

## **AN-2231 LM3492HC Evaluation Board Reference Design**

### **1 Introduction**

The LM3492HC integrates a boost converter and a two-channel current regulator to implement a high efficient and cost effective LED driver for driving two individually dimmable LED strings with a maximum power of 15W and an output voltage of up to 65V. The boost converter employs a proprietary Projected-On-Time control method to give a fast transient response with no compensation required, and a nearly constant switching frequency programmable from 200 kHz to 1 MHz. The application circuit is stable with ceramic capacitors and produces no audible noise on dimming. The programmable peak current limit and soft-start features reduce current surges at startup, and an integrated 190 mΩ, 3.9A N-Channel MOSFET switch minimizes the solution size. The fast slew rate current regulator allows high frequency and narrow pulse width dimming signals to achieve a very high contrast ratio of 10000:1 at a dimming frequency of 200Hz. The LED current is programmable from 50 mA to 250 mA by a single resistor.

To maximize the efficiency, Dynamic Headroom Control (DHC) automatically adjusts the output voltage to a minimum. To increase the contrast ratio, the DHC can be over-ridden when the contrast ratio is high. DHC also facilitates a single BOM for different number of LED in a string, which is required for backlight panels of different size, thereby reducing overall development time and cost. The LM3492HC comes with a versatile COMM pin which serves as a bi-directional I/O pin interfacing with an external MCU for the following functions: power-good, over-temperature, IOUT over- and under-voltage indications, switching frequency tuning, and channel 1 disabling. Other supervisory functions of the LM3492HC include precise enable, VCC under-voltage lock-out, current regulator Over-Power protection, and thermal shutdown protection. The LM3492HC is available in the thermally enhanced HTSSOP-20 package.

This application note details the design of a LM3492HC evaluation board which drives two LED strings, each of which consists of 10 LEDs running at 150 mA and the forward voltage of each LED is typically 3.8V. The input voltage is from 9V to 16V. The evaluation board schematic, PCB layout, Bill of Materials, and circuit design descriptions are shown. Typical performance and operating waveforms are also provided for reference.

