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HV9805
$230V_{AC}$ Off-Line LED Driver
Evaluation Board
User's Guide

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Object of Declaration: HV9805 230V_{AC} Off-Line LED Driver Evaluation Board

EU Declaration of Conformity

Manufacturer: Microchip Technology Inc.
2355 W. Chandler Blvd.
Chandler, Arizona, 85224-6199
USA

This declaration of conformity is issued by the manufacturer.

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Signed for and on behalf of Microchip Technology Inc. at Chandler, Arizona, USA

Derek Carlson
VP Development Tools

12-Sep-14
Date

NOTES:

Table of Contents

NOTES:

Preface

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Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXXXXA", where "XXXXXXXX" is the document number and "A" is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the HV9805 230V$_{AC}$ Off-Line LED Driver Evaluation Board. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Recommended Reading
- The Microchip Web Site
- Customer Support
- Revision History

DOCUMENT LAYOUT

This document describes how to use the HV9805 230V$_{AC}$ Off-Line LED Driver Evaluation Board as a development tool for specific applications driven by HV9805. The document is organized as follows:

- **Chapter 1. "Product Overview"** – Important information about the HV9805 230V$_{AC}$ Off-Line LED Driver Evaluation Board.
- **Chapter 2. "Installation and Operation"** – Includes instructions on how to get started with this user's guide and a description of the user's guide.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the HV9805 230V$_{AC}$ Off-Line LED Driver Evaluation Board.
- **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the HV9805 230V$_{AC}$ Off-Line LED Driver Evaluation Board.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

<table>
<tr><th>Description</th><th>Represents</th><th>Examples</th></tr>
<tr><td colspan="3">Arial font:</td></tr>
<tr><td rowspan="2">Italic characters</td><td>Referenced books</td><td>MPLAB® IDE User's Guide</td></tr>
<tr><td>Emphasized text</td><td>...is the only compiler...</td></tr>
<tr><td rowspan="3">Initial caps</td><td>A window</td><td>the Output window</td></tr>
<tr><td>A dialog</td><td>the Settings dialog</td></tr>
<tr><td>A menu selection</td><td>select Enable Programmer</td></tr>
<tr><td>Quotes</td><td>A field name in a window or dialog</td><td>"Save project before build"</td></tr>
<tr><td>Underlined, italic text with right angle bracket</td><td>A menu path</td><td><u>File>Save</u></td></tr>
<tr><td rowspan="2">Bold characters</td><td>A dialog button</td><td>Click OK</td></tr>
<tr><td>A tab</td><td>Click the Power tab</td></tr>
<tr><td>N'Rnnnn</td><td>A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.</td><td>4'b0010, 2'hF1</td></tr>
<tr><td>Text in angle brackets < ></td><td>A key on the keyboard</td><td>Press <Enter>, <F1></td></tr>
<tr><td colspan="3">Courier New font:</td></tr>
<tr><td rowspan="7">Plain Courier New</td><td>Sample source code</td><td><code>#define START</code></td></tr>
<tr><td>Filenames</td><td><code>autoexec.bat</code></td></tr>
<tr><td>File paths</td><td><code>c:\mcc18\h</code></td></tr>
<tr><td>Keywords</td><td><code>_asm, _endasm, static</code></td></tr>
<tr><td>Command-line options</td><td><code>-Opa+, -Opa-</code></td></tr>
<tr><td>Bit values</td><td><code>0, 1</code></td></tr>
<tr><td>Constants</td><td><code>0xFF, 'A'</code></td></tr>
<tr><td>Italic Courier New</td><td>A variable argument</td><td><code>file.o</code>, where <code>file</code> can be any valid filename</td></tr>
<tr><td>Square brackets [ ]</td><td>Optional arguments</td><td><code>mcc18 [options] file [options]</code></td></tr>
<tr><td>Curly brackets and pipe character: { | }</td><td>Choice of mutually exclusive arguments; an OR selection</td><td><code>errorlevel {0|1}</code></td></tr>
<tr><td rowspan="2">Ellipses...</td><td>Replaces repeated text</td><td><code>var_name [, var_name...]</code></td></tr>
<tr><td>Represents code supplied by user</td><td><code>void main (void)
{ ...
}</code></td></tr>
</table>

RECOMMENDED READING

This user's guide describes how to use HV9805 230V_{AC} Off-Line LED Driver Evaluation Board. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

- **HV9805 Data Sheet – *"Off-Line LED Driver with True DC Output Current"* (DS20005374).**

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- Technical Support

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http://www.microchip.com/support.

REVISION HISTORY

Revision A (March 2015)

This is the initial release of this document.

NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the HV9805 230V_{AC} Off-Line LED Driver Evaluation Board and covers the following topics:

- HV9805 Device Short Overview
- What is the HV9805 230VAC Off-Line LED Driver Evaluation Board?
- What does the HV9805 230VAC Off-Line LED Driver Evaluation Board Include?

1.2 HV9805 DEVICE SHORT OVERVIEW

The HV9805 driver integrated circuit (IC) is targeted at general light-emitting diode (LED) lighting products, such as LED lamps and LED lighting fixtures with a maximum power rating of about 25W at 120V_{AC}, and about 50W at 230V_{AC}.

A two-stage topology provides true constant-current drive for the LED load while drawing mains power with high power factor. The first stage, a boundary conduction mode boost converter, transfers power from the AC line to a second stage, with high power factor and high efficiency.

The second stage, a linear regulator arranged for operation with low overhead voltage, transfers power from the first stage to the LED load with true constant current and protects the LED load from overvoltage that may pass from mains to the output of the first stage.

The IC is particularly geared to drive a high-voltage LED load. An LED load arranged as a high-voltage load is capable of offering cost advantages in terms of heat management and optics.

The boost converter employs a cascode switch for high-speed switching and convenient generation of the V_{DD} supply. The control device of the cascode switch is integrated into the HV9805 and is rated for a peak current of 0.7A.

The current for powering the V_{DD} supply is derived by way of an internal connection to the cascode switch.

Applications which require lower load voltage can be accommodated by adapting the first stage to the SEPIC topology.

1.2.1 HV9805 Device Key Features

- Provides True DC Light and Protects Load from Line Voltage Transients
- Driver Topology Includes:
  - Boundary Conduction Mode (BCM) boost converter with power factor correction
    a) High power factor (0.98 typical)
    b) High efficiency (90% typical)
  - Linear post-regulator with low overhead voltage
    a) Zero LED current/brightness ripple
    b) Overvoltage protection for LEDs
    c) High efficiency
    d) ±4% temperature reference accuracy
- Simple V_{DD} Supply:
  - No auxiliary winding required
- Boost Converter Cascode Switch:
  - Internal switch rated at 700 mA peak
  - Supports up to 25W at 120V_{AC}
  - Supports up to 50W at 230V_{AC}
- Compatibility with SEPIC Topology for Low Output Voltage Applications
- Available Package: 10-Lead MSOP

