EVM User's Guide: LMG1020EVM-006

Using the LMG1020EVM-006

Alberto Doronzo, Daniel Ruiz

1 Introduction

The LMG1020 device is a single, low-side driver designed for driving GaN FETs and logic-level MOSFETs in high-frequency applications including LiDAR, time-of-flight, facial recognition, and any power converters involving low side drivers. The LMG1020EVM-006 is designed to evaluate the LMG1020. This EVM consists of one Gallium Nitride (GaN) enhancement mode FET driven by one LMG1020 and the drain of the GaN FET is connected to an unpopulated resistive load representing a typical laser diode load for LiDAR (Light Detection And Ranging) applications.

This User's Guide shows a circuit and the list of materials describing how to power the board up and how to configure the board. The EVM is designed to accelerate the evaluation of the LMG1020.

This EVM is not intended to be used as a standalone product but is intended to evaluate the switching performance of LMG1020.

This User's Guide describes correct operation and measurement of the EVM, as well as the EVM construction and typical performance.

2 Description

The LMG1020EVM-006 is a small, easy-to-use power stage that comes with a place to populate a resistive load, representing a typical Lidar laser diode load, as well as a place to populate a laser diode. Section 6 explains the procedure to set up the board out-of-the-box and accommodate the resistive load. The unpopulated resistive load will help achieve the applications required pulses before populating and powering the laser diode. The EVM takes a short-pulse input that can either be buffered (and shortened), or passed directly to the power stage.

The input pulse signal is used to pulse the current through the load (not populated out-of-the-box), to achieve 1-ns to 2-ns wide current pulses, which are the state-of-the-art target for LiDAR systems.

The EVM features a LMG1020, driving a single EPC2019 FET referenced to ground and with the drain connected to the unpopulated resistive load.

The board comes with a place to populate a resistive load, as well as larger pads where a laser diode of choice can be mounted. The load (when populated) is split between two current loops to reduce the effective inductance.

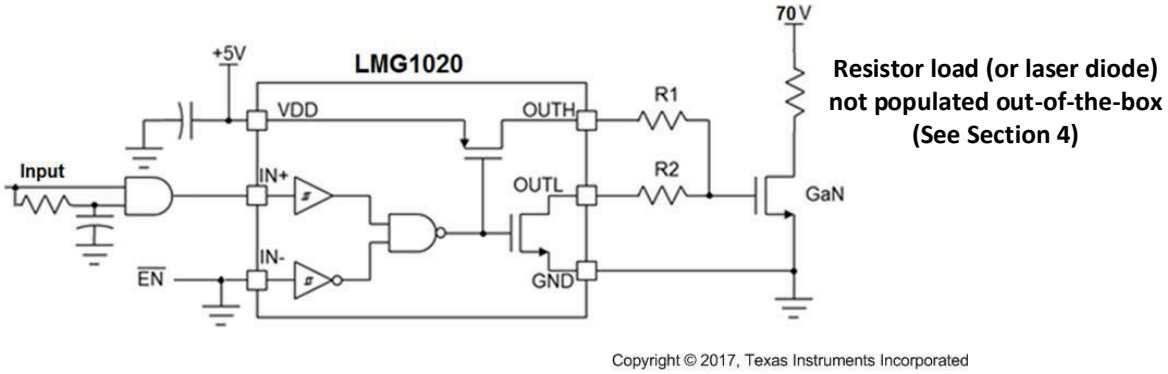

Figure 2-1. LiDAR Power Stage with LMG1020

The power stage can deliver up to 40 A of current to the load (when populated) at duty cycles ~0.1% and frequencies up to 2MHz. It includes adequate thermal management (case temperature should be monitored and adequate airflow should be ensured).

2.1 Typical Applications

The LMG1020 is suited for use in high frequency applications which may require nano-second pulse width. The extremely short pulse capability and short propagation delay, allow for state-of-the-art solutions.

Typical applications include:

- LiDAR power stage
- Wireless power
- VHF converters

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 LMG1020 has the following features and specifications:

- Single low-side ultra-fast driver for 5-V drive GaN and silicon FETs
- Single 5-V supply
- Schmitt-trigger type CMOS inputs for robustness
- 2.5-ns typical, 4.5-ns max propagation delay
- 400-ps typical rise/fall time

- UVLO and over-temperature protection
- Minimum package 0.8 x 1.2 WCSP minimizes gate loop inductance and maximizes power density

The LMG1020EVM also includes the SN74LVC1G08, a single 2-input positive AND gate which provides the following features:

- Buffer for the LMG1020 input
- Used to shorten input pulse width by using a R-C filter on one input of the AND gate (Figure 10-1)
- Bypass the buffer by populating R3 with a 0-Ω resistor and removing R10 to disconnect the AND gate output.

The EVM also features a low ESL, 0.47-uF feed through capacitor (C4 in Figure 7-1)

- Feed through structure makes distance to GND shorter and obtains low ESL
- Low ESL to prevent ringing on VDD (5.4-V Recommended Max)
- Can be substituted with a 0201 capacitor placed as close to the pins as possible

3 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 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 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.

4 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 should be handled with care by a professional.