## 2 Evaluation Board Schematic and PCB Layout

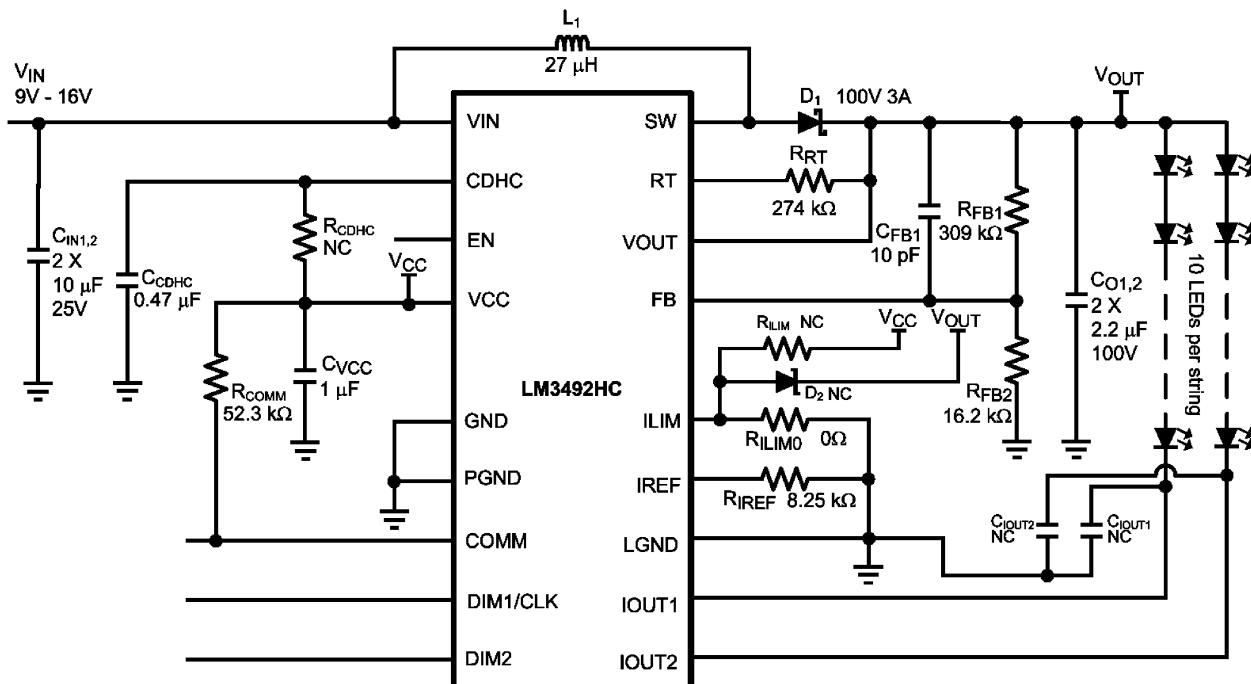


Figure 1. LM3492HC Evaluation Board Schematic

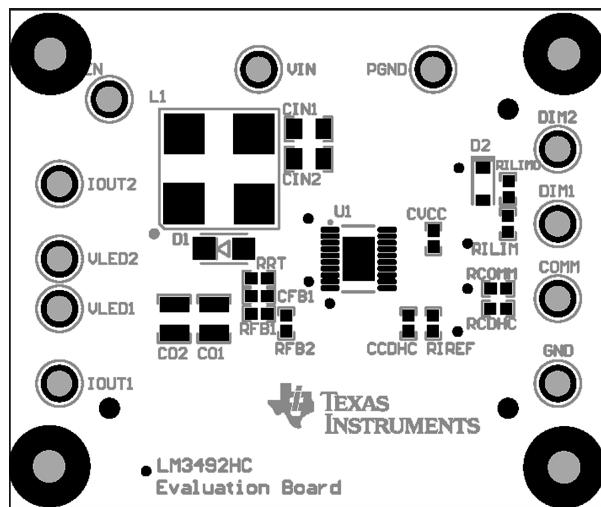


Figure 2. LM3492HC Evaluation Board Top Overlay

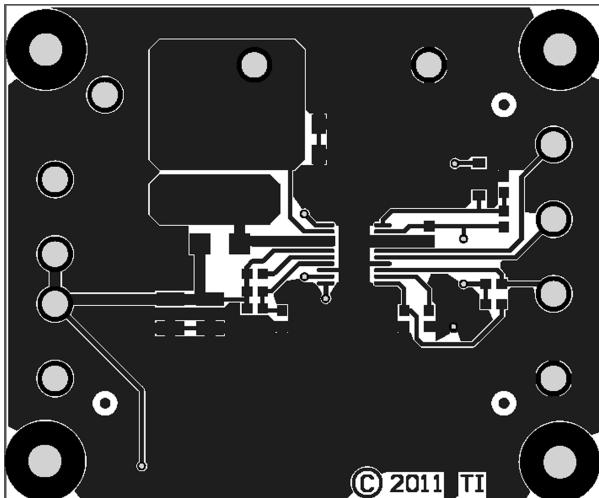


Figure 3. LM3492HC Evaluation Board Top View

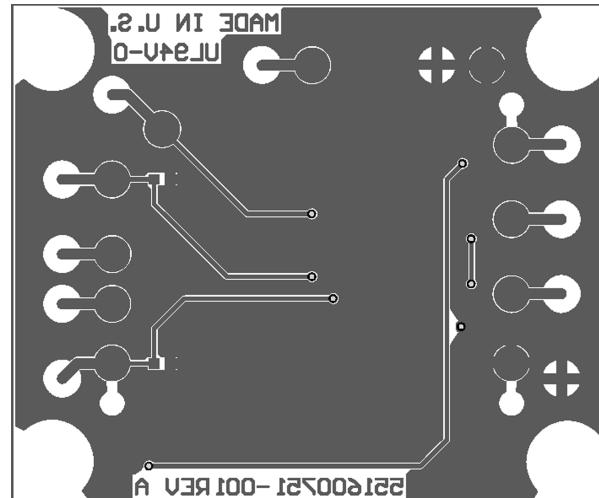


Figure 4. LM3492HC Evaluation Board Bottom View

**Table 1. Evaluation Board Quick Setup Procedures**

Step	Description	Notes
1	Connect a power supply to VIN and PGND terminals	$V_{IN}$ range: 9V to 16V
2	Connect 2 LED strings: from VLED1 to IOUT1 terminals, and VLED2 to IOUT2 terminals	Each LED string consists of 10 LEDs with a forward voltage of 3.8V per LED at 150 mA
3	The EN terminal should be left open for normal operation. Ground this terminal to shutdown	
4	Connect DIM1 and DIM2 terminals to a voltage > 2V, apply $V_{IN} = 12V$	Nominal LED current is 150 mA per channel
5	Ground the EN terminal to check the shutdown function	

