



HyperLynx[®] 3D EM

SpiralSyn for Windows User's Manual

An IE3DLibrary Spiral Module

Software Version 15.2

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Introduction to SpiralSyn for Windows

SpiralSyn is a spiral simulation and synthesis module integrated with IE3DLibrary.

SpiralSyn has the following useful features.

- SpiralSyn performs electromagnetic simulation and synthesis using IE3D.
- SpiralSyn has a friendly graphical user interface.
- SpiralSyn creates spiral objects and exports them to IE3D.
- SpiralSyn can be invoked from a spiral component layout as well.

SpiralSyn currently handles the following 7 spiral structures from inductors to transformers. In addition, it even handles interdigital and metal-insulator-metal (MIM) capacitors.

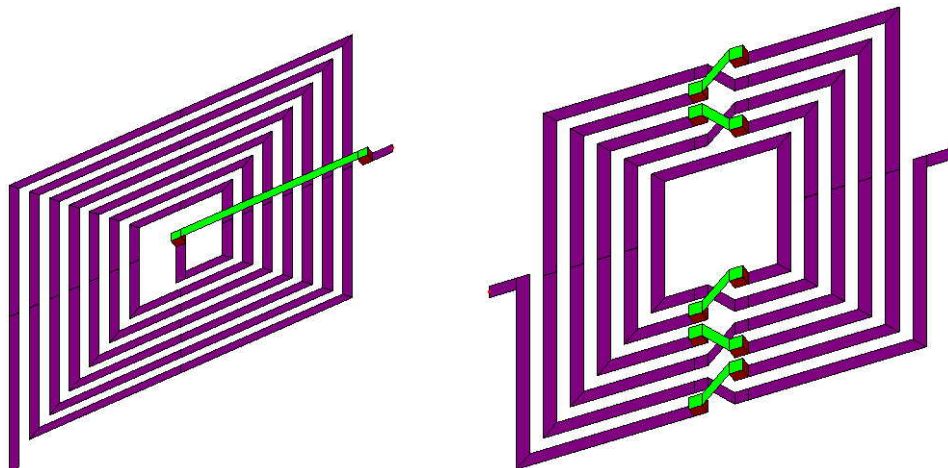
- Simulate and synthesize single-ended rectangular spiral inductors.
- Simulate and synthesize differential rectangular spiral inductors.
- Simulate and synthesize single-ended octagonal/polygonal spiral inductors.
- Simulate and synthesize differential octagonal/polygonal spiral inductors.
- Simulate and synthesize double-layer rectangular spiral inductors.
- Simulate partly bifilar rectangular spiral transformers.
- Simulate entirely bifilar rectangular spiral transformers.
- Simulate and synthesize interdigital capacitors.
- Simulate and synthesize metal-insulator-metal (MIM) capacitor.

