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# **MCP1650 Multiple White LED Demo Board User's Guide**

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# MCP1650 MULTIPLE WHITE LED DEMO BOARD USER'S GUIDE

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## Preface

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### NOTICE TO CUSTOMERS

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Documents are identified with a “DS” number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is “DSXXXXA”, where “XXXX” 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 on-line help files.

## INTRODUCTION

This chapter contains general information that will be useful to know before using the MCP1650 Multiple White LED Demo Board. 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 MCP1650 Multiple White LED Demo Board. The manual layout is as follows:

- **Chapter 1. “Product Overview”** – Important information about the MCP1650 Multiple White LED Demo Board.
- **Chapter 2. “Installation and Operation”** – Includes a detailed description of each function, as well as instructions on how to get started with this board.
- **Appendix A. “Schematic and Layouts”** – Shows the schematic and layout diagrams for the MCP1650 Multiple White LED Demo Board.
- **Appendix B. “Bill Of Materials (BOM)”** – Lists the parts to build the MCP1650 Multiple White LED Demo Board.
- **Appendix C. “Demo Board Firmware”** – Provides information about the application firmware and where the source code can be obtained.

# MCP1650 Multiple White LED Demo Board User's Guide

## CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

### DOCUMENTATION CONVENTIONS

Description	Represents	Examples
<b>Arial font:</b>		
Italic characters	Referenced books	<i>MPLAB<sup>®</sup> IDE User's Guide</i>
	Emphasized text	...is the <i>only</i> 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	<u><i>File&gt;Save</i></u>
Bold characters	A dialog button	Click <b>OK</b>
	A tab	Click the <b>Power</b> tab
'bnnnn'	A binary number where <i>n</i> is a digit	'b00100, 'b10
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
<b>Courier New font:</b>		
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
Italic Courier New	A variable argument	<i>file.o</i> , where <i>file</i> can be any valid filename
0xnnnnn	A hexadecimal number where <i>n</i> is a hexadecimal digit	0xFFFF, 0x007A
Square brackets [ ]	Optional arguments	mcc18 [options] <i>file</i> [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 MCP1650 Multiple White LED Demo Board. The following Microchip documents are available and recommended as supplemental reference resources.

### MCP1650 Data Sheet, "750 kHz Boost Controller" (DS21876)

This data sheet provides detailed information regarding the MCP1650 product family.

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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
- Development Systems Information Line

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Technical support is available through the web site at: <http://support.microchip.com>

## DOCUMENT REVISION HISTORY

### Revision A (November 2005)

- Initial Release of this Document.



# MCP1650 Multiple White LED Demo Board User's Guide

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NOTES:

