

MCP1630
SEPIC Automotive LED Driver Reference Design

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MCP1630 SEPIC AUTOMOTIVE LED DRIVER REFERENCE DESIGN

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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 "DSXXXXXA", 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:

DOCUMENTATION CONVENTIONS

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

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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.

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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: 42 V_{IN} for 180 ms
- High efficiency over the entire operating input and output voltage ranges: 85% 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.

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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 T_A = +25°C)
- Fully Protected Against Short-Circuit and No-Load Condition

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

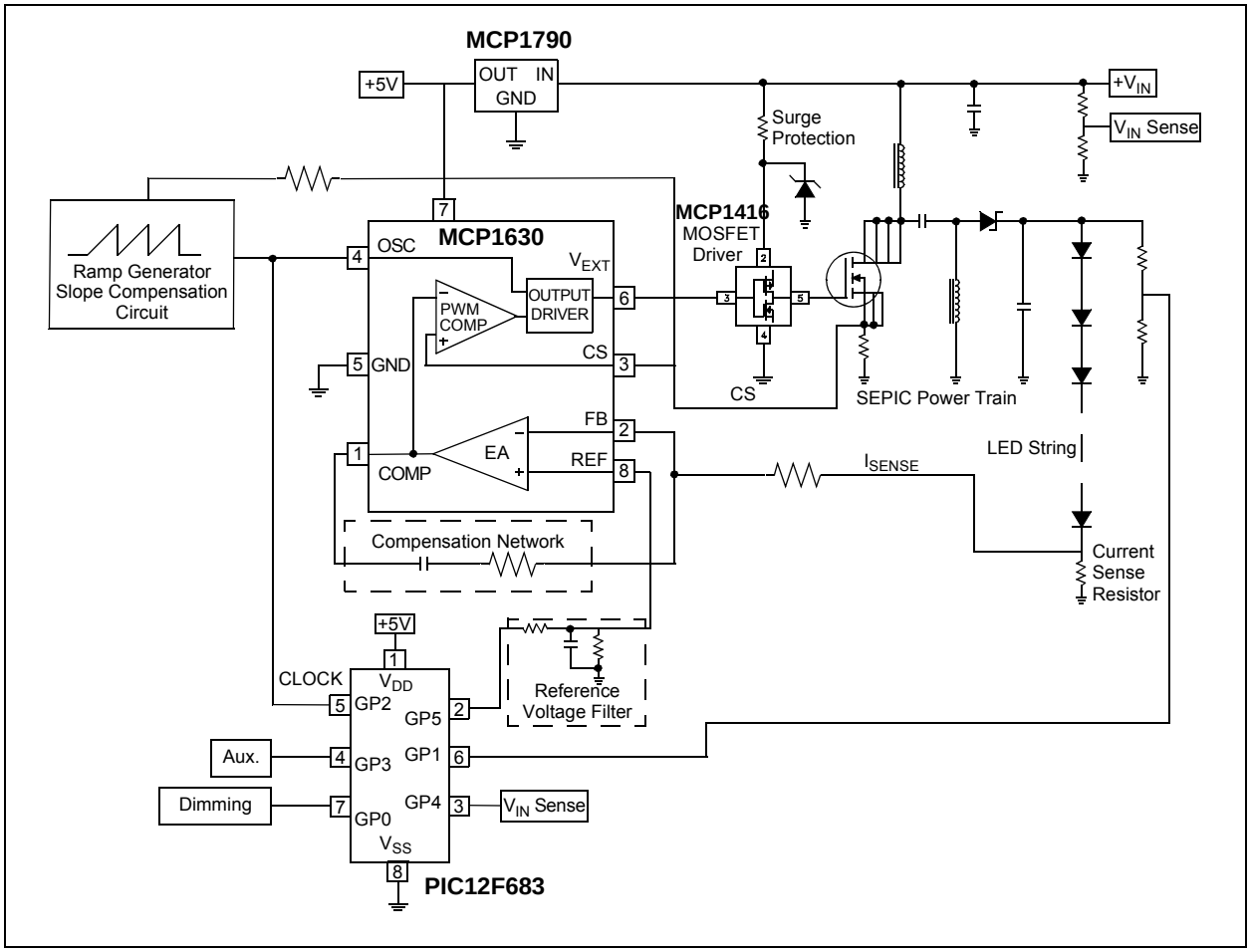


FIGURE 1-1: *MCP1630 Sepic Automotive LED Driver Reference Design Block Diagram.*

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 V_{REF} 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:

EQUATION 1-1:

$$I_{OUT} = \frac{V_{REF}}{0.5}$$

Where:

$$V_{REFmax} = \left(\frac{R3}{R3 + R4}\right) \times 5V = 178mV$$

$$I_{OUTmax} = \frac{178mV}{0.5} = 357mA$$

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 V_{DS} 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

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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).

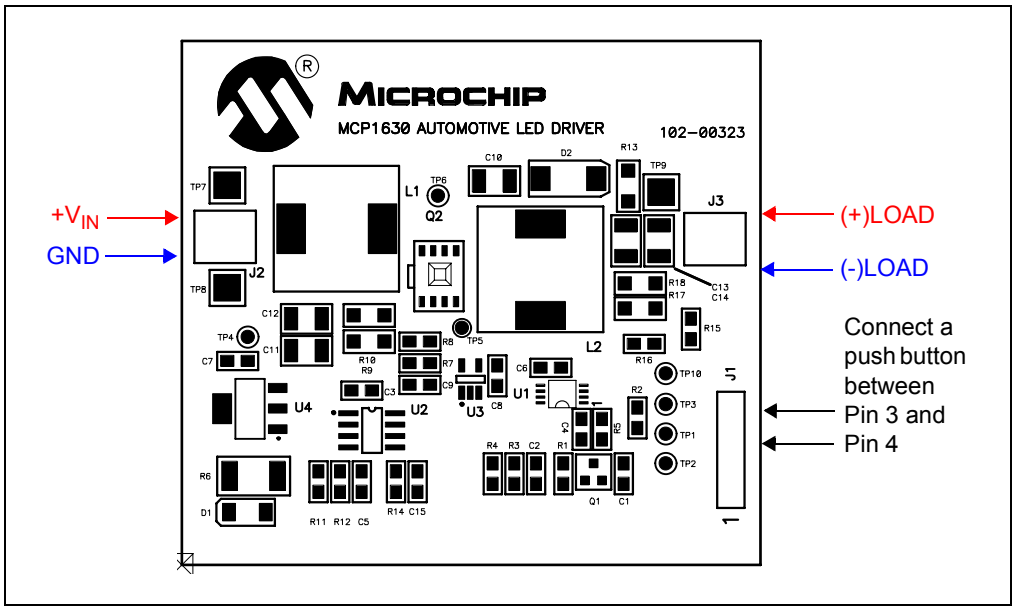


FIGURE 2-1: *Power Supply and Load Connection Diagram.*

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.

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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 V_{DC} and 17 V_{DC}, respectively.

