

# **Using the TPS92010EVM-592 TRIAC Dimmable 6-W LED Driver**

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The TPS92010EVM-592 is a TRIAC dimmable LED driver. It can provide a 0.325-A constant current to four or five high-brightness LEDs. The EVM includes a five-LED load. It is powered from the mains which is rated at 100 Vrms to 130 Vrms. The output current can be modified for constant levels from 0.2 A to 0.7 A.

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## 1 Description

This EVM uses the TPS92010 high efficiency offline LED lighting driver controller. The power topology is a quasi resonant mode flyback. This makes for a cost competitive solution. This TPS92010 EVM implements a constant current, high efficiency, low ripple AC-DC LED lighting driver.

Current is sensed directly via a resistor and operational-amplifier. This in turn drives an opto-coupler which sets the PWM pulses via the TPS92010 to control the output current at a constant level. The design also incorporates a circuit to ensure compatibility with a large number of commonly available TRIAC based dimmers. This circuit monitors the line voltage for TRIAC operation. When the TRIAC is operating the line voltage is chopped. This information is used by the circuit to reduce the constant output current level thus dimming the LEDs. It also applies a current path at the input to ensure the TRIAC triggers correctly and maintains triggered condition.

### 1.1 Typical Applications

- Household light bulb replacement

### 1.2 Features

- TRIAC compatible dimming
- Low-cost line powered LED driver solution
- Includes 5 HB-LEDs as a sample load
- Allows easy use of user own LED load
- Test points for LED voltage and current
- Accurate current sensing to maintain constant current to LEDs
- Modifiable output current from 0.2 A to 0.7 A, 0.325 A is default

## 2 Electrical Performance Specifications

Table 1 gives the EVM performance specifications and qualifications.

**Table 1. TPS92010EVM-592 Electrical Performance Specifications**

| SPECIFICATION |                       | TEST CONDITIONS | MIN | TYP | MAX | UNITS      |
|---------------|-----------------------|-----------------|-----|-----|-----|------------|
| <b>INPUT</b>  |                       |                 |     |     |     |            |
| $V_{IN}$      | Input voltage range   |                 | 100 |     | 130 | $V_{RMS}$  |
| $I_{MAX}$     | Maximum input current |                 |     | 132 |     | $mA_{RMS}$ |
| <b>OUTPUT</b> |                       |                 |     |     |     |            |
| $V_{OUT}$     | Output voltage        |                 | 14  |     | 18  | $V_{DC}$   |
| $I_{OUT}$     | Output current        |                 | 310 | 325 | 340 | $mA_{DC}$  |
| <b>SYSTEM</b> |                       |                 |     |     |     |            |
| $\eta$        | Efficiency            |                 |     | 84% |     |            |

