Using the LMG1205HBEVM

User's Guide



Literature Number: SNVU552
March 2017

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General TI High Voltage Evaluation User Safety Guidelines



Always follow TI's setup and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and the safety of those working around you. Contact TI's Product Information Center http://support/ti./com for further information.

Save all warnings and instructions for future reference.

Failure to follow warnings and instructions may result in personal injury, property damage, or death due to electrical shock and/or burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open-framed, unenclosed printed-circuit board assembly. It is intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise, and knowledge of electrical safety risks in development and application of high-voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments. If you are not suitably qualified, you should immediately stop from further use of the HV EVM.

- **Work Area Safety:**
  - Maintain a clean and orderly work area.
  - Qualified observer(s) must be present anytime circuits are energized.
  - Effective barriers and signage must be present in the area where the TI HV EVM and its interface electronics are energized, indicating operation of accessible high voltages may be present, for the purpose of protecting inadvertent access.
  - All interface circuits, power supplies, evaluation modules, instruments, meters, scopes and other related apparatus used in a development environment exceeding 50 V_{RMS}/75 VDC must be electrically located within a protected Emergency Power Off (EPO) protected power strip.
  - Use a stable and non-conductive work surface.
  - Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
- **Electrical Safety:**

  As a precautionary measure, it is always a good engineering practice to assume that the entire EVM may have fully accessible and active high voltages.
  - De-energize the TI HV EVM and all its inputs, outputs, and electrical loads before performing any electrical or other diagnostic measurements. Confirm that TI HV EVM power has been safely de-energized.
  - With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
  - When EVM readiness is complete, energize the EVM as intended.

WARNING: While the EVM is energized, never touch the EVM or its electrical circuits as they could be at high voltages capable of causing electrical shock hazard.

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- **Personal Safety:**
  - Wear personal protective equipment, for example, latex gloves and/or safety glasses with side shields or protect EVM in an adequate lucent plastic box with interlocks from accidental touch.
- **Limitation for Safe Use:**
  - EVMs are not to be used as all or part of a production unit.

Safety and Precautions

The EVM is designed for professionals who have received the appropriate technical training, and is designed to operate from an AC power supply or a high-voltage DC supply. Please read this user guide and the safety-related documents that come with the EVM package before operating this EVM.

CAUTION



Do not leave the EVM powered when unattended.

WARNING



Hot surface! Contact may cause burns. Do not touch!

WARNING



Hot surface! Contact may cause burns. Do not touch!

WARNING



High Voltage! Electric shock is possible when connecting board to live wire. Board should be handled with care by a professional.

For safety, use of isolated test equipment with overvoltage and overcurrent protection is highly recommended.

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Using the LMG1205HBEVM GaN Half-Bridge Power Stage EVM

The LMG1205HBEVM is designed to evaluate the LMG1205 100-V half-bridge driver for enhancement-mode GaN FETs. The main circuit in this EVM consists of two Gallium Nitride (GaN) FETs connected in a half-bridge configuration, driven by an LMG1205.

This EVM guide describes correct operation and measurement of the EVM, as well as the EVM construction and typical performance. Additionally, setup instructions, including power up, are described to achieve DC-DC conversion at a certain regulation voltage. The EVM board is designed to accelerate the evaluation of the LMG1205.

This board is not intended to be used as a standalone product, but rather is intended for use to evaluate the switching performance of the LMG1205.

1 Description

The LMG1205HBEVM evaluation module is a small, easy-to-use power stage with an external PWM signal. The board can be configured as a buck converter, boost converter, or other converter topology using a half bridge.

Because this is an open-loop board with an external PWM signal, it is not intended for evaluation of transient response. This EVM can be used to evaluate the performance of the LMG1205 in a hard-switched converter to sample measurements such as efficiency, switching speed, and slew rate.

The EVM features an LMG1205 half-bridge driver coupled with two 100-V, 7-mΩ GaN FETs in a half-bridge configuration. The module can deliver up to 10 A of current if the application includes adequate thermal management (monitor case temperature and ensure adequate airflow is present, if required). The thermal management considerations include forced air, heat sink, and lower operating frequency to minimize the power dissipation in the module.

1.1 EVM Features

LMG1205HBEVM features include:

- Input voltage operates up to 80 VDC
- Optimized PCB layout minimizes gate and power loop inductances to mitigate ringing effects
- Single-input, onboard for PWM signal with 8-ns dead time
- Configurable onboard dead-time adjustment by simple resistance change
- Onboard LDO for generating 5-V VCC supply from a poorly regulated supply between 5.5 V and 10 V
- Convenient test points for DC and switching signal evaluation
- Kelvin sense capability for efficiency measurements for input and output voltage

CAUTION

High-voltage levels may be present on the evaluation module whenever it is energized. Proper precautions must be taken when working with the EVM.

