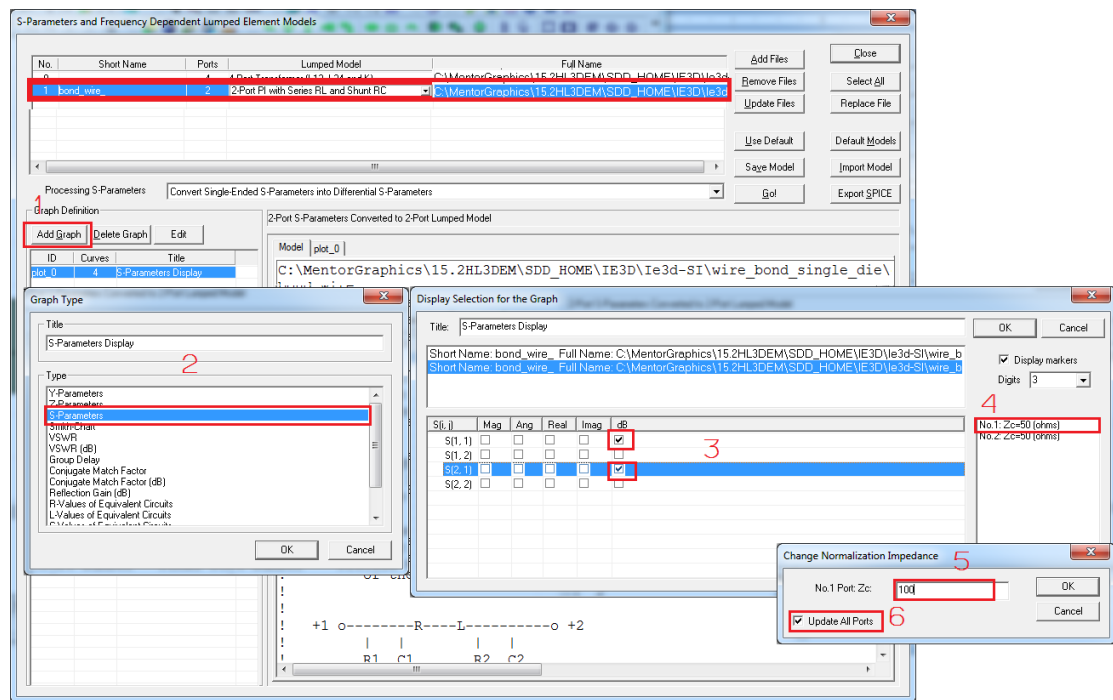
According to the original APD design,  $CLK0\#$  and  $CLK0$  are a differential pair. Therefore the simulation results of the four single-ended ports should be converted to two differential ports. Fig. 26 illustrates how to do the conversion:

- Choose *Convert Single-Ended S-parameters into Differential S-parameters* in the combo box
- Click *Differential Port* button, and choose the ports that need to be converted. For this case, Port1 and Port2 is a pair of differential port, and Port3 and Port4 is the other pair.
- After defining the differential pairs, the program will prompt user to save a new set of S-parameters in the project directory. Click *Save* button to exit to the result window:



