120 V_{AC} Valley Fill Buck Triac Dimmable LED Driver

This user's guide describes the characteristics, use, performance data and typical characteristic curves of the LM3445 valley fill evaluation module. This evaluation module (EVM) implements a dimming solution using the LM3445 integrated circuit from TI. A complete circuit description, schematic diagram, printed-circuit-board (PCB) layout, and bill of materials (BOM) are also included.

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1 Introduction

The LM3445 Valley Fill EVM is a 120-V_{AC} non-isolated dimmable LED driver whose form factor is intended for A-15, A-19, A-21, A-23, R-20, R-25, R-27, R-30, R-40, PS-25, PS-30, PS-35, BR-30, BR-38, BR-40, PAR-20, PAR-30, PAR-30L, G-25, G-30, G-40, and other LED bulbs.

2 Description

The LM3445 Valley Fill EVM implements a dimming solution using the LM3445 integrated circuit from TI. The LM3445 is an adaptive constant off-time AC/DC buck constant current controller with built-in phase-dimming decoder. Line cycles are analyzed continuously by an internal low-power digital controller for shape and symmetry. An analog current reference is then generated and used by the power converter stage to regulate the output current. The analog reference is manipulated using control algorithms developed to optimize dimmer compatibility, power factor, and THD. Using constant off-time control, the solution achieves low part count, high efficiency, and inherently provides variation in the switching frequency. This variation creates an emulated spread spectrum effect easing the converters' EMI signature and allowing a smaller input filter.

2.1 Typical Applications

Triac compatible LED lighting, including forward- and reverse-phase compatibility.

2.2 LM3445 Features

- Triac dim decoder circuit for LED dimming
- Integrated phase-angle decoder
- Adjustable switching frequency
- Low quiescent current
- Adaptive programmable off-time allows for constant ripple current
- Leading- and trailing-edge dimmer compatibility
- Dimming implemented via an analog reference
- Smooth dimming transitions
- Low BOM cost and small PCB footprint
- Low profile 10-pin MSOP Package or 14-pin SOIC

3 Electrical Performance Specifications

Table 1 lists the LM3445EVM-695 electrical performance specifications.

Table 1. LM3445EVM-695 Electrical Performance Specifications

Parameter	Test Conditions	MIN	TYP	MAX	UNITS
Input Characteristics					
Voltage range		90	120	135	V
Maximum input current				0.150	A
Output Characteristics					
Output current	Output voltage = 20 V	470	500	530	mA
Output current regulation	Line regulation: Input voltage = 90 to 135		±1		%
	Load regulation: 15-V to 25-V change		±1		%
LED Ripple			80		mApp
Systems Characteristics					
Switching frequency			100		kHz
Power efficiency	120-V, 60-Hz input, 20-V LED stack		82		%
Operating temperature			25	125	ºC

4 Schematic

Figure 1 illustrates the LM3445EVM-695 schematic.