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1.2 Typical Applications

The LMG1205 is suited for use in high frequency DC-DC converters. It is simple to use and requires few external components. Typical applications include:

- High-speed, synchronous buck converters
- Class D amplifiers for audio
- 48-V point-of-load converters for industrial, computing, and telecom

2 EVM Kit Contents

The kit contains the following:

- Safety instructions
- LMG1205HBEVM PCB assembly

3 Electrical Performance Specifications

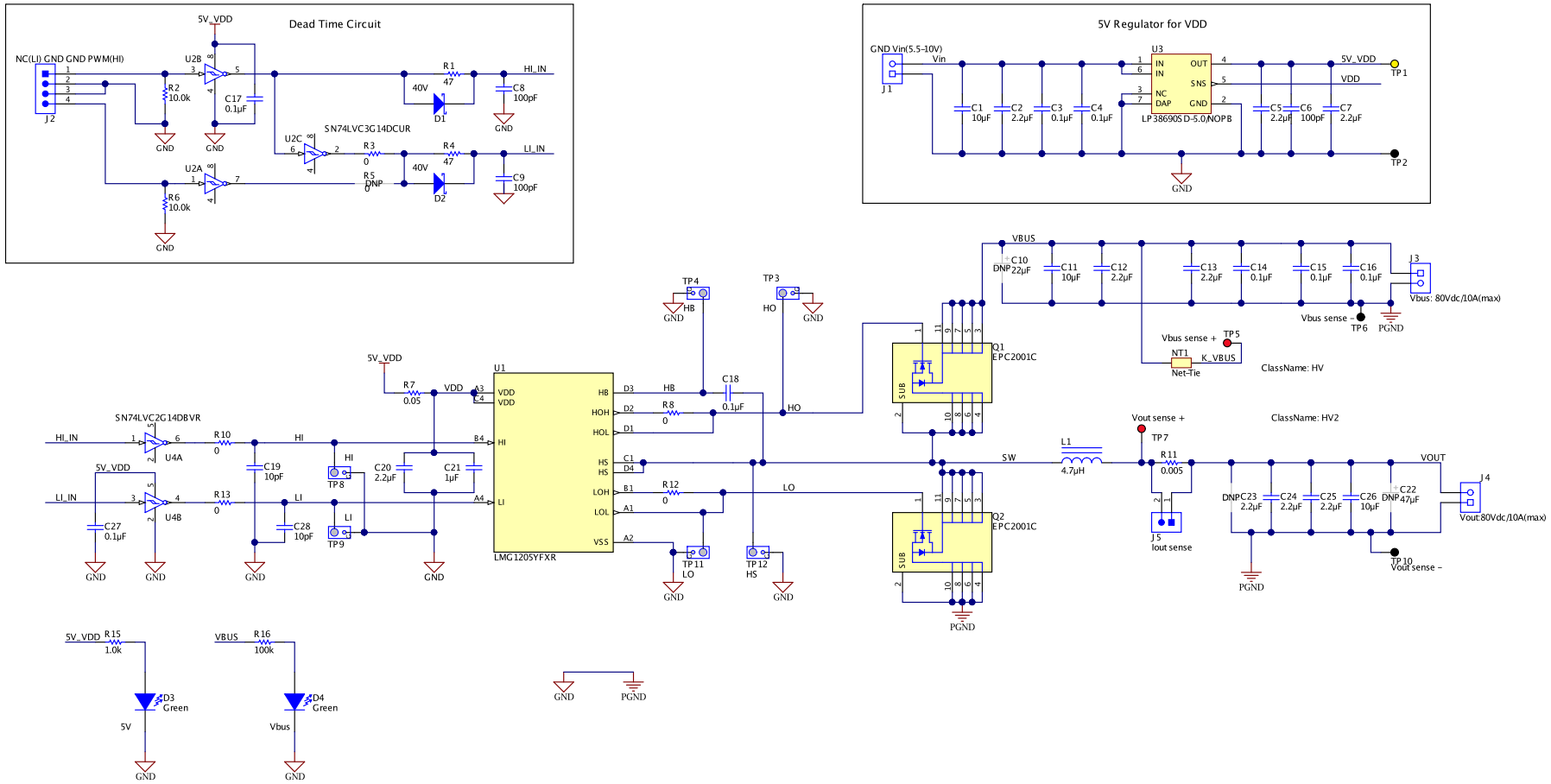
Table 1. LMG1205HBEVM Electrical Performance Specifications

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNITS
V_{BUS}	Half-bridge input voltage	Connected to drain of high-side FET			80	V
V_{OUT}	Half-bridge output voltage	Connected through inductor L1 to SW			80	V
V_{IN}	Input voltage for 5-V VDD LDO		5.5		10	V
V_{PWM}	PWM input voltage		0		5	V
I_{OUT}	Half-bridge output current				10	A
P_{OUT}	Half-bridge output power	LMG1205 and GaN FETs $T_J \leq 125^oC$			160	W
f_{SW}	Switching frequency		0.1	1	5	MHz

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4 EVM Schematic

Figure 1 shows the schematic of the evaluation module.



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Figure 1. LMG1205HBEVM Schematic

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5 Test Setup

This section describes the EVM hardware and outlines the procedure to set it up for evaluation. Figure 2 and Figure 3 show the top and bottom views of the LMG1205HBEVM, respectively.

