VirtualBench™ Bode Analyzer

This user's guide describes the operation of the VirtualBench Bode Analyzer software. This user's guide also discusses how to set up the software and reviews various aspects of software operation.

Contents

List of Figures

List of Tables

1 Overview

The VirtualBench Bode Analyzer software is used with the VirtualBench hardware to evaluate the small-signal ac performance of various operational amplifiers.

VirtualBench integrates many pieces of lab equipment into one device, including a mixed-signal oscilloscope, digital multimeter, function generator, dc power supply, and digital I/O. The Bode Analyzer software uses the function generator and oscilloscope to perform an ac gain and phase analysis of a circuit.

While any printed circuit board (PCB) may be used with this software, the TI-PLABS-AMP-EVM is a convenient test platform. The TI-PLABS-AMP-EVM provides inverting-, noninverting-, cascaded-, and filter-amplifier circuits that may be populated with various op amps. This evaluation module (EVM) also includes power and analog input and output connections that are designed to easily interface with the VirtualBench hardware.

1.1 Related Documentation from Texas Instruments

The following documentation provides information related to the VirtualBench Bode Analyzer software. This user's guide is available from the TI web site under literature number SBOU151. Any letter appended to the literature number corresponds to the document revision that is current at the time of the writing of this document. The latest revision can be obtained by clicking on the literature number link, from the TI web site at http://www.ti.com/, or by calling the Texas Instruments Literature Response Center at (800) 477-8924 or the Product Information Center at (972) 644-5580. When ordering, identify the document by both title and literature number.

Table 1. Related Documentation

Document	Lit Number
TI-PLABS-AMP-EVM	SBOU150

2 Hardware Setup

2.1 Electrostatic Discharge Warning

Many of the integrated circuits (ICs) and PCBs typically used with VirtualBench are susceptible to damage by electrostatic discharge (ESD).

CAUTION

Observe proper ESD handling precautions when handling any integrated circuits and printed circuit boards, including the use of a grounded wrist strap at an approved ESD workstation.

2.2 AC Power and USB Connections

Before using the VirtualBench Bode Analyzer software, the VirtualBench hardware must be powered and connected to a computer with a Windows® operating system. Figure 1 shows the USB and ac power connections on the VirtualBench rear panel. Connect the hardware as follows:

1. Connect the included USB cord to its port on the VirtualBench rear panel. Screw in the attached screw for a secure mechanical connection. Plug the other end of the cable into an available USB port on your computer.
2. Connect the included ac power cord to its port on the VirtualBench rear panel. Plug the other end of the cable into an available AC power outlet.

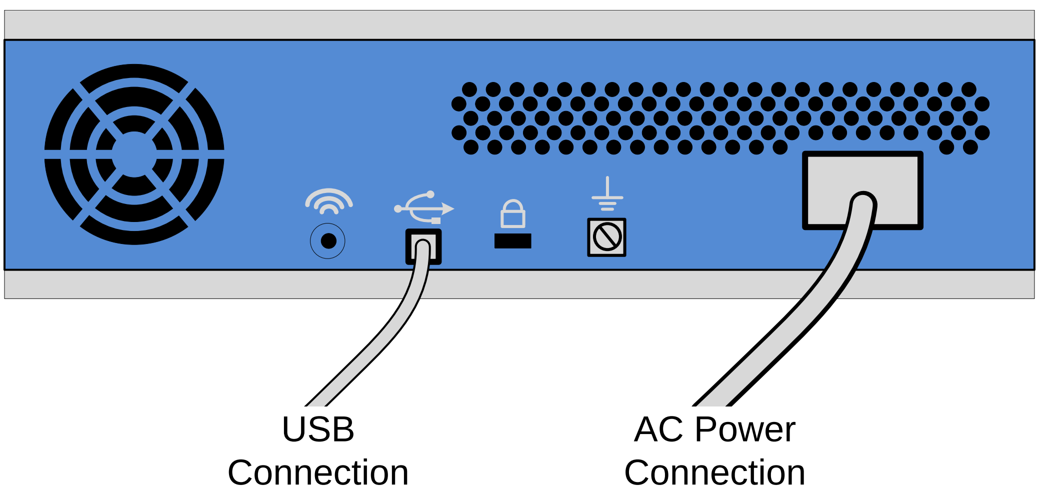

Figure 1. VirtualBench Rear Panel Connections

2.3 Typical Hardware Connections

Figure 2 shows the required connections between the VirtualBench hardware and the PCB under test. In this example, the TI-PLABS-AMP-EVM is used, but any circuit may be used. Connect the hardware as follows:

