

General TI High Voltage Evaluation User Safety Guidelines



Always follow TI's set-up and application instructions, including the use of all interface components within the 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 at <http://support/ti.com> for further information.

NOTE: 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 PCB (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 or application is strictly prohibited by Texas Instruments. If you are not suitably qualified, you must 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 VRMS/75 VDC must be electrically located within a protected Emergency Power Off (EPO) 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.
- After confirming the EVM is de-energized, proceed with the 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.

- **Personal Safety:**
 - Wear personal protective equipment like latex gloves and safety glasses with side shields, or protect the EVM from accidental touch in an adequate translucent plastic box with interlocks.
- **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. 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



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

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

Using the LMG1210EVM-012 300 V Half-Bridge Driver for GaN

1 Introduction

The LMG1210EVM-012 is designed to evaluate the LMG1210 300 V half-bridge driver for GaN FETs. This EVM consists of two Gallium Nitride (GaN) eFETs connected in a half-bridge configuration driven by one LMG1210.

This guide shows a circuit and the list of materials describing how to power and set the board up for a certain regulation voltage. The EVM board is designed to accelerate the evaluation of the LMG1210.

This board is not intended to be used as a standalone product but to evaluate the switching performance of LMG1210.

This EVM guide describes correct operation and measurement of the EVM, as well as the EVM construction and typical performance.

2 Description

The LMG1210EVM-012 is a small, easy-to-use power stage with an external PWM signal (or HI and LI). 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, do not use it to evaluate transient response. It can be used to evaluate the performance of the LMG1210 as a driver for the GaN FET half-bridge converter to sample measurements such as efficiency, switching speed, dv/dt, and adjustable dead time.

The EVM features a LMG1210 half-bridge driver coupled with two 100 V, 7 mΩ GaN FETs in a half-bridge configuration

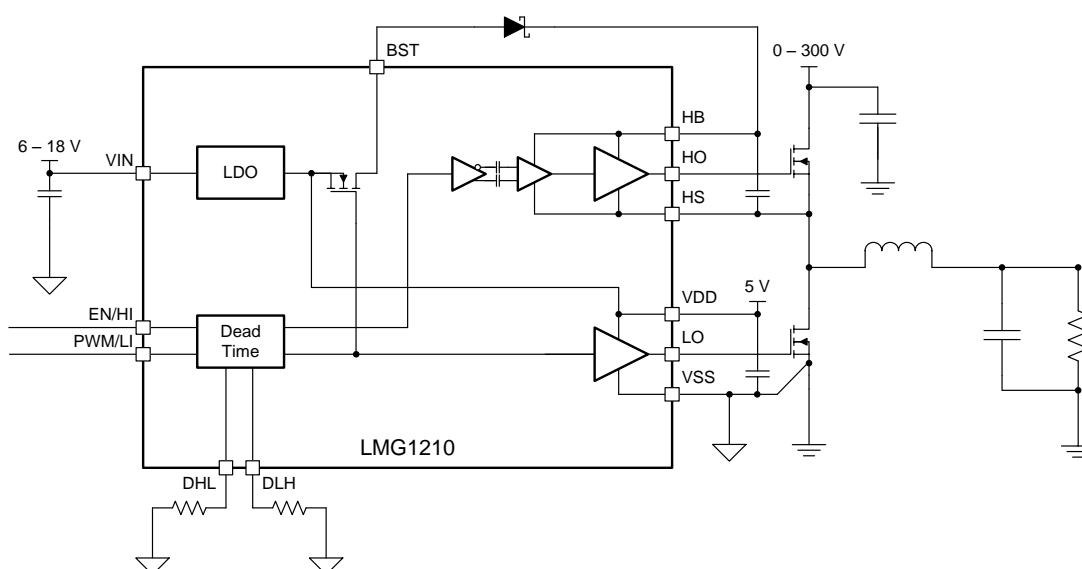


Figure 1. GaN Half-Bridge Driven by One LMG1210

The module can deliver up to 10 A of current if the application includes adequate thermal management (monitor the 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.

2.1 Typical Applications

The LMG1210 is designed for high-frequency DC-DC converters. With built-in features, the LMG1210 is flexible, simple to use, and reduces component count.

Typical applications include:

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

CAUTION

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

2.2 Features

The LMG1210EVM-012 has the following features and specifications:

- 10 ns typical delay (Independent Input Mode) with 1.5 ns maximum matching
- High-speed operation up to 50 MHz
- Minimum pulse width of 4 ns
- High slew rate immunity of 150 V/ns
- Internal LDO
- External bootstrap diode for flexibility
- 1 pF high-side to low-side capacitance
- Independent high-side and low-side control or a single PWM input with externally adjustable dead time
- UVLO and Over-temperature protection

