MCP1630
SEPIC Automotive LED Driver
Reference Design
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ISBN: 978-1-61341-606-8

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company’s quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELog® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip’s quality system for the design and manufacture of development systems is ISO 9001:2000 certified.
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Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our web site (www.microchip.com) to obtain the latest documentation available.

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 “DSXXXXXXA”, where “XXXXX” 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 MCP1630 SEPIC Automotive LED Driver Reference Design User’s Guide. Items discussed in this chapter include:

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

DOCUMENT LAYOUT

This document describes how to use the MCP1630 SEPIC Automotive LED Driver Reference Design User’s Guide 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 MCP1630 SEPIC Automotive LED Driver Reference Design.
- Chapter 2. “Installation and Operation” – This chapter includes a detailed description of each function of the demonstration board and instructions for how to begin using the board.
- Appendix A. “Schematic and Layouts” – Shows the schematic and layout diagrams for the MCP1630 SEPIC Automotive LED Driver Reference Design.
- Appendix B. “Bill of Materials (BOM)” – Lists the parts used to build the MCP1630 SEPIC Automotive LED Driver Reference Design.
- Appendix C. “Firmware Flowchart” – Shows the board flowchart.
- Appendix D. “Test Points and Waveforms” – Describes the main test points and waveforms for the MCP1630 SEPIC Automotive LED Driver Reference Design.
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>Arial font:</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Italic characters</td>
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<td><em>MPLAB® IDE User’s Guide</em></td>
<td>is the only compiler...</td>
</tr>
<tr>
<td></td>
<td>Emphasized text</td>
<td>the Output window</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>“Save project before build”</td>
<td></td>
</tr>
<tr>
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<td>A field name in a window or dialog</td>
<td></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 Power 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>
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<td>A key on the keyboard</td>
<td>Press &lt;Enter&gt;, &lt;F1&gt;</td>
<td></td>
</tr>
<tr>
<td>Courier New font:</td>
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<tr>
<td>Plain Courier New</td>
<td>Sample source code</td>
<td>#define START</td>
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</tr>
<tr>
<td></td>
<td>Filenames</td>
<td>autoexec.bat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>File paths</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Keywords</td>
<td>_asm, _endasm, static</td>
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<tr>
<td></td>
<td>Command-line options</td>
<td>-Opa+, -Opa-</td>
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<tr>
<td></td>
<td>Bit values</td>
<td>0, 1</td>
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</tr>
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<td></td>
<td>Constants</td>
<td>0xFF, ‘A’</td>
<td></td>
</tr>
<tr>
<td>Italic Courier New</td>
<td>A variable argument</td>
<td><em>file.o, where file can be any valid filename</em></td>
<td></td>
</tr>
<tr>
<td>Square brackets [ ]</td>
<td>Optional arguments</td>
<td>mcc18 [options] file [options]</td>
<td></td>
</tr>
<tr>
<td>Curly brackets and pipe character: { }</td>
<td>Choice of mutually exclusive arguments; an OR selection</td>
<td>errorlevel {0</td>
<td>1}</td>
</tr>
<tr>
<td>Ellipses...</td>
<td>Replaces repeated text</td>
<td>var_name [, var_name...]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Represents code supplied by user</td>
<td>void main (void) { ... }</td>
<td></td>
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</tbody>
</table>
RECOMMENDED READING

This user’s guide describes how to use the MCP1630 SEPIC Automotive LED Driver Reference Design User’s Guide. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

- MCP1630/MCP1630V Data Sheet – “High-Speed, Microcontroller-Adaptable, Pulse Width Modulator” (DS21896)
- PIC12F683 Data Sheet – “8-Pin Flash-Based, 8-Bit CMOS Microcontrollers with nanoWatt Technology” (DS41211)
- MCP1790 Data Sheet – “70 mA, High Voltage Regulator” (DS22075)
- MCP1415/16 Data Sheet – “Tiny 1.5A, High-Speed Power MOSFET Driver” (DS22092)
- AN1137 – “Using the MCP1631 Family to Develop Low-Cost Battery Chargers” (DS01137)

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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

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: http://support.microchip.com
DOCUMENT REVISION HISTORY

Revision A (September 2011)

• Initial Release of this Document.
Chapter 1. Product Overview

1.1 INTRODUCTION

The MCP1630 Sepic Automotive LED Driver Reference Design is a step-up/down, Switch mode, DC-DC converter used for powering LED applications. The demo board provides a 350 mA (700 mA, with hardware modification) constant current source. Other output currents can be obtained with minor modifications to the board components' values.

