

AN-2056 LM3492 Evaluation Board Reference Design

1 Introduction

The LM3492 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 1000:1 at a dimming frequency of more than 3 kHz. The LED current is programmable from 50 mA to 200 mA by a single resistor.

To maximize the efficiency, Dynamic Headroom Control (DHC) automatically adjusts the output voltage to a minimum. 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 LM3492 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 LM3492 include precise enable, VCC under-voltage lock-out, current regulator Over-Power protection, and thermal shutdown protection. The LM3492 is available in the thermally enhanced HTSSOP-20 package.

This user's guide details the design of a LM3492 evaluation board that drives 2 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 included. Typical performance and operating waveforms are also provided for reference.

Table 1. 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 | ΔI_{LED} | ALL V_{IN} conditions | -3 | | +3 | % |
| Efficiency | | $V_{IN} = 9V$ | | 85.7 | | % |
| | | $V_{IN} = 12V$ | | 88.2 | | % |
| | | $V_{IN} = 16V$ | | 89.1 | | % |

2 Evaluation Board Schematic

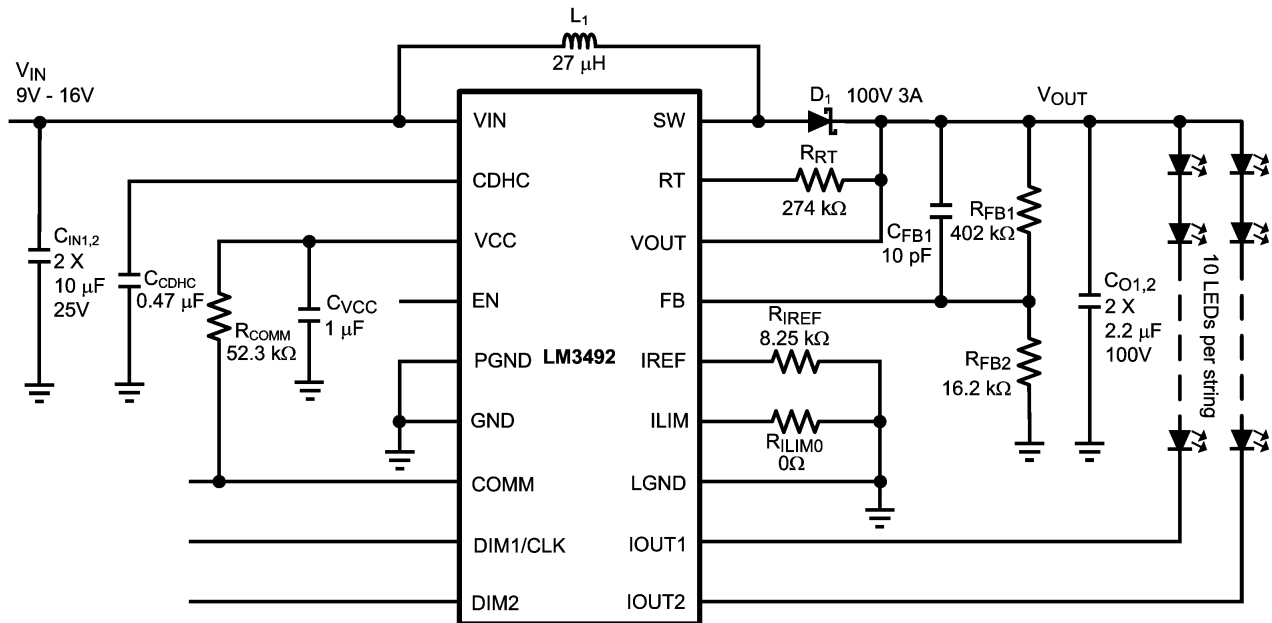


Figure 1. LM3492 Evaluation Board Schematic

3 Quick Setup Procedure

Step 1: Connect a power supply to VIN and PGND terminals. V_{IN} range: 9V to 16V.

Step 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.

Step 3: The EN terminal should be left open for normal operation. Ground this terminal to shutdown.