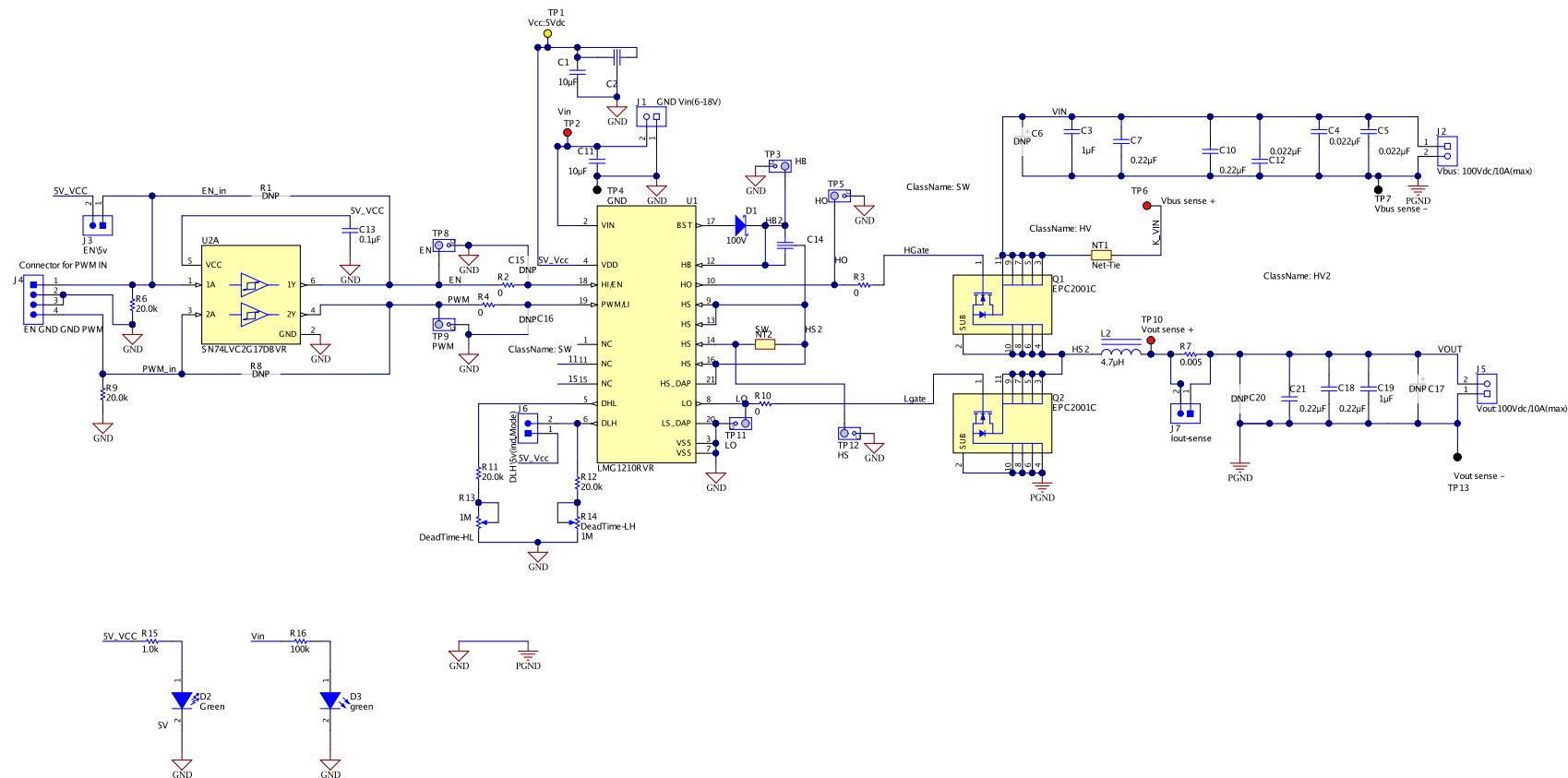
3 Electrical Performance Specifications

Table 1. LMG1210EVM-012 Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT AND OUTPUT CHARACTERISTICS					
Input voltage/ output voltage		0		100	V
Input current/ output current		0		10	A
Bias voltage	$I_{OUT,MAX} = 300 \text{ mA}$	6		18	V
SYSTEM CHARACTERISTICS					
Switching frequency		0.1	1	15 ⁽¹⁾	MHz
Full load efficiency	$V_{IN} = 48 \text{ V}$, $V_{OUT} = 12 \text{ V}$, $I_{OUT} = 9 \text{ A}$, $F_{sw} = 1 \text{ MHz}$		95.1%		

⁽¹⁾ Using EPC2001 relatively large FETs limits the usable maximum frequency, smaller FETs allow operations up to 50 MHz.

4 EVM Schematic



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Figure 2. Power Stage Schematic

5 EVM Kit Contents

The kit contains the following:

- *Using the LMG1210EVM-012* user's guide
- Safety instructions
- LMG1210EVM-012 EVM PCB assembly

6 Test Setup

6.1 Test Equipment

DC Voltage Source: capable of supplying the input of the EVM up to 100 V as desired. Capable of supplying 10 A and supports current limiting.

DC Bias Source: capable of 6 V to 18 V output at up to 0.3 A.

Oscilloscope: capable of at least 200 MHz operation, using oscilloscope probes with a *pigtail* spring ground clip instead of the standard alligator clip.

DC Multimeter(s): Capable of 100 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 mode, dual synchronous output for Independent mode, capable of at least 0-3 V signal (operating maximum digital input is 5 V)

Fan: 200 LFM minimum airflow is recommended to cool the PCB when operating above 10 A output current.

(Optional) Power Meter: Capable of 100 V operation at up to 10 A

6.2 Recommended Test Setup

Connect the input and bias supplies and DC electronic load as indicated in [Figure 3](#).