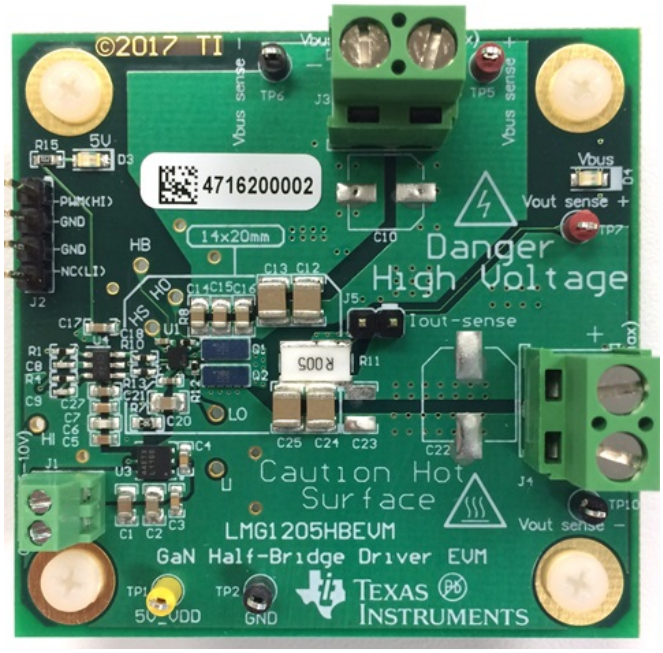


Figure 2. LMG1205HBEVM Board Top View

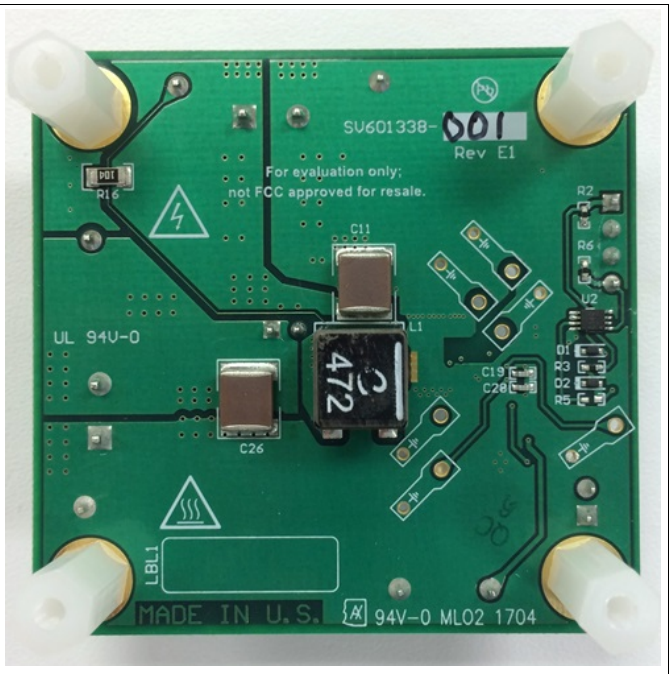


Figure 3. LMG1205HBEVM Board Bottom View

WARNING

High voltages that may cause injury exist on this evaluation module (EVM). Please ensure all safety procedures are followed when working on this EVM. Never leave a powered EVM unattended.

5.1 Test Equipment

- **DC Voltage Source**: capable of supplying the input of the EVM up to 80 V as desired. Capable of supplying 10 A and supports current limiting
- **DC Bias Source**: capable of 5.5-V to 10-V output at up to 500 mA
- **Oscilloscope**: capable of at least 200-MHz operation (≥ 500 MHz preferred), using oscilloscope probes with a spring-type ground connection
- **DC Multimeter(s)**: Capable of 80-V measurement, suitable for determining operation and efficiency (if desired)
- **DC Load**: Capable of 100-V operation at up to 10 A in constant current-mode operation
- **Function Generator**: single output for PWM operation, dual synchronous output for Independent mode (requires EVM modification), capable of at least 0-V to 3-V signal (operating maximum digital input is 5 V)

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5.2 List of Test Points

The test points for switching voltage signals on this EVM have been designed for use with oscilloscope probes with the included spring-type ground connections (often called pigtails). Using the small pigtails instead of the ground clips will minimize measurement error and produce a cleaner signal with the fast switching GaN devices used on this EVM. Refer to Figure 4 through Figure 9 to see the intended probe usage for each of the switching signals. The switching voltage data shown in this user guide has been obtained using such a measurement method.

Table 2. Test Point Functional Descriptions

TEST POINT	NAME	DESCRIPTION
TP1	5V_VDD	5-V VDD onboard generated supply
TP2	GND	GND
TP3	HO	High-side GaN FET gate signal
TP4	HB	High-side Floating Bias Supply
TP5	Vbus sense +	High-sense connection for Vbus input voltage
TP6	Vbus sense –	Low-sense connection for Vbus input voltage (PGND)
TP7	Vout sense +	High-sense connection for Vout output voltage
TP8	HI	High-side GaN FET control input signal
TP9	LI	Low-side GaN FET control input signal
TP10	Vout sense –	Low-sense connection for Vbus output voltage (PGND)
TP11	LO	Low-side GaN FET gate signal
TP12	HS	High-side GaN FET source signal (that is, SW node)
J5	Iout sense	Output current sense through 5-mΩ shunt resistor (1V:20A)



Figure 4. HI Test Point (TP8)



Figure 5. LI Test Point (TP9)



Figure 6. HS Test Point (TP12)



Figure 7. HB Test Point (TP4)



Figure 8. HO Test Point (TP3)



Figure 9. LO Test Point (TP11)

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5.3 List of Terminals

Table 3. List of Terminals

TERMINAL	NAME	DESCRIPTION
J1	V_{IN}	LDO bias input for 5-V VDD onboard generated supply
J2	PWM_IN	Function generator input. See Section 5.4.1.
J3	V_{BUS}	GaN half-bridge input bus voltage
J4	V_{OUT}	GaN half-bridge output voltage

5.4 EVM Connections

Figure 10 shows the required connections for basic operation of the EVM.