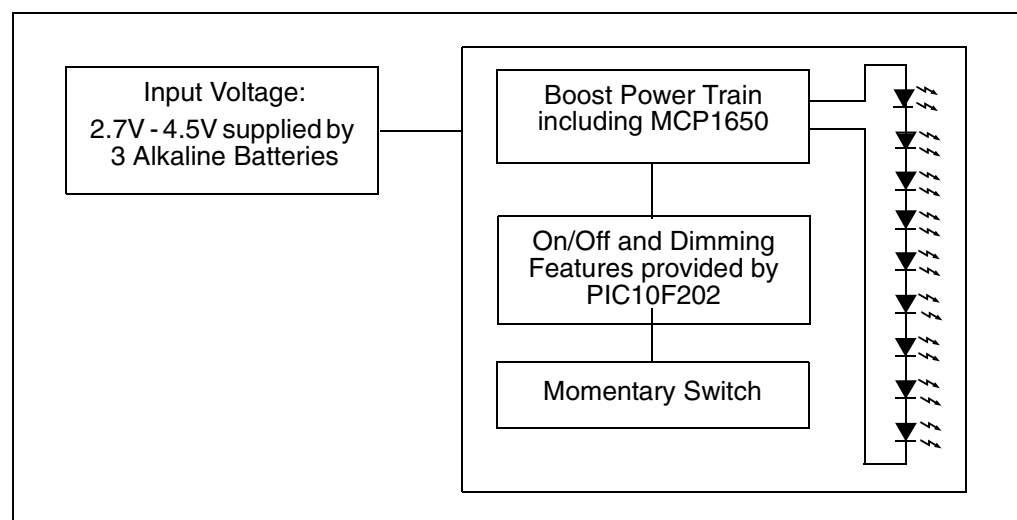
## Chapter 1. Product Overview

### 1.1 INTRODUCTION

The number of applications that utilize white LEDs has steadily increased due to the extended usage of Liquid Crystal Displays (LCDs) in automotive and cellular telephone displays, PDAs, handheld electronic games and computer monitors. In order to view the information on these displays, a light source is needed. Typically, this light source has been provided by Cold Cathode Fluorescent Tubes (CCFT). New product designs are using White or Blue LEDs as the backlighting source. The MCP1650 is an excellent choice for driving nine white LEDs with an efficiency of 80%. The peak intensity is set by the feedback (FB) to the MCP1650. Dimming is accomplished by pulse-width modulating the shutdown pin of the device.

This chapter covers the following topics:

- What is the MCP1650 Multiple White LED Demo Board?
- What the MCP1650 Multiple White LED Demo Board Kit includes?



**FIGURE 1-1:** MCP1650 Multiple White LED Demo Board Block Diagram.

## 1.2 WHAT IS THE MCP1650 MULTIPLE WHITE LED DEMO BOARD?

The MCP1650 Multiple White LED Demo Board demonstrates the use of a conventional boost topology in a LED application. The board also serves as a platform to evaluate the MCP1650 boost controller.

Since designers are tasked with improving efficiency, lowering cost and decreasing size, white LEDs are now being used. Powering white LEDs, which have a forward drop ( $V_F$ ) of 3.6V, typically becomes more difficult when the application requires multiple LEDs. It also requires the output current to be maintained constant with the degrading battery life and temperature variation. In the MCP1650 Multiple White LED Demo Board, a solution using the MCP1650 is discussed and shown to be greater than 80% efficient and also controls the intensity of the LEDs through the PIC10F microcontroller. The intensity of the LEDs can be controlled through a momentary switch.

The MCP1650 Multiple White LED Demo Board demonstrates the use of the PIC10F microcontroller in controlling the intensity of the nine white LEDs connected in series. The board also serves the purpose of evaluating the MCP1650 device.

The design of the demo board is done with boost controller IC MCP1650, which is capable of generating an output voltage of over 100V. The MCP1650 family has numerous features that include soft-start operation, peak inductor current monitoring, scalable external MOSFET, a shutdown pin for external control, low battery detect and a power good output. The MCP1650 can be configured in either, the conventional boost topology (Figure 1-1), a boot-strapped boost topology or a SEPIC topology. The output voltage of the boost converter is determined by the number of LEDs being driven and accordingly, the external MOSFET, Schottky diode and the output capacitor need to be selected.

The feedback voltage ( $V_{FB}$ ) for the MCP1650 is 1.22V. This is only 4% of the total output voltage when powering nine white LEDs. When the voltage developed across the sense resistor ( $R_{SENSE}$ ) is below the internal reference voltage, the internal oscillator is gated on and the external N-channel MOSFET is pulsed on and off to transfer energy from the source to the load. This continues until the voltage across  $R_{SENSE}$  is above the 1.22V threshold, gating off the internal oscillator.

## 1.3 WHAT THE MCP1650 MULTIPLE WHITE LED DEMO BOARD KIT INCLUDES

This MCP1650 Multiple White LED Demo Board kit includes:

- MCP1650 Multiple White LED Demo Board
- MCP1650 Multiple White LED Demo Board User's Guide

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## **Chapter 2. Installation and Operation**

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### **2.1 INTRODUCTION**

The MCP1650 Multiple White LED Demo Board uses the MCP1650 IC to power the nine white LEDs which are connected in series. A PIC10F202 microcontroller in a SOT-23 6 pin package is used to provide the PWM signal to the MCP1650. It also accepts a push button input that allows the user to adjust the white LED's to three different intensities of 100%, 50% and 25%.

The PIC10F202 microcontroller is programmable, allowing the user to modify or develop their own firmware routines to further evaluate the MCP1650 in this application.