The board is protected for the No-Load condition. The typical threshold value is 55 V_{DC} 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 (V_{REF} 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 CCPR1L register and to the CCP1CON<5:4> bits. A resolution, up to 10-bit, is available. The CCPR1L contains the eight MSbs, while the CCP1CON<5:4> contains the two LSbs. This 10-bit value is represented by the CCPR1L: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.

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.

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Appendix A. Schematic and Layouts

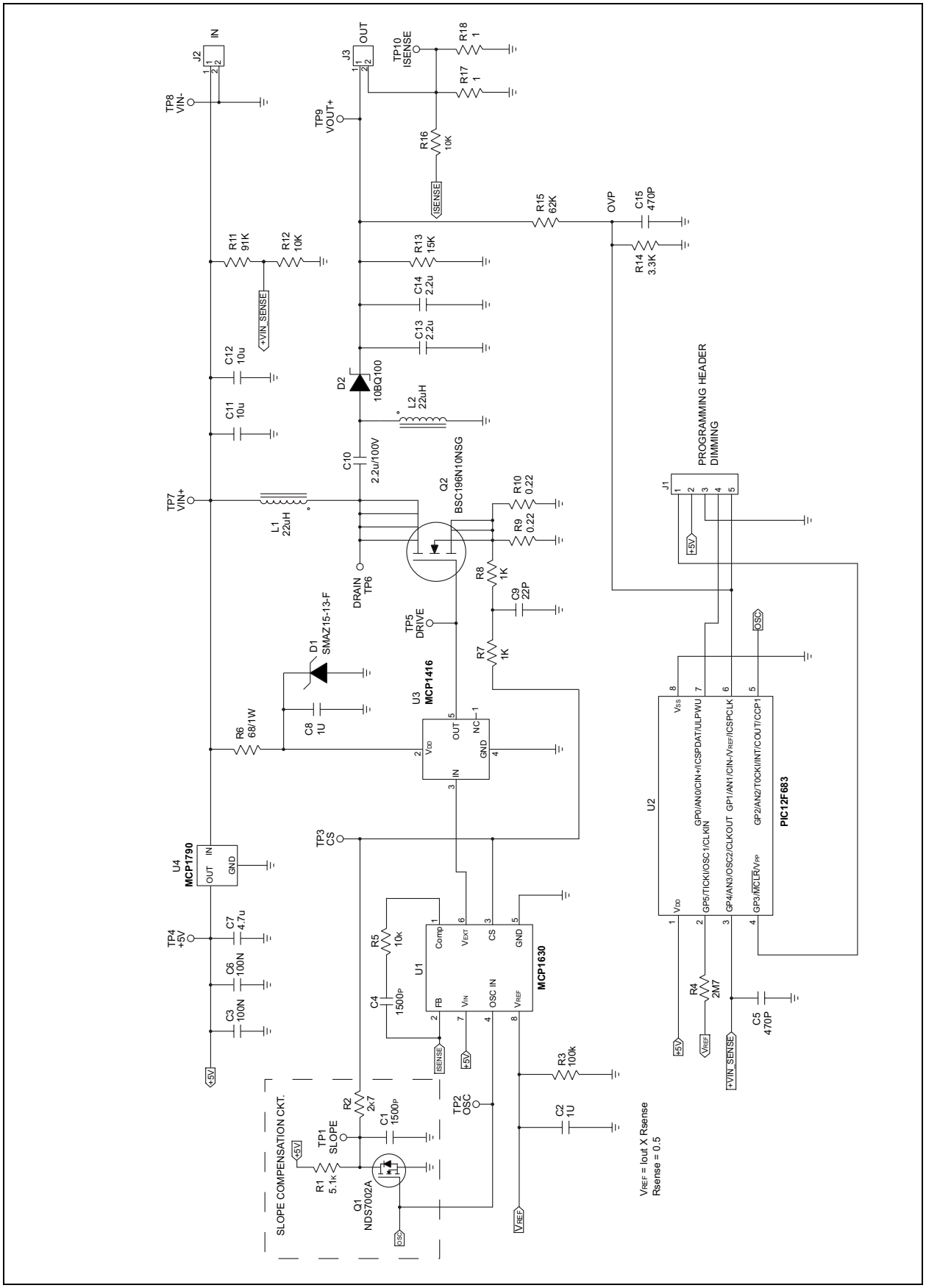
A.1 INTRODUCTION

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

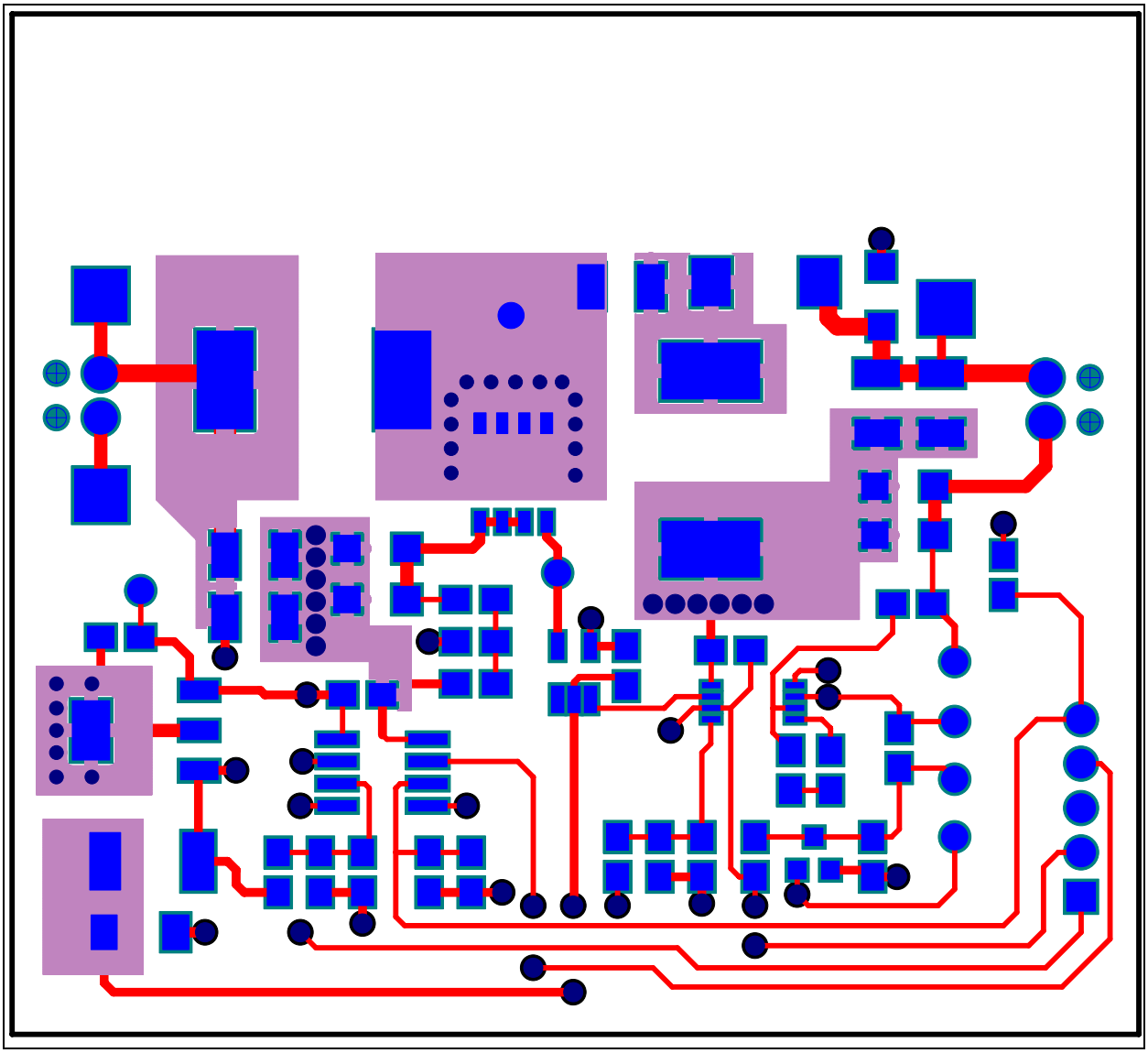
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A.2 BOARD – SCHEMATIC

