AN-2074 LMZ1050xEXT Evaluation Board

1 Introduction

The LMZ1050xEXT SIMPLE SWITCHER® power module is a complete, easy-to-use DC-DC solution capable of driving up to 3A, 4A, or 5A load with exceptional power conversion efficiency, output voltage accuracy, line and load regulation. The LMZ1050xEXT is available in an innovative package that enhances thermal performance and allows for hand or machine soldering.

The LMZ1050xEXT can accept an input voltage rail between 2.95V and 5.5V and deliver an adjustable and highly accurate output voltage as low as 0.8V. One megahertz fixed frequency PWM switching provides a predictable EMI characteristic. Two external compensation components can be adjusted to set the fastest response time, while allowing the option to use ceramic and/or electrolytic output capacitors. Externally programmable soft-start capacitor facilitates controlled startup. The LMZ1050xEXT is a reliable and robust solution with the following features: lossless cycle-by-cycle peak current limit to protect for over current or short-circuit fault, thermal shutdown, input under-voltage lock-out, and pre-biased startup.

2 Board Specifications

- V_{IN} = 2.95V to 5.5V
- V_{OUT} = 2.5V (default output voltage setting, refer to Table 2 for other output settings)
- ±2.5% feedback voltage accuracy at 2.5V output (Including line and load regulation from T_J = -55°C to 125°C)
- ±1.63% feedback voltage accuracy over temperature
- I_{OUT} = 0A to 3A, 4A, and 5A
- θ_{JA} = 20°C/W, θ_{JC} = 1.9°C/W
- Designed on four layers, the top and bottom layers are 1oz. copper and the two inner layers are 1/2 oz. copper weight
- Measures 2.25 in. x 2.25 in. (5.8 cm x 5.8 cm) and is 62mil (.062”) thick on a FR4 laminate

3 Evaluation Board Design Concept

The evaluation board is designed to demonstrate low conducted noise on the input and output lines, as seen in Figure 11 and Figure 14. Four input capacitors (C_{in1} - C_{in4}) and three output capacitors (C_{o1} - C_{o3}) are populated for this purpose. All the input and output filter capacitors are not necessary to comply with radiation standards. For a circuit example that passes radiated emissions standards (EN55022, class B) please refer to Figure 19. Additionally, C_{in5} is present to reduce the resonance of the input line produced by the inductance and resistance in the cables connecting the bench power supply to the evaluation board and the input capacitors.

4 Additional Component Footprints

When the tracking feature of the LMZ1050xEXT is used, remove the soft-start capacitor C_{SS} and use a resistor divider on designators R_{trkb} and R_{trkt}. The ground and V_{trk} post have been provided for easy connection.

The LMZ1050xEXT eval board incorporates a precision enable circuit which is pulled high by a 100 kΩ pull up resistor to VIN. This allows the user to pull low on the enable pin to ground. The top enable resistor is R_{ent} and the bottom enable resistor is R_{enb}. Refer to the *Design Guideline and Operating Description* section of the LMZ1050xEXT data sheet for detailed design implementation.

Select FPGAs specify input inrush currents for particular power-up sequences and others require sequencing rails to avoid start-up or latch-up problems. To prevent early turn-on of the LMZ1050xEXT in systems with multiple power rails, precision enable and tracking are useful as the main input voltage rail rises at power-up.

5 Component Circuit Schematic

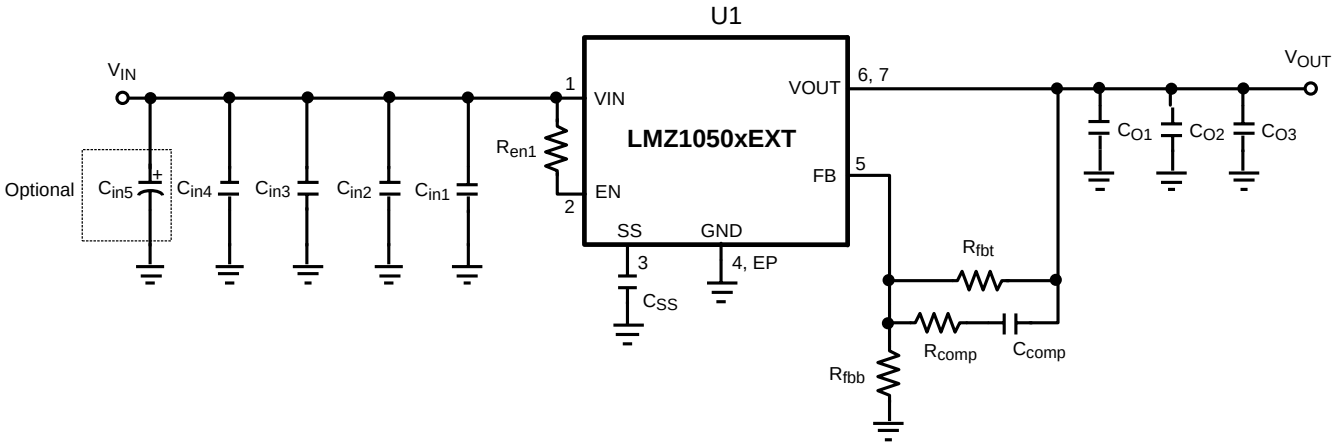


Figure 1. Component Schematic for Evaluation Board

Table 1. Bill of Materials for Evaluation Board, V_{IN} = 3.3V to 5V, V_{OUT} = 2.5V

