

AN-2134 LMZ13610/8/6 and LMZ12010/8/6 Evaluation Board

1 Introduction

The LMZ13610/8/6 and LMZ12010/8/6 SIMPLE SWITCHER® power modules are easy-to-use DC-DC solution capable of driving up to a 10, 8 or 6 ampere load. They are available in an innovative package that enhances thermal performance and allows for hand or machine soldering. The LMZ13610/8/6 can accept an input voltage rail between 6V and 36V and the LMZ12010/8/6 can accept an input voltage rail between 6V and 20V.

The evaluation board is highly configurable. The output voltage can be adjusted to 5V, 3.3V, 2.5V or 1.2V with a jumper change. The external soft-start capacitor facilitates a controlled and adjustable startup rise time of the output. The board temperature can be measured with the onboard resistor and the UVLO can be adjusted by changing one resistor. In addition the board comes preconfigured with an LC input filter to pass CISPR-22 class B conducted and radiated emissions.

The LMZ13610 and LMZ12010 family is a reliable and robust solution with the following features: loss-less cycle-by-cycle valley current limit to protect for over current or short-circuit fault, thermal shutdown, input under-voltage lockout, and will start up into a pre-biased output.

2 Board Specifications

- V_{IN} = 6V to 36V (LMZ13610/8/6)
- V_{IN} = 6V to 20V (LMZ12010/8/6)
- V_{OUT} = 1.2V, 2.5V, 3.3V or 5V (minimum input voltage of 7V required for 5V output)
- I_{OUT} = 0 to 10, 8, or 6 Amps
- θ_{JA} = 9.9 °C / W, θ_{JC} = 1.0 °C/W
- Designed on four layers; Inner are 1 oz copper; Outer are 2 oz copper.
- Measures 2.95" x 3.54" (75 mm x 90 mm) and is 62 mils (1.57 mm) thick of FR4 laminate material

For additional circuit considerations, including additional output voltage options, see the *Applications* section of the *LMZ13610 10A SIMPLE SWITCHER® Power Module with 36V Maximum Input Voltage* ([SNVS709](#)) or *LMZ12010 10A SIMPLE SWITCHER® Power Module with 20V Maximum Input Voltage* ([SNVS667](#)) data sheets. For negative output voltage connections, see *AN-2027 Inverting Application for the LMZ14203 SIMPLE SWITCHER Power Module* ([SNVA425](#)) .