**Table 2. Evaluation Board Performance Characteristic**

Description	Symbol	Condition	Min	Typ	Max	Unit
Input Voltage	$V_{IN}$		9	12	16	V
Rail Voltage	$V_{OUT}$			39		V
LED Current	$I_{LED}$			150		mA
LED Current Regulation	$\Delta I_{LED}$	ALL $V_{IN}$ conditions	-3		+3	%
Efficiency		$V_{IN} = 9V$		86.3		%
		$V_{IN} = 12V$		88.9		%
		$V_{IN} = 16V$		89.8		%

### 3 Design Procedure

The following procedures detail the design of the LM3492HC evaluation board driving 2 LED strings consists of 10 LEDs per string. The forward voltage of each LED is 3.8V, and the LED current is 150 mA. The input voltage is ranged from 9V to 16V. The switching frequency  $f_{SW}$  is designed to be 500 kHz.

#### Design Parameters:

$V_{IN}$  = 9V to 16V, typical 12V

$I_{LED}$  = 150 mA

#### Step 1: Calculate the output voltage feedback circuit

The nominal voltage of the LED string with 10 LEDs is 38V, and the minimum voltage of the  $IOUTn$  pin ( $n = 1, 2$ ) is 0.75V for an  $I_{LED}$  of 150 mA. Hence,  $V_{OUT(NOM)}$  is 38.75V. We design  $V_{OUT}$  to be 50V when  $V_{FB}$  is 2.5V. Then at  $V_{OUT(NOM)}$ ,  $V_{FB(NOM)}$  is about 1.95V, which is within the suggested dynamic range of  $V_{FB}$  under DHC (from 1.05V to 2V). By designing  $R_{FB2}$  to be 16.2 k $\Omega$ ,  $R_{FB1}$  is calculated as follows:

$$R_{FB1} = R_{FB2}((V_{OUT(MAX)}/2.5V) - 1) \quad (1)$$

$R_{FB1}$  is calculated to be 307.8 k $\Omega$ , and a standard resistor value of 309 k $\Omega$  is selected.  $C_{FB1}$  is selected to be 10 pF as recommended.

#### Step 2: Determine the inductance

The main parameter affected by the inductor is the peak to peak inductor current ripple ( $I_{LR}$ ). To maintain a continuous conduction mode (CCM) operation, the average inductor current  $I_{L1}$  should be larger than half of  $I_{LR}$ .

For a boost converter,  $I_{L1}$  equals to the input current  $I_{IN}$ . The minimum  $I_{IN}$  occurs when  $V_{IN}$  is maximum, which is 16V in this example, and only 1 LED string is turned on (the 2 LED strings are individually dimmable). Hence,

$$I_{IN(MIN)} = (V_{OUT(NOM)} \times I_{LED}) / V_{IN(MAX)} \quad (2)$$

Also

$$t_{on} = (1 - V_{IN}/V_{OUT}) / f_{SW} \quad (3)$$

To ensure a CCM operation,

$$L_1 = (V_{IN(MAX)} \times t_{on}) / 2I_{IN(MIN)} \quad (4)$$

It can be calculated that  $I_{IN(MIN)}$ ,  $t_{on}$ , and  $L_1$  are 0.363A, 1.17  $\mu$ s, and 25.8  $\mu$ H. On the other hand,  $I_{IN}$  is maximum when  $V_{IN}$  is minimum, which is 9V in this example, and 2 LED strings are turned on. Hence  $I_{IN(MAX)}$  is 1.29A. From (3),  $t_{on}$  is 1.54  $\mu$ s when  $V_{IN}$  is 9V. Then  $I_{LR}$  is

$$I_{LR} = (V_{IN} \times t_{on}) / L_1 \quad (5)$$

From (5),  $I_{LR}$  is 0.53A. The steady state peak inductor current  $I_{L1(Peak)}$  is

$$I_{L1(Peak)} = I_{L1} + I_{LR} / 2 \quad (6)$$

As a result,  $I_{L1(Peak)}$  is 1.56A. A standard value of 27  $\mu$ H is selected for  $L_1$ , and the saturation current of  $L_1$  should be larger than 1.56A.