Designator	Description	Case Size	Manufacturer	Manufacturer P/N	Quantity
U1	SIMPLE SWITCHER®	PFM-7	Texas Instruments	LMZ10503/LMZ10504/LMZ10505EXTTZ	1
C_{in1}	1 µF, X7R, 16V	0805	TDK	C2012X7R1C105K	1
C_{in2}, C_{O1}	4.7 µF, X5R, 6.3V	0805	TDK	C2012X5R0J475K	2
C_{in3}, C_{O2}	22 µF, X5R, 16V	1210	TDK	C3225X5R1C226M	2
C_{in4}	47 µF, X5R, 6.3V	1210	TDK	C3225X5R0J476M	1
C_{O3}	100 µF, X5R, 6.3V	1812	TDK	C4532X5R0J107M	1
R_{fbt}	75 kΩ	0805	Vishay Dale	CRCW080575K0FKEA	1
R_{fbb}	34.8 kΩ	0805	Vishay Dale	CRCW080534K8FKEA	1
R_{comp}	1.1 kΩ	0805	Vishay Dale	CRCW08051K10FKEA	1
C_{comp}	180 pF, ±5%, C0G, 50V	0603	TDK	C1608C0G1H181J	1
R_{en1}	100 kΩ	0805	Vishay Dale	CRCW0805100KFKEA	1
C_{SS}	10 nF, ±5%, C0G, 50V	0805	TDK	C2012C0G1H103J	1

Table 2. Output Voltage Setting (R_{fbt} = 75 kΩ)

V_{OUT}	R_{fbb}
3.3 V	23.7 kΩ
2.5 V	34.8 kΩ
1.8 V	59 kΩ
1.5 V	84.5 kΩ
1.2 V	150 kΩ
0.9 V	590 kΩ

6 Complete Circuit Schematic

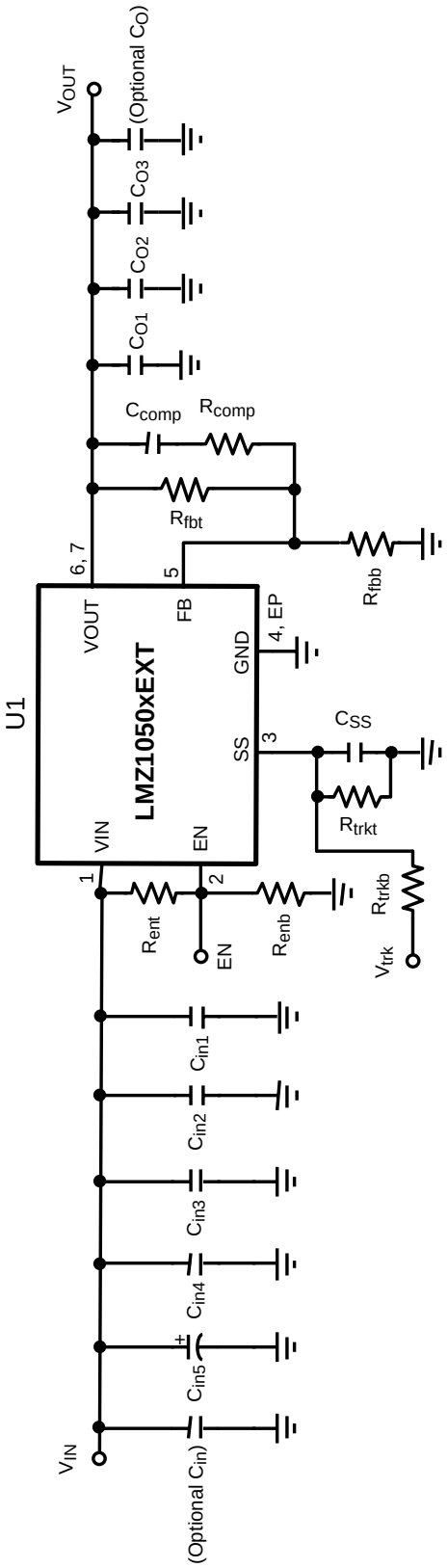


Figure 2. Complete Evaluation Board Schematic

7 Connection Diagram

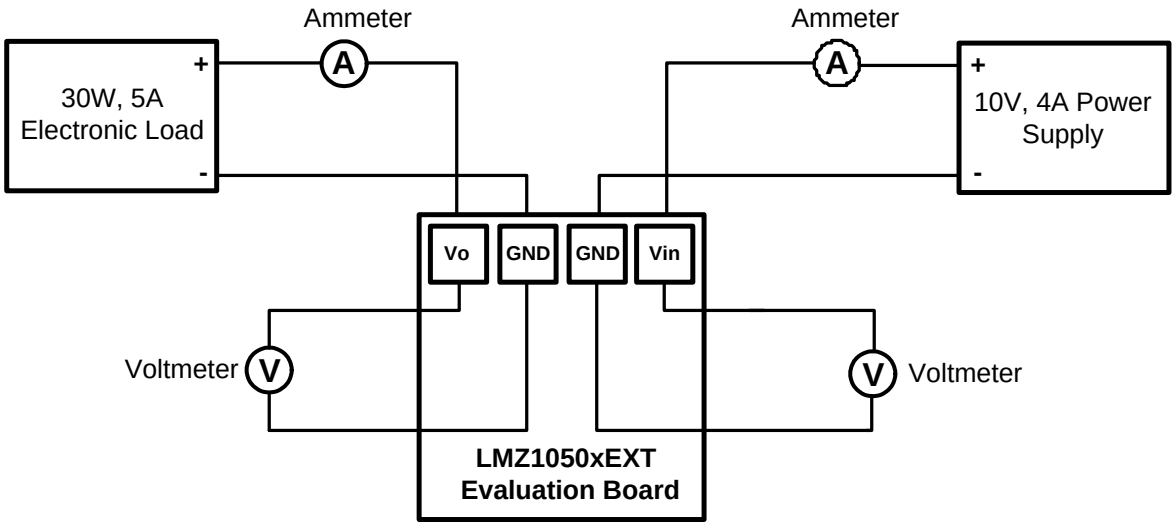


Figure 3. Efficiency Measurement Setup

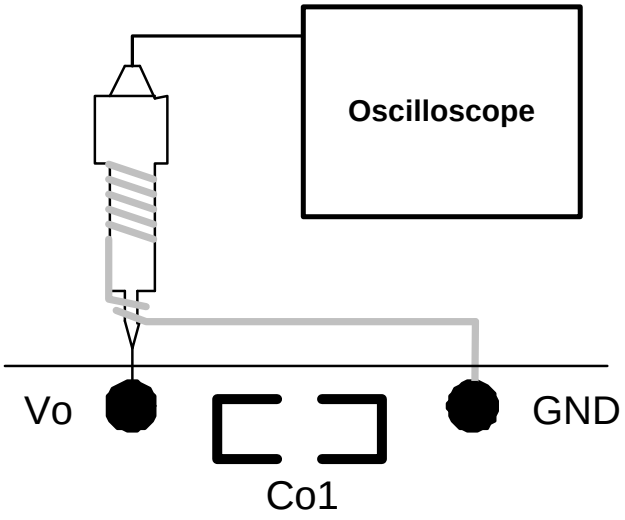
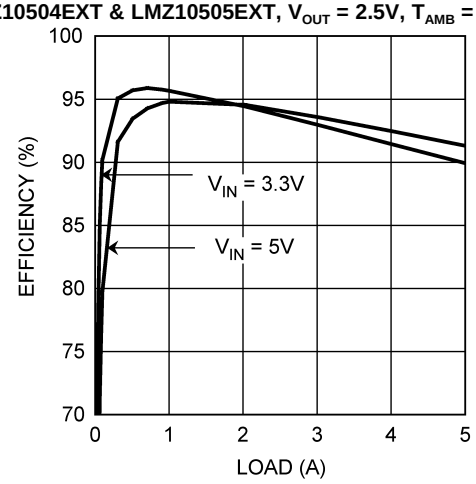
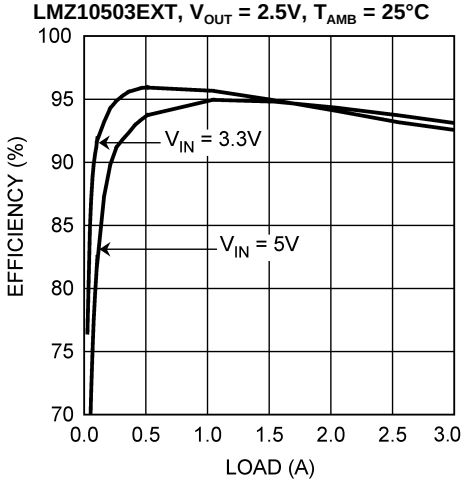


Figure 4. Output Voltage Ripple Measurement Setup

Efficiency vs. Load Current
LMZ10504EXT & LMZ10505EXT, V_{OUT} = 2.5V, T_{AMB} = 25°C



Efficiency vs. Load Current
LMZ10503EXT, V_{OUT} = 2.5V, T_{AMB} = 25°C



8 Performance Characteristics

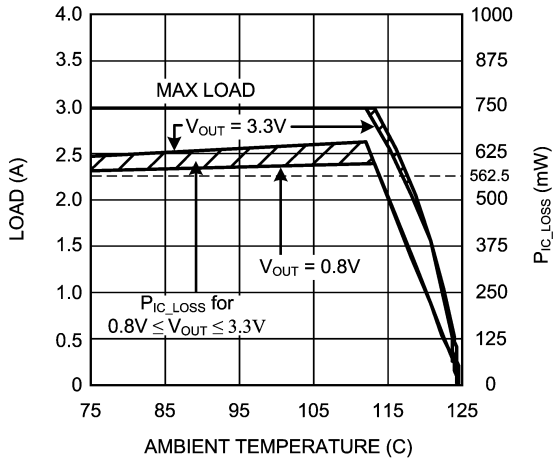


Figure 5. Current Derating vs. Ambient Temperature LMZ10503EXT, V_{IN} = 5.0V, θ_{JA} = 20°C/W

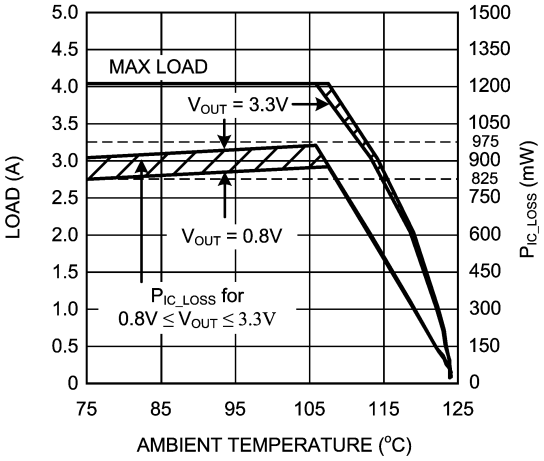


Figure 6. Current Derating vs. Ambient Temperature LMZ10504EXT, V_{IN} = 5.0V, θ_{JA} = 20°C/W

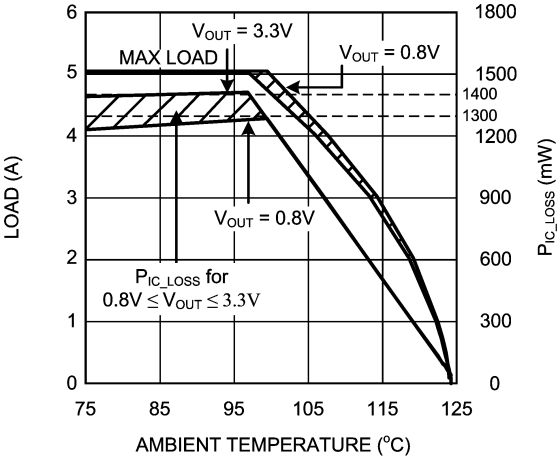


Figure 7. Current Derating vs. Ambient Temperature LMZ10505EXT, V_{IN} = 5.0V, θ_{JA} = 20°C/W

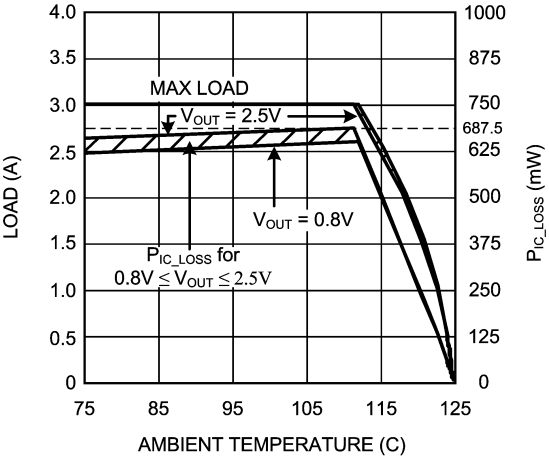


Figure 8. Current Derating vs. Ambient Temperature LMZ10503EXT, V_{IN} = 3.3V, θ_{JA} = 20°C/W

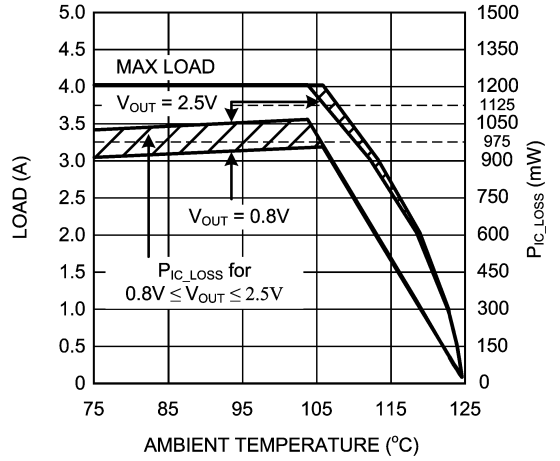


Figure 9. Current Derating vs. Ambient Temperature LMZ10504EXT, V_{IN} = 3.3V, θ_{JA} = 20°C/W

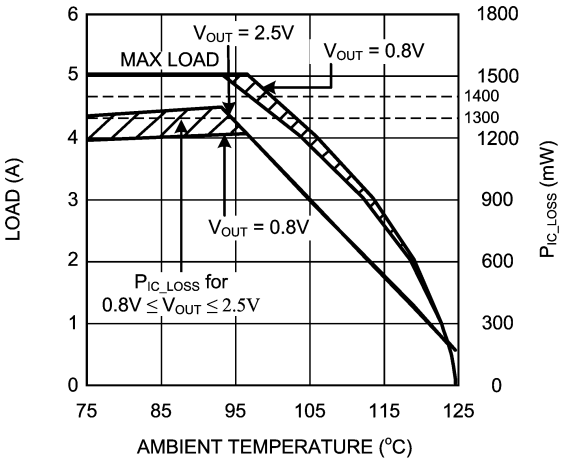


Figure 10. Current Derating vs. Ambient Temperature LMZ10505EXT, V_{IN} = 3.3V, θ_{JA} = 20°C/W

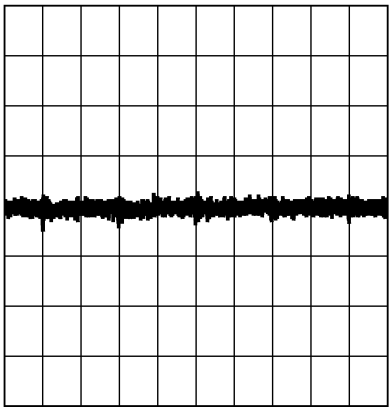


Figure 11. Output Voltage Ripple
V_{IN} = 5V, V_{OUT} = 2.5V, I_{OUT} = 3A, 4A, & 5A
LMZ10503EXT / LMZ10504EXT / LMZ10505EXT

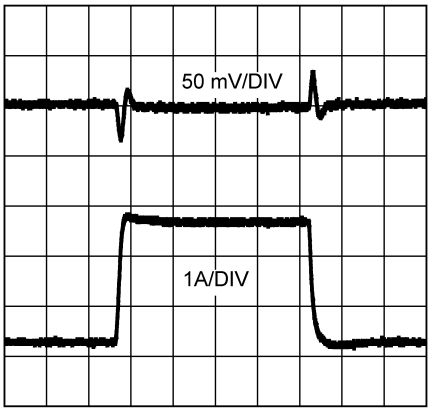


Figure 12. Load Transient Response
V_{IN} = 5.0V, V_{OUT} = 2.5V
LMZ10503EXT, I_{OUT} = 400 mA to 2.7A, 20 MHz Bandwidth Limit

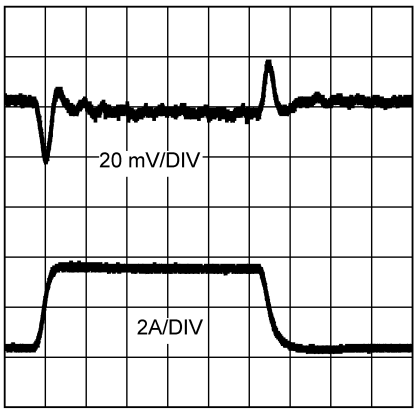


Figure 13. Load Transient Response
V_{IN} = 5V, V_{OUT} = 2.5V
LMZ10504EXT, I_{OUT} = 400 mA to 3.6A, 20 MHz Bandwidth Limit

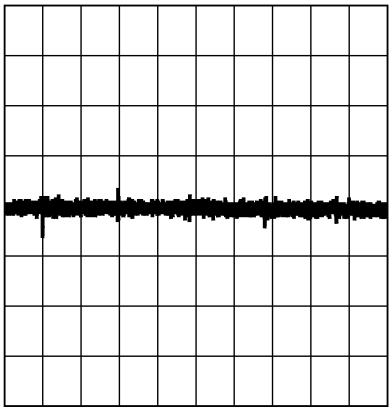


Figure 14. Output Voltage Ripple
V_{IN} = 3.3V, V_{OUT} = 2.5V, I_{OUT} = 3A, 4A, & 5A
LMZ10503EXT / LMZ10504EXT / LMZ10505EXT

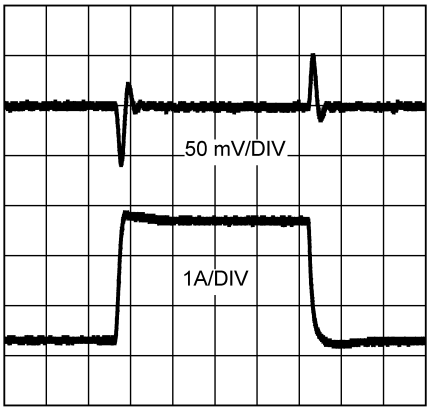


Figure 15. Load Transient Response
V_{IN} = 3.3V, V_{OUT} = 2.5V
LMZ10503EXT, I_{OUT} = 300 mA to 2.7A, 20 MHz Bandwidth Limit

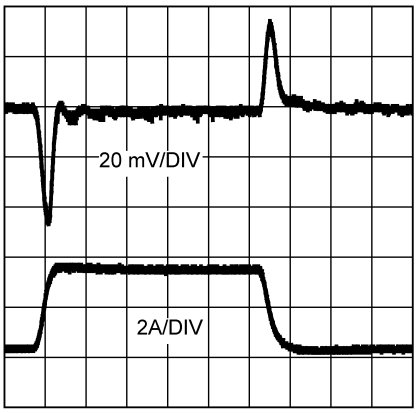


Figure 16. Load Transient Response
V_{IN} = 3.3V, V_{OUT} = 2.5V
LMZ10504EXT, I_{OUT} = 400 mA to 3.6A, 20 MHz Bandwidth Limit

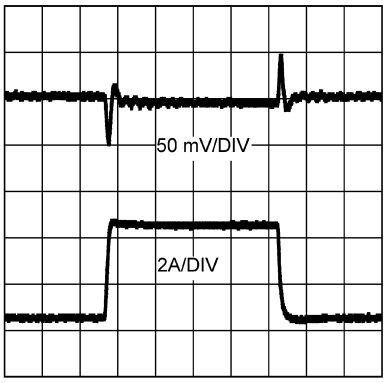


Figure 17. Load Transient Response
V_{IN} = 5.0V, V_{OUT} = 2.5V
LMZ10505EXT, I_{OUT} = 500 mA to 4.5A, 20 MHz Bandwidth Limit

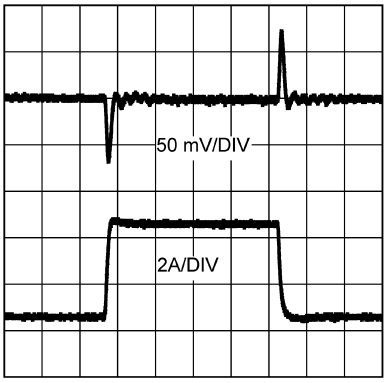


Figure 18. Load Transient Response
V_{IN} = 3.3V, V_{OUT} = 2.5V
LMZ10505EXT, I_{OUT} = 500 mA to 4.5A, 20 MHz Bandwidth Limit

9 Circuit Example: Complies with EN55022 Class B Radiated Emissions

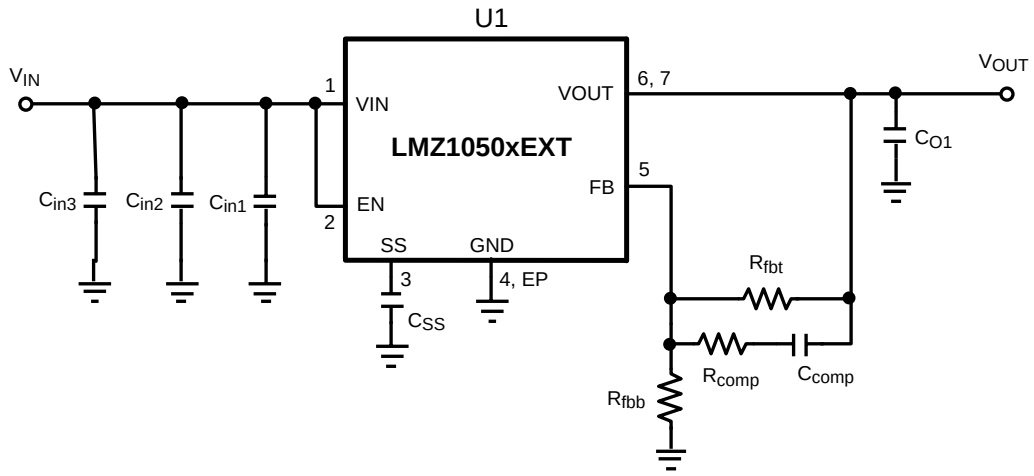


Figure 19. Component Schematic, V_{IN} = 5V, V_{OUT} = 2.5V, Complies with EN55022 Class B Radiated Emissions

Table 3. Bill of Materials

Designator	Description	Case Size	Manufacturer	Manufacturer P/N	Quantity
U1	SIMPLE SWITCHER®	PFM-7	Texas Instruments	LMZ10503/LMZ10504/LMZ10505EXTTZ	1
C_{in1}	1 µF, X7R, 16V	0805	TDK	C2012X7R1C105K	1
C_{in2}	4.7 µF, X5R, 6.3V	0805	TDK	C2012X5R0J475K	1
C_{in3}	47 µF, X5R, 6.3V	1210	TDK	C3225X5R0J476M	1
C_{O1}	100 µF, X5R, 6.3V	1812	TDK	C4532X5R0J107M	1
R_{fbt}	75 kΩ	0805	Vishay Dale	CRCW080575K0FKEA	1
R_{fbb}	34.8 kΩ	0805	Vishay Dale	CRCW080534K8FKEA	1
R_{comp}	1.1 kΩ	0805	Vishay Dale	CRCW08051K10FKEA	1
C_{comp}	180 pF, ±5%, C0G, 50V	0603	TDK	C1608C0G1H181J	1
C_{SS}	10 nF, ±5%, C0G, 50V	0805	TDK	C2012C0G1H103J	1

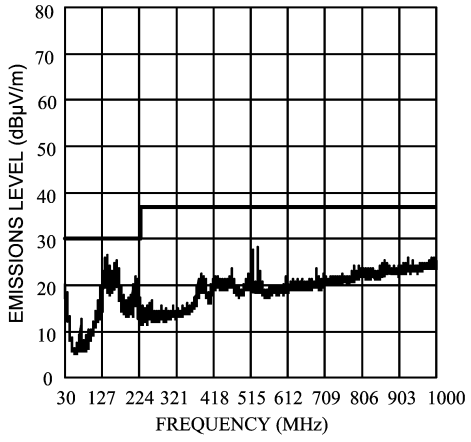


Figure 20. Radiated Emissions (EN55022, Class B)
V_{IN} = 5V, V_{OUT} = 2.5V, I_{OUT} = 3A
Tested on LMZ10503EXT Evaluation Board

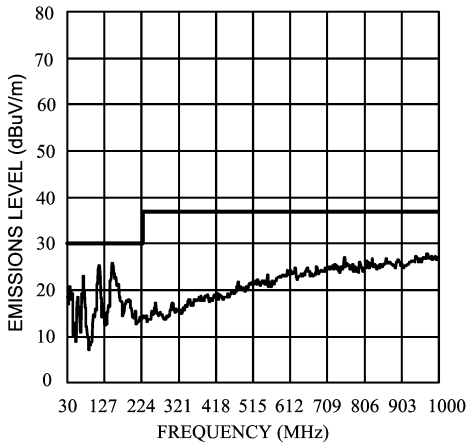


Figure 21. Radiated Emissions (EN55022, Class B)
V_{IN} = 5V, V_{OUT} = 2.5V, I_{OUT} = 4A
Tested on LMZ10504EXT Evaluation Board

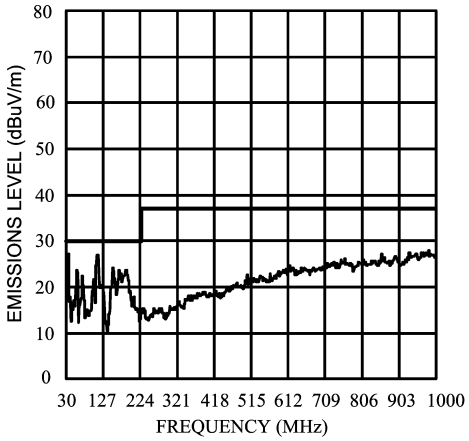


Figure 22. Radiated Emissions (EN55022, Class B)
V_{IN} = 5V, V_{OUT} = 2.5V, I_{OUT} = 5A
Tested on LMZ10505EXT Evaluation Board

10 PCB Layout Diagram

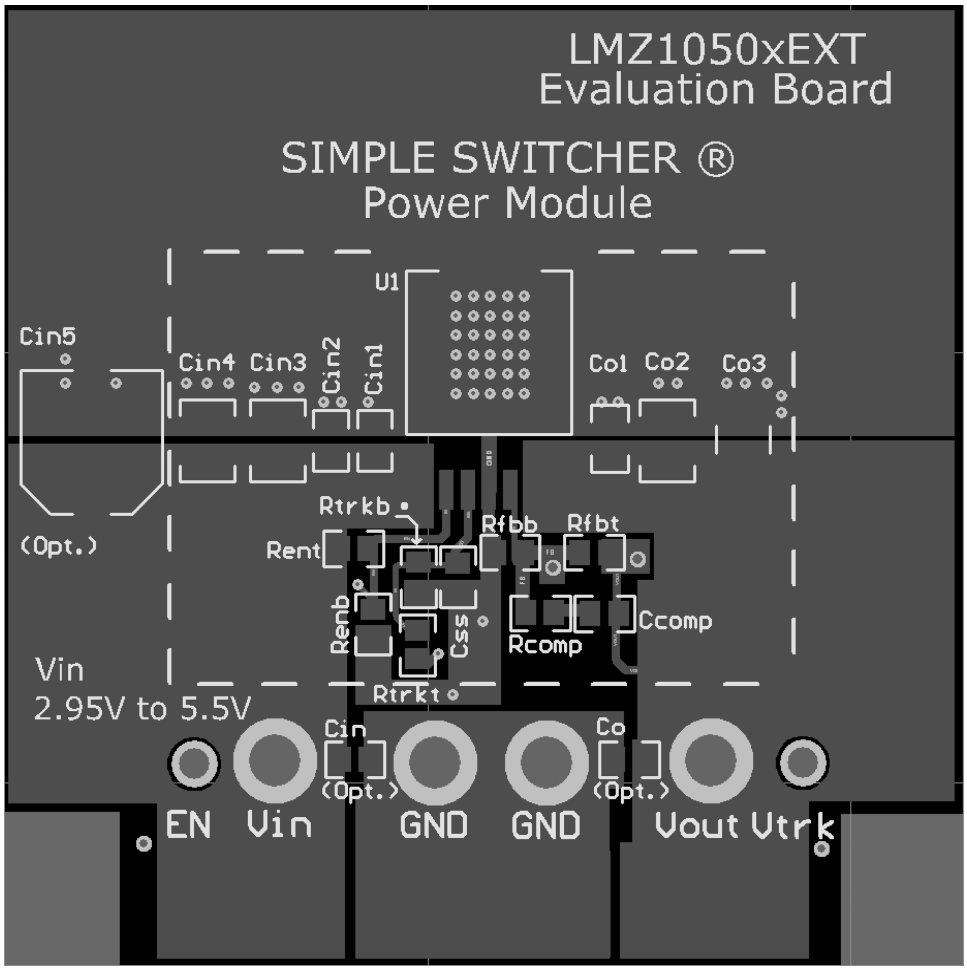


Figure 23. Top Layer

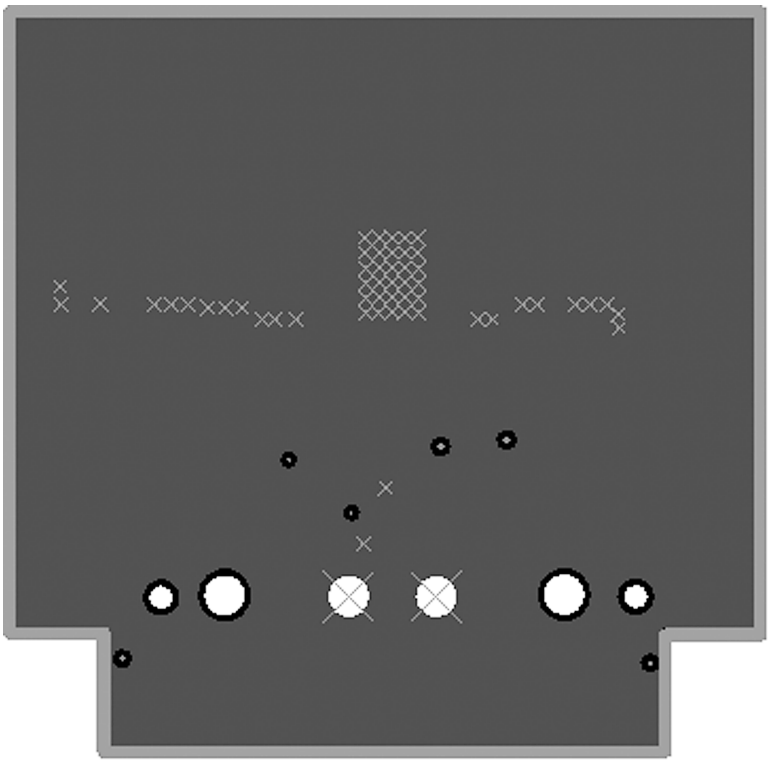


Figure 24. Internal Layer I (Ground)

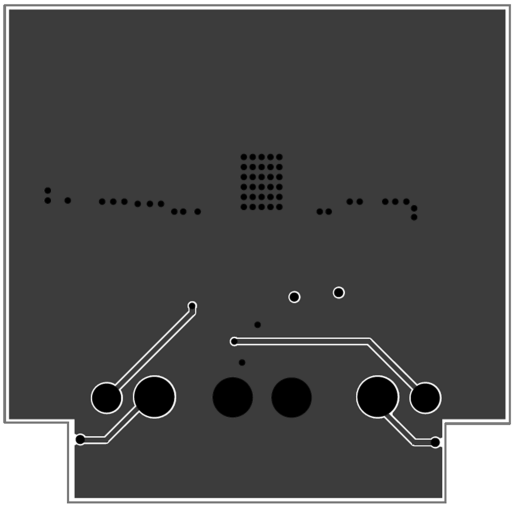


Figure 25. Internal Layer II (Ground)

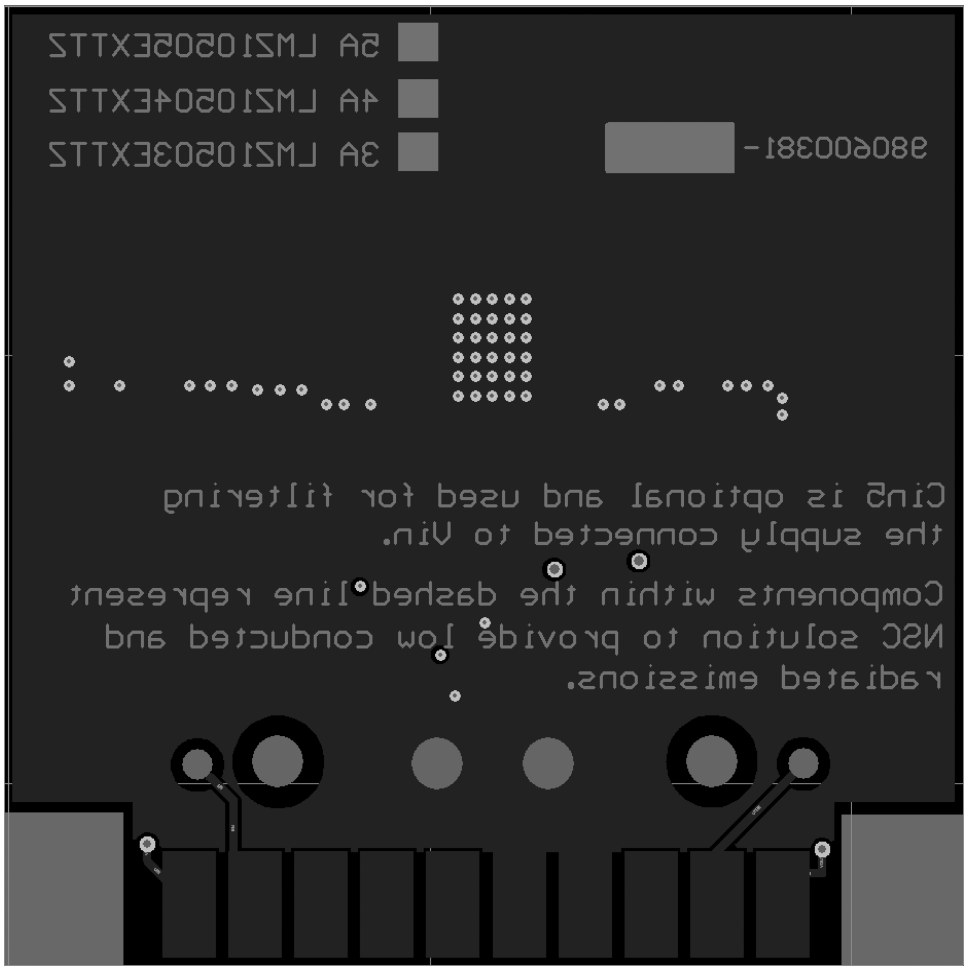


Figure 26. Bottom Layer

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.

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