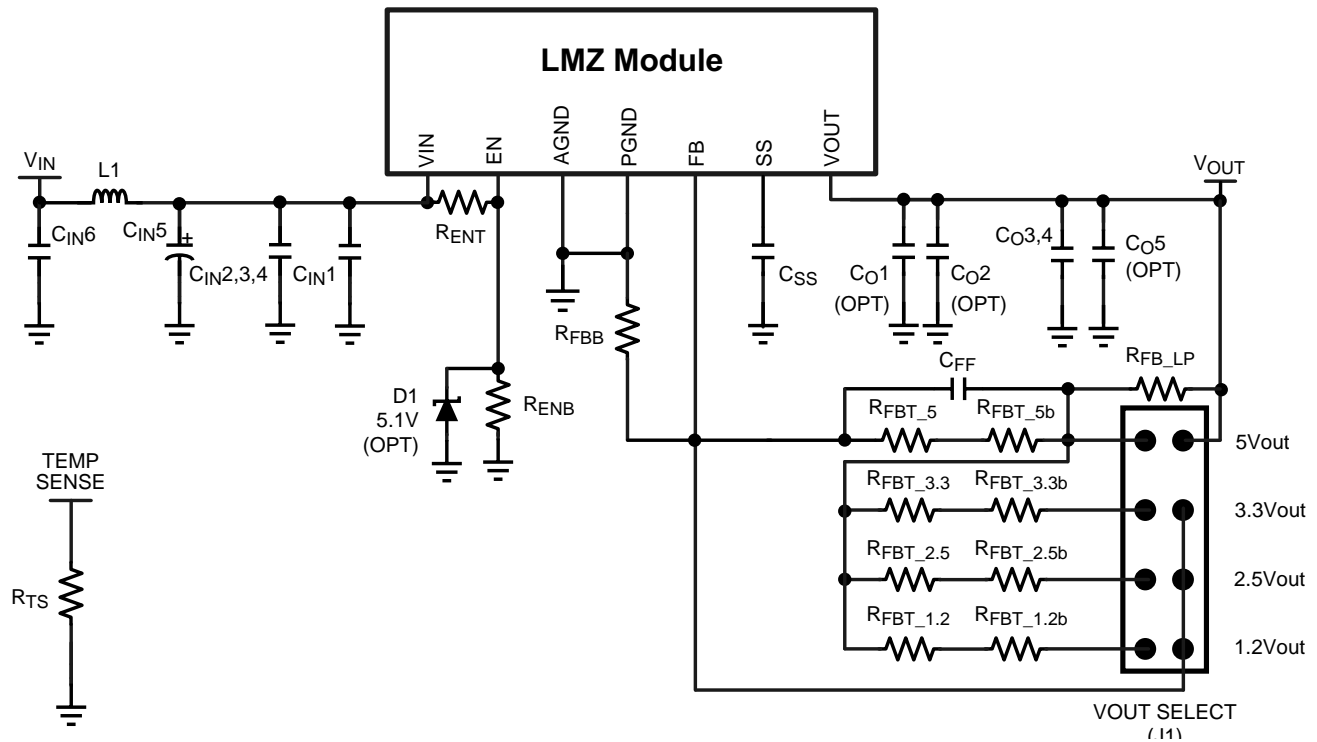


Figure 1. Simplified Schematic

3 Test Connections

The board should be connected to a power supply and load as shown below in [Figure 2](#). The EN post is connected to the UVLO circuit on the back of the board. There is a resistive divider implemented on the board that can be used to establish a precision UVLO level for the board that is currently set to 5.7V. A common user change to this circuit is to adjust the value of RENT and RENB to adjust the operating UVLO to that of the target application. for calculations, see the device-specific data sheet. Note that if in the end application the EN pin voltage does not exceed 5.5V at maximum V_{in} , then the enable clamp zener D1 can be omitted. (On revision A of the board the overlay for the zener diode has the cathode and anode incorrectly labeled). Pull EN low to shutdown the module.

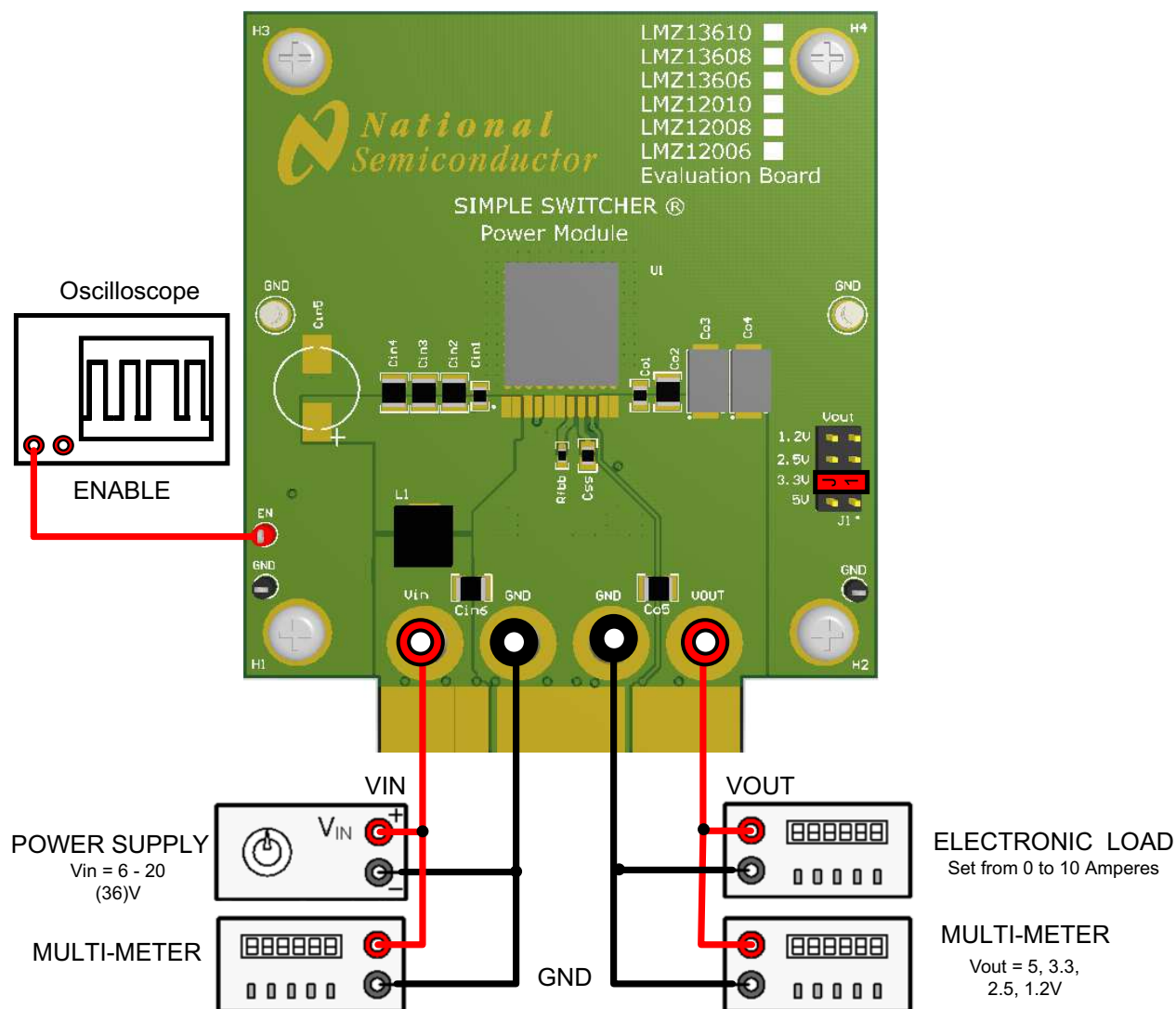
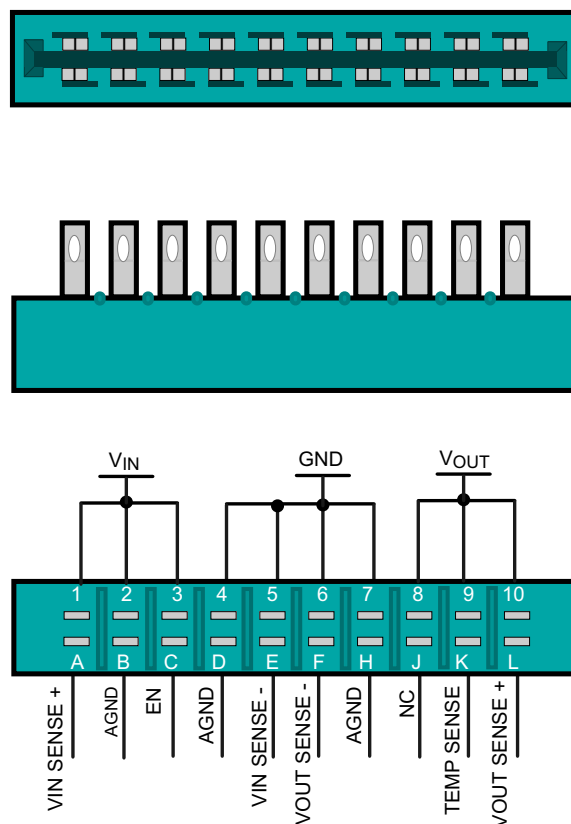