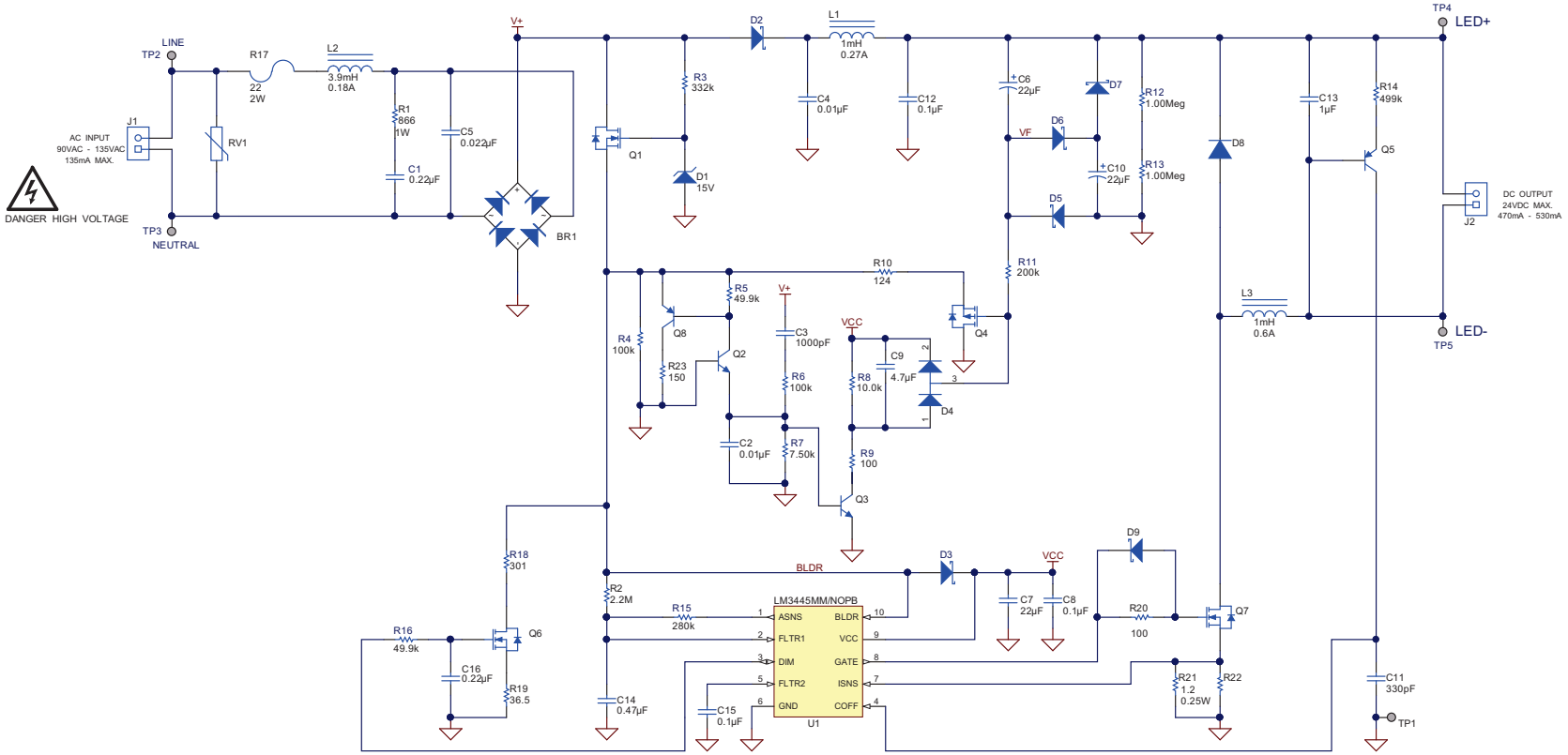

Figure 1. LM3445EVM-695 Schematic

4.1 Suggested Dimming Connection (Remove Dimmer for Non-Dimming!)

Figure 2 displays a dimming connection scenario.

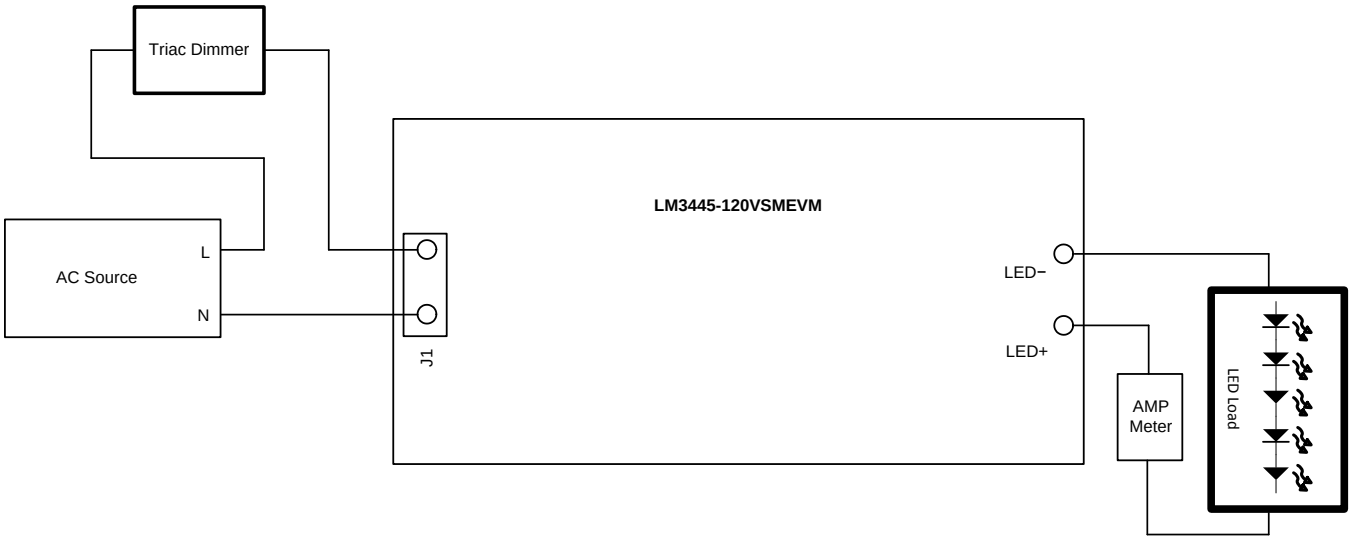

Figure 2. Suggested Dimming Connection

5 Performance Data and Typical Characteristic Curves

(Unless otherwise stated, the input voltage is 120 V, 60 Hz and the LED stack voltage is 22 V.)

5.1 Power Factor

The LM3445EVM-695 power factor is displayed in Figure 3.