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

5 Electrical Performance Specifications

Table 5-1. LMG1020EVM Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input and Output Characteristics					
Input Voltage		0		75(1)	VDC
Input current		0		0.1	A
Bias voltage	Iout,MAX = 100 mA	5.5		16	VDC
System Characteristics					
Switching frequency		0.1	1	50(1)	MHz

(1) Determined by the thermal dissipation; depending on the magnitude of the current pulse and duty cycle. The thermal limitation of the resistor load, R5–R8, when populated is explained in more detail in *Section 6*.

6 EVM Operation Out-of-the-Box

The EVM, out-of-the-box, has a place to put a resistor load and a place to put a laser diode. The purpose of the resistor load is to set up the appropriate pulses required for a laser diode application. When operating the EVM, out-of-the-box, follow the procedure to properly fine tune the gate drive pulses before powering on a laser diode:

1. Size the resistor load, R5-R8, to represent the application's typical laser diode resistance
2. Populate the resistor load, R5-R8, by soldering 4 parallel 0603 size, 100 mW resistors
3. Achieve the required pulses for the laser diode application
4. Take the resistors, R5-R8, off before powering a laser diode
5. Populate a laser diode

CAUTION

Take off the resistor load, R5-R8, before powering on a laser diode.

When using LMG1020EVM out-of-the-box, the resistor load, R5 - R8, is not populated. With R5 - R8 not populated, the power loop is open and therefore the K waveform is not switching. For full functionality of the power loop without a laser diode connected, a resistor load R5 - R8 must be soldered on. The resistor load can be soldered by populating the four parallel resistors R5 - R8 as seen in Figure 6-2. To properly solder R5 - R8, use a soldering iron by hand and also hot air directed to the bottom of the board if needed. When selecting a resistor load, use 4 parallel 0603 size, 100 mW resistors and a typical laser diode resistance value of 1 Ω to 20 Ω. To achieve nanosecond pulses, a 1 Ω resistor load is recommended, in which four 4 Ω parallel resistors for R5 - R8 would be needed. The higher the resistor load value, the longer the switching rise and fall times as well as lower peak current. To avoid excessive power dissipation, damaging the R5 - R8 load resistors as seen in Figure 6-1, start by testing the EVM without a bus voltage to achieve the required pulse width, frequency, and repetition rate on the gate test point, Vg (TP4). When first testing the LMG1020EVM, start without a bus voltage. Try to achieve a short 1–2 ns gate pulse width to limit the peak current and thermal dissipation in the load resistors to a safe point when a bus voltage would be present. The on-board pulse shortener can be used to create a 1–2 ns pulse. The pulse shortener is explained in more detail in *Section 10.2*. After the required gate pulses are achieved, apply a small bus voltage. Begin with 5–10 V and gradually increase. When operating the EVM at 75 V while using the R5 - R8 resistor load, make sure to proceed with high voltage safety and caution. Operating at 75 V, the EVM can achieve high switching frequencies by using very short pulse widths and repetition rates. If the load resistors become damaged, the load resistance can be increased to an appropriate amount to limit the peak current or higher wattage resistors can be used. After achieving the required pulses on the gate, switch out the resistor load, R5-R8, for a laser diode of choice.