Step 4: Connect DIM1 and DIM2 terminals to a voltage >2V, apply $V_{IN} = 12V$. Nominal LED current is 150 mA per channel.

Step 5: Ground the EN terminal to check the shutdown function.

4 Design Procedure

The following procedures detail the design of the LM3492 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. Since the dynamic range of V_{FB} under DHC is from 1.05V to 2V, the nominal voltage on the FB pin $V_{FB(NOM)}$ is designed to be around 1.5V. Hence, $V_{OUT(MAX)}$ is designed to be 65V. Since:

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

By designing R_{FB2} to be 16.2 kΩ, R_{FB1} is calculated to be 405 kΩ, and a standard resistor value of 402 kΩ 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 μ s, and 25.8 μ 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 Equation 3, t_{on} is 1.54 μ s when V_{IN} is 9V. Then I_{LR} is

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

From Equation 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 μ 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 Equation 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 μ F 25V ceramic capacitor are used for C_{IN} , and two 2.2 μ F 100V ceramic capacitor are used for C_{OUT} .

C_{VCC} : The capacitor on the VCC pin provides noise filtering and stabilizes the LDO regulator. It also prevents false triggering of the VCC UVLO. C_{VCC} is recommended to be a 1 μ F good quality and low ESR ceramic capacitor.

C_{CDHC} : The capacitor at the CDHC pin mainly determines the soft-start time t_{SS} , i.e. the time for the output voltage to reach its maximum. t_{SS} is determined from the following equation:

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

In this example, C_{CDHC} is recommended to be a 0.47 μ F good quality and low ESR ceramic capacitor.

R_{RT} and R_{IREF} : The resistors R_{RT} and R_{IREF} set the switching frequency f_{SW} of the boost converter and the LED current I_{LED} respectively. From LM3492/LM3492Q Two-Channel Individual Dimmable LED Driver with Boost Converter and Fast Current Regulator (SNVS656), R_{RT} is selected to be 274 k Ω if f_{SW} is 500 kHz (Figure 1 of the datasheet (SNVS656)), and R_{IREF} is selected to be 8.25 k Ω if I_{LED} is 150 mA (Figure 4 of the datasheet (SNVS656)).

R_{COMM} : Since the COMM pin is open drain, a resistor R_{COMM} of 52.3 k Ω is used to connect the VCC and COMM pins to implement a pull-up function.

5 PC Board Layout

The layout of the printed circuit board is critical to optimize the performance of the LM3492 application circuit. In general, external components should be placed as close to the LM3492 and each other as possible in order to make copper traces short and direct. In particular, components of the boost converter C_{IN} , L_1 , D_1 , C_{OUT} , and the LM3492 should be closed. Also, the output feedback capacitor C_{FB1} should be closed to the output capacitor C_{OUT} . The ground plane connecting the GND, PGND, and LGND pins and the exposed pad of the LM3492 and the ground connection of the C_{IN} and C_{OUT} should be placed on the same copper layer.

