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QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
== ISO/TS 16949 ==

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Object of Declaration: HV98100 120 VAC 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.

The development/evaluation tool is designed to be used for research and development in a laboratory environment. This development/evaluation tool is not a Finished Appliance, nor is it intended for incorporation into Finished Appliances that are made commercially available as single functional units to end users under EU EMC Directive 2004/108/EC and as supported by the European Commission's Guide for the EMC Directive 2004/108/EC (8th February 2010).

This development/evaluation tool complies with EU RoHS2 Directive 2011/65/EU.

This development/evaluation tool, when incorporating wireless and radio-telecom functionality, is in compliance with the essential requirement and other relevant provisions of the R&TTE Directive 1999/5/EC and the FCC rules as stated in the declaration of conformity provided in the module datasheet and the module product page available at www.microchip.com.

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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
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INTRODUCTION
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• Document Layout
• Conventions Used in this Guide
• Recommended Reading
• The Microchip Website
• Customer Support
• Document Revision History

DOCUMENT LAYOUT
This document describes how to use the HV98100 120 VAC Off-Line LED Driver Evaluation Board as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:
• Chapter 1. “Product Overview” – Important information about the HV98100 120 VAC Off-Line LED Driver Evaluation Board.
• Chapter 2. “Installation and Operation” – This chapter includes a detailed description of each function of the demonstration board, instructions on how to begin using the board, and shows the typical waveforms and measurements that are obtained from the HV98100 120 VAC Off-Line LED Driver Evaluation Board.
• Appendix A. “Schematic and Layouts” – Shows the schematic and layout diagrams for the HV98100 120 VAC Off-Line LED Driver Evaluation Board.
• Appendix B. “Bill of Materials (BOM)” – Lists the parts used to build the HV98100 120 VAC Off-Line LED Driver Evaluation Board.
CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

<table>
<thead>
<tr>
<th>DOCUMENTATION CONVENTIONS</th>
<th>Description</th>
<th>Represents</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arial font:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italic characters</td>
<td>Referenced books</td>
<td><em>MPLAB® IDE User’s Guide</em></td>
<td>...is the only compiler...</td>
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<td>Emphasized text</td>
<td>the Output window</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial caps</td>
<td>A window</td>
<td>the Settings dialog</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A dialog</td>
<td>select Enable Programmer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A menu selection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quotes</td>
<td>A field name in a window or dialog</td>
<td>“Save project before build”</td>
<td></td>
</tr>
<tr>
<td>Underlined, italic text with right angle bracket</td>
<td>A menu path</td>
<td><em>File&gt;Save</em></td>
<td></td>
</tr>
<tr>
<td>Bold characters</td>
<td>A dialog button</td>
<td>Click OK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A tab</td>
<td>Click the <em>Power</em> tab</td>
<td></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>
<td></td>
</tr>
<tr>
<td>Text in angle brackets &lt; &gt;</td>
<td>A key on the keyboard</td>
<td>Press &lt;Enter&gt;, &lt;F1&gt;</td>
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</tr>
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<td><strong>Courier New font:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plain Courier New</td>
<td>Sample source code</td>
<td>#define START</td>
<td></td>
</tr>
<tr>
<td>Filenames</td>
<td>autoexec.bat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>File paths</td>
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<td></td>
<td></td>
</tr>
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<td></td>
</tr>
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<td>Command-line options</td>
<td>-Opa+, -Opa-</td>
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<td>Bit values</td>
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<td></td>
</tr>
<tr>
<td>Constants</td>
<td>0xFF, ‘A’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italic Courier New</td>
<td>A variable argument</td>
<td><em>file.o</em>, where <em>file</em> can be any valid filename</td>
<td></td>
</tr>
<tr>
<td>Square brackets []</td>
<td>Optional arguments</td>
<td>mcc18 [options] <em>file</em> [options]</td>
<td></td>
</tr>
<tr>
<td>Curly brackets and pipe character: {}</td>
<td>Choice of mutually exclusive arguments; an OR selection</td>
<td><em>errorlevel</em> {0</td>
<td>1}</td>
</tr>
<tr>
<td>Ellipses...</td>
<td>Replaces repeated text</td>
<td><em>var_name</em> [, <em>var_name</em>...]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Represents code supplied by user</td>
<td>void main (void) { ... }</td>
<td></td>
</tr>
</tbody>
</table>
RECOMMENDED READING

This user’s guide describes how to use the HV98100 120 V_{AC} Off-Line LED Driver Evaluation Board. Another useful document is listed below. The following Microchip document is available and recommended as supplemental reference resource.

