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MCP1640
Single Quadruple-A Battery
Boost Converter
Reference Design

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MCP1640 SINGLE QUADRUPLE-A BATTERY BOOST CONVERTER REFERENCE DESIGN

Table of Contents

NOTES:

MCP1640 SINGLE QUADRUPLE-A BATTERY BOOST CONVERTER REFERENCE DESIGN

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 on-line 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 MCP1640 Single Quadruple-A Battery Boost Converter Reference Design. 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 MCP1640 Single Quadruple-A Battery Boost Converter Reference Design 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 MCP1640 Single Quadruple-A Battery Boost Converter Reference Design.
- **Chapter 2. "Installation and Operation"** – Includes instructions on how to get started with MCP1640 Single Quadruple-A Battery Boost Converter Reference Design and a description of the user's guide.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the MCP1640 Single Quadruple-A Battery Boost Converter Reference Design.
- **Appendix B. "Bill of Materials"** – Lists the parts used to build the MCP1640 Single Quadruple-A Battery Boost Converter Reference Design.
- **Appendix C. "MCP1640 Single Quadruple-A Battery Boost Converter Reference Design Firmware"** – Lists the board firmware flowchart.

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)` `{ ...` `}`

RECOMMENDED READING

This user's guide describes how to use MCP1640 Single Quadruple-A Battery Boost Converter Reference Design. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

- **MCP1640 Data Sheet** – *"0.65V Start-up Synchronous Boost Regulator with True Output Disconnect or Input/Output Bypass Option"* **(DS22234)**
- **AN1311 –** *"Single Cell Input Boost Converter Design"* **(DS01311)**

THE MICROCHIP WEB SITE

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- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- 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 B (August 2011)

- Added Figures 2-4 and 2-5 in **Section Chapter 2. "Installation and Operation"**, (**Section 2.2.2**).
- Corrected board schematic in **Appendix A. "Schematic and Layouts"**.

Revision A (October 2010)

- Initial Release of this Document.

NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the MCP1640 Single Quadruple-A Battery Boost Converter Reference Design and covers the following topics:

- MCP1640 Short Overview
- What Is the MCP1640 Single Quadruple-A Battery Boost Converter Reference Design?
- MCP1640 Single Quadruple-A Battery Boost Converter Reference Design Kit Contents

1.2 MCP1640 SHORT OVERVIEW

The MCP1640 device is a compact, high-efficiency, fixed frequency, step-up DC-DC converter. It provides an easy-to-use power supply solution, with a minimum number of external components for applications powered by one-cell, two-cell, or three-cell alkaline, NiCd, NiMH, one-cell Li-Ion or Li-Polymer batteries.

The MCP1640 device automatically selects the best operating mode for efficiency, PWM (Pulse-Width Modulation) or PFM (Pulse Frequency Modulation). It has a low quiescent current (19 µA typically), a wide input voltage range (0.35 to 5.5V) and a low start-up voltage (0.65V at 1 mA load current). The MCP1640 device consumes less than 1 µA in Shutdown mode.

Microchip Technology Inc. provides the MCP1640 device in four variants, which help engineers to meet different system requirements. The devices and their available options are presented in Table 1-1.

TABLE 1-1: PART NUMBER SELECTION

Part Number	PWM/PFM Mode	PWM Mode	True Output Disconnect Shutdown Option	Input to Output Bypass Shutdown Option
MCP1640	X	—	X	—
MCP1640B	—	X	X	—
MCP1640C	X	—	—	X
MCP1640D	—	X	—	X

The MCP1640 is available in a SOT23-6 and 8-LD DFN (2x3 mm) packages. For additional information on the MCP1640 device, refer to the MCP1640/B/C/D Data Sheet.
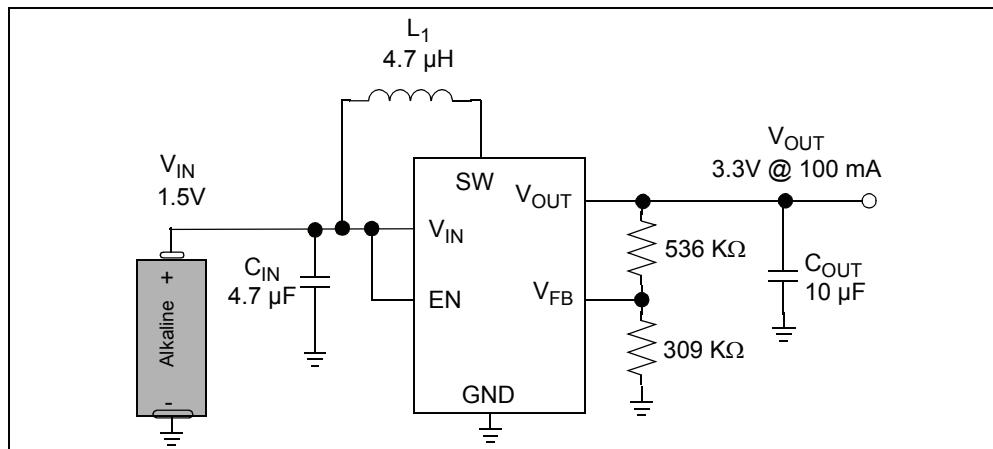
FIGURE 1-1: *Typical MCP1640 Single Cell Input Boost Converter.*

1.3 WHAT IS THE MCP1640 SINGLE QUADRUPLE-A BATTERY BOOST CONVERTER REFERENCE DESIGN?

The MCP1640 Single Quadruple-A Battery Boost Converter Reference Design is designed to demonstrate the MCP1640 features in a microcontroller application that optimizes the battery lifetime. The MCP1640 Single Quadruple-A Battery Boost Converter Reference Design was developed to help engineers reduce product design cycle time.