### **2.2 FEATURES**

The MCP1650 Multiple White LED Demo Board has the following features:

- Programmed MCP1650 White LED intensity control via the PIC10F202
- Nine white LEDs connected in series
- PIC10F202 is used to generate the PWM signal which controls the intensity of the LEDs
- Push button selection for three levels of intensity control
- Includes one battery holder for three AA batteries (batteries not included)

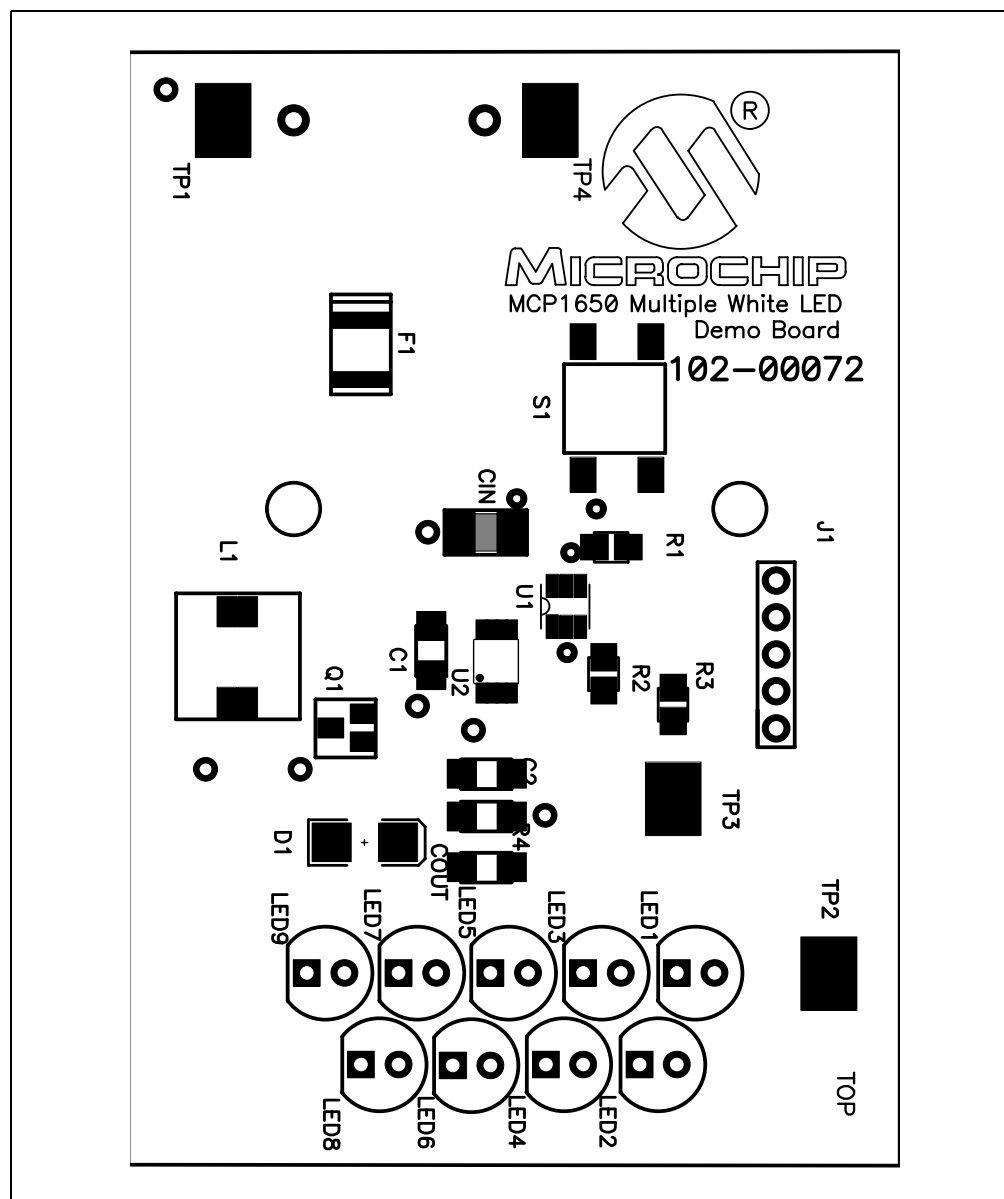
## 2.3 GETTING STARTED

The MCP1650 Multiple White LED Demo Board comes fully assembled and tested. The board requires three AA batteries as a power source for the application.