3 Schematic

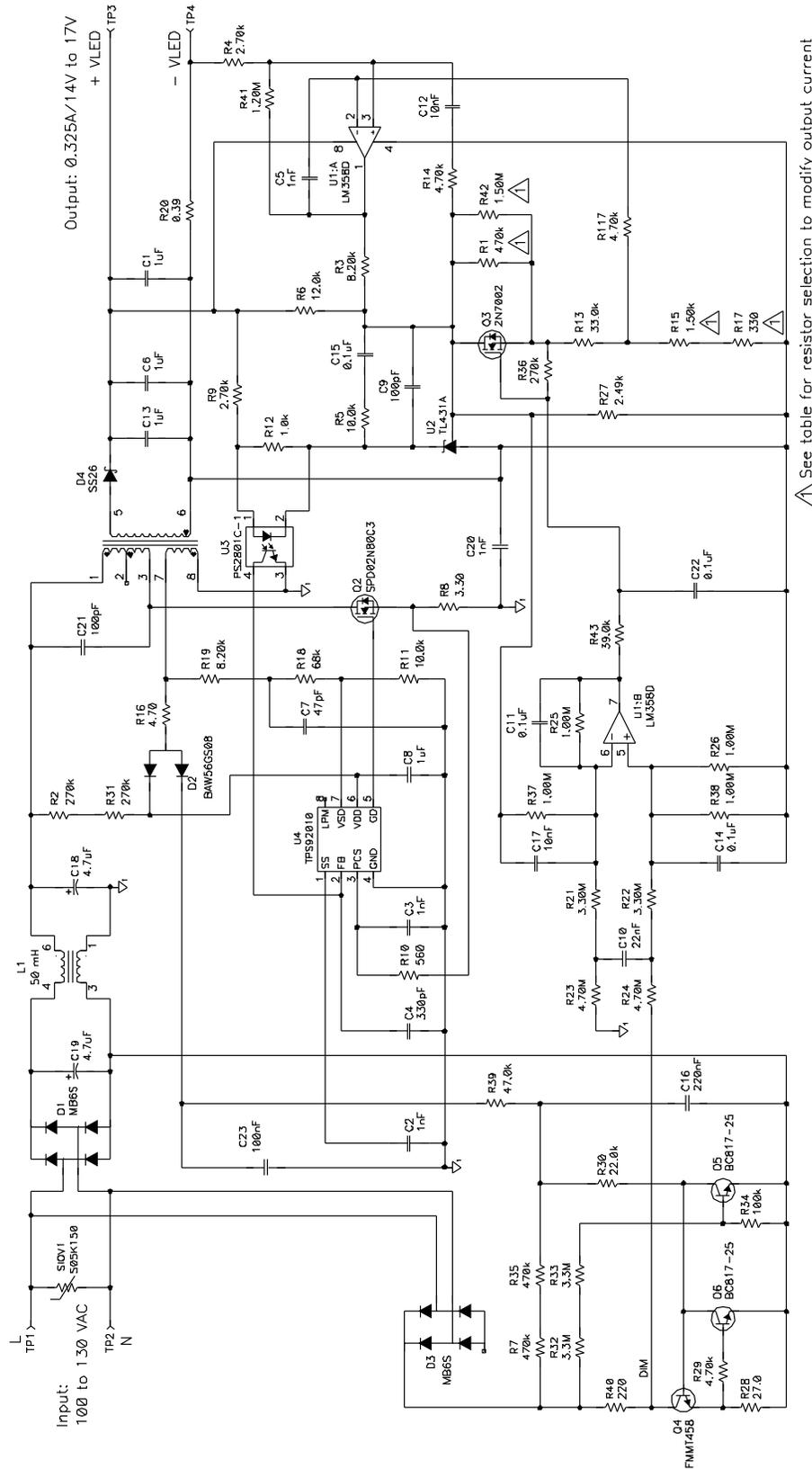
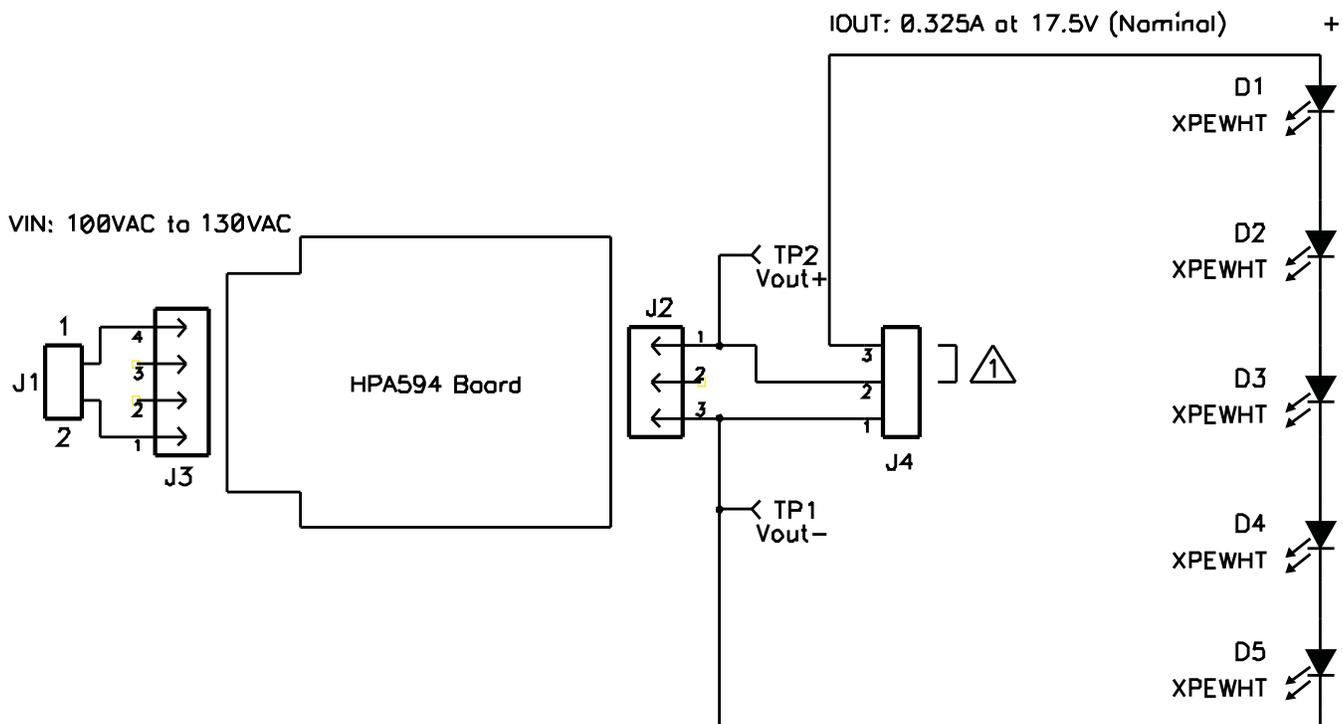


Figure 1. TPS92010EVM-592 PSU (HPA594) Schematic



 Short J4 pins 2 and 3 together to use on-board LEDs

**Figure 2. TPS92010EVM-592 LED Load Board Schematic**

## 4 Test Setup

### 4.1 Test Equipment

Connect test equipment and TPS51125AEVM board as shown in [Section 4.3](#).