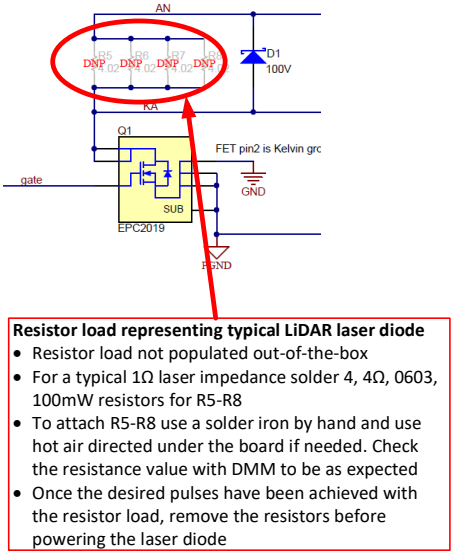

Figure 6-1. Schematic View of Unpopulated Load Resistors R5–R8

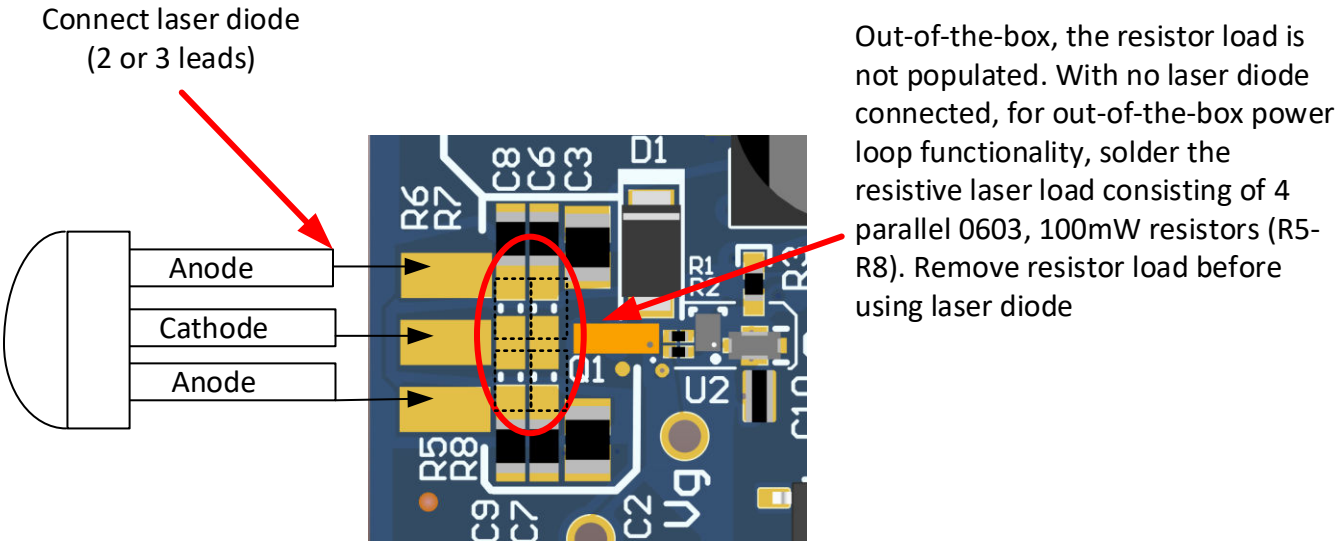

Figure 6-2. Populate Load Resistors R5–R8 Out-of-the-Box and Depopulate Before Testing Laser Diode

7 EVM Schematic

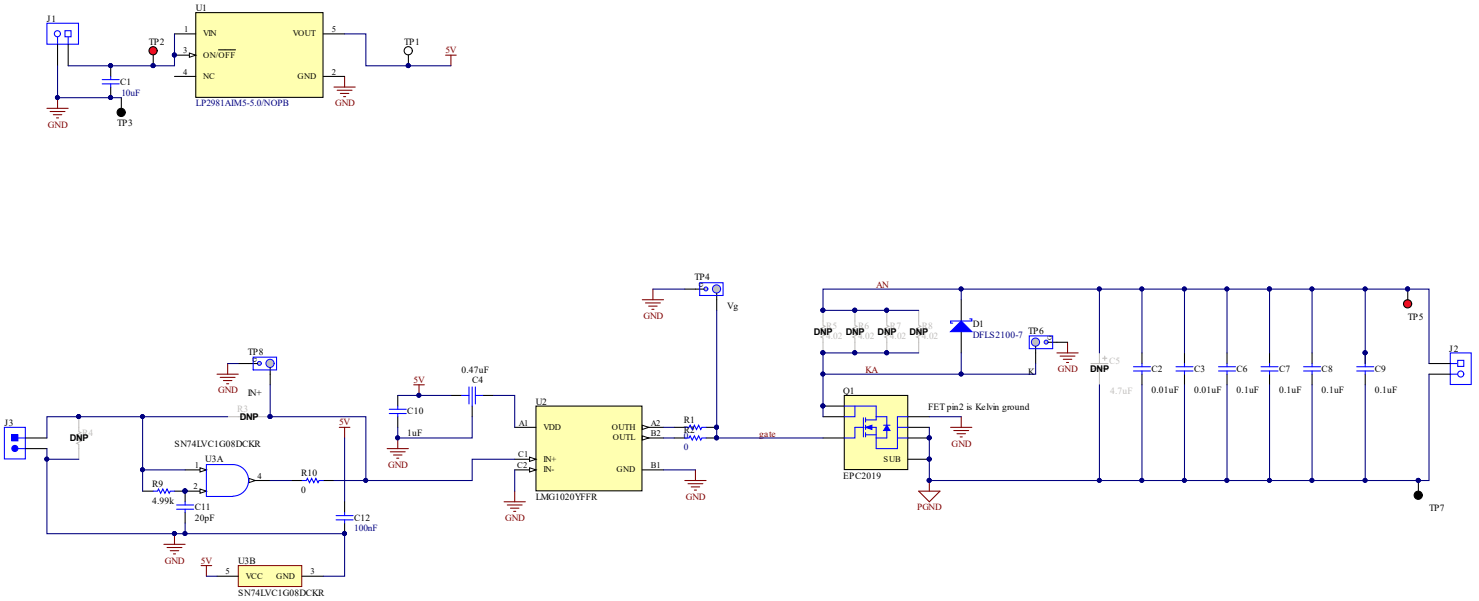

Figure 7-1. Power Stage Schematic (DNP = Do Not Place, Not Present On Board)

8 EVM Kit Contents

The kit contains the following:

- Using the LMG1020EVM-006 (this user's guide)
- Safety instructions
- LMG1020EVM-006 EVM PCB assembly

9 Test Setup

9.1 Test Equipment

DC Voltage Source: capable of supplying the input of the EVM up to 75 V_{DC} as desired. Capable of supplying 100 mA and supports current limiting.

DC Bias Source: capable of 5.5-V_{DC} to 15-V_{DC} output at up to 100 mA.