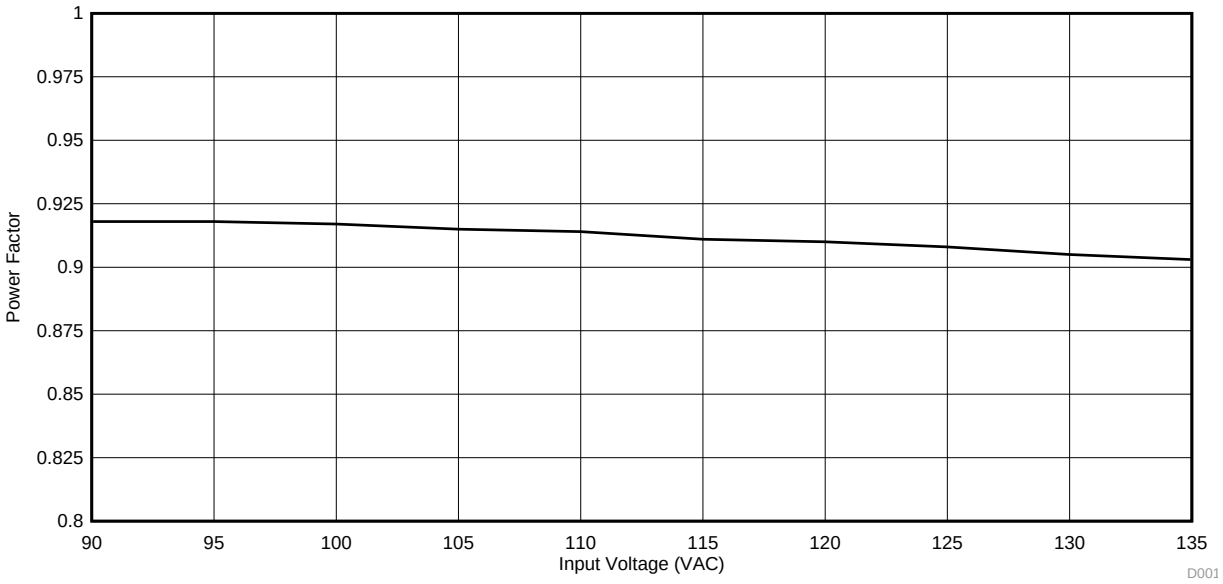

Figure 3. LM3445EVM-695 Power Factor

5.2 Line Regulation

Figure 4 illustrates the LM3445EVM-695 line regulation.

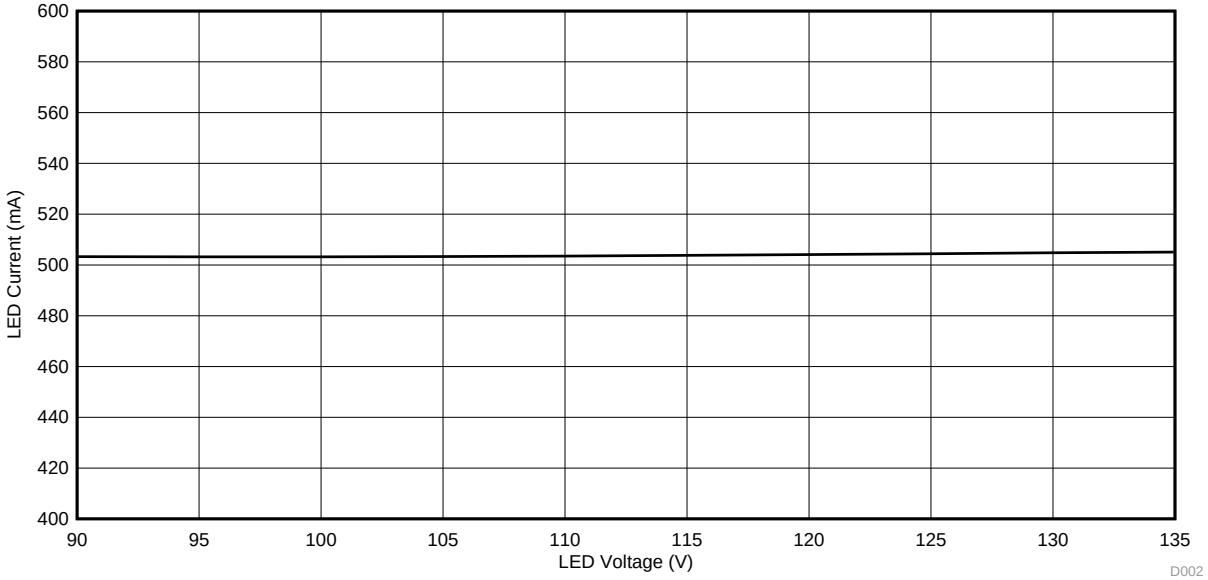

Figure 4. LM3445EVM-695 Line Regulation

5.3 Load Regulation

Figure 5 contains the LM3445EVM-695 load regulation data.

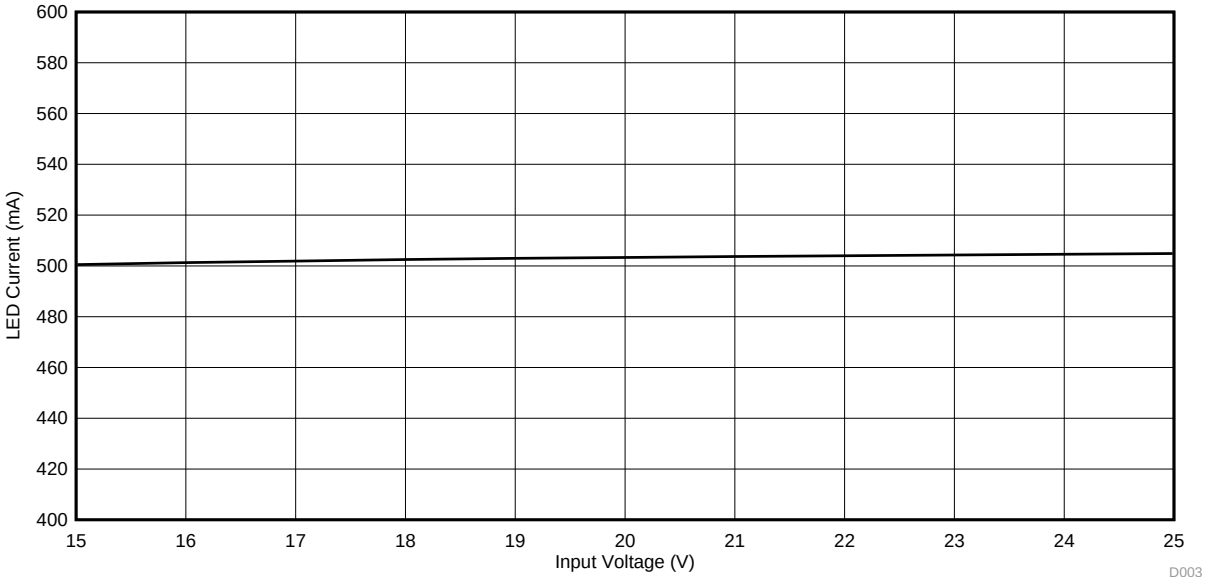

Figure 5. LM3445EVM-695 Load Regulation

5.4 Efficiency

Figure 6 illustrates the LM3445EVM-695 efficiency for 5, 6, and 7 LEDs.