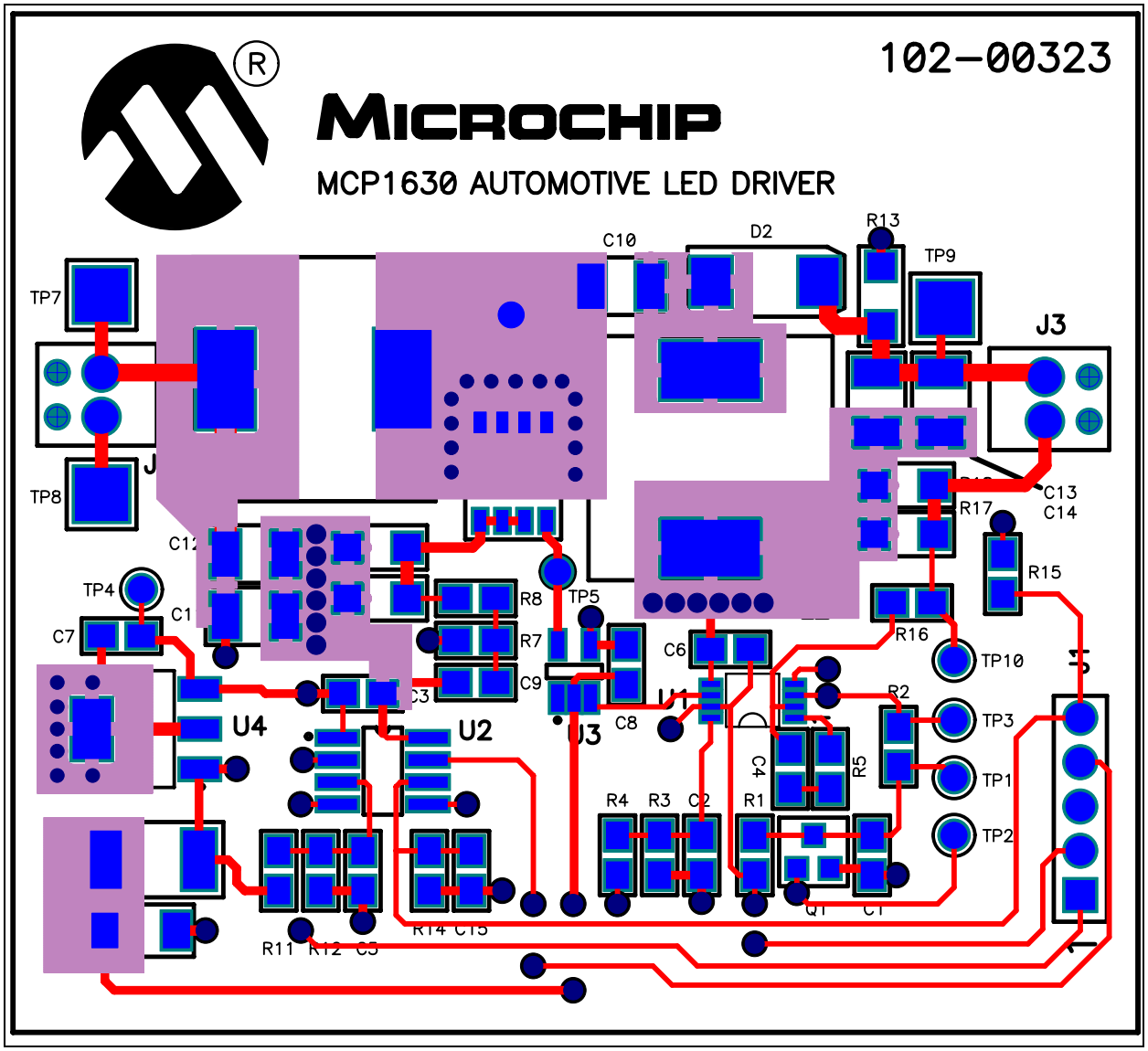


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A.3 BOARD – TOP COPPER AND PADS