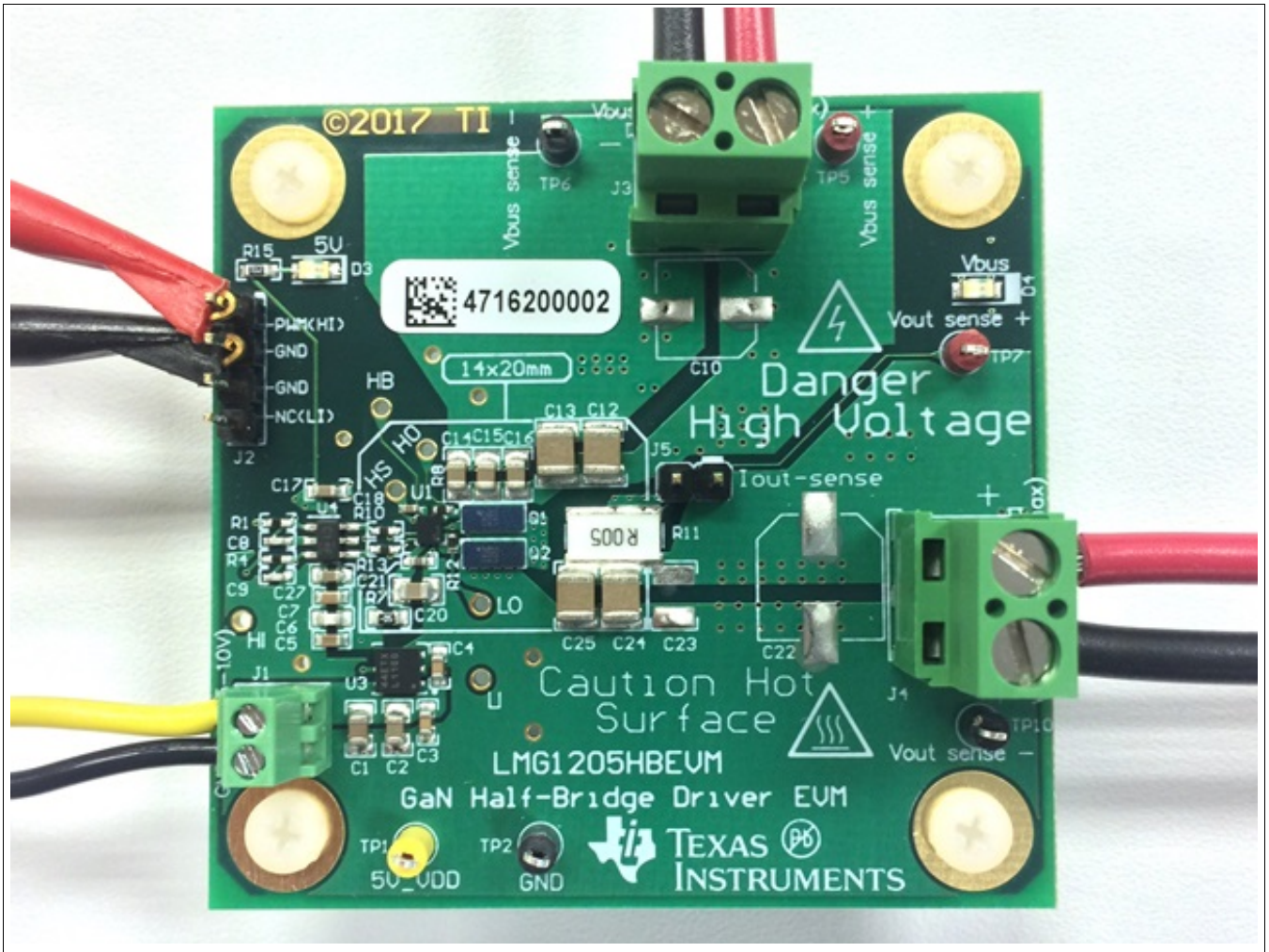


Figure 10. LMG1205HBEVM Test Setup Connections

5.4.1 PWM Input

Provide the PWM input using a function generator that is capable of providing the desired switching frequency and duty cycle. This function generator output should be connected to the J2 connector as shown in Figure 10. The top-most pin (J2-pin1) in this view is the positive input of the PWM supply and the remaining three pins are connected to GND in the default assembly for the board.

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Alternatively, two separate PWM inputs may be applied to control HI and LI independently. To apply this type of control, R3 must be removed and R5 must be populated with a 0-Ω resistor. Once these modifications have been done, the HI signal should be applied at pin 1 of J2, and the LI signal at pin 4 of J2. Note that with this control scheme, the EVM will no longer generate a dead time separating HI and LI transitions. Careful consideration must be applied to the control signals in this mode of operation to prevent a shoot-through condition.

5.4.2 Setting Dead Time

Dead times are set by the RC delays between the inverted and noninverted PWM inputs to the LMG1205 driver. The dead time typically does not require to be changed, however to evaluate impact of dead time on efficiency, you can vary the RC delay, its easy to change resistors R1 and R4 to get the appropriate dead time. Ensure that the dead time is not reduced so much that it causes a shoot-through condition.

Setting the dead time correctly will improve efficiency and prevent damage to the GaN FETs. The duration of the dead time needed depends on operating conditions: monitor this parameter over the operating range and adjust accordingly.

5.4.3 Test Point Connections

Ensure that any test point connections — both DC and high-speed probe connections — are made prior to powering up the EVM.

6 Test Procedure

This section describes different tests that can be performed using the LMG1205HBEVM in its default buck-converter configuration. Never leave a powered EVM unattended for any length of time. Also, the unit should never be handled while power is applied to it. A high-voltage power supply with overcurrent protection enabled and/or connected in series with a properly-rated use is recommended for safe operation. Ensure that the electrical characteristic table conditions are met to prevent damage to any components on this EVM.

WARNING

There are very high voltages present on the EVM. Some components reach temperatures above 50°C. Precautions must be taken when handling the board.

