EVM User's Guide: LM65645EVM

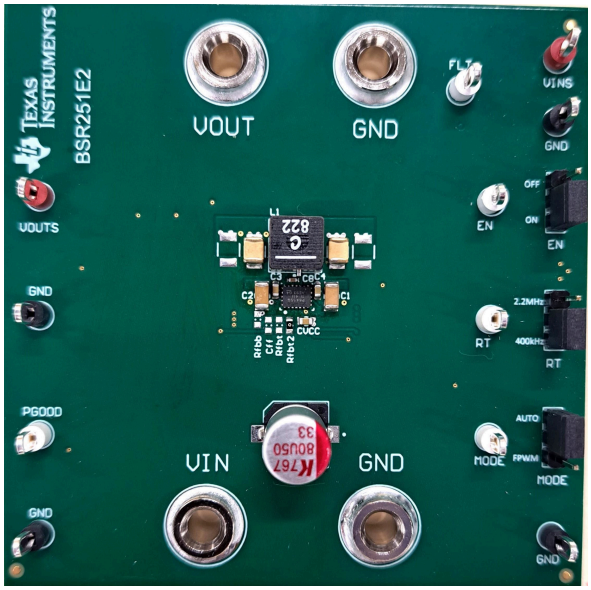
LM65645EVM Evaluation Module

Description

The Texas Instruments LM65645EVM evaluation module (EVM) helps designers evaluate the operation and performance of the LM65645 family of wide input voltage buck converters. The LM65645 family are easy to use, synchronous, step-down converters capable of supplying up to 2.5A, 3.5A, or 4.5A of load current from an input voltage as high as 65V.

Features

- 3V to 65V wide input voltage range
- 5V, 3.3V, and adjustable output voltage options
- Up to 4.5A output current
- 300kHz to 2.2MHz switching frequency
- Minimized switch node ringing to reduce Electromagnetic Interference (EMI)
- Input transient capability up to 70V



LM65645EVM

1 Evaluation Module Overview

1.1 Introduction

The LM65645EVM is configured to deliver a 5V output to a load requiring 4.5A or less. The LM65645EVM can be used in many different configurations by substituting other versions of the LM656x5 and re-configuring the board components. See Section 1.4 for more details.

1.2 Kit Contents

This kit includes one LM65645EVM.

1.3 Specification

Performance characteristics for the LM65645EVM are found in Table 1-1

Unless otherwise stated: V_{IN} = 24V, V_{OUT} = 5V, T_A = 25ºC.

Table 1-1. LM65645EVM Electrical Performance Characteristics

Parameter	Test Conditions		MIN	TYP	MAX	UNITS
INPUT CHARACTERISTICS						
Input voltage range, V_{VIN}	EVM input voltage operating range		6	24	63	V
Input current, no load, $I_{IN(NL)}$	I_{OUT} = 0A	AUTO mode		5.5		µA
Input current, disabled, $I_{IN(OFF)}$	$V_{EN/UVLO}$ = 0V, no EN divider	V_{IN} = 24V		0.9		µA
OUTPUT CHARACTERISTICS						
Output voltage, V_O	I_{OUT} = 0A, AUTO mode			5.027		V
	I_{OUT} = 4.5A			5.003		V
Output voltage regulation, ΔV_{OUT}	Load regulation, AUTO mode	I_{OUT} = 0A to 4.5A		24		mV
Output voltage regulation, ΔV_{OUT}	Load regulation, FPWM mode	I_{OUT} = 0A to 4.5A		1		
Output voltage regulation, ΔV_{OUT}	Line regulation, V_{IN} = 12V to 48V	I_{OUT} = 4.5A		1		
Maximum output current	V_{IN} = 24V			5.8		A
SYSTEM CHARACTERISTICS						
Switching frequency	I_{OUT1} = 4.5A			400		kHz
Peak efficiency	I_{OUT} = 1.5A	V_{IN} = 24V		93%		
Full load efficiency	I_{OUT} = 4.5A	V_{IN} = 24V		89%		

1.4 Device Information

The default EVM incorporates the LM65645. Table 1-2 provides a list of additional devices that can be used with the LM65645EVM. Appropriate passive component changes must be made to use another device in the EVM.