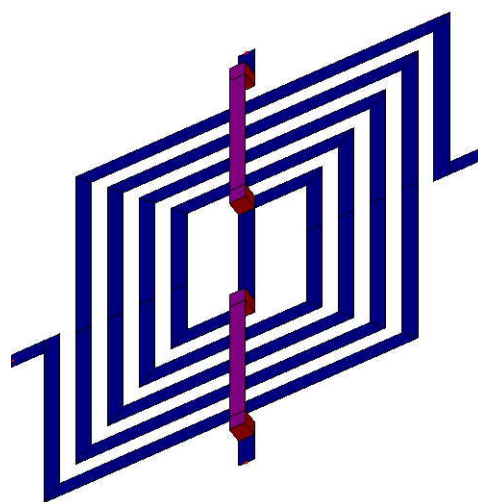
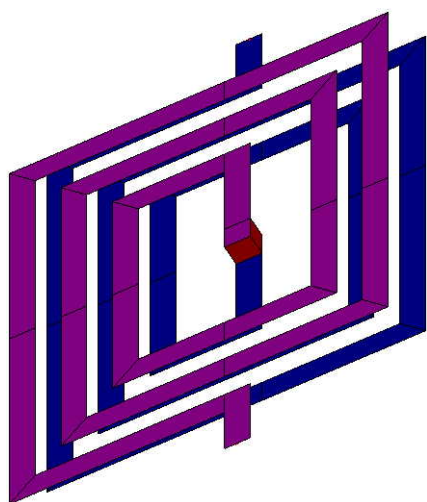
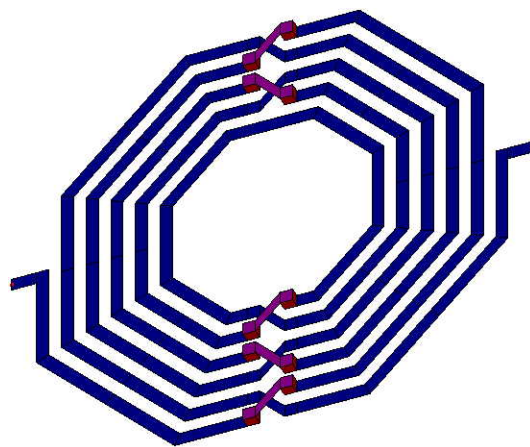
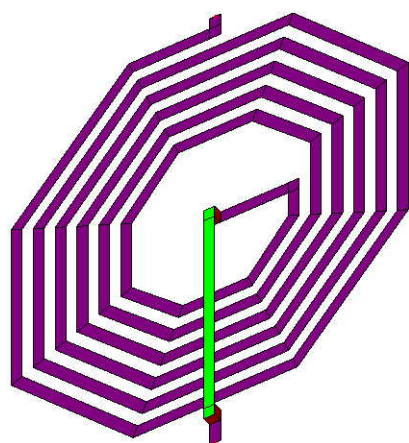
Installing SpiralSyn

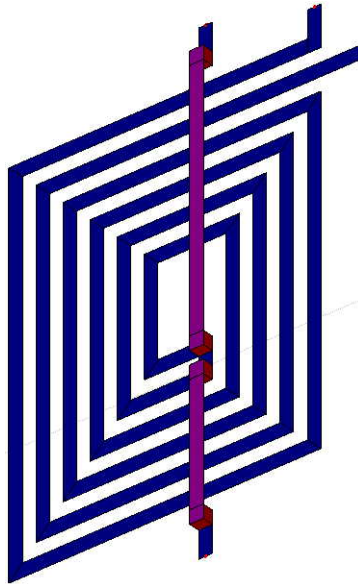
SpiralSyn is part of the IE3D product group and is included in a CD. Follow installation guide of IE3D product to install SpiralSyn.