At 1.5V input and 3.3V output, the board is capable of 130 mA load current.

The EN signal is used to enable and disable the MCP1640 device. When enabled, the MCP1640 will regulate the output voltage. When disabled, the MCP1640 disconnects the path from the input to output for True Output Disconnect Shutdown option. The MCP1640 Single Quadruple-A Battery Boost Converter Reference Design uses this feature to reduce no load Standby current. During Standby, the enable signal has a low frequency, with less than 1% positive duty cycle. This board demonstrates that this solution increases the battery life.

1.4 MCP1640 SINGLE QUADRUPLE-A BATTERY BOOST CONVERTER REFERENCE DESIGN KIT CONTENTS

This MCP1640 Single Quadruple-A Battery Boost Converter Reference Design kit includes:

• MCP1640 Single Quadruple-A Battery Boost Converter Reference Design, 102-00318
• Important Information Sheet

Chapter 2. Installation and Operation

2.1   INTRODUCTION

2.1.1   MCP1640 Features

The MCP1640 device has been developed to increase battery life. The MCP1640 is capable of regulating the output voltage over a wide range (2.0V to 5.5V), and typically delivers over 100 mA load current at 3.3V output, when supplied from a single 1.5V cell.

The key features of the MCP1640 that help optimize the battery life include:

- Up to 96% efficiency
- PFM switching mode for light loads
- Low input start-up voltage, typically 0.65V at 1 mA load current
- Low shutdown voltage (continuously operating down to 0.35V input under light load condition)
- True Output Disconnect Shutdown option, preventing leakage current from input to output (less than 1 μA is consumed from the battery in this mode)
- 19 μA typically quiescent current

For applications powered by alkaline cells that consume few milliamperes, the MCP1640 device can operate to the minimum input voltage necessary to completely drain the battery.

2.1.2 MCP1640 Single Quadruple-A Battery Boost Converter Reference Design Features

The MCP1640 Single Quadruple-A Battery Boost Converter Reference Design is developed to demonstrate how the MCP1640 device with True Output Disconnect Shutdown option is working attached to a microcontroller application. The board demonstrates how to optimize battery life using the MCP1640 and an 8-bit low-cost PIC® microcontroller, to reduce the No Load Input Current for applications that operate in Standby mode for a longer period of time.
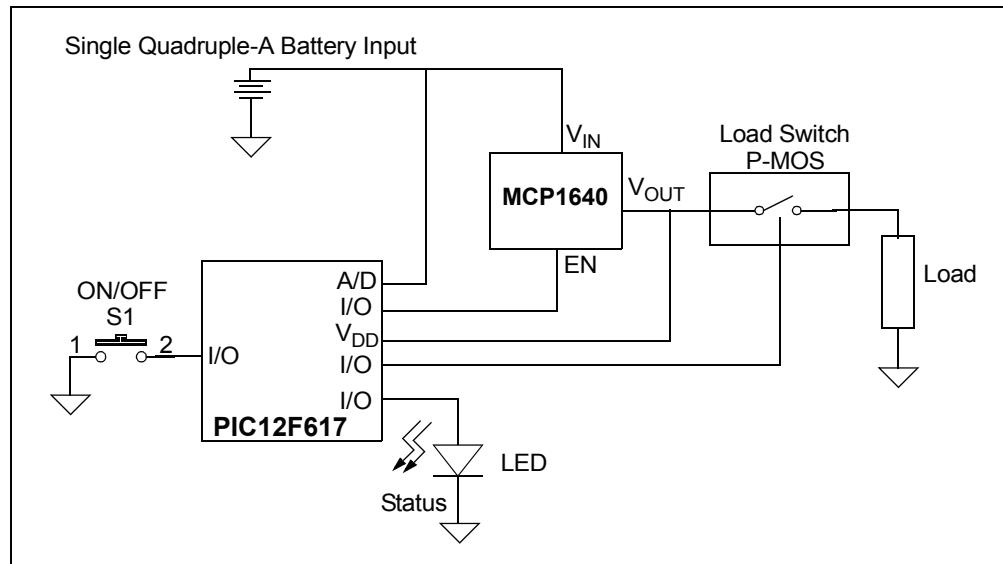
FIGURE 2-1: *MCP1640 Single Quadruple-A Battery Boost Converter Reference Design Block Diagram.*

The MCP1640 Single Quadruple-A Battery Boost Converter Reference Design has the following features:

- Input voltage: one AAAA Alkaline battery
- Output voltage: 3.3V
- Output current: < 130 mA
- Up to 75% efficiency
- Standby battery current: 14.5 µA @ 1.5V input
- Start-up voltage: 0.65V at V_{IN} = 1.2V, V_{OUT} = 3.3V and I_{OUT} = 1 mA, resistive load
- Automatic PFM/PWM operation
- PWM Switching Frequency = 500 kHz
- ON/OFF switch button, with approximately 25 seconds ON
- LED status indication (Output ON and Low Battery)
- Energizer® Battery Holder with reverse battery protection

2.2   GETTING STARTED

The MCP1640 Single Quadruple-A Battery Boost Converter Reference Design is fully assembled and tested to evaluate and demonstrate the MCP1640 products.

2.2.1   Power Input and Output Connection

2.2.1.1   POWERING THE MCP1640 SINGLE QUADRUPLE-A BATTERY BOOST CONVERTER REFERENCE DESIGN

The MCP1640 Single Quadruple-A Battery Boost Converter Reference Design is equipped with an innovative Energizer Battery Holder, which protects against the reverse insertion of the AAAA alkaline battery. If the battery is inserted correctly, the board will start in Standby mode. To switch the output ON, press the button S1 for 2 seconds. The output is active for approximately 25 seconds. Pressing the button during this period will turn OFF the output.