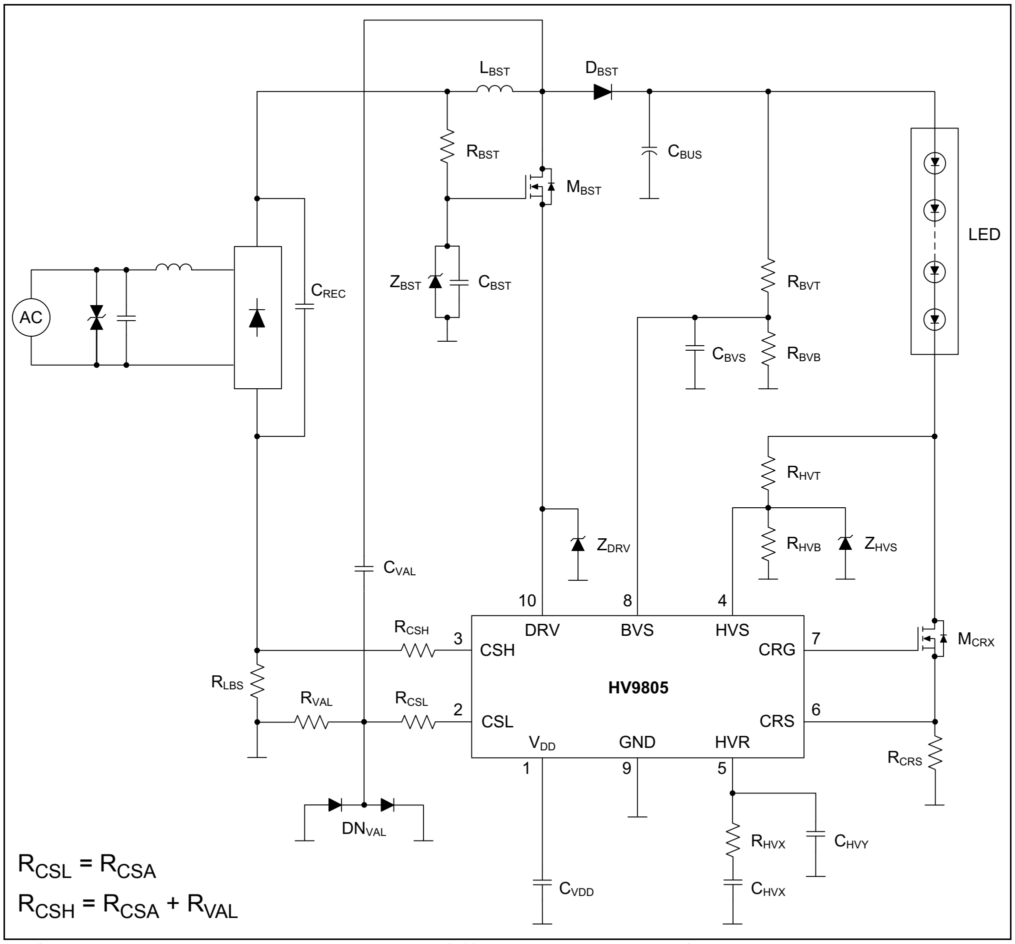

FIGURE 1-1: *Typical HV9805 Off-Line LED Driver Circuit.*

1.2.2 Two-Stage Topology:

The two-stage topology of the HV9805 device consists of:

- Boundary Conduction Mode (BCM) and Power Factor Correction (PFC) Boost Converter
- LED-Side Linear Regulator

1.2.2.1 FIRST STAGE: BCM PFC BOOST CONVERTER

- Produces a DC bus voltage V_{BUS} with high efficiency (95%) with 100 Hz (120 Hz) ripple and slow regulation (10 Hz BW)
- Direct connection of HV LEDs to the bus results in:
  - relatively large LED current ripple
  - direct exposure of LEDs to line voltage transients

1.2.2.2 SECOND STAGE: LINEAR REGULATOR IN SERIES WITH LED LOAD

- Arranged as a constant-current regulator with fast response (>1 kHz)
- LED current is true DC
- LEDs are protected from line overvoltage
- Linear regulator lowers efficiency about 2%
- Continuous Current Regulator (CCR) maintains the headroom voltage V_{HDR} at a small value (~ 6V)
- Uses smaller electrolytic capacitors possible (efficiency versus cost trade-off)
- Smooth DC LED current, CCR rejects the larger bus voltage ripple

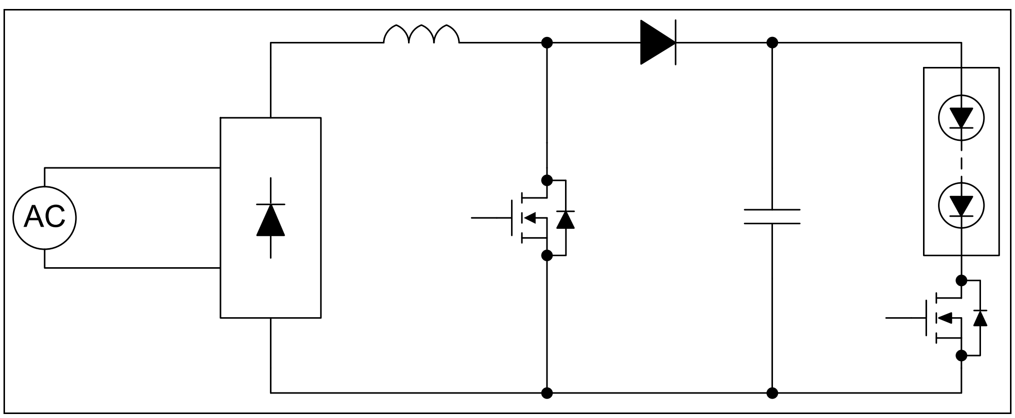

FIGURE 1-2: *Principle Diagram Two-Stage Topology.*

1.3 WHAT IS THE HV9805 230V_{AC} OFF-LINE LED DRIVER EVALUATION BOARD?

The HV9805 230V_{AC} Off-Line LED Driver Evaluation Board is used to evaluate and demonstrate Microchip Technology Inc.'s HV9805 device in the following topology:

- 420-430V output Boost Converter application followed by a LED-side linear current regulator, supplied from the mains 230V_{AC}, to drive a 130-150 LED string.

The HV9805 230V_{AC} Off-Line LED Driver Evaluation Board was developed to help engineers reduce the product design cycle time.

1.4 WHAT DOES THE HV9805 230V_{AC} OFF-LINE LED DRIVER EVALUATION BOARD INCLUDE?

The HV9805 230V_{AC} Off-Line LED Driver Evaluation Board kit includes:

- HV9805 230V_{AC} Off-Line LED Driver Evaluation Board (ADM00657)
- Information Sheet

Chapter 2. Installation and Operation

2.1 INTRODUCTION

The HV9805 control IC provides true current drive for LED lamps and fixtures by way of a simple two-stage power supply topology comprised of a boundary mode (BCM) boost converter and a linear constant-current regulator. The constant-current regulator removes the influence of bus voltage variation on the LED load operating and current, and protects the LED load from potentially damaging transients that may originate from mains overvoltage events. The IC is targeted at designs operating at a single line voltage, such as 120V$_{AC}$ or 230V$_{AC}$, and thus, does not support designs for the universal input voltage range. The efficiency of the constant-current regulator is maximized by minimizing the DC component of the headroom voltage.

The main sections of the application are presented in the following chapters.

2.1.1 Board Features

The HV9805 230V$_{AC}$ Off-Line LED Driver Evaluation Board has the following features:

- Input Voltage: 230V$_{AC}$ ±15%, at 50 Hz Typical
- Output Capability: up to 125 mA
- Efficiency: over 90%
- Pulse-Width Modulation (PWM) Operation: up to 135 kHz

2.2 GETTING STARTED

The HV9805 230V$_{AC}$ Off-Line LED Driver Evaluation Board is fully assembled and tested to evaluate and demonstrate the HV9805 LED driver.