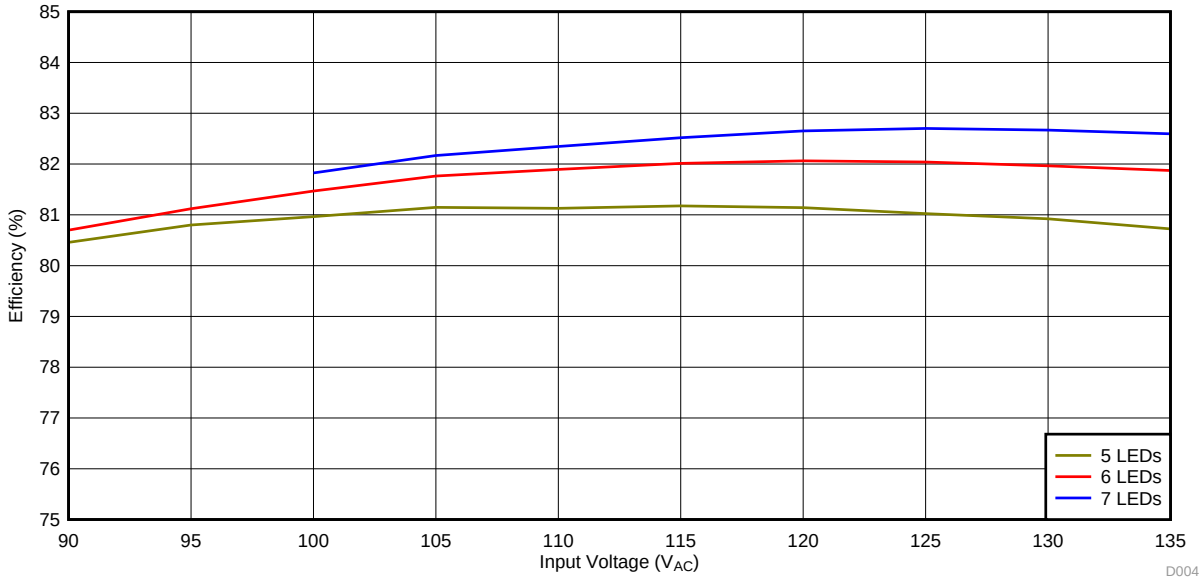

Figure 6. LM3445EVM-695 Efficiency

5.5 Input Current

Figure 7 displays the LM3445EVM-695 off-line valley fill Buck EVM input current.

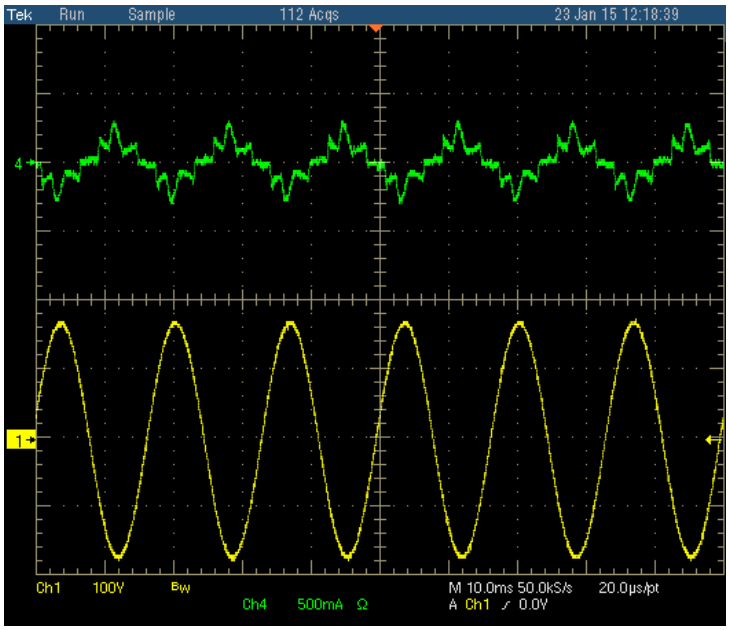

Figure 7. LM3445EVM-695 Off-Line Valley Fill Buck EVM Input Current

5.6 Output Current

Figure 8 displays the LM3445EVM-695 off-line valley fill Buck EVM output current.