#### 4.1.1 Voltage Source

100 Vrms to 130 Vrms AC source.

#### 4.1.2 Multimeters

Voltmeter for up to 20 Vdc and an ammeter for up to 1 A.

#### 4.1.3 Output Load

Load provided or LED load that sinks 0.325 Adc and has a voltage drop between 14 Vdc to 18 Vdc.

#### 4.1.4 Recommended Wire Gauge

18 AWG.

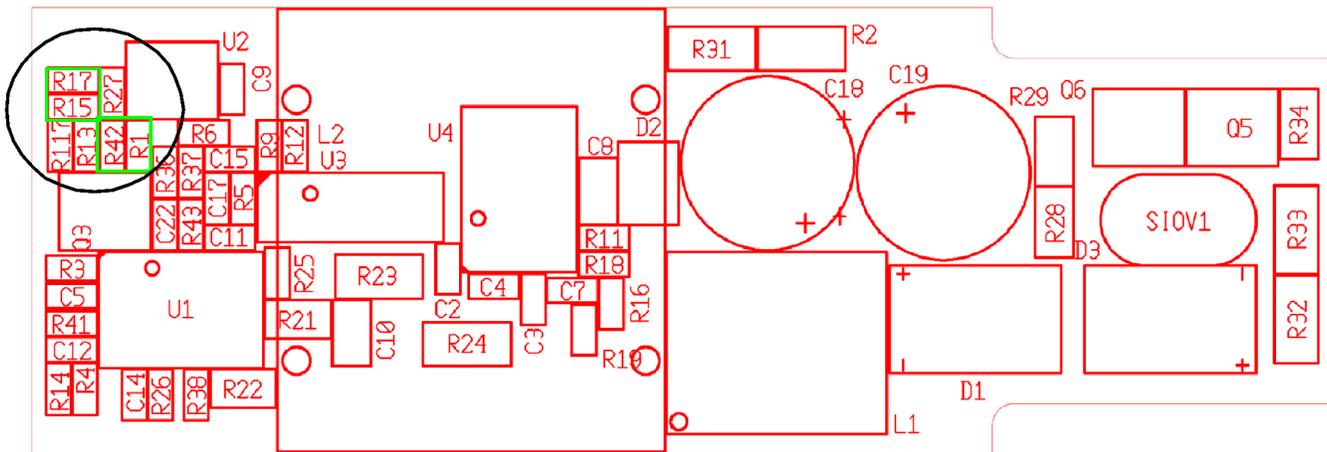
## 4.2 Configuring the Output Current

The TPS92010EVM-592 can be configured for different output current levels by soldering the 0402 parts. Table 2 below shows the resistor values necessary for various current levels. Figure 3 shows the location of these resistors on the top side of the PSU board.

**Table 2. Resistor Values to Modify Output Current**

| MAXIMUM OUTPUT CURRENT (mA) | MINIMUM OUTPUT CURRENT (mA) | R15 (kΩ) | R17 (Ω) | R1 (kΩ) | R42 (MΩ) |
|-----------------------------|-----------------------------|----------|---------|---------|----------|
| 200                         | 10                          | 1.00     | 150     | 330     | 1.00     |
| 225                         | 10                          | 1.20     | 86      | 390     | 1.00     |
| 250                         | 10                          | 1.20     | 220     | 470     | 1.00     |
| 275                         | 10                          | 1.00     | 560     | 680     | 0.68     |
| 300                         | 10                          | 1.50     | 220     | 680     | 0.68     |
| 325 <sup>(1)</sup>          | 10                          | 1.50     | 330     | 470     | 1.50     |
| 350                         | 10                          | 1.00     | 1000    | 820     | 1.00     |
| 400                         | 10                          | 1.80     | 470     | 1000    | 1.00     |
| 450                         | 10                          | 2.20     | 390     | 1500    | 1.00     |
| 500                         | 12                          | 2.70     | 220     | 1500    | 1.00     |
| 600                         | 12                          | 3.30     | 150     | 1500    | 1.50     |
| 700                         | 13                          | 3.90     | 270     | 2200    | 1.50     |

<sup>(1)</sup> EVM default setting.