1. Make the required power connections between the dc power supply on the VirtualBench front panel and the PCB under test. Both single-supply and split-supply power schemes are possible.
2. Connect *Mixed-Signal Oscilloscope CH1* to the input of the PCB under test with a BNC cable.
3. Connect *Mixed-Signal Oscilloscope CH2* to the output of the PCB under test with a BNC cable.
4. Connect the function generator (*FGEN*) to the input of the PCB under test with a BNC cable.
5. Press the power button on the top-left of the VirtualBench front panel to power up the system.

This connection scheme allows VirtualBench to apply a small-signal input to the circuit under test while measuring the circuit input and output simultaneously. This configuration is required in order to determine the circuit ac gain and phase responses.

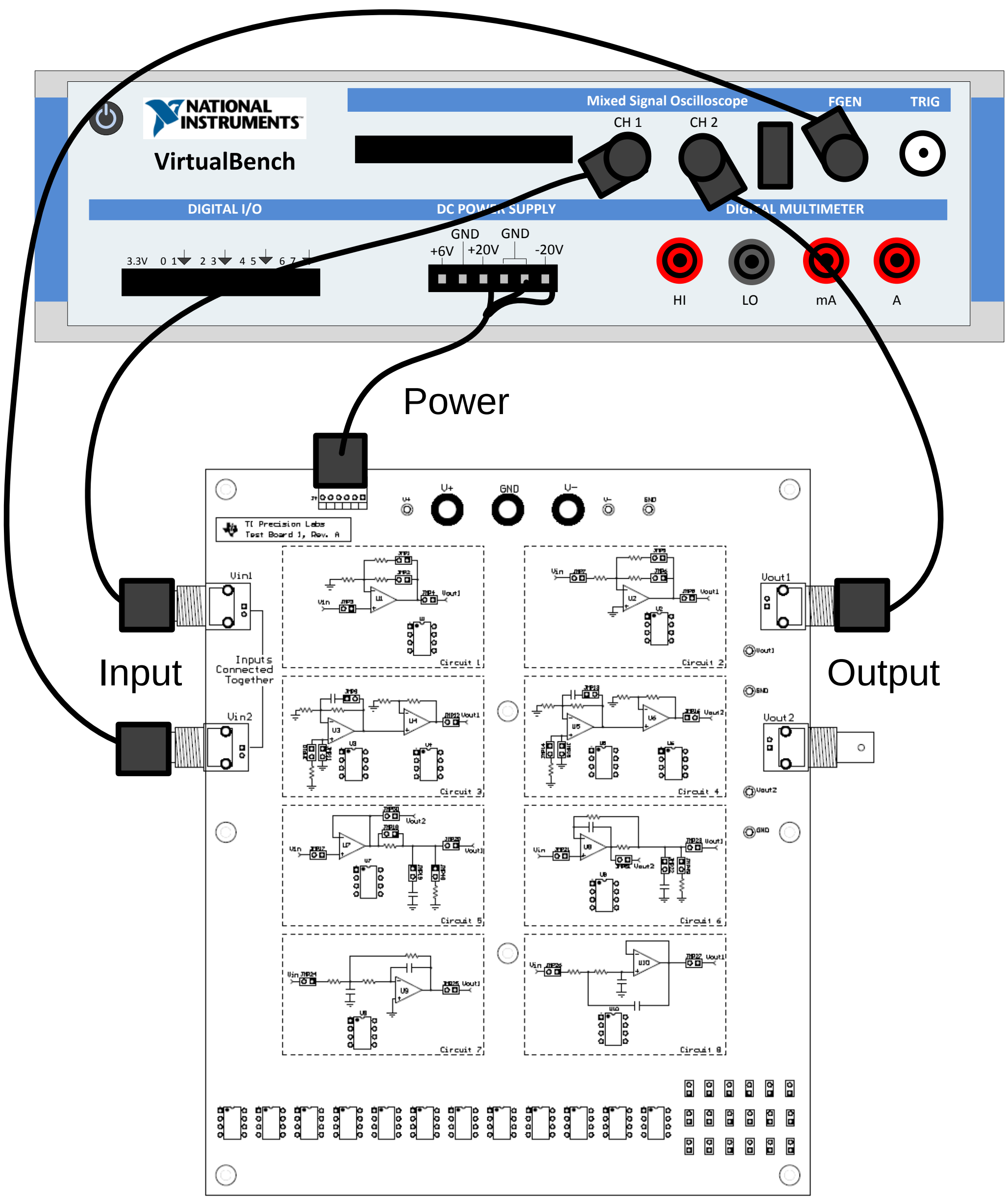

Figure 2. Input, Output, and Power Connections

3 Software Setup

This section describes how to install the VirtualBench Bode Analyzer software.

3.1 Operating Systems for VirtualBench Bode Analyzer Software

The VirtualBench Bode Analyzer software is tested for use with the Windows 7® operating system (OS) with United States and European regional settings. The software also functions on other Windows operating systems. Please report any OS compatibility issues to the Precision Amplifiers E2E Forum.