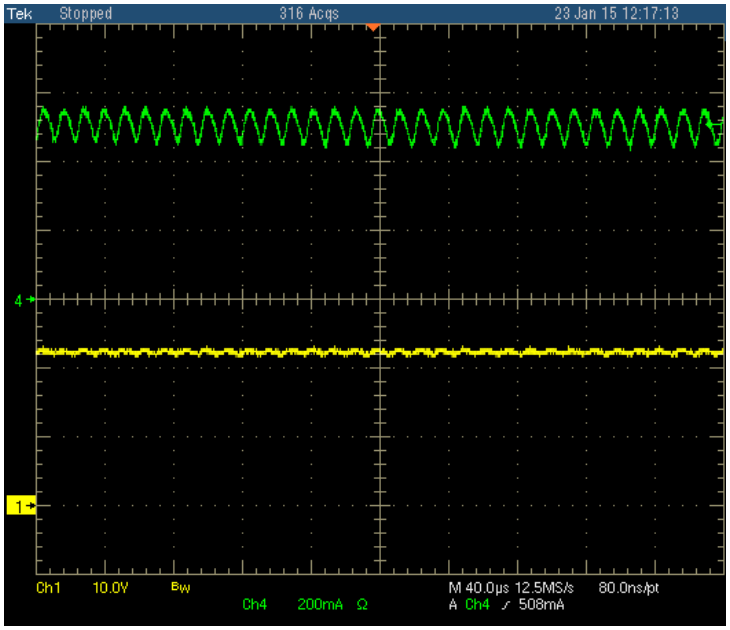

Figure 8. LM3445EVM-695 Off-Line Valley Fill Buck EVM Output Current

5.7 Turn On Waveform

The LM3445EVM-695 off-line valley fill Buck EVM start-up is displayed in Figure 9.

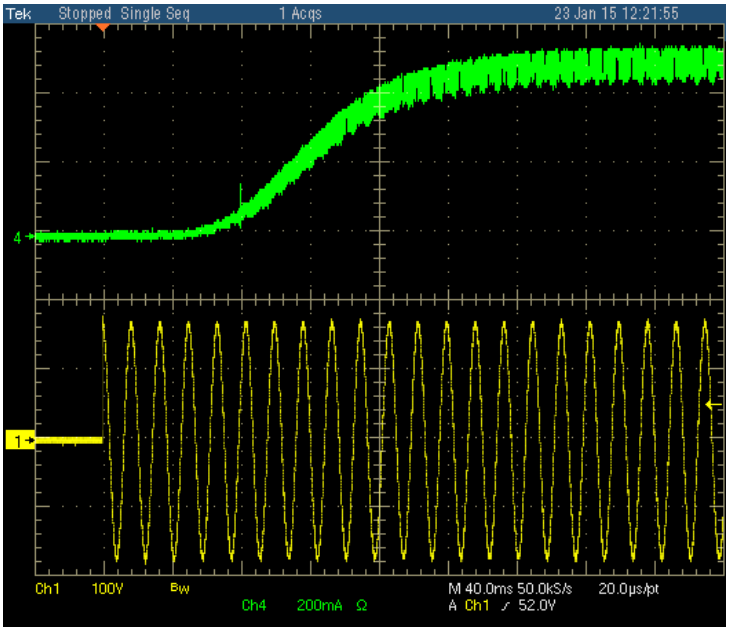

Figure 9. LM3445EVM-695 Off-Line Valley Fill Buck EVM Start-Up

5.8 Turn Off Waveform

Figure 10 displays the LM3445EVM-695 off-line valley fill Buck EVM turn off.

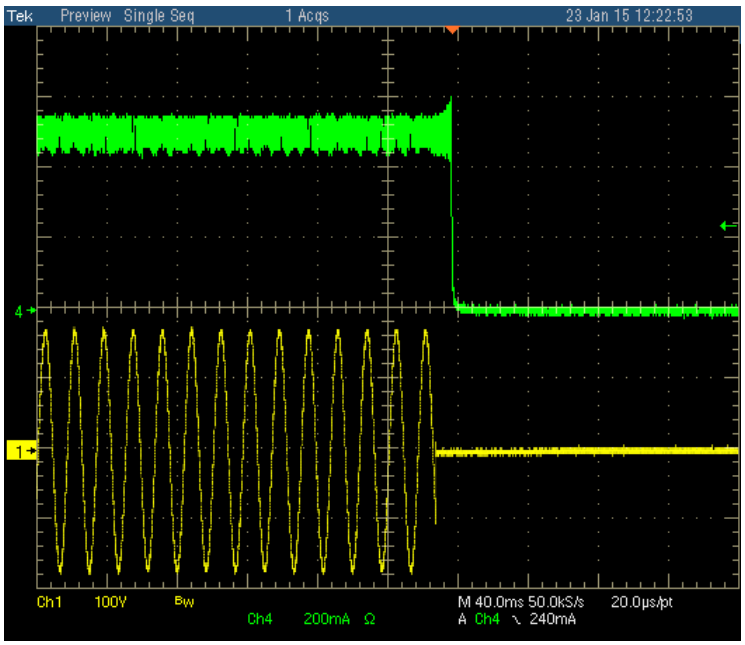

Figure 10. LM3445EVM-695 Off-Line Valley Fill Buck EVM Turn Off

5.9 Dimming – Lutron DVELV-303P Dimmer

Figure 11 illustrates the Lutron trailing edge DVELV-303P, output = 150 mA, V_{LED} = 22 V.

Figure 11. Lutron Trailing Edge DVELV-303P, Output = 150 mA, V_{LED} = 22 V

5.10 Dimming – Lutron DVLV-6006 Dimmer

Figure 12 displays the Lutron leading edge DVLV-6006, output = 20 mA, V_{LED} = 22 V.

