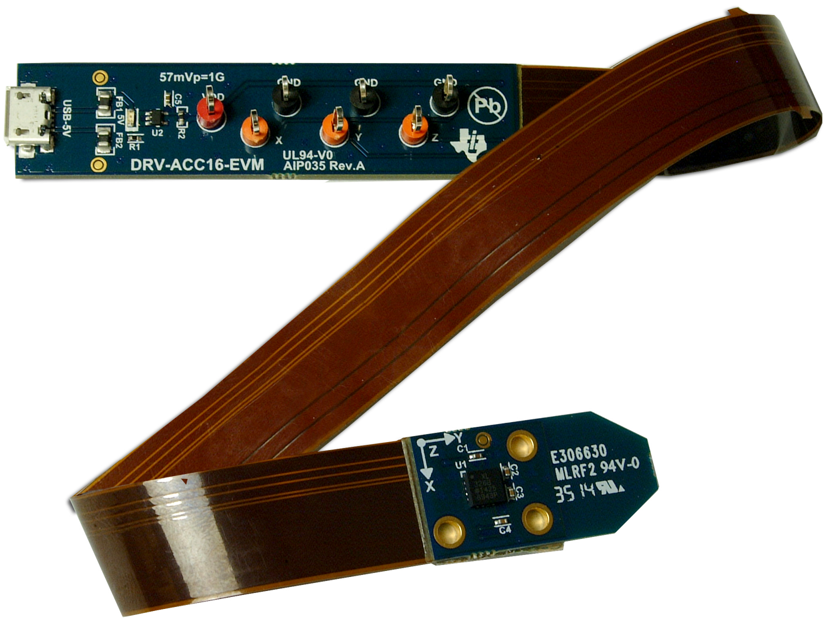
DRV-ACC16-EVM Accelerometer User's Guide

The DRV-ACC16-EVM is a three-axis accelerometer for use in lab acceleration or vibration testing of haptic feedback systems. The accelerometer allows vibrations to be quantified making haptic feedback evaluation, reporting, and comparisons easier.

This document contains instructions and general guidelines for using the DRV-ACC16-EVM and measuring acceleration.



Features

- Measure X, Y, and Z acceleration simultaneously using three independent analog outputs
- Connect to oscilloscope for simple acceleration readings
- Up to 16 g_{peak} acceleration measurements
- Small size and flex cable, minimize interference with natural motion of the system

Kit Contents

- DRV-ACC16-EVM accelerometer board
- Micro-USB cable for power
- Texas Instruments Black Carrying and Storage Case

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Contents

List of Figures

List of Tables

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1 Overview

There are various types of accelerometers available with different measurement ranges, thresholds, precision, and accuracy, but in general, they all convert mechanical vibration into an electrical signal, which can then be converted to acceleration.

The DRV-ACC16-EVM can measure acceleration up to 16 *g* ("*g*" is the acceleration due to Earth's gravity or 9.81 m/s^2). The EVM converts the acceleration from mechanical movement to mV at a rate of 57 mV_{peak} per g_{peak}. This means that every 57 millivolts of peak voltage equals 1 *g* of peak acceleration and 114 mV_{peak} equals 2 *g*'s of peak acceleration.

1.1 Required Equipment and Materials

- DRV-ACC16-EVM accelerometer board
- Micro-USB cable for power
- Oscilloscope for measuring voltage
- Adhesive transfer tape (see Mounting Guidelines)

1.2 Quick Start Connections

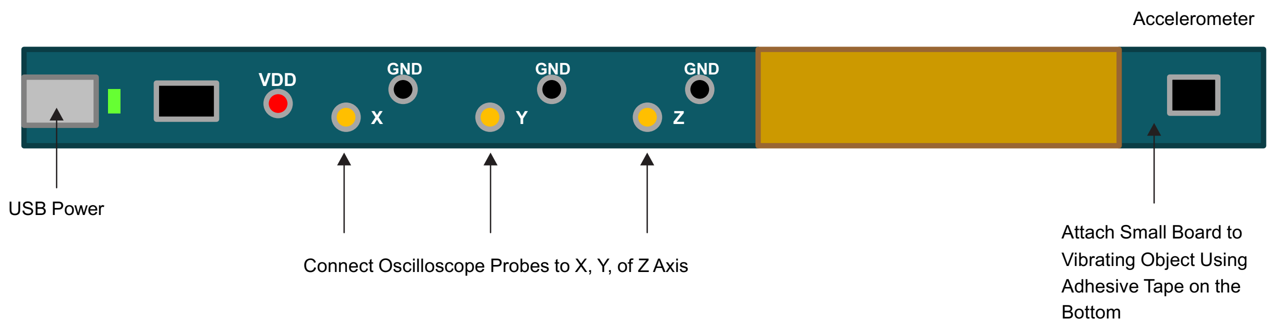

Figure 1. Board Connections

1. Attach the small accelerometer board to the vibrating object
2. Connect an oscilloscope to test points X, Y, and/or Z
3. Provide USB 5-V power

1.3 DRV-ACC16-EVM Specifications

Table 1 lists the DRV-ACC16-EVM specifications.

