



OpenAMP Framework Performance Measurements Guide

**© 2011-2014 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 HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

U.S. GOVERNMENT LICENSE RIGHTS: The software and documentation were developed entirely at private expense and are commercial computer software and commercial computer software documentation within the meaning of the applicable acquisition regulations. Accordingly, pursuant to FAR 48 CFR 12.212 and DFARS 48 CFR 227.7202, use, duplication and disclosure by or for the U.S. Government or a U.S. Government subcontractor is subject solely to the terms and conditions set forth in the license agreement provided with the software, except for provisions which are contrary to applicable mandatory federal laws.

TRADEMARKS: The trademarks, logos and service marks ("Marks") used herein are the property of Mentor Graphics Corporation or other parties. No one is permitted to use these Marks without the prior written consent of Mentor Graphics or the owner of the Mark, as applicable. 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.

The registered trademark Linux[®] is used pursuant to a sublicense from LMI, the exclusive licensee of Linus Torvalds, owner of the mark on a world-wide basis.

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

OpenAMP Framework Performance Measurements	5
Performance Measurements	5
Average RPMsg Round-Trip Time	5
remoteproc Boot Latency	5
remoteproc Shutdown	6
Retrieving OpenAMP Framework Performance Numbers	6

Third-Party Information

Embedded Software and Hardware License Agreement

List of Tables

Table 1-1. Average RMPmsg Round-Trip Time Measurements	5
Table 1-2. remoteproc Boot Latency Time Measurements	5
Table 1-3. remoteproc Shutdown Time Measurements	6

Chapter 1

OpenAMP Framework Performance Measurements

This document presents details of performance measurements using the OpenAMP Framework, as well as instructions for how to retrieve OpenAMP Framework performance numbers.

Performance Measurements

Measured performance times are provided for several cases and configurations.

Average RPMsg Round-Trip Time

For this test, the remote firmware application used is a simple echo application (that echoes the messages received back to the master).

The time measured is the average time taken from the point a message is transmitted from master, till the point in time we received an echo response from the remote back to the master (rpmmsg RX call back on master). [Table 1-1](#) provides the performance measurements for the Average RPMsg round-trip.

Table 1-1. Average RPMsg Round-Trip Time Measurements

Configuration	Time (microseconds)
Nucleus Master – Nucleus Remote	19.9
Nucleus Master – Bare metal Remote	16

remoteproc Boot Latency

Latency from the point the remoteproc boot API was invoked, till the point the remote application starts execution.

[Table 1-2](#) provides the performance measurements for the remoteproc boot latency.

Table 1-2. remoteproc Boot Latency Time Measurements

Configuration	Time (microseconds)
Nucleus Master – Nucleus Remote	609
Nucleus Master – Bare metal Remote	341

remoteproc Shutdown

Latency from the point the remoteproc shut-down API was invoked, till the point the remote CPU is shut-down.

Table 1-3 provides the performance measurements for the remoteproc shutdown.

Table 1-3. remoteproc Shutdown Time Measurements

Configuration	Time (microseconds)
Nucleus Master – Nucleus Remote	66
Nucleus Master – Bare metal Remote	74

Retrieving OpenAMP Framework Performance Numbers

For Nucleus Master - Nucleus Remote and Nucleus Master - Baremetal Remote Configuration Instructions are provided for how to build and execute a performance test.

Restrictions and Limitations

Prerequisites

This section assumes that you have gone through the 'OpenAMP Framework Getting Started Guide'. You should be able to setup the OpenAMP Framework build environment and execute OpenAMP Framework sample applications.

Procedure

1. Build Performance Test

Assuming that the OpenAMP Framework library is installed at location \$OPENAMP
Change directory to \$OPENAMP

```
$ cd $OPENAMP
```

2. Execute the build script.

This operation will build remote applications for Nucleus and Baremetal environments as well as Nucleus master applications required to test performance.