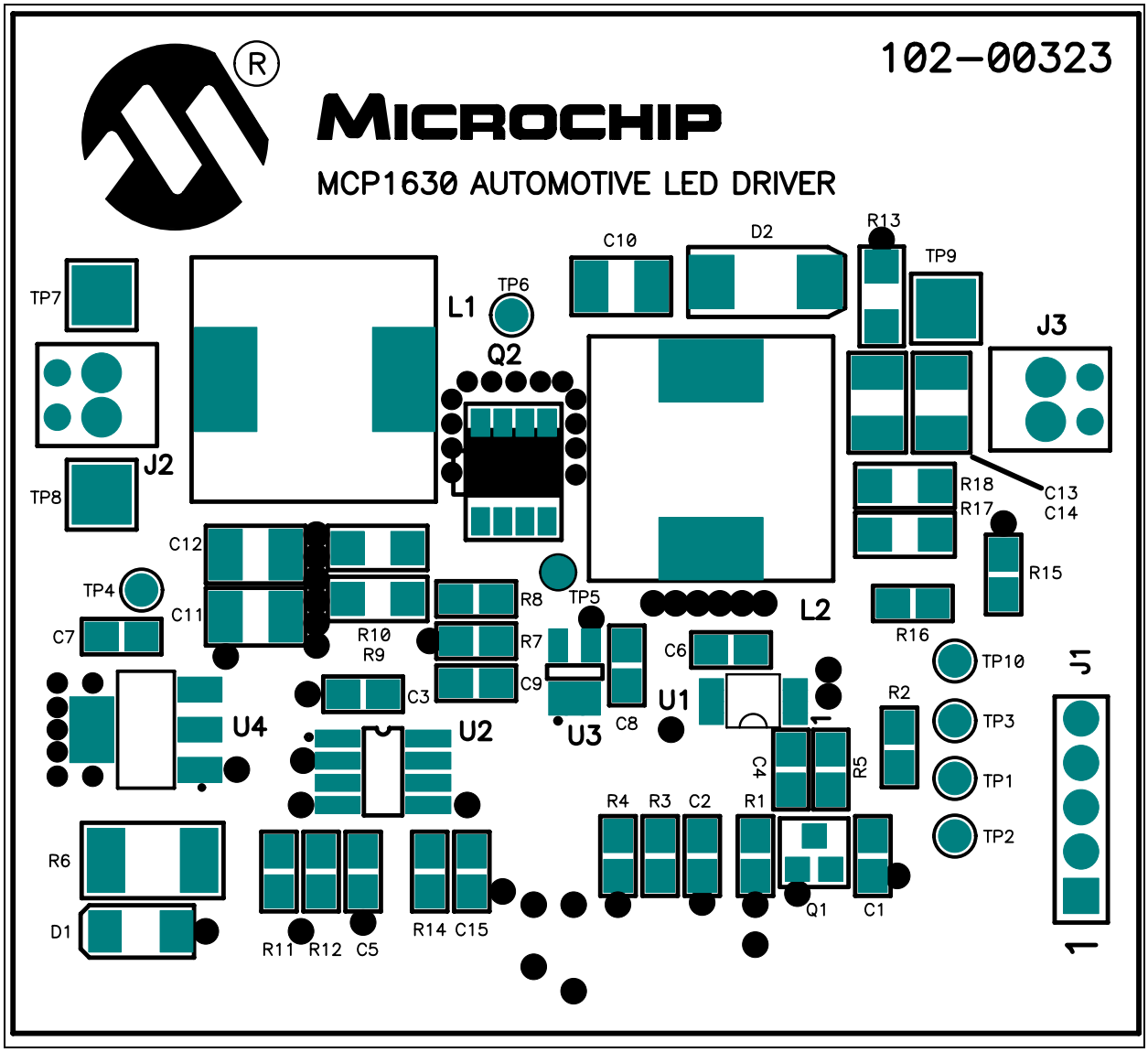


A.4 BOARD – TOP COPPER PADS AND SILK

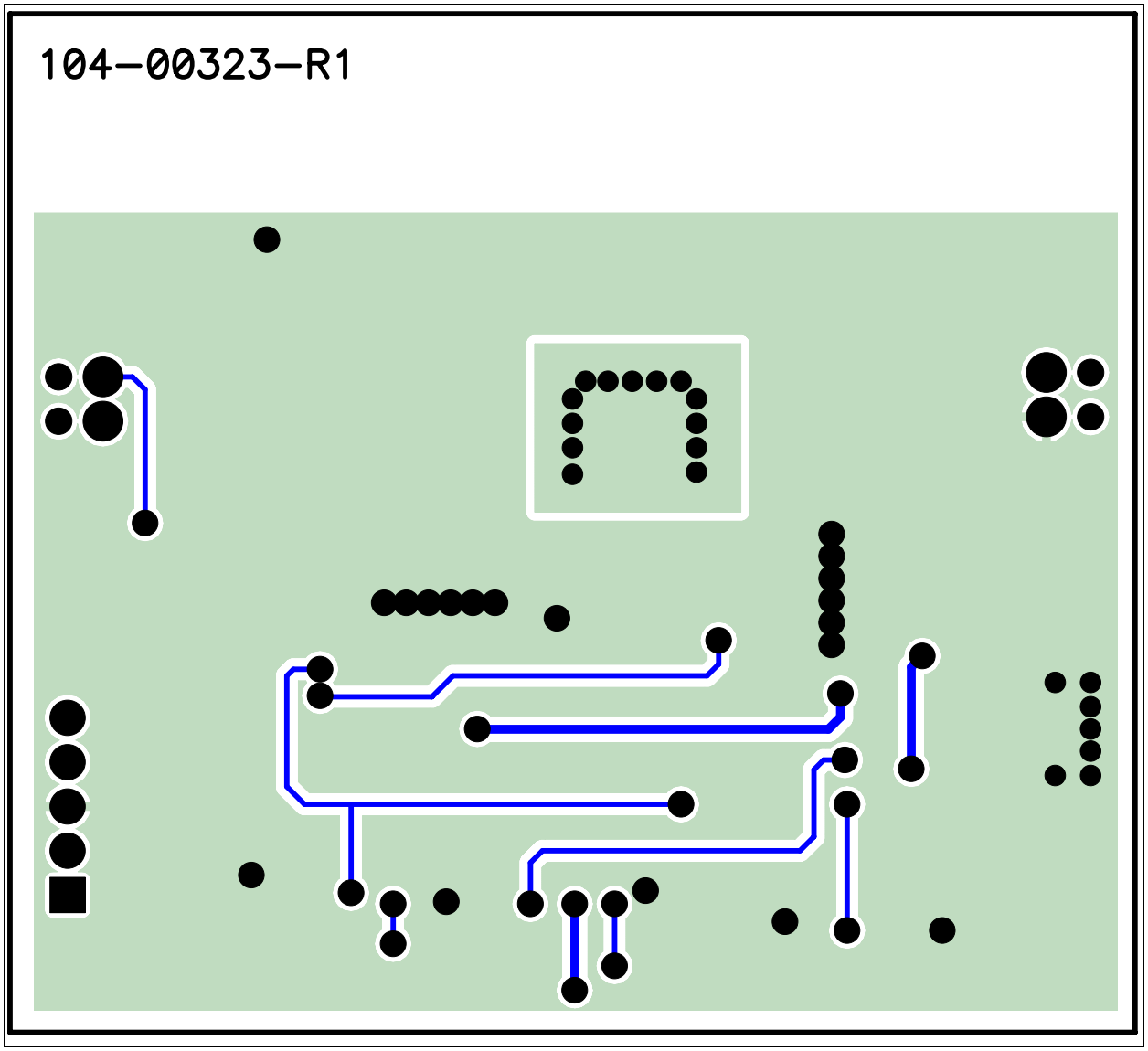


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A.5 BOARD – TOP SILK AND PADS



A.6 BOARD – BOTTOM COPPER AND PADS



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Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)