**Figure 3. Resistor Locations Modify Output Current**

### 4.3 Recommended Test Setup

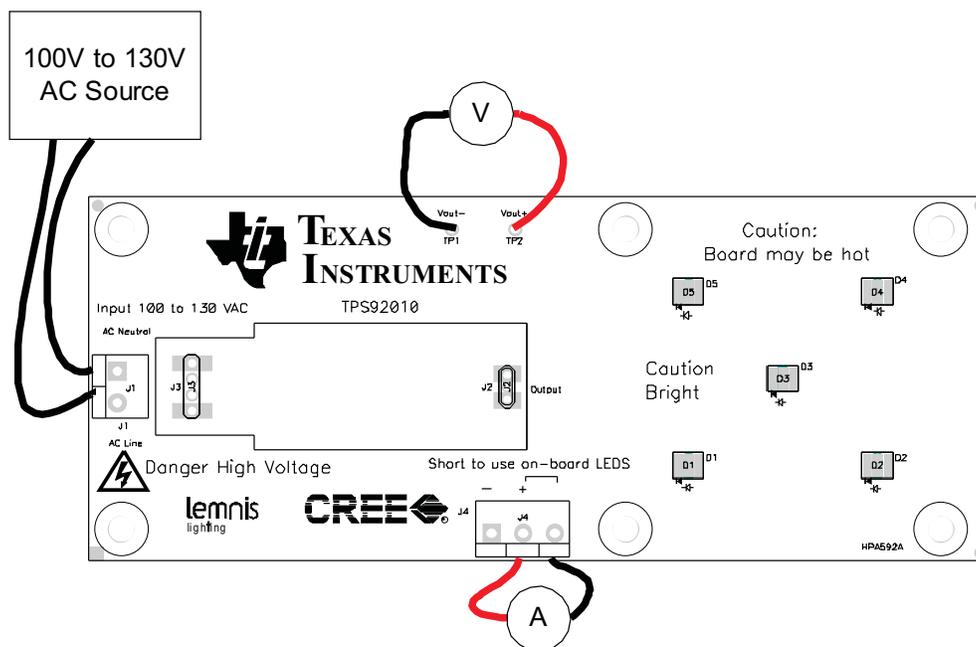


Figure 4. Recommended Test Set-Up Using Internal Load

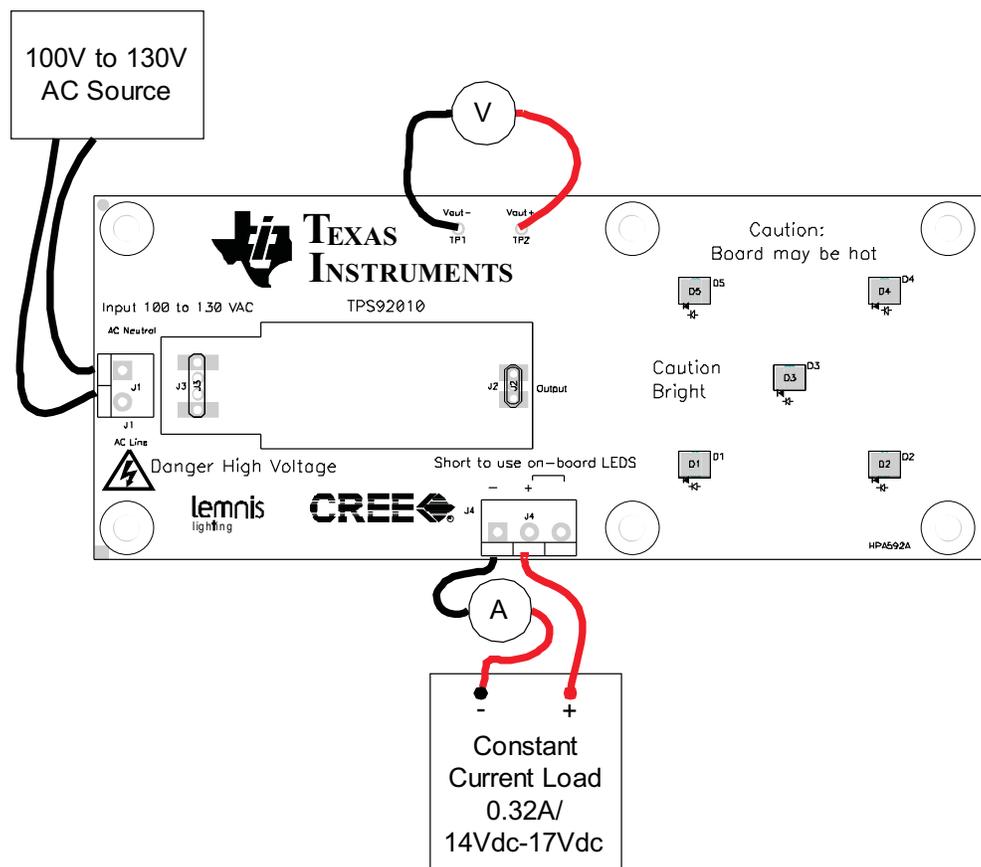


Figure 5. Recommended Test Set-Up using External Load

## 5 Test Procedure

### CAUTION

High voltages exist on this EVM. Please handle with care. Do not touch EVM when powered

The user can set up the EVM in two different ways, with either an internal load or with an external load.