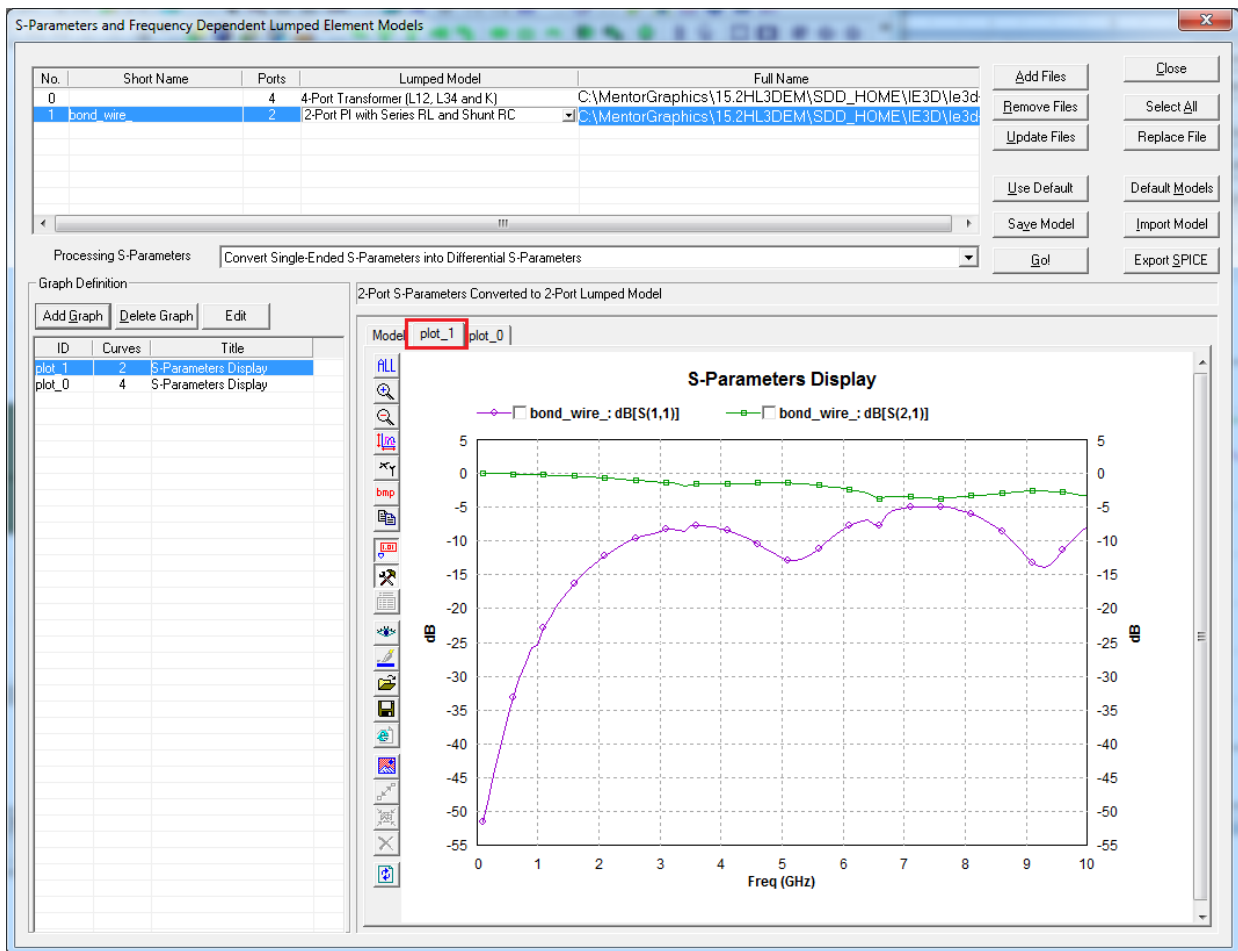
**Fig. 26 Added S-parameter File of the Differential Pair**

Now we are ready to show the new S-parameters of the differential pair. Fig. 27 shows the steps on displaying the new results:



**Fig. 27 Steps of Displaying New Results**

- Click *Add Graph* button.
- Highlight *S-parameters*.
- Choose *dB* values for  $S_{11}$  and  $S_{21}$ .
- Double click *No.1:  $Z_c=50$  (ohms)* to change the normalization impedance, and set the new impedance value to *100* ohms since the termination impedane for a differential pair is 100-ohm.
- Check *Update All Ports* checkbox.
- Click *OK*, and exit to the result window.
- Click *plot\_1* tab to see the new S-parameters:



**Fig. 28 S-parameters of the Differential Pair**

As can be seen in Fig. 28, the differential pair has some high attenuation at high frequency range from 6GHz to 10GHz that might cause serious signal loss. Also there is a resonance at about 6.6GHz point. The return loss from 5.8GHz to 8.7 GHz is above -10 dB that might need to be fine tuned. Whether the differential pair would have any signal integrity issues needs to be further investigated by looking at its time-domain response as well as eye pattern with a given time-domain source. Users are recommended to use *Mentor Graphics HyperLynx* to conduct time-domain analysis.

### **SPICE Equivalent Circuit**

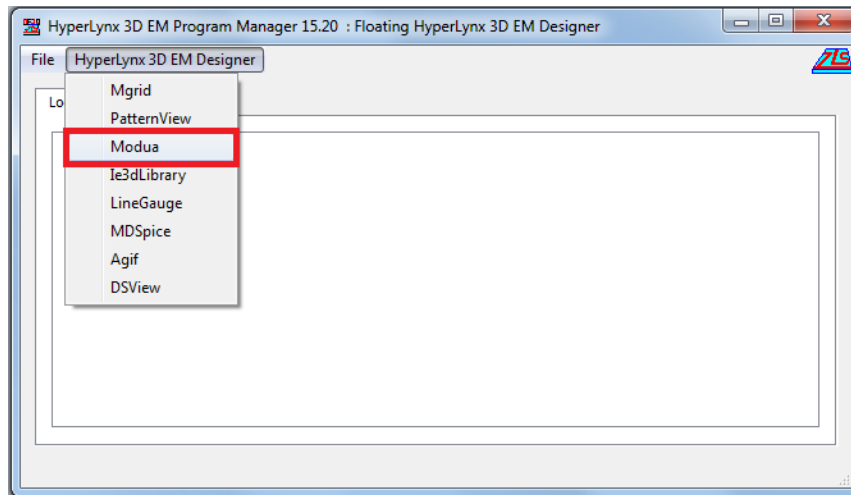
**HyperLynx 3D EM Designer** provides SPICE model extraction based on the simulated S-parameters. It is recommended to use the S-parameters directly in a SPICE simulator for wide band transient analysis. However, some designers may also want to use RLC equivalent circuit and perform SPICE simulation on the extracted RLC equivalent circuit.