Qty	Reference	Description	Manufacturer	Part Number
4	B1, B2, B3, B4	BUMPON HEMISPHERE .44X.20 CLEAR	3M	SJ-5303 (CLEAR)
2	C1,C4	CAPACITOR 1500P 50V COG 5% SMD 0805	KEMET®	C0805C152J5GACTU
1	C2	CAPACITOR 1U 16V X7R 10% SMD 0805	KEMET	C0805C105K4RACTU
2	C3, C6	CAPACITOR 100N 100V X7R 10% SMD 0805	KEMET	C0805C104K1RACTU
2	C5, C15	CAPACITOR 470P 50V COG 5% SMD 0805	KEMET	C0805C471J5GACTU
1	C7	CAPACITOR 4.7U 10V X7R 10% SMD 0805	TAIYO YUDEN Co., Ltd.	LMK212B7475KG-T
1	C8	CAPACITOR 1U 25V X7R 10% SMD 0805	KEMET	C0805C105K3RACTU
1	C9	CAPACITOR 22P 50V COG 5% SMD 0805	KEMET	C0805C220J5GACTU
3	C10, C13, C14	CAPACITOR 2.2U 100V X7R 10% SMD 1210	KEMET	C1210C225K1R1C
2	C11, C12	CAPACITOR 10U 25V X7R 10% SMD 1210	KEMET	C1210X106K3RACTU
1	D1	SMAZ15-13-F DIODE ZENNER 15V/1W SMD SMA	Diodes Incorporated®	SMAZ15-13-F
1	D2	10BQ100 DIODE SCHOTTKY 100V 1A SMB	Vishay Intertechnology, Inc.	10BQ100TRPBF
1	J1	CONN HEADER 5POS .100 VERT TIN	Molex® Connector Corp.	22-03-2051
2	J2, J3	CONN TERM BLOCK 2.54MM 2POS	Phoenix Contact	1725656
2	L1, L2	INDUCTOR POWER 22UH 6.0A SMD	Wurth® Group	7443551221
1	PCB	RoHS Compliant Bare PCB, MCP1630 SEPIC Automotive LED Driver Reference Design	—	104-00323
1	Q1	NDS7002A MOSFET N-CH 60V 280MA SOT-23	Fairchild Semiconductor®	NDS7002A
1	Q2	BSC196N10NS G MOSFET N-CH 100V 45A TDSON-8	Infineon Technologies AG	BSC196N10NS G
1	R1	RESISTOR 5.1K OHM 1/8W 1% SMD 0805	Vishay Intertechnology, Inc.	CRCW08055K10FKEA
1	R2	RESISTOR 2.7K OHM 1/8W 1% SMD 0805	Vishay Intertechnology, Inc.	CRCW08052K70FKEA

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)

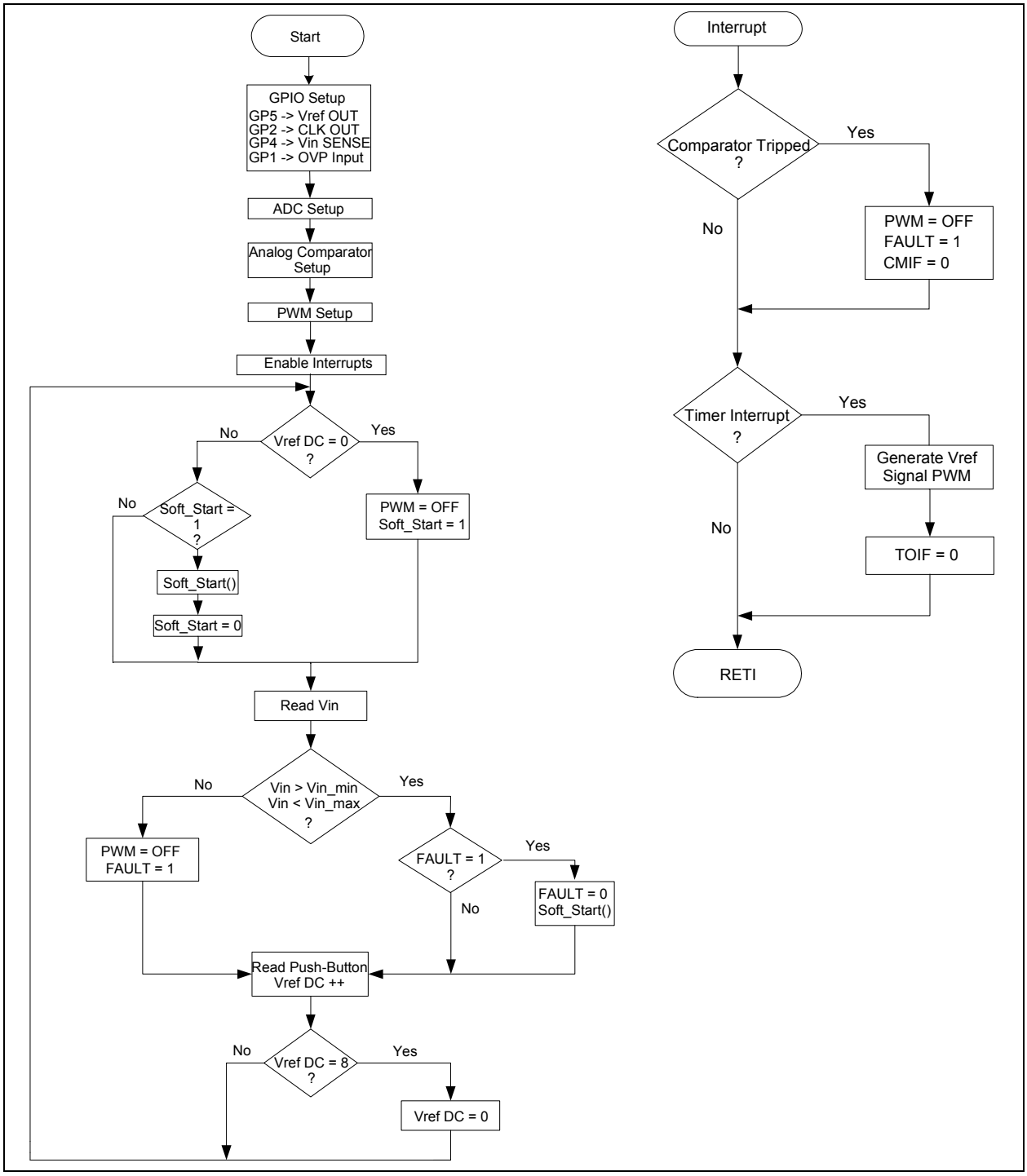
Qty	Reference	Description	Manufacturer	Part Number
1	R3	RESISTOR 100K OHM 1/8W 1% SMD 0805	Vishay Intertechnology, Inc.	CRCW0805100KFKEA
1	R4	RESISTOR 2.7M OHM 1/8W 1% SMD 0805	Vishay Intertechnology, Inc.	CRCW08052M70FKEA
3	R5, R12, R16	RESISTOR 10K OHM 1/8W 1% SMD 0805	Vishay Intertechnology, Inc.	CRCW080510K0FKEA
1	R6	RESISTOR 68 OHM 1W 5% SMD 2512	Vishay Intertechnology, Inc.	CRCW251268R0JNEG
2	R7, R8	RESISTOR 1K OHM 1/8W 1% SMD 0805	Vishay Intertechnology, Inc.	CRCW08051K00FKEA
2	R9, R10	RESISTOR 0.22 OHM 1/2W 1% SMD 1206	Vishay Intertechnology, Inc.	RCWE1206R220FKEA
1	R11	RESISTOR 91K OHM 1/8W 1% SMD 0805	Vishay Intertechnology, Inc.	CRCW080591K0FKEA
1	R13	RESISTOR 15K OHM 1/4W 1% SMD 1206	Vishay Intertechnology, Inc.	CRCW120615K0FKEA
1	R14	RESISTOR 3.3K OHM 1/8W 1% SMD 0805	Vishay Intertechnology, Inc.	CRCW08053K30FKEA
1	R15	RESISTOR 62K OHM 1/8W 1% SMD 0805	Vishay Intertechnology, Inc.	CRCW120615K0FKEA
2	R17, R18	RESISTOR 1 OHM 1/4W 1% SMD 1206	Vishay Intertechnology, Inc.	CRCW12061R00FKEA
3	TP7, TP8, TP9	TEST POINT PC COMPACT SMT	Keystone® Electronics Corp.	5016
1	U1	MCP1630 HIGH-SPEED uC ADAPTABLE PWM CONTROLLER MSOP10	Microchip Technology Inc.	**MCP1630-E/MS**
1	U2	PIC12F683 8BIT FLASH MICROCONTROLLER SOIC8	Microchip Technology Inc.	**PIC12F683-E/SN**
1	U3	MCP1416 TINY 1.5A POWER MOSFET DRIVER SOT23-5	Microchip Technology Inc.	**MCP1416T-E/OT**
1	U4	MCP1790 70MA HIGH-VOLTAGE REGULATOR SOT-223	Microchip Technology Inc.	**MCP1790-5002E/DB**