- HV98100/HV98101 Data Sheet – “Non-Dimmable, Off-Line, LED Driver with Low Total Harmonic Distortions” (DS20005640)

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- General Technical Support – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
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- Field Application Engineer (FAE)
- Technical Support

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Technical support is available through the website at: http://www.microchip.com/support

DOCUMENT REVISION HISTORY

Revision A (October 2016)

- Initial release of this document.
Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the HV98100 120 V<sub>AC</sub> Off-Line LED Driver Evaluation Board and covers the following topics:

- HV98100 Device – Short Overview
- HV98100 Device – Key Features
- What Is the HV98100 120 V<sub>AC</sub> Off-Line LED Driver Evaluation Board?
- Board – Technical Specifications
- What Does the HV98100 120 V<sub>AC</sub> Off-Line LED Driver Evaluation Board Kit Include?

1.2 HV98100 DEVICE – SHORT OVERVIEW

The HV98100 LED driver integrated circuit (IC) is an off-line, high-power factor, buck-boost controller targeted at general LED lighting products, such as LED lamps and LED lighting fixtures with a maximum power rating of about 15W. The HV98100 IC is specifically designed to work from a nominal 120V<sub>AC</sub> input voltage.

Valley-switching buck-boost converters are preferred in off-line applications since they reduce switching losses. A typical solution is to pair a constant on-time control scheme with valley switching to achieve both high-power factor and good efficiency. However, this control scheme results in a higher Total Harmonic Distortion (THD), and the actual value is dependent on the input and output voltages. The HV98100 IC uses a unique control scheme (patent pending) to achieve high power factor and low THD simultaneously under all line and load conditions, while maximizing efficiency utilizing valley switching. The average output current is also controlled in a closed-loop manner to achieve high LED current accuracy.

Another HV98100 unique feature is the bootstrap of the IC supply voltage from the output, as well as the unique valley-sensing scheme, which allows the use of a standard off-the-shelf inductor to minimize the overall system cost.

1.2.1 HV98100 Device – Key Features

- Good average LED current regulation
- Better than 5% current accuracy
- Output overvoltage and output short-circuit protection
- Valley switching buck-boost converter with power factor correction:
  - high power factor (> 0.95)
  - low THD (< 10%)
- Uses a standard off-the-shelf inductor:
  - no auxiliary winding required
- Single input voltage range: 120V<sub>AC</sub> ± 15%
- Supports 5W – 15W output power
- Available in small, space-saving SOT-23-6L package
1.3 WHAT IS THE HV98100 120 VAC OFF-LINE LED DRIVER EVALUATION BOARD?

The HV98100 120 VAC Off-Line LED Driver Evaluation Board is used to evaluate and demonstrate Microchip’s HV98100 device in the following topology:

- Buck-boost converter application, supplied from the mains (120 VAC), to drive an 92 – 133V LED load.

The HV98100 120 VAC Off-Line LED Driver Evaluation Board was developed to help engineers reduce product design cycle time.

1.3.1 Board – Technical Specifications

- Input Voltage = 100V to 135VAC, 50 Hz
- LED String Voltage = 92V – 133V
- LED Current = 120 mA ± 5%
- Output short-circuit protection with auto-restart
- Output open-circuit protection with auto-restart
- Meets CISPR-15 conducted emissions standards

1.4 WHAT DOES THE HV98100 120 VAC OFF-LINE LED DRIVER EVALUATION BOARD KIT INCLUDE?

The HV98100 120 VAC Off-Line LED Driver Evaluation Board kit includes:

- HV98100 120 VAC Off-Line LED Driver Evaluation Board (ADM00786)
- Important Information Sheet
Chapter 2. Installation and Operation

2.1 GETTING STARTED

The HV98100 120 V<sub>AC</sub> Off-Line LED Driver Evaluation Board is fully assembled and tested. The board requires the use of an external input voltage source (120 V<sub>AC</sub> nominal) and an external LED load.

2.1.1 Additional Tools Required for Operation

1. A DC ammeter capable of measuring currents up to 200 mA is recommended to measure the LED current under different line and load conditions.
2. An oscilloscope and/or a multi-meter to observe the waveforms and measure the electrical parameters (optional).

2.2 SETUP PROCEDURE

The board will be connected directly to 120 V<sub>AC</sub>. 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 V<sub>AC</sub> to 135 V<sub>AC</sub>. This can be provided by an autotransformer supplied from the mains or by an electronic AC power supply (for example, Chroma ATE Inc.’s 61500 series).

The power connectors include the following:
- The input connector, W1, placed on the left side of the board and marked AC, as shown in Figure 2-1.
  - The AC input should be connected between AC1 and AC2 terminals of connector W1.
- The output connector, W2, called LED and placed on the right side of the board.
  - The anode of the LED string should be connected to the LEDP terminal (positive) and the cathode of the LED string should be connected to the LEDN terminal (negative).