Note

The build operation will generate application outputs in the respective application directories.

```
$ source open_amp_build.sh -p
```

3. A performance test application will be built at the following location:

```
$OPENAMP/apps/tests/master/nucleus/latency_test/nucleus_nucleusbm/latency_test.bin
```

4. Execute the performance test

- a. Refer to the 'OpenAMP Framework Getting Started Guide' for instructions on how to setup an SD card to load a Nucleus master application image.
- b. Place the application *latency_test.bin* on the SD card before powering up the board to a u-boot prompt.
- c. Start the *latency_test* application from uboot prompt using the following command:

```
U-Boot-PetaLinux> dcache off;fatload mmc 0:0 0x10000000
                    latency_test.bin;
go 0x10000000
```

Results

Expected Output is as follows:

```
Executing tests for remote context : firmware1. It corresponds to Nucleus
remote firmware
WARNING rx_vq: freeing non-empty virtqueue
WARNING tx_vq: freeing non-empty virtqueue
Executing tests for remote context : firmware2. It corresponds to
Baremetal remote firmware
WARNING rx_vq: freeing non-empty virtqueue
WARNING tx_vq: freeing non-empty virtqueue
*****
OpenAMP Latency Test Results
*****
Nucleus Remote: Average rpmsg_send API Round-Trip:          19909 ns
Nucleus Remote: remoteproc_boot API:                        609420 ns
Nucleus Remote: remoteproc_shutdown API:                    65753 ns
Baremetal Remote: Average rpmsg_send API Round-Trip:        16024 ns
Baremetal Remote: remoteproc_boot API:                       340909 ns
Baremetal Remote: remoteproc_shutdown API:                  1115759 ns
```

Related Topics

Third-Party Information

This software application may include zlib version 1.2.5 third-party software, which is distributed on an "AS IS" basis, WITHOUT WARRANTY OF ANY KIND, either express or implied.

This software application may include libfdt version 17 third-party software, which is distributed on an "AS IS" basis, WITHOUT WARRANTY OF ANY KIND, either express or implied. libfdt version 17 may be subject to the following copyrights:

For the below copyright notice Mentor elects to distribute libfdt under the terms of the BSD license.

© 2006 David Gibson, IBM Corporation.

© 2012 Kim Phillips, Freescale Semiconductor.

libfdt is dual licensed: you can use it either under the terms of the GPL, or the BSD license, at your option.

a) This library is free software; you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation; either version 2 of the License, or (at your option) any later version.

This library is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

You should have received a copy of the GNU General Public License along with this library; if not, write to the Free Software Foundation, Inc., 51 Franklin St, Fifth Floor, Boston, MA 02110-1301 USA

Alternatively,

b) Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.

2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

Embedded Software and Hardware License Agreement

The latest version of the Embedded Software and Hardware License Agreement is available on-line at:
www.mentor.com/eshla

IMPORTANT INFORMATION

USE OF ALL PRODUCTS IS SUBJECT TO LICENSE RESTRICTIONS. CAREFULLY READ THIS LICENSE AGREEMENT BEFORE USING THE PRODUCTS. USE OF PRODUCTS 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.

EMBEDDED SOFTWARE AND HARDWARE LICENSE AGREEMENT (“Agreement”)

This is a legal agreement concerning the use of Products (as defined in Section 1) 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 Products received electronically, certify destruction of Products and all accompanying items within five days after receipt of such Products and receive a full refund of any license fee paid.