Table 1-2. LM65645EVM Device Options

Device OPN	Output Current	Q-Grade ?
LM65635SRZTRQ1	3.5A	Y
LM65625SRZTRQ1	2.5A	Y
LM65635SRZTR	3.5A	N
LM65625SRZTR	2.5A	N

2 Hardware

2.1 Additional Images

Figure 2-1 and Figure 2-2 show the front and back of the LM65645EVM respectively.

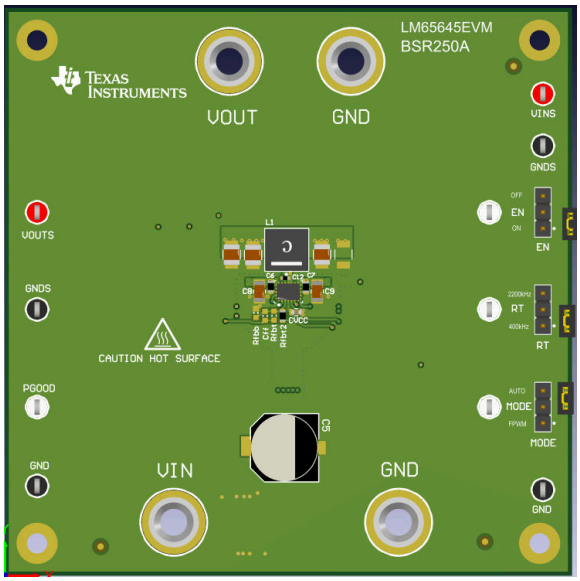


Figure 2-1. LM65645EVM Top Side

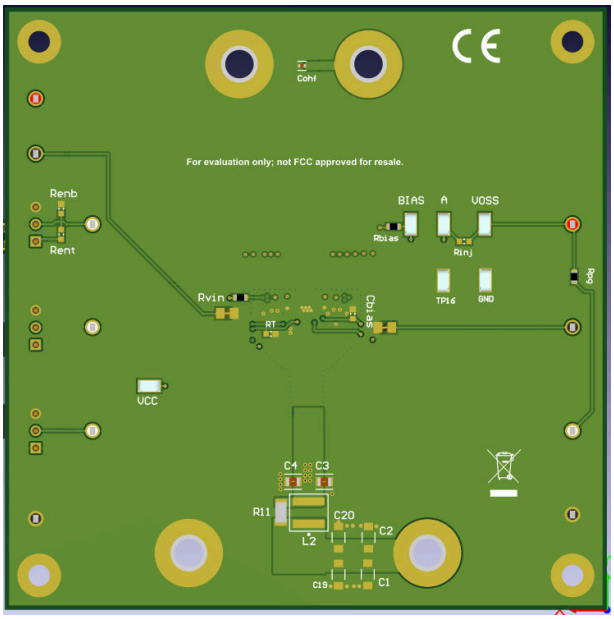


Figure 2-2. LM65645EVM Bottom Side

2.2 Power Requirements

Any power source in the range of 6V to 63V, and capable of delivering 3A, can be used to evaluate the LM65645EVM, under normal conditions.

2.3 Setup and Operation

This section describes the connectors, test points, and jumpers on the EVM and how to properly connect, set up, and use the LM65645EVM See Figure 2-3 for location of connectors and jumpers and typical setup.