SpiralSyn's Components

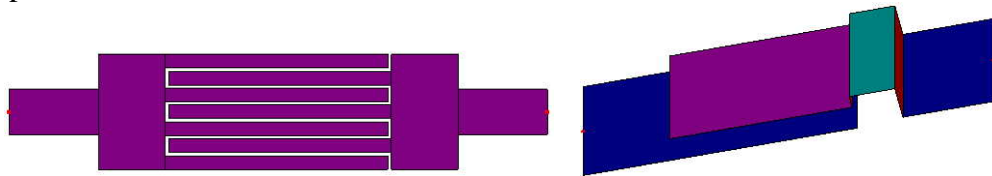
- Spirals



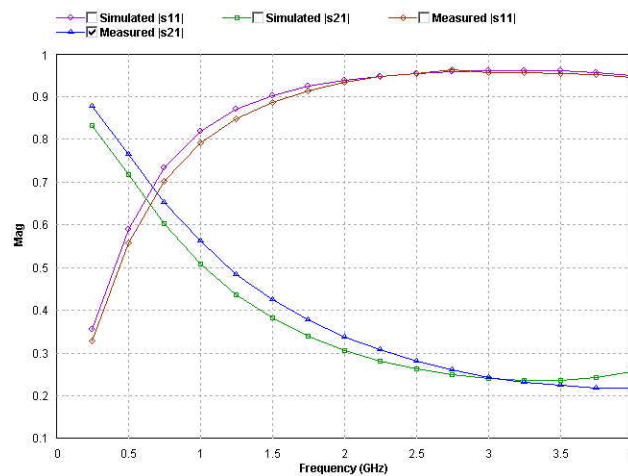




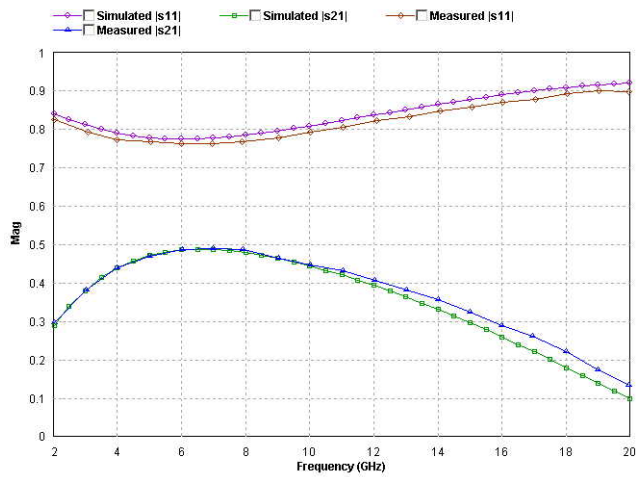
- Capacitors



Experimental Verification



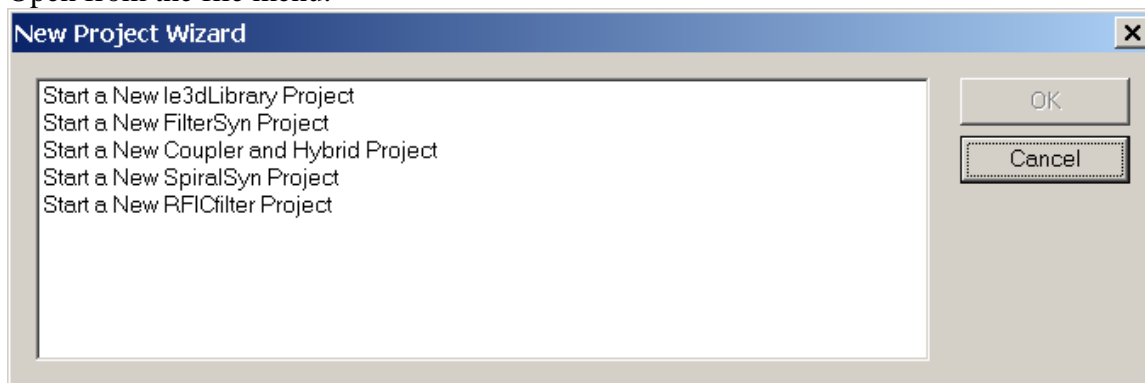
Simulated and measured response of a rectangular spiral inductor.



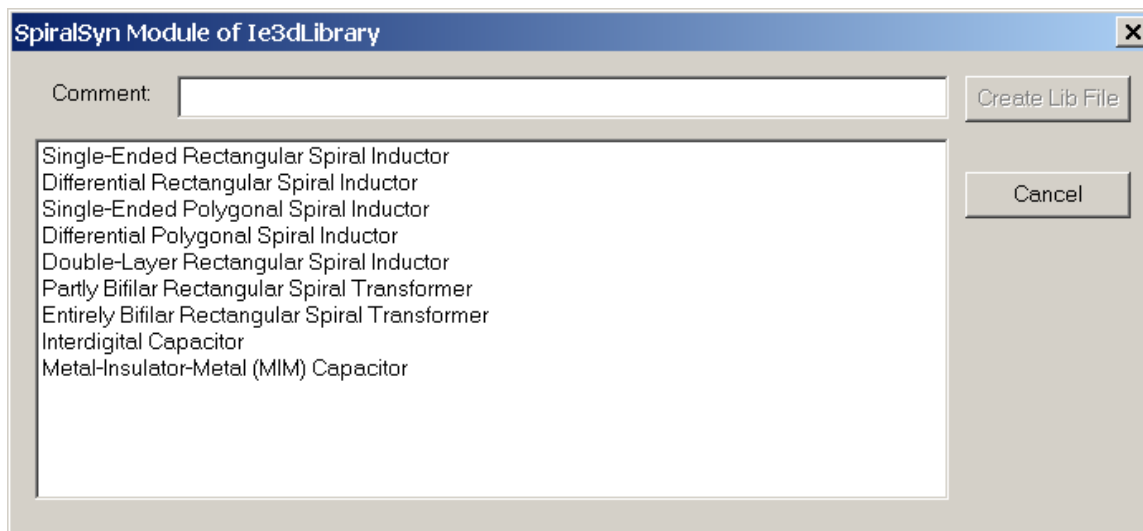
Simulated and measured response of a rectangular spiral transformer.