1. **Definitions.** As used in this Agreement and any applicable quotation, supplement, attachment and/or addendum (“Addenda”), these terms shall have the following meanings:
 - 1.1. “Customer’s Product” means Customer’s end-user product identified by a unique SKU (including any Related SKUs) in an applicable Addenda that is developed, manufactured, branded and shipped solely by Customer or an authorized manufacturer or subcontractor on behalf of Customer to end-users or consumers;
 - 1.2. “Developer” means a unique user, as identified by a unique user identification number, with access to Embedded Software at an authorized Development Location. A unique user is an individual who works directly with the embedded software in source code form, or creates, modifies or compiles software that ultimately links to the Embedded Software in Object Code form and is embedded into Customer’s Product at the point of manufacture;
 - 1.3. “Development Location” means the location where Products may be used as authorized in the applicable Addenda;
 - 1.4. “Development Tools” means the software that may be used by Customer for building, editing, compiling, debugging or prototyping Customer’s Product;
 - 1.5. “Embedded Software” means Software that is embeddable;
 - 1.6. “End-User” means Customer’s customer;
 - 1.7. “Executable Code” means a compiled program translated into a machine-readable format that can be loaded into memory and run by a certain processor;
 - 1.8. “Hardware” means a physically tangible electro-mechanical system or sub-system and associated documentation;
 - 1.9. “Linkable Object Code” or “Object Code” means linkable code resulting from the translation, processing, or compiling of Source Code by a computer into machine-readable format;
 - 1.10. “Mentor Embedded Linux” or “MEL” means Mentor Graphics' tools, source code, and recipes for building Linux systems;
 - 1.11. “Open Source Software” or “OSS” means software subject to an open source license which requires as a condition for redistribution of such software, including modifications thereto, that the: (i) redistribution be in source code form or be made available in source code form; (ii) redistributed software be licensed to allow the making of derivative works; or (iii) redistribution be at no charge;
 - 1.12. “Processor” means the specific microprocessor to be used with Software and implemented in Customer’s Product;
 - 1.13. “Products” means Software, Term-Licensed Products and/or Hardware;
 - 1.14. “Proprietary Components” means the components of the Products that are owned and/or licensed by Mentor Graphics and are not subject to an Open Source Software license, as more fully set forth in the product documentation provided with the Products;

- 1.15. "Redistributable Components" means those components that are intended to be incorporated or linked into Customer's Linkable Object Code developed with the Software, as more fully set forth in the documentation provided with the Products;
- 1.16. "Related SKU" means two or more Customer Products identified by logically-related SKUs, where there is no difference or change in the electrical hardware or software content between such Customer Products;
- 1.17. "Software" means software programs, Embedded Software and/or Development Tools, including any updates, modifications, revisions, copies, documentation and design data that are licensed under this Agreement;
- 1.18. "Source Code" means software in a form in which the program logic is readily understandable by a human being;
- 1.19. "Sourcery CodeBench Software" means Mentor Graphics' Development Tool for C/C++ embedded application development;
- 1.20. "Sourcery VSIPL++" is Software providing C++ classes and functions for writing embedded signal processing applications designed to run on one or more processors;
- 1.21. "Stock Keeping Unit" or "SKU" is a unique number or code used to identify each distinct product, item or service available for purchase;
- 1.22. "Subsidiary" means any corporation more than 50% owned by Customer, excluding Mentor Graphics competitors. Customer agrees to fulfill the obligations of such Subsidiary in the event of default. To the extent Mentor Graphics authorizes any Subsidiary's use of Products under this Agreement, Customer agrees to ensure such Subsidiary's compliance with the terms of this Agreement and will be liable for any breach by a Subsidiary; and
- 1.23. "Term-Licensed Products" means Products licensed to Customer for a limited time period ("Term").

2. Orders, Fees and Payment.

- 2.1. 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 and any applicable Addenda, 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.
- 2.2. Amounts invoiced will be paid, in the currency specified on the applicable invoice, within 30 days from the date of such invoice. All invoices will be sent electronically to Customer on the date stated on the invoice unless otherwise specified in an Addendum. 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, consumption 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.
- 2.3. All Products are delivered FCA factory (Incoterms 2010), freight prepaid and invoiced to Customer, except Software delivered electronically, which shall be deemed delivered when made available to Customer for download. Mentor Graphics' delivery of Software by electronic means is subject to Customer's provision of both a primary and an alternate e-mail address.

3. Grant of License.

- 3.1. The Products installed, downloaded, or otherwise acquired by Customer under this Agreement constitute or contain copyrighted, trade secret, proprietary 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 as described in the applicable Addenda. The limited licenses granted under the applicable Addenda shall continue until the expiration date of Term-Licensed Products or termination in accordance with Section 12 below, whichever occurs first. **Mentor Graphics does NOT grant Customer any right to (a) sublicense or (b) use Software beyond the scope of this Section without first signing a separate agreement or Addenda with Mentor Graphics for such purpose.**
- 3.2. License Type. The license type shall be identified in the applicable Addenda.
 - 3.2.1. Development License: During the Term, if any, Customer may modify, compile, assemble and convert the applicable Embedded Software Source Code into Linkable Object Code and/or Executable Code form by the number of Developers specified, for the Processor(s), Customer's Product(s) and at the Development Location(s) identified in the applicable Addenda.