VOUT	Output voltage of the converter. VOUT banana post. Apply load to this connector.
VOUTS	The VOUTS test point is used to monitor output voltage.
GNDS	Test point next to VOUTS test point This GNDS test point is used as the negative DMM connection for VOUT sensing.
VIN	Input voltage to the converter. VIN banana post. Apply input voltage to this connector.
VINS	The VINS test point is used to monitor input voltage.
GNDS	Test point next to VINS test point This GNDS test point is used as the negative DMM connection for VIN sensing.
GND	Ground of the converter GND banana posts. Apply load ground and input voltage ground to these connectors.
EN	The use of the EN jumper is self-explanatory. To supply an external signal to the EN input of the device, remove the EN jumper shunt and apply the signal to the EN test point. To use the external UVLO feature, populate Rent (R3) and Renb (R4) as desired and remove the EN jumper shunt. Note that for accurate shutdown current measurement, these resistors must be removed (if used) and the EN jumper shunt moved to "OFF".
RT	The RT jumper is used to select the switching frequency and is self explanatory. The default inductor on the EVM is designed for 400kHz operation. Other frequencies require a different value of inductance. To adjust the switching frequency, remove the RT jumper shunt and populate RT (R5) with the desired value. See the LM656x5 data sheet for frequency vs. RT resistor value.
MODE	MODE jumper is used to select the operating mode of the device. With MODE in the AUTO position, the device operates in automatic PFM/FPWM mode depending on load current. With the MODE in the FPWM position, the device operates at fixed frequency at all load currents. The MODE pin is also the frequency synchronization input. To synchronize the device to an external clock, remove the MODE jumper shunt and apply the clock to the MODE test point.
Feed-back Connections	The EVM is set for a fixed 5V output, with Rfbt2 (R6), 0Ω, populated. To set the output voltage to 3.3V, remove Rfbt2 (R6) and populate Rfbb (R9) with a 0Ω resistor. To use the adjustable output voltage mode, populate Rfbt (R8) and Rfbb (R9) with the appropriate value resistors. Rinj (R7) must also be populated with a 10Ω to 50Ω resistor. The reference voltage is 0.8V. See the LM656x5 data sheet for appropriate values of feed-back resistors. When using the adjustable output voltage mode, a Bode plot can be taken using the Rinj (R7) resistor. This resistor becomes the injection point for the frequency response analyzer, allowing the loop frequency response to be taken in the usual way. In the fixed output voltage mode, a loop response can not be taken.
PGOOD	The PGOOD test point is used to monitor the power-good indicator. This flag indicates whether the output voltage has reached the regulation level. PGOOD is an open-drain output that is tied to VOUT through a 100kΩ, resistor Rpg (R1).
VCC	VCC test point The VCC pin is the output of the internal LDO. The LDO voltage is typically 3.3V. This point can be used for logic input and/or logic pull-ups. Do not connect to external loads.
BIAS	Auxiliary input to LDO regulator

Connected to VOUT through Rbias (R10) on EVM. To change the input supply of the LDO, remove Rbias (R10) and connect external input to BIAS pin, or ground BIAS pin as required. Populate Cbias (C11) with a 0.1µF capacitor when using external supply to BIAS pin. See LM656x5 data sheet for more information.

Loop Response Plot When using the adjustable output voltage mode, a Bode plot can be taken using the connection shown in Figure 2-4. Rinj (R7) must be populated for this test.

EMI Filter The EMI filter is not populated on this EVM. To evaluate the EMI filter, components L2, C1-C2, C19-C20 must be populated, while R11 must be removed. Typical values for these components are given in Table 4-1.