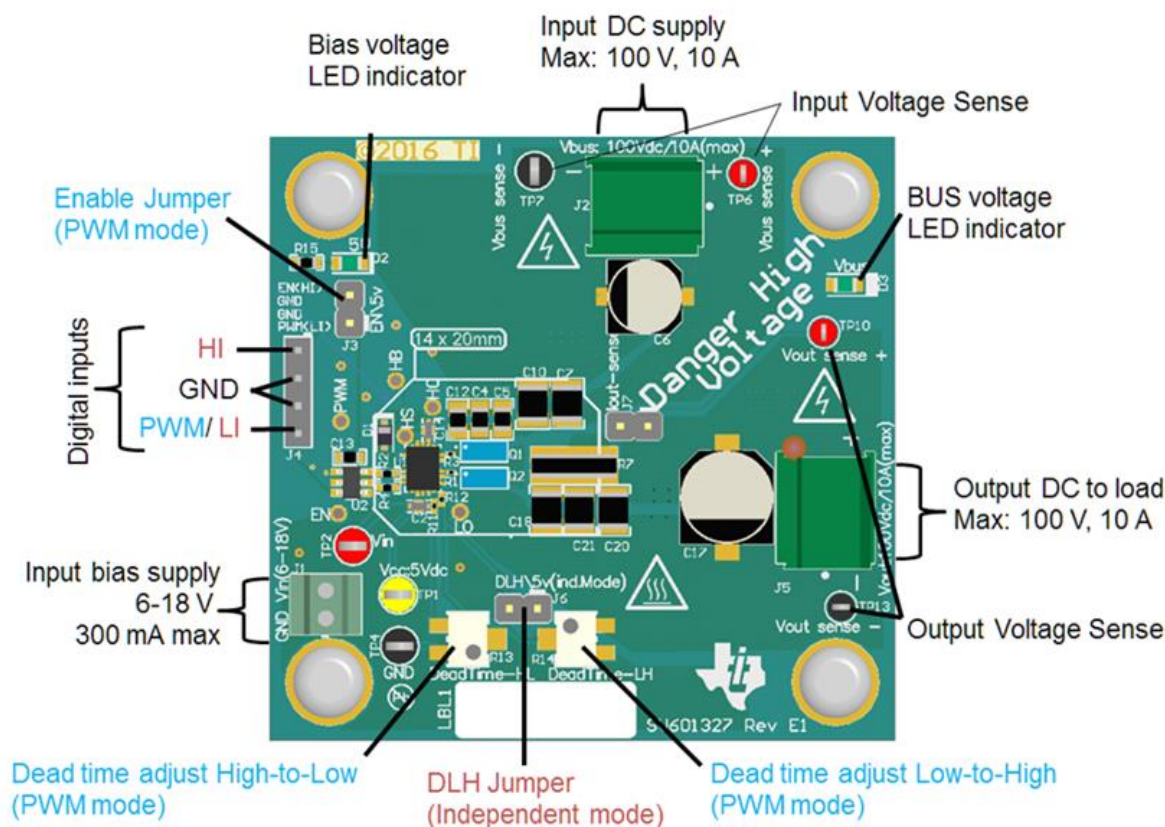


Figure 3. Recommended Connection Points and Feature Description

WARNING

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

6.3 List of Test Points

The test points on this EVM have been designed for use with oscilloscope probes with the included spring-type ground connections, often called pigtailed. Using the small pigtailed without the probe clips will minimize measurement error and produce a cleaner signal with the fast switching GaN devices used on this EVM. The data shown in this user guide has been obtained using such a measurement method.

Table 2. Test Point Functional Description

TEST POINT	NAME	DESCRIPTION
TP1	VDD	Connected to the VDD pin of the LMG1210 and derived from the internal LDO. This is 5 V nom.
TP2	Vin	Connected to the Vin pin of the LMG1210. This is the input bias supply voltage.
TP3 ⁽¹⁾	HB	Connected the HB pin of the LMG1210. This is the positive plate of the bootstrap capacitor.
TP4	GND	Connected to the common reference of the board. Use this to measure accurate voltage for Vin.
TP5 ⁽¹⁾	HO	Connected the HO pin of the LMG1210. This is the high-side FET gate signal.
TP6	Vbus sense+	Kelvin connection for positive input voltage. Use this for accurate voltage for Vbus.
TP7	Vbus sense–	Kelvin connection for negative input voltage. Use this for accurate voltage for Vbus. When the board is unpowered, this is at same potential as GND.
TP8 ⁽¹⁾	EN/HI	Connected to the EN/HI pin of the LMG1210. This is the logic input to either enable (in PWM mode) or to control the high-side FET gate output (Independent mode).
TP9 ⁽¹⁾	PWM/LI	Connected to the PWM/LI pin of the LMG1210. This is the logic input to either derive the PWM for both FETs (in PWM mode) or to control only the low-side FET gate output (Independent mode).
TP10	Vout sense+	Kelvin connection for positive output voltage. Use this for accurate voltage for Vout.
TP11 ⁽¹⁾	LO	Connected the LO pin of the LMG1210. This is the low-side FET gate signal.
TP12 ⁽¹⁾	HS	Connected the HS pin of the LMG1210. This is the Switched Node of the Half-Bridge and is also the reference point for the high-side circuitry and driver.
TP13	Vout sense–	Kelvin connection for negative output voltage. Use this for accurate voltage for Vout. When the board is unpowered, this is at same potential as GND.