3.2 VirtualBench Bode Analyzer Software Installation

Follow these steps to install the VirtualBench Bode Analyzer software:

1. Download the software from the VirtualBench Bode Analyzer tool folder.
2. Find the file called *setup.exe*. Double-click the file to start the installation process.
3. Follow the on-screen prompts to install the software.

If at any point you wish to remove the software, use the *Programs and Features* utility in the Windows Control Panel.

4 Software Overview

4.1 Starting the VirtualBench Bode Analyzer Software

The VirtualBench Bode Analyzer software can be started by double-clicking the *Bode Analyzer* icon placed on the desktop during installation, as shown in Figure 3. The software may also be started through the Windows *Start* menu. Click *Start* → *All Programs* → *Bode Analyzer* → *Bode Analyzer* to launch the software.

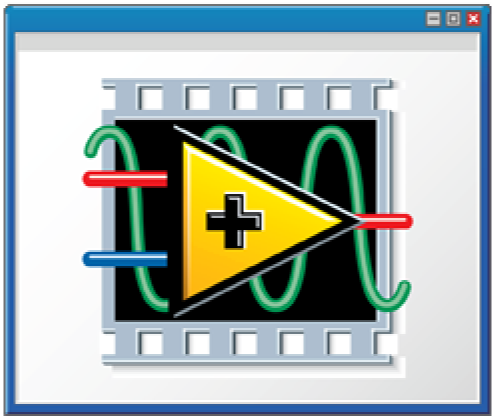

Figure 3. VirtualBench Bode Analyzer Desktop Icon

The VirtualBench Bode Analyzer software starts up as shown in Figure 4. The following sections describe how to configure and use the software for typical ac gain and phase measurements.