Table 1. DRV-ACC16-EVM Specifications

	Value	Units
Board Size (Total)	15 x 290	mm
Board Size (Accelerometer Only)	16.6 x 15	mm
Cable / Flex Length	203	mm
Interface	Analog	-
VDD	3.5 – 5.5	V
Acceleration Range	±16	g_{peak}
Bandwidth (X, Y channels)	1600	Hz
Bandwidth (Z channel)	550	Hz
Noise Density	300	µ*g* / √Hz rms
Conversion Ratio	57	mV_{peak} / g_{peak}
DC Offset (at 0 *g*)	1.5	V
Typical Temperature Dependency (-25°C to 70°C)	< 3	mg

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1.4 Power Requirements

The accelerometer board has the following electrical specifications:

Table 2. Board Power Requirements

	Value	Units
USB-5V	3.5 – 5	V
IDD	10	mA

The V_S, accelerometer supply voltage, determines the ratio of acceleration to voltage conversion. There is an on-board LDO that converts USB-5 V to 3 V for the accelerometer. The LDO can be bypassed, if required.

Table 3. Power Requirements When Bypassing LDO

	Value	Units
V_S	1.8 – 3.6	V
IDD (V_S = 3 V)	350	µA

2 Getting Started

The following instructions should be used for placing, mounting, and measuring acceleration with the DRV-ACC16-EVM.

1. Attach the small accelerometer board to the surface of the vibrating object. Use the 3M tape adhesive on the bottom of the board to attach it to the surface.

Figure 2. 3M Tape on Backside of DRV-ACC16-EVM

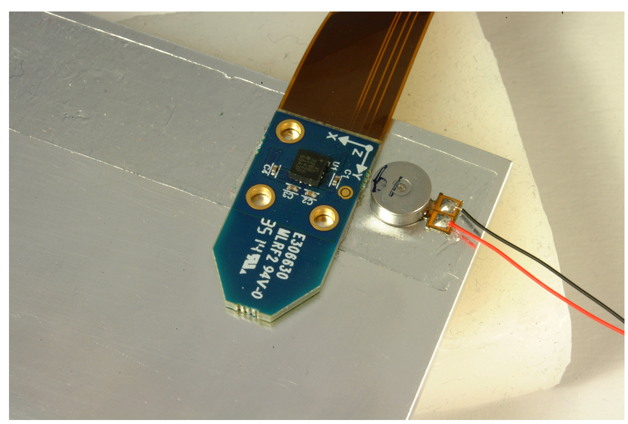

Figure 3. Attach Accelerometer to Vibrating Object

2. Place the vibrating object on a soft surface such as packing foam, bubble wrap, silicone, or gel material so that the object does not rattle or move when vibrating on the table. The surface should mimic the object's final operating environment. See Mounting an Actuator for Testing for additional information.

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3. Connect an oscilloscope to the X, Y, and/or Z axis test points on the measurement board. See Determining the Axis of Vibration for additional instructions.

Figure 4. DRV-ACC16-EVM - Measurement Board

4. Apply power to the board by connecting the micro-USB cable to a USB power source such as a computer or USB charger.
5. AC couple the measurement channels on the oscilloscope and reduce the “V/div” to 50–100 mV. The “V/div” may need to be adjusted later.
6. As the object vibrates, the acceleration should appear as a sine wave on the oscilloscope.
7. Convert the voltage to units of gravity. The conversion ratio is shown in Equation 1:

$$57\ \text{mV}_{peak} = 1\ g_{peak} \quad (1)$$

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3 Converting Voltage to Acceleration

The output voltage of the three accelerometer channels has a DC offset of 1.5 V at 0 *g*. The channels of the DRV-ACC16-EVM can be AC coupled to only show changes in acceleration. This is recommended for measuring the acceleration of haptic systems.

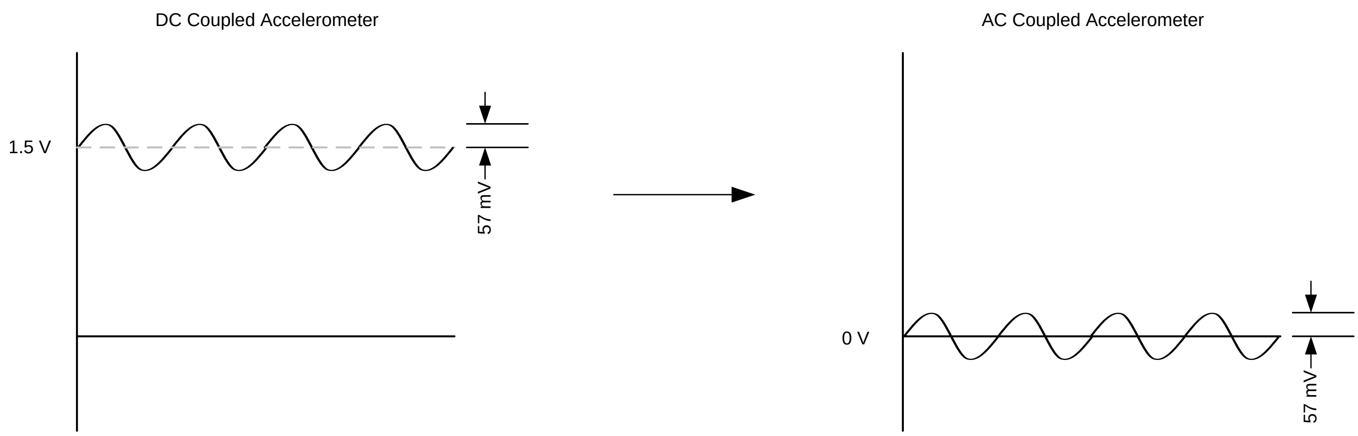

Figure 5. AC-Coupled Accelerometer

To calculate the acceleration, take the peak voltage of a single accelerometer output and divide by 57 mV. Every 57 mV of peak voltage corresponds to 1 *g* of peak acceleration.

$$\text{Acceleration (g)} = \frac{V_{peak}}{57\text{ mV}} \quad (2)$$

V_{peak} – measured peak voltage on test point X, Y, or Z.