Figure 2. Board Connection Diagram


Figure 3. Edge Connector Diagram

The evaluation board is also compatible with the 20-pin edge connector shown in [Figure 3. Table 1](#) explains the functionality of the pins.

Table 1. Functionality of the Pins

Pin	Name	Description
1, 2, 3	VIN	Input supply — Nominal operating range is from 6V to 20V for the LMZ12010/8/6 and from 6V to 36V for the LMZ13610/8/6.
4, 5, 6, 7	GND	Power Ground — Electrical path for the power circuits within the module.
8, 9, 10	VOUT	Output Voltage — Regulated 5, 3.3, 2.5 or 1.2V.
A	VIN SENSE +	Positive Kelvin Sense of Input voltage — Tied to VIN pin of the LMZ module.
E	VIN SENSE -	Negative Kelvin Sense of Input voltage — Tied to PGND (EP) of the LMZ module.
L	VOUT SENSE +	Positive Kelvin Sense of Output voltage — Tied to Vout banana jack.
F	VOUT SENSE -	Negative Kelvin Sense of Output voltage — Tied to AGND of the LMZ module.
B, D, H	AGND	AGND Ground — Tied to AGND pin of module.
J	NC	No Connect — This pin must remain floating, do not ground.
C	EN	Enable — Input to the precision enable comparator of the LMZ Module.
K	TEMP SENSE	Connected to top of the R _{ts} temperature sensing resistor. Temperature measurements can be made by measuring the temperature dependant resistance between TEMP SENSE and VIN SENSE -. Convert the resistance to temperature with the following equation: Temperature (C) $\approx 2.6245 \times \text{Resistance } (\Omega) - 262.7$

4 Adjusting the Output Voltage

The output voltage of the evaluation board is adjusted to either 5V, 3.3V, 2.5V, or 1.2V by moving jumper J1. For other voltage options see the data sheet for adjusting the feedback resistors.

5 Optional Components

The evaluation board has many options for input and output filtering. C_{O1} , C_{O2} and C_{O5} have been installed to decrease high frequency noise on the output. Their removal will not effect other performance parameters of the design. Similarly, C_{IN1} has been installed to provide a high frequency bypass for the input current. The second order filter consisting of L1 and C_{IN6} has been designed to provide enough attenuation of the conducted noise to comply with EN 55022. This filtering is not required for normal operation of the module.