- 3.2.2. End-User Product License: During the Term, if any, and unless otherwise specified in the applicable Addenda, Customer may incorporate or embed an Executable Code version of the Embedded Software into the specified number of copies of Customer's Product(s), using the Processor Unit(s), and at the Development Location(s) identified in the applicable Addenda. Customer may manufacture, brand and distribute such Customer's Product(s) worldwide to its End-Users.
- 3.2.3. Internal Tool License: During the Term, if any, Customer may use the Development Tools solely: (a) for internal business purposes and (b) on the specified number of computer work stations and sites. Development Tools are licensed on a per-seat or floating basis, as specified in the applicable Addenda, and shall not be distributed to others or delivered in Customer's Product(s) unless specifically authorized in an applicable Addenda.
- 3.2.4. Sourcery CodeBench Professional Edition License: During the Term specified in the applicable Addenda, Customer may (a) install and use the Proprietary Components of the Software (i) if the license is a node-locked license, by a single user who uses the Software on up to two machines provided that only one copy of the Software is in use at any one time, or (ii) if the license is a floating license, by the authorized number of concurrent users on one or more machines provided that only the authorized number of copies of the Software are in use at any one time, and (b) distribute the Redistributable Components of the Software in Executable Code form only and only as part of Customer's Object Code developed with the Software that provides substantially different functionality than the Redistributable Component(s) alone.
- 3.2.5. Sourcery CodeBench Standard Edition License: During the Term specified in the applicable Addenda, Customer may (a) install and use the Proprietary Components of the Software by a single user who uses the Software on up to two machines provided that only one copy of the Software is in use at any one time, and (b) distribute the Redistributable Component(s) of the Software in Executable Code form only and only as part of Customer's Object Code developed with the Software that provides substantially different functionality than the Redistributable Component(s) alone.
- 3.2.6. Sourcery CodeBench Personal Edition License: During the Term specified in the applicable Addenda, Customer may (a) install and use the Proprietary Components of the Software by a single user who uses the Software on one machine, and (b) distribute the Redistributable Component(s) of the Software in Executable Code form only and only as part of Customer Object Code developed with the Software that provides substantially different functionality than the Redistributable Component(s) alone.
- 3.2.7. Sourcery CodeBench Academic Edition License: During the Term specified in the applicable Addenda, Customer may (a) install and use the Proprietary Components of the Software for non-commercial, academic purposes only by a single user who uses the Software on one machine, and (b) distribute the Redistributable Component(s) of the Software in Executable Code form only and only as part of Customer Object Code developed with the Software that provides substantially different functionality than the Redistributable Component(s) alone.
- 3.3. Mentor Graphics may from time to time, in its sole discretion, lend Products to Customer. For each loan, Mentor Graphics will identify in writing the quantity and description of Software loaned, the authorized location and the Term of the loan. Mentor Graphics will grant to Customer a temporary license to use the loaned Software solely for Customer's internal evaluation in a non-production environment. Customer shall return to Mentor Graphics or delete and destroy loaned Software on or before the expiration of the loan Term. Customer will sign a certification of such deletion or destruction if requested by Mentor Graphics.