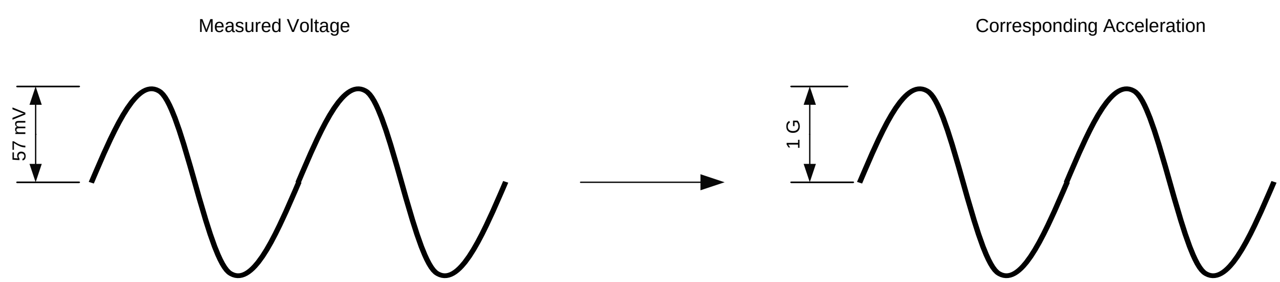

Figure 6. Accelerometer Conversion Voltage

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4 Determining the Axis of Vibration

The orientation of the accelerometer can be determined by the 3-axis label on the small accelerometer board. The direction of the arrows corresponds to the axis which the acceleration is measured. The Z-direction is measured normal to, or coming out of, the board.

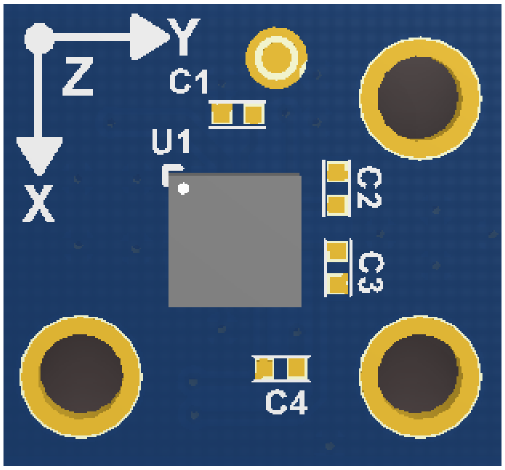

Figure 7. Acceleration Axis

For haptic applications, the axis of vibration is determined by the motion of the actuator. Take for example a DC motor that spins around the X axis and creates force in the Y and Z axes. In this case, measure vibration by connecting to the Y and Z test points of the accelerometer.

The axis of vibration can often be found in the actuator datasheet; if not, the axis is usually easily determined by measuring all axes and finding the axis with the highest acceleration. Below are example diagrams of ERM, LRA, and Piezo actuators and their axes of vibration.

NOTE: Not all actuators will have these same axes of vibration.

4.1 Eccentric Rotating Mass

The ERM motor in Figure 8 spins around the X axis and produces rotational vibration in the YZ plane. Acceleration can be observed on the Y and Z accelerometer channels.

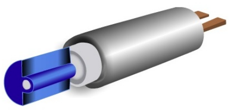

Figure 8. ERM Axes of Vibration

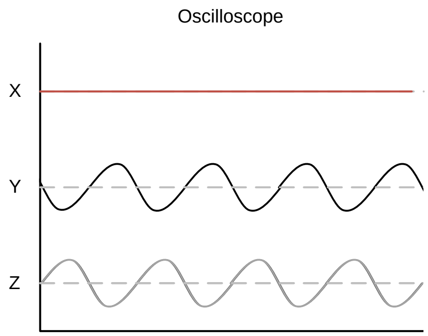

Figure 9. Y and Z Axes Acceleration Measurement

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4.2 Linear Resonant Actuator

The following LRA motor (Figure 10) moves along the Z axis and produces vibration only on the Z axis. Acceleration can be observed on the Z accelerometer channel.

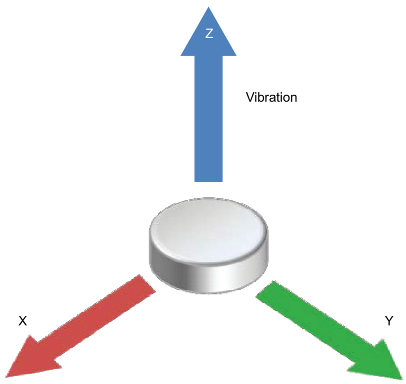

Figure 10. Z-Direction LRA

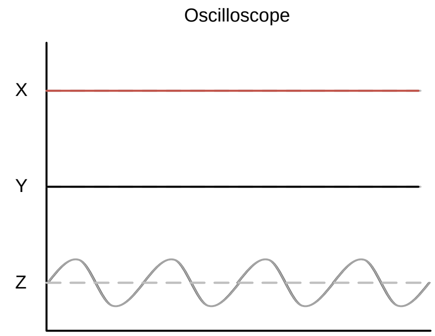

Figure 11. Z-Axis Acceleration Measurement

4.3 Piezo

Figure 12 illustrates a piezo module. A Piezo module is made using a thin piece of piezo (a piezo bender), a mass, and a mechanical housing. The piezo bender and mass will move side-to-side when a high-voltage sine wave is applied to the module's input terminals.