Extra connectors are placed on the top side of the board:

- TP1 and TP5 for positive (V_{IN})
- TP2 and TP4 for negative (GND)

These two connectors help engineers power the board from an external power supply. In this case, the maximum input voltage should not exceed the 3.3V output ($V_{IN} < V_{OUT}$). The output voltage will not remain regulated for input voltages that are greater than or equal to the output voltage.

The output connector is called "OUT", and is referenced to GND. The maximum output current is 130 mA when the board is powered by a quadruple-A alkaline battery, which has a typical capacity of 600 mAh.

2.2.1.2   BOARD TESTING

To test the board, follow the next steps:

1. Insert the quadruple-A battery in its holder, paying attention to respect the polarity.
2. Connect a voltmeter and a 47Ω/0.5W resistor, between "OUT" and "–" connectors, as shown in Figure 2-2.
3. Press and hold the push button for approximately 2 seconds. The LED should be lit.
4. The LED will be ON for approximately 25 seconds. During this period, verify the presence of 3.3V at "OUT".
5. Press and hold the push button for 2 seconds to verify that power turns ON and OFF.

The resistor R9 is not populated. The component pads are provided for experimental use. The header J3 is also not populated. It can be used to re-program the microcontroller.
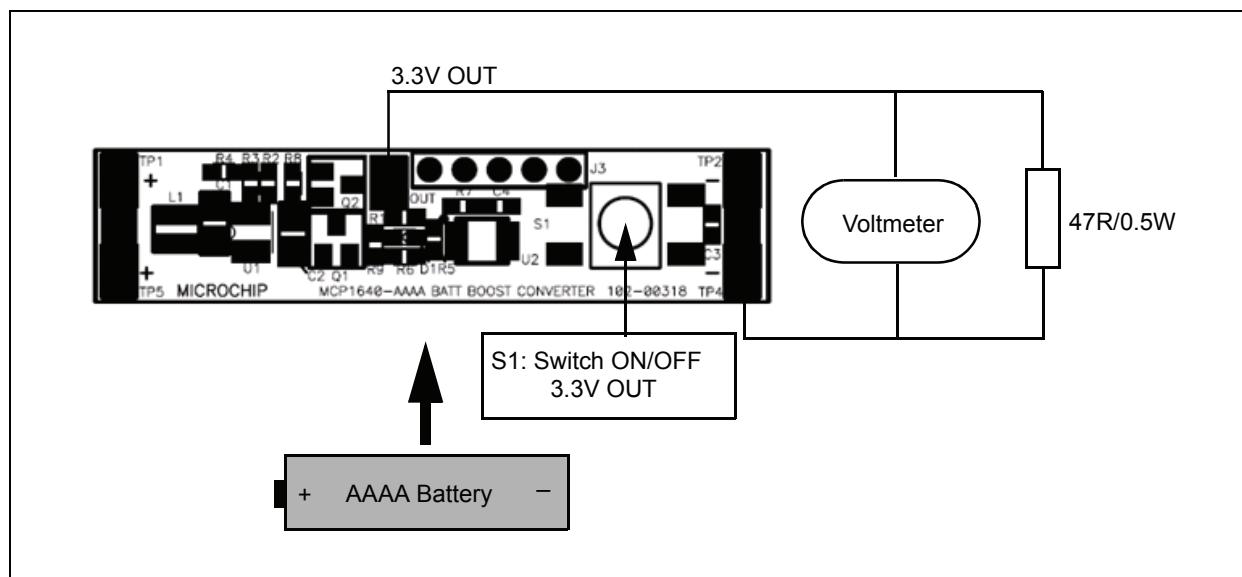
FIGURE 2-2: *MCP1640 Single Quadruple-A Battery Boost Converter Reference Design Setup Circuit.*

2.2.2 How the MCP1640 Single Quadruple-A Battery Boost Converter Reference Design is working?

The board is powered from a quadruple-A battery which has 600 mAh typical capacity. If the battery is inserted in the holder, the application will start running in Standby mode. In this mode, the PIC12F617 works in Sleep Mode most of the time, consuming a few µA from the battery. The MCP1640 consumes 0.75 µA typically in Shutdown mode. When the MCP1640 is in Normal operating mode, the No Load Input Current is approximately 70 µA at 1.5V input. To reduce the average input current of the board, the MCP1640's EN input is pulsed at a slow rate. Figure 2-3 shows that this current is reduced up to 80%.
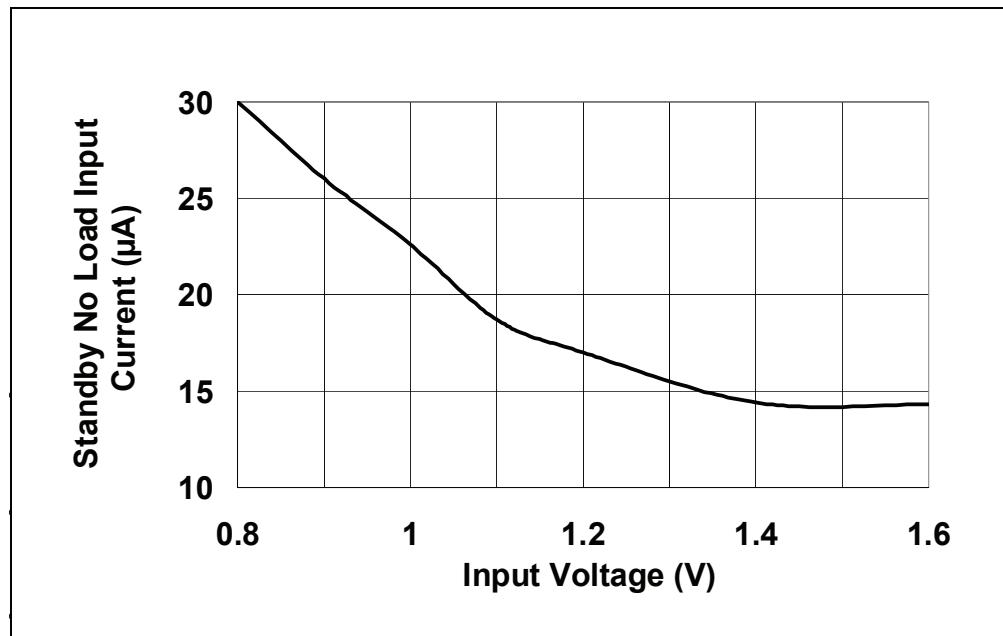
FIGURE 2-3: *The Average Current Consumed from the Battery in Standby Mode.*