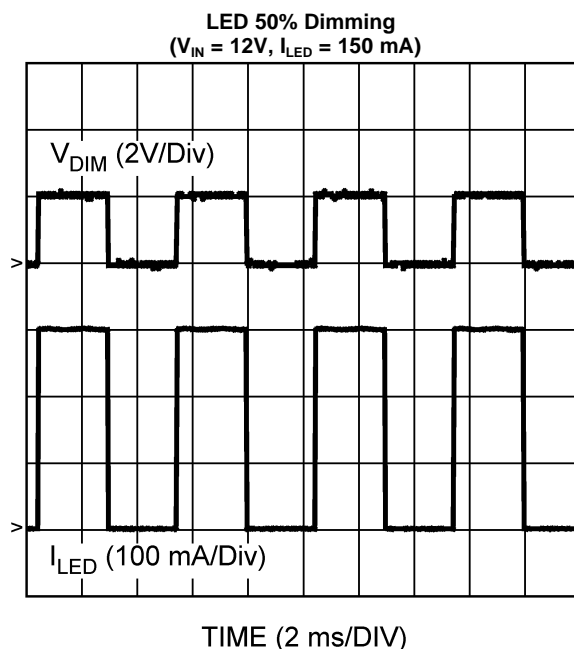
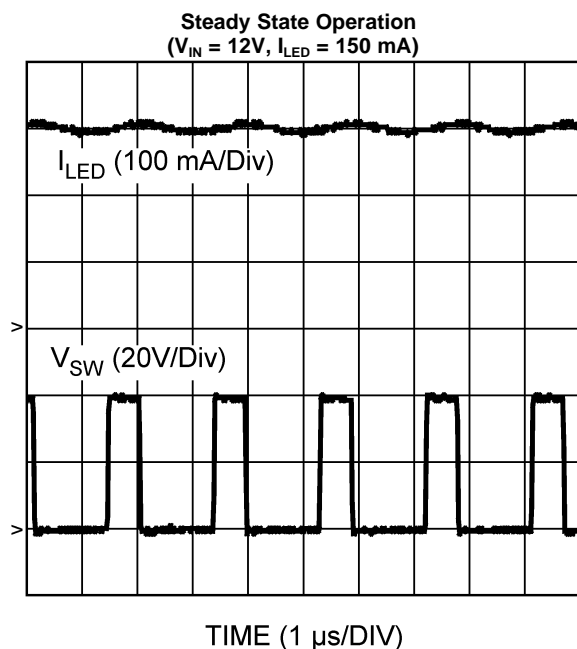
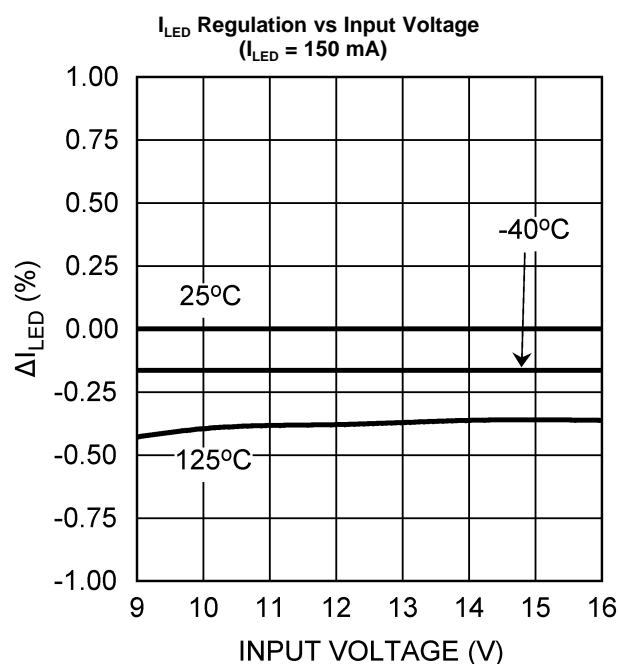
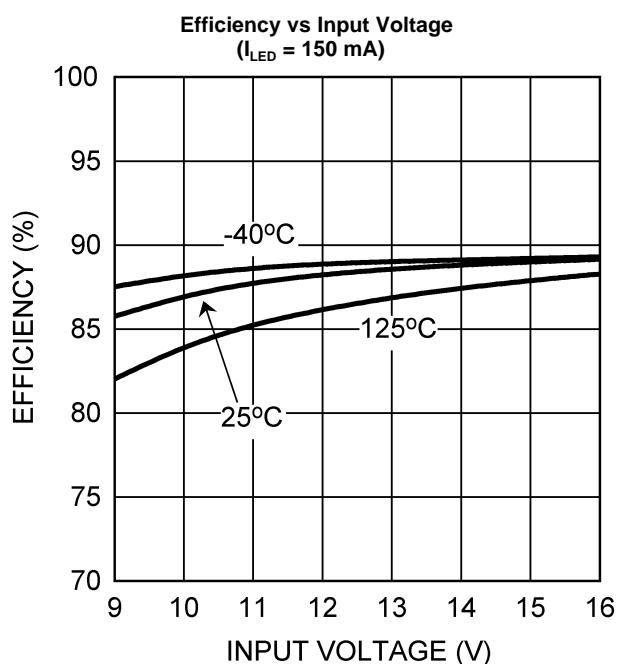
Good heat dissipation helps optimize the performance of the LM3492. The ground plane should be used to connect the exposed pad of the LM3492, which is internally connected to the LM3492 die substrate. The area of the ground plane should be extended as much as possible on the same copper layer around the LM3492. Using numerous vias beneath the exposed pad to dissipate heat of the LM3492 to another copper layer is also a good practice.