2.2.1 Powering the HV9805 230V$_{AC}$ Off-Line LED Driver Evaluation Board

The board is connected directly to 230V$_{AC}$. A variable AC power supply is needed for testing and evaluation in the laboratory. The power supply requires an output capability of at least 1A and a voltage range of 100 to 280V$_{AC}$. This can be obtained from an autotransformer supplied from the mains or an electronic AC/AC power supply (for example, Chroma ATE Inc.'s 61500 series).

The power connectors are the following:

- The input connectors, J1 and J2, are placed on the left side of the board and marked 230V$_{AC}$, as shown in Figure 2-1.
- The output connectors, J3 and J4, are called LED+ and LED- and are placed on the right side of the board.

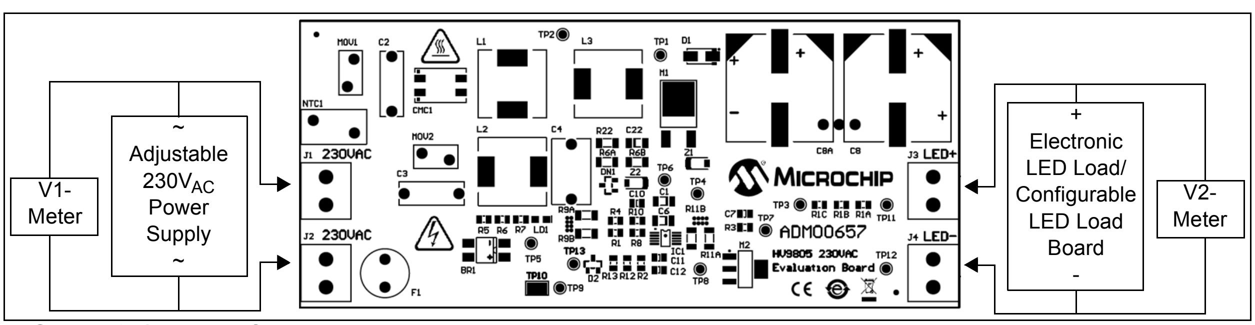

FIGURE 2-1: Connection Diagram.

To power the board, follow these steps:

1. Connect the power at terminals J1, 230V_{AC}~ and J2, 230V_{AC}~.
2. Connect a voltmeter and the LED string at J3 (V+ LED) and J4 (V- LED) connectors, as shown in Figure 2-1. The LED string can be formed with 132 to 150 LED cells (3 LEDs in parallel), 80 mA SMD LED, 280 mW. An example is shown in Figure 2-2.

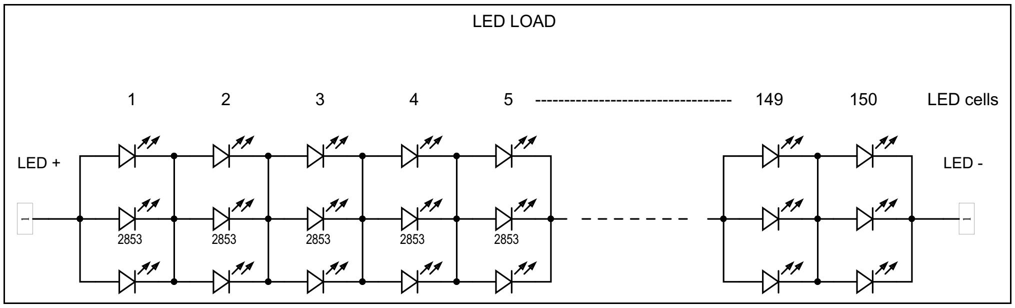

FIGURE 2-2: *LED Load String Example.*

2.3 HOW DOES THE HV9805 230V$_{AC}$ OFF-LINE LED DRIVER EVALUATION BOARD WORK?

The board was designed to supply, by means of a common-mode filter, a rectifier; a boost converter followed by a linear regulator, both conducted by the HV9805 driver directly from the 230V_{AC} mains; and an LED load; with constant current also controlling the power factor. The topology used in this evaluation board is a Boundary Conduction Mode (BCM) boost converter followed by a linear current regulator on the LED side in order to assure true current and high efficiency.

The HV9805 device has the following regulators:

- The V_{DD} regulator, which is inside the chip (only the filter capacitor is outside)
- The LED current regulator
- The headroom voltage regulator
- The line current waveform regulator

The LED current can be programmed using Equation 2-1.

EQUATION 2-1: SENSE RESISTORS RELATIONSHIP

$$V_{REF}, CCR = I_{LED} \times R_{CRS}$$

Where:

V_{REF}, CCR	=	1.0V (at 100% current level)
I_{LED}	=	LED current
R_{CRS}	=	Resistor's value is selected by the designer

EXAMPLE 2-1:

If:	I_{LED}	=	$90\ mA$
Then:	R_{CRS}	=	11.11Ω
Choose:	$R11A$	=	$R11B = 22\Omega = 2 \times R_{CRS}$

The headroom voltage is programmed to the desired level using Equation 2-2.

EQUATION 2-2: THE DESIRED DC LEVEL OF HEADROOM VOLTAGE

$$V_{REF},HVR = V_{HDC} \times K_{DIV}$$

$$K_{DIV} = \frac{R_{HVB}}{R_{HVB} + R_{HVT}}$$

Where:

$V_{REF,}$ HVR	=	1.25V
V_{HDC}	=	DC level of the headroom voltage
K_{DIV}	=	Attenuation of the headroom voltage divider
$R_{HVT,}$ R_{HVB}	=	Top and bottom resistor of the headroom voltage divider

EXAMPLE 2-2:

For:	V_{HDC}	=	$7.5V$
Then:	K_{DIV}	=	$1.25/7.5 = 0.166$
Therefore:	R_{HVT}/R_{HVB}	=	5.0
Then:	R_{HVB}	=	$10\ k\Omega$
Choose:	R_{HVT}	=	$50\ k\Omega$

The DC level of the bus voltage is regulated to be the total sum of the DC level of the headroom voltage and the operating voltage of the LED load, and will thereby vary during operation with changes in the forward voltage of the LED load.

EXAMPLE 2-3:

If a 140 LED string is used, a forward voltage drop of 3V on each LED is assumed. Then, the Bus Voltage level will be:

$$V_{DC} = 140 \times 3 + V_{HDC} = 420 + 7.5 = 427.5V_{DC}$$

Note: In order to have a good Valley detection, choose an LED string voltage 20-30V greater than the peak input voltage (which is usually 264V_{AC}). In this condition, the minimum LED load voltage is
$V_{LED\ MIN}$ = 20 + 1.41 × 264 = 392V_{DC}

The power dissipation of the LED current regulator must be low, so the DC level of the headroom voltage (V_{HDC}) will be minimized, the dissipation being calculated using Equation 2-3.

EQUATION 2-3: THE POWER DISSIPATION OF THE LED CURRENT REGULATOR

$$P_{DIS} = I_{LED} \times V_{HDC}$$

Where:

P_{DIS}	=	Power dissipation of the current LED regulator
I_{LED}	=	LED current
V_{HDC}	=	DC level of the headroom voltage

P_{DIS} = 0.090A × 7.5V= 0.675W

The output voltage of the control amplifier provides the on-time reference for the boost converter control circuitry, according to Equation 2-4.