Periodically, the microcontroller will come out from Sleep mode for a short period of time to search if its power supply (V_{DD}), which comes from the MCP1640 V_{OUT} pin, reaches 2.3V threshold. This is accomplished by the internal analog comparator of the microcontroller.

This compares a fraction of V_{OUT} (from R4) with the 0.6V internal voltage reference. To avoid losing power on the passive components and reduce the complexity of the schematic, the application also uses the feedback network (R2-R3-R4) of the MCP1640 as the input to the PIC MCU comparator.

The PIC12F617 microcontroller works down to 2.0V V_{DD}. If a 2.3V threshold is detected, the GP2 pin of the microcontroller will set the EN pin of the MCP1640 high for a short time, to pump up the output capacitor to a 3.3V regulated voltage. After that, EN is pulled down again and the MCP1640 enters into the True Output Disconnect Shutdown option. V_{OUT} is sustained by the output capacitor (C2) for approximately 2 seconds until it reaches the 2.3V threshold.
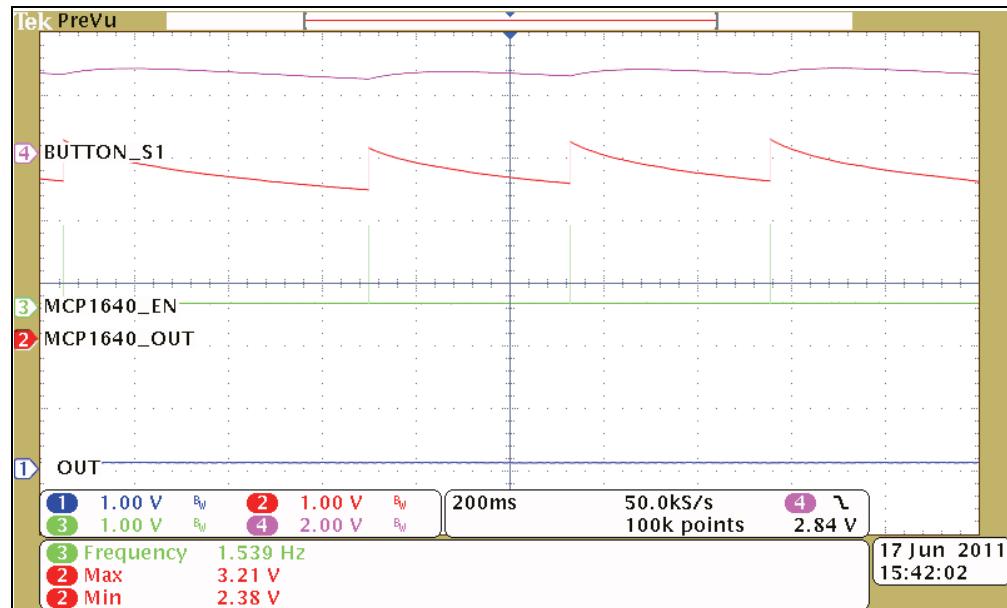
**FIGURE 2-4:** *Waveforms while MCP1640 is Shutdown (OUT is off).*

Generally, the EN drive signal frequency depends on the MCP1640 devices' output capacitor value and the PIC12F617 MCUs Sleep current. The typical time to charge the output capacitor to 3.3V is 750 ns, with a load less than 10 µA.

The EN signal is inverted using the transistor Q1 to ensure the start of the application when a battery is inserted.

By pressing the button S1, the GP1 microcontroller port switches the P-MOS transistor ON (Q2), powering the load. The load is supplied for a fixed period of time (approximately 25 seconds), unless the button is pressed.
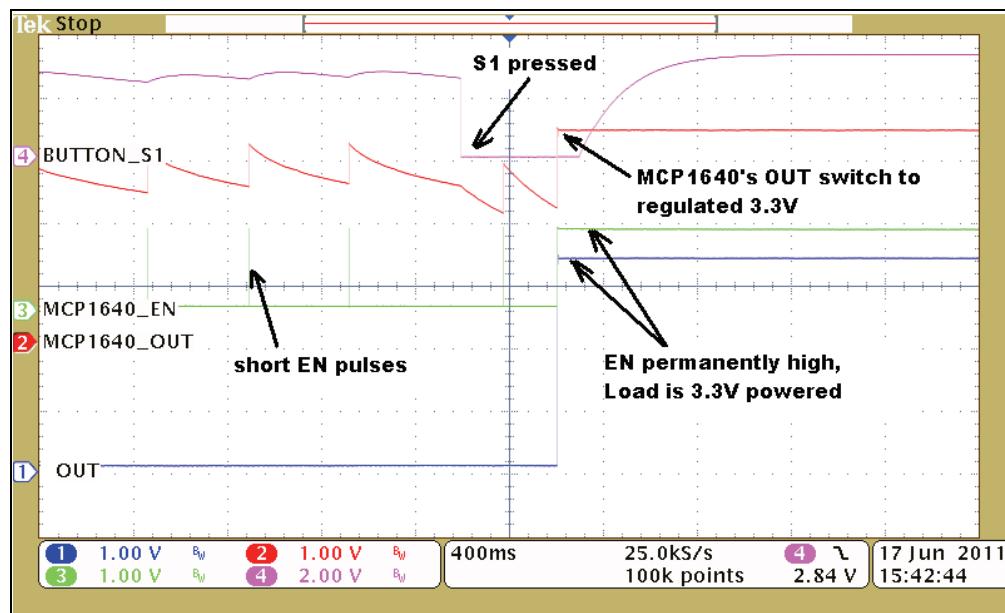

