AN-2125 LMZ23605/03, LMZ22005/03 Demonstration Board

1 Introduction

The LMZ23605/03, LMZ22005/03 demonstration boards are designed to be an easy-to-use platform to evaluate the basic capabilities of this family of SIMPLE SWITCHER® power modules. The PCB has excellent thermal performance and implements the most common applications for the product.

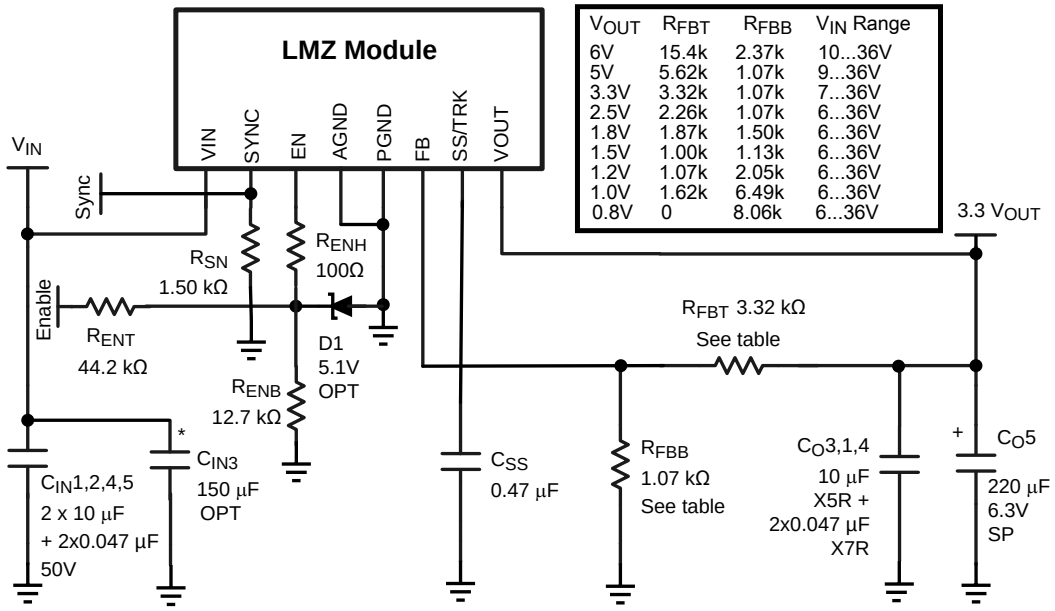
The LMZ23605/03 can accept an input voltage rail between 6V and 36V and the LMZ22005/03 can accept an input voltage rail between 6V and 20V. The devices can deliver an adjustable and highly accurate output voltage as low as 0.8V and as high as 6V. The internal control architecture is constant frequency PWM with emulated current mode sensing. The control loop operates well with low ESR output capacitors such as ceramics or specialty polymer. The precision enable input allows for programmable UVLO on the input supply. The external soft-start capacitor facilitates controlled output rise time at startup. The LMZ23605/03 and LMZ22005/03 family is a reliable and robust solution with loss-less cycle-by-cycle valley current limit to protect for over current or short-circuit faults. Additionally there is thermal shutdown protection, and they will start up into a pre-biased output. Free-running switching frequency is 812 kHz and a 650 kHz to 950 kHz synchronization range is supported.

2 Board Specifications

- V_{IN} = 6V to 36V (LMZ22005/03 limited to 20V)
- Enable UVLO = 5.7V
- V_{OUT} = 3.3V
- I_{OUT} = 0 to 5A (3A)
- θ_{JA} = 12°C / W, θ_{JC} = 1.9°C/W
- Max ambient temp of 70°C for 12Vin and 3.3Vout @ 5A
- Designed on four layers; Inner are 2 oz; Outer are 3 oz.
- Measures 3.5 in. × 3.5 in. (8.9 cm × 8.9 cm) and is 62mil (.062”) thick of FR4 laminate material

For additional circuit considerations, refer to the Applications Section of the LMZ23605/03 and LMZ22005/03 data sheets. For negative output voltage connections, see *AN-2027 Inverting Application for the LMZ14203 SIMPLE SWITCHER Power Module Application Report* (SNVA425).

3 Simplified Schematic

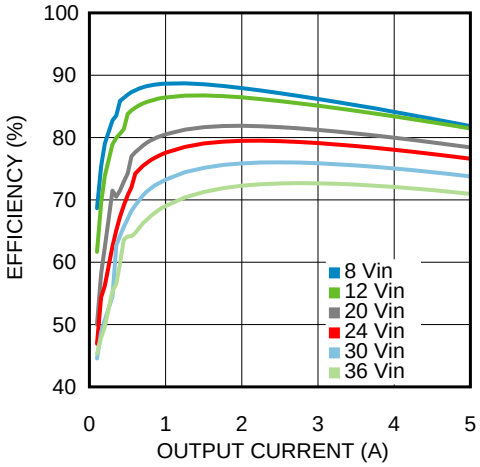


V_{OUT}	R_{FBT}	R_{FBB}	V_{IN} Range
6V	15.4k	2.37k	10...36V
5V	5.62k	1.07k	9...36V
3.3V	3.32k	1.07k	7...36V
2.5V	2.26k	1.07k	6...36V
1.8V	1.87k	1.50k	6...36V
1.5V	1.00k	1.13k	6...36V
1.2V	1.07k	2.05k	6...36V
1.0V	1.62k	6.49k	6...36V
0.8V	0	8.06k	6...36V

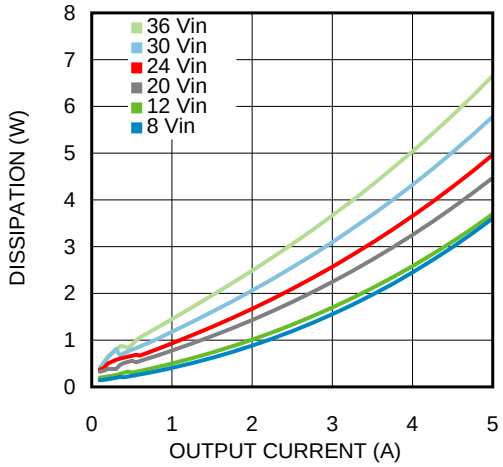
Figure 1. Demonstration Board Simplified Schematic

4 Performance Characteristics

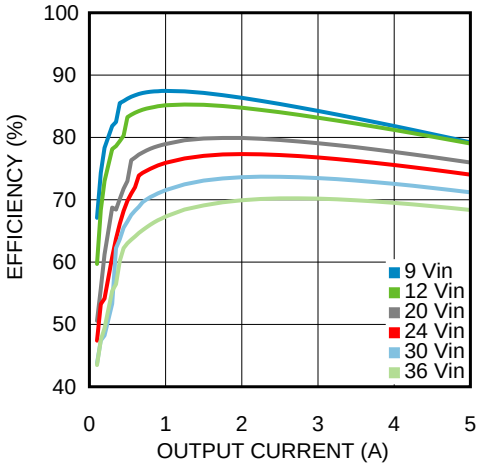
LMZ23605 Efficiency @ 25°C Ambient



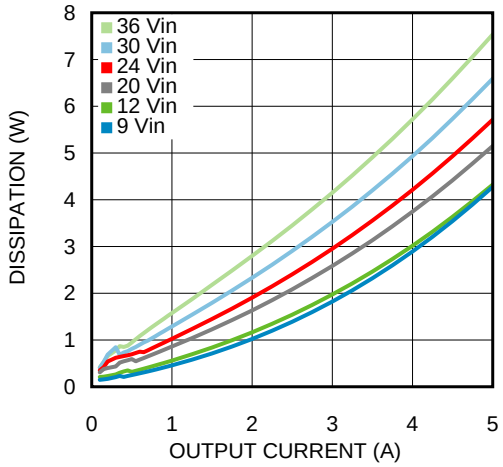
LMZ23605 Dissipation @ 25°C Ambient



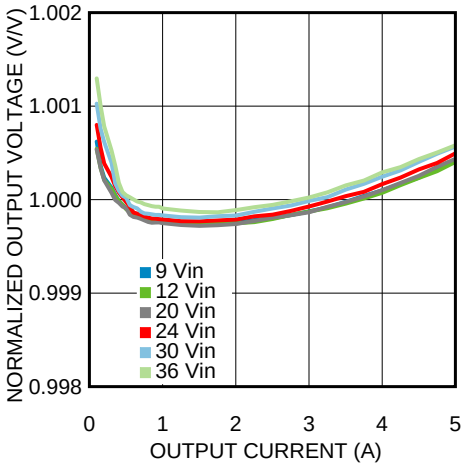
LMZ23605 Efficiency @ 85°C



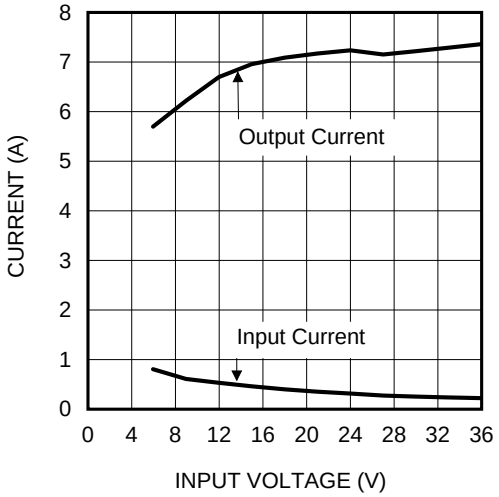
LMZ23605 Dissipation @ 85°C



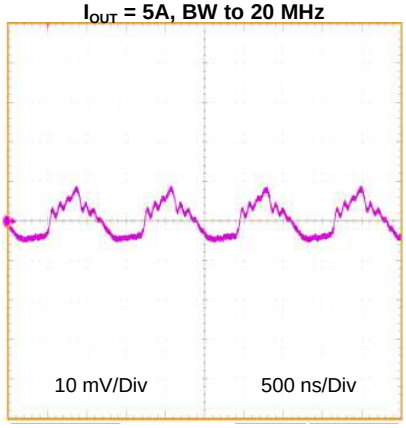
LMZ23605 Load and Line Regulation @ 25°C Ambient



LMZ23605 Current Limit V_{OUT} = 3.3V

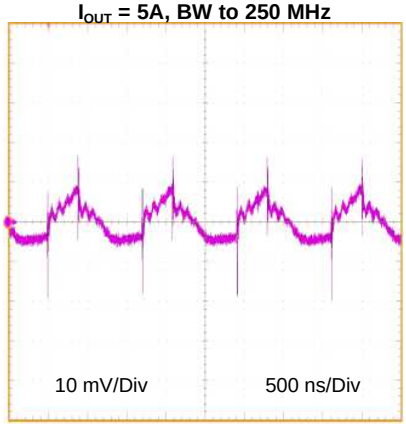


LMZ23605 Output Ripple V_{OUT} = 3.3V
I_{OUT} = 5A, BW to 20 MHz



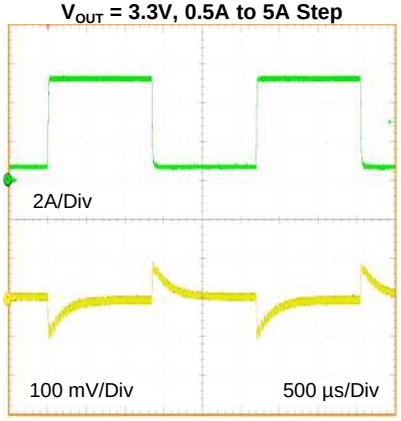
Cout = 220 µF Poscap + 10µF X5R + 2 × 0.047µF

Output Ripple V_{OUT} = 3.3V
I_{OUT} = 5A, BW to 250 MHz

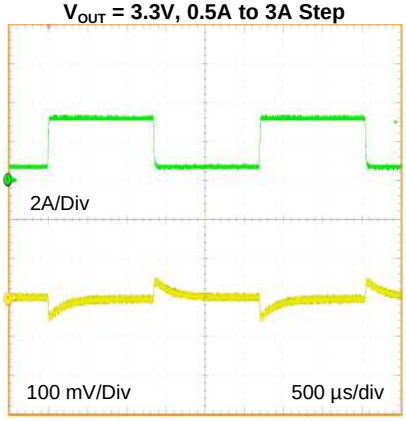


Cout = 220 µF Poscap + 10µF X5R + 2 × 0.047µF

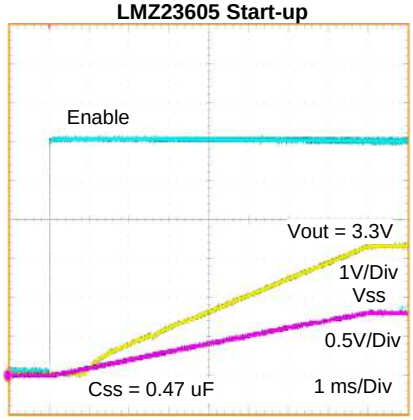
LMZ23605 Load Step Response V_{IN} = 12V
V_{OUT} = 3.3V, 0.5A to 5A Step



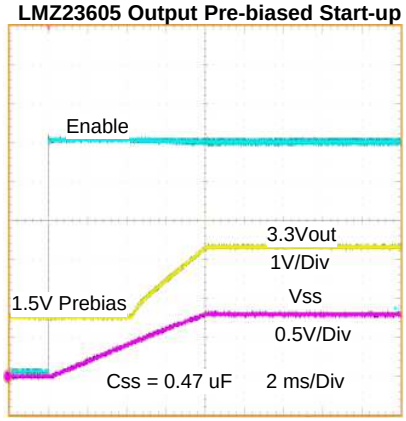
LMZ23603 Load Step Response V_{IN} = 12V
V_{OUT} = 3.3V, 0.5A to 3A Step



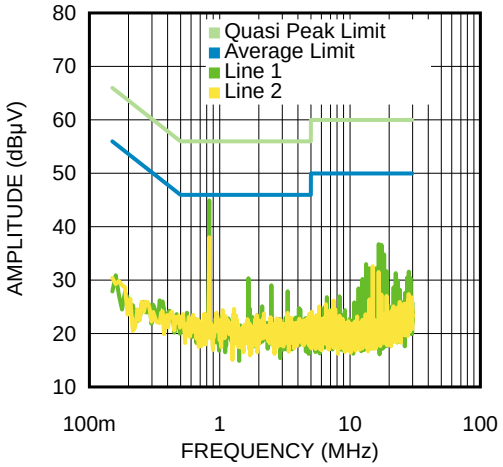
LMZ23605 Start-up



LMZ23605 Output Pre-biased Start-up

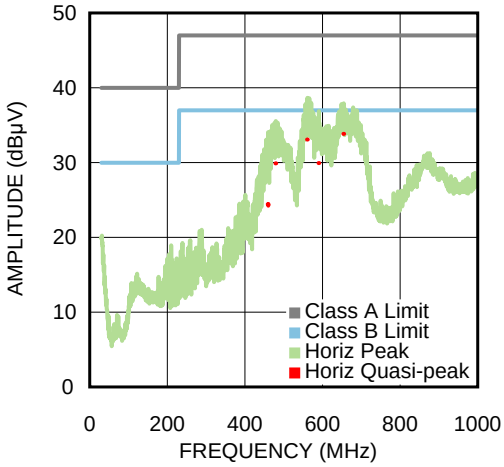


LMZ23605 Conducted EMI



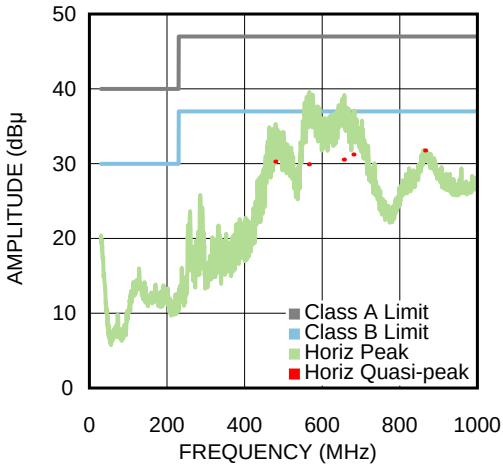
2.2 µH / 10 µF input LC filter
and 10uF in || w/ $C_{IN}1$

LMZ23605 24Vin to 3.3Vout @ 5A – EN 55022



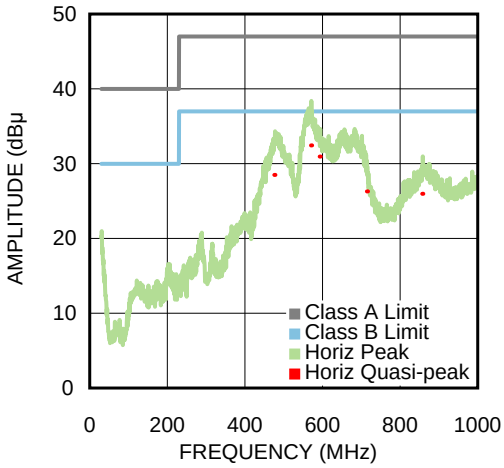
Cin = default +10 µF +3 × 0.01µF
C_O = default + 2 × 0.01µF

LMZ23603 24Vin to 3.3V @ 3A – EN55022

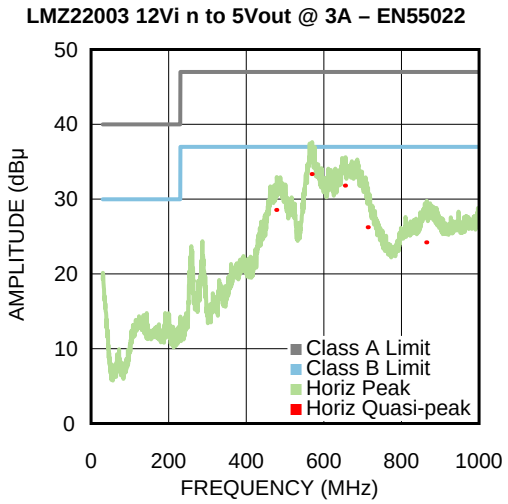


Cin = default +10 µF +3 × 0.01µF
C_O = default + 2 × 0.01µF

LMZ22005 12Vin to 3.3Vout @ 5A – EN55022



Cin = default +10 µF +3 × 0.01µF
C_O = default + 2 × 0.01µF



Cin = default +10 µF +3 × 0.01µF
C_O = default + 2 × 0.01µF

5 Notes

Solder turrets are located on the edge of the PCB assembly for demonstration hookup to bench test equipment. The Enable input turret is designed for direct connection to the V_{IN} turret. There is a resistive divider implemented on the board that establishes the precision 5.7V UVLO level of the board. A common user change to this divider is to raise the value of R_{ENT} to increase the operating UVLO to that of the target application. Refer to the respective data sheet for calculation. Note that if in the end application the module pin 3 enable input voltage does not exceed 5.5V at maximum Vin then enable clamp zener D1 can be omitted.

Each implementation of the demonstration board is preset to 3.3V output; with current rating and maximum input voltage dictated by the model of module installed. A common user change is to adjust the output voltage for different requirements. A table of suggested resistor pairs are listed in figure 1 for quick reference.

A turret is provided for applying a clock to synchronize the module switching frequency anywhere between 650 kHz and 950 kHz. Note that a sustained “logic one” on this input corresponds to “zero hertz” and will cause the module to stop switching.

Inductor current can be observed by cutting the bottom side conducting etch connecting module pin 7 V_{OUT} and the Co array. Install a 5” loop of 22 ga insulated wire in the two vias. Monitor the inductor sense loop with an AC/DC oscilloscope current probe.

The top side Vin plane has solder mask openings where an input LC network can be placed to accommodate improved differential mode and conducted EMI performance.

Additional component mounting pads are available to experiment with alternative Cin and Cout combinations. See figure 6 for corresponding schematic locations.

6 Gerber and CAD Files

Gerber and CAD files can be downloaded from the associated product folder.

7 PCB Layout Diagrams

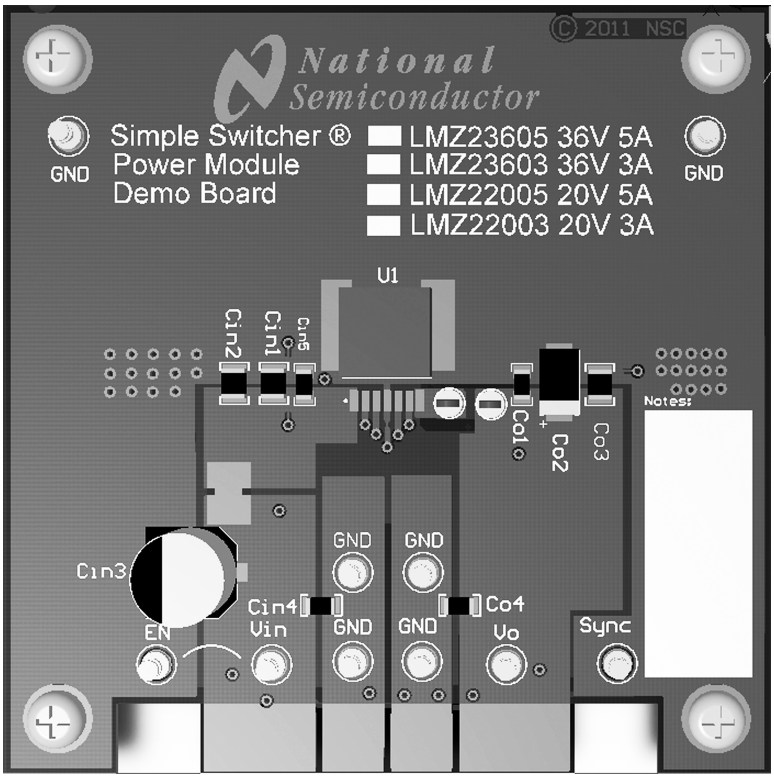


Figure 2. Top View of Assembly

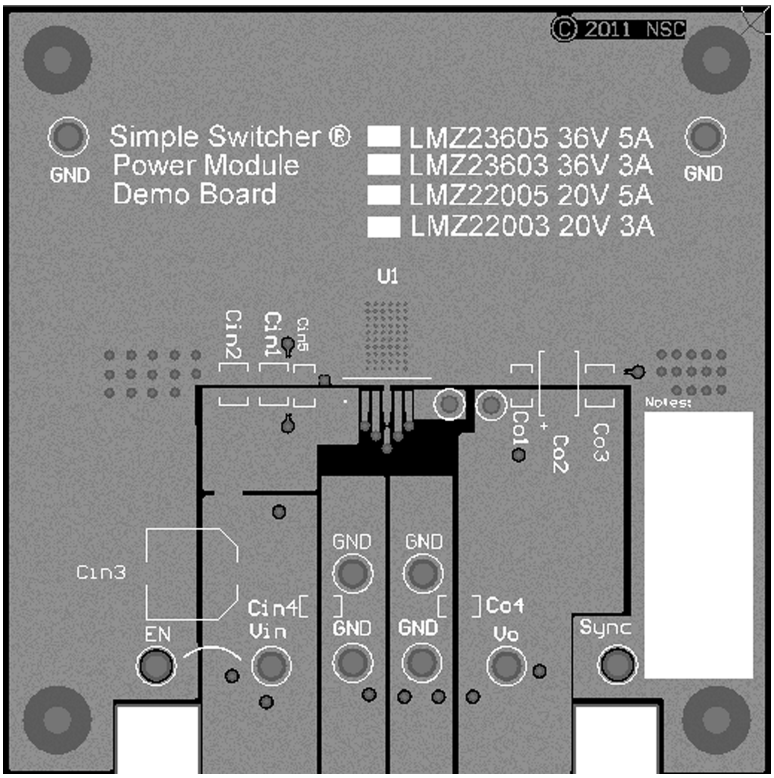


Figure 3. Top Layer

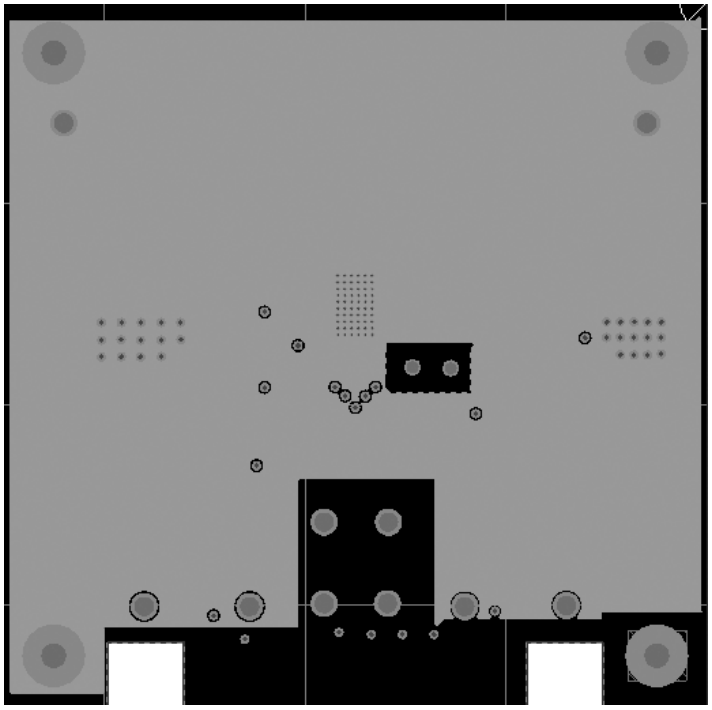


Figure 4. Internal Layer I (Ground)
Heat Sinking Layer

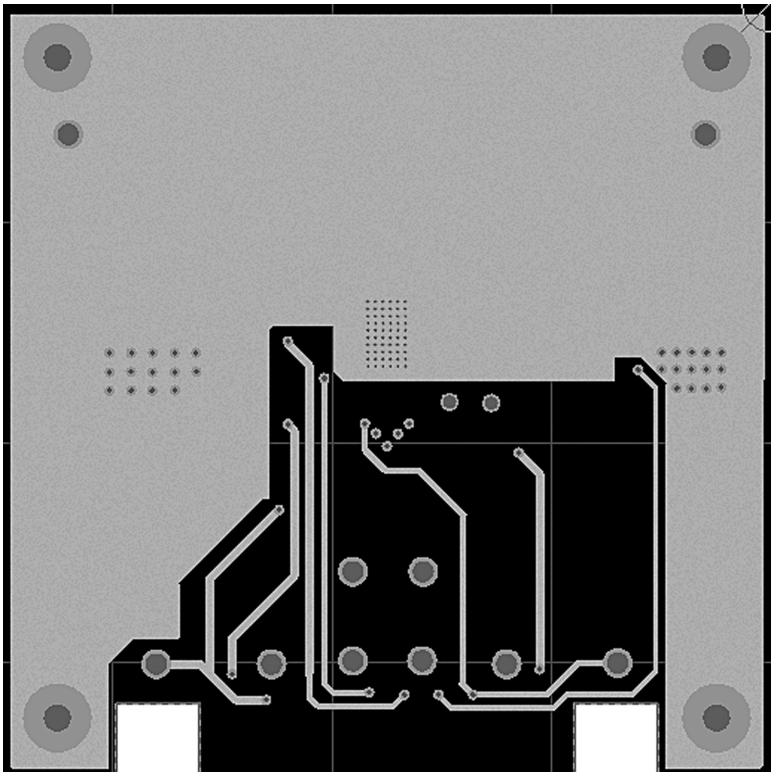


Figure 5. Internal Layer II (Ground and Routing)
Heat Sinking Layer

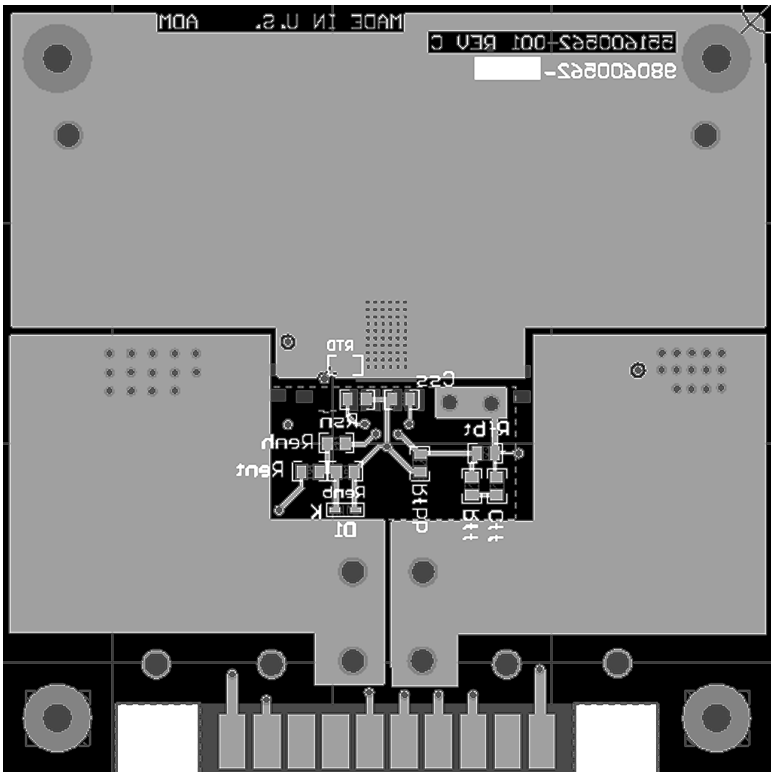
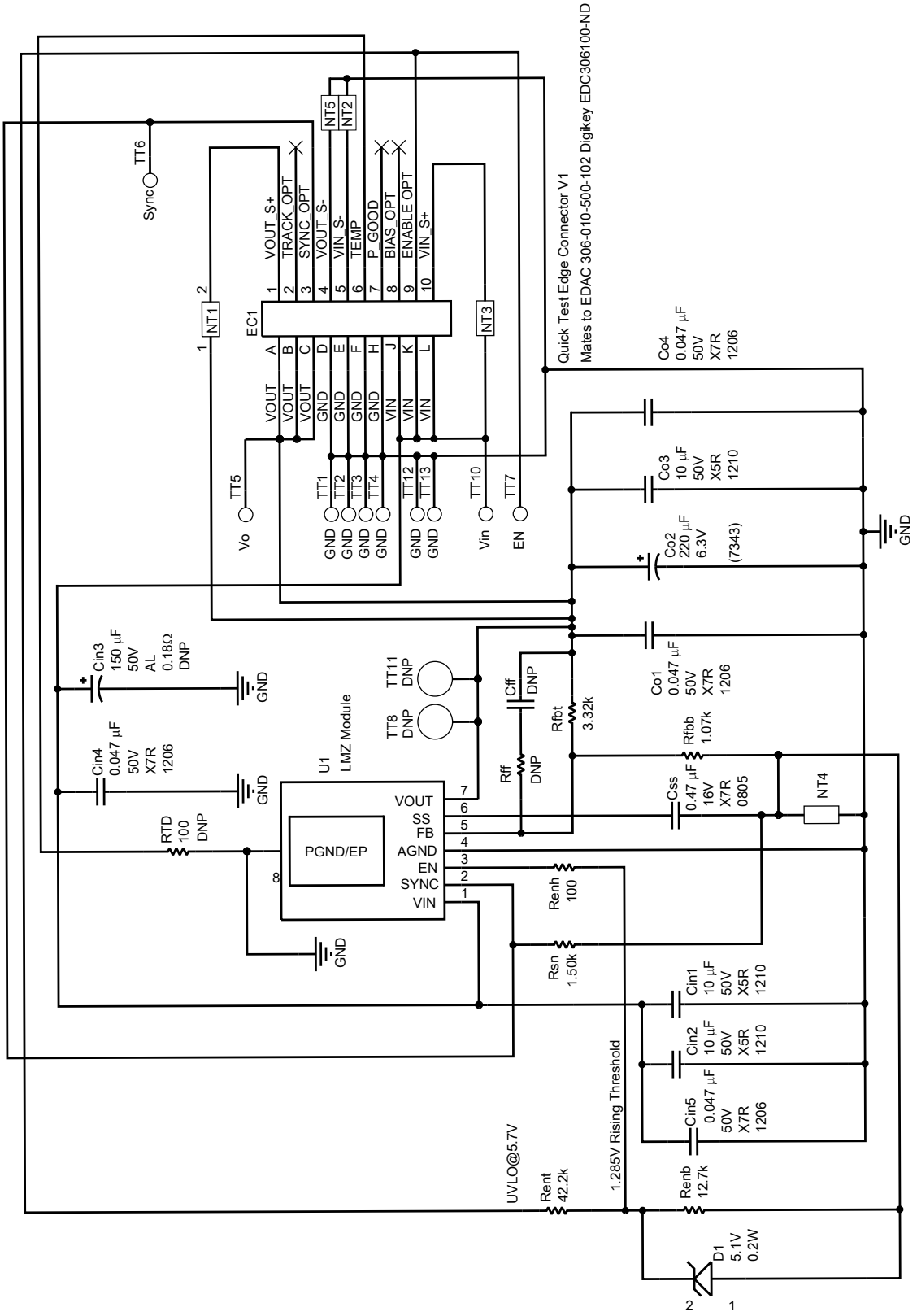


Figure 6. Bottom Layer (Ground)
Heat Sinking Layer

8 Schematic



DNP = Component not populated

Figure 7. LMZ23605/03, LMZ22005/03 PCB CAD package schematic

9 Bill of Materials

Table 1. Bill of Materials (V_{IN} = 6V to Vmax 36V (20V), V_{OUT} = 3.3V, $I_{OUT\ (MAX)}$ = 5A (3A))[(1)]

Designator	Description	Case Size	Manufacturer	Manufacturer P/N	Qty
U1	SIMPLE SWITCHER®	PFM-7	Texas Instruments	LMZ23605, LMZ23603, LMZ22005, LMZ22003	1
$C_{IN}4$, $C_{IN}5$, C_O1, C_O4,	0.047 µF, X7R, 50V	1206	Yageo America	CC1206KZX7R9BB473	4
$C_{IN}1$, $C_{IN}2$	10 µF, X5R, 50V	1210	Taiyo Yuden	UMK325BJ106MM-T	2
$C_{IN}3$ OPT	150 µF,Aluminum Electrolytic, 50V	G	Panasonic	EEE-FK1H151P	1
C_O3	10 µF, X5R, 50V	1210	TDK	UMK325BJ106MM-T	1
C_O2	220 µF, Specialty Polymer, 6.3V		Panasonic	EEF-UE0J221LR	1
C_{FF}	DNP				
C_{SS}	0.47µF, X7R, 16V	0805	AVX	0805YC474KAT2A	1
D1	5.1V 200mW	SOD-323	Diodes Inc.	MMSZ5231BS-7-F	1
R_{ENB}	12.7 kΩ	0805	Panasonic	ERJ-6ENF1272V	1
R_{ENT}	42.2 kΩ	0805	Panasonic	ERJ-6ENF4222V	1
R_{ENH}	100 Ω	0805	Vishay-Dale	CRCW0805100RFKEA	1
R_{FBT}	3.32 kΩ	0805	Vishay-Dale	CRCW08053K32FKEA	1
R_{FBB}	1.07 kΩ	0805	Vishay-Dale	CRCW08051K07FKEA	1
R_{FF}	DNP				
R_{SN}	1.50 kΩ	0805	Vishay-Dale	CRCW08051K50FKEA	1

(1) The same BOM applies to all implementations.

STANDARD TERMS FOR EVALUATION MODULES

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   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.

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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.

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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

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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.

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