#### Step 3: Determine the diode

The selection of the boost diode  $D_1$  depends on two factors. The first factor is the reverse voltage, which equals to  $V_{OUT}$  in a boost converter. The second factor is the peak diode current at the steady state, which equals to the peak inductor current as shown in (6). In this example, a 100V 3A schottky diode is selected.

#### Step 4: Determine the value of other components

**$C_{IN}$  and  $C_{OUT}$ :** The function of the input capacitor  $C_{IN}$  and the output capacitor  $C_{OUT}$  is to reduce the input and output voltage ripples. Experimentation is usually necessary to determine their value. The rated DC voltage of capacitors used should be higher than the maximum DC voltage applied.

Owing to the concern of product lifetime, ceramic capacitors are recommended. But ceramic capacitors with high rated DC voltage and high capacitance are rare in general. Multiple capacitors connecting in parallel can be used for  $C_{IN}$  and  $C_{OUT}$ . In this example, two 10  $\mu$ F 25V ceramic capacitor are used for  $C_{IN}$ , and two 2.2  $\mu$ F 100V ceramic capacitor are used for  $C_{OUT}$ .

**C<sub>VCC</sub>**: The capacitor on the VCC pin provides noise filtering and stabilizes the LDO regulator. It also prevents false triggering of the VCC UVLO. C<sub>VCC</sub> is recommended to be a 1  $\mu$ F good quality and low ESR ceramic capacitor.

**C<sub>CDHC</sub>**: The capacitor at the CDHC pin mainly determines the soft-start time t<sub>ss</sub>, i.e. the time for the output voltage to reach its maximum. t<sub>ss</sub> is determined from the following equation:

$$t_{ss} = \frac{C_{CDHC} \times 2.25V}{120 \mu A} \quad (7)$$

In this example, C<sub>CDHC</sub> is recommended to be a 0.47  $\mu$ F good quality and low ESR ceramic capacitor.

**R<sub>RT</sub> and R<sub>IREF</sub>**: The resistors R<sub>RT</sub> and R<sub>IREF</sub> set the switching frequency f<sub>sw</sub> of the boost converter and the LED current I<sub>LED</sub> respectively. From the LM3492HC datasheet, R<sub>RT</sub> is selected to be 274 k $\Omega$  if f<sub>sw</sub> is 500 kHz (Figure 3), and R<sub>IREF</sub> is selected to be 8.25 k $\Omega$  if I<sub>LED</sub> is 150 mA (Figure 4).

**R<sub>COMM</sub>**: Since the COMM pin is open drain, a resistor R<sub>COMM</sub> of 52.3 k $\Omega$  is used to connect the VCC and COMM pins to implement a pull-up function.

## 4 PC Board Layout

The layout of the printed circuit board is critical to optimize the performance of the LM3492HC application circuit. In general, external components should be placed as close to the LM3492HC and each other as possible in order to make copper traces short and direct. In particular, components of the boost converter C<sub>IN</sub>, L<sub>1</sub>, D<sub>1</sub>, C<sub>OUT</sub>, and the LM3492HC should be closed. Also, the output feedback capacitor C<sub>FB1</sub> should be closed to the output capacitor C<sub>OUT</sub>. The ground plane connecting the GND, PGND, and LGND pins and the exposed pad of the LM3492HC and the ground connection of the C<sub>IN</sub> and C<sub>OUT</sub> should be placed on the same copper layer.