FIGURE 2-5: *Waveforms when Reference Board is Turned ON by pressing S1 Button.*

The PIC12F617 measures the battery voltage when the switch load (Q2) is ON. If the battery voltage is lower than 0.8V, the LED (D1) will flash. Battery voltage is measured using the R7-C4 filter and the A/D channel present on pin 3 (GP4) of the microcontroller.

2.2.3   Programming the PIC12F617 Microcontroller

For board evaluation, Microchip provides a firmware package, downloadable from Microchip's web site. The board is factory programmed for an active 10 seconds output, after the button S1 is pressed. The green LED on the board flashes when a low battery condition (less than 0.8V input) is detected, but the board will operate at the lowest input voltage possible. All parameters may be changed in firmware to the desired value, according to the output/input capability. The source code is rich in comments and helps the user to define the board.

The HI-TECH C$^®$ compiler is used to compile the source code and create the hex files for downloading to the reference board. The HI-TECH compiler is available for download on Microchip's web site. The compiler is not included with the evaluation board kit.

Header J3 can be used for in-system circuit programming. J3 is not populated on the board. A five-pin header connector may be soldered in J3's place. A PICkit™ 3 programmer may be connected to J3 to program the evaluation board.

Appendix A. Schematic and Layouts

A.1 INTRODUCTION

This appendix contains the following schematics and layouts for the MCP1640 Single Quadruple-A Battery Boost Converter Reference Design:

- Board – Schematic
- Board – Top Silk And Pads
- Board – Top Trace And Pads
- Board – Bottom Silk Layer
- Board – Bottom Trace, Pads And Silk