Oscilloscope: capable of at least 1-GHz 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).

Function Generator: single output capable of at least 0-3 Vdc pulse signal (operating maximum digital input is 5 V_{DC}),1MHz frequency or higher, 50ns minimum pulse or smaller.

9.2 Recommended Test Setup

Connect the input and bias supplies as indicated in Figure 9-1.

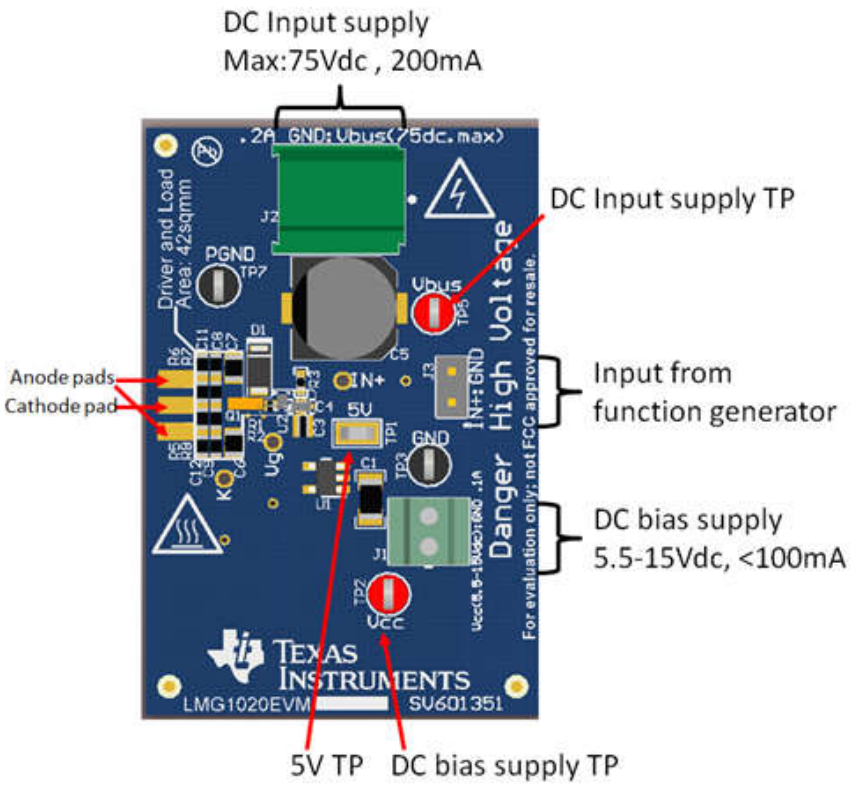

Figure 9-1. Recommended Connection Points and Feature Description

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.

9.3 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 pigtails. Using the small pigtails 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 9-1. Test Point Functional Description

TEST POINT	NAME	DESCRIPTION
TP1	5 V	Connected to the VDD pin of the LMG1020. This is 5Vdc nom
TP2	V_{CC}	Connected to the Vin of the on board LDO, this is the input bias supply voltage (5.5V-15Vdc)
TP3	GND	Connected to GND, the common reference for the board
TP4	Vg	Gate voltage, connected to the Gate of the GaN FET
TP5	V_{BUS}	Connected to the positive of the input supply for the power stage
TP6	K	Connected to the cathode of the laser diode, or negative of the unpopulated load. This is also the drain of the GaN FET
TP7	PGND	Connected to PGND, the common for the input supply of the power stage, internally star-connected to GND
TP8	IN+	Connected to IN+ pin of the LMG1020, this is the positive logic input.