Using SpiralSyn

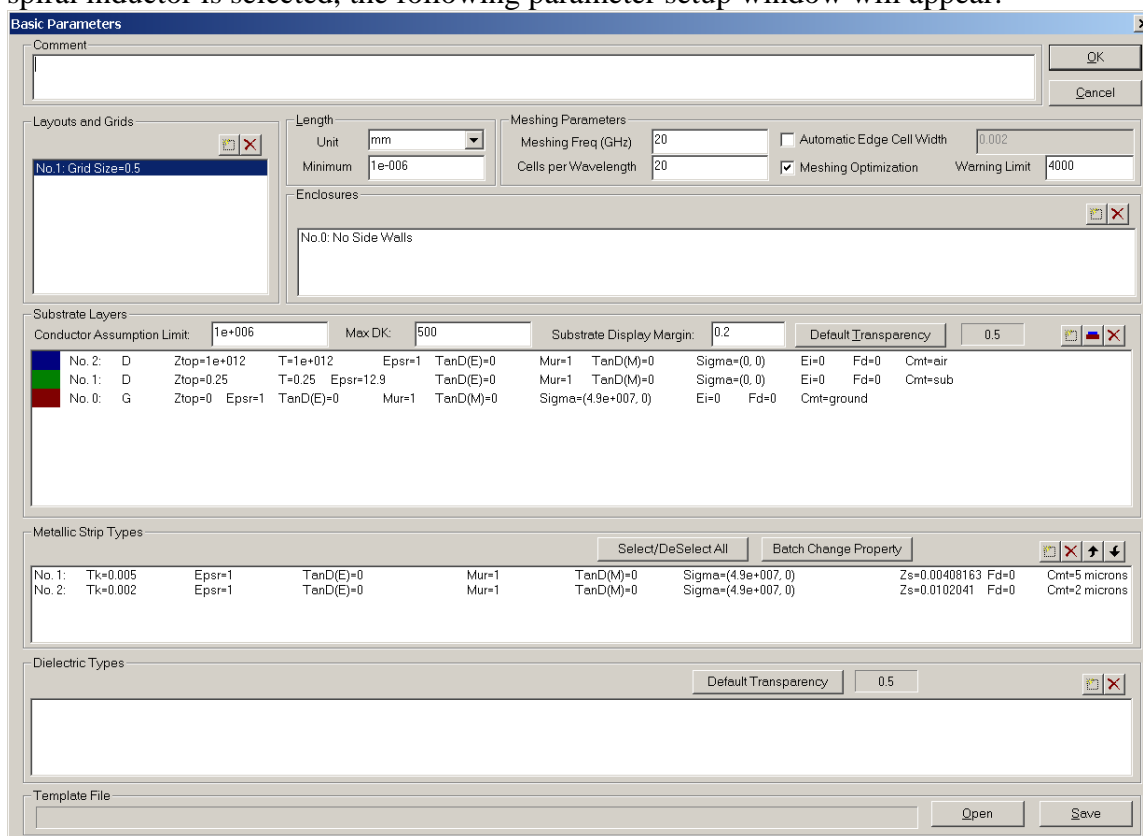
Once IE3DLibrary is started, you can select New from the file menu to display the following window. Or, if you want to modify or simply examine a previous project, you will be selecting Open from the file menu.



From the listed options, you can select one to start a new project. If you select the last option and click OK, you will have the following window.



From the list of SpiralSyn components, you can select one to perform analysis and synthesis. Although SpiralSyn looks like a tool dedicated to spiral synthesis, it also cover two popular RF IC capacitors, i.e., interdigital capacitors and metal-insulator-metal (MIM) capacitors. If the first spiral inductor is selected, the following parameter setup window will appear.