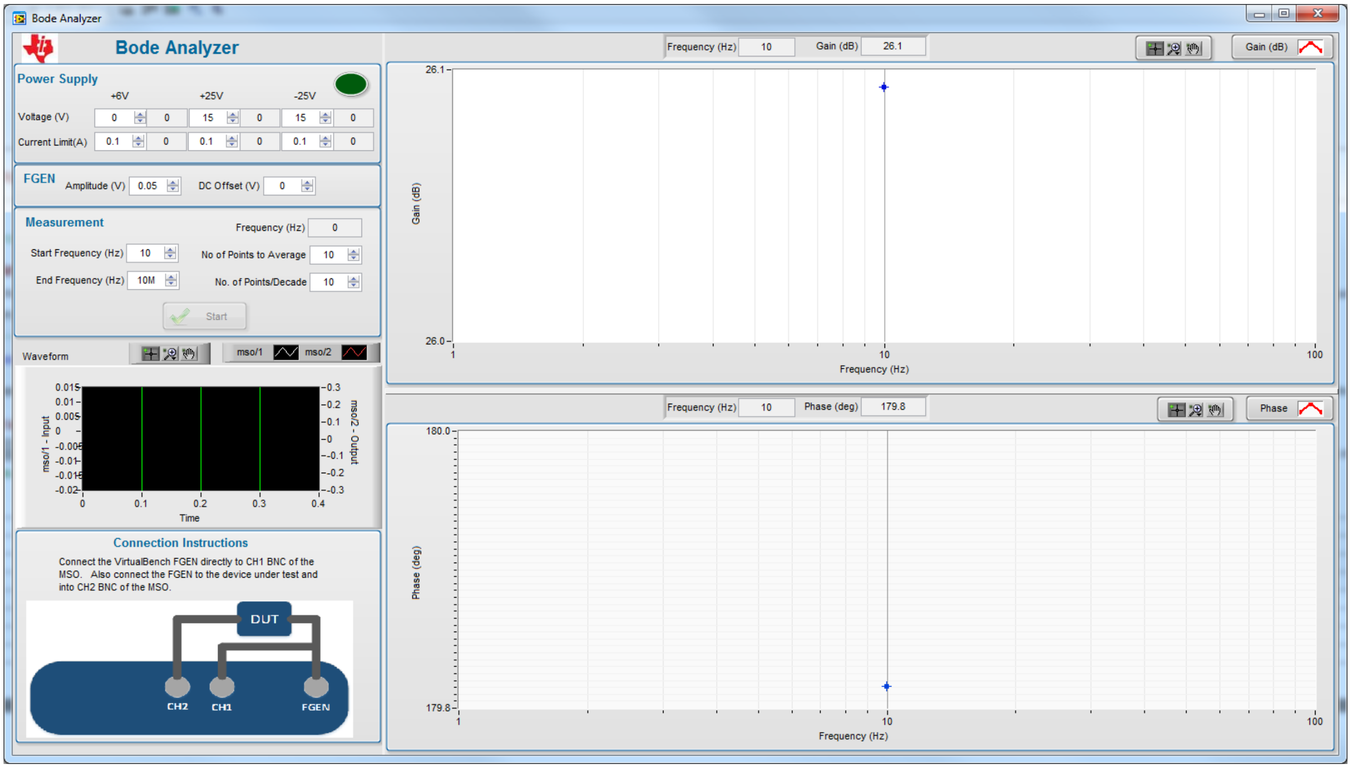

Figure 4. VirtualBench Bode Analyzer Software

4.2 Power Supply

This section of the Bode Analyzer graphical user interface (GUI) configures the *+6V, +25V* and *–25V* power supplies of the VirtualBench hardware, as shown in Figure 5. The maximum output voltage and output current levels of each supply are specified in Table 2.

- *Voltage (V)* sets the output voltage of each supply in volts.
- *Current Limit (A)* sets the maximum output current of each supply in amperes.

Click the green button at the top-right corner to turn on the dc power supply. After turning on the power supply, the measured voltage and current output is displayed in the cell to the right of each setting. The blue LEDs in the *DC Power Supply* area of the VirtualBench front panel are illuminated when the power supply is active.

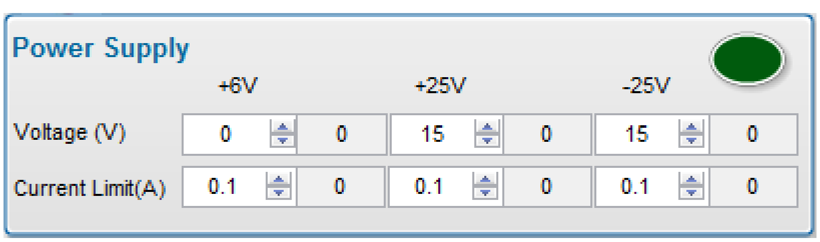

Figure 5. Power-Supply Configuration

Table 2. VirtualBench DC-Power Supply Maximum Ratings

Power-Supply Rail	Minimum Voltage (V)	Maximum Voltage (V)	Maximum Current (A)
+6V	0	6	1
+25V	0	25	0.5
–25V	–25	0	0.5

4.3 FGEN (Function Generator)

This section configures the analog function generator of the Bode Analyzer, as shown in Figure 6.