Figure 9-2. Recommended Use for Ground Spring Clip Test Points

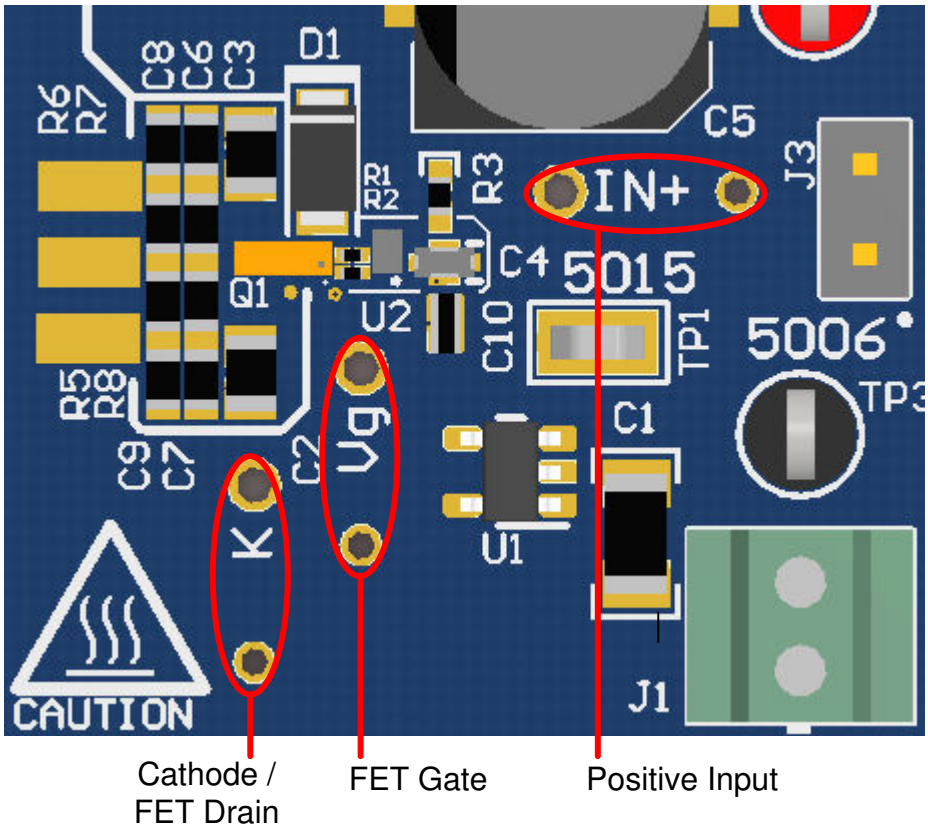

Figure 9-3. Visual and Description of Ground Spring Clip Test Points

9.4 List of Terminals

Table 9-2. List of Terminals

TERMINALS	NAME	DESCRIPTION
J1	DC Bias Supply (V_{CC})	Bias supply connection terminals (5.5-15 V_{DC}, 0.1 A)
J2	DC Input Supply (V_{BUS})	Input voltage connection terminals (MAX: 75 V_{DC}, 0.2 A)
J3	Input signal	Connector for function generator input, connected through a buffer to the positive input of the LMG1020

10 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.

10.1 Nanosecond Pulse Measurements

WARNING

Before populating the EVM with a laser diode, read the out-of-the-box procedure to set the board up correctly before powering the laser diode, found in *Section 6*.

The following procedure is used to obtain and measure nano-second(s) pulse at the output:

1. Connect the input(J2) and bias supplies(J1) as shown in Figure 9-1, but do not power them on yet.
2. Power up the DC bias supply (J1) maintaining it in the 5.5 V to 15 V range and setting the current limit to 0.1 A.
3. Connect the function generator and apply the following settings:
   - Frequency to 100 kHz
   - Signal range 0 V to 3 V
   - Pulse width 100 ns
   - Enable the output
4. Power up the input supply(J2) (as shown in Figure 9-1) and set to the desired input voltage, but no higher than 75Vdc. Set the current limit to 0.2 A. It is recommended to begin measurements at lower voltage, such as 10 V to ensure the correct waveforms are being captured.
5. Tune the length of the pulse on the function generator, so that the Cathode voltage pulse is reduced to the desired width, this will be close to 1-2ns. **Notice that if a resistive load is populated, the rising edge of the pulse is given by the RC constant of the load in series with the COSS of the FET.**
6. Perform the desired measurements

10.2 Pulse Shortener

The digital input buffer includes the lowpass filter plus AND gate as seen in Figure 10-1. The combination can be used as a pulse shortener allowing a regular function generator to achieve 1-2 ns pulses on IN+. Most function generators can only output pulses as low as 10 ns, therefore the ability to create a 1-2 ns pulse can be achieved on the EVM using the AND gate input (J3). The AND gate compares the input (J3) to a RC delayed version and when both inputs are high the output will go high. The input pulse width or falling edge from the function generator can then be fine tuned in order to see the desired pulse width on IN+. When first starting to fine tune the function generator input to see the pulse on IN+, start with 100 ns then reduce the pulse width down by the nanosecond or smaller to make 1-2 ns visible on the IN+ test point. To bypass the pulse shortener populate R3 with a 0-Ω resistor and remove R9 and R10 to disconnect the AND gate input and output respectively.