4. **Beta Code.**

- 4.1. Portions or all of certain Products 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, including archival and backup purposes. 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. Except where embedded in Executable Code form in Customer's Product, Customer shall maintain a record of the number and location of all copies of Software, including copies merged with other software and products, 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, authorized manufacturers or authorized 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 Products except as permitted by this Agreement. Customer shall give Mentor Graphics immediate 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.
 - 5.2. Customer acknowledges that the Products provided hereunder may contain Source Code which is proprietary and its confidentiality is of the highest importance and value to Mentor Graphics. Customer acknowledges that Mentor Graphics may be seriously harmed if such Source Code is disclosed in violation of this Agreement. 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 Products that are not provided in Source Code form. Except as embedded in Executable Code in Customer's Product and distributed in the ordinary course of business, in no event shall Customer provide Products to Mentor Graphics competitors. Log files, data files, rule files and script files generated by or for the Software (collectively "Files") constitute and/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. Under no circumstances shall Customer use Products or allow their use for the purpose of developing, enhancing or marketing any product that is in any way competitive with Products, or disclose to any third party the results of, or information pertaining to, any benchmark.
 - 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, which shall not be unreasonably withheld, 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. Notwithstanding any provision in an OSS license agreement applicable to a component of the Sourcery CodeBench Software that permits the redistribution of such component to a third party in Source Code or binary form, Customer may not use any Mentor Graphics trademark, whether registered or unregistered, in connection with such distribution, and may not recompile the Open Source Software components with the --with-pkgversion or --with-bugurl configuration options that embed Mentor Graphics' trademarks in the resulting binary.
 - 5.5. The provisions of this Section 5 shall survive the termination of this Agreement.
6. **Support Services.**
- 6.1. Except as described in Sections 6.2, 6.3 and 6.4 below, and unless otherwise specified in any applicable Addenda to this Agreement, to the extent Customer purchases support services, Mentor Graphics will provide Customer updates and technical support for the number of Developers at the Development Location(s) for which support is purchased in accordance with Mentor Graphics' then-current End-User Software Support Terms located at <http://supportnet.mentor.com/about/legal/>.
 - 6.2. To the extent Customer purchases support services for Sourcery CodeBench Software, support will be provided solely in accordance with the provisions of this Section 6.2. Mentor Graphics shall provide updates and technical support to Customer as described herein only on the condition that Customer uses the Executable Code form of the Sourcery CodeBench Software for internal use only and/or distributes the Redistributable Components in Executable Code form only (except as provided in a separate redistribution agreement with Mentor Graphics or as required by the applicable Open Source license). Any other distribution by Customer of the Sourcery CodeBench Software (or any component thereof) in any form, including distribution permitted by the applicable Open Source license, shall automatically terminate any remaining support term. Subject to the foregoing and the payment of support fees, Mentor Graphics will provide Customer updates and technical support for the number of Developers at the Development Location(s) for which support is purchased in accordance with Mentor Graphics' then-current Sourcery CodeBench Software Support Terms located at <http://www.mentor.com/codebench-support-legal>.
 - 6.3. To the extent Customer purchases support services for Sourcery VSIPL++, Mentor Graphics will provide Customer updates and technical support for the number of Developers at the Development Location(s) for which support is purchased solely in accordance with Mentor Graphics' then-current Sourcery VSIPL++ Support Terms located at <http://www.mentor.com/vsipl-support-legal>.
 - 6.4. To the extent Customer purchases support services for Mentor Embedded Linux, Mentor Graphics will provide Customer updates and technical support for the number of Developers at the Development Location(s) for which support is purchased solely in accordance with Mentor Graphics' then-current Mentor Embedded Linux Support Terms located at <http://www.mentor.com/mel-support-legal>.