EQUATION 2-4: THE ON-TIME REFERENCE FOR THE BOOST CONVERTER CONTROL (T_{ON})

$$T_{ON} = K_{HVR} \times V_{HVR}$$

Where:

T_{ON}	=	On-time reference signal from the headroom voltage regulator
K_{HVR}	=	On-time modulator gain
V_{HVR}	=	5V
K_{HVR}	=	2.2 µs/V
T_{ON}	=	5 × 2.2 µs = 11 µs

2.4 BOARD TESTING, TEST POINTS WAVEFORMS AND OVERALL MEASURED PARAMETERS

2.4.1 Board Testing

To start testing the evaluation board, follow these steps:

1. Power the board at 230V$_{AC}$.
2. Check that the voltmeter indicates the LED load voltage (do not exceed 440V$_{DC}$).
3. With a power supply of 230V$_{AC}$, verify if the current regulated through the LED strings is about 90 mA (by means of an ampere-meter connected in series with the LEDs).

The following steps are possible if a variable AC power supply or an autotransformer is available:

4. Set the power supply to 190V$_{AC}$ and verify if the output current on the LED side stays regulated (I_{OUT} ~90 mA).
5. Set the power supply to 270V$_{AC}$ and verify if the output current on the LED side stays regulated (I_{OUT} ~90 mA). Also, check that the voltage stays regulated on V2 near the value 415V.

2.4.2 Test Points Waveforms

The board has several test points that help engineers to analyze the switch node's waveforms of HV9805 device output:

TABLE 2-1: TEST POINTS

Test Point	Description
TP1	Boost inductor (L3) voltage
TP2	Rectified line voltage V_{DC}
TP3	Bus voltage sense (BVS pin voltage)
TP4 (SW)	Voltage on switching node (DRV pin) of the HV9805 device
TP5	Inductor current sense voltage
TP6	V_{DD} voltage on IC (V_{DD} pin voltage), (6.5 to 8V)
TP7	Gate control voltage (CRG pin) of the linear regulator
TP8	LED current sense (CRS pin)
TP10	GND
TP11 – TP12	LED string voltage
TP13	High-voltage sense (HVS pin voltage)

The regulated headroom voltage is approximately 8V in order to reduce the losses on the linear regulator.

The signal waveforms from the significant points of the design are presented in Figures 2-3 – 2-11.

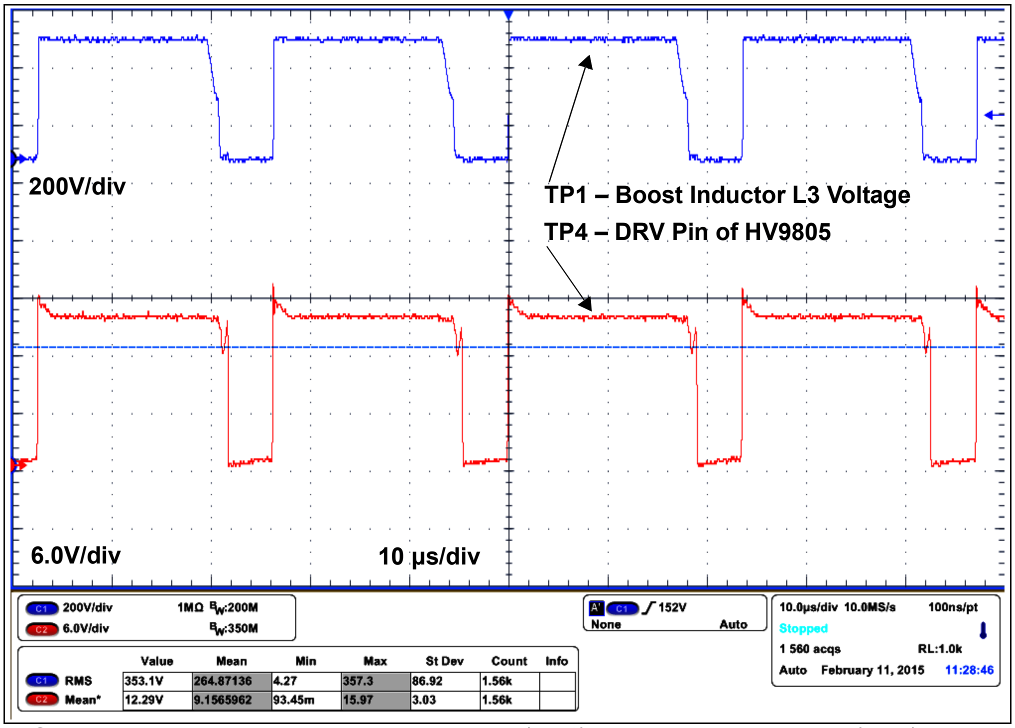

FIGURE 2-3: *Boost Inductor Voltage (TP1) and DRV Pin Voltage (TP4), Working on the Lower Side of the Sinus Wave Input Voltage.*

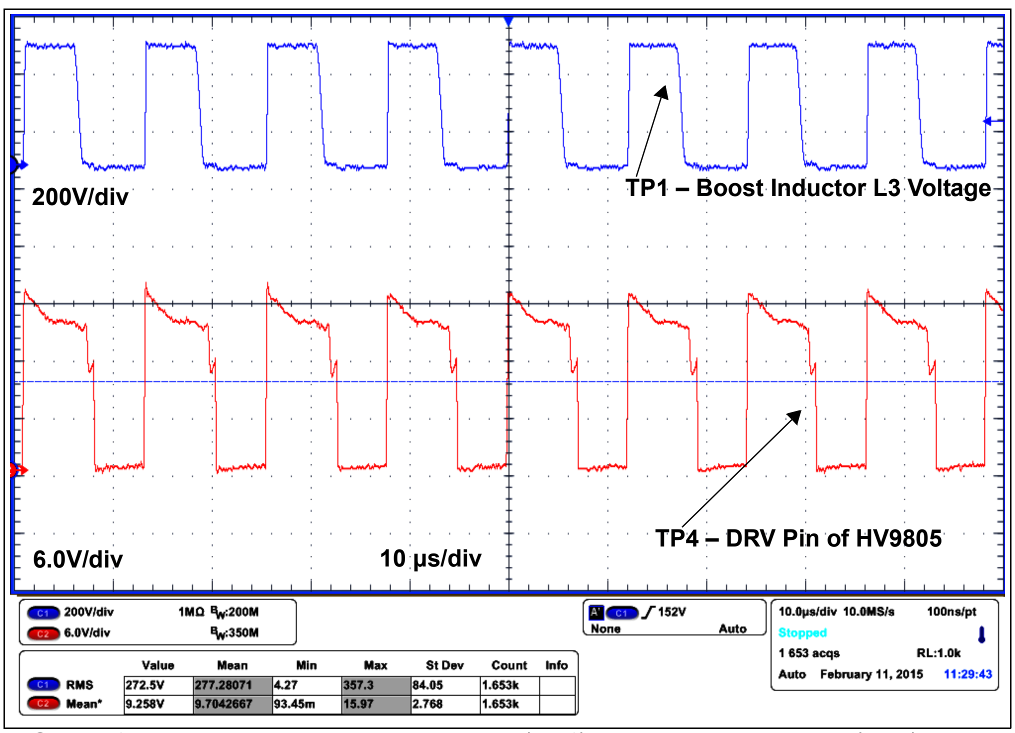

FIGURE 2-4: *Boost Inductor Voltage (TP1) and DRV Pin Voltage (TP4), Working on the Upper Side of the Sinus Wave Input Voltage.*