⁽¹⁾ These are ground spring clip test points, see [Figure 4](#) and [Figure 5](#) as references.

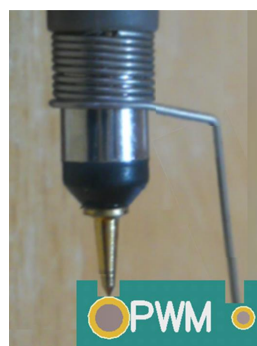


Figure 4. Recommended Use for Ground Spring Clip Test Points

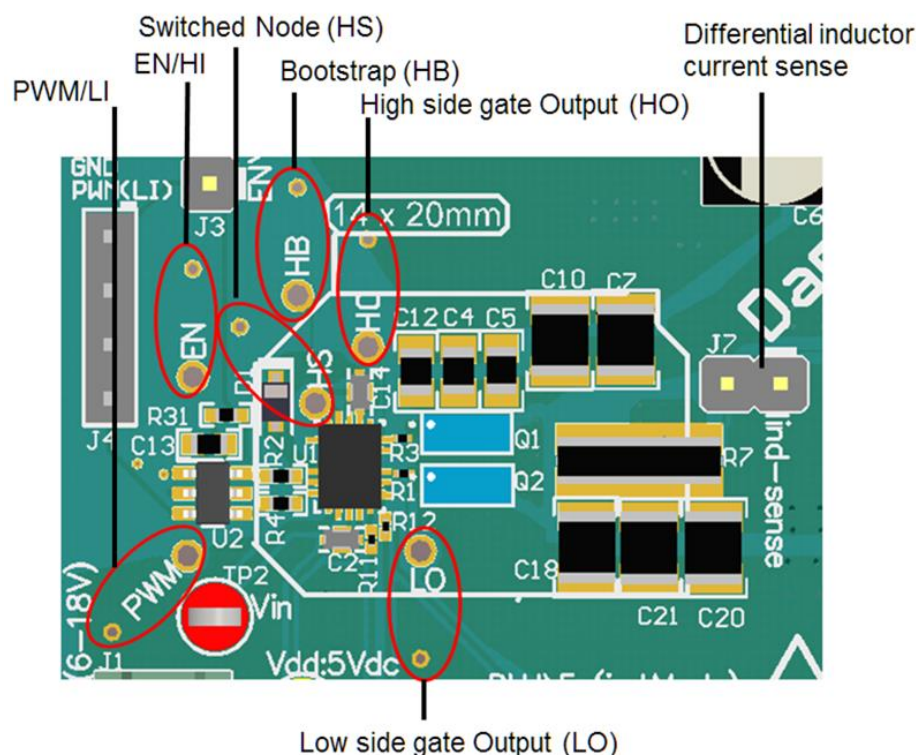


Figure 5. Visual and Description of Ground Spring Clip Test Points

6.4 List of Terminals

Table 3. List of Terminals

TERMINAL	NAME	DESCRIPTION
J1	Bias Supply	Bias supply connection terminals (6-18 Vdc, 0.3 A)
J2	DC Input Voltage (Vbus)	Input voltage connection terminals (MAX: 100 Vdc, 10 A)
J3	Enable Jumper	Use this jumper to connect the onboard 5 V to the EN/Hi signal. This will enable the LMG1210 if it is operating in PWM mode.
J4	Logic input PWM	Input from function generator, coupled with return ground. Use only PMW in PWM mode, or use both LI/Hi in independent mode
J5	Vout	Output voltage terminal
J6	Independent mode Jumper	Short this jumper to configure the LMG1210 in Independent input mode
J7	Current sense	This connector is placed across a 50mΩ resistor, to measure the inductor current. Either use a differential probe or two ground referenced probes to have an accurate reading of the current.

7 Test Procedure

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.

7.1 Efficiency Measurement Procedure

The following procedure is used to measure the efficiency of the converter:

1. Connect the input(J2) and output supplies (J5) as shown in [Figure 3](#), but do not power them on yet.
2. Connect kelvin voltage sense (from multimeters or power meter) to test points TP6, TP7, TP10, and TP13.
3. Select either PWM or Independent input mode:
 - For PWM mode, short jumper J3 and leave J6 open. Leave EN(HI) on J4 unconnected. Connect single output of the signal generator to PWM and GND on J4.
 - For independent mode, short jumper J6 and leave J3 open. Connect the complementary PWMs from the signal generator to the respective pins of J4: HI for high-side, LI for low-side.
4. Power the bias supply (J1) up to between 6 V and 18 V, as shown in [Figure 3](#). The LMG1210 internal LDO provides 5 V to power internal circuitry and gate drivers. Its presence is verified by LED D2.
5. Enable the output(s) of the function generator and verify that the gate signals are not overlapping:
 - PWM mode: adjust the dead time between transitions using potentiometers R13 for High-to-Low and R14 for Low-to-High transitions. The dead time can be varied from 0 to 20 ns.
 - Independent mode: adjust values at signal generator

NOTE: There is no automatic protection against cross-conduction. Setting the dead time correctly will improve efficiency and prevent damage to the FETs. The amount of dead-time needed depends on the operating conditions. Monitor the dead-time over the operating range and adjust accordingly.