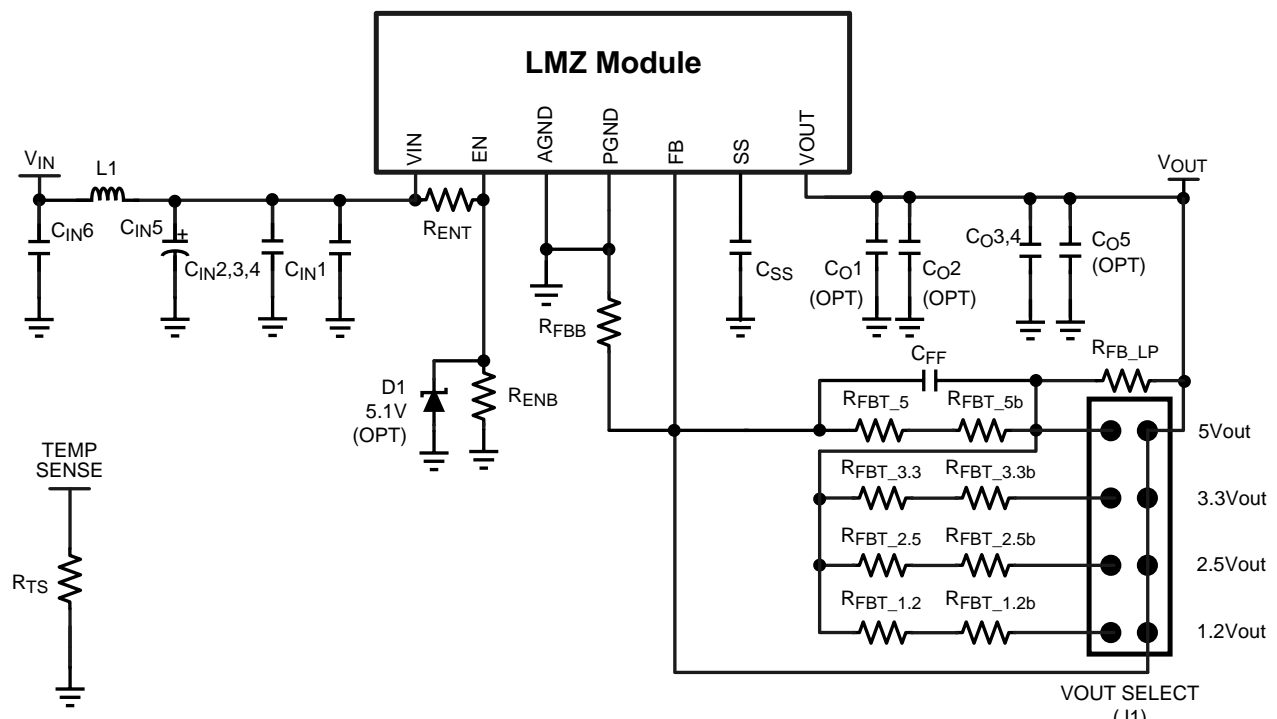


Figure 4. Evaluation Board Schematic

6 Bill of Materials

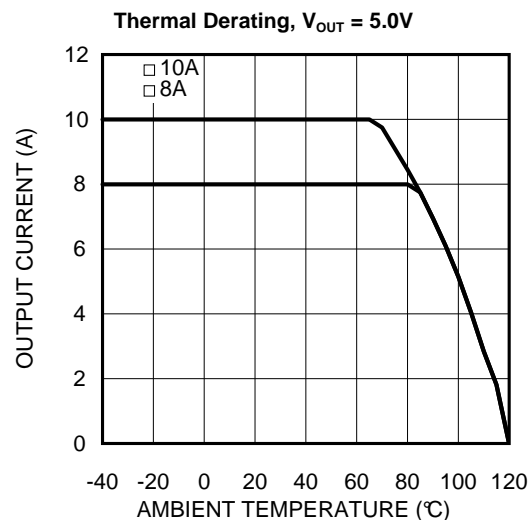
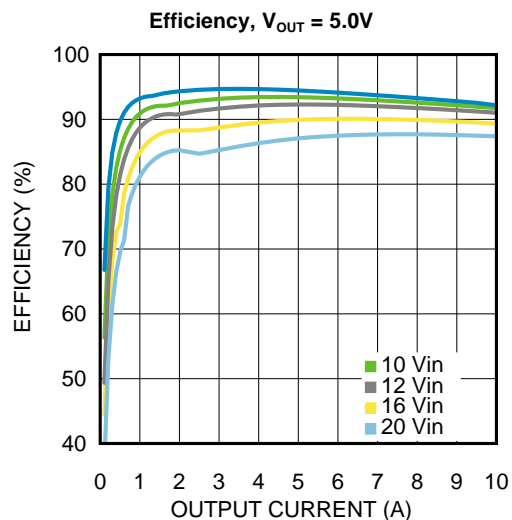
Table 2. Evaluation Board Bill of Materials, $V_{IN} = 6V$ to $36V$ (20V), $V_{OUT} = 1.2 / 3.3V / 5V$, $I_{OUT (MAX)} = 10/08/06A$