### 5.1 Internal Load

The EVM provides five on-board LEDs. A short or ammeter must be connected between pins 2 and 3 of J4, see [Figure 3](#).

### 5.2 External Load

To validate the EVM with an external load, pins 1 and 2 of J4 should be used. Any short between pins 2 and 3 should be removed to avoid damaging the EVM. See [Figure 5](#).

### 5.3 Line Regulation and Efficiency Measurement Procedure

1. Connect EVM per [Figure 4](#) or [Figure 5](#) .
2. Set AC source to 100 Vrms.
3. Turn on AC source.
4. Record output voltage reading from voltmeter and output current reading from ammeter
5. Increase output voltage by 5 Vrms
6. Repeat steps 4 and 5 until 130 Vrms is reached
7. Shutdown equipment per [Figure 5](#) .

## 5.4 Verifying Dimming Function

Figure 6 shows the recommended test set-up using the TRIAC dimmer.

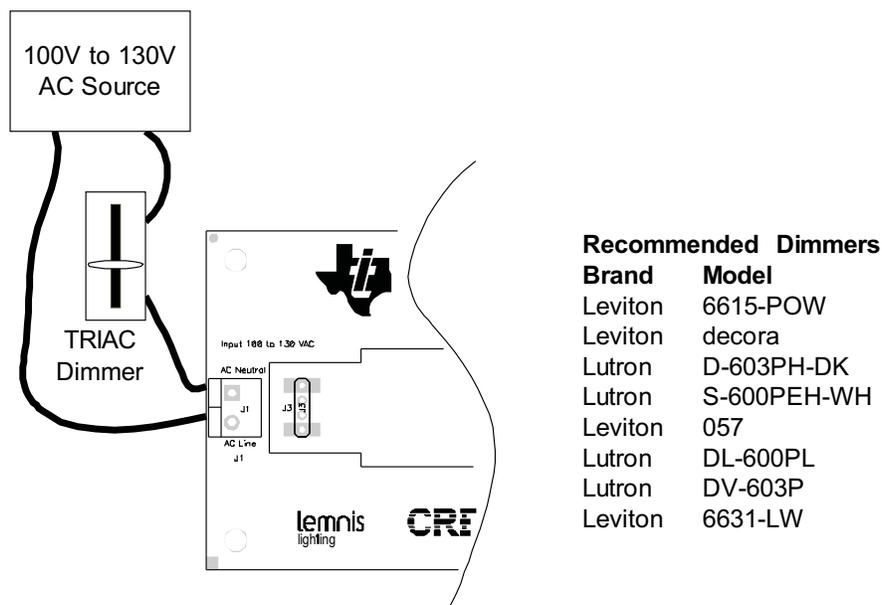


Figure 6. Recommended Test Set-Up Using TRIAC Dimmer

### 5.4.1 Equipment Start-Up

1. Set up the EVM per [Figure 4](#) or [Figure 5](#).
2. Add TRIAC dimmer to the input as shown in [Figure 6](#).
3. Set AC source to 120 Vrms.
4. Set TRIAC to maximum output.
5. Measure output current.
6. Slowly slide TRIAC dimmer to minimum output.
7. Observe output current reduces.

### 5.4.2 Equipment Shut-Down

1. Turn off AC source.
2. Wait several minutes before handling the EVM.

## 6 Performance Data and Typical Characteristic Curves

Figure 7 through Figure 10 show typical performance curves for the TPS92010EVM-592.