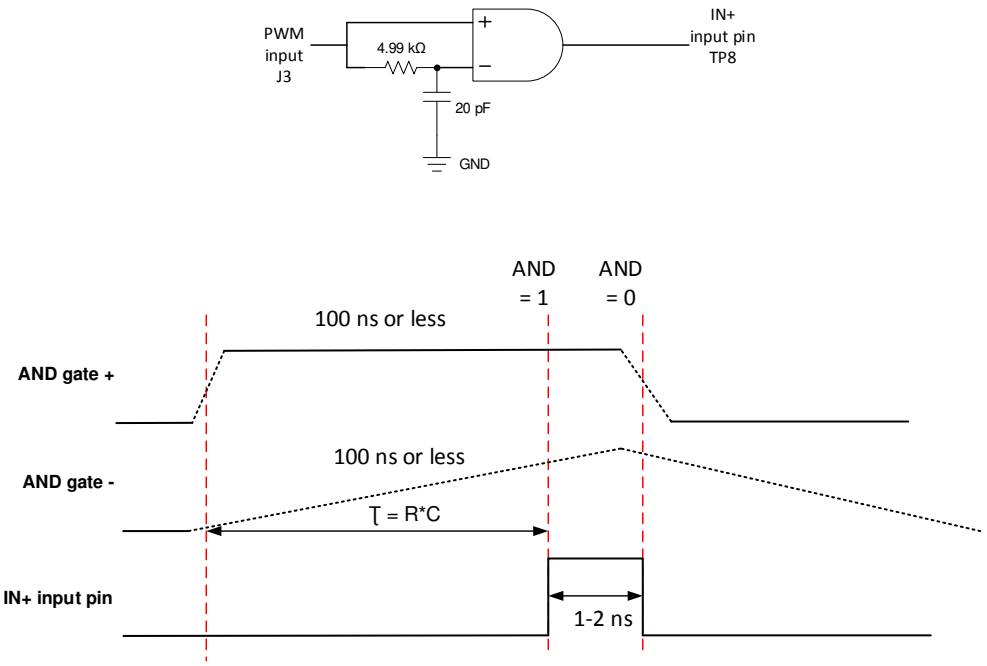

Figure 10-1. Pulse Shortener Yielding 1-ns to 2-ns Pulse on IN+

10.3 Shutdown Procedure

Once 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 bias supply(J1)

10.3.1 Components rating and DNPs

- All input capacitors are 100 V rated
- The EPC2019 FET is 200 V rated to withstand inductive voltage spikes
- The digital input buffer is placed to generate clean input signals on the board and to shorten the input pulse. To bypass it, the DNP resistor R3 has to be placed and resistor R10 has to be removed.
- Out-of-the-box the resistor load, R5 - R8, is not populated (DNP).

11 Performance Data and Typical Characteristics

Figure 11-1 through Figure 11-4 present typical performance curves for LMG1020EVM-006.

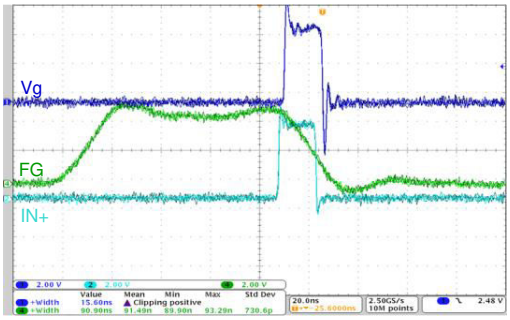

Figure 11-1. 90-ns Pulse from Function Generator Yielding 15-ns Pulse on the Gate

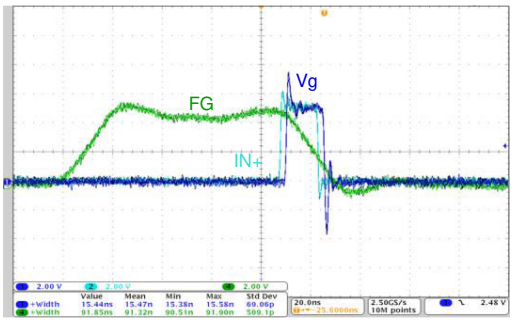

Figure 11-2. 90-ns Pulse from Function Generator Yielding 15-ns Pulse on the Gate

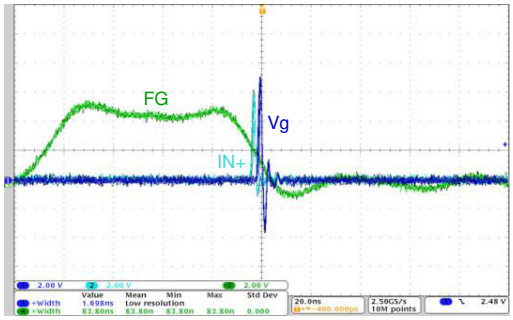

Figure 11-3. 84-ns Pulse from Function Generator Yielding 1.5-ns Pulse on the Gate

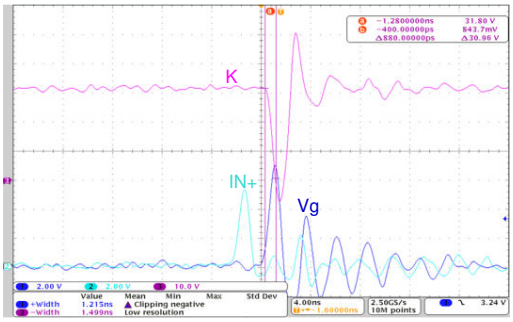

Figure 11-4. 1.2-ns Gate Pulse Yielding 1.5 ns, 30 V into 1-Ω Pulse (500-MHz Scope)

Figure 11-1 through Figure 11-3 show how the input stage performs and how the buffer cleans up and shortens the input pulse. This allows the use of a function generator with lower specifications.

Figure 11-4, taken with a 500MHz oscilloscope, shows typical operation waveforms. On the (K) waveform it is possible to see a 20V overshoot, this is due to the inductance in the power loop. Vg seems to be oscillating, but this is caused by pickup noise, which is inevitable even when using a spring ground connection. The expected resonant frequency for the gate loop is ~70-90MHz (given Gate capacitance of ~10nF and Gate inductance of 3-5nH), the oscillation observed is at 250MHz, which would imply a gate loop inductance of ~40pH. This is therefore pickup noise.