- *Amplitude (V)* sets the amplitude of the test signal in volts peak-to-peak (V_{PP}). For small-signal ac analysis, keep the amplitude in the range of 0.01 V_{PP} to 0.05 V_{PP}.
- *DC Offset (V)* sets the dc offset of the test signal in volts. For most split-supply circuits, set the dc offset of the test signal to 0 V. However, some single-supply circuits may require a non-zero offset to meet the circuit input common-mode voltage (V_{CM}) specifications.

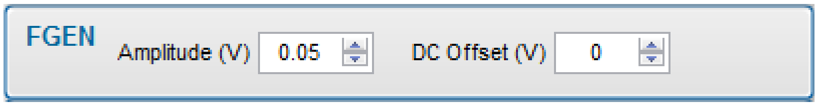

Figure 6. Function Generator (FGEN) Configuration

4.4 Measurement

This section configures the measurement options of the Bode Analyzer, as shown in Figure 7.

- *Start Frequency (Hz)* sets the start frequency of the gain and phase analysis in hertz (Hz). Select an appropriate start frequency based on the bandwidth of the circuit under test. Lower frequencies take more time to measure.
- *End Frequency (Hz)* sets the stop frequency of the gain and phase analysis in hertz (Hz). Select an appropriate stop frequency based on the bandwidth of the circuit under test. The maximum frequency supported by the Bode Analyzer is 20 MHz.
- *Frequency (Hz)* displays the current measurement frequency.
- *No. of Points to Average* sets the number of measurements made and averaged at each frequency point. More averaging can improve the measurement, but requires more time to complete. A setting of 10 points is sufficient for most measurements.
- *No. of Points/Decade* sets the number of frequency points measured per decade. Using more points improves the resolution of the measurement, but requires more time to complete. A setting of 20 or 30 points per decade is sufficient for most measurements.

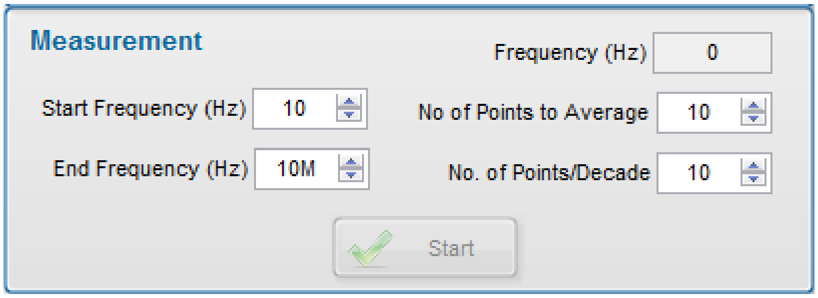

Figure 7. Measurement Configuration

4.5 Waveform Display

This section displays the measurement results at the current frequency, as shown in Figure 8. The measurement is displayed in the time domain.

- *mso/1*, the white plot, shows the input signal.
- *mso/2*, the red plot, shows the output signal.