6. Power up the input supply (J2) (as shown in [Figure 3](#)) and set J2 to the desired input voltage no higher than 100 V. Set the current limit to 10 A. Presence of Vbus is verified by LED D3.
7. Enable the electronic load and set it to the desired load current
8. Perform the desired measurements

7.2 Shutdown Procedure

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

1. Turn off the DC input power supply (J2)
2. Disable the function generator
3. Disable the electronic load
4. Disable the bias supply (J1)

NOTE: Both LMG1210's outputs have a powered-off Vgs clamp that holds the HO and LO signals low (which is clamped to the source of the respective FET) when the bias supply is not present. Therefore it is allowed to power off the bias supply while the DC input supply is still on.

7.3 Additional Tests and Parameters

7.3.1 Propagation Delay and Matching

The following section describes the procedure to measure the timing of the LMG1210.

A digital buffer is provided on the board to ensure a precise signal is available to measure propagation and matching between inputs and outputs. This buffer is operational by default (read [Section 7.3.3](#) on how to disable it), and its output are tied to the test points marked EN/HI and PWM/LI. These signals can be used as reference to time the delay to outputs HO and LO, to verify minimum pulse operation, to verify other switching characteristics of the LMG1210.

Note that all delays and timings are reported as “unloaded” in the data sheet. When driving FETs, finding different delay and timing values is expected.

7.3.2 Operating Frequency and Inductor Selection

7.3.2.1 Maximum Frequency

The maximum operating frequency for LMG1210 is limited by the LDO current limit and the behaviour of the FETs at given frequencies and duty cycle. When testing for maximum frequency, TI suggests monitoring the behaviour contiguously through the following steps:

1. Using the function generator, find an acceptable operating frequency with no Vbus present
2. Apply Vbus starting at 0 V and gradually increase it to the desired operating voltage
3. Apply the electronic load gradually
4. Pay particular attention to the temperature of the EPC FETs when doing this test to avoid overheating them.

7.3.2.2 Inductor Selection

The EVM comes equipped with a 4.7-μH, 10.5-A inductor. If a different operating point in frequency, voltage, or current ripple is desired, it is likely that a new value of inductor is required. When selecting the new inductor, it is important that the value of the inductor respects the value found in [Equation 1](#):

$$L_{ind} \geq \frac{V_{BUS}}{\min(I_{L_sat}, I_{FET_DCmax})} \times t_{on}$$

where

- L_{ind} is the inductor value in H
- V_{BUS} is the voltage present on the bus
- t_{on} is the on-time for the high-side FET
- I_{L_sat} is the saturation current of the selected inductor
 - For the installed induction, this is 10.5 A
- I_{FET_DCmax} is the maximum rated DC current for the FET
 - This last parameter is selected to leave a wide operating margin on the FET
 - For the installed EPC2001, this is 25 A

(1)

7.3.3 Components Rating and DNPs

- All placed input and output capacitors are 250 V rated. The footprint is made available for extra electrolytic that will have to be sized and rated by the operator.
- Two filtering capacitors C15 and C16 are not placed on the board by default; these would have to be placed if high frequency transient is found disturbing the inputs of the LMG1210 during testing. This could provide additional capacitance in the RC filter including R2 and R4.
- The digital input buffer is placed to generate clean input signals on the board. To bypass it, DNP resistors R1 and R8 would have to be placed and R2 and R4 would be removed. To disconnect power to the input buffer, remove R31.

8 Performance Data and Typical Characteristics

Figure 6 through Figure 11 present typical performance curves for LMG1210EVM-012

8.1 Efficiency

The efficiency results in this section exclude driver losses can be seen in Figure 6.