The MCP1630 Sepic Automotive LED Driver Reference Design sustains the high-voltage peaks that can be found in typical automotive applications. This board provides useful information about typical high-voltage applications that can be found in the automotive field.

The MCP1630 Sepic Automotive LED Driver Reference Design utilizes Microchip's MCP1630 high-speed, Pulse-Width Modulator (PWM) device. The 8-pin MCP1630 device contains all the analog components necessary for a peak current switch-mode control loop, including an error amplifier, a PWM comparator and a high-current driver output pin. The switching frequency and the maximum duty cycle for the MCP1630 are determined by an external clock source.

An 8-pin PIC12F683 microcontroller is used to provide a 330 kHz switching clock for the MCP1630 device. In addition, the PIC12F683 firmware supervises the input and output voltage, and can optionally dim the LEDs when a button is attached.

In this reference design, the MCP1630 device is used for Peak Current Mode Control in a SEPIC power train circuit. Because the duty cycle exceeds 50%, a ramp generator provides an additional reference signal to the MCP1630 for slope compensation.

Note: This application uses a Peak Current Mode Control. Use only the MCP1630 device option for this board.
1.2 FEATURES

The MCP1630 Sepic Automotive LED Driver Reference Design has the following features:

- Compact size with high output power
- Can operate in Buck (step-down) or Boost (step-up) mode
- Sustains voltage stresses typically found in automotive products:
  \[ V_{\text{IN}} \text{ for } 180 \text{ ms} \]
- High efficiency over the entire operating input and output voltage ranges:
  \[ 85\% \text{ typical} \]
- Maximum Output Current = 350 mA; this value can be modified with minor changes in hardware
- Maximum Output Power = 18W
- Optional software dimming control for both methods: PWM or Current mode
- Preprogrammed source code
- The switching frequency, maximum duty cycle and the MCP1630 reference voltage can be modified in firmware
- Additional application functions can be implemented in firmware

1.3 DEVICE SUMMARY

The MCP1630 Sepic Automotive LED Driver Reference Design uses the following devices:

- MCP1630 High-Speed Pulse-Width Modulator IC – When used in conjunction with a microcontroller, the MCP1630 controls the power system duty cycle to provide output current and/or voltage regulation.
- PIC12F683 Microcontroller (8-bit MCU) – Used to generate the MCP1630’s reference voltage, the oscillator signal at 330 kHz, and to provide additional software functions.
- MCP1790 HV LDO Regulator – Used to supply the regulated voltage to the PIC12F683 and MCP1630. The MCP1790 is capable of delivering 70 mA and sustaining 42V surge voltage on input for 180 ms (30 seconds repetition rate).
- MCP1416 – Is a high-speed MOSFET driver, capable of providing 1.5A of peak current for driving the switching power transistor.
1.4 TECHNICAL SPECIFICATIONS

- Input Voltage = 9V to 16V (surge voltage of 42V for maximum 180 ms, 30 seconds repetition rate)
- Software Configurable Under Voltage Lock-Out Circuit (UVLO) and Over Voltage Lock-Out Circuit (OVLO) (8V and 17V default thresholds)
- Software Configurable Load Disconnect Protection
- Typical Output Current = 350 mA
- Maximum Output Current = 700 mA (with hardware modifications)
- Typical Output Power = 18W (maximum 20W at TA = +25°C)
- Fully Protected Against Short-Circuit and No-Load Condition

Figure 1-1 shows a simplified block diagram of the application.

**FIGURE 1-1:** MCP1630 Sepic Automotive LED Driver Reference Design Block Diagram.
1.5 FUNCTIONAL DESCRIPTION

The MCP1630 device provides all the analog functions necessary to implement a Peak Current Mode PWM DC-DC Converter. The power train is based on the Single-Ended Primary Inductor Converter (SEPIC) topology. This topology offers the buck-boost functionality and also has non-pulsating input current.

The converter provides adjustable constant current at the output, necessary to drive high-power LED applications.

The MCP1630 PWM controller requires an external clock for operation. This clock is provided by an external 8-bit microcontroller, PIC12F683. The PWM frequency and the maximum duty cycle are set by this clock.

The output (load) current is sensed with a 0.5Ω shunt resistor (R17 and R18). The voltage across this shunt resistor is compared with the reference voltage by the MCP1630 device’s PWM controller.

The reference voltage for the MCP1630 device is also provided by PIC12F683, at the VREF pin (Pin 8). R4, R3 and C2 form a low-pass filter that smooths the PWM signal produced by the PIC® microcontroller. The maximum output current is set by the R4 and R3 voltage dividers. The duty cycle of the PWM signal is adjusted in eight steps.