A.2   BOARD – SCHEMATIC
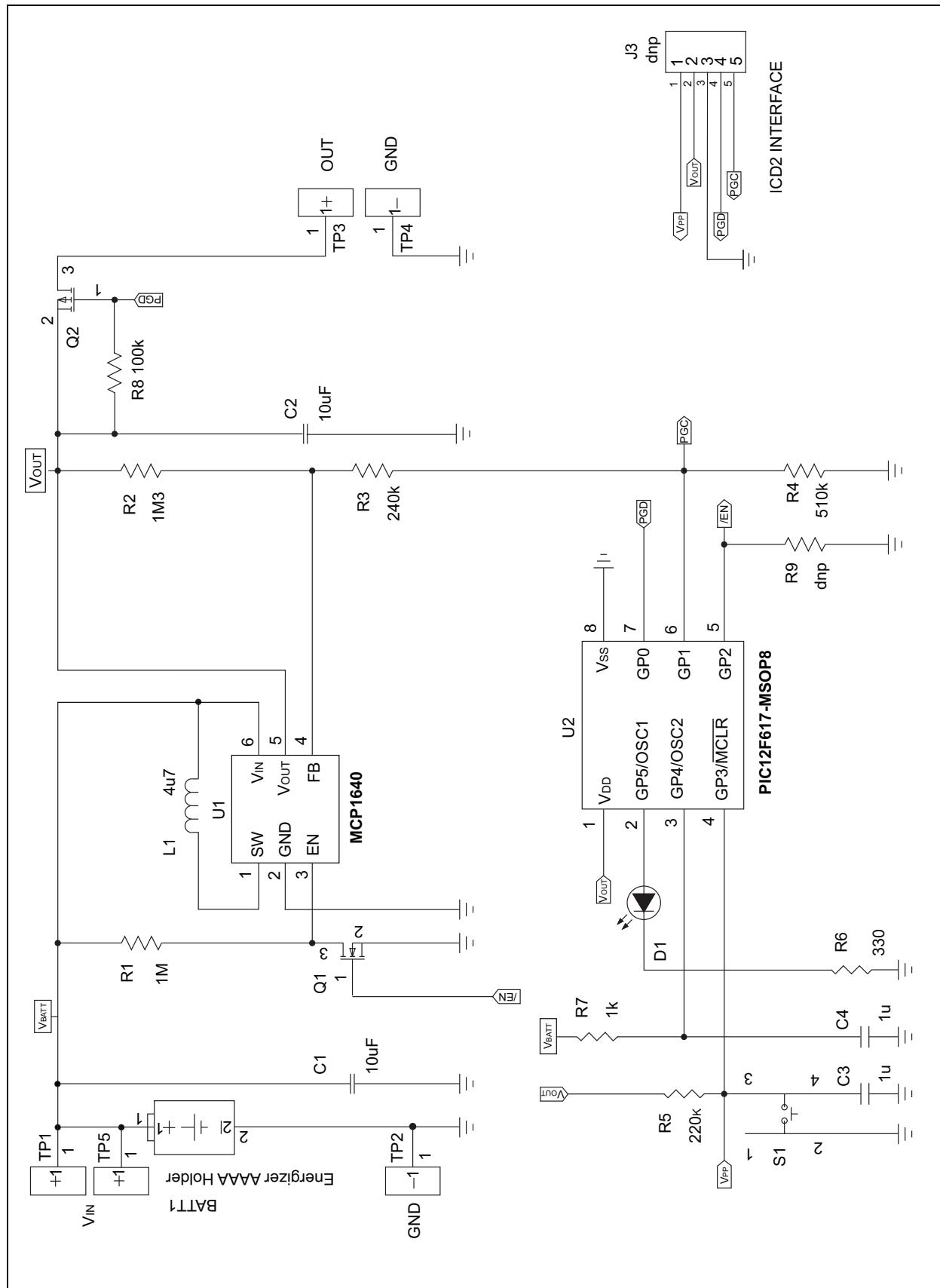
A.3   BOARD – TOP SILK AND PADS
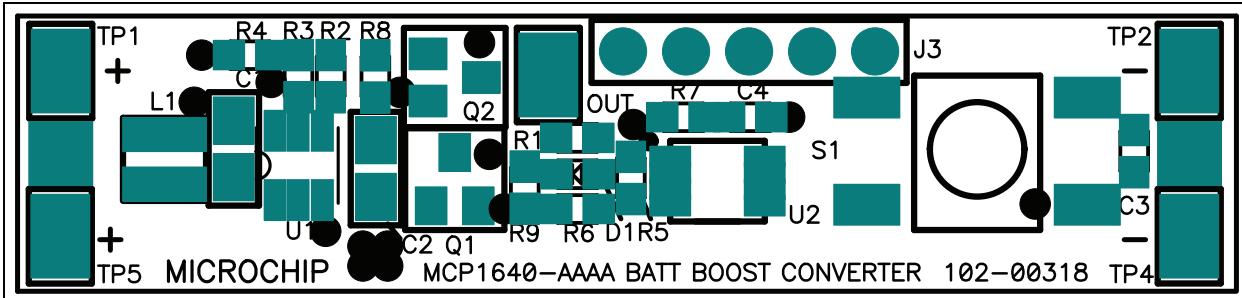
A.4   BOARD – TOP TRACE AND PADS
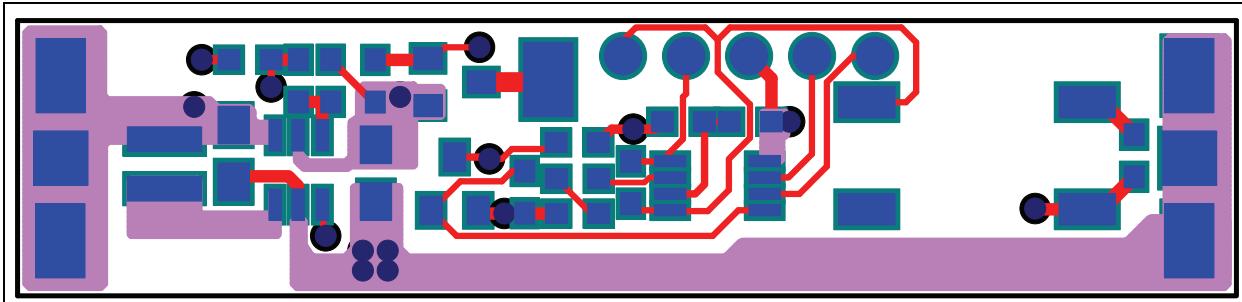
A.5   BOARD – BOTTOM SILK LAYER

A.6   BOARD – BOTTOM TRACE, PADS AND SILK
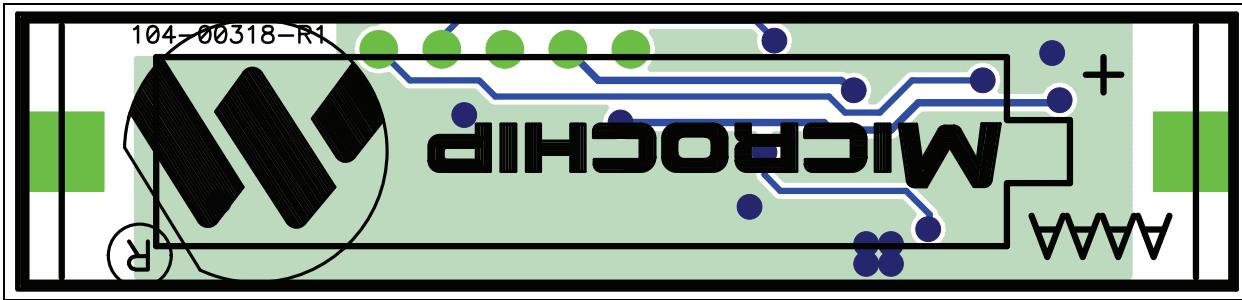
NOTES:

Appendix B. Bill of Materials

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

Qty	Reference	Description	Manufacturer	Part Number
1	AAAA Battery	AAAA/E96 Alkaline Battery	Energizer®	E96BP-2
1	BATT1	AAAA Battery Holder	Energizer	-
2	C1, C2	CAP CER 10 µF 6.3V X7R 10% 0805	Taiyo Yuden®	JMK212B7106KG-T
2	C3, C4	CAP CER 1.0 µF 10V X7R 0805	Taiyo Yuden	LMK212B7105KG-T
1	D1	LED CHIPLED 570 nm GREEN 0603 SMD	OSRAM Opto Semiconductors Inc	LG Q971-KN-1-0-20-R18
0	J3	DO NOT POPULATE CONN HEADER 5POS .100 VERT TIN	Molex® Electronics	22-03-2051
1	L1	INDUCTOR POWER 4.7 µH	Coilcraft	EPL3015-472MLB (XFL3012-472ME)
1	PCB	RoHS Compliant Bare PCB, MCP1640 Single Quadruple-A Battery Boost Converter Reference Design	—	104-00318
1	Q1	MOSFET N-CH 60V 280 mA SOT-23	Fairchild Semiconductor®	NDS7002A
1	Q2	MOSFET P-CH 20V 1A SSOT3	Fairild Semiconductor	NDS332P
1	R1	RES 1M OHM 1/10W 5% 0603 SMD	Stackpole Electronics Inc	RMCF0603JT1M00
1	R2	RESISTOR 1.30M OHM 1/10W 1% 0603	Panasonic® – ECG	ERJ-3EKF1304V
1	R3	RES 240k OHM 1/10W .1% 0603 SMD	Panasonic – ECG	ERA-3AEB244V
1	R4	RES 510k OHM 1/10W 1% 0603 SMD	Yageo	RC0603FR-07510KL
1	R5	RES 220k OHM 1/10W 5% 0603 SMD	Panasonic – ECG	ERJ-3GEYJ224V
1	R6	RES 330 OHM 1/10W 5% 0603 SMD	Stackpole Electronics, Inc.	RMCF0603JT330R
1	R7	RES 1k OHM 1/10W 5% 0603 SMD	Stackpole Electronics, Inc.	RMCF0603JT1K00
1	R8	RES 100k OHM 1/10W 5% 0603 SMD	Stackpole Electronics, Inc.	RMCF0603JT100K
0	R9	DO NOT POPULATE RES 1M OHM 1/10W 5% 0603 SMD	Stackpole Electronics, Inc.	RMCF0603JT1M00
5	TP1 – TP5	PC TEST POINT TIN SMD	Harwin	S1751-46R
1	S1	SWITCH TACT 6 mm 260GF SMT	E-Switch, Inc	TL3301NF260QG
1	U1	MCP1640 Synchronous Boost Converter - SOT23-6	Microchip Technology Inc.	MCP1640T-I/CHY
1	U2	PIC12F617 IC MCU 8BIT 3.5KB FLASH 8MSOP	Microchip Technology Inc.	PIC12F617T-I/MS

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.

NOTES:

Appendix C. MCP1640 Single Quadruple-A Battery Boost Converter Reference Design Firmware

C.1 DEVICE FIRMWARE

This chapter presents the MCP1640 Single Quadruple-A Battery Boost Converter Reference Design firmware flowchart.

For the latest copy of the MCP1640 Single Quadruple-A Battery Boost Converter Reference Design firmware, visit our web site at www.microchip.com.

START

Initialize: Processor, Parameters (BATT_Low = 0.8V), WDT, Comparator, A/D

SLEEP ()

WDT?
No

LED=ON & Timer>0 ?

No → MCP1640 = OFF Q2 = OFF

Yes → Decrement Timer (10s)

Blink?
No

LED flashes

LED State?