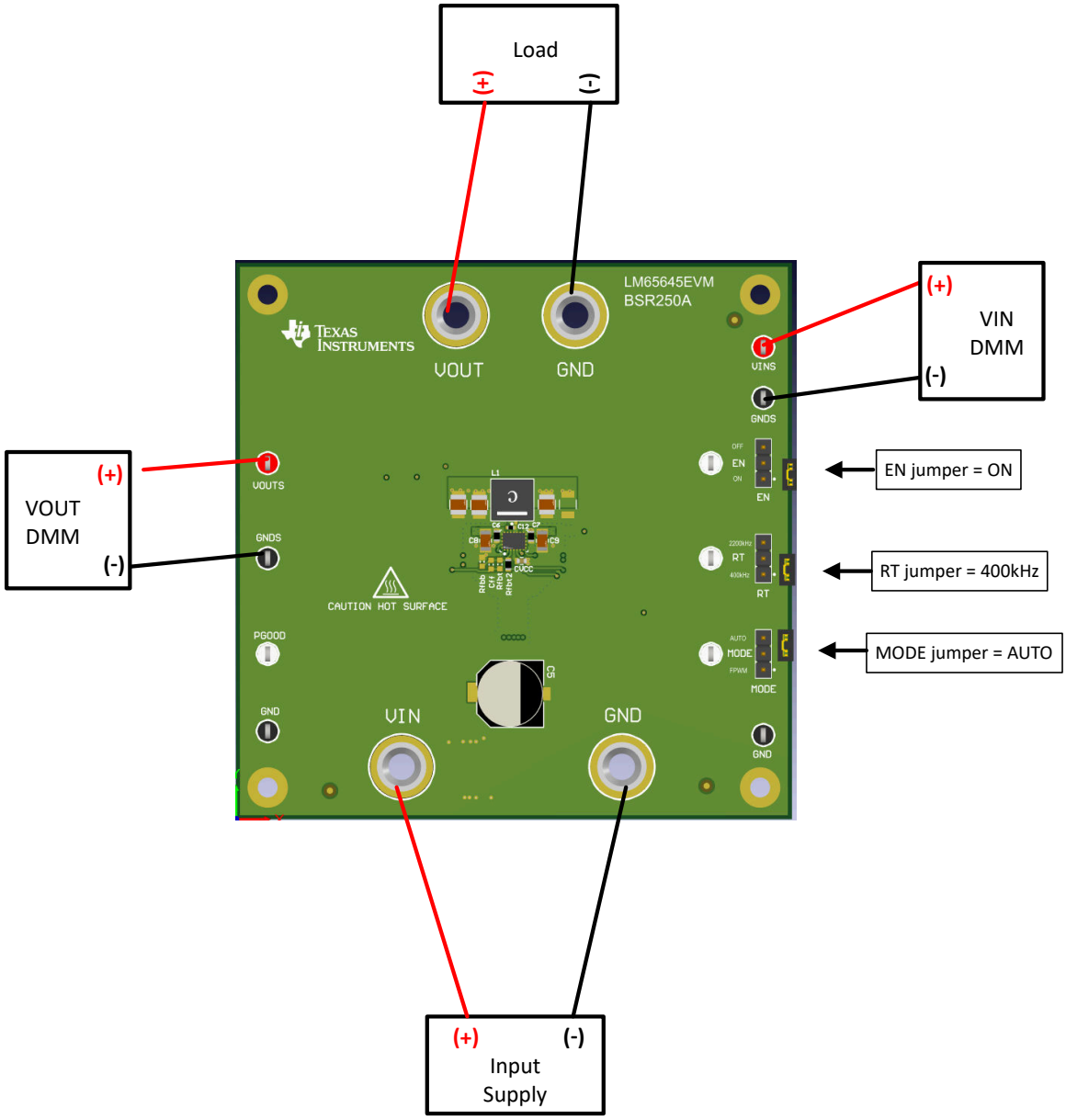


Figure 2-3. LM65645EVM Setup

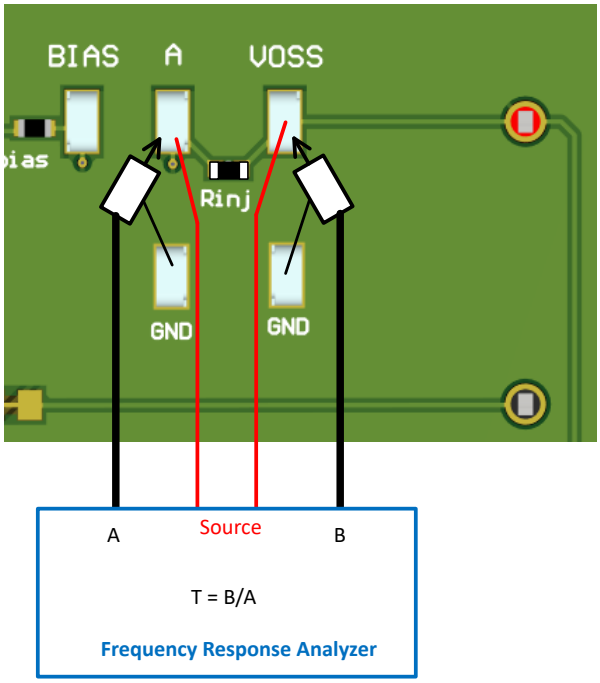


Figure 2-4. LM65645EVM Loop Response Connections

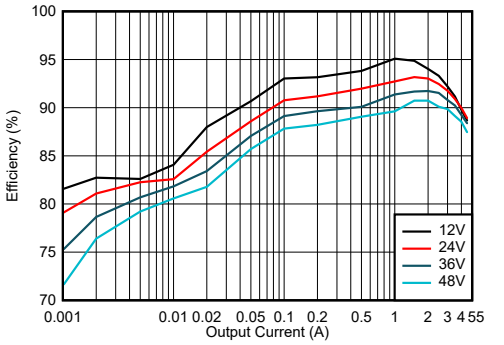
3 Implementation Results

3.1 Evaluation Setup

The LM65645VM was used to take the following data with the setup shown in Figure 2-3.