The output current is calculated with Equation 1-1:

\[
I_{OUT} = \frac{V_{REF}}{0.5}
\]

Where:

\[
V_{REF_{max}} = \left(\frac{R3}{R3 + R4}\right) \times 5V = 178mV
\]

\[
I_{OUT_{max}} = \frac{178mV}{0.5} = 357mA
\]

Because the operating duty cycle is bigger than 50%, a slope compensation circuit is required to avoid subharmonic oscillations that occur in Peak Current mode controllers. A ramp generator is constructed with Q1 and the associated components. The ramp is then summed with the inductor current, measured across R9 and R10 resistors.

A 100V VDS MOSFET transistor is also used in this application. The MCP1416 MOSFET driver drives the gate of this transistor. This is necessary because the high-voltage transistors usually have high gate charge and also require at least 7V for gate-to-source voltage.

Note: The MCP1416 MOSFET driver must be protected against input voltage surges. This protection is ensured by R6 and D1.

1.6 WHAT THE MCP1630 SEPIC AUTOMOTIVE LED DRIVER REFERENCE DESIGN KIT INCLUDES

The MCP1630 Sepic Automotive LED Driver Reference Design includes:

• MCP1630 Sepic Automotive LED Driver Reference Design (102-00323)
• Important Information Sheet
Chapter 2. Installation and Operation

2.1 GETTING STARTED

The MCP1630 Sepic Automotive LED Driver Reference Design is fully assembled and tested. The board requires the use of an external input voltage source (9V to 16V) and an external LED load, provided by Microchip.

2.1.1 Additional Tools Required for Operation

1. A DC power supply, a bench supply that can produce 12V, 2.5A, is recommended to operate the board at the full rated power.
2. An oscilloscope and/or a multi-meter to observe the waveforms and measure the electrical parameters (optional).

2.2 SETUP PROCEDURE

To operate the MCP1630 Sepic Automotive LED Driver Reference Design, the following steps must be completed:

1. Attach an LED load (or dummy load) to the Output Connector J3 (observe the polarity).
2. Attach the push button to the J1 header (between Pins 3 and 4 is optional).
3. Connect a power supply to the Input Connector J2 (observe the polarity).

Detailed instructions are provided below for each step.

**WARNING**

Please observe the polarity for all steps to avoid board damage.

2.2.1 Demo Board Output Current Configuration

The board is configured to deliver a maximum of 350 mA to the LEDs’ load. UVLO and OVLO thresholds are set to 8V and 17V, respectively. The maximum output voltage is set to be approximately 55V.

2.2.2 Connecting the Load

A string of up to sixteen white LEDs (1W each) can be powered by this board. The LED's string must be mounted on an appropriate heat sink to keep the maximum junction temperature at safe level (consult the LED data sheet for details). The maximum current delivered by the board to the LED's string is set to 350mA and the maximum output voltage is 55V.

The LED's string can be replaced by a resistor of 150Ω and 20W dissipated power (dummy load). In this case, the power delivered to the load will be about 18W.

Connect the LEDs’ string to the J3 connector. It is very important to use the correct polarity (see Figure 2-1).
2.2.3 Connecting the Dimming Push Button (optional)

The Dimming Push Button provides the option to adjust the LEDs’ luminous intensity in eight steps. Connect the Dimming Push Button to the J1 header between GND (Pin 3) and Pin 4.

2.2.4 Powering the Board

Connect a power supply to J2 to power up the MCP1630 Sepic Automotive LED Driver Reference Design. Ensure that the power supply has the (+) terminal connected to the J2 terminal block at Pin 1 (left), and the (–) terminal connected to Pin 2 (right). The input voltage source should be limited to a range from 9V to 16V. Ensure that the chosen power supply can provide enough current at the selected voltage to properly power the LEDs.

For 12V input voltage, the current drain will be around 1.8A at full load (18W).

**Note:** This board has no Thermal Shut-Down function implemented. Please ensure that the load is properly cooled.
2.2.5 Using the Reference Board

When the board is powered up, it supplies the maximum output current (350mA). The user has the option to adjust this output current connecting an external push button (see Figure 2-1). The push button controls the output current in eight steps from 0 to 350mA.

The board has Under Voltage Lock-Out and Over Voltage Lock-Out protections. The thresholds are set in firmware and are 8 VDC and 17 VDC, respectively.