6.1 Power-Up Procedure

1. Connect the V_{IN} bias supply to J1, the V_{BUS} supply to J3, and output load to J4 as shown in Figure 10, but do not power them on yet. J4 can be left open if unloaded operation is desired.
2. If you will be performing efficiency measurements, connect multimeters or power meter across kelvin voltage sense points TP5 and TP6 for the input voltage, and across TP7 and TP10 for the output voltage.
3. Connect the function generator per Section 5.4.1. Do not enable the output(s) yet.
4. Power up the V_{IN} bias supply to J1 to between 5.5 and 10 V. The onboard LDO will provide 5 V to power internal circuitry and the gate driver. LED D3 should illuminate and you should be able to measure 5 V from TP1 to TP2.
5. Enable the output(s) of the function generator and verify that the gate signals are not overlapping. If you notice overlap, power down the board and ensure board is populated as described in Section 5.4.2.
6. Set the current limit for the V_{BUS} supply to 10 A or less, and the voltage to the desired level (80 maximum). LED D4 should illuminate.
7. If using an electronic load, enable it now and set it to the desired load current (10 A or less).
8. Perform the desired measurements.

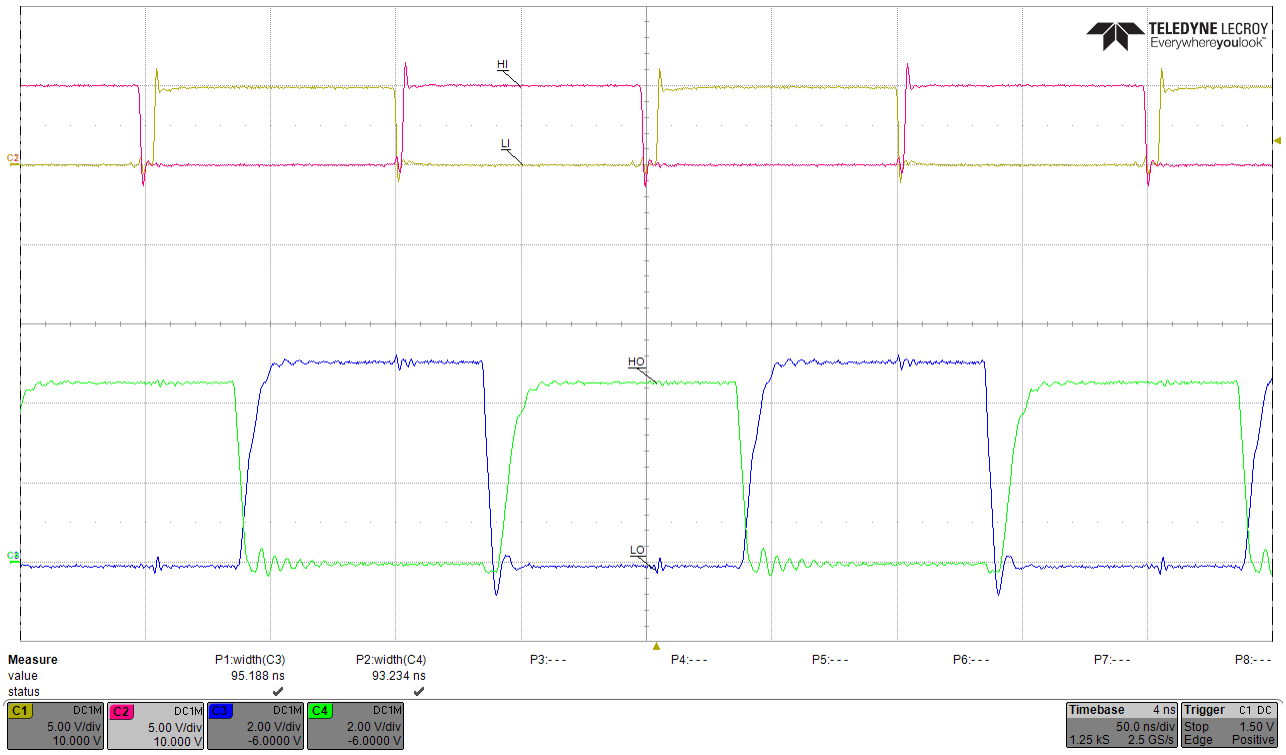
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6.2 Shutdown Procedure

Once the desired measurements have been completed, shut down the EVM by following these steps:

1. Turn off the V_{BUS} supply on J3.
2. Disable the function generator.
3. Disable the electronic load.
4. Disable the V_{IN} bias supply on J1.