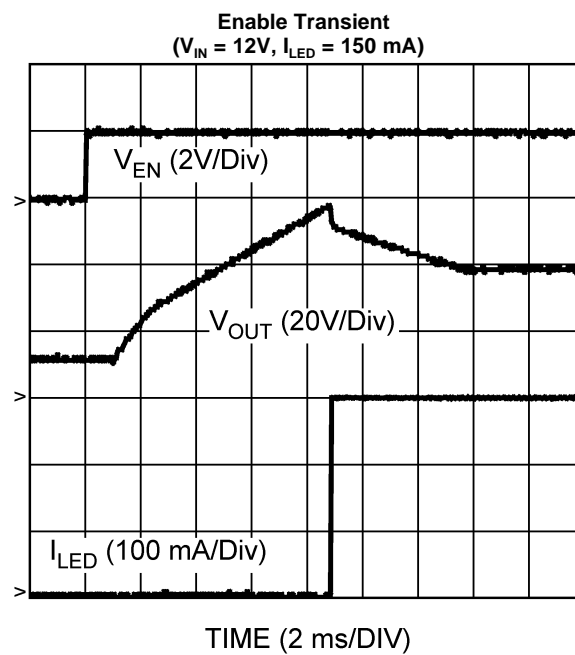
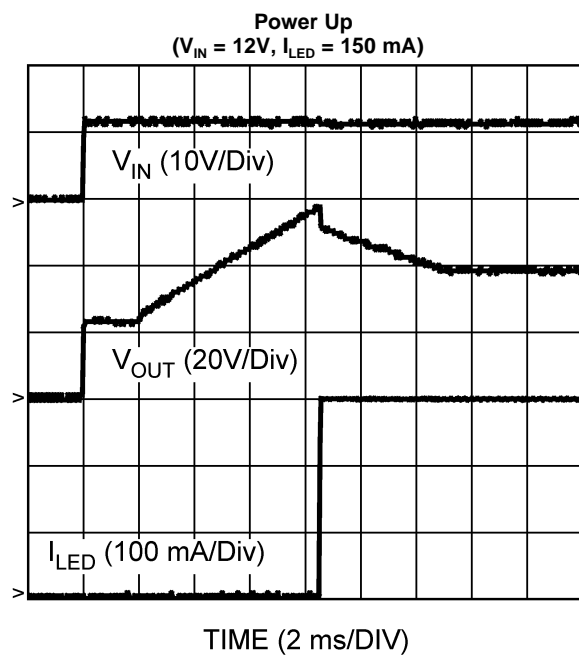
6 Bill of Materials