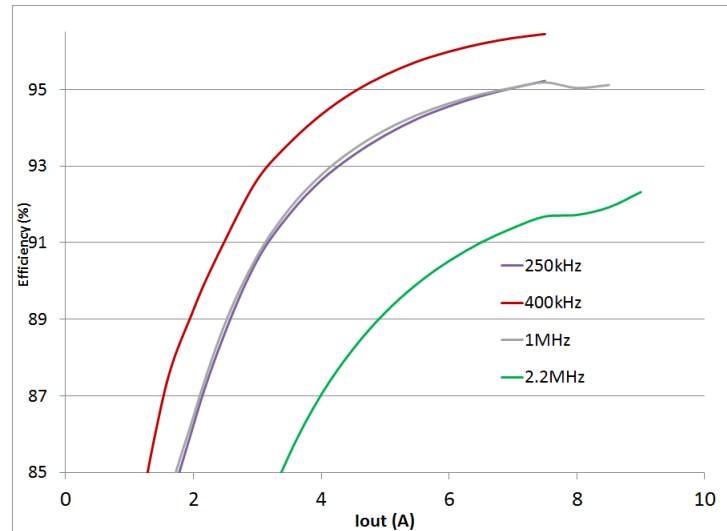
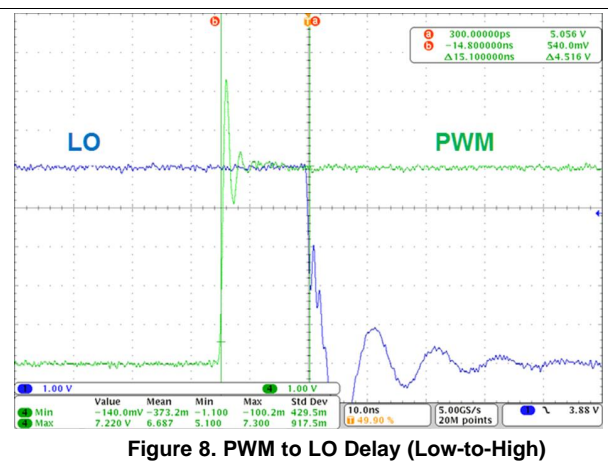
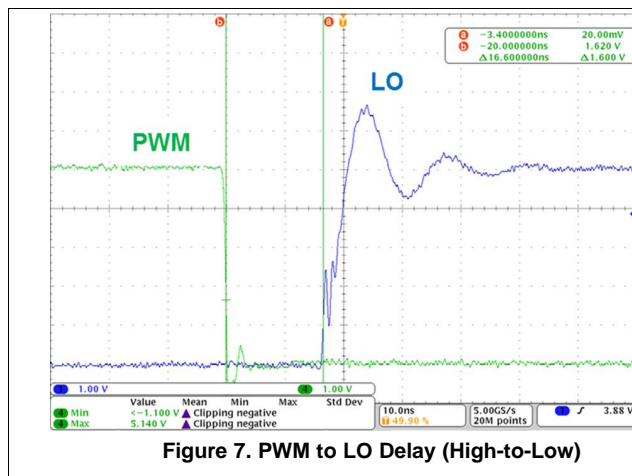


Figure 6. LMG1210EVM-012 Efficiency With EPC2001 4.7-μH Inductor vs. Output Current

8.2 Switching Waveforms