Yes → ADC Setup Measure V_BATT

No → Comparator Enabled

V_BATT<0.8V?
No

Yes → Blink

VOUT<2.3V?
No

Yes → MCP1640 = ON

Delay 2 ms

MCP1640 = OFF

A

B
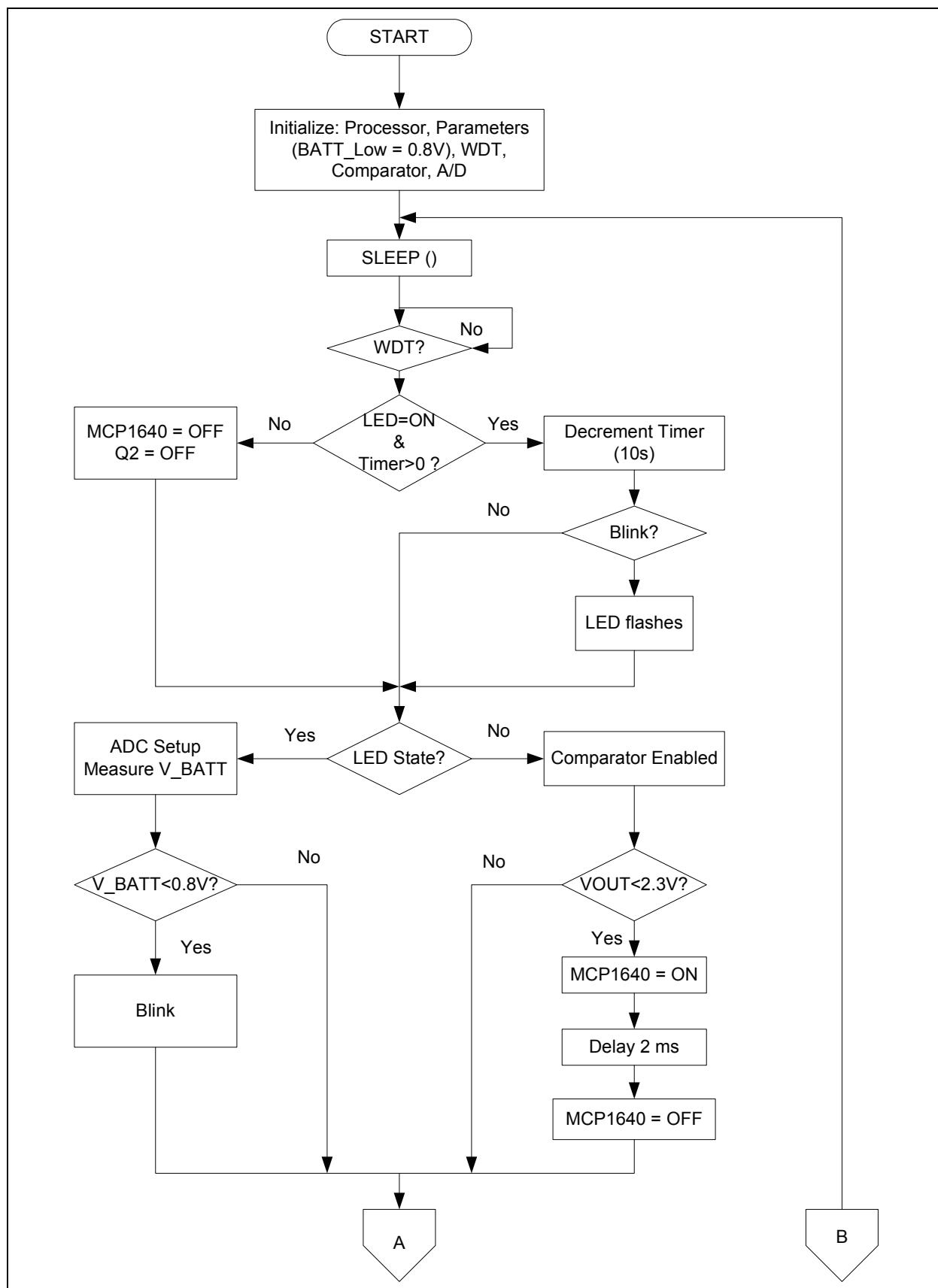
FIGURE C-1: *Firmware Flowchart.*

```
       B                    A

                    ┌──────────┐
         No         ╱ Button S1? ╲        Yes
    ◄───────────────◄            ►───────────────┐
                    ╲           ╱                │
                     └──────────┘                │
                                                 ▼
                ┌──────────┐      ╱──────╲      ┌──────────────┐
       Yes      │ LED = OFF │     ╱ LED   ╲  No │  LED = ON     │
    ◄───────────│ Q2 = OFF  │◄────╲ State? ╱────►│ MCP1640 = ON │
                └──────────┘      ╲──────╱      │  Q2 = ON      │
                                                 └──────────────┘
                                                        │
                                                        ▼
                                            ┌────────────────────┐
    ◄───────────────────────────────────────│ Decrement Timer (10s)│
                                            └────────────────────┘
```
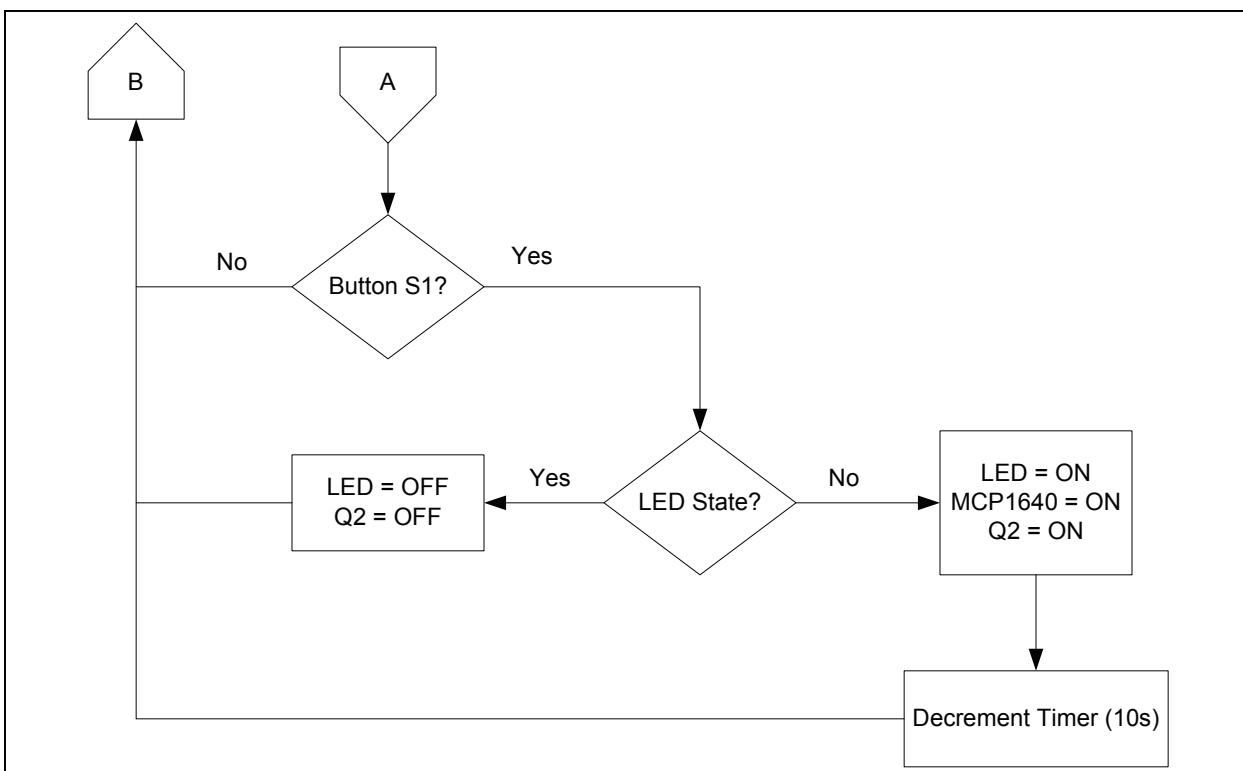
**FIGURE C-2:** *Firmware Flowchart (Continuation).*

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