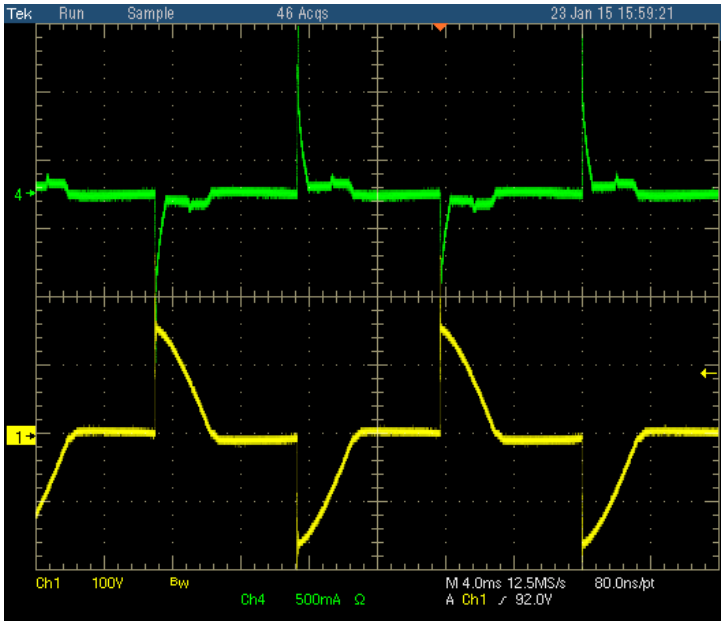

Figure 12. Lutron Leading Edge DVLV-6006, Output = 20 mA, V_{LED} = 22 V

5.11 EMI Scan – 6 LEDs

Figure 13 illustrates the EMI scan data.

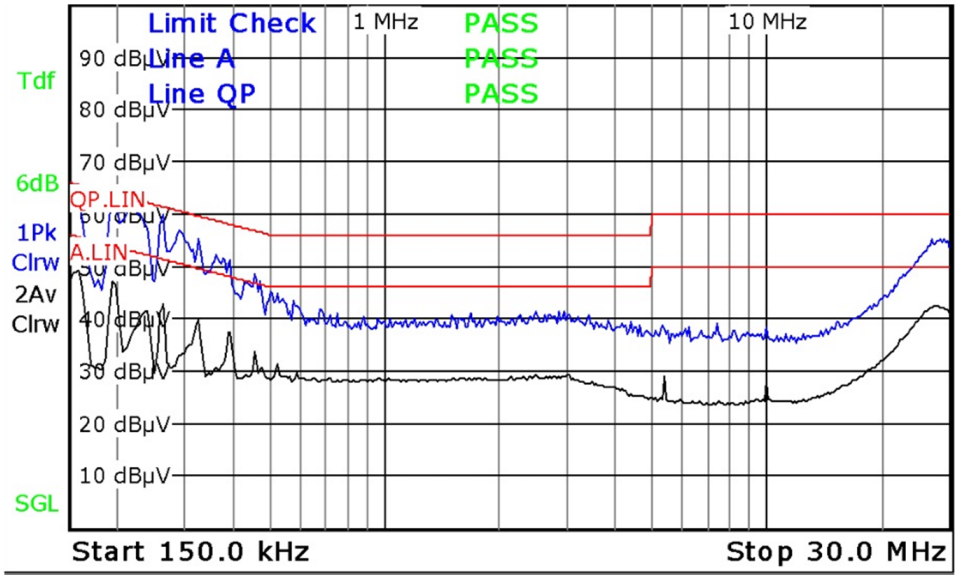

Figure 13. EMI Scan

5.12 Dimmer Testing

Table 2 lists the dimmer testing results.

Table 2. Dimmer Testing

Make	Model	Flicker-Free
Lutron	DVELV-303P	Y
Lutron	DVLV-6006	Y
Lutron	MACL-153M	Y
Lutron	D-600P	Y
Lutron	SCL153P	Y
Leviton	IP106-1LZ	Y
Lutron	DVNCL-153PLH	Y
Lutron	AY-600P	Y
Lutron	NTLV-600	Y
Lutron	TG-600PH	Y
Lutron	S-600P	Y
Lutron	DV600P-IV	Y
Lutron	DVPDC-203P-IV	Y
Lutron	6684	Y
Lutron	NLV-600-IV	Y
Lutron	Q600P	Y
Lutron	SLV-600P	Y
Lutron	AYCL-153P	Y
Lutron	VZM10-1LZ	Y

6 PCB Layout

Figure 14 and Figure 15 show the design of the LM3445EVM-695 printed circuit board