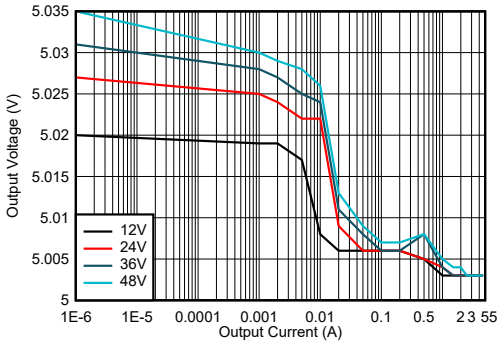
3.2 Performance Data and Results

Unless otherwise specified the following condition apply: T_A = 25ºC, V_{IN} = 24V, 400kHz.



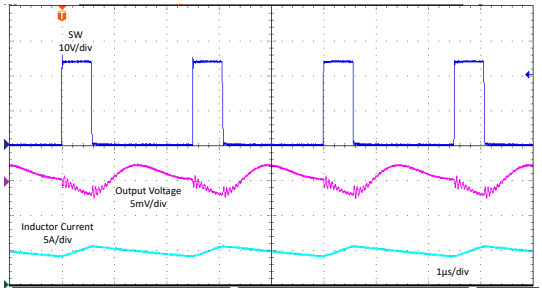
V_{OUT} = 5V 400kHz, Auto Mode

Figure 3-1. Efficiency



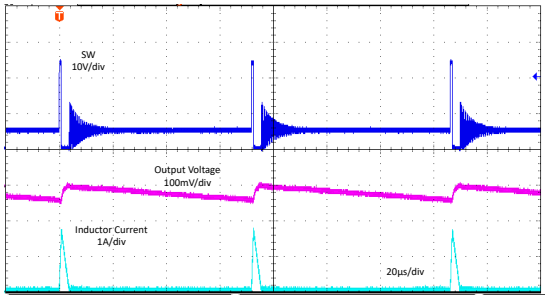
V_{OUT} = 5V 400kHz, Auto Mode

Figure 3-2. Line and Load Regulation



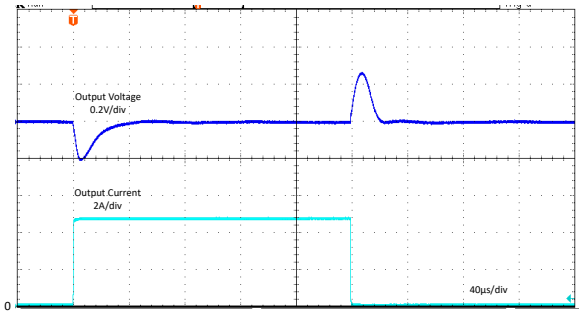
I_{OUT} = 4.5A V_{IN} = 24V V_{OUT} = 5V

Figure 3-3. Typical Switching Waveform in PWM



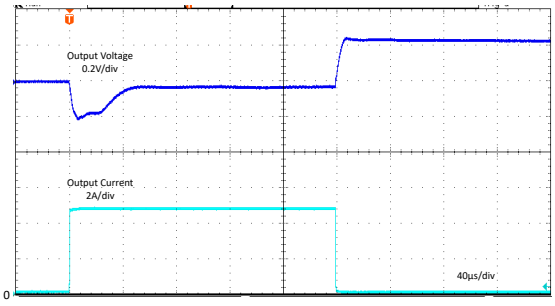
I_{OUT} = 40mA V_{IN} = 24V V_{OUT} = 5V

Figure 3-4. Typical Switching Waveform in PFM



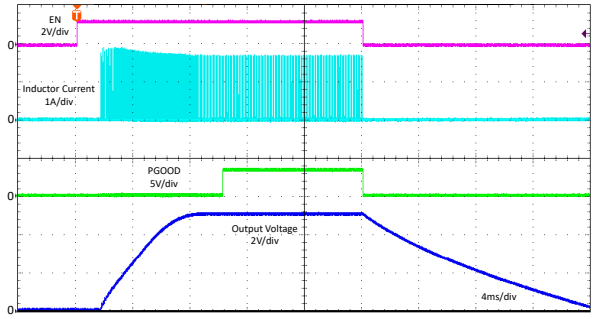
I_{OUT} = 0A to 4.5A (1µs) V_{IN} = 24V FPWM Mode V_{OUT} = 5V

Figure 3-5. Load Transient (FPWM)