7. **Third Party and Open Source Software.** Products may contain Open Source Software or code distributed under a proprietary third party license agreement. Please see applicable Products documentation, including but not limited to license notice files, header files or source code for further details. Please see the applicable Open Source Software license(s) for additional rights and obligations governing your use and distribution of Open Source Software. Customer agrees that it shall not subject any Product provided by Mentor Graphics under this Agreement to any Open Source Software license that does not otherwise apply to such Product. In the event of conflict between the terms of this Agreement, any Addenda and an applicable OSS or proprietary third party agreement, the OSS or proprietary third party agreement will control solely with respect to the OSS or proprietary third party software component. The provisions of this Section 7 shall survive the termination of this Agreement.
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 and/or specification. 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 Products under an Order and does not renew or reset, for example, with the delivery of (a) Software updates or (b) authorization codes. 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; OR (B) PRODUCTS PROVIDED AT NO CHARGE, WHICH ARE PROVIDED "AS IS" UNLESS OTHERWISE AGREED IN WRITING.
- 8.2. THE WARRANTIES SET FORTH IN THIS SECTION 8 ARE EXCLUSIVE TO CUSTOMER AND DO NOT APPLY TO ANY END-USER. NEITHER MENTOR GRAPHICS NOR ITS LICENSORS MAKE ANY OTHER WARRANTIES, EXPRESS, IMPLIED, OR STATUTORY, WITH RESPECT TO PRODUCTS OR OTHER MATERIAL 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, AND EXCEPT FOR EITHER PARTY'S BREACH OF ITS CONFIDENTIALITY OBLIGATIONS, CUSTOMER'S BREACH OF LICENSING TERMS OR CUSTOMER'S OBLIGATIONS UNDER SECTION 10, IN NO EVENT SHALL: (A) EITHER PARTY OR ITS RESPECTIVE 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 SUCH PARTY OR ITS LICENSORS HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES; AND (B) EITHER PARTY OR ITS RESPECTIVE LICENSORS' LIABILITY UNDER THIS AGREEMENT, INCLUDING, FOR THE AVOIDANCE OF DOUBT, LIABILITY FOR ATTORNEYS' FEES OR COSTS, EXCEED THE GREATER OF THE FEES PAID OR OWING TO MENTOR GRAPHICS FOR THE PRODUCT OR SERVICE GIVING RISE TO THE CLAIM OR \$500,000 (FIVE HUNDRED THOUSAND U.S. DOLLARS). NOTWITHSTANDING THE FOREGOING, 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.**
- 10.1. Customer agrees that Mentor Graphics has no control over Customer's testing or the specific applications and use that Customer will make of Products. Mentor Graphics Products are not specifically designed for use in the operation of nuclear facilities, aircraft navigation or communications systems, air traffic control, life support systems, medical devices or other applications in which the failure of Mentor Graphics Products could lead to death, personal injury, or severe physical or environmental damage ("Hazardous Applications").
- 10.2. CUSTOMER ACKNOWLEDGES IT IS SOLELY RESPONSIBLE FOR TESTING PRODUCTS USED IN HAZARDOUS APPLICATIONS AND SHALL BE SOLELY LIABLE FOR ANY DAMAGES RESULTING FROM SUCH USE. NEITHER MENTOR GRAPHICS NOR ITS LICENSORS SHALL BE LIABLE FOR ANY DAMAGES RESULTING FROM OR IN CONNECTION WITH THE USE OF PRODUCTS IN ANY HAZARDOUS APPLICATIONS.
- 10.3. CUSTOMER AGREES TO INDEMNIFY AND HOLD HARMLESS MENTOR GRAPHICS AND ITS LICENSORS FROM ANY CLAIMS, LOSS, COST, DAMAGE, EXPENSE OR LIABILITY, INCLUDING REASONABLE ATTORNEYS' FEES, ARISING OUT OF OR IN CONNECTION WITH THE USE OF PRODUCTS AS DESCRIBED IN SECTION 10.1.
- 10.4. THE PROVISIONS OF THIS SECTION 10 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.
11. **Infringement.**