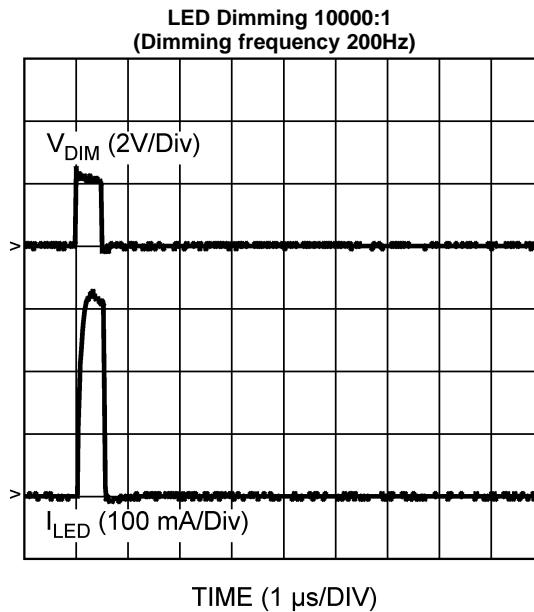
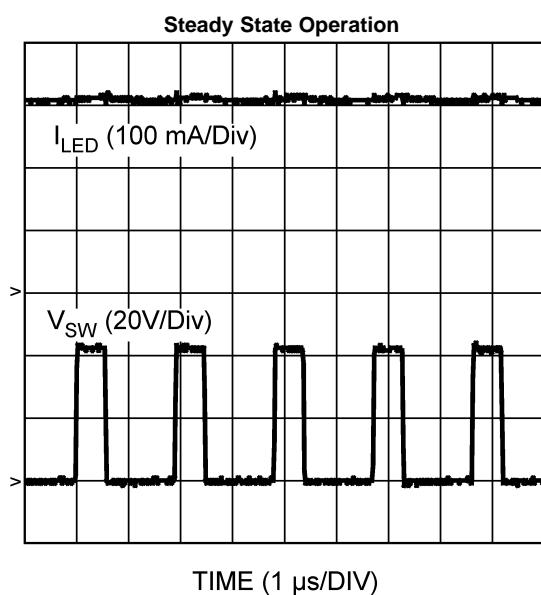
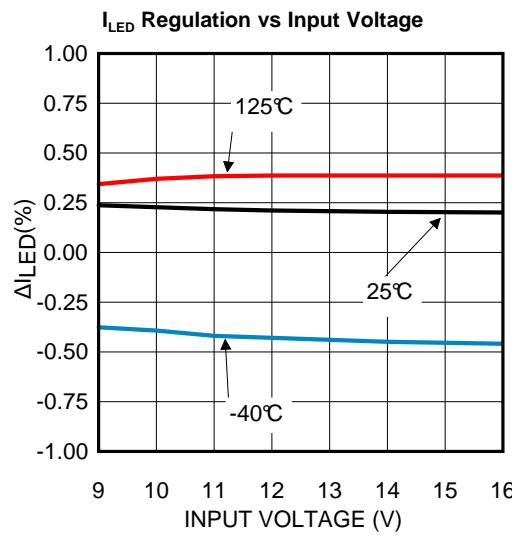
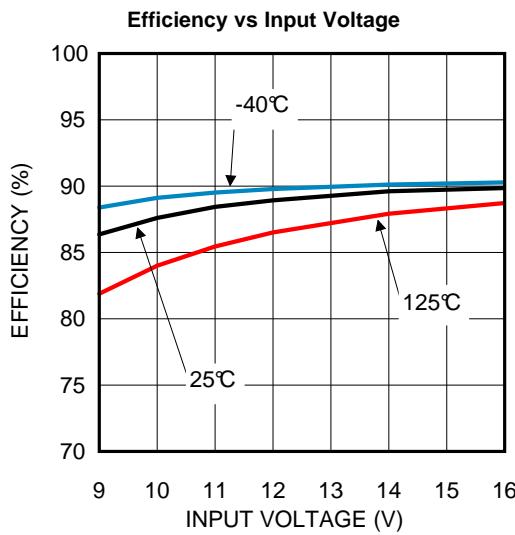
Good heat dissipation helps optimize the performance of the LM3492HC. The ground plane should be used to connect the exposed pad of the LM3492HC, which is internally connected to the LM3492HC die substrate. The area of the ground plane should be extended as much as possible on the same copper layer around the LM3492HC. Using numerous vias beneath the exposed pad to dissipate heat of the LM3492HC to another copper layer is also a good practice.