12 EVM Assembly Drawing and PCB Layout

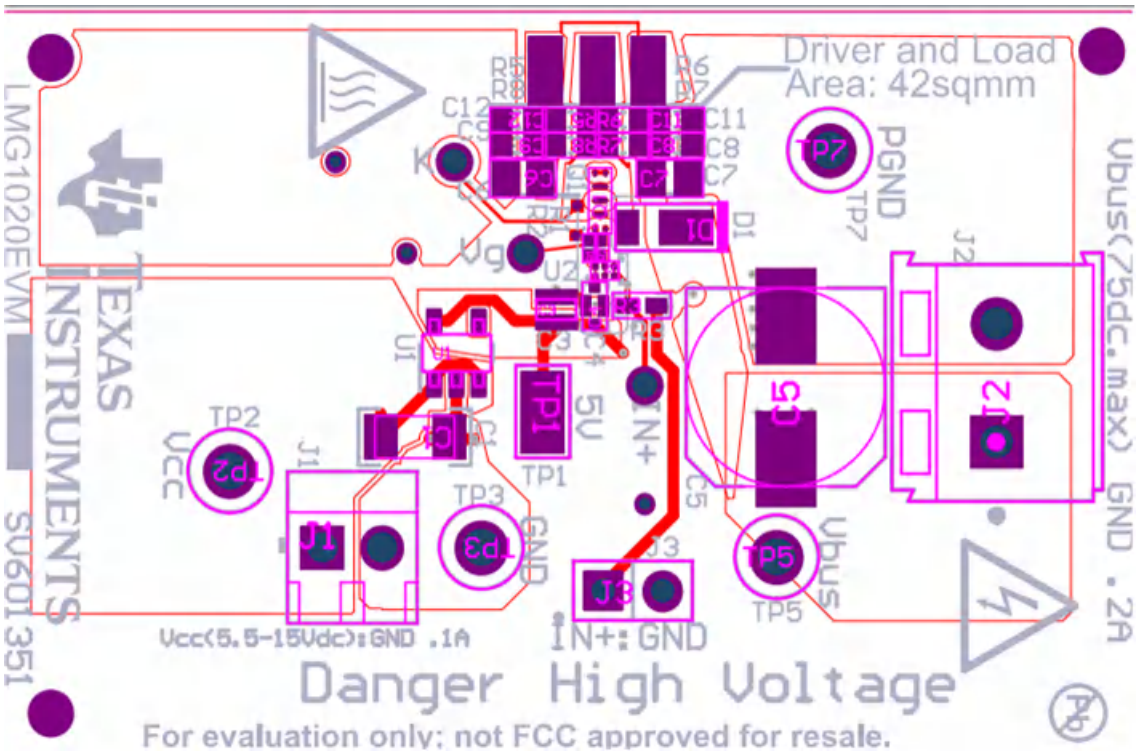

Figure 12-1. LMG1020EVM-006 Top Layer and Components

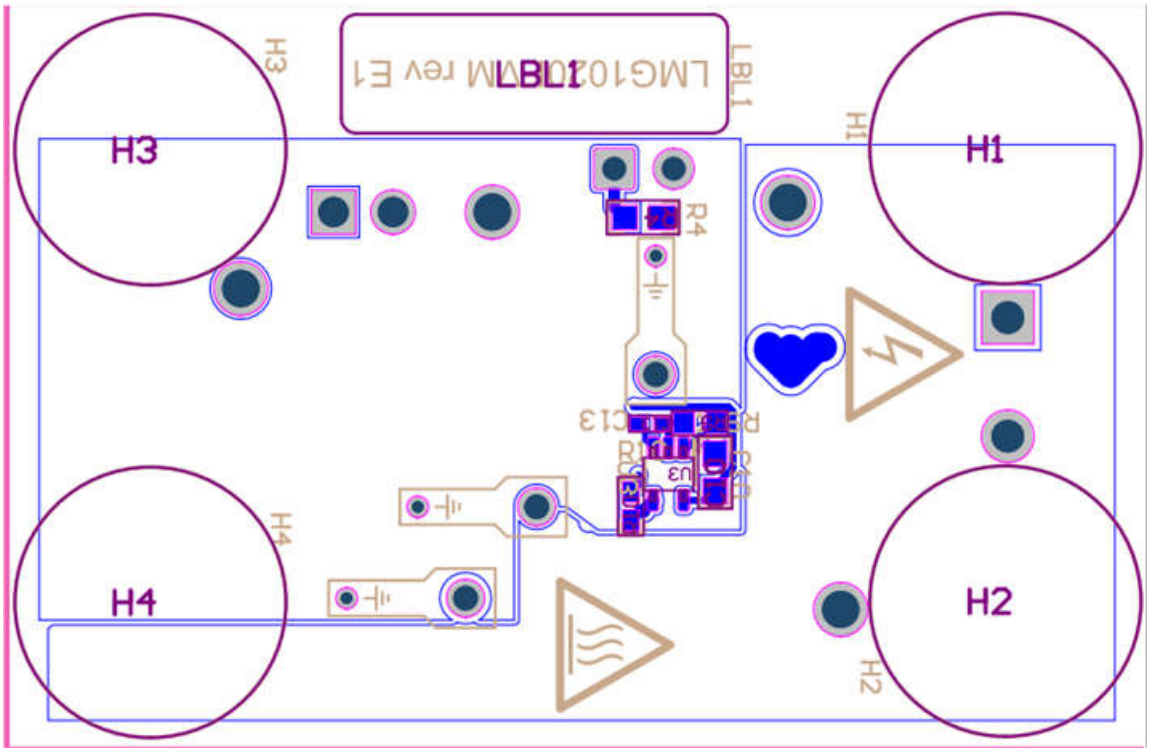

Figure 12-2. LMG1020EVM-006 Bottom Layer and Components

13 List of Materials

Table 13-1. LMG1020EVM-006 List of Materials

QUANTITY	DESIGNATOR	DESCRIPTION	PART NUMBER
1	C1	Capacitor ceramic, 10 µF, 25 V, ±10%, X7R, 1206	885012208069
2	C2, C3	Capacitor ceramic, 0.01 µF, 100 V, ±1%, C0G/NP0, 0805	C0805C103F1GACTU
1	C4	Feedthru Capacitor, 0.47 µF, 6.3V, SMD	YFF18PW0J474M
4	C6, C7 , C8, C9	Capacitor ceramic, 0.1 µF, 100 V, ±10%, X7R, 0603	GRM188R72A104KA35D
1	C10	Capacitor ceramic, 1 µF, 10V, ±20%, X5R, 0306	LWK107BJ105MV
1	C11	Capacitor ceramic, 20 pF, 50 V, +±5%, C0G/NP0, 0402	GRM1555C1H200JA01D
1	C12	Capacitor ceramic, 0.1 µF, 25 V, ±10%, X7R, 0603	GRM188R71E104KA01D
1	D1	Diode, Schottky, 100 V, 2 A, PowerDI123	DFLS2100-7
4	H1, H2, H3, H4	Bumpon, hemisphere, 0.44 X 0.20, Clear	SJ-5303 (CLEAR)
1	J1	Terminal block, 2.54 mm, 2 x 1, Brass, TH	OSTVN02A150
1	J2	Terminal block, 2 x 1, 5.08 mm, TH	282841-2
1	J3	Header, 100mil, 2 x 1, gold, TH	HTSW-102-07-G-S
1	Q1	MOSFET, N-channel, 200 V, 8.5 A, 2.766 x 0.68 mm	EPC2019
2	R1, R2	Resistor, 0, 5%, 0.05 W, 0201	ERJ-1GE0R00C
0	R5, R6, R7, R8	Resistor, 4.02 Ω, 0.5%, 0.1 W, 0603 (DNP)	RT0603DRE074R02L
1	R9	Resistor, 4.99 kΩ, 1%, 0.1 W, 0603	CR0603-FX-4991ELF
1	R10	Resistor, 0 Ω, 5%, 0.063 W, 0402	CRCW04020000Z0ED
1	TP1	Test point, miniature, SMT	5015
2	TP2, TP5	Test point, compact, red, TH	5005
2	TP3 , TP7	Test point, compact, black, TH	5006
3	TP4, TP6, TP8	Test point, pig tail	TESTPOINT_PIGTAIL
1	U1	Micropower 100 mA Ultra Low-Dropout Regulator in SOT-23 Package, DBV0005A (SOT-23-5)	LP2981AIM5-5.0/NOPB
1	U2	High Speed Gate Driver in WCSP Package, YFF	LMG1020YFFR
1	U3	Single 2-Input Positive-AND Gate, DCK0005A (SOT-5)	SN74LVC1G08DCKR
0	C5	Capacitor, aluminum, 4.7 µF, 100 V, ±20%, SMD	UUX2A4R7MCL1GS
0	FID1, FID2, FID3	Fiducial mark. There is nothing to buy or mount.	N/A