### 2.3.1 Powering the MCP1650 Multiple White LED Demo Board

Insert three AA batteries into the battery pack provided on the bottom of the board. As soon as the system powers up, the internal program of the PIC10F202 will initialize and remain in a low-power Sleep mode ( $<0.1 \mu\text{A}$ ) until the S1 button is pressed by the user.

The MCP1650 Multiple White LED Demo Board does not need a power switch or power jumper because of the "Stand-by" or "Sleep" mode of the PIC10F202 microcontroller and low shutdown current of the MCP1650. Upon entering Sleep mode, the system requires less than  $0.1 \mu\text{A}$  (typ) of current. So, with three AA batteries used in the application, the system's power requirements in Sleep mode are minimal.



**FIGURE 2-1:** Setup Configuration Diagram.

## 2.3.2 Activating Application and Changing the LED Intensity

1. To activate the LEDs, press the push button momentary switch S1. The LEDs turn on at full intensity level when the push button is pressed, changing intensity when the push button is pressed again. There are 3 levels of 100%, 50% and 25% LED intensities (plus the "OFF" state). The input is fused for overcurrent protection. The intensity of the LEDs are controlled via the SHDN input pin of MCP1650. A pulse width modulated (PWM) signal is generated by the PIC10F202 and routed to the SHDN pin of the MCP1650. The MCP1650 is actually pulsed, and the duty cycle of the PWM waveform is varied depending on the intensity required. The narrow pulses create a low intensity while wider pulses create a high intensity.
2. The LEDs will be turned off, and the system will enter Sleep mode, when the LEDs are at 25% intensity state and the push button is pressed. Subsequent push button presses will cycle the LEDs as described in step 1.

## 2.3.3 Evaluating the Application

The best way to evaluate the MCP1650 Multiple White LED Demo Board is to analyze the circuit. Measure voltages and currents with a DVM and probe the board with an oscilloscope.

The firmware program in the PIC10F202 can also be edited to modify the operation of the application. For example, the subroutine written to generate the different pulse widths can be changed to suit the needs of various applications with different intensities.

## Typical Example

Let's consider a practical application for driving nine white LEDs with the MCP1650 using a three-cell Li-Ion input.

Input voltage:	2.7V to 4.5V
Output voltage:	32.4V ( $9 \times V_F$ )
Output current:	15 mA
Switching Frequency:	750 kHz
Duty Cycle:	80% for $V_{IN} < 3.8V$
Duty Cycle:	56% for $V_{IN} > 3.8V$

$R_{SENSE}$  is determined by the following equation:

$$R_{SENSE} = \frac{V_{FB}}{I_{OUT}}$$

## 2.3.4 Inductor Selection

Since a high boost ratio is needed, the boost regulator will operate in Discontinuous Current mode. Therefore, the energy going into the inductor every switching cycle must be greater than the energy needed to supply the load for that switching cycle. The conservative efficiency estimate of 80% was chosen to provide margin so that the boost regulator will operate in Discontinuous Current mode.

$$\begin{aligned}P_{OUT} &= V_{OUT} \times I_{OUT} \\P_{OUT} &= 32.4V \times 15mA \\P_{OUT} &= 0.486 \text{ watts}\end{aligned}$$

$$P_{IN} = \frac{P_{OUT}}{\text{Efficiency}}$$
$$P_{IN} = \frac{0.486\text{w}}{80\%}$$
$$P_{IN} = 0.608 \text{ watts}$$

The equation for the energy flowing into the inductor is given below. The power in the inductor is equal to the inductor energy times the switching frequency ( $F_{SW}$ ).

$$\text{Energy} = \frac{1}{2} \times L \times I_{PK}^2$$
$$\text{Power} = \text{Energy} \times F_{SW}$$

The peak inductor current is:

$$I_{PK} = \frac{V_{IN}}{L} \times T_{ON}$$

Using a standard inductor value of 4.7  $\mu\text{H}$ , the power in the inductor is calculated.

$$T_{ON} = (1/F_{SW}) \times \text{Duty Cycle}$$
$$I_{PK} (2.7\text{V}) = 0.612\text{A}$$
$$\text{Energy} (2.7\text{V}) = 0.880 \mu\text{-Joules}$$
$$\text{Power} (2.7\text{V}) = 0.66\text{W}$$