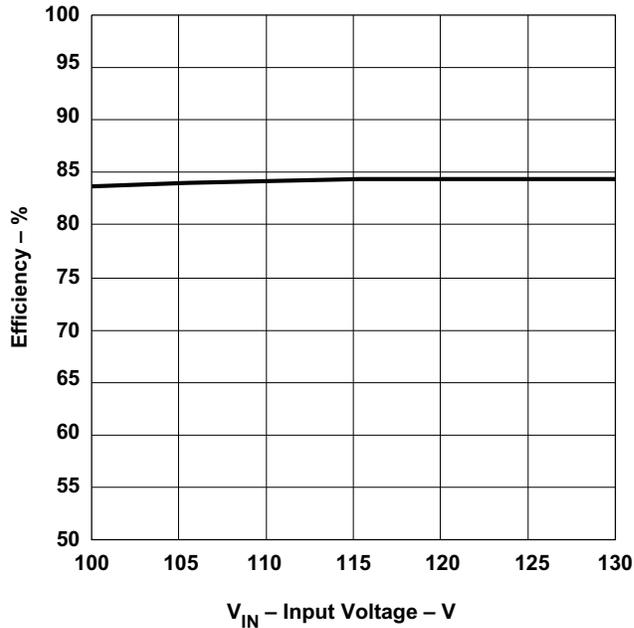


Figure 7. Efficiency vs. Input Voltage

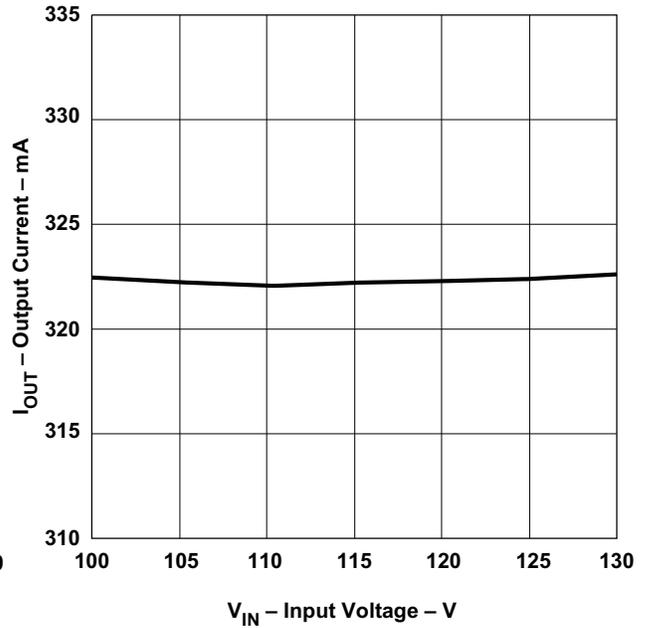


Figure 8. Line Regulation

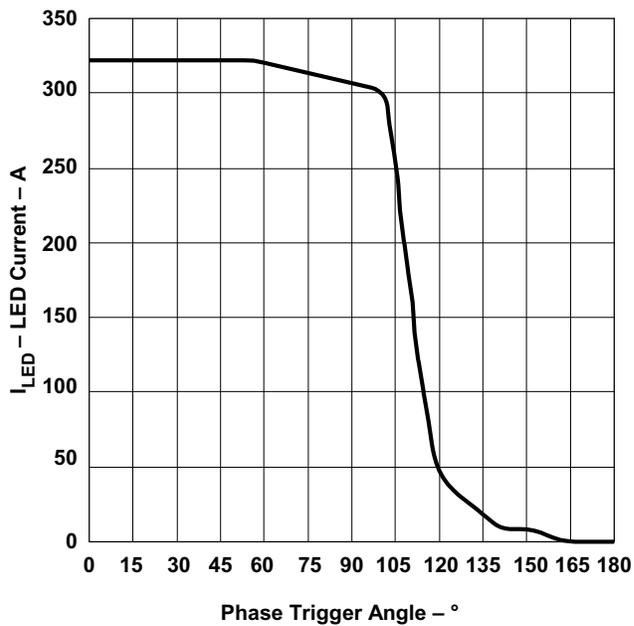


Figure 9. TPS92010EVM-592 Output Current vs Dimmer Phase Angle

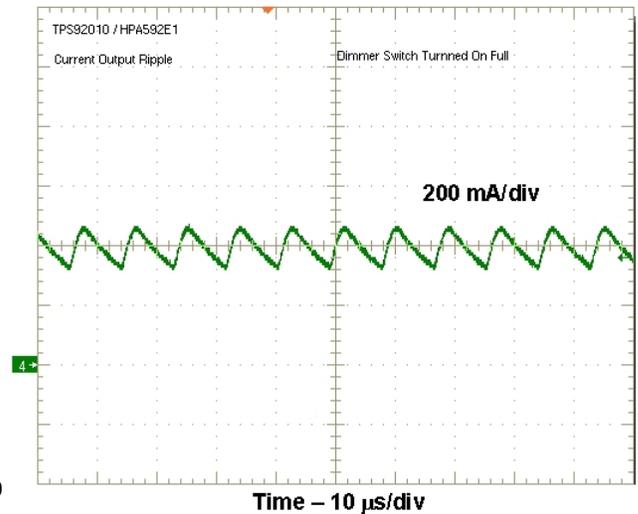


Figure 10. TPS92010EVM-592 Output Current Ripple with Dimmer at 0% Dim

## 7 List of Materials

List of materials for the TPS92010EVM-592.