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.

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Appendix C. Firmware Flowchart

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



NOTES:

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Appendix D. Test Points and Waveforms

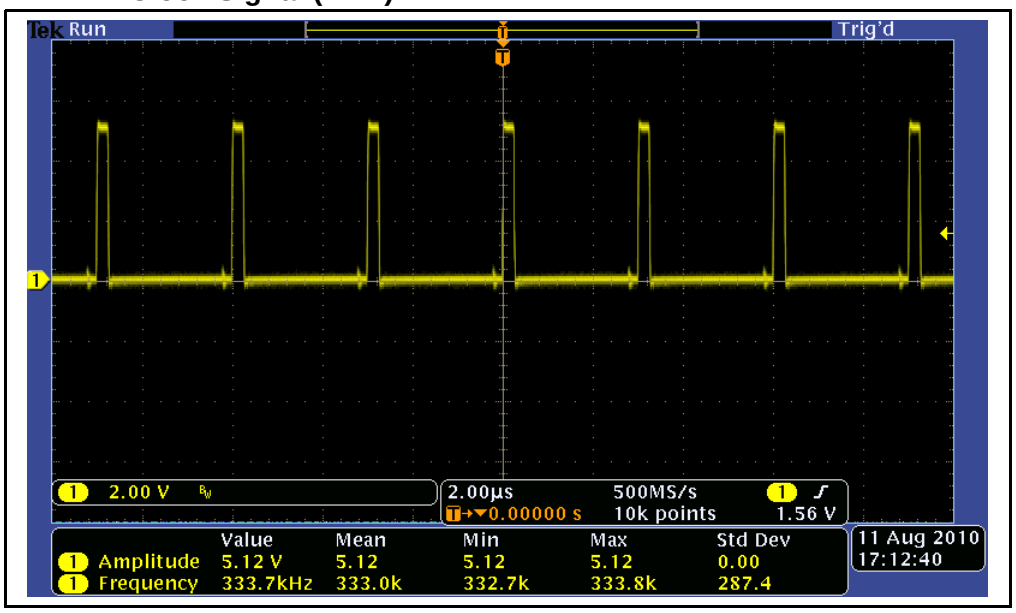
D.1 TEST POINTS DESCRIPTION

TABLE D-1: TEST POINTS

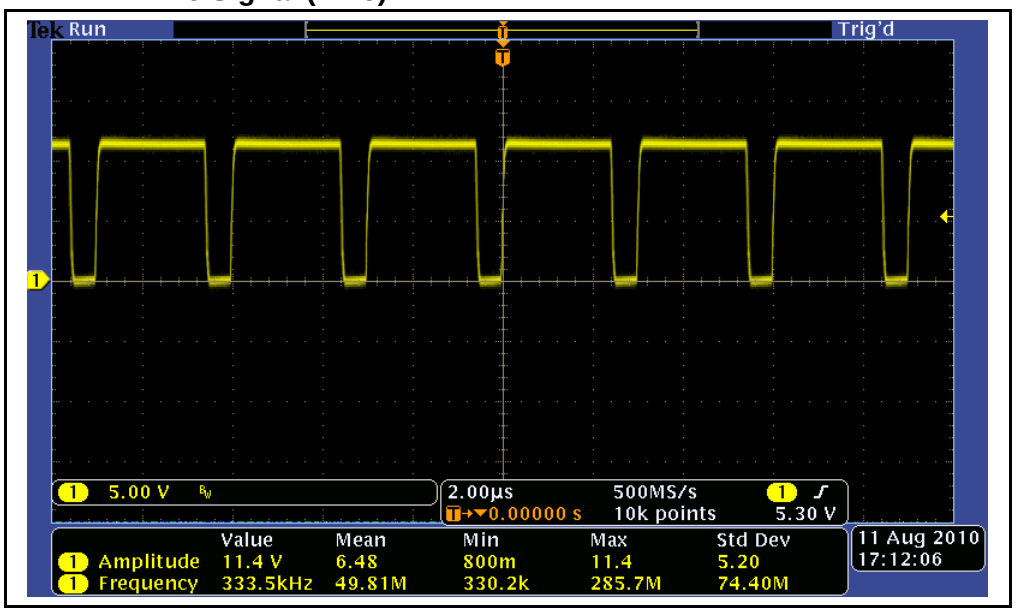
Testpoint	Name	Description
TP1	RAMP	Artificial ramp for Slope Compensation
TP2	CLK	Master clock for PWM controller
TP3	CS	Current sense pin for PWM controller
TP4	+5V	Microcontroller and PWM controller supply voltage
TP5	DRIVE	Gate drive of Power MOSFET
TP6	DRAIN	Drain terminal of the Power MOSFET
TP7	$+V_{IN}$	Input Voltage
TP8	GND	Board ground. All measurements are referred to this test point.
TP9	V_{OUT}	Output Voltage
TP10	I_{SENSE}	Main current sense test point. The output current is estimated by dividing the voltage from this test pint with 0.5.