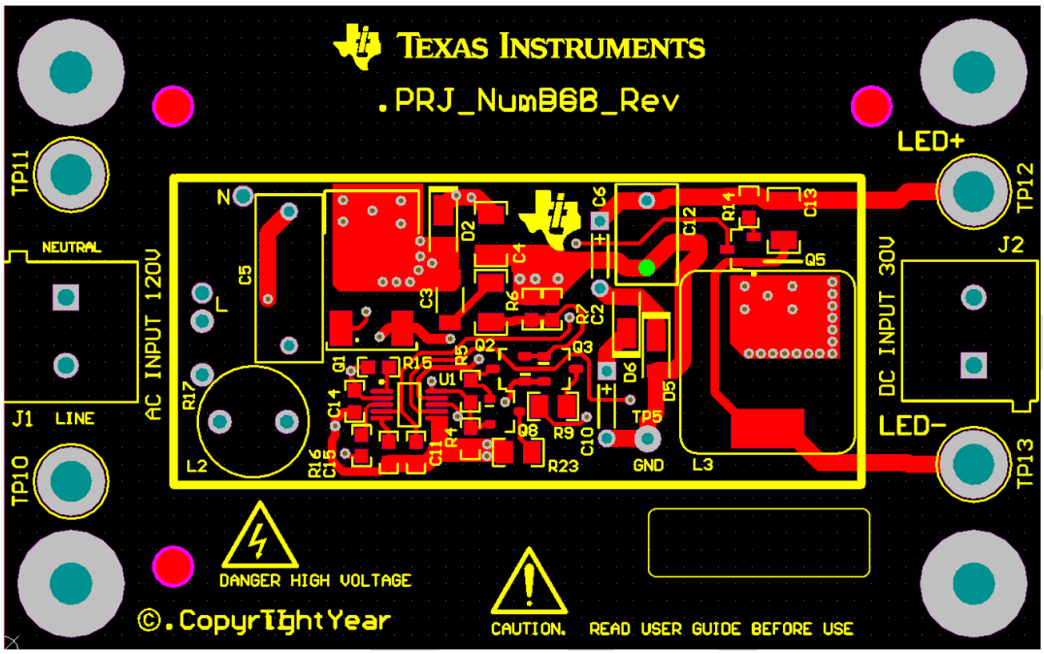

Figure 14. LM3445EVM-695 Top Layer Assembly Drawing (Top View)

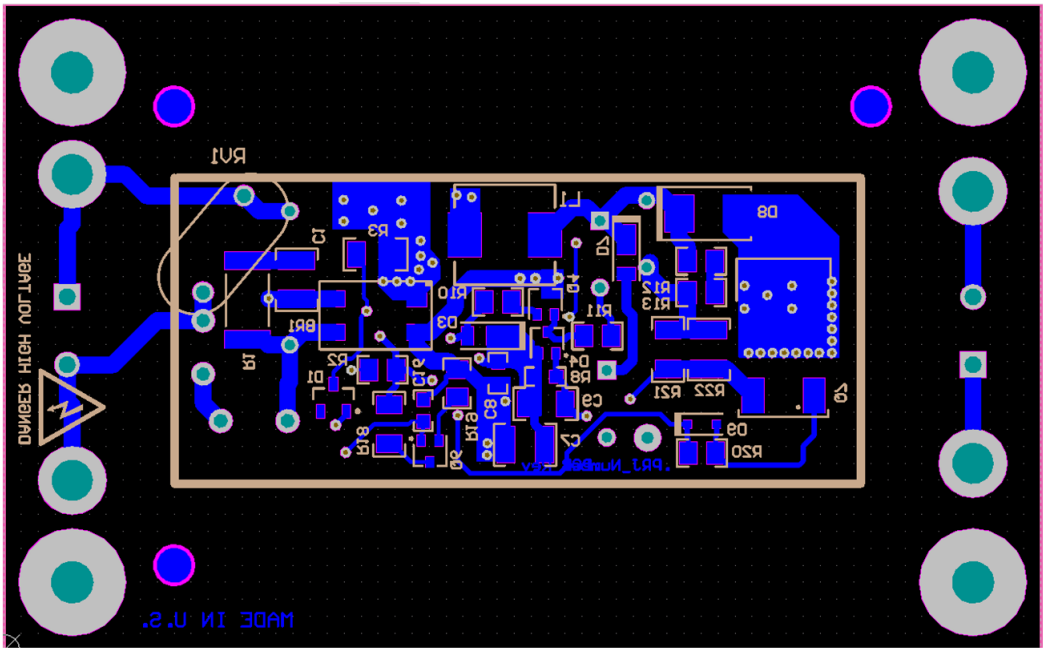

Figure 15. LM3445EVM-695 Bottom Assembly Drawing (Bottom View)

7 Bill of Materials

Table 3 lists the LM3445EVM-695 components list according to the schematic shown in Figure 1.