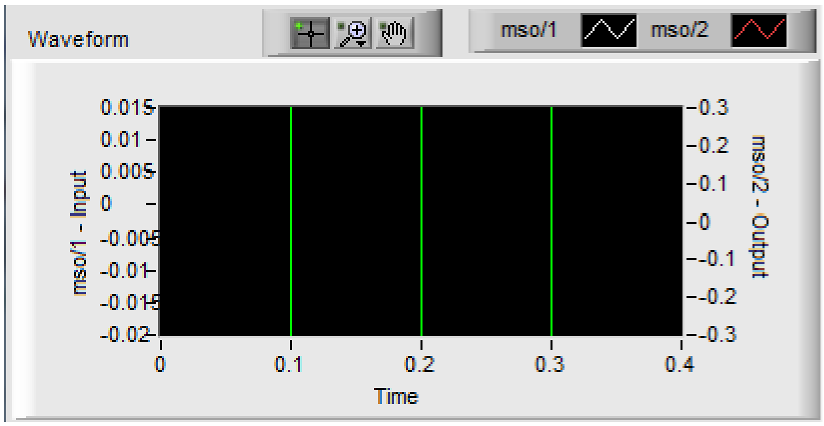

Figure 8. Waveform Display

4.6 Connection Diagram

This section shows the required connections between the VirtualBench hardware and the device under test (DUT), as shown in Figure 9.

- Connect *Mixed-Signal Oscilloscope CH1* to the input of the DUT with a BNC cable.
- Connect *Mixed-Signal Oscilloscope CH2* to the output of the DUT with a BNC cable.
- Connect the function generator, *FGEN*, to the input of the DUT with a BNC cable.

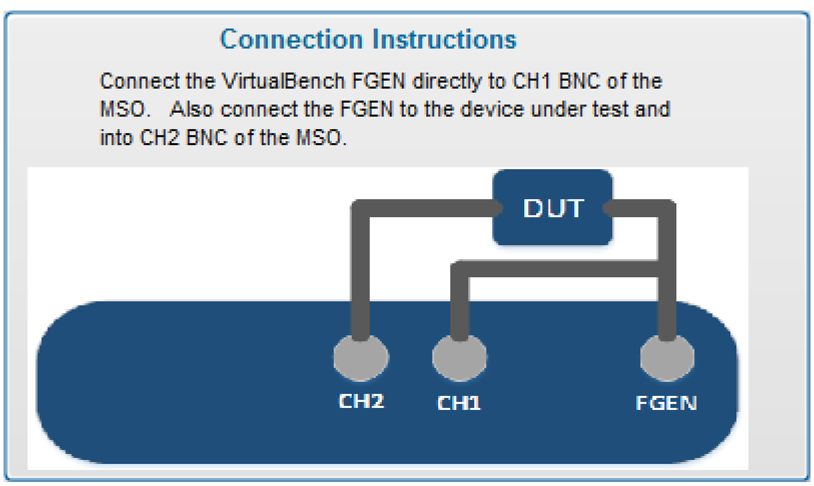

Figure 9. Connection Diagram

4.7 Gain/Phase Display

This section displays the results of the gain and phase measurements over frequency. Figure 10 shows the display area before a measurement occurs. The top section displays the gain measurement result in decibels (dB). The bottom section displays the phase measurement result in degrees (º).