This is exactly IE3D's basic parameters setup window. It allows you to set up layout and grid, length unit, mesh parameters, dielectric layers, metal types, and other things. After setting up these basic parameters, clicking OK will produce the following SpiralSyn setup window.

Electromagnetic Simulation and Synthesis of Single-Ended Rectangular Spiral Inductor

Common Parameters

Basic Parameters Status: Modified Simulation Parameters

Comment: _____ AEC Enabled
AIF Enabled

Length Unit: (mm)

Spiral Strip Type: No. 1:ITk=0.005IEpsr=1ITanD(E)=0IMur=1ITanD(M)=0ISigma=(4.9e+007, 0)IZs=0.00408163IFd: _____

Bridge Strip Type: No. 1:ITk=0.005IEpsr=1ITanD(E)=0IMur=1ITanD(M)=0ISigma=(4.9e+007, 0)IZs=0.00408163IFd: _____

Preselected Parameters

Spiral @z=: 0.25
Bridge @z=: 0.26
Strip Width: 0.02
Gap Width: 0.02
Width of 1st Rectangle: 0.205
Length of 1st Rectangle: 0.205
Design Freq f(GHz): 2

Spiral Type

☒ Clockwise ☐ Counterclockwise

Starting from

☐ Center of Rectangle
☒ Middle of Side
☐ Corner of Rectangle

Pass Direction

☐ 90 Degrees
☐ 180 Degrees
☒ 270 Degrees

Calculated Performance

Freq(GHz)	Turns	PassDir	L(nH)	Q

Clear Results
Save Results
Graph Results

Job to be Performed

☒ Simulation ☐ Synthesis

Given or Synthesized Turns

Turns (round to 1/8): 7.125

Single Simulation

Simulate at f

Swept Simulation

Start Freq f1(GHz): 0.25
Stop Freq f2(GHz): 4
Freq Points: 16
Simulate over range

Synthesis Parameters

Target Inductance at f (nH): 5
Maximum Turns: 8
Synthesize

Preview

From this window, you can enter your desired parameters and let SpiralSyn do simulation or synthesis. Use of edge cells gives higher accuracy at the expense of longer computation time. Although the default settings for Automatic Edge Cell (AEC) and Automatic Intelli-Fit (AIF) are both enabled, one can disable AEC by clicking the button **Simulation Parameters** during synthesis of a spiral to save time. Let's use the default single-ended rectangular spiral inductor shown in the figure above as an example. Suppose we use the default data in the dialog and want to do a single simulation using edge cells. We just click the button **Simulate at f**. After a while, the simulation results will be shown in the table in the same dialog window. Portion of the window is shown below.

Preselected Parameters

Spiral @z= 0.25
 Bridge @z= 0.26
 Strip Width 0.02
 Gap Width 0.02
 Width of 1st Rectangle 0.205
 Length of 1st Rectangle 0.205
 Design Freq f(GHz) 2

Job to be Performed

☒ Simulation ☐ Synthesis

Given or Synthesized Turns

Turns (round to 1/8) 7.125

Single Simulation

Simulate at f

Spiral Type

☒ Clockwise ☐ Counterclockwise

Starting from

☐ Center of Rectangle ☒ Middle of Side ☐ Corner of Rectangle

Pass Direction

☐ 90 Degrees ☐ 180 Degrees ☒ 270 Degrees

Calculated Performance

Freq(GHz)	Turns	PassDir	L(nH)	Q
2	7.125	270	24.8482	72.136

Clear Results
Save Results
Graph Results

Preview

Similarly, if we want to do a swept simulation, we would enter **Start Freq**, **Stop Freq**, and **Freq Points** and click the button **Simulate over range** instead of **Simulate at f**. For the same example, swept simulation using the default parameters gives results as shown below.