D.2 WAVEFORMS EXAMPLES

D.2.1 Clock Signal (TP 2)

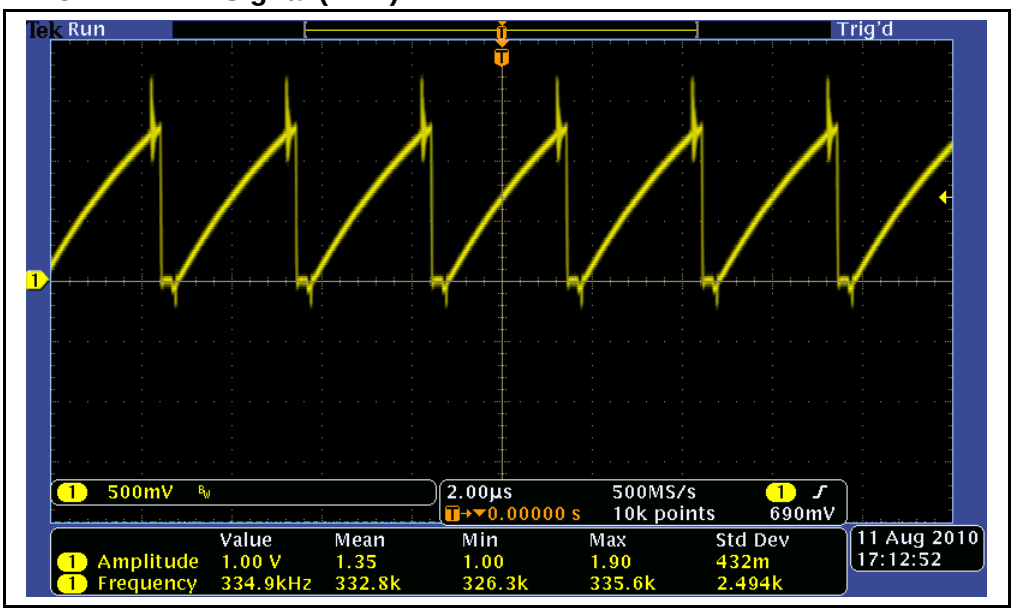


D.2.2 Drive Signal (TP 5)

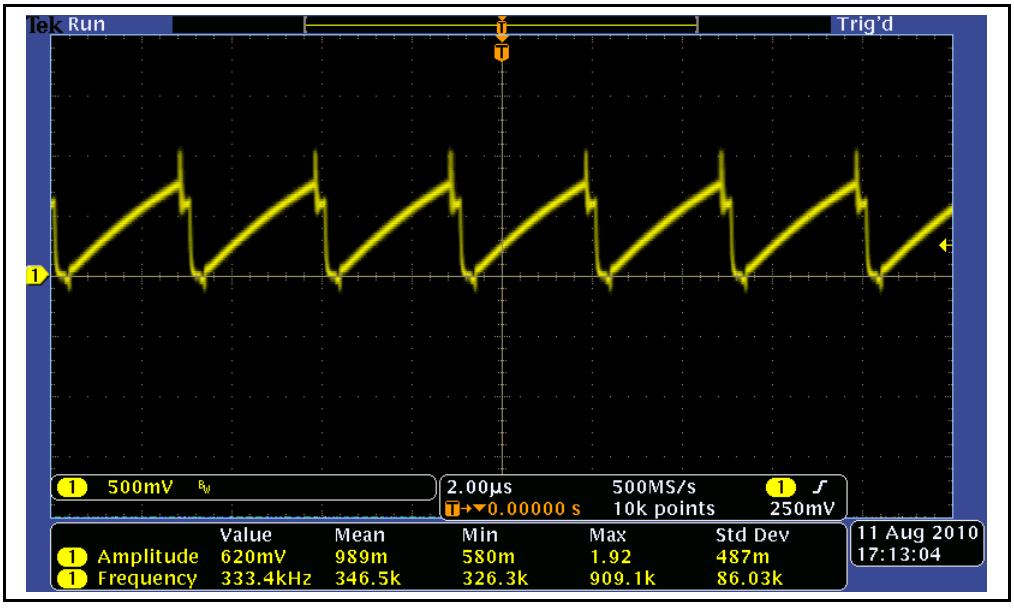


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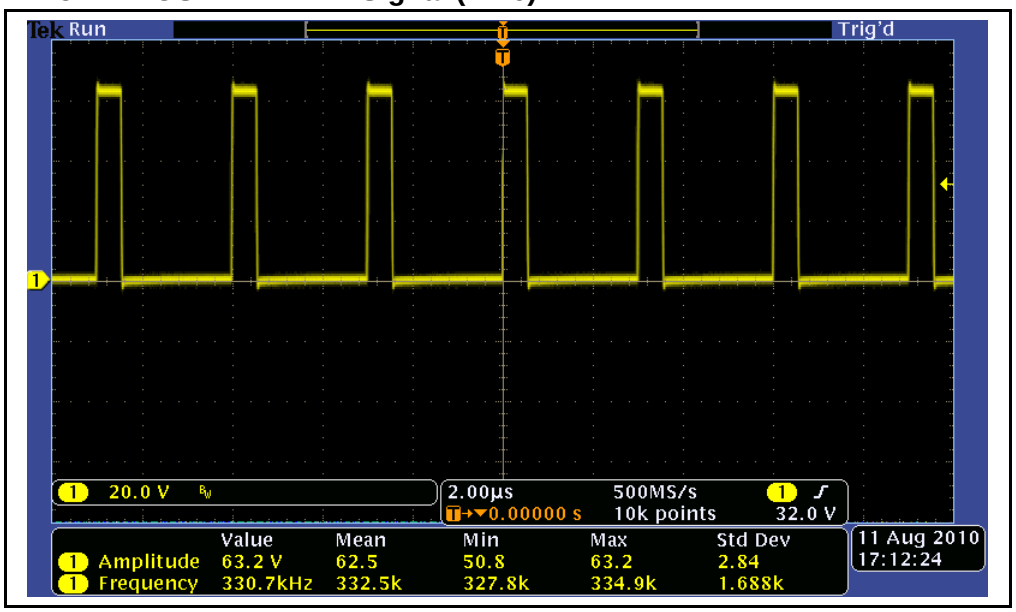
D.2.3 RAMP Signal (TP 1)



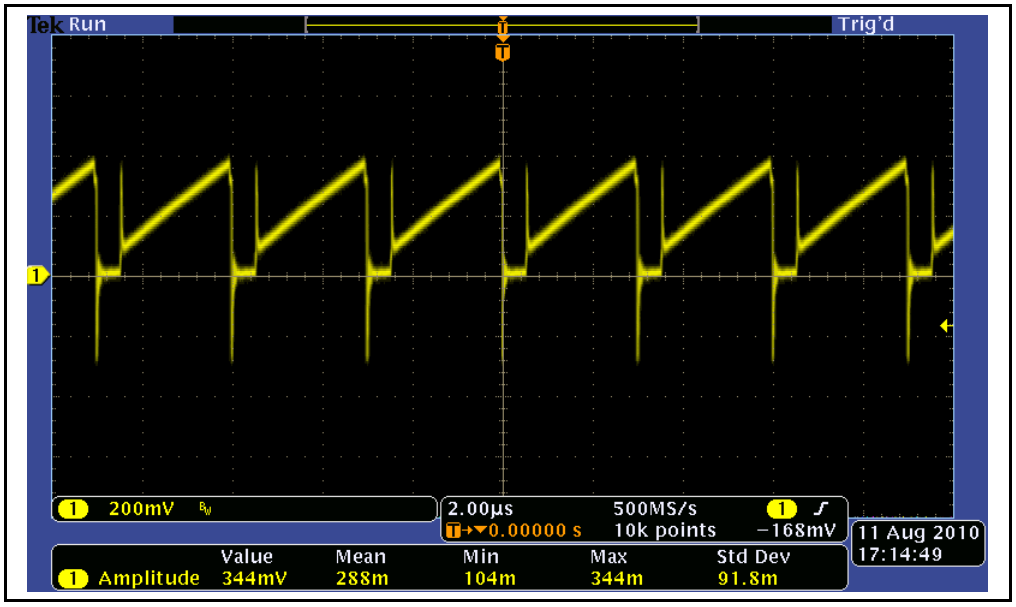
D.2.4 CS Signal (TP 3)