| Item | Part Number | Mfg name | Part Description | Qty | Ref Designator(s) | Size |
|------|---------------------|-------------------|-----------------------------------|-----|--|-----------|
| 1 | GRM31CR61E106KA12L | muRata | Cap 10 μ F 25V X5R | 2 | C_{IN1} , C_{IN2} | 1206 |
| 2 | GRM188R71C474KA88D | muRata | 0603/X7R/0.47 μ F/16V | 1 | C_{CDHC} | 0603 |
| 3 | GRM1885C2A100RA01D | muRata | 0603/COG/10 pF/100V | 1 | C_{FB1} | 0603 |
| 4 | GRM188R71C105KA12D | muRata | 0603/X7R/1 μ F/16V | 1 | C_{VCC} | 0603 |
| 5 | GRM32ER72A225KA35L | muRata | Cap 2.2 μ F 100V X7R | 2 | C_{O1} , C_{O2} | 1210 |
| 6 | CRCW060352K3FKEA | Vishay | Resistor Chip 52.3 k Ω 1% | 1 | R_{COMM} | 0603 |
| 7 | CRCW0603274KFKEA | Vishay | Resistor Chip 274 k Ω 1% | 1 | R_{RT} | 0603 |
| 8 | CRCW0603402KFKEA | Vishay | Resistor Chip 402 k Ω 1% | 1 | R_{FB1} | 0603 |
| 9 | CRCW060316K2FKEA | Vishay | Resistor Chip 16.2 k Ω 1% | 1 | R_{FB2} | 0603 |
| 10 | CRCW06038K25FKEA | Vishay | Resistor Chip 8.25 k Ω 1% | 1 | R_{REF} | 0603 |
| 11 | CRCW06030000Z0EA | Vishay | Resistor Chip 0 Ω 1% | 1 | R_{ILIM0} | 0603 |
| 12 | CDRH10D68/ANP-270MC | Sumida | Inductor 27 μ H 1.9A | 1 | L_1 | 10x10x6.8 |
| 13 | SK310A-TP | Micro Commercial | Schottky 100V 3A | 1 | D_1 | 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 | LM3492EVAL | Texas Instruments | LM3492 demo board | 1 | PCB | |
| 16 | LM3492 | Texas Instruments | IC LM3492 | 1 | U1 | HTSSOP-20 |