Designator	Description	Case Size	Manufacturer	Manufacturer P/N	Quantity
U1	SIMPLE SWITCHER	PFM-11	Texas Instruments	LMZ13610/LMZ13608/LMZ13606 or LMZ12010/LMZ12008/LMZ12006	1
Cin1 Co1 Co5	0.047uF, X7R, 50V	0805	Kemet	C0805C473K5RACTU	3
Cin2 Cin3 Cin4 Cin6	10 μ F, X7S, 50V	1210	TDK	C3225X7S1H106M	4
Cin5	150 μ F, Aluminum Electrolytic, 50V	G	Panasonic	EEE-FK1H151P	1
Co2	47uF, X5R, 10V	1210	Murata	GRM32ER61A476KE20L	1
Co3 Co4	330 μ F, 6.3V, 0.015 ohm,	2917	Kemet	T520D337M006ATE015	2
Cff	4700 pF, X7R, 50V	0805	Kemet	C0805C472K5RACTU	1
Css	0.15uF, X7R, 10V	0603	Murata	GRM188R71A154KA01D	2
L1	Shielded Drum Core, Powdered Iron, 3.3uH, 12A, 0.011 ohm		Würth	744314330	1
L1_alternate *used in conducted EMI measurement	Shielded Drum Core, 3.3uH, 0.011 ohm		Toko	892NAS-3R3M	
D1	4.7V, 500mW	SOD-123	Vishay	MMSZ4688-V-GS08	1
Rent	4.12k ohm, 1%, 0.125W	0805	Vishay-Dale	CRCW08054K12FKEA	1
Renb	1.27k ohm, 1%, 0.125W	0805	Vishay-Dale	CRCW08051K27FKEA	1
Rfbb	1.07k ohm, 1%, 0.125W	0805	Vishay-Dale	CRCW08051K07FKEA	1
Rfbt_1.2	576 ohm, 1%, 0.125W	0805	Vishay-Dale	CRCW0805576RFKEA	1
Rfbt_1.2b	9.53 ohm, 1%, 0.125W	0805	Vishay-Dale	CRCW08059R53FKEA	1
Rfbt_2.5	3.74k ohm, 1%, 0.125W	0805	Vishay-Dale	CRCW08053K74FKEA	1
Rfbt_2.5b	84.5 ohm, 1%, 0.125W	0805	Vishay-Dale	CRCW080584R5FKEA	1
Rfbt_3.3	8.06k ohm, 1%, 0.125W	0805	Vishay-Dale	CRCW08058K06FKEA	1
Rfbt_3.3b	169 ohm, 1%, 0.125W	0805	Vishay-Dale	CRCW0805169RFKEA	1
Rfbt_5	5.6k ohm, 1%, 0.125W	0805	Vishay-Dale	CRCW08055K60FKEA	1
Rfbt_5b	73.2 ohm, 1%, 0.125W	0805	Vishay-Dale	CRCW080573R2FKEA	1
RFB_LP	20 Ω	0805	Vishay-Dale	CRCW080520R0FKEA	1
Rts	100 ohm, Temp Sense Resistor	0805	Vishay	PTS08051B100RP 100	1
EN	Test Point, TH, Miniature, Red		Keystone Electronics	5000	1
GND GND	Test Point, TH, Miniature, Black		Keystone Electronics	5001	2
GND GND VIN VOUT	Banana Jack Connector		Keystone Electronics	575-8	4
SH-1	Shunt, 100mil, Gold plated, Black		Amp	382811-6	1

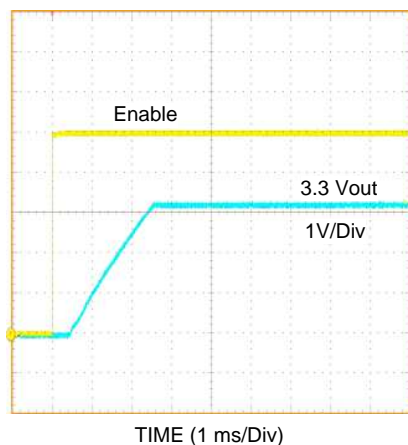
Table 2. Evaluation Board Bill of Materials, $V_{IN} = 6V$ to $36V$ (20V), $V_{OUT} = 1.2 / 3.3V / 5V$, $I_{OUT (MAX)} = 10/08/06A$ (continued)

Designator	Description	Case Size	Manufacturer	Manufacturer P/N	Quantity
H1 H2 H3 H4	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead		B and F Fastener Supply	NY PMS 440 0025 PH	4
H5 H6 H7 H8	Standoff, Hex, 0.5"L #4-40 Nylon		Keystone	1902C	4
J1	Header, 4x2, Gold plated, 230 mil above insulator	TH, 100mil	Samtec Inc.	TSW-104-07-G-D	1
J2	20-Pin Dual Edge Connector, 0.156" pitch		EDAC	305-020-500-202	0