The board is protected for the No-Load condition. The typical threshold value is 55 VDC for the output voltage.

**Note:** It is not recommended to operate the board without a proper load connected to the output. The maximum power at the output must be limited to 19W at ambient temperature.

2.3 EVALUATING THE APPLICATION

The best way to evaluate the MCP1630 Sepic Automotive LED Driver Reference Design is to dig into the circuit and measure the voltages and currents with a Digital Voltage Meter (DVM), and probe the board with an oscilloscope.

Additional tools are necessary to evaluate some technical parameters of the board (temperature of power components, ability to withstand surge voltage pulse on input, EMI).

Some typical voltage and waveforms are provided in Appendix D. “Test Points and Waveforms”.

The firmware program of the PIC12F683 can also be edited to modify the operation of the application.

2.4 FIRMWARE DESCRIPTION

The PIC12F683 is preprogrammed with firmware to operate the system, as described in the previous sections. The firmware flow diagram is shown in Appendix C. “Firmware Flowchart”. The program is simple and straightforward.

The TRISIO register controls the direction of the GPIO pins, and is configured to set GP2 (oscillator pulses to the MCP1630) and GP5 (VREF voltage to MCP1630) as output ports. GP1 and GP4 are configured as analog inputs. These inputs are used to measure the input and output voltages.

The Capture/Compare/PWM (CCP) block is used to generate the master clock for the MCP1630 device. This module is configured for PWM mode operation. The PWM period can be calculated by writing to the PR2 register. The PWM duty cycle is specified by writing to the CCP1L register and to the CCP1CON<5:4> bits. A resolution, up to 10-bit, is available. The CCP1L contains the eight MSbs, while the CCP1CON<5:4> contains the two LSbs. This 10-bit value is represented by the CCP1L:CCP1CON<5:4> bits. The switching frequency is set to 330 kHz.

The reference voltage for the MCP1630 device is produced by the software PWM. This allows the user to adjust the LED’s intensity in eight steps.

The No-Load condition protection is provided by using the internal comparator. If the output voltage is too high, an interrupt occurs and the master clock for PWM operation is disabled.

The internal ADC is used to monitor the input voltage. If the input voltage is too low or too high, the board will be in a “Power Off” condition.

The Soft Start feature is also provided in this firmware. The duty cycle is gradually increased until it reaches the maximum value.

Note: It is not recommended to operate the board without a proper load connected to the output. The maximum power at the output must be limited to 19W at ambient temperature.
2.5 PROGRAMMING THE PIC12F683 MICROCONTROLLER

The firmware package provides the source and .hex files for the LED driver. The board is factory programmed with the LED driver firmware. UVLO, OVLO thresholds and dimming steps can be modified. The source code is commented extensively and helps the user to define the board.

This firmware was developed using MPLAB® Integrated Development Environment and HI-TECH C® for the PIC10/12/16 MCU Family (v9.7).

Header J1 provides in-system circuit programming. Follow the next steps to program the board:

1. Connect the PICkit™ 3 to the USB port.
2. Connect the PICkit 3 device to the board at J1 pin. Ensure the polarity is correctly applied.
3. Open the project00323.prj file with MPLAB Integrated Development Environment.
4. Select Programmer from the menu bar, click Select Programmer and choose PICkit 3 from the submenu list.
5. Return to the Programmer menu and select Settings. From the Properties window that appears, click the Power tab.
   Set the voltage to 5V and select the “Power target circuit from PICkit 3” check box. Press Apply.
6. On the warning message that appears click, OK.
7. From the Programmer menu, choose Program. Check the Output window if the programming was performed without errors.

The board is now ready to operate.
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

This appendix contains the following schematics and layouts for the MCP1630 Sepic Automotive LED Driver Reference Design User’s Guide:

• Board – Schematic
• Board – Top Copper and Pads
• Board – Top Copper Pads and Silk
• Board – Top Silk and Pads
• Board – Bottom Copper and Pads
A.3 BOARD – TOP COPPER AND PADS
A.6 BOARD – BOTTOM COPPER AND PADS

104-00323-R1
## Table B-1: Bill of Materials (BOM)