![FIGURE 2-1: HV98100 120 V<sub>AC</sub> Off-Line LED Driver Evaluation Board – Connection Diagram.](image-url)
2.3 HOW DOES THE HV98100 120 VAC OFF-LINE LED DRIVER EVALUATION BOARD WORK?

The evaluation board is designed to control the current through the LED load while maintaining high-input power factor (PF) and low Total Harmonic Distortion (THD). The topology used in this evaluation board is an off-line, non-isolated, buck-boost converter.

The IC adopts a novel control mechanism to vary both on-time and switching period at the same instant over the line cycle in such a way as to force the average input current to be proportional to input voltage, realizing high-power factor and low THD which is independent of the load voltage ($V_O$) (unlike a constant on-time control where the THD is dependent on the LED string voltage).

The LED current ($I_{LED}$) is sensed directly using an external sense resistor $R_{CS}$ and compared to an internal fixed reference ($CS_{REF}$). An internal transconductance amplifier is used to close the loop on the LED current with an external compensation capacitor. The LED current can be programmed per Equation 2-1.

**EQUATION 2-1:**

$$I_{LED} = \frac{CS_{REF}}{R_{CS}}$$

The driver incorporates valley switching (quasi-resonant switching), a technique for reducing switching loss at the turn-on event of the buck-boost converter FET. Valley detect is accomplished by sensing the current sunk into the IND pin when the M1 GATE is low. Apart from the valley detect, the current sunk into the IND pin when the M1 GATE is low is used to sense an output overvoltage or open-circuit event.

2.4 TESTING THE BOARD

**WARNING**

There are high voltages present on the board when powered up. No part of the board must be handled when the board is being powered.

**Note:** Since there is significant capacitance at the output, it takes time for the output capacitor to discharge once the input AC source is powered down. There is a green LED indicator on the evaluation board that stays lit as long as high voltage is present on the board.

To start testing the evaluation board, follow these steps:

1. Connect the input AC source and the output LED load as shown in Figure 2-1.
2. Power the board at 120 VAC.
3. Check that the voltmeter measures a voltage between 92V and 133V on the LED load.
4. Verify the current through the LEDs. It should be within 114 mA and 126 mA (120 mA ± 5%).
5. If a variable AC source is available, set the input voltage to any value between 100 VAC and 135 VAC. The LED current should still be within ±5% of 120 mA.
6. Power down the AC source.
2.5 TYPICAL WAVEFORMS

This section shows the typical waveforms that are obtained from the evaluation board.

**FIGURE 2-2:** Input Voltage and Current Waveforms at Full Load and 120 V\(_{AC}\) Input.

**FIGURE 2-3:** Drain Voltage Waveform Showing Valley Switching at Different Instantaneous Input Voltage Conditions, Sample 1 and 2 of 3.
FIGURE 2-4: Drain Voltage Waveform Showing Valley Switching at Different Instantaneous Input Voltage Conditions, Sample 3 of 3.

FIGURE 2-5: LED Current Waveform.
FIGURE 2-6: Start-Up Waveforms Showing Start-Up Delay and the Smooth Rise of the LED Current.

FIGURE 2-7: Open-Circuit Protection and Recovery from an Open-Circuit Condition.
2.6 TYPICAL MEASUREMENTS

This section shows the typical measurements that are obtained from the evaluation board.

**FIGURE 2-8:** Variation of LED Current vs. Input Voltage, at 133V LED String Voltage.

**FIGURE 2-9:** Variation of LED Current vs. LED string Voltage, at 120 V\(_{AC}\) Line Voltage.
FIGURE 2-10: Efficiency vs. Line Voltage, at 133V LED String Voltage.

FIGURE 2-11: Efficiency vs. LED String Voltage, at 120 V\textsubscript{AC} Line Voltage.
**FIGURE 2-12:** Power Factor vs. Line Voltage, at 133V LED String Voltage.

**FIGURE 2-13:** Power Factor vs. LED String Voltage, at 120 V<sub>AC</sub> Line Voltage.
**FIGURE 2-14:** Total Harmonic Distortion (THD) vs. Line Voltage, at 133V LED String Voltage.

**FIGURE 2-15:** Total Harmonic Distortion (THD) vs. LED String Voltage, at 120 V$_{AC}$ Line Voltage.
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

This appendix contains the following schematics and layouts for the HV98100 120 V<sub>AC</sub> Off-Line LED Driver Evaluation Board:

- Board – Schematic
- Board – Top Copper and Pads
- Board – Top Copper, Pads and Silk
- Board – Top Silk and Pads
- Board – Bottom Copper and Pads
A.5 BOARD – TOP SILK AND PADS

A.6 BOARD – BOTTOM COPPER AND PADS
## Appendix B. Bill of Materials (BOM)