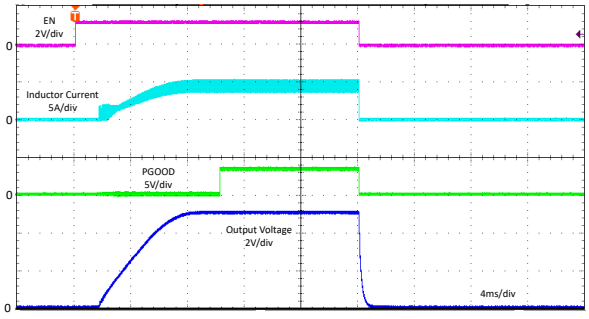
I_{OUT} = 0A to 4.5A (1µs) V_{IN} = 24V Auto Mode V_{OUT} = 5V

Figure 3-6. Load Transient (AUTO)



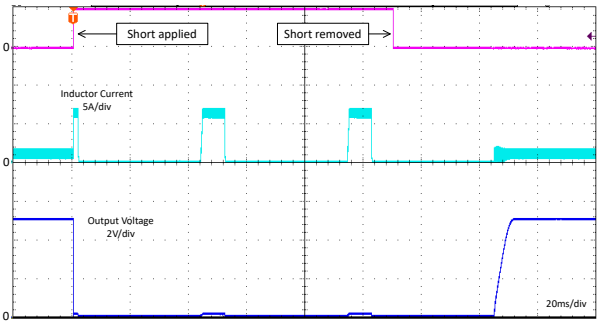
I_{OUT} = 40mA V_{IN} = 24V Auto Mode V_{OUT} = 5V

Figure 3-7. Start-Up



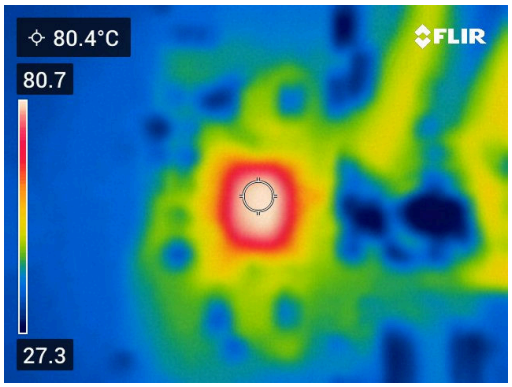
I_{OUT} = 4.5A V_{IN} = 24V Auto Mode V_{OUT} = 5V