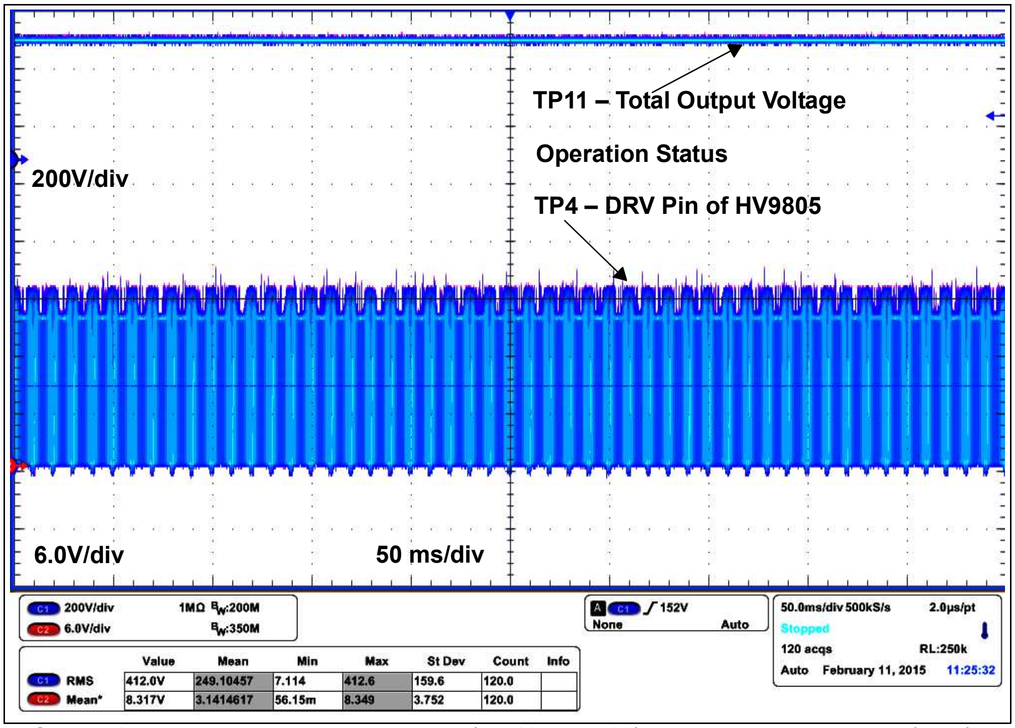

FIGURE 2-5: LED Load Voltage (TP12 – TP13) and DRV Pin Voltage (TP4) in Operation Mode.

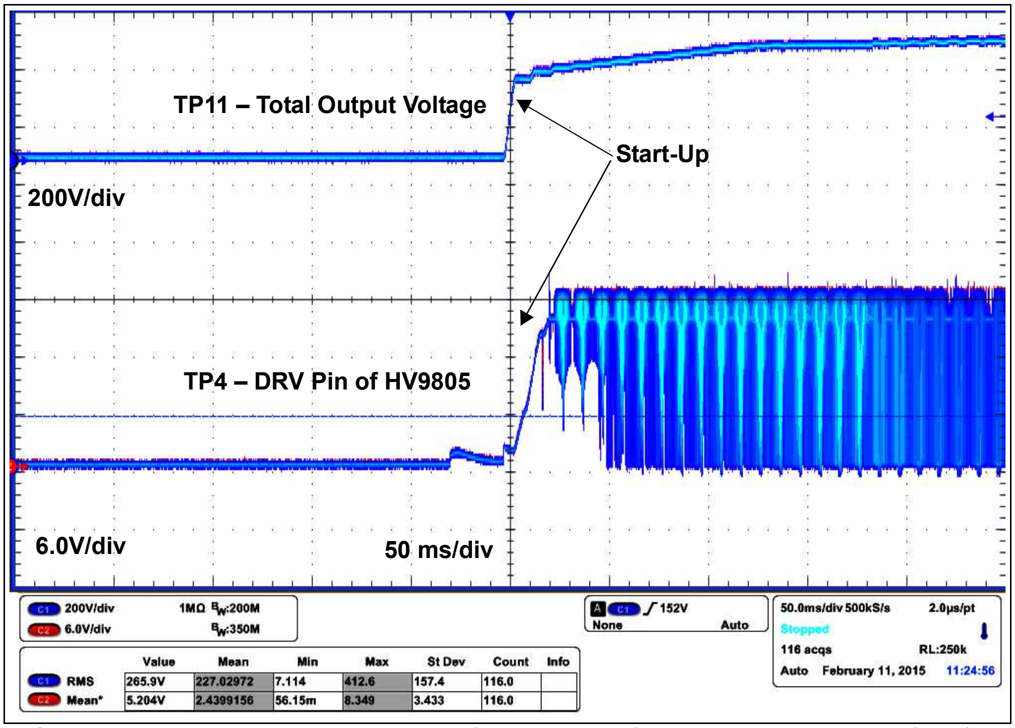

FIGURE 2-6: LED Load Voltage (TP12 – TP13) and DRV Pin Voltage (TP4) in Start-up Mode.

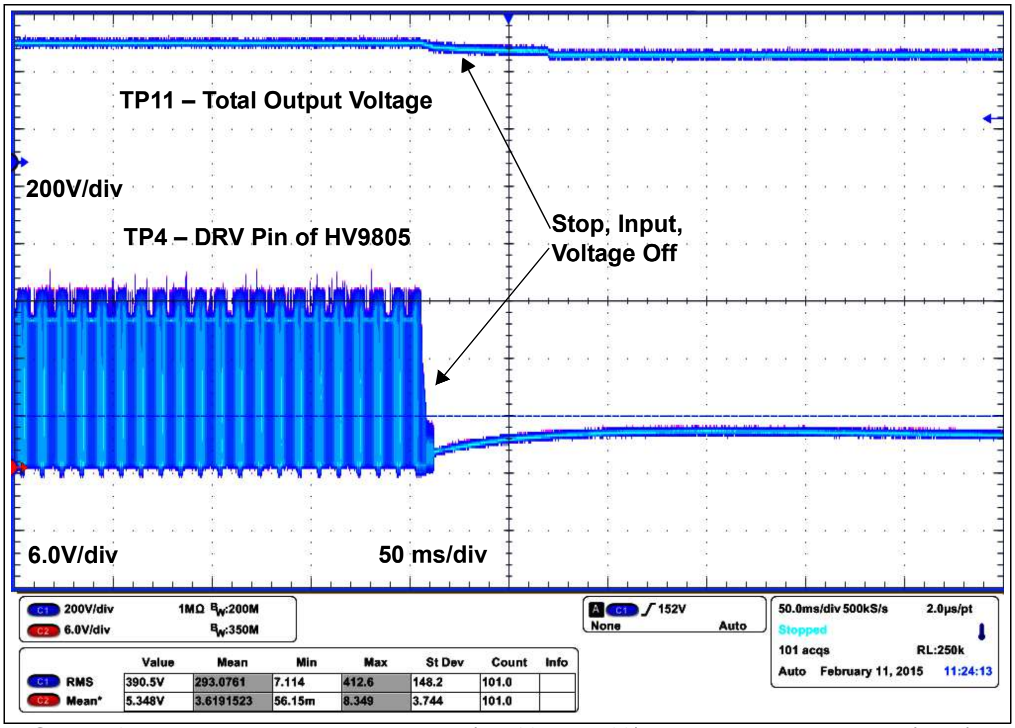

FIGURE 2-7: LED Load Voltage (TP12 – TP13) and DRV Pin Voltage (TP4) in Stop Mode.