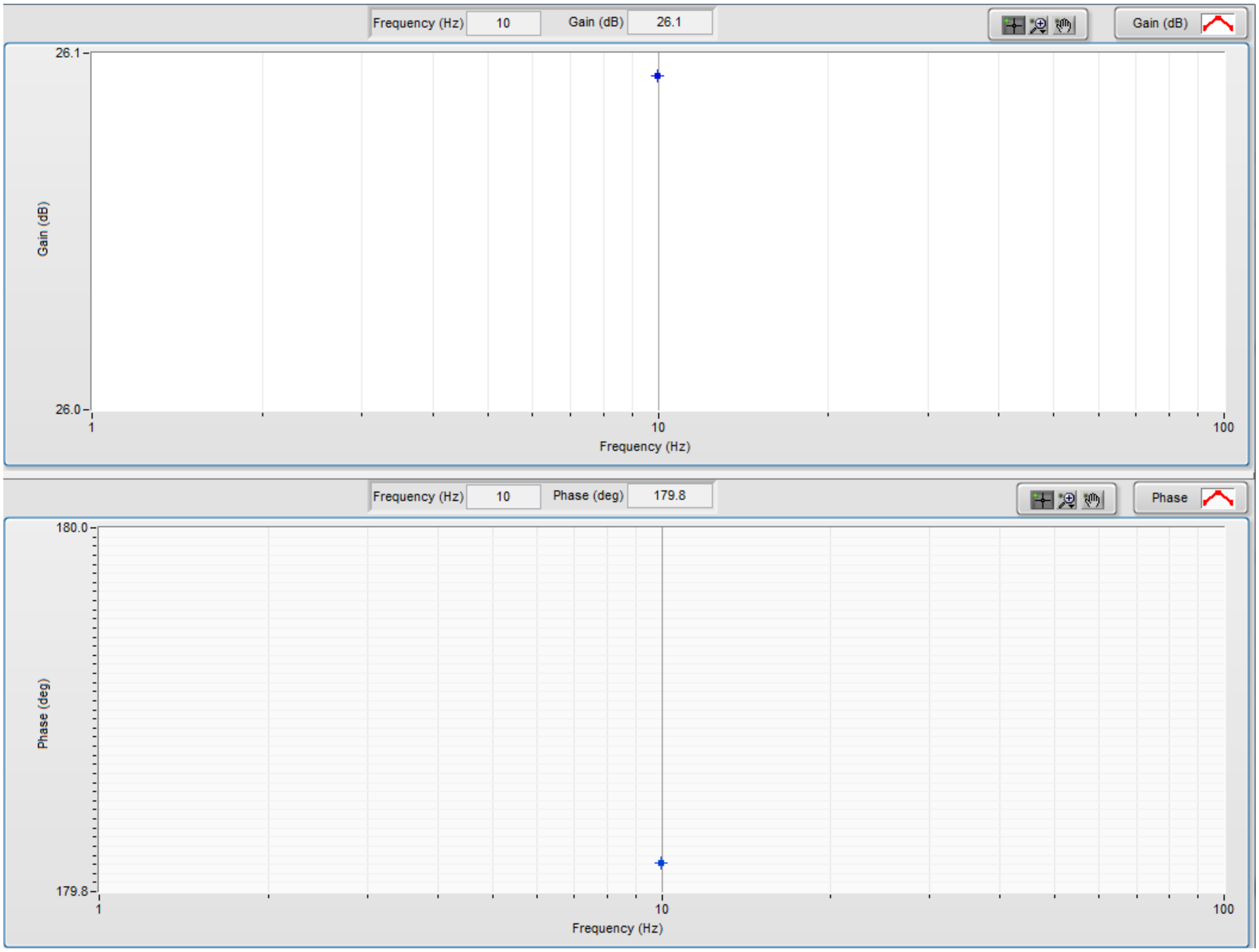

Figure 10. Gain and Phase Displays (Premeasurement)

An example measurement result is shown in Figure 11. After the measurement is complete, click the small blue cursor and drag to show the numerical measurement result at each frequency point. The values are given in the fields at the top of each section. In this example, the start frequency is 10 kHz. At 10 kHz, the gain and phase of this circuit are measured to be 0.21 dB and 0.23º, respectively.