There is a second operating point that needs to be addressed when  $V_{IN}$  is 3.8V and the duty cycle is 56%.

$$T_{ON} = (1/F_{SW}) \times \text{Duty Cycle}$$
$$I_{PK} (3.8\text{V}) = 0.603\text{A}$$
$$\text{Energy} (3.8\text{V}) = 0.854 \mu\text{-Joules}$$
$$\text{Power} (3.8\text{V}) = 0.640\text{W}$$

For both operating points, the inductor power is close to the necessary maximum input power, forcing the converter to operate in Continuous Current mode. Therefore, a 4.7  $\mu\text{H}$  inductor is too large and the peak input current needs to be increased. A 3.3  $\mu\text{H}$  inductor is selected.

$$T_{ON} = (1/F_{SW}) \times \text{Duty Cycle}$$
$$I_{PK} (2.7\text{V}) = 0.872\text{A}$$
$$\text{Energy} (2.7\text{V}) = 1.256 \mu\text{-Joules}$$
$$\text{Power} (2.8\text{V}) = 0.942\text{W}$$
$$I_{PK} (3.8\text{V}) = 0.859\text{A}$$
$$\text{Energy} (3.8\text{V}) = 1.219 \mu\text{-Joules}$$
$$\text{Power} (3.8\text{V}) = 0.914\text{W}$$

Now that the inductor energy is greater than the maximum required input energy, the converter will operate in Discontinuous Current mode.

When selecting the MOSFET, a low  $R_{DSon}$  logic-level N-channel is recommended. Since the input voltage ranges from 2.7V to 4.5V, the MOSFET must have a turn-on voltage as low as 2.7V. Ideally, the MOSFET would have  $R_{DSon}$  as low as possible and, therefore, help increase the overall efficiency of the regulator. However, a lower  $R_{DSon}$  typically results in higher gate charge, leading to slower transition times in the MOSFET, thereby causing increased switching losses. The MOSFET's drain-to-source breakdown voltage must be rated to handle the boost output voltage plus margin. There is a very limited selection for MOSFET's with a drain to source rating greater than 30V with a gate-to-source voltage less than 5V. By using a 1:1 coupled inductor for the boost converter, the MOSFET drain-to-source voltage rating is cut in half.

The boost diode requires very fast turn-on and turn-off characteristics because it switches at the switching frequency of the converter. Schottky diodes are recommended because they are capable of this switching characteristic and have a low forward drop. As with the MOSFET, the Schottky diode must be rated to handle the boost output voltage plus margin.

The input and output capacitor size depends on the respective voltages of the converter. While low value parts are desired because of cost and size, they typically result in higher ripple voltages. The capacitors should be chosen to provide an appropriate ripple voltage for the intended application. Ceramic or low effective series resistance (ESR) tantalum capacitors are appropriate for most applications.

## 2.3.5 Firmware

The PIC10F202 comes with preprogrammed firmware to operate the system as described above. The firmware flow diagram is shown in **Appendix C. "Demo Board Firmware"**.

There is an initialization routine at the beginning of the program. The program initially checks for the key press and goes into Sleep mode if there is no key press. The device will come out of Sleep mode on pin change. The OPTION register is configured to wake-up on port pin change.

The GPIO port is configured to set GP0 (PWM to the MCP1650) as an output and GP3 (Push Button) as inputs. There are three different subroutines for the three different intensities provided. Every time the key is pressed, the variable key buffer is incremented to store the next value of the key and move to the respective subroutine in a cyclic order.

The effect of key de-bounce is accomplished by providing a delay which checks for the prerequisite time and recognizes only a valid key press. There is a key press check in each of the subroutine which recognizes the key press and goes to the next subroutine for a valid key press.

### 2.3.5.1 PROGRAMMING

Header J1 is provided for in circuit programming. This is an optional feature since the demo board comes preprogrammed with firmware to operate the system. The PIC10F202 can be reprogrammed with the Baseline Flash Microcontroller Programmer (BFMP).