Table 3. LM3445EVM-695 Bill of Materials

Designator	Qty	Value	Description	Size	PartNumber	Manufacturer
BR1	1	400V	Diode, Switching-Bridge, 400 V, 0.8 A	MiniDIP	HD04-T	Diodes Inc.
C1	1	0.22uF	CAP, CERM, 0.22 µF, 250 V, +/- 10%, X7R	1210	GRM32DR72E224KW01L	Murata
C2	1	0.01uF	CAP, CERM, 0.01 µF, 25 V, +/- 10%, X7R	0603	GRM188R71E103KA01D	Murata
C3	1	1000pF	CAP, CERM, 1000 pF, 500 V, +/- 10%, X7R	1206	C1206C102KCRACTU	Kemet
C4	1	0.01uF	CAP, CERM, 0.01 µF, 250 V, +/- 10%, X7R	1206	C1206C103KARACTU	Kemet
C5	1	0.022uF	CAP, Film, 0.022 µF, 630 V	12.5x5.5x11	B32921C3223M289	EPCOS
C6, C10	2	22uF	CAP, AL, 22 µF, 100 V, +/- 20%, 0.8 ohm, TH	10x12.5mm	UBT2A220MPD1TD	Nichicon
C7	1	22uF	CAP, CERM, 22 µF, 25 V, +/- 10%, X5R	1210	GRM32ER61E226KE15L	Murata
C8, C15	2	0.1uF	CAP, CERM, 0.1 µF, 16 V, +/- 10%, X7R	0603	GRM188R71C104KA01D	Murata
C9	1	4.7uF	CAP, CERM, 4.7 µF, 25 V, +/- 10%, X7R	1206	GRM31CR71E475KA88L	Murata
C11	1	330pF	CAP, CERM, 330 pF, 100 V, +/- 5%, C0G/NP0	0603	GRM1885C2A331JA01D	MuRata
C12	1	0.1uF	CAP, Film, 0.1 µF, 250 V, +/- 5%,	7.2x4.5x9.5mm	R82IC3100DQ60J	Kemet
C13	1	1uF	CAP, CERM, 1 µF, 100 V, +/- 10%, X7R	1206	GRM31CR72A105KA01L	MuRata
C14	1	0.47uF	CAP, CERM, 0.47 µF, 16 V, +/- 10%, X7R	0603	GRM188R71C474KA88D	MuRata
C16	1	0.22uF	CAP, CERM, 0.22 µF, 25 V, +/- 10%	0603	GRM188R71E224KA88D	MuRata
D1	1	15V	Diode, Zener, 15 V, 225 mW	SOT-23	BZX84C15LT1G	ON Semiconductor
D2, D3, D5, D6, D7	5	200V	Diode, Schottky, 200 V, 1 A	PowerDI123	DFLS1200-7	Diodes Inc.
D4	1	70V	Diode, P-N, 70 V, 0.2 A, SOT-323	SOT-323	BAV99WT1G	Fairchild
D8	1	200V	Diode, Superfast Rectifier, 200 V, 1 A	SMB	MURS120-13-F	Diodes Inc.
D9	1	30V	Diode, Schottky, 30 V, 0.2 A	SOD-323	BAT54HT1G	ON Semiconductor
L1	1	1mH	Inductor, Shielded, 1 mH, 0.27 A, 4.9 ohm, SMD	SMD, 7.3x7.3mm	46105C	MuRata
L2	1	3.9mH	Inductor, Wirewound, Ferrite, 3.9 mH, 0.18 A, 9.5 ohm, TH	7.8xL7.5mm	744730392	Wurth Elektronik
L3	1	1mH	Inductor, Shielded Drum Core, Ferrite, 1 mH, 0.6 A, 1.82 ohm, SMD	WE-PD-XL	74477030	Wurth Elektronik
Q1, Q7	2	250V	MOSFET, N-CH, 250 V, 4.4 A	DPAK	FDD6N25TM	Fairchild
Q2, Q3	2	40 V	Transistor, NPN, 40 V, 0.15 A	SOT-23	MMBT4401-7-F	Diodes Inc.
Q4	1	-50V	MOSFET, P-CH, -50 V, -0.13 A	SOT-323	BSS84W-7-F	Diodes Inc.
Q5	1	300 V	Transistor, PNP, 300 V, 0.2 A	SOT-23	MMBTA92	Fairchild
Q6	1	100V	MOSFET, N-CH, 100 V, 0.17 A	SOT-323	BSS123W-7-F	Diodes Inc.
Q8	1	30 V	Transistor, PNP, 30 V, 0.1 A	SOT-23	BC858CLT1G	ON Semiconductor
R1	1	866	RES, 866, 1%, 1 W	2512	CRCW2512866RFKEG	Vishay-Dale
R2	1	2.2M	RES, 2.2 M, 1%, 0.125 W	0805	RC0805FR-072M2L	Yageo America
R3	1	332k	RES, 332 k, 1%, 0.25 W	1206	CRCW1206332KFKEA	Vishay-Dale
R5, R16	2	49.9k	RES, 49.9 k, 1%, 0.1 W	0603	CRCW060349K9FKEA	Vishay-Dale
R6	1	100k	RES, 100 k, 1%, 0.25 W	1206	CRCW1206100KFKEA	Vishay-Dale
R7	1	7.50k	RES, 7.50 k, 1%, 0.1 W	0603	CRCW06037K50FKEA	Vishay-Dale
R8	1	10.0k	RES, 10.0 k, 1%, 0.1 W	0603	CRCW060310K0FKEA	Vishay-Dale
R9, R20	2	100	RES, 100, 1%, 0.125 W	0805	CRCW0805100RFKEA	Vishay-Dale
R10	1	124	RES, 124, 1%, 0.125 W	0805	CRCW0805124RFKEA	Vishay-Dale
R11	1	200k	RES, 200 k, 1%, 0.125 W	0805	CRCW0805200KFKEA	Vishay-Dale
R12, R13	2	1.00M	RES, 1.00 M, 1%, 0.125 W	0805	CRCW08051M00FKEA	Vishay-Dale
R14	1	499k	RES, 499 k, 1%, 0.1 W	0603	CRCW0603499KFKEA	Vishay-Dale
R15	1	280k	RES, 280 k, 1%, 0.1 W	0603	CRCW0603280KFKEA	Vishay-Dale
R17	1	22	RES, 22, 10%, 2 W, Fusible	Axial	EMC2-22RKI	TT Electronics
R18	1	301	RES, 301, 1%, 0.25 W	1206	CRCW1206301RFKEA	Vishay-Dale
R19	1	36.5	RES, 36.5, 1%, 0.125 W	0805	CRCW080536R5FKEA	Vishay-Dale
R21	1	1.20	RES, 1.20, 1%, 0.25 W	1206	CRCW12061R20FKEA	Vishay-Dale
R23	1	150	RES, 150, 1%, 0.125 W	0805	CRCW0805150RFKEA	Vishay-Dale
RV1	1	300Vac	SIOV Metal Oxide Leaded Varistor, 300VAC, 3500A, TH	12 x 5.6 x 14.5 mm	B72210S2301K101	EPCOS Inc
U1	1		Triac Dimmable Offline LED Driver, 10-pin MSOP, Pb-Free	MUB10A	LM3445MM/NOPB	Texas Instruments
R4	0					
R22	0					

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

   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 and conditions 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 and conditions 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 any defects that are 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. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, 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.

3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      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*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). 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。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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 by Radio Law of Japan to follow the instructions below with respect to EVMs:

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

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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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