### TABLE B-1: BILL OF MATERIALS (BOM) *(Note 1)*

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Reference</th>
<th>Description</th>
<th>Manufacturer</th>
<th>Part Number</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>BR1</td>
<td>Bridge rectifier single-phase 600V 800 mA surface mount 4-Mini DIP</td>
<td>Diodes Incorporated®</td>
<td>HD06-T</td>
</tr>
<tr>
<td>2</td>
<td>C1, C2</td>
<td>0.1 µF film capacitor 305V polypropylene (PP) radial 0.512&quot; L x 0.236&quot; W (13.00 mm x 6.00 mm)</td>
<td>EPCOS (TDK)</td>
<td>B32921C3104M</td>
</tr>
<tr>
<td>1</td>
<td>C3</td>
<td>4.7 µF 25V ceramic capacitor X7R 1206 (3216 metric) 0.126&quot; L x 0.063&quot; W (3.20 mm x 1.60 mm)</td>
<td>Samsung Electro-Mechanics America, Inc.</td>
<td>CL31B475KAHNNNF</td>
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<td>C4</td>
<td>1 µF 50V ceramic capacitor X7R 0805 (2012 metric) 0.079&quot; L x 0.049&quot; W (2.00 mm x 1.25 mm)</td>
<td>Samsung Electro-Mechanics America, Inc.</td>
<td>CL21B105KBFNNNF</td>
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<tr>
<td>1</td>
<td>C5</td>
<td>47 µF 200V aluminum capacitors radial, Can 10000 hrs. @ 105°C</td>
<td>Panasonic® - ECG</td>
<td>EEUEE2D470</td>
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<td>D1</td>
<td>Diode standard 75V 200 mA Surface Mount SOT-23-3</td>
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<td>D3, D4</td>
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<td>38311000000</td>
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<td>HV98100</td>
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<td>LG R971-KN-1</td>
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<td>MOSFET N-ch. 600V 3.7A SOT223</td>
<td>Infineon Technologies</td>
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<td>1</td>
<td>PCB</td>
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</tr>
</tbody>
</table>

**Note 1:** The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.
### TABLE B-1: BILL OF MATERIALS (BOM) (CONTINUED)(Note 1)

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Reference</th>
<th>Description</th>
<th>Manufacturer</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R1</td>
<td>Current sense resistors - SMD 1.62Ω 1% 100 PPM</td>
<td>KOA Speer Electronics, Inc.</td>
<td>SR732ETTE1R62F</td>
</tr>
<tr>
<td>1</td>
<td>R2</td>
<td>Resistor SMD 10Ω 5% 1/8W 0805</td>
<td>Vishay/Dale</td>
<td>CRCW080510R0JNEA</td>
</tr>
<tr>
<td>2</td>
<td>R3A, R3B</td>
<td>Resistor SMD 49.9 kΩ 1% 1/4W 1206</td>
<td>Vishay/Dale</td>
<td>CRCW120649K9KEA</td>
</tr>
<tr>
<td>2</td>
<td>R4A, R4B</td>
<td>Resistor SMD 7.5 kΩ 5% 1/4W 1206</td>
<td>Vishay/Dale</td>
<td>CRCW12067K50JNEA</td>
</tr>
<tr>
<td>1</td>
<td>R5</td>
<td>Resistor SMD 390 kΩ 5% 1/4W 1206</td>
<td>Vishay/Dale</td>
<td>CRCW1206390KJNEA</td>
</tr>
<tr>
<td>2</td>
<td>R9A, R9B</td>
<td>Resistor SMD 56 kΩ 5% 1/8W 0805</td>
<td>Vishay/Dale</td>
<td>CRCW080556K0JNEA</td>
</tr>
<tr>
<td>2</td>
<td>R10, R11</td>
<td>Resistor SMD 10 kΩ 5% 1/4W 1206</td>
<td>Vishay/Dale</td>
<td>CRCW120610K0JNEA</td>
</tr>
<tr>
<td>1</td>
<td>SHU1</td>
<td>2 (1 x 2) position shunt connector black open top, grip 0.100&quot; (2.54 mm) gold</td>
<td>TE Connectivity, Ltd.</td>
<td>881545-2</td>
</tr>
<tr>
<td>1</td>
<td>W1</td>
<td>3-position wire-to-board terminal block horizontal with board 0.138&quot; (3.50 mm) Through Hole</td>
<td>TE Connectivity, Ltd.</td>
<td>1776275-3</td>
</tr>
<tr>
<td>1</td>
<td>W2</td>
<td>2-position wire-to-board terminal block horizontal with board 0.138&quot; (3.50 mm) Through Hole</td>
<td>TE Connectivity, Ltd.</td>
<td>1776275-2</td>
</tr>
<tr>
<td>4</td>
<td>CON1 – CON4</td>
<td>Test point PC compact .063*D black</td>
<td>Keystone Electronics</td>
<td>5006</td>
</tr>
</tbody>
</table>

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