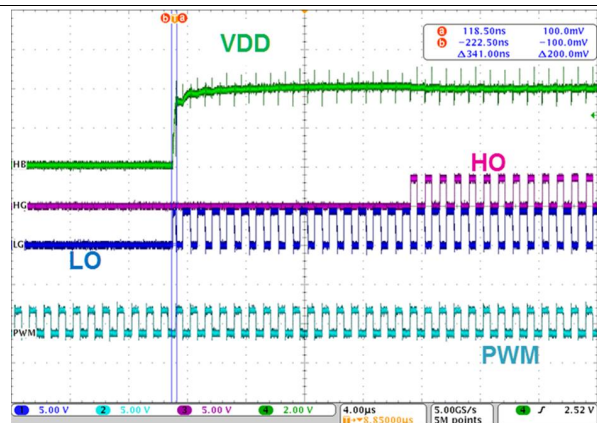


Figure 9. Start-Up Behavior for Low-Side and High-Side



Figure 10. 1-MHz, 80-V Operation

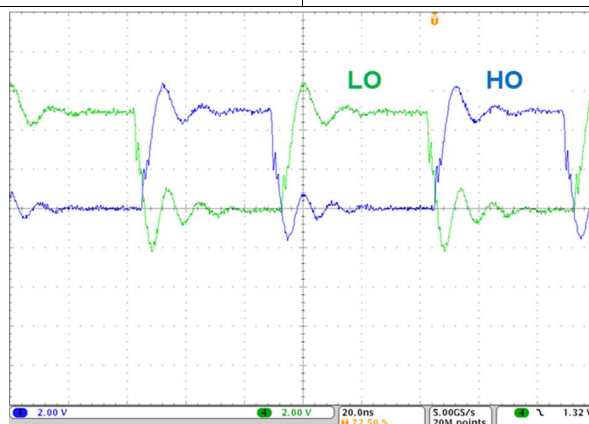
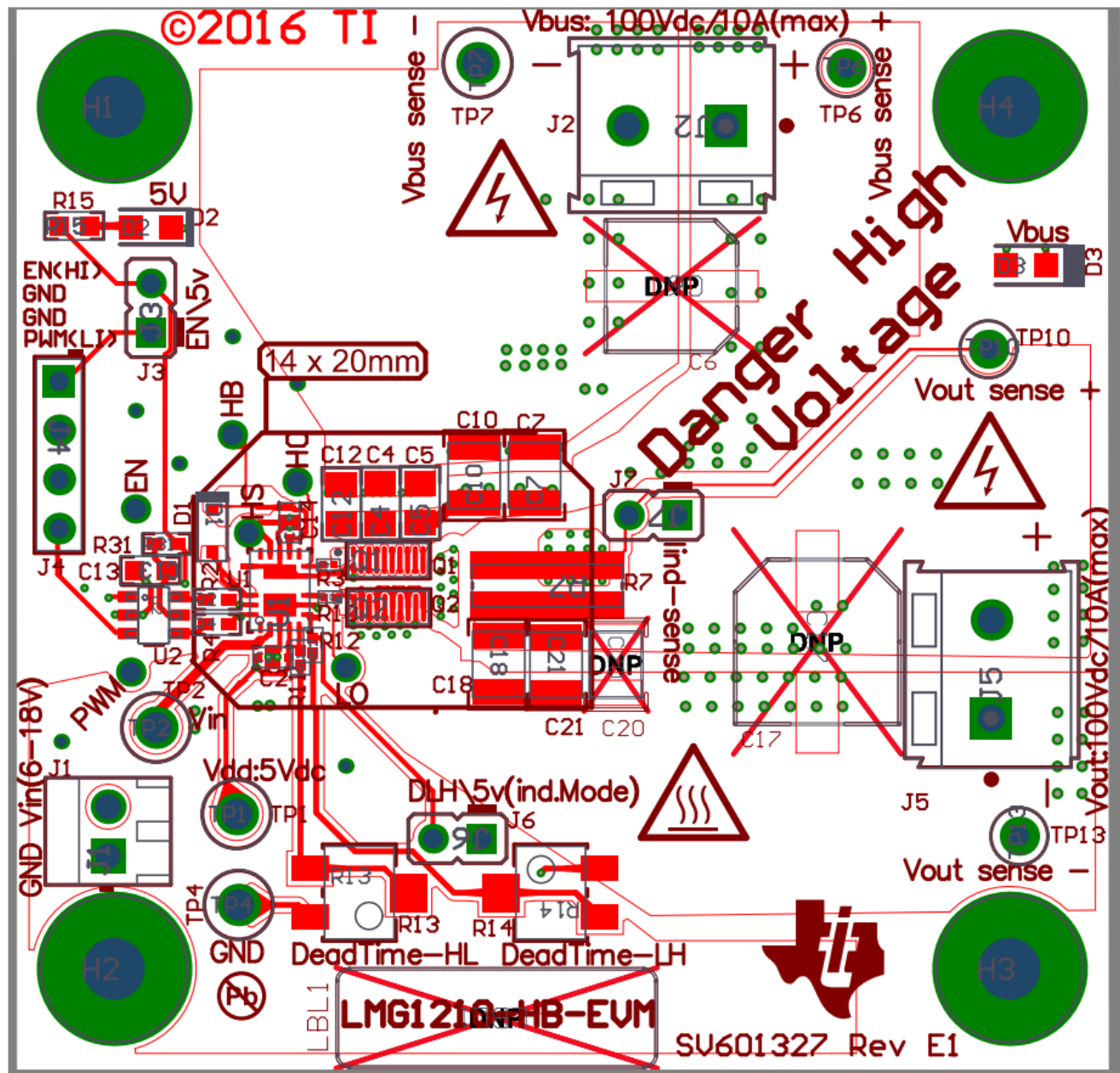