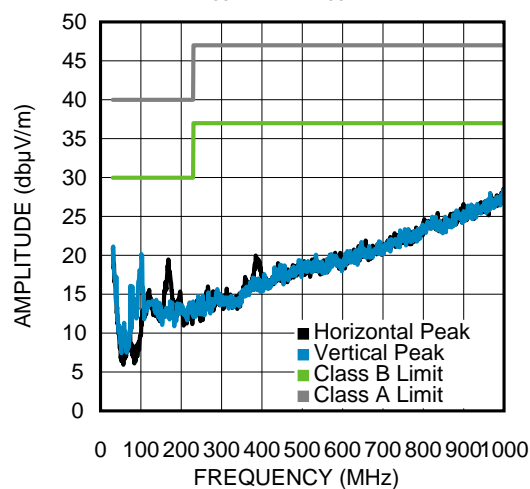
7 Performance Characteristics



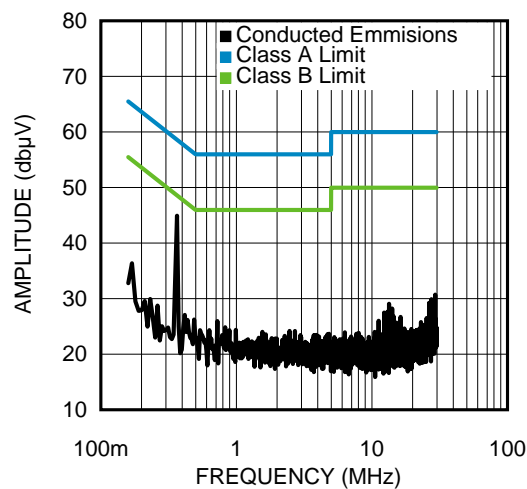
Startup, $V_{IN} = 12V$, $V_{OUT} = 3.3V$



Radiated EMI (EN 55022)
 $V_{IN} = 12V$, $V_{OUT} = 5.0V$, $I_{OUT} = 10A$



Conducted EMI (EN 55022) *L1_alternate
 $V_{IN} = 12V$, $V_{OUT} = 5.0V$, $I_{OUT} = 10A$