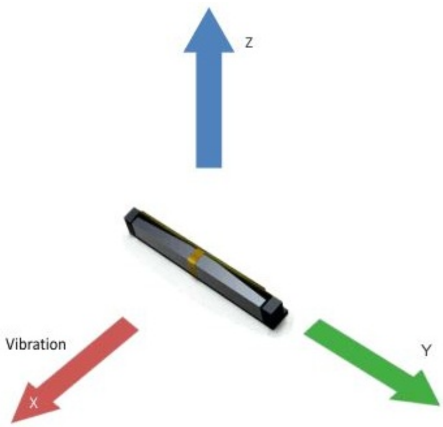

Figure 12. Piezo Module

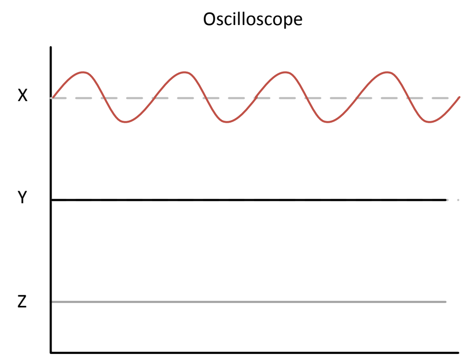

Figure 13. X Axis Acceleration Measurement

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5 Mounting Guidelines

In general, actuators should be mounted in an application using a combination of adhesion and compression. The adhesive ensures the actuator remains in place and the compression mitigates manufacturing tolerances and ensures that the vibration is transferred to the body of the device.

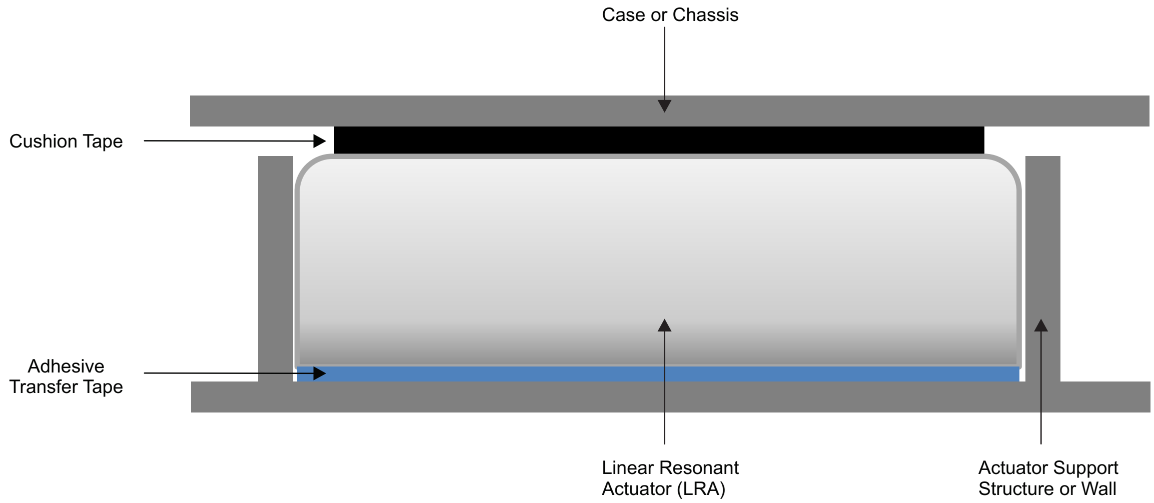

Figure 14. LRA Mounting Stack Up

Actuators are often mounted using an adhesive transfer tape from 3M. This double-sided tape is very strong and intended to withstand a long lifetime of vibration. Many actuator manufacturers provide the option to include the adhesive tape on the actuator for production builds.

Table 4. Adhesive Transfer Tape for Mounting Actuators

Part Number	Manufacturer	Description
3-5-468MP	3M	Adhesive transfer tape

Alternatively, some ERM and LRA actuators can be soldered to the PCB board directly to ensure long lasting vibration performance; however, care must be taken to ensure that vibration is transferred from the PCB to the chassis of the device.

6 Mounting an Actuator for Testing

The acceleration of an actuator often needs to be measured outside of the final system or application to compare actuator strengths, run life-tests, or create haptic effects. The best way to measure acceleration is to mount the actuator on a fixture that has similar mass to the final application. We call this a haptic test fixture. To do this:

1. Create a test fixture that has a similar size and weight as the final application. An aluminum or similar material block works well for most applications.
2. Place the actuator in a similar location as it would appear in the final application and attach it to the mass using strong adhesive tape, epoxy, or glue.
3. Place the test fixture on a material that can isolate the vibration such as a piece of foam or a silicone gel. The mechanical isolation prevents rattling and transferring vibration to the table. Test the material and make sure it roughly mimics the final application environment.
4. Place the accelerometer board on the fixture using the adhesive tape, near the actuator and begin measuring.