7 Typical Performance and Waveforms

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





8 PCB Layout

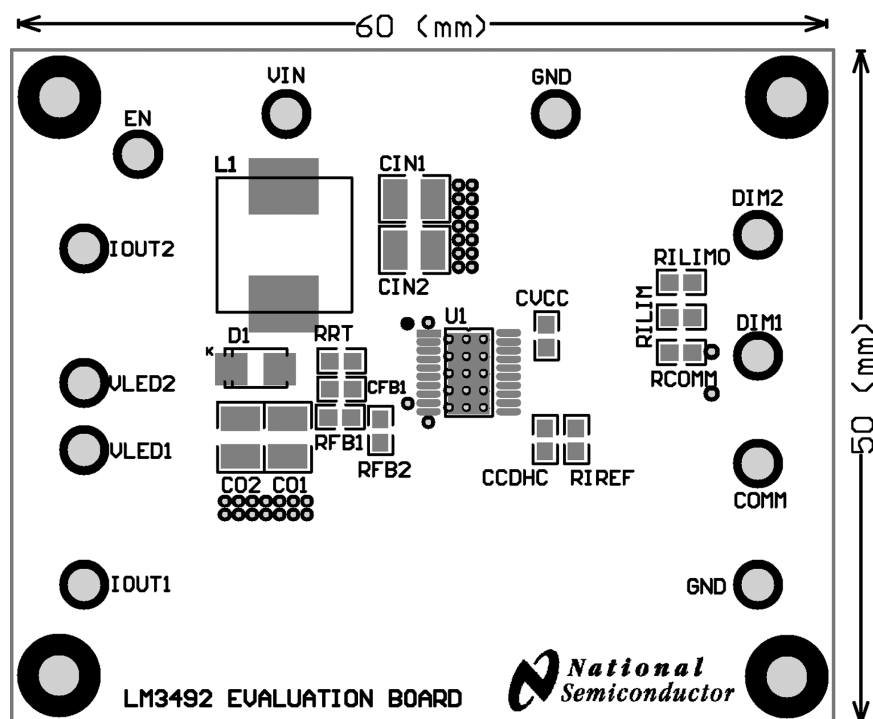


Figure 2. LM3492 Evaluation Board Top Overlay

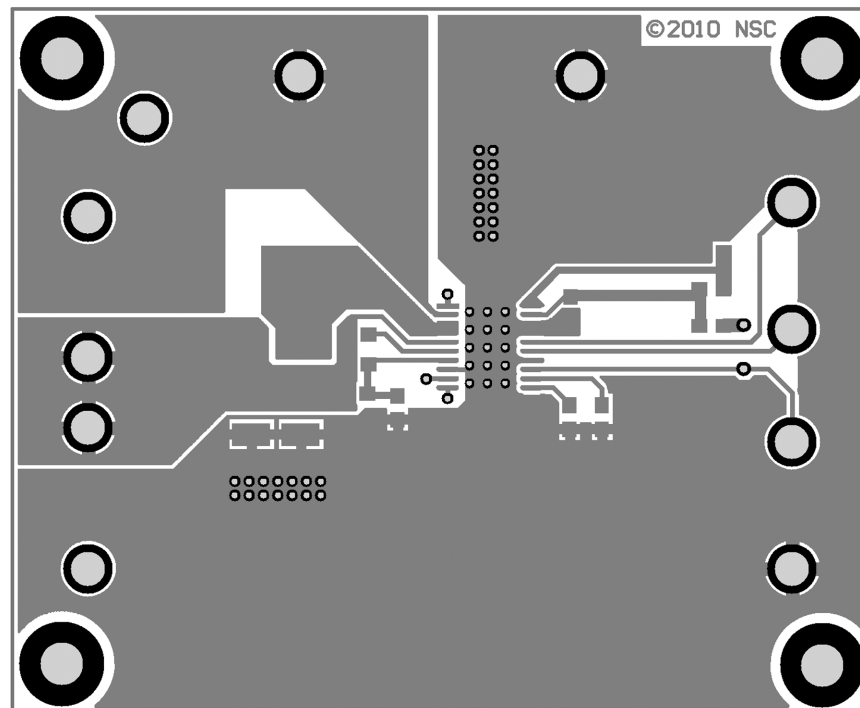


Figure 3. LM3492 Evaluation Board Top View

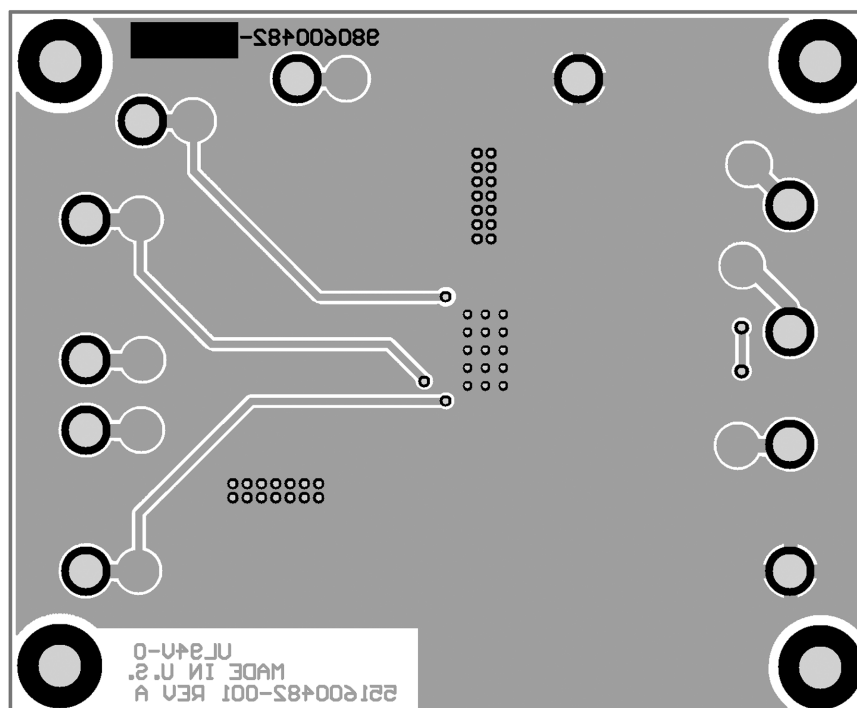


Figure 4. LM3492 Evaluation Board Bottom View

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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.*

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(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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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.

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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 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.

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