8 PCB Layout Diagrams

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

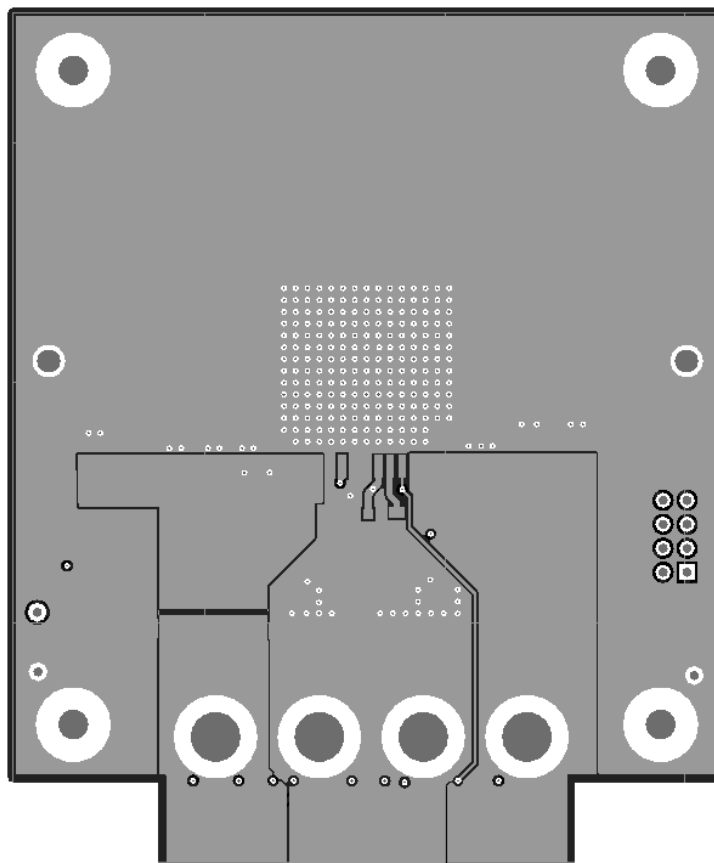
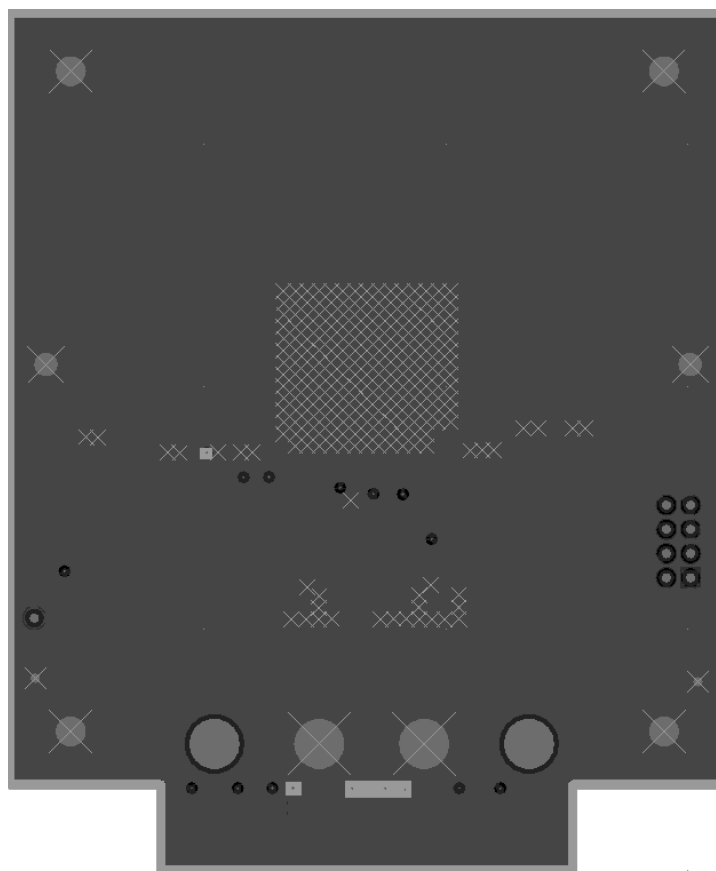
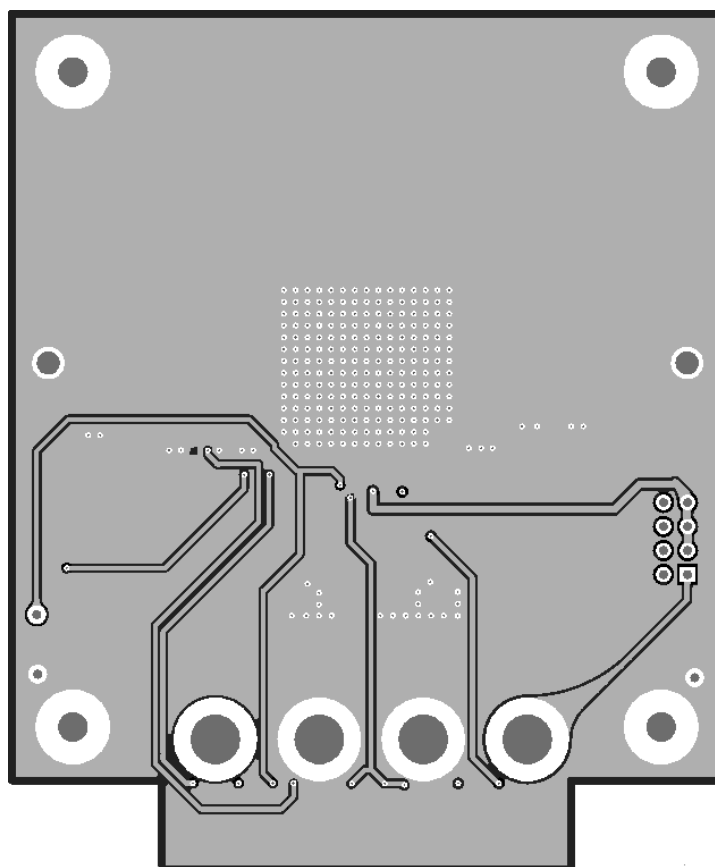