**Table 3. TPS92010EVM-592 List of Materials**

| REFERENCE DESIGNATOR | QTY | DESCRIPTION  | MANUFAC       | PART NUMBER      |
|----------------------|-----|--|---------------|------------------|
| C1, C6, C13          | 3   | Capacitor, ceramic, 1 $\mu$ F, 100 V, X7R, 10%, 1210             | Std           | Std              |
| C2, C3, C5           | 3   | Capacitor, ceramic, 1 nF, 50 V, X7R, 10%, 0402                   | Std           | Std              |
| C4                   | 1   | Capacitor, ceramic, 330 pF, 50 V, X7R, 10%, 0402                 | Std           | Std              |
| C7                   | 1   | Capacitor, ceramic, 47 pF, 50 V, COG, 5%, 0402                   | Std           | Std              |
| C8                   | 1   | Capacitor, ceramic, 1 $\mu$ F, 25 V, X7R, 10%, 0805              | Std           | Std              |
| C9                   | 1   | Capacitor, ceramic, 100 pF, 50 V, COG, 5%, 0402                  | Std           | Std              |
| C10                  | 1   | Capacitor, ceramic, 22 nF, 100 V, X7R, 10%, 0805                 | Std           | Std              |
| C11, C14, C15        | 3   | Capacitor, ceramic, 0.1 $\mu$ F, 16 V, X5R, 10%, 0402            | Std           | Std              |
| C12, C17             | 2   | Capacitor, ceramic, 10 nF, 50 V, X7R, 10%, 0402                  | Std           | Std              |
| C16                  | 1   | Capacitor, ceramic, 220 nF, 16 V, X7R, 10%, 0603                 | Std           | Std              |
| C18, C19             | 2   | Capacitor, Aluminum, 4.7 $\mu$ F, $\pm$ 20%, 250V, , 8 x 11.5 mm | Rubycon       | 250BXC4.7M8X11.5 |
| C20                  | 1   | Capacitor, ceramic, 1 nF, X1Y2, 5kV, X7R, 10%, 1808              | Std           | Std              |
| C21                  | 1   | Capacitor, ceramic, 100 pF, 1000 V, COG, 5%, 1206                | Std           | Std              |
| C22                  | 1   | Capacitor, ceramic, 0.1 $\mu$ F, 100 V, X5R, 10%, 0402           | Std           | Std              |
| C23                  | 1   | Capacitor, ceramic, 100 nF, 50 V, X7R, 10%, 0603                 | Std           | Std              |
| D1, D3               | 2   | Diode, bridge rectifier, 0.5 A, x 00 V                           | Fairchild     | MB6S             |
| D2                   | 1   | Diode, dual , 250-mA, 70 V                                       | Vishay-Liteon | BAW56GS08        |
| D4                   | 1   | Diode, Schottky, 2-A, 60-V                                       | STD           | STD              |
| L1                   | 1   | Inductor, common choke, $\pm$ 10%                                | Würth         | 750310784        |
| L2                   | 1   | Xfmr, flyback  | Würth         | 750310787        |
| Q2                   | 1   | MOSFET, N-channel, 800 V, 2.0 A, 2.7 $\Omega$                    | Infineon      | SPD02N80C3       |
| Q3                   | 1   | MOSFET, N-channel, 60 V, 115 mA, 1.2 $\Omega$                    | Diodes        | 2N7002           |
| Q4                   | 1   | Transistor, NPN  | Diodes        | FMMT458TA        |
| Q5, Q6               | 2   | Transistor, NPN  | Std           | BC817-25         |
| R1                   | 1   | Resistor, chip, 470 k $\Omega$ , 1/16W, 1%, 0402                 | Std           | Std              |
| R10                  | 1   | Resistor, chip, 560 $\Omega$ , 1/16W, 1%, 0402                   | Std           | Std              |
| R12                  | 1   | Resistor, chip, 1.0 $\Omega$ k, 1/16W, 5%, 0402                  | Std           | Std              |
| R13                  | 1   | Resistor, chip, 33.0 k $\Omega$ , 1/16W, 1%, 0402                | Std           | Std              |
| R14, R117            | 2   | Resistor, chip, 4.70 k $\Omega$ , 1/16W, 1%, 0402                | Std           | Std              |
| R15                  | 1   | Resistor, chip, 1.50 k $\Omega$ , 1/16W, 1%, 0402                | Std           | Std              |
| R16                  | 1   | Resistor, chip, 4.7 $\Omega$ , 1/16W, 5%, 0402                   | Std           | Std              |
| R17                  | 1   | Resistor, chip, 330 $\Omega$ , 1/16W, 1%, 0402                   | Std           | Std              |
| R18                  | 1   | Resistor, chip, 68 k $\Omega$ , 1/16W, 5%, 0402                  | Std           | Std              |
| R2, R31              | 2   | Resistor, chip, 270 k $\Omega$ , 1/4W, 5%, 1206                  | Std           | Std              |
| R20                  | 1   | Resistor, chip, 0.39 $\Omega$ , 1/10W, 1%, 0805                  | Std           | Std              |
| R21, R22             | 2   | Resistor, chip, 3.30 M $\Omega$ , 1/10W, 1%, 0805                | Std           | Std              |
| R23, R24             | 2   | Resistor, chip, 4.70 M $\Omega$ , 1/4W, 1%, 1206                 | Std           | Std              |
| R25, R26, R37, R38   | 4   | Resistor, chip, 1.00 M $\Omega$ , 1/16W, 1%, 0402                | Std           | Std              |
| R27                  | 1   | Resistor, chip, 2.49 k $\Omega$ , 1/16W, 1%, 0402                | Std           | Std              |
| R28                  | 1   | Resistor, chip, 27 $\Omega$ , 1/16W, 5%, 0603                    | Std           | Std              |
| R29                  | 1   | Resistor, chip, 4.70 k $\Omega$ , 1/16W, 1%, 0603                | Std           | Std              |
| R3, R19              | 2   | Resistor, chip, 8.20 k $\Omega$ , 1/16W, 1%, 0402                | Std           | Std              |
| R30                  | 1   | Resistor, chip, 22.0 k $\Omega$ , 1/16W, 1%, 0402                | Std           | Std              |