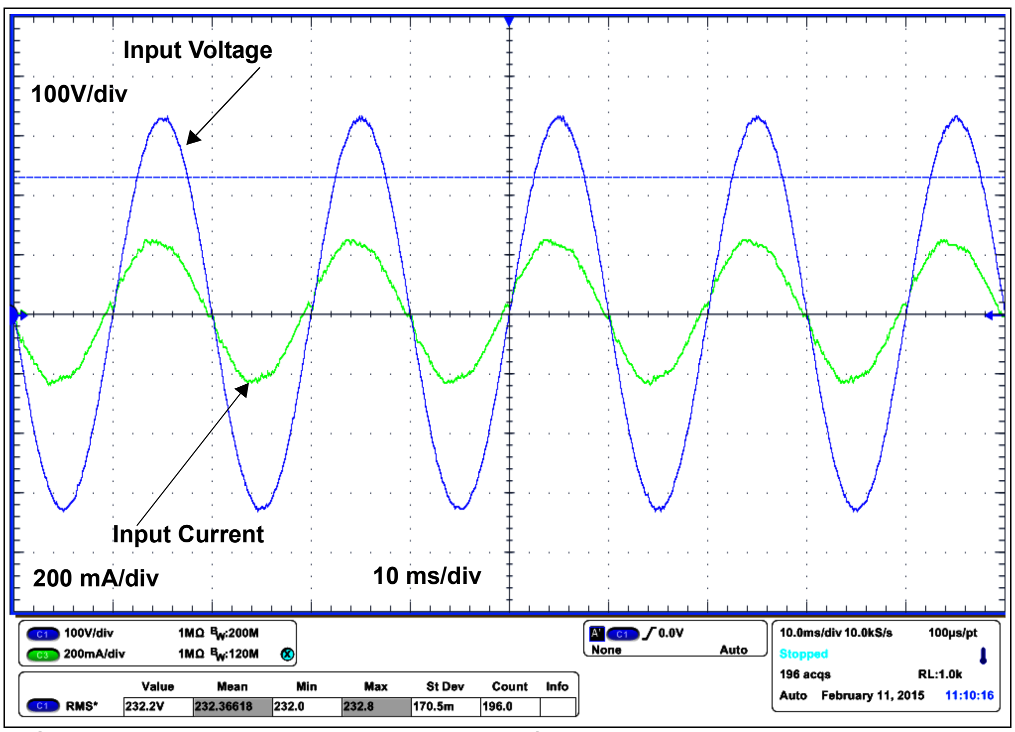

FIGURE 2-8: Input Voltage and Input Current, Phase Look.

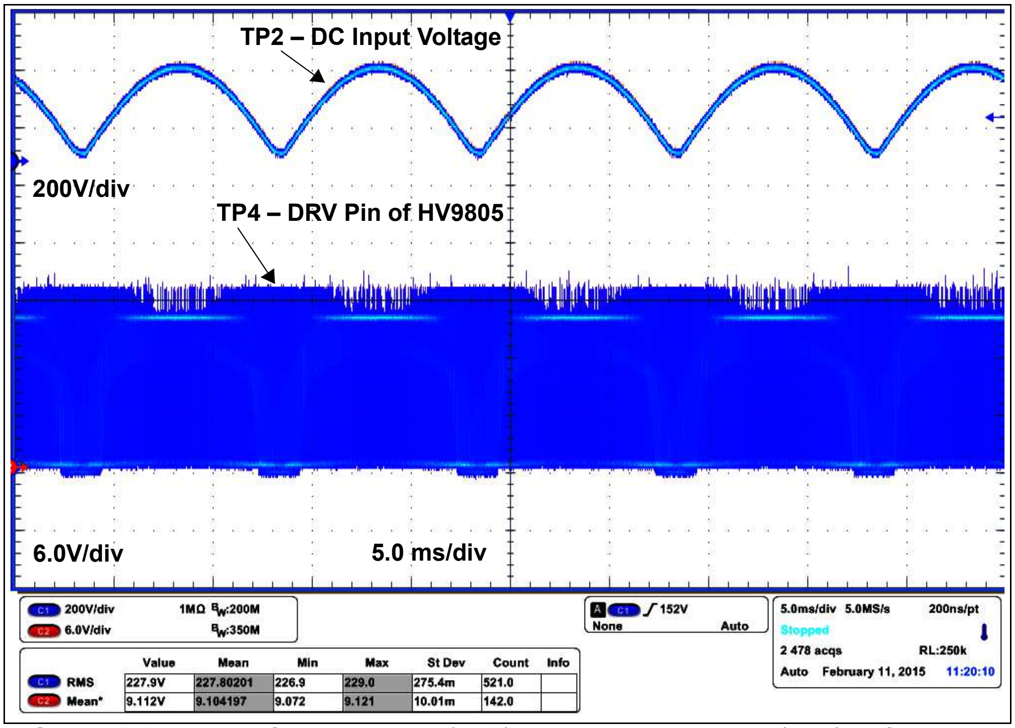

FIGURE 2-9: DC Line Voltage (TP2) and DRV Pin Voltage (TP4) in Operation Mode.

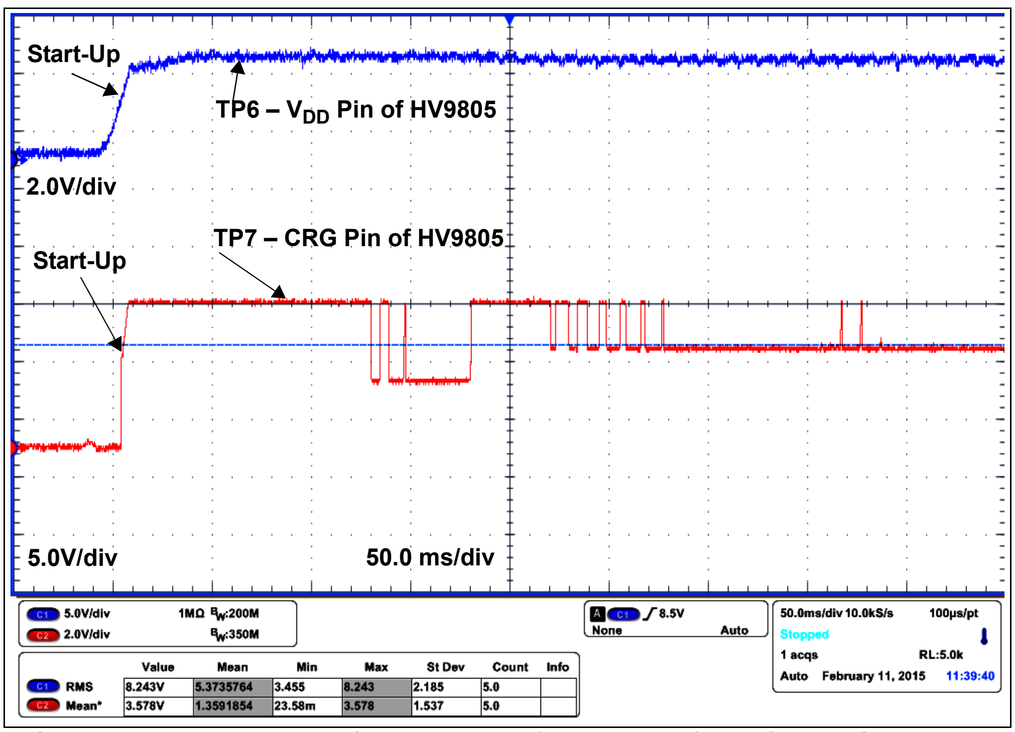

FIGURE 2-10: HV9805 Supply Voltage (V$_{DD}$ pin, TP6) and Control Gate Voltage (TP7 CRG PIN) at Start-up Mode.