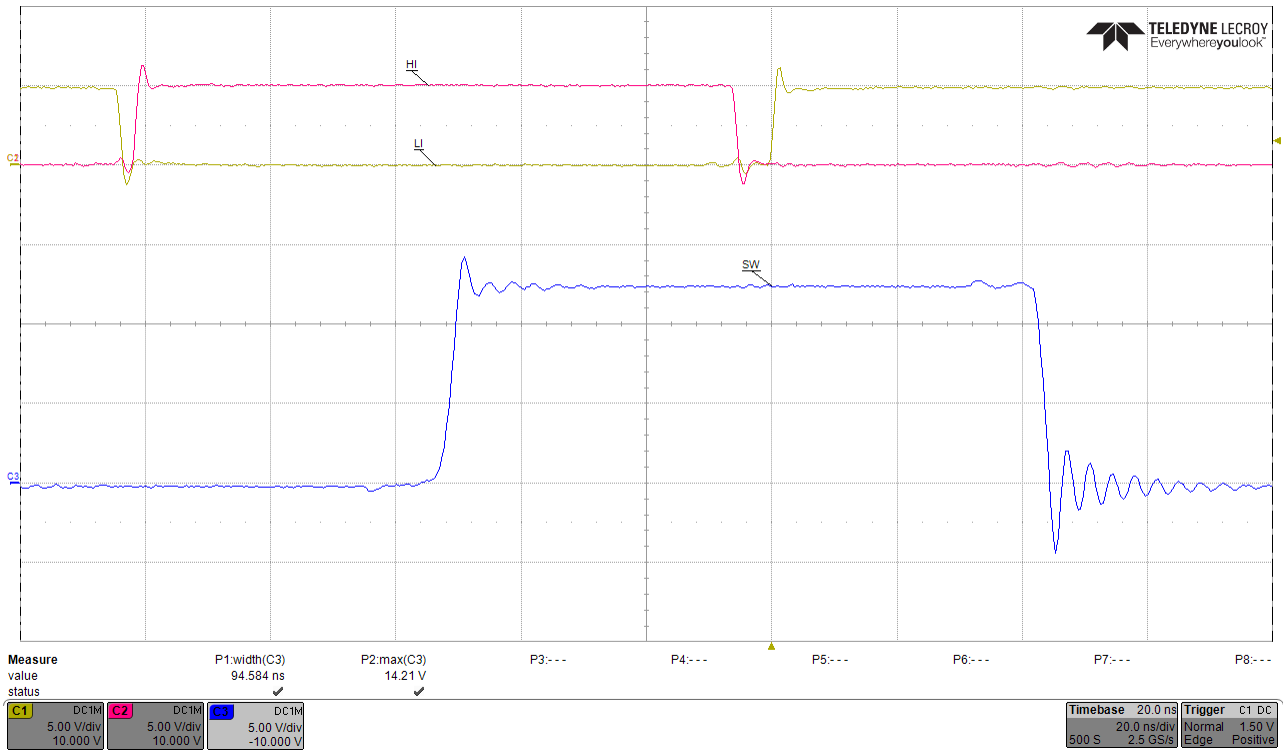
7 Switching Waveforms



V_{DD} = 5 V, V_{HS} = VSS = 0 V, f_{SW} = 5 MHz

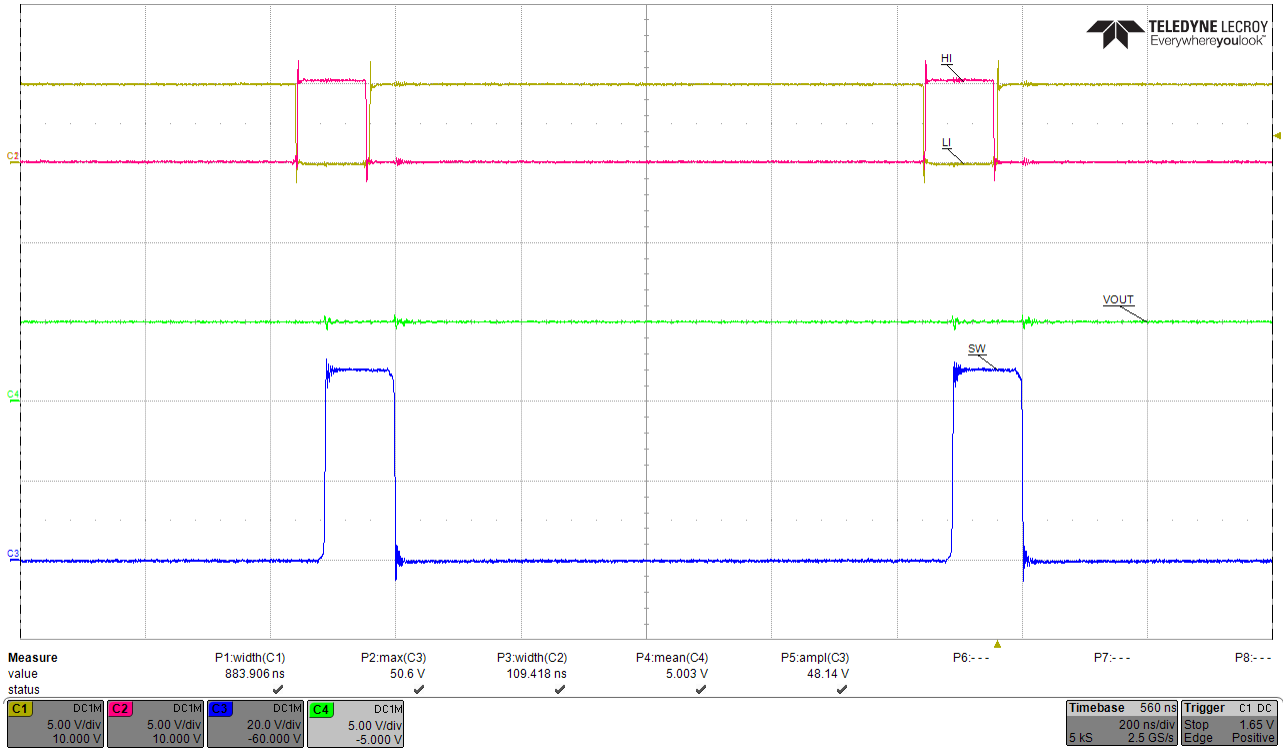
Figure 11. Input and Output Waveforms Showing the Dead Time

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V_{IN} = 12 V, f_{SW} = 5 MHz, No Load

Figure 12. Zoom in of the SW Node Running at 50% Duty Cycle



V_{IN} = 48 V, f_{SW} = 1 MHz, V_{OUT} = 5 V, No Load

Figure 13. 48-V to 5-V Synchronous Buck Converter Operation Showing Inputs, SW Node, and V_{OUT}