Preselected Parameters

Spiral @z= 0.25
 Bridge @z= 0.26
 Strip Width 0.02
 Gap Width 0.02
 Width of 1st Rectangle 0.205
 Length of 1st Rectangle 0.205
 Design Freq f(GHz) 2

Job to be Performed

☒ Simulation ☐ Synthesis

Given or Synthesized Turns

Turns (round to 1/8) 7.125

Single Simulation

Simulate at f

Swept Simulation

Start Freq f1(GHz) 0.25
 Stop Freq f2(GHz) 4
 Freq Points 16
 Simulate over range

Spiral Type

☒ Clockwise ☐ Counterclockwise

Starting from

☐ Center of Rectangle ☒ Middle of Side ☐ Corner of Rectangle

Pass Direction

☐ 90 Degrees ☐ 180 Degrees ☒ 270 Degrees

Calculated Performance

Freq(GHz)	Turns	PassDir	L(nH)	Q
0.25	7.125	270	26.6773	12.
0.5	7.125	270	26.4871	23.
0.75	7.125	270	26.343	33.
1	7.125	270	26.1768	42.
1.25	7.125	270	25.9645	50.
1.5	7.125	270	25.6867	57.

Clear Results
Save Results
Graph Results

Preview

To synthesize a spiral, we would check **Synthesis** radio button instead of the **Simulation** one. After checking **Synthesis** as the job type, we can enter our target inductance and allowable maximum number of turns and then click **Synthesize** button to start the synthesis. If we simply use all the default parameters with the single-ended rectangular spiral inductor but disable AEC to do a synthesis, we will see the synthesis process that searches the appropriate number of turns between the minimum (1) and the maximum entered. Note that once the simulation of the one-turn spiral is complete, the results are shown immediately in the table and the number of turns is changed to the maximum for the next simulation. This is why the results are for the one-turn spiral while the preview is for the ten-turn one for a while. This process will go on until the

target is met within the tolerance of number of turns. Note also that the maximum number of turns may result in a small or even negative inductance and fail the synthesis. In this case, it is most likely that the spiral of so many turns exhibits a resonance below the design frequency. To avoid this, one needs to reduce the maximum number of turns or change the preselected dimensions. The following shows the final results.

Electromagnetic Simulation and Synthesis of Single-Ended Rectangular Spiral Inductor

Common Parameters

Basic Parameters Status: Modified Simulation Parameters

Comment: _____

Length Unit: (mm)

Spiral Strip Type: No. 1: $ITk=0.005IEpsr=1ITanD(E)=0IMur=1ITanD(M)=0ISigma=(4.9e+007, 0)IZs=0.00408163IFd=$

Bridge Strip Type: No. 1: $ITk=0.005IEpsr=1ITanD(E)=0IMur=1ITanD(M)=0ISigma=(4.9e+007, 0)IZs=0.00408163IFd=$

Preselected Parameters

Spiral @z= 0.25

Bridge @z= 0.26

Strip Width 0.02

Gap Width 0.02

Width of 1st Rectangle 0.205

Length of 1st Rectangle 0.205

Design Freq f(GHz) 2

Spiral Type

☒ Clockwise

☐ Counterclockwise

Starting from

☐ Center of Rectangle

☒ Middle of Side

☐ Corner of Rectangle

Pass Direction

☐ 90 Degrees

☒ 180 Degrees

☐ 270 Degrees

Calculated Performance

Freq(GHz)	Turns	PassDir	L(nH)	Q
2	1	90	0.976025	32.
2	8	90	30.1711	11.
2	4.5	180	10.5506	63.
2	2.75	180	4.14755	48.
2	3.625	180	6.98733	57.
2	3.125	180	5.38672	53.

Clear Results

Save Results

Graph Results

Job to be Performed

☐ Simulation

☒ Synthesis

Given or Synthesized Turns

Turns (round to 1/8) 3

Single Simulation

Simulate at f

Swept Simulation

Start Freq f1(GHz) 0.25

Stop Freq f2(GHz) 4

Freq Points 16

Simulate over range

Synthesis Parameters

Target Inductance at f (nH) 5

Maximum Turns 8

Synthesize

Preview

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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 **HAZARDOUS APPLICATIONS** 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 **HAZARDOUS APPLICATIONS**. THE PROVISIONS OF THIS SECTION **INDEMNIFICATION** 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 Mentor Graphics will defend or settle, at its option and expense, any action brought against Customer in the United States, Ca 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 **INFRINGEMENT** IS SUBJECT TO SECTION **LIMITATION OF LIABILITY** 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 FLEXIm 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 **REVIEW OF LICENSE USAGE** 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.

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