D.2.5 MOSFET DRAIN Signal (TP 6)

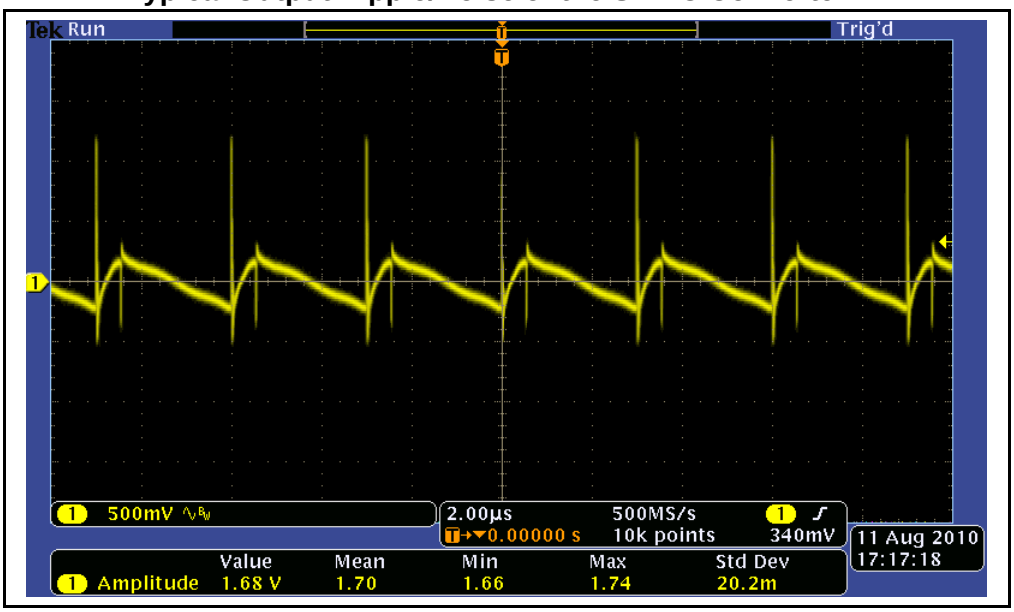


D.2.6 Main Inductor Current

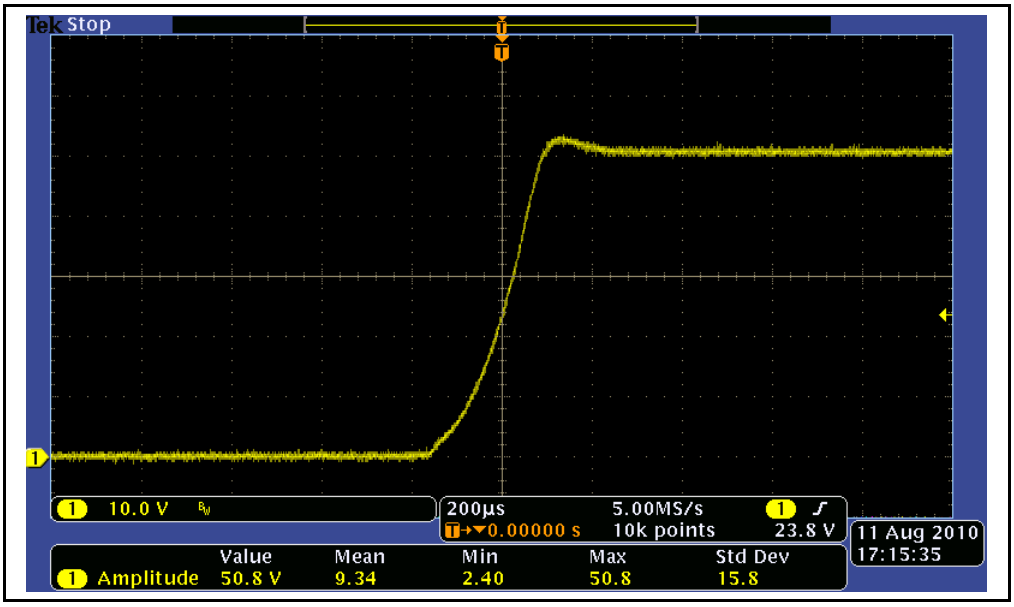


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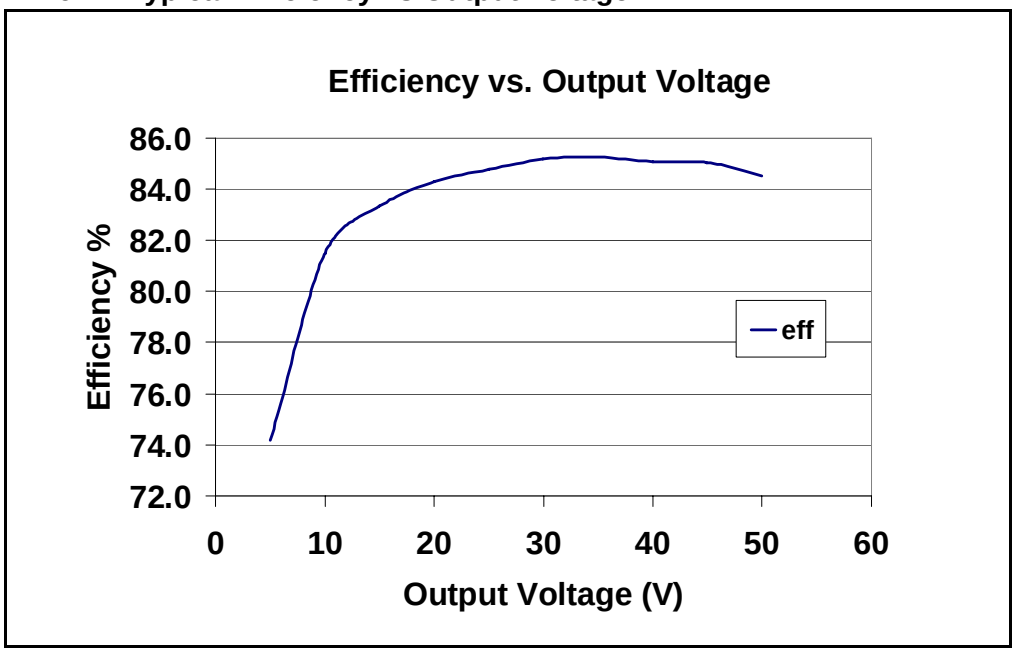
D.2.7 Typical Output Ripple/Noise of the SEPIC Converter



D.2.8 Typical Step Response (Zero to Full Load)



D.2.9 Typical Efficiency vs Output Voltage



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