**Table 3. TPS92010EVM-592 List of Materials (continued)**

| REFERENCE DESIGNATOR  | QTY | DESCRIPTION  | MANUFAC | PART NUMBER          |
|-----------------------|-----|--|---------|----------------------|
| R32, R33              | 2   | Resistor, chip, 3.3 M $\Omega$ , 1/4W, 5%, 1206            | Std     | Std                  |
| R34                   | 1   | Resistor, chip, 100 k $\Omega$ , 1/16W, 1%, 0603           | Std     | Std                  |
| R7, R35               | 2   | Resistor, chip, 470 k $\Omega$ , 1/4W, 5%, 1206            | Std     | Std                  |
| R36                   | 1   | Resistor, chip, 270 k $\Omega$ , 1/16W, 1%, 0402           | Std     | Std                  |
| R39                   | 1   | Resistor, chip, 47.0 k $\Omega$ , 1/4W, 1%, 1206           | Std     | Std                  |
| R4, R9                | 2   | Resistor, chip, 2.70k, 1/16W, 1%, 0402                     | Std     | Std                  |
| R40                   | 1   | Resistor, chip, 220 $\Omega$ , 1/16W, 5%, 0603             | Std     | Std                  |
| R41                   | 1   | Resistor, chip, 1.20 M $\Omega$ , 1/16W, 1%, 0402          | Std     | Std                  |
| R42                   | 1   | Resistor, chip, 1.50 M $\Omega$ , 1/16W, 1%, 0402          | Std     | Std                  |
| R43                   | 1   | Resistor, chip, 39.0 k $\Omega$ , 1/16W, 1%, 0402          | Std     | Std                  |
| R5, R11               | 2   | Resistor, chip, 10.0 k $\Omega$ , 1/16W, 1%, 0402          | Std     | Std                  |
| R6                    | 1   | Resistor, chip, 12.0 k $\Omega$ , 1/16W, 1%, 0402          | Std     | Std                  |
| R8                    | 1   | Resistor, chip, 3.3 $\Omega$ , 1/16W, 5%, 0603             | Std     | Std                  |
| SIOV1                 | 1   | Varistor, disk, 150 V, 1W, TA @ 85C°                       | Epcos   | SIOV-S05K150         |
| U1                    | 1   | IC, dual operational amplifiers                            | TI      | LM358AD              |
| U2                    | 1   | Diode, adjustable shunt regulator, 2.49 V to 36 V, 20 mA   | TI      | TL431A               |
| U3                    | 1   | IC, high-isolation voltage photocoupler                    | CEL     | PS2801C-1-A          |
| U4                    | 1   | IC, 8-pin high-efficiency, offline LED lighting controller | TI      | TPS92010             |
| --                    | 1   | PCB, 60 mm x 20.6 mm x 1.62 mm                             | Any     | HPA594               |
| <b>LOAD MATERIALS</b> |     |  |         |                      |
| D1, D2, D3, D4, D5    | 5   | HB-LED, 0.7 A (maximum), 3.9 Vdc                           | Cree    | XPEWHT-L1-0000-00BE7 |

## 8 References

TPS92010 Datasheet, High Efficiency Offline LED Lighting Driver Controller ([SLUSA14](#))

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