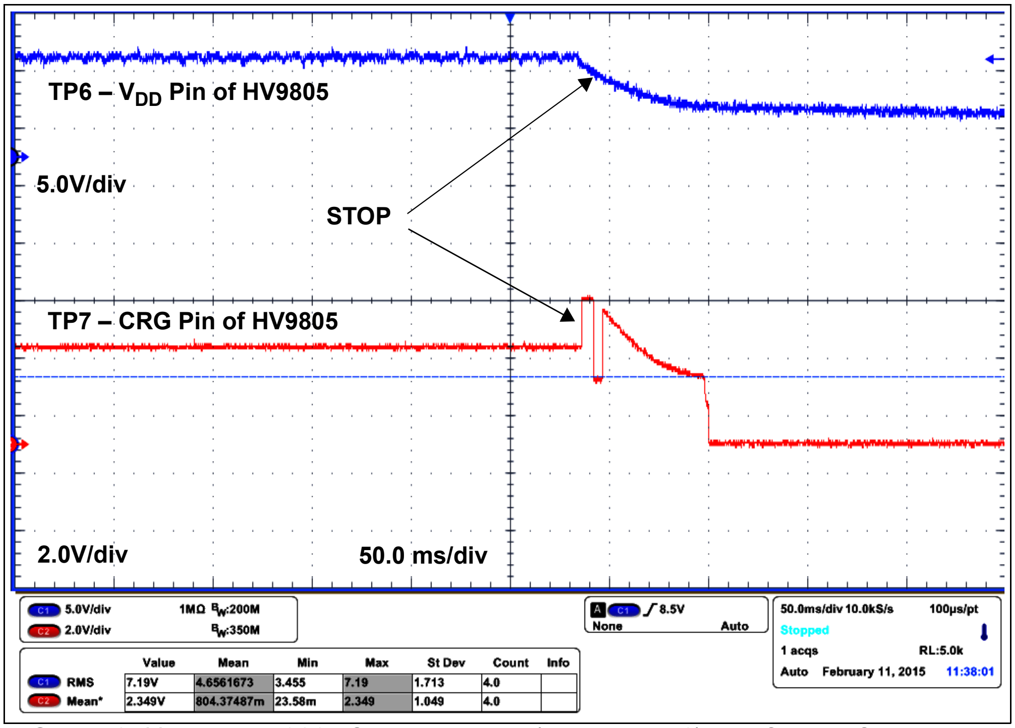

FIGURE 2-11: HV9805 Supply Voltage (V_{DD} pin, TP6) and Control Gate Voltage (TP7 CRG PIN) at Stop Mode.

2.4.3 Overall Measured Parameters

The overall parameters of the evaluation board are presented in the Figures 2-12 – 2-16.

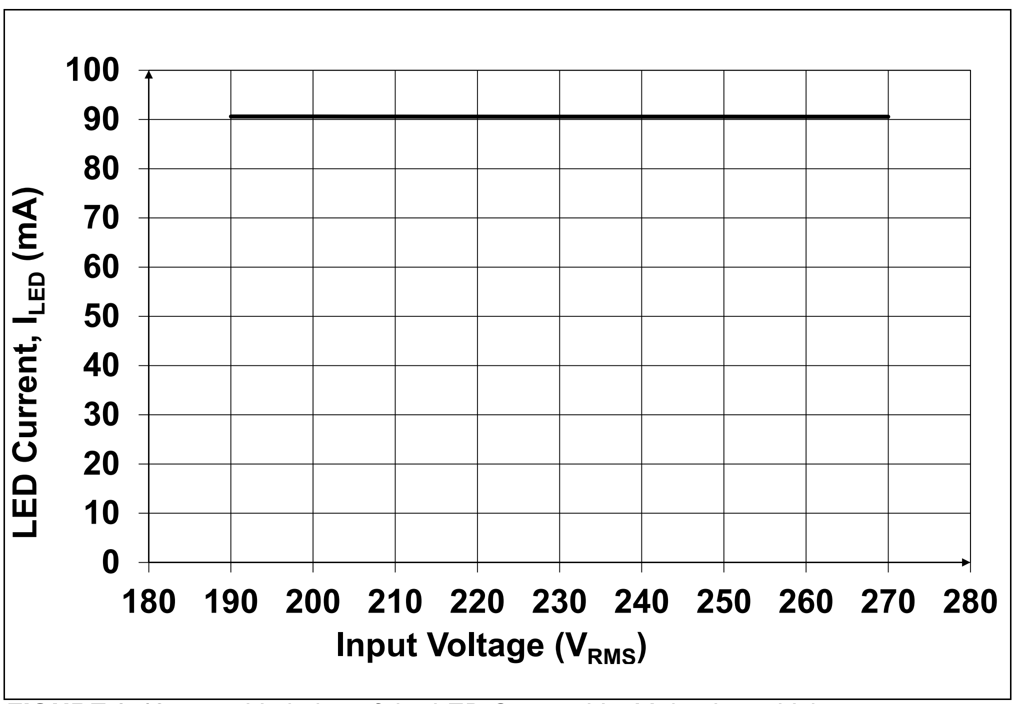

FIGURE 2-12: Variation of the LED Current Vs. Mains Input Voltage.