Figure 3-8. Start-Up



I_{OUT} = 1A V_{IN} = 24V V_{OUT} = 5V

Figure 3-9. Short Circuit



I_{OUT} = 4.5A 400kHz V_{IN} = 24V V_{OUT} = 5V
LM65645EVM

Figure 3-10. Thermal Image

4 Hardware Design Files

4.1 Schematics

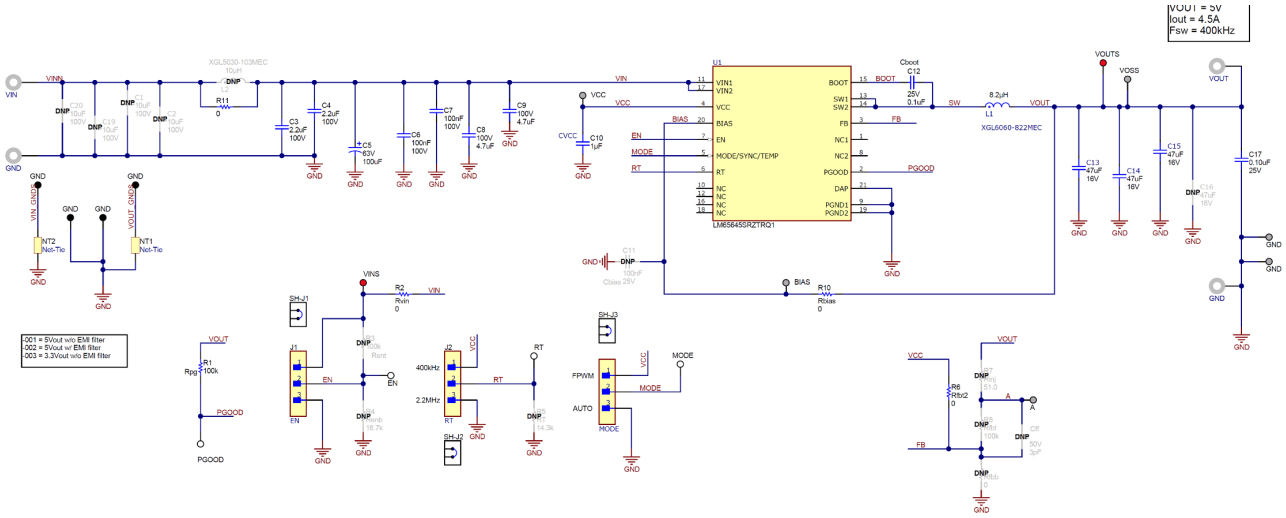


Figure 4-1. LM65645EVM Schematic

4.2 PCB Layouts

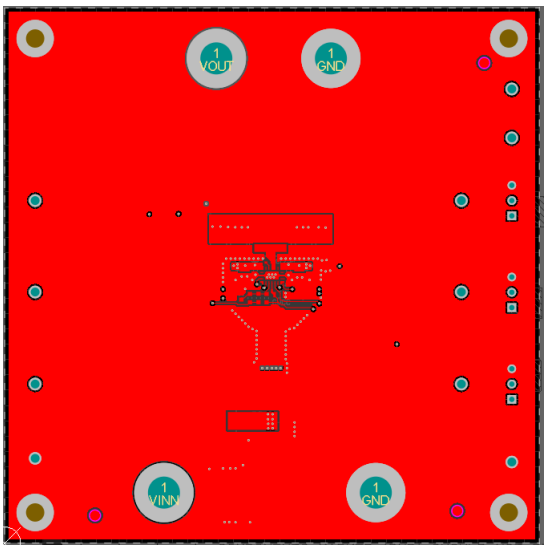


Figure 4-2. PCB Top Layer

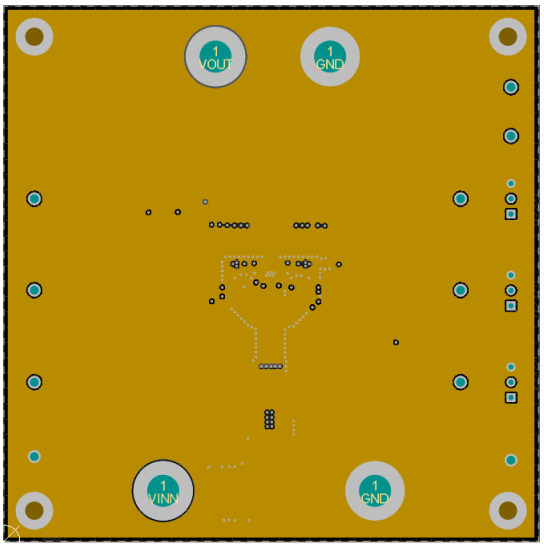


Figure 4-3. PCB Ground Layer (Directly Below Top Layer)

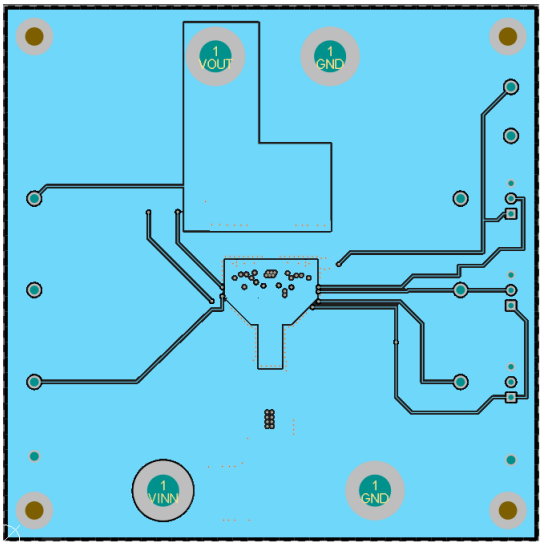


Figure 4-4. PCB Signal Layer

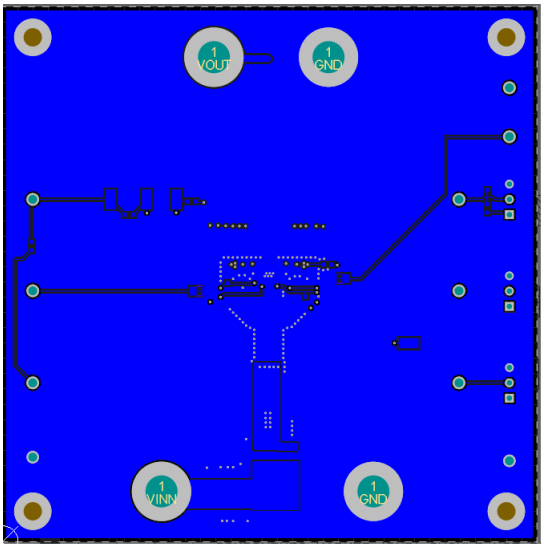


Figure 4-5. PCB Bottom Layer

4.3 Bill of Materials (BOM)

Table 4-1. LM65645EVM BOM (With Options)