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8 EVM Assembly Drawing and PCB Layout

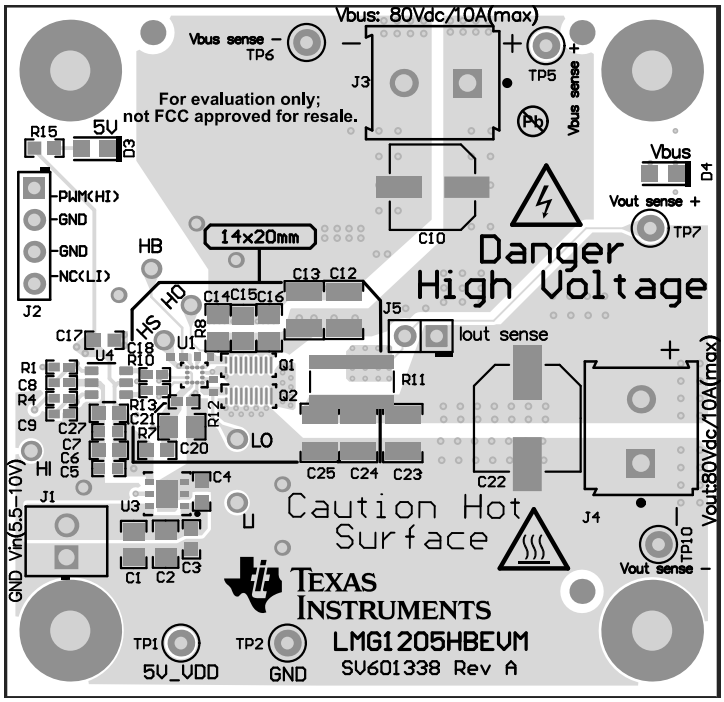


Figure 14. LMG1205HBEVM-10 Top Layer and Components

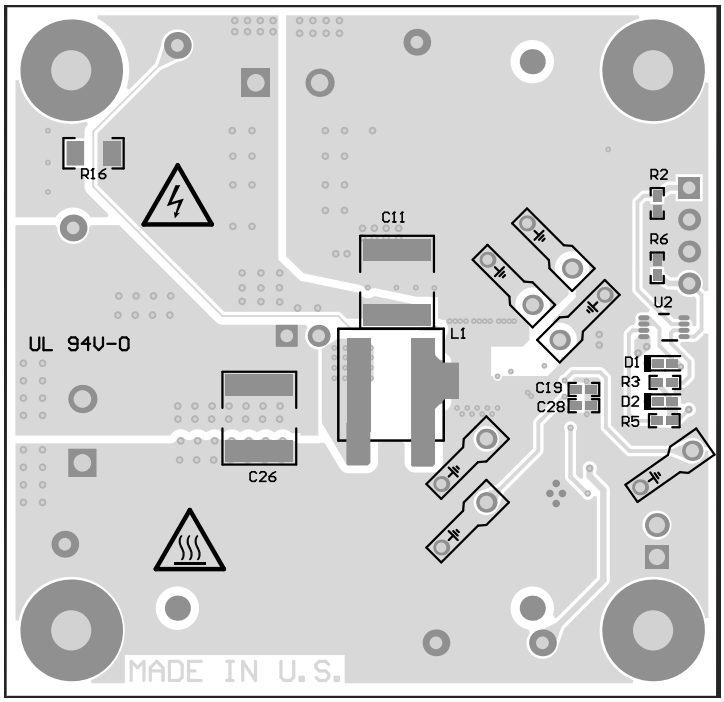


Figure 15. LMG1205HBEVM-10 Bottom Layer and Components

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9 List of Materials

NOTE: Moisture and other contaminants in the air may provide an environment which allows dendrite growth under the LMG1205 driver or the GaN MOSFETs on this EVM and lead to leakage or shorting across high-voltage terminals. The standard assembly of this EVM does not have underfill material and should be used in low-contaminant conditions. An underfill material such as Loctite Hysol FP4549Si or Shin-Etsu SMC375X7 should be used in applications where the board is exposed to moisture.

Table 4. LMG1205HBEVM List of Materials[(1)]