To measure the acceleration of an actuator for use inside a smartphone, place the actuator on a 100 g block that has a similar size and shape as the phone. Next, place the block on a piece of packing or ESD foam to represent a hand, which is where a phone is normally held. Finally, measure the acceleration of the block on the foam and compare it to when a person holds it in their hand.

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7 Example Waveforms

The following waveforms are acceleration measurements taken with an LRA using the DRV2605L Haptic Driver. The blue waveform is the acceleration and the orange waveform is the output voltage of the DRV2605L.

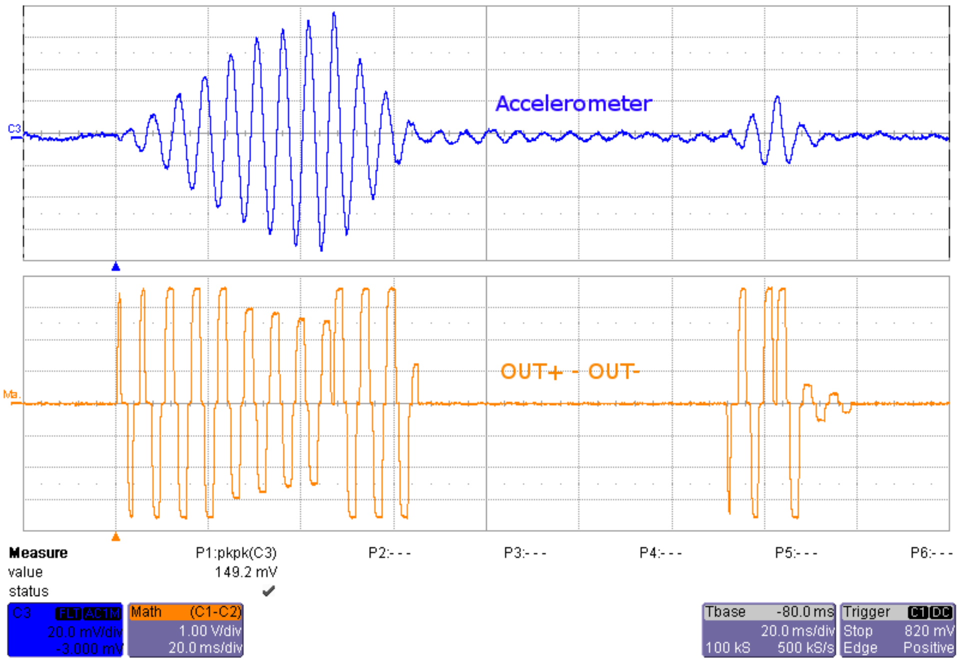

Figure 15. Click and Release Effect

Equation 3 is the measured acceleration calculation for Figure 15.

$$\text{Acceleration} = \frac{149.2\text{ mVpp}}{2 \times 57\text{ mVp}} = 1.309\ g_{\text{peak}} \tag{3}$$

The peak-to-peak voltage of the accelerometer voltage waveform is divided by 2 to obtain the peak voltage and then divided by 57 mVp to calculate the acceleration.

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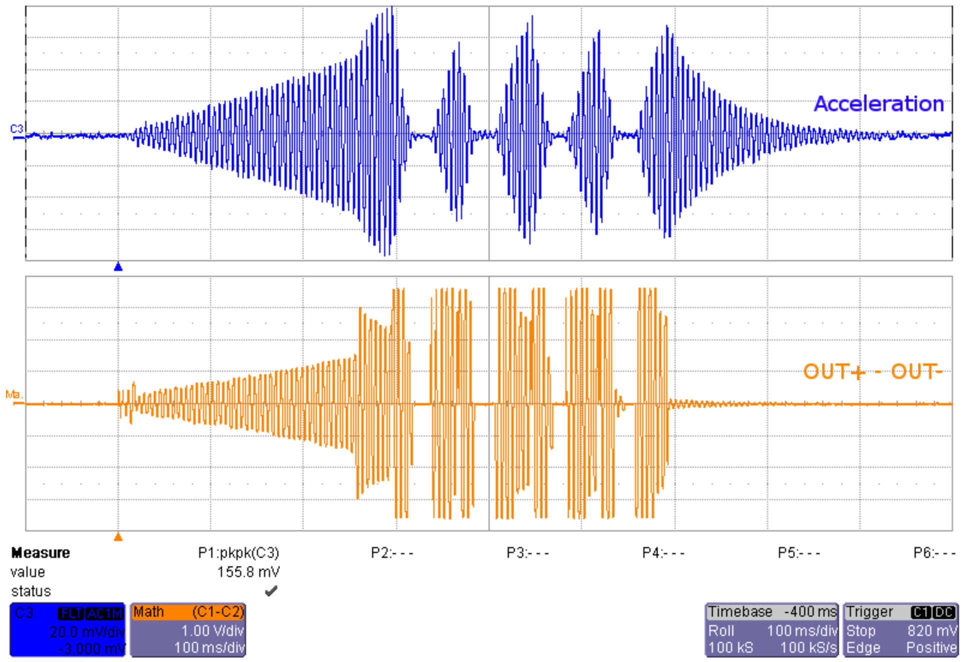

Figure 16. Ramp Up and Pulsing Effect

Equation 4 is the measured acceleration calculation for Figure 16.

$$\text{Acceleration} = \frac{155.8\ \text{mVpp}}{2 \times 57\ \text{mVp}} = 1.367\ g_{\text{peak}} \tag{4}$$

Alternatively, use the Math function to find the acceleration at each point in the graph automatically.