- 11.1. 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 any 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.
 - 11.2. If a claim is made under Subsection 11.1 Mentor Graphics may, at its option and expense, and in addition to its obligations under Section 11.1, either (a) replace or modify the Product so that it becomes noninfringing; or (b) procure for Customer the right to continue using the Product. If Mentor Graphics determines that neither of those alternatives is financially practical or otherwise reasonably available, Mentor Graphics may require the return of the Product and refund to Customer any purchase price or license fee(s) paid.
 - 11.3. Mentor Graphics has no liability to Customer if the claim is based upon: (a) the combination of the Product with any product not furnished by Mentor Graphics, where the Product itself is not infringing; (b) the modification of the Product other than by Mentor Graphics or as directed by Mentor Graphics, where the unmodified Product would not infringe; (c) the use of the infringing Product when Mentor Graphics has provided Customer with a current unaltered release of a non-infringing Product of substantially similar functionality in accordance with Subsection 11.2(a); (d) the use of the Product as part of an infringing process; (e) a product that Customer makes, uses, or sells, where the Product itself is not infringing; (f) any Product provided at no charge; (g) any software provided by Mentor Graphics' licensors who do not provide such indemnification to Mentor Graphics' customers; (h) Open Source Software, except to the extent that the infringement is directly caused by Mentor Graphics' modifications to such Open Source Software; or (i) infringement by Customer that is deemed willful. In the case of (i), Customer shall reimburse Mentor Graphics for its reasonable attorneys' fees and other costs related to the action.
 - 11.4. THIS SECTION 11 IS SUBJECT TO SECTION 9 ABOVE AND STATES: (A) THE ENTIRE LIABILITY OF MENTOR GRAPHICS AND ITS LICENSORS AND (B) 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.
12. **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.
- 12.1. Termination for Breach. This Agreement shall remain in effect until terminated in accordance with its terms. Mentor Graphics may terminate this Agreement and/or any licenses granted under this Agreement, and Customer will immediately discontinue use and distribution of Products, if Customer (a) commits any material breach of any provision of this Agreement and fails to cure such breach upon 30-days prior written notice; 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. 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. For the avoidance of doubt, nothing in this Section 12 shall be construed to prevent Mentor Graphics from seeking immediate injunctive relief in the event of any threatened or actual breach of Customer's obligations hereunder.
 - 12.2. Effect of Termination. Upon termination of this Agreement, the rights and obligations of the parties shall cease except as expressly set forth in this Agreement. Upon termination or expiration of the Term, Customer will discontinue use and/or distribution of Products, 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, except to the extent an Open Source Software license conflicts with this Section 12.2 and permits Customer's continued use of any Open Source Software portion or component of a Product. Upon termination for Customer's breach, an End-User may continue its use and/or distribution of Customer's Product so long as: (a) the End-User was licensed according to the terms of this Agreement, if applicable to such End-User, and (b) such End-User is not in breach of its agreement, if applicable, nor a party to Customer's breach.
13. **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, information about the products, and direct or indirect products thereof, 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. Customer acknowledges that the regulation of product export is in continuous modification by local governments and/or the United States Congress and administrative agencies. Customer agrees to complete all documents and to meet all requirements arising out of such modifications.
14. **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.
15. **Third Party Beneficiary.** For any Products licensed under this Agreement and provided by Customer to End-Users, Mentor Graphics or the applicable licensor is a third party beneficiary of the agreement between Customer and End-User. Mentor

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

16. **Review of License Usage.** Customer will monitor the access to and use of Software. With prior written notice, during Customer's normal business hours, and no more frequently than once per calendar year, Mentor Graphics may engage an internationally recognized accounting firm to review Customer's software monitoring system, records, accounts and sublicensing documents 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 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 Customer 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. Such license review shall be at Mentor Graphics' expense unless it reveals a material underpayment of fees of five percent or more, in which case Customer shall reimburse Mentor Graphics for the costs of such license review. Customer shall promptly pay any such fees. If the license review reveals that Customer has made an overpayment, Mentor Graphics has the option to either provide the Customer with a refund or credit the amount overpaid to Customer's next payment. The provisions of this Section 16 shall survive the termination of this Agreement.
17. **Controlling Law, Jurisdiction and Dispute Resolution.** This Agreement shall be governed by and construed under the laws of the State of California, USA, excluding choice of law rules. All disputes arising out of or in relation to this Agreement shall be submitted to the exclusive jurisdiction of the state and federal courts of California, USA. Nothing in this section shall restrict Mentor Graphics' right to bring an action (including for example a motion for injunctive relief) against Customer or its Subsidiary in the jurisdiction where Customer's or its Subsidiary's place of business is located. The United Nations Convention on Contracts for the International Sale of Goods does not apply to this Agreement.
18. **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.
19. **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. This Agreement may only be modified in writing, signed by an authorized representative of each party. Waiver of terms or excuse of breach must be in writing and shall not constitute subsequent consent, waiver or excuse.