<table>
<thead>
<tr>
<th>Qty</th>
<th>Reference</th>
<th>Description</th>
<th>Manufacturer</th>
<th>Part Number</th>
</tr>
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<tbody>
<tr>
<td>4</td>
<td>B1, B2, B3, B4</td>
<td>BUMPON HEMISPHERE .44X.20 CLEAR</td>
<td>3M</td>
<td>SJ-5303 (CLEAR)</td>
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<tr>
<td>2</td>
<td>C1, C4</td>
<td>CAPACITOR 1500P 50V COG 5% SMD 0805</td>
<td>KEMET®</td>
<td>C0805C152J5GACTU</td>
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<td>C0805C105K4RACTU</td>
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<td>CAPACITOR 4.7U 10V X7R 10% SMD 0805</td>
<td>TAIYO YUDEN Co., Ltd.</td>
<td>LMK212B7475KG-T</td>
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<td>SMAZ15-13-F DIODE ZENNER 15V/1W SMD SMA</td>
<td>Diodes Incorporated®</td>
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<td>Molex® Connector Corp.</td>
<td>22-03-2051</td>
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<td>Phoenix Contact</td>
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<td>BSC196N10NS G MOSFET N-CH 100V 45A TDSON-8</td>
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**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>
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<td>3</td>
<td>TP7, TP8, TP9</td>
<td>TEST POINT PC COMPACT SMT</td>
<td>Keystone® Electronics Corp.</td>
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<td>MCP1630 HIGH-SPEED uC ADAPTABLE PWM CONTROLLER MSOP10</td>
<td>Microchip Technology Inc.</td>
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<td>MCP1416 TINY 1.5A POWER MOSFET DRIVER SOT23-5</td>
<td>Microchip Technology Inc.</td>
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<td>Microchip Technology Inc.</td>
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Appendix C. Firmware Flowchart

C.1 MCP1630 SEPIC AUTOMOTIVE LED DRIVER REFERENCE DESIGN
FIRMWARE FLOWCHART

Start

GPIO Setup
GP5 -> Vref OUT
GP2 -> CLK OUT
GP4 -> Vin SENSE
GP1 -> OVP Input

ADC Setup
Analog Comparator Setup
PWM Setup
Enable Interrupts

No

Soft_Start = 1?

Yes

Vref DC = 0?

Soft_Start()

Soft_Start = 0

Read Vin

Vin > Vin_min
Vin < Vin_max?

PWM = OFF
FAULT = 1

Vref DC ++

Vref DC = 8?

Yes

Vref DC = 0

No

Fault = 1?

PWM = OFF

CMIF = 0

No

PWM = OFF

FAULT = 1

Generate Vref Signal PWM

TOIF = 0

Yes

Timer Interrupt?

No

Comparator Tripped?

Yes

Interrupt

RETI
### Appendix D. Test Points and Waveforms

#### D.1 TEST POINTS DESCRIPTION

<table>
<thead>
<tr>
<th>Testpoint</th>
<th>Name</th>
<th>Description</th>
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</thead>
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<tr>
<td>TP1</td>
<td>RAMP</td>
<td>Artificial ramp for Slope Compensation</td>
</tr>
<tr>
<td>TP2</td>
<td>CLK</td>
<td>Master clock for PWM controller</td>
</tr>
<tr>
<td>TP3</td>
<td>CS</td>
<td>Current sense pin for PWM controller</td>
</tr>
<tr>
<td>TP4</td>
<td>+5V</td>
<td>Microcontroller and PWM controller supply voltage</td>
</tr>
<tr>
<td>TP5</td>
<td>DRIVE</td>
<td>Gate drive of Power MOSFET</td>
</tr>
<tr>
<td>TP6</td>
<td>DRAIN</td>
<td>Drain terminal of the Power MOSFET</td>
</tr>
<tr>
<td>TP7</td>
<td>+VIN</td>
<td>Input Voltage</td>
</tr>
<tr>
<td>TP8</td>
<td>GND</td>
<td>Board ground. All measurements are referred to this test point.</td>
</tr>
<tr>
<td>TP9</td>
<td>VOUT</td>
<td>Output Voltage</td>
</tr>
<tr>
<td>TP10</td>
<td>ISENSE</td>
<td>Main current sense test point. The output current is estimated by dividing the voltage from this test pint with 0.5.</td>
</tr>
</tbody>
</table>
D.2 WAVEFORMS EXAMPLES

D.2.1 Clock Signal (TP 2)

D.2.2 Drive Signal (TP 5)
D.2.3 RAMP Signal (TP 1)

D.2.4 CS Signal (TP 3)
D.2.5 MOSFET DRAIN Signal (TP 6)

D.2.6 Main Inductor Current
D.2.7 Typical Output Ripple/Noise of the SEPIC Converter

D.2.8 Typical Step Response (Zero to Full Load)
D.2.9 Typical Efficiency vs Output Voltage

![Graph showing typical efficiency vs output voltage](image-url)