Basically there are two types of SPICE equivalent circuit models users can obtain from **HyperLynx 3D EM Designer**:

- Low frequency RLC equivalent circuit with physical meaning, and

- Wide-band SPICE equivalent circuit without physical meaning

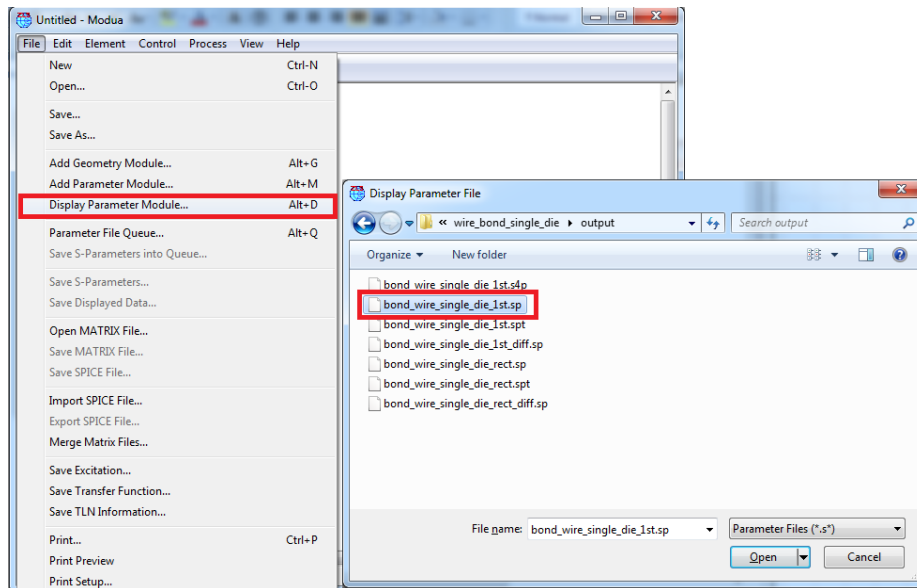
Both equivalent circuit can be obtained by using *Modua*



**Fig. 29 Modua On HyperLynx 3D EM Designer Program Manager**

(1) Low Frequency RLC Equivalent Circuit Extraction:

1. Launch *Modua* from **HyperLynx 3D EM Designer Program Manager** (see Fig. 29).



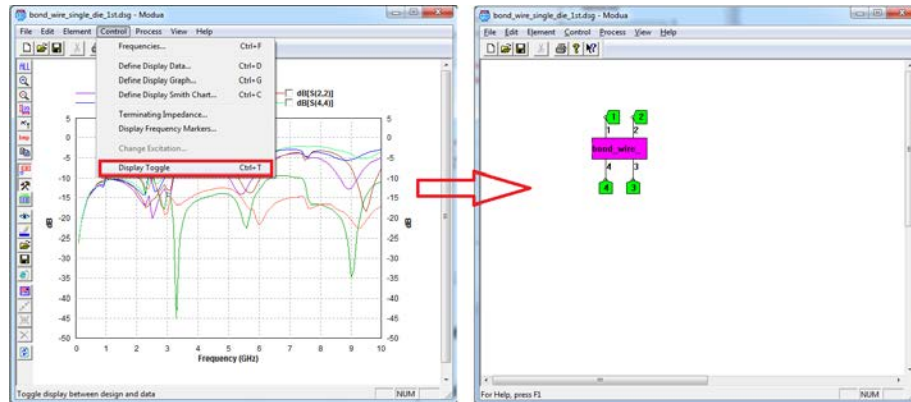
**Fig. 30 Modua Window for Displaying S-parameter File.**

2. Select **MODUA->File->Display Parameter Module** (see Fig. 30). Select the file:

.\SDD\_HOME\IE3D\Ie3d-SI\wire\_bond\_single\_die\output\ bond\_wire\_single\_die\_1st.sp.