NOTES:



# MCP1650 MULTIPLE WHITE LED DEMO BOARD USER'S GUIDE

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## Appendix A. Schematic and Layouts

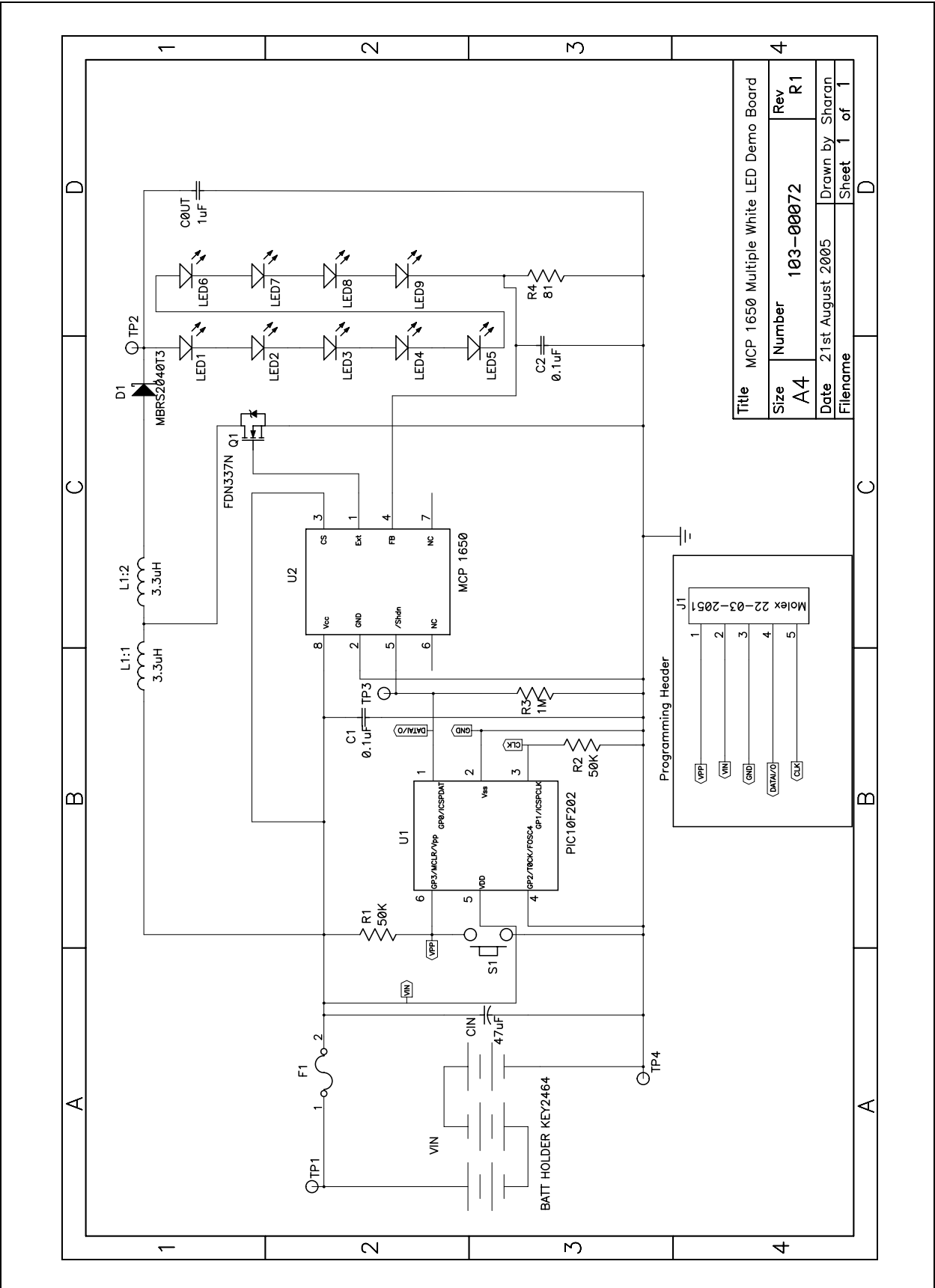
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### A.1 INTRODUCTION