Figure 11. 10-MHz Operation, No Bus Voltage

9 EVM Assembly Drawing and PCB Layout



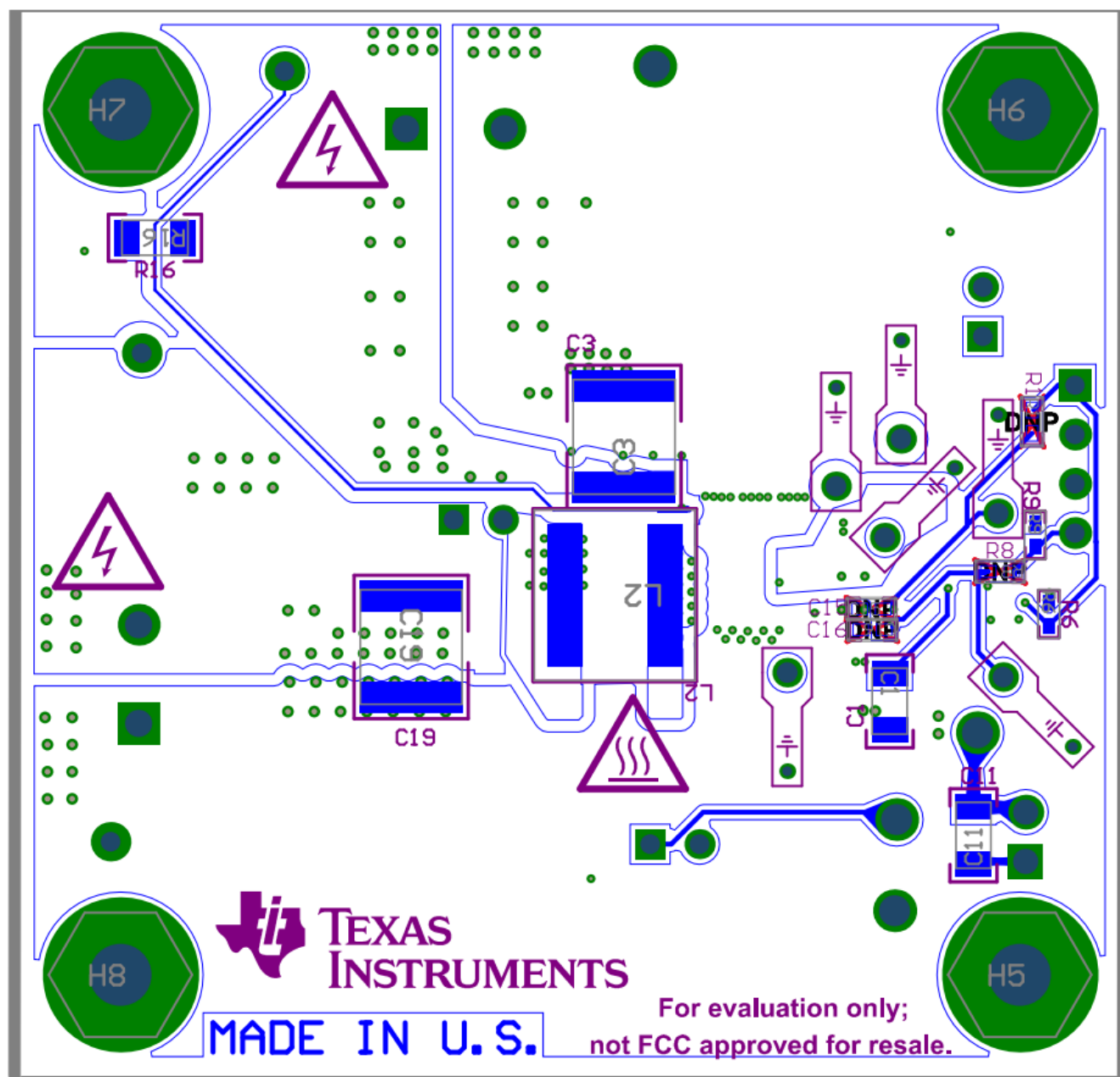


Figure 13. LMG1210EVM-012 Bottom Layer and Components

10 Bill of Materials

Table 4. LMG1210EVM-012 Bill of Materials

QTY	DESIGNATOR	DESCRIPTION	PART NUMBER	MANUFACTURER
2	C1, C11	CAP, CERM, 10 μ F, 25 V, +/- 10%, X7R, 1206	885012208069	Würth Elektronik
2	C2, C14	Feedthru Capacitor, 0.47 μ F, 6.3V, SMD	YFF18PW0J474M	TDK
2	C3, C19	CAP, CERM, 1 μ F, 250 V, +/- 10%, X7R, 2220	GRM55DR72E105KW01L	MuRata
3	C4, C5, C12	CAP, CERM, 0.022 μ F, 250 V, +/- 10%, X7R, 0805	QMK212B7223KG-T	Taiyo Yuden
4	C7, C10, C18, C21	CAP, CERM, 0.22 μ F, 250 V, +/- 10%, X7R, 1210	GRM32DR72E224KW01L	MuRata
1	C13	CAP, CERM, 0.1 μ F, 25V, +/-10%, X7R, 0603	GRM188R71E104KA01D	MuRata
1	D1	Diode, Schottky, 100 V, 0.25 A, SOD-323F	BAT46WJ,115	NXP Semiconductor
2	D2, D3	LED, Green, SMD	LTST-C170KGKT	Lite-On
4	H1, H2, H3, H4	Machine Screw, Round, #4-40 x 1/4,Nylon, Philips panhead	NY PMS 440 0025 PH	B&F Fastener Supply
4	H5, H6, H7, H8	Standoff, Hex, 0.5"L #4-40 Nylon	1902C	Keystone
1	J1	Terminal Block, 2.54mm, 2x1, Brass, TH	OSTVN02A150	On-Shore Technology
2	J2, J5	Terminal Block, 2x1, 5.08mm, TH	282841-2	TE Connectivity
3	J3, J6, J7	Header, 2.54 mm, 2x1, Gold, TH	GBC02SAAN	Sullins Connector Solutions
1	J4	Header, 100mil, 4x1, Tin, TH	5-146278-4	TE Connectivity
1	L2	Inductor, Shielded, Composite, 4.7 μ H, 10.5 A, 0.00889 ohm, SMD	XAL8080-472ME	Coilcraft
2	Q1, Q2	MOSFET, N-CH, 100 V, 25 A, Bumped Die	EPC2001	EPC
2	R2, R4	RES, 0, 5%, 0.063 W, 0402	ERJ-2GE0R00X	Panasonic
2	R3, R10	RES, 0, 5%, 0.05 W, 0201	ERJ-1GE0R00C	Panasonic
2	R6, R9	RES, 20.0 k, 1%, 0.063 W, 0402	CRCW040220K0FKED	Vishay-Dale
1	R7	RES, 0.05, 1%, 2 W, 3008	RL7520WT-R050-F	Susumu Co Ltd
2	R11, R12	RES, 20.0 k, 1%, 0.05 W, 0201	CRCW020120K0FKED	Vishay-Dale
2	R13, R14	TRIMMER 1M OHM 0.25W SMD	3224X-1-105E	Bourns
1	R15	RES, 1.0k ohm, 5%, 0.1W, 0603	CRCW06031K00JNEA	Vishay-Dale
1	R16	RES, 100 k, 5%, 0.25 W, 1206	CRCW1206100KJNEA	Vishay-Dale
1	TP1	Test Point, Compact, Yellow, TH	5009	Keystone
1	TP2	Test Point, Compact, Red, TH	5005	Keystone
2	TP4, TP7	Test Point, Compact, Black, TH	5006	Keystone
2	TP6, TP10	Test Point, Miniature, Red, TH	5000	Keystone
1	TP13	Test Point, Miniature, Black, TH	5001	Keystone
1	U1	Advanced eGaN FET 300V Half-bridge Drive, RVR0019A	LMG1210RVR	Texas Instruments
1	U2	Dual Schmitt Trigger Buffer, DBV0006A (SOT-6)	SN74LVC2G17DBVR	Texas Instruments

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 semiconductor 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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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:*

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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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