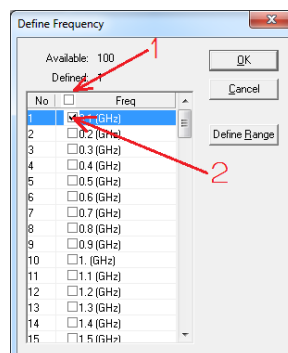
Modua is a utility for frequency-domain circuit simulation. It automatically sets up a black box for the 4-port S-parameter data block. You can see the S-parameters displayed on the window.

3. Select **Modua->Control->Display Toggle** and you will see the 4-port black box representing the 4-port S-parameters data on Modua.



**Fig. 31 S-parameters Display to Circuit Model**

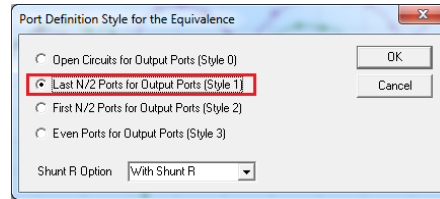
4. Select **Modua->Process->LC-Equivalent** command. Modua will prompt you the simulation results will be abandoned. Select **YES** to continue.
5. In the *Define Frequency* dialog, uncheck the the main check box to de-select all frequency points (see Fig. 33). Check the check box for *No.1: 0.1 GHz* frequency point. We are going to extract the RLC equivalent circuit at 0.1 GHz. Select **OK** to continue.



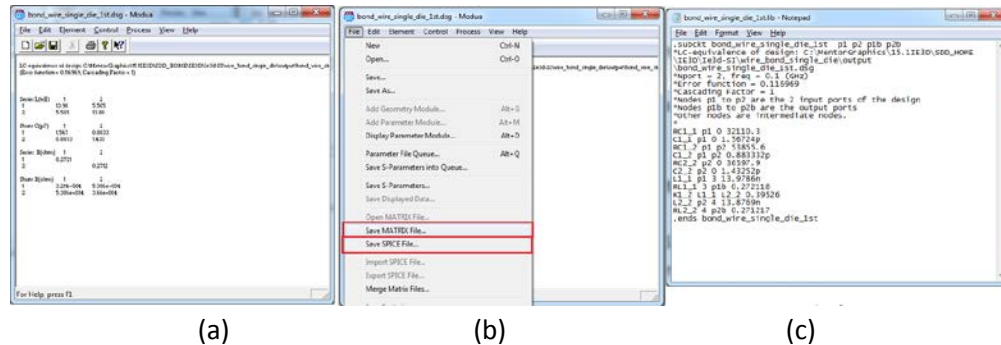
**Fig. 32 Select Frequency Point for SPICE Model Extraction**

6. Make sure the selection is *“First N/2 Ports for Output ports (Style 1)”* when Modua prompts you for *Port Definition Style for the Equivalence*. This command is to extract the RLC equivalent circuit of coupled interconnects. For our example, we have 4 ports or  $N = 4$ . Port 1 to port 3 is the 1<sup>st</sup> interconnect, while port 2 to port 4 is the 2<sup>nd</sup> interconnect. Port 1 and port 2 are the input ports of the coupled interconnects. Port 3

and port 4 are the output ports of the coupled interconnects. We are extracting the coupled RLC equivalent circuit from it (see Fig. 33).



**Fig. 33 Extracting Low Frequency RLC Equivalent Circuit on Modua**



**Fig. 34 Extracting RLC Equivalent Circuit of the Coupled Interconnects**

7. Select OK and Modua will extract the RLC and display the results in matrix form (see Fig. 34a). You can also select:

- **MODUA->FILE->Save MATRIX File** to save the data into the matrix form in an ASCII file (see Fig. 34b), or
- **MODUA->FILE->Save SPICE File** to save the data into a SPICE sub-circuit (see Fig. 34c). The SPICE data is saved into file: *bond\_wire\_single\_die.lib*. You can import the .lib file into other SPICE simulators to do circuit simulations.

## (2) Wide-Band SPICE Equivalent Circuit:

Wide-band SPICE equivalent circuit can be performed on S-parameters data on either Modua or on MGrid:

- On Modua, you can select *Process->General Lumped Equivalent Circuit*.
- On MGRID, you can open *Window->S-Parameters Display* button. Then, you can select *Export Spice* and choose *Wide Band Extraction*.

The elements of the extracted SPICE netlist do not have physical meaning. The subcircuit does not guarantee all the components are passive due to the fact of fitting an N-port S-parameters into some specific topology. Designers are strongly suggested to perform time-domain analysis directly on S-parameters by using *Mentor Graphics Hyperlynx*.



The example showing here is primarily for new **HyperLynx 3D EM Designer** AGIF users. For more details and advanced topics, please refer to **AGIF User Manual** where more complicated structures and more functionalities on AGIF will be discussed.

# End-User License Agreement

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