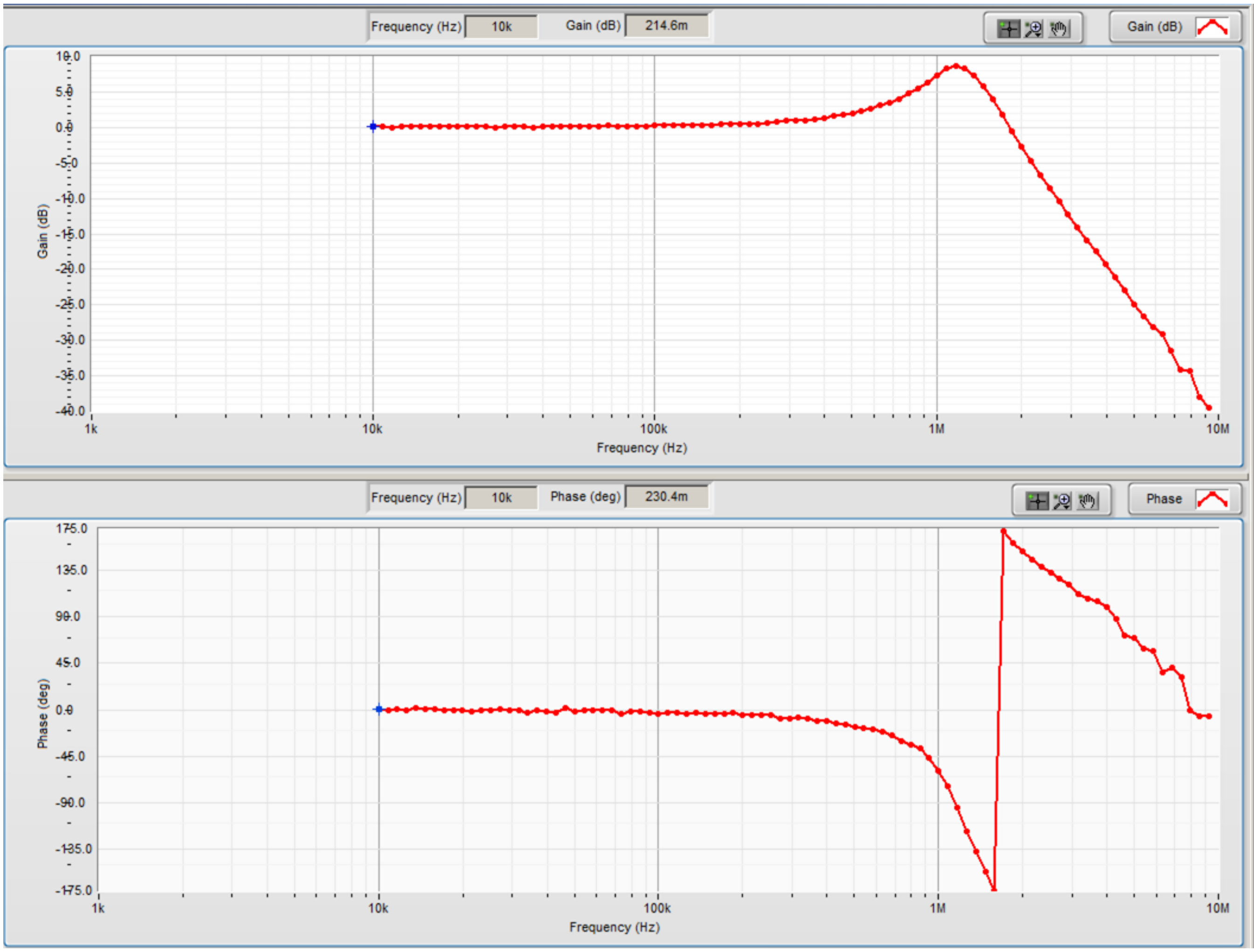

Figure 11. Gain and Phase Displays (Postmeasurement)

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms and conditions that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms and conditions do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for any defects that are caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d’usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。 http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered “Radio Frequency Products” in Japan:* EVMs entering Japan are NOT certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry’s Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】

本開発キットは技術基準適合証明を受けておりません。

本製品のご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。

日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿６丁目２４番１号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page
電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

   6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY WRITTEN DESIGN MATERIALS PROVIDED WITH THE EVM (AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

   6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS AND CONDITIONS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT MADE, CONCEIVED OR ACQUIRED PRIOR TO OR AFTER DELIVERY OF THE EVM.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS AND CONDITIONS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS ANDCONDITIONS OR THE USE OF THE EVMS PROVIDED HEREUNDER, REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN ONE YEAR AFTER THE RELATED CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY WARRANTY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS AND CONDITIONS, OR ANY USE OF ANY TI EVM PROVIDED HEREUNDER, EXCEED THE TOTAL AMOUNT PAID TO TI FOR THE PARTICULAR UNITS SOLD UNDER THESE TERMS AND CONDITIONS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM AGAINST THE PARTICULAR UNITS SOLD TO USER UNDER THESE TERMS AND CONDITIONS SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265