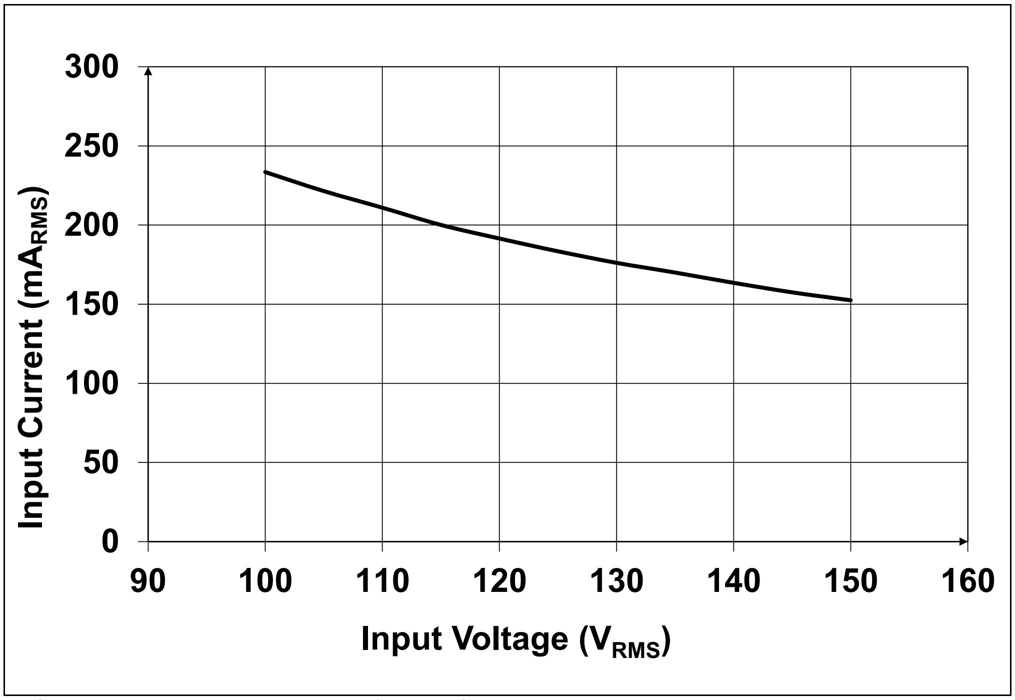

FIGURE 2-13: *Variation of Input Current and Input Voltage.*

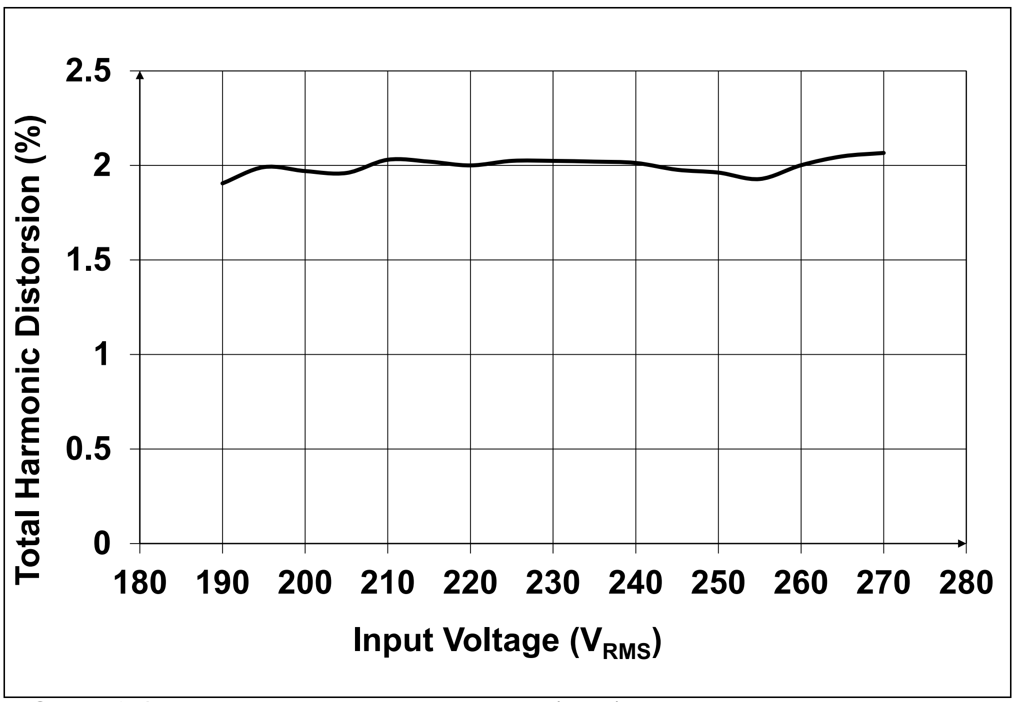

FIGURE 2-14: *Total Harmonic Distortion (THD) and Input Voltage.*

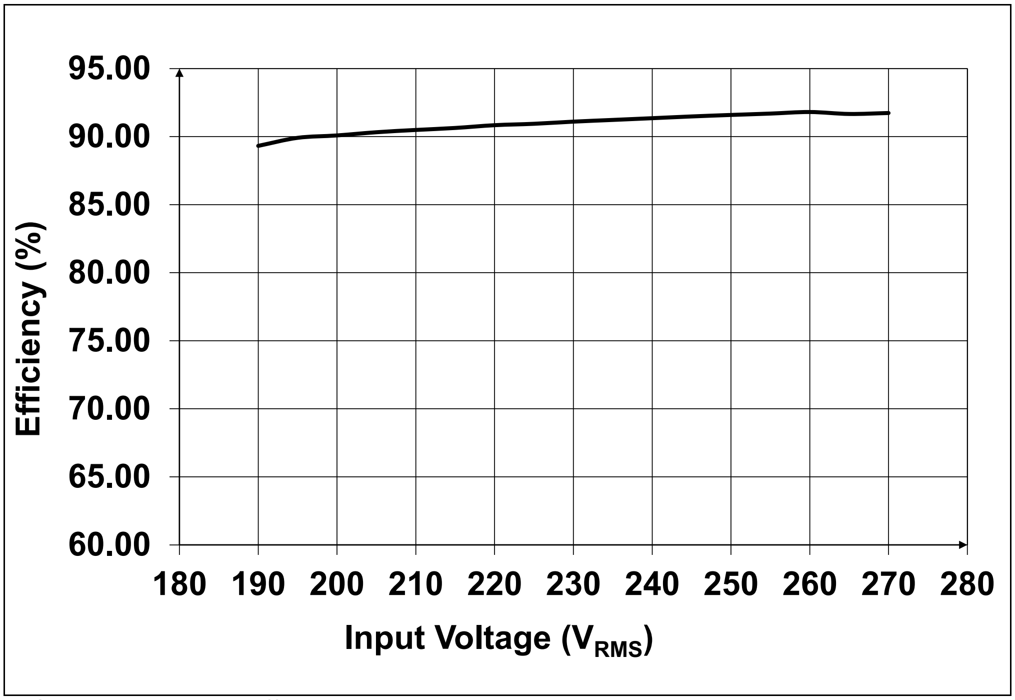

FIGURE 2-15: Efficiency and Input Voltage.

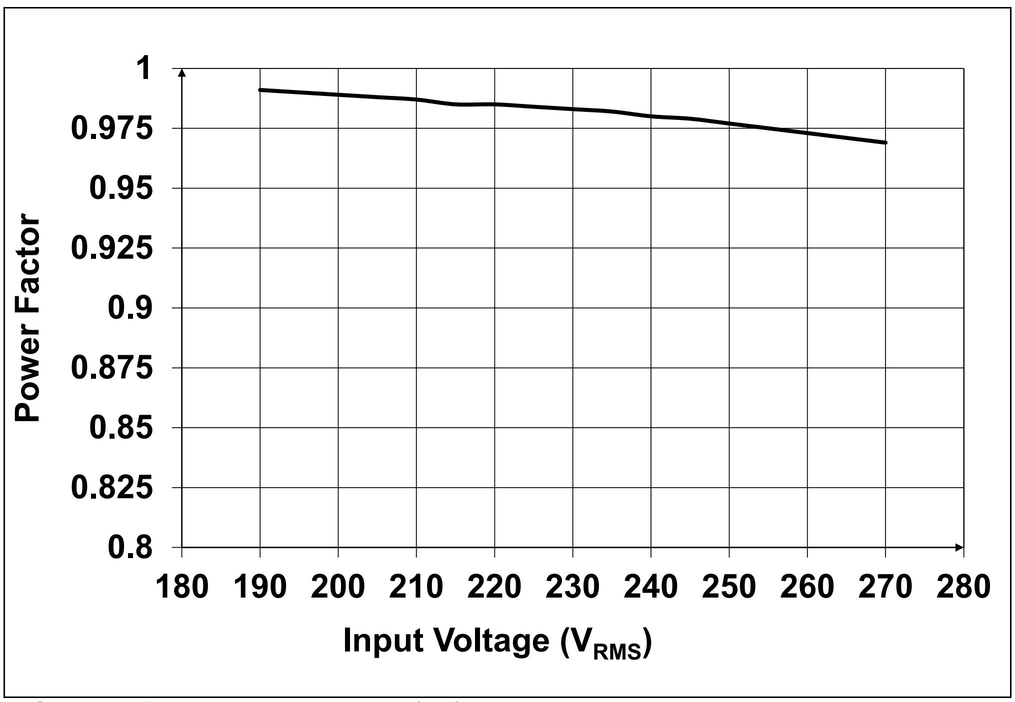

FIGURE 2-16: Power Factor (PF) and Input Voltage.