DESIGNATOR	QTY	VALUE	DESCRIPTION	PART NUMBER	MANUFACTURER
PCB1	1		Printed-Circuit Board	SV601338	Any
C1	1	10 µF	CAP, CERM, 10 µF, 25 V, ±10%, X5R, 0805	C2012X5R1E106K125AB	TDK
C2, C20	2	2.2 µF	CAP, CERM, 2.2 µF, 16 V, ±10%, X7R, 0805	C0805C225K4RACTU	Kemet
C3, C4	2	0.1 µF	CAP, CERM, 0.1 µF, 16 V, ±5%, X7R, 0603	0603YC104JAT2A	AVX
C5, C7	2	2.2 µF	CAP, CERM, 2.2 µF, 10 V, ±10%, X7R, 0603	GRM188R71A225KE15D	MuRata
C6	1	100 pF	CAP, CERM, 100 pF, 25 V, ±10%, X7R, 0603	06033C101KAT2A	AVX
C8, C9	2	100 pF	CAP, CERM, 100 pF, 50 V, ±5%, C0G/NP0, 0402	CC0402JRNPO9BN101	Yageo America
C11, C26	2	10 µF	CAP, CERM, 10 µF, 100 V, ±20%, X7R, 2220	22201C106MAT2A	AVX
C12, C13, C24, C25	4	2.2 µF	CAP, CERM, 2.2 µF, 100 V, ±10%, X7R, 1210	C1210C225K1RACTU	Kemet
C14, C15, C16	3	0.1 µF	CAP, CERM, 0.1 µF, 100 V, ±10%, X7R, 0805	C0805C104K1RACTU	Kemet
C17, C27	2	0.1 µF	CAP, CERM, 0.1uF, 25 V, ±10%, X7R, 0603	GRM188R71E104KA01D	MuRata
C18	1	0.1 µF	CAP, CERM, 0.1 µF, 10 V, ±10%, X5R, 0402	C1005X5R1A104K050BA	TDK
C19, C28	2	10 pF	CAP, CERM, 10 pF, 50 V, ±5%, C0G/NP0, 0402	500R07S100JV4T	Johanson Technology
C21	1	1 µF	CAP, CERM, 1 µF, 25 V, ±10%, X5R, 0402	C1005X5R1E105K050BC	TDK
D1, D2	2	40 V	Diode, Schottky, 40 V, 0.03 A, SOD-523	SDM03U40-7	Diodes Inc.
D3, D4	2	Green	LED, Green, SMD	LTST-C170KGKT	Lite-On
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	1902C	Keystone
J1	1		Terminal Block, 2.54 mm, 2x1, Brass, TH	OSTVN02A150	On-Shore Technology
J2	1		Header, 100 mil, 4x1, Tin, TH	5-146278-4	TE Connectivity
J3, J4	2		Terminal Block, 2x1, 5.08 mm, TH	282841-2	TE Connectivity
J5	1		Header, 100 mil, 2x1, Gold, TH	TSW-102-07-G-S	Samtec
L1	1	4.7 µH	Inductor, Shielded, Composite, 4.7 µH, 10.5 A, 0.00889 Ω, SMD	XAL8080-472ME	Coilcraft
Q1, Q2	2	100 V	MOSFET, N-CH, 100 V, 36 A, 4.105x1.632mm	EPC2001C[(2)]	EPC
R1, R4	2	47	RES, 47 Ω, 5%, 0.063 W, 0402	CRCW040247R0JNED	Vishay-Dale
R2, R6	2	10.0 k	RES, 10.0 kΩ, 1%, 0.063 W, 0402	CRCW040210K0FKED	Vishay-Dale
R3	1	0	RES, 0 Ω, 5%, 0.063 W, 0402	CRCW04020000Z0ED	Vishay-Dale
R7	1	0.05	RES, 0.05 Ω, 1%, 0.1 W, 0603	ERJ-L03KF50MV	Panasonic
R8, R10, R12, R13	4	0	RES, 0, 5%, 0.063 W, 0402	ERJ-2GE0R00X	Panasonic
R11	1	0.005	RES, 0.005, 1%, 2 W, 2512 WIDE	FCSL64R005FER	Ohmite
R15	1	1.0 k	RES, 1.0 kΩ, 5%, 0.1 W, 0603	CRCW06031K00JNEA	Vishay-Dale
R16	1	100 k	RES, 100 k, 5%, 0.25 W, 1206	CRCW1206100KJNEA	Vishay-Dale
TP1	1		Test Point, Miniature, Yellow, TH	5004	Keystone
TP2, TP10	2	Black	Test Point, Miniature, Black, TH	5001	Keystone
TP5, TP7	2	Red	Test Point, Miniature, Red, TH	5000	Keystone

(1) Unless otherwise noted, all parts may be substituted with equivalents
(2) EPC2001 is an acceptable substitute and some EVMs may be assembled using this part number

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Table 4. LMG1205HBEVM List of Materials[1] (continued)

DESIGNATOR	QTY	VALUE	DESCRIPTION	PART NUMBER	MANUFACTURER
TP6	1		Test Point, Miniature, Black, TH	5001	Keystone
U1	1		80-V, 1.2-A / 5-A, Half-Bridge Gate Driver for Enhancement Mode GaN FETs, YFX0012AHAP (DSBGA-12)	LMG1205YFXR	Texas Instruments[3]
U2	1		Triple Schmitt-Trigger Inverter, DCU0008A (VSSOP-8)	SN74LVC3G14DCUR	Texas Instruments[3]
U3	1		1-A Low Dropout CMOS Linear Regulators Stable with Ceramic Output Capacitors, 6-pin LLP, Pb-Free	LP38690SD-5.0/NOPB	Texas Instruments[3]
U4	1		Dual Schmitt-Trigger Inverter, DBV0006A (SOT-6)	SN74LVC2G14DBVR	Texas Instruments[3]
C10	0	22 µF	CAP, AL, 22 µF, 20 V, ±20%, 0.06 Ω, SMD	APXH200ARA220MF60G	Chemi-Con
C22	0	47 µF	CAP, AL, 47 µF, 20 V, ±20%, 0.045 Ω, SMD	APXH200ARA470MH70G	Chemi-Con
C23	0	2.2 µF	CAP, CERM, 2.2 µF, 100 V, ±10%, X7R, 1210	C1210C225K1RACTU	Kemet
R5	0	0	RES, 0 Ω, 5%, 0.063 W, 0402	CRCW04020000Z0ED	Vishay-Dale

(3) No alternate component manufacturer

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STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   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 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 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 a nonconforming EVM if (a) the nonconformity was 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, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, 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:*

      FCC NOTICE: 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 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. 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 to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

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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2. 実験局の免許を取得後ご使用いただく。
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西新宿三井ビル

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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

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 MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS 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 EPIDEMIC FAILURE WARRANTY OR 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 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, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

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. 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 OR THE USE OF THE EVMS , 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 TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM 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.

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