8 Screw Hole Dimensions

The accelerometer board can be mounted using the screw holes shown in Figure 17. Figure 17 is the screw hole mechanical footprint.

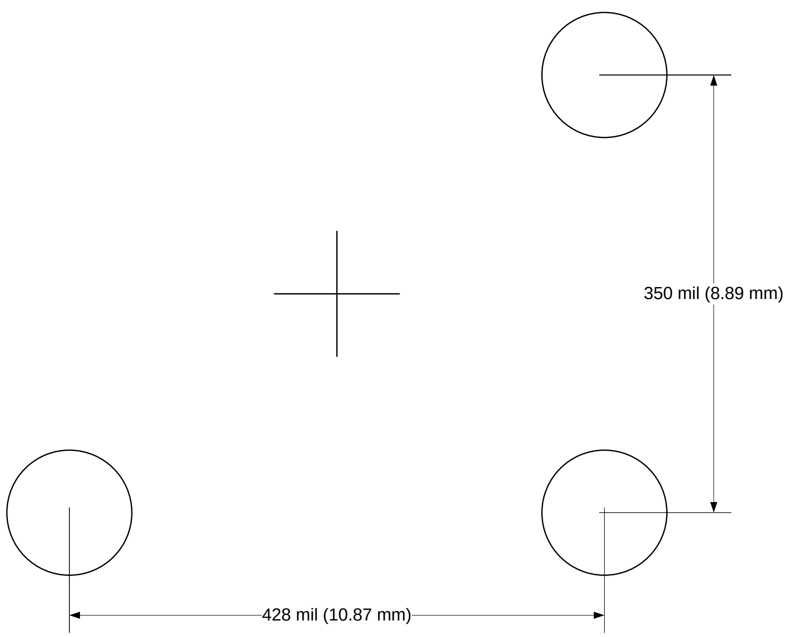

Figure 17. Screw-Hole Footprint

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9 Schematic, Layout, and Bill of Materials

This section contains the schematic, PCB layout, and bill of materials.

9.1 Schematic

Figure 18 illustrates the DRV-ACC16-EVM schematic.