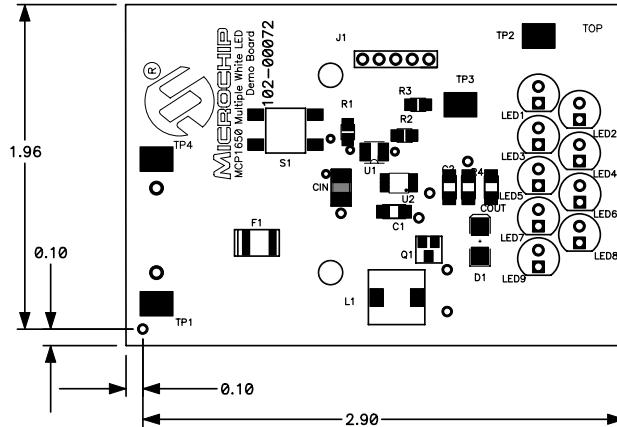
This appendix contains the following schematics and layouts for the MCP1650 Multiple White LED Demo Board:

- Board – Schematic
- Board – Assembly Drawing
- Board – Top Metal Layer
- Board – Bottom Metal Layer

A.2 BOARD – SCHEMATIC



## A.3 BOARD – TOP ASSEMBLY

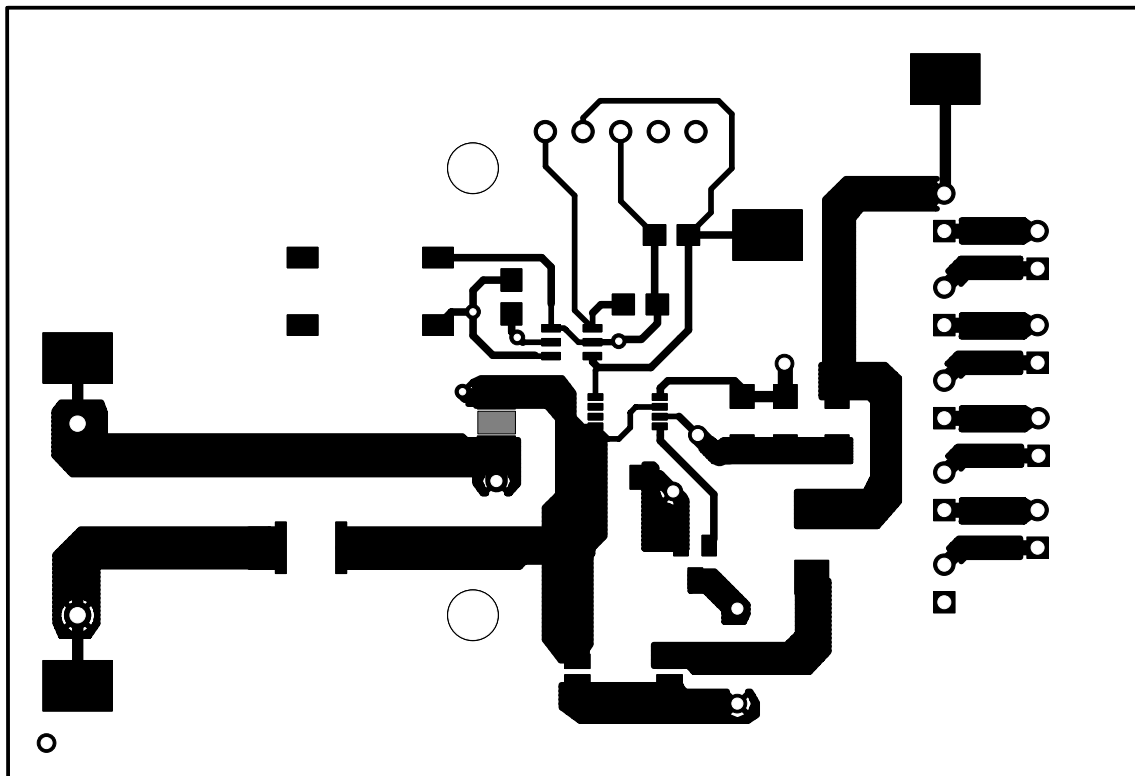


### NOTES

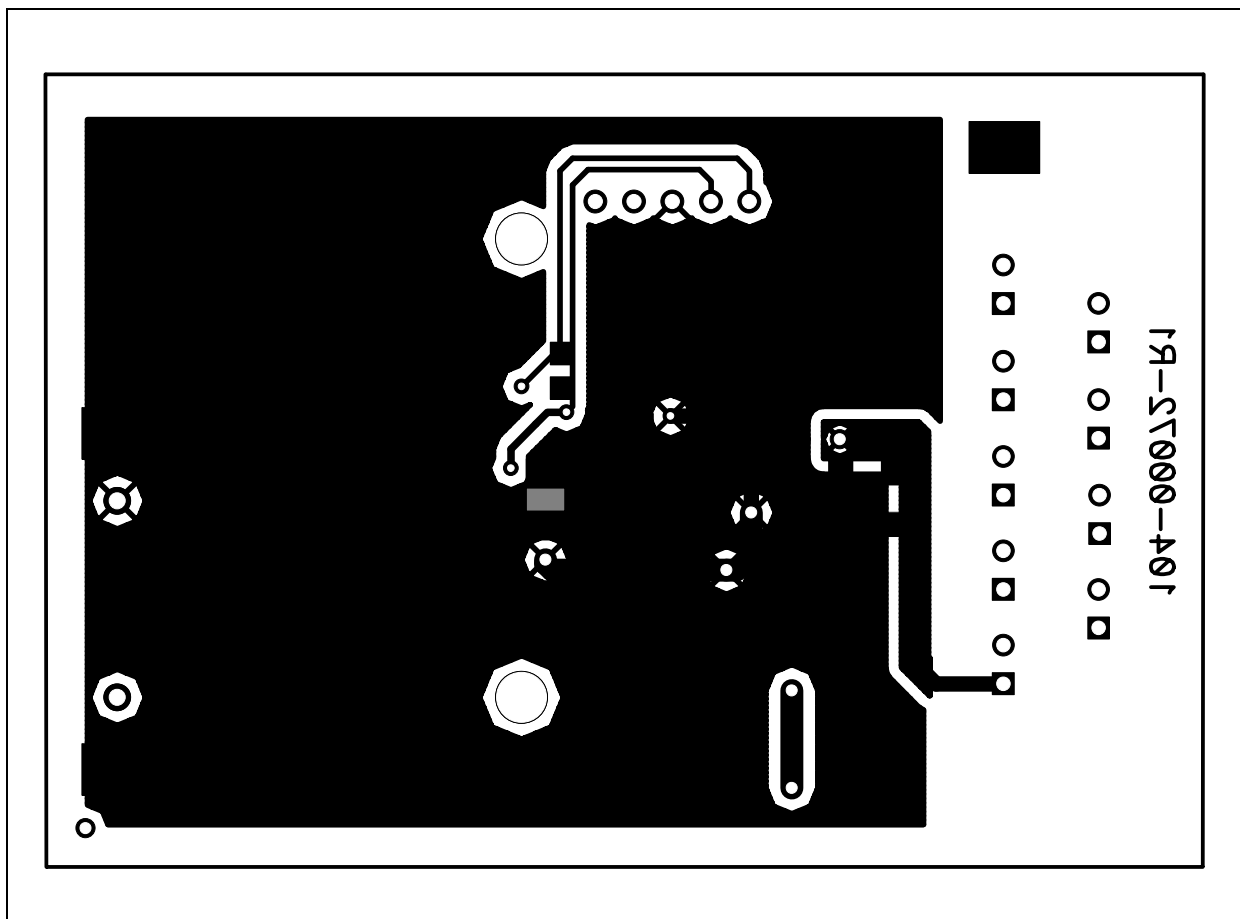
1. BOARD MATERIAL FR4 OR EQUIVALENT 0.062" THICK.
2. 2 LAYERS OF 1oz. COPPER.
3. SOLDERMASK ON BOTH SIDES WITH HASL ON EXPOSED COPPER.
4. WHITE SILKSCREEN ON TOP LAYER.

Drill Table			
Hole Dia (inch)	Symbol	Quantity	Plated
0.0180	+	4	Yes
0.0300	X	7	Yes
0.0354	Y	18	Yes
0.0380	+	5	Yes
0.0420	X	2	Yes
0.1299	M	2	Yes

## A.4 BOARD – TOP METAL LAYER



## A.5 BOARD – BOTTOM METAL LAYER



## Appendix B. Bill Of Materials (BOM)

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