0	R3	Resistor, 10 Ω, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040210R0JNED
0	R4	Resistor, 50 Ω, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060350R0FKEA

14 Trademarks

All trademarks are the property of their respective owners.

15 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision C (May 2020) to Revision D (April 2025) **Page**

- Changed part U1 from LP2981A-50DBVR to LP2981AIM5-5.0/NOPB....9
- Changed part U1 from LP2981A-50DBVR to LP2981AIM5-5.0/NOPB....17

Changes from Revision B (May 2020) to Revision C (May 2020) **Page**

- Changed Description to explain the unpopulated resistor load 2

Changes from Revision A (March 2019) to Revision B (May 2020) **Page**

- Added EVM Operation Out-of-the-Box to include procedure of how to populate resistor load out-of-the-box ... 7

Changes from Revision * (January 2018) to Revision A (March 2019) **Page**

- Added text to the introduction 1
- Changed LMG1020-HB-EVM to LMG1020EVM-006 1
- Changed 1-2MHz to 2MHz in Description section 2
- Changed 210ps to 400ps in Features section 2
- Added SN74LVC1G08 description to the features list 2
- Changed LMG1020 part number from XLMG1020A0 to LMG1020YFFR 9
- Added Pulse Shortener description to the test procedure 13

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.

WARNING

Evaluation Kits 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 shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

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。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

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

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

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿 6 丁目 2 4 番 1 号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

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.

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

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

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