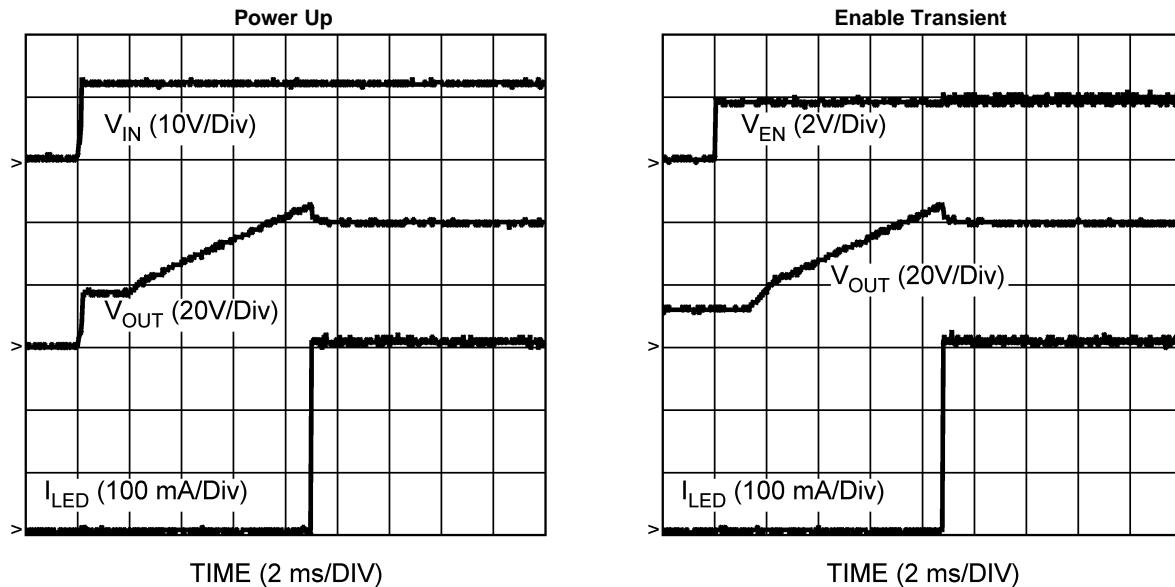
## 5 Bill of Materials

Item	Part Number	Mfg name	Part Description	Qty	Ref Designator(s)	Size
1	GRM31CR61E106KA12L	muRata	Cap 10 $\mu$ F 25V X5R	2	C <sub>IN1</sub> , C <sub>IN2</sub>	1206
2	GRM188R71C474KA88D	muRata	0603/X7R/0.47 $\mu$ F/16V	1	C <sub>CDHC</sub>	0603
3	GRM1885C2A100JA01D	muRata	0603/COG/10 pF/100V	1	C <sub>FB1</sub>	0603
4	GRM188R71C105KA12D	muRata	0603/X7R/1 $\mu$ F/16V	1	C <sub>VCC</sub>	0603
5	GRM32ER72A225KA35L	muRata	Cap 2.2uF 100V X7R	2	C <sub>O1</sub> , C <sub>O2</sub>	1210
6	CRCW060352K3FKEA	Vishay	Resistor Chip 52.3 k $\Omega$ 1%	1	R <sub>COMM</sub>	0603
7	CRCW0603274KFKEA	Vishay	Resistor Chip 274 k $\Omega$ 1%	1	R <sub>RT</sub>	0603
8	CRCW0603309KFKEA	Vishay	Resistor Chip 309 k $\Omega$ 1%	1	R <sub>FB1</sub>	0603
9	CRCW060316K2FKEA	Vishay	Resistor Chip 16.2 k $\Omega$ 1%	1	R <sub>FB2</sub>	0603
10	CRCW06038K25FKEA	Vishay	Resistor Chip 8.25 k $\Omega$ 1%	1	R <sub>REF</sub>	0603
11	CRCW06030000Z0EA	Vishay	Resistor Chip 0 $\Omega$ 1%	1	R <sub>ILIM0</sub>	0603
12	CDRH10D68/ANP-270MC	Sumida	Inductor 27 $\mu$ H 1.9A	1	L <sub>1</sub>	10x10x6.8
13	SK310A-TP	Micro Commercial	Schottky 100V 3A	1	D <sub>1</sub>	SMA
14	1502-2k-ND	KEYSTONE	Terminal DBL Turret 0.109" L Brass	11	VIN, GND, PGND, VLED1, VLED2, IOUT1, IOUT2, DIM1, DIM2, COMM, EN	
15	LM3492HC	TI	LM3492HC Evaluation Board	1	PCB	
16	LM3492HC	TI	IC LM3492HC	1	U1	HTSSOP-20

## 6 Typical Performance and Waveforms

All curves and waveforms taken at  $V_{IN} = 12V$  with the evaluation board and  $T_A = 25^{\circ}\text{C}$  unless otherwise specified.





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##### 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

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- 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.

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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 isotope 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

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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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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.

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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.

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