Designator	Alias	Quantity	Value	Description	Part Number
C3, C4		2	2.2µF	Chip Multilayer Ceramic Capacitor for General Purpose 2.2uF ±20% 100V X7T SMD 0805	GRM21BD72A225ME01K
C5		1	100uF	CAP, AL, 100uF, 63V, +/– 20%, 0.35 ohm, AEC-Q200 Grade 2, SMD	EEE-FK1J101P
C6, C7		2	0.1uF	CAP, CERM, 0.1µF, 100V,+/– 10%, X7R, AEC-Q200 Grade 1, 0603	HMK107B7104KAHT
C8, C9		2	4.7µF	4.7µF ±10% 100V Ceramic Capacitor X7S 1206 (3216 Metric)	GRM31CC72A475KE11L
C10	CVCC	1	1µF	Cap Ceramic 1uF 16V X7R 20% Pad SMD 0603 +125°C Automotive T/R	CGA3E1X7R1C105M080AC
C12	Cboot	1	0.1uF	CAP, CERM, 0.1uF, 25V, +/– 20%, X7R, 0402	C1005X7R1E104M050BB
C13, C14, C15		3	47µF	Chip Multilayer Ceramic Capacitors for General Purpose, 1210, 47uF, X6S, 22%, 10%, 16V	GRM32EC81C476KE15K
C17		1	100nF	Chip Multilayer Ceramic Capacitors for General Purpose, 0402, 0.10uF, X7R, 15%, 10%, 25V	GRM155R71E104KE14J
L1		1	8.2uH	8.2µH Shielded Inductor 10.1A 16.8mOhm Max Nonstandard	XGL6060-822MEC
R1	Rpg	1	100k	RES, 100k, 1%, 0.1W, 0603	RC0603FR-07100KL
R2, R6, R10	R10 = Rbias	1	0	RES, 0, 1%, 0.1W, AEC-Q200 Grade 0, 0603	RMCF0603ZT0R00
	R6 = Rfb2	1			
	R2 = Rvin	1			
R11		1	0	RES, 0, 1%, 0.5W, 1206	5108
U1		1		Synchronous Step-Down Voltage Regulator, WQFN-FCRLF20	LM65645SRZTRQ1
C1, C2, C19, C20		0	10µF	10µF ±10% 100V Ceramic Capacitor X6S 1206 (3216 Metric)	C3216X6S2A106K160AC
C11	Cbias	0	0.1uF	CAP, CERM, 0.1uF, 25V, +/– 10%, X7R, 0603	06033C104KAT2A
C16		0	47µF	Chip Multilayer Ceramic Capacitors for General Purpose, 1210, 47uF, X6S, 22%, 10%, 16V	GRM32EC81C476KE15K
C18	Cff	0	3pF	CAP, CERM, 3pF, 50V, +/– 8.3%, C0G/NP0, 0603	C0603C309C5GACTU
L2		0	10uH	10µH Shielded Molded Inductor 5.7A 48.4mOhm Max Nonstandard	XGL5030-103MEC
R3, R8	R3 = Rent	0	100k	RES, 100k, 1%, 0.1W, 0603	RC0603FR-07100KL
	R8 = Rfbt				
R4	Renb	0	18.7k	RES, 18.7k, 1%, 0.1W, 0603	RC0603FR-0718K7L
R5	RT	0	14.3k	RES, 14.3k, 1%, 0.1W, 0603	RC0603FR-0714K3L
R7	Rinj	0	51.0	RES, 51.0, 1%, 0.1W, 0603	RC0603FR-0751RL
R9	Rfbb	0	0	RES, 0, 1%, 0.1W, AEC-Q200 Grade 0, 0603	RMCF0603ZT0R00

5 Additional Information

5.1 Trademarks

All trademarks are the property of their respective owners.

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.

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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

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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