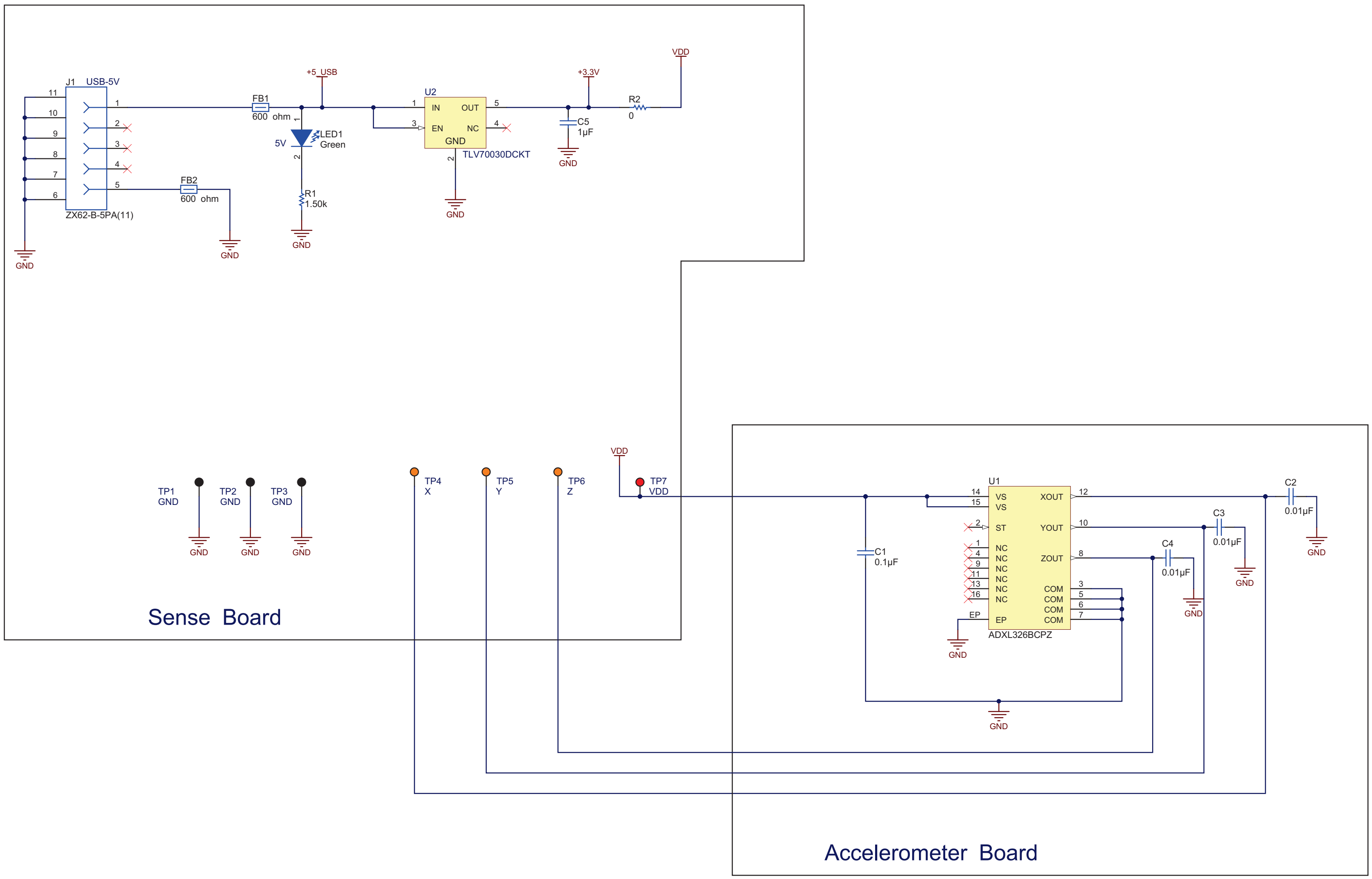

Figure 18. DRV-ACC16-EVM Schematic

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9.2 Layout

Figure 19 through Figure 25 display the DRV-ACC16-EVM printed-circuit board (PCB) layout.

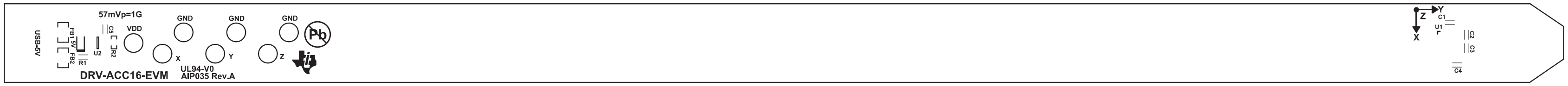

Figure 19. DRV-ACC16-EVM Top Overlay

Figure 20. DRV-ACC16-EVM

Figure 21. DRV-ACC16-EVM Top Layer

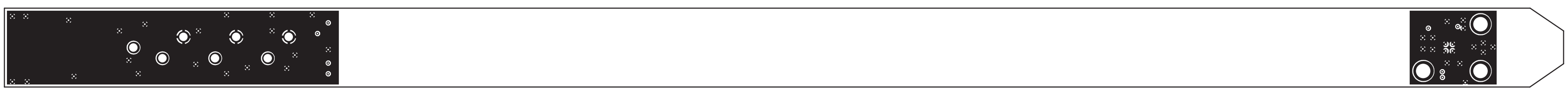

Figure 22. DRV-ACC16-EVM Bottom Layer

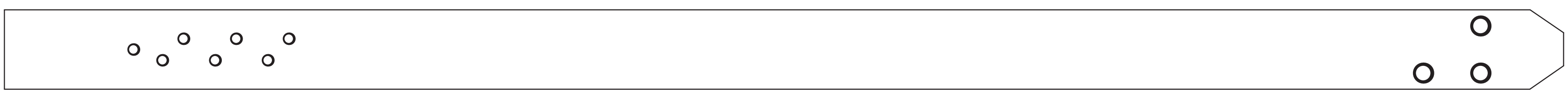

Figure 23. DRV-ACC16-EVM Bottom Solder

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Symbol	Hit Count	Tool Size	Plated	Hole Type
□	47	12mil (0.305mm)	PTH	Round
○	7	63mil (1.6mm)	PTH	Round
▽	3	108mil (2.743mm)	PTH	Round
	57 Total			

Drill Table

Figure 24. DRV-ACC16-EVM Drill Drawing

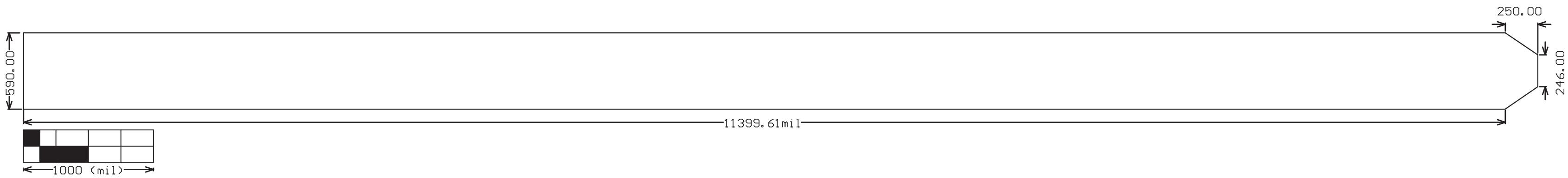

Figure 25. DRV-ACC16-EVM Board Dimensions

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Figure 25 illustrates the DRV-ACC16-EVM fabrication drawing.

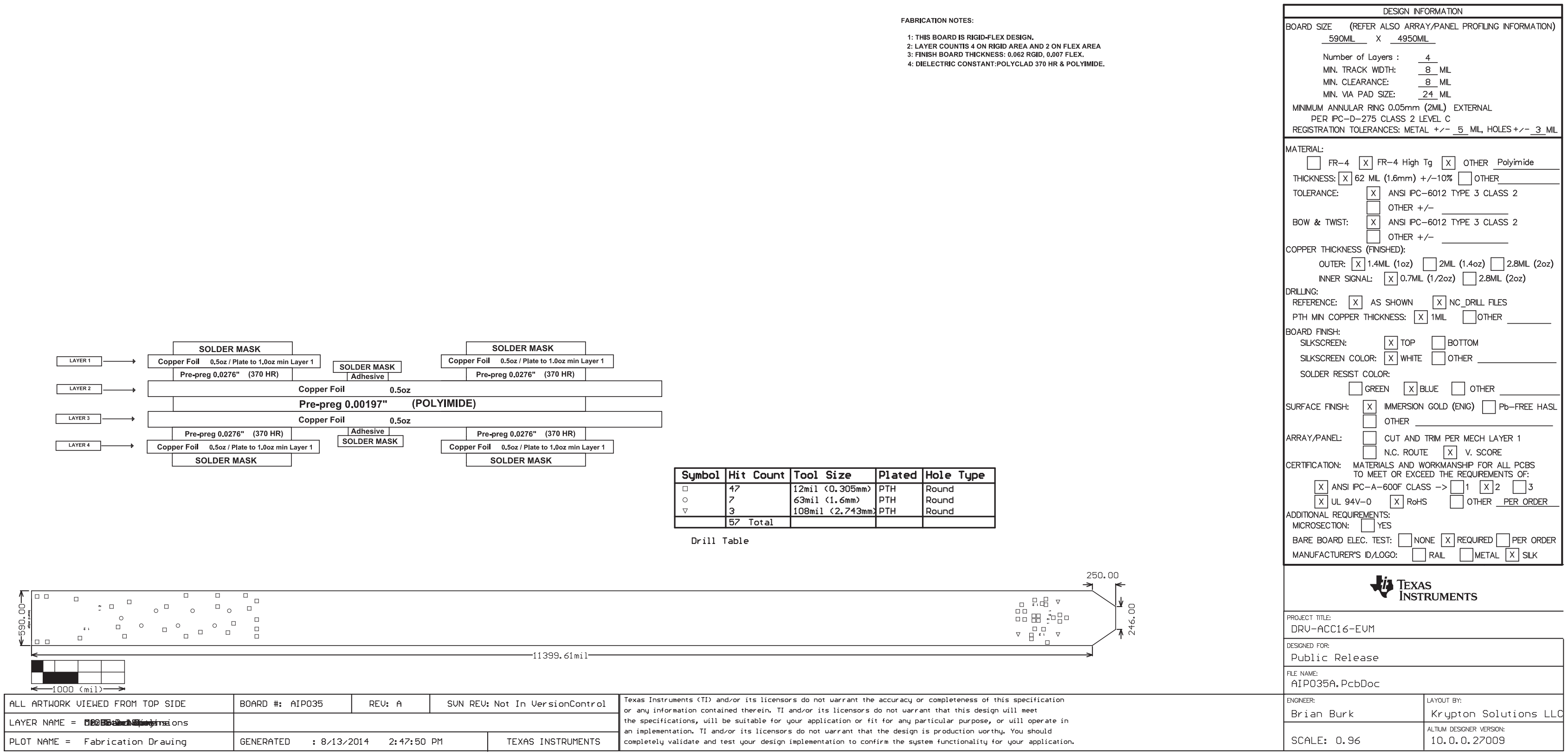

Figure 26. DRV-ACC16-EVM Fabrication Drawing

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9.3 Bill of Material (BOM)

Table 5 lists the DRV-ACC16-EVM bill of materials (BOM).

Table 5. Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
C1	1	0.1uF	CAP, CERM, 0.1 µF, 6.3 V, +/- 10%, X5R, 0402	0402	C1005X5R0J104K	TDK
C2, C3, C4	3	0.01uF	CAP, CERM, 0.01uF, 10V, +/-10%, X5R, 0402	0402	GRM155R61A103KA01D	Murata
C5	1	1uF	CAP, CERM, 1uF, 25V, +/-10%, X5R, 0402	0402	C1005X5R1E105K050BC	TDK
FB1, FB2	2	600 ohm	Ferrite Bead, 600 ohm @ 100MHz, 2A, 0805	0805	MPZ2012S601A	TDK
H1	1		EVM EVA Black zipper case with TI Logo	Used in PnP output	TI-EVACASE-BLACK	Royal Case
H2	1		CABLE USB-A TO MICRO USB-B 2M	Used in PnP output	AK67421-2-R	Assmann WSW Components
H3	1		TAPE TRANSFER ADHESIVE 3" X 5YD	Used in PnP output	3M9724-ND	3M (TC)
J1	1		Connector, Receptacle, Micro-USB Type B, R/A, Bottom Mount SMT	Micro USB-B receptacle	ZX62-B-5PA(11)	Hirose Electric Co. Ltd.
LED1	1	Green	LED, Green, SMD	1.6x0.8x0.8mm	LTST-C190GKT	Lite-On
R1	1	1.50k	RES, 1.50k ohm, 1%, 0.063W, 0402	0402	CRCW04021K50FKED	Vishay-Dale
R2	1	0	RES, 0, 5%, 0.063 W, 0402	0402	ERJ-2GE0R00X	Panasonic
TP1, TP2, TP3	3	Black	Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone
TP4, TP5, TP6	3	Orange	Test Point, Multipurpose, Orange, TH	Orange Multipurpose Testpoint	5013	Keystone
TP7	1	Red	Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone
U1	1		Small, Low Power, 3-Axis ±16 g Accelerometer, QFN16	QFN16, 4x4 mm	ADXL326BCPZ	
U2	1		Single Output LDO, 200 mA, Fixed 3 V Output, 2 to 5.5 V Input, with Low IQ, 5-pin SC70 (DCK), -40 to 125 degC, Green (RoHS & no Sb/Br)	DCK0005A	TLV70030DCKT	Texas Instruments

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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

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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 may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of 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.

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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
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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:*

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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.

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