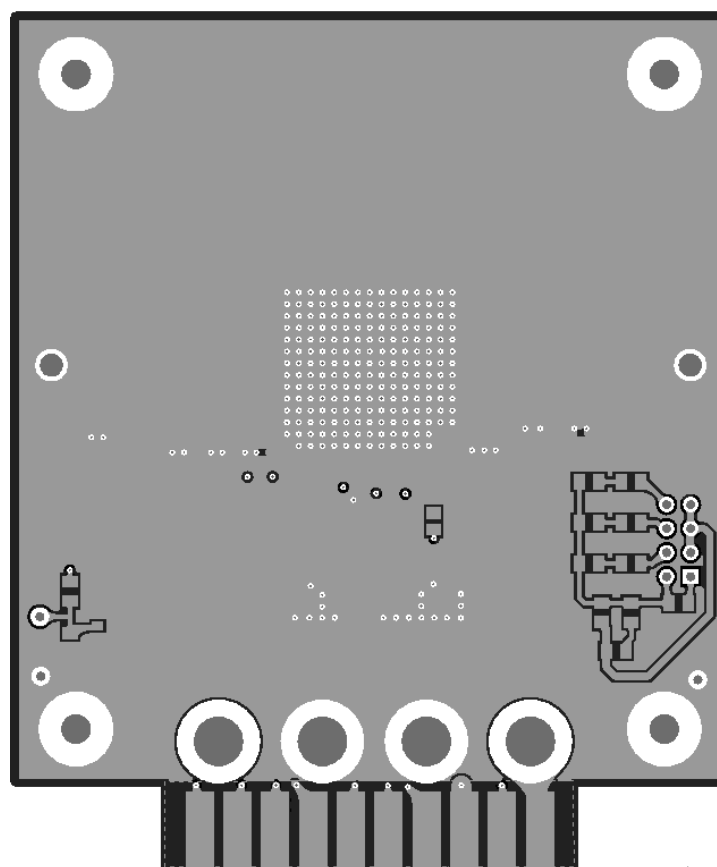
Figure 5. Top Layer



**Figure 6. Internal Layer I (Ground)
Heat Sinking Layer**



**Figure 7. Internal Layer II (Routing)
Heat Sinking Layer**



**Figure 8. Bottom Layer (Ground and Routing)
Heat Sinking Layer**

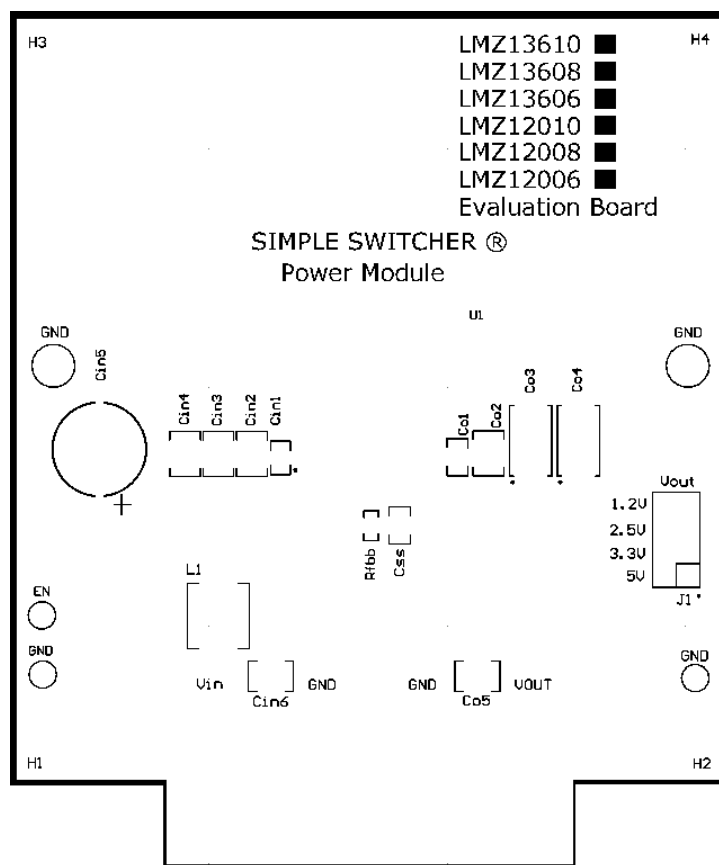


Figure 9. Top Silkscreen

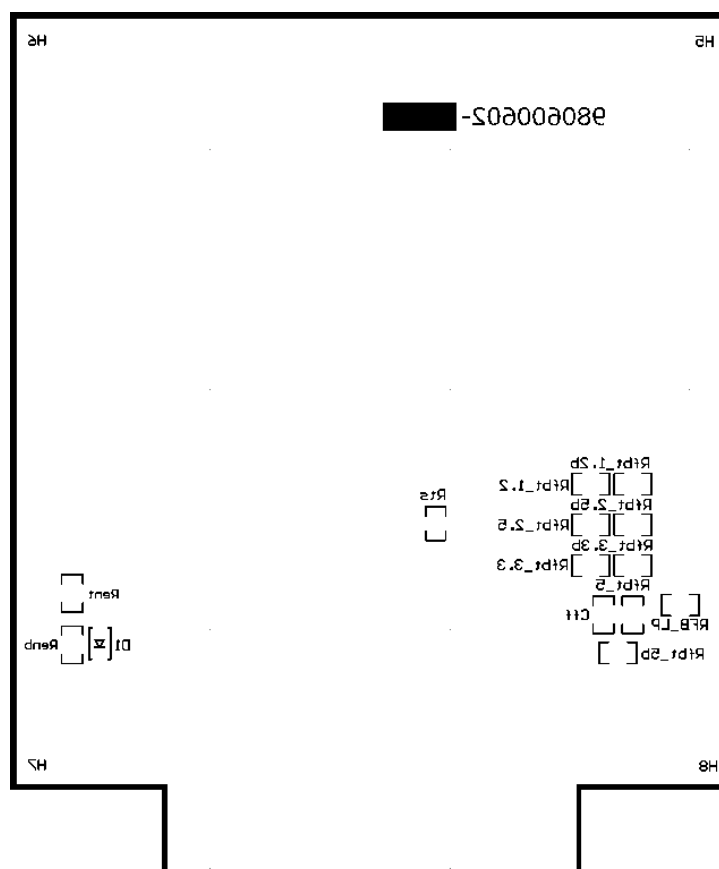


Figure 10. Bottom Silkscreen

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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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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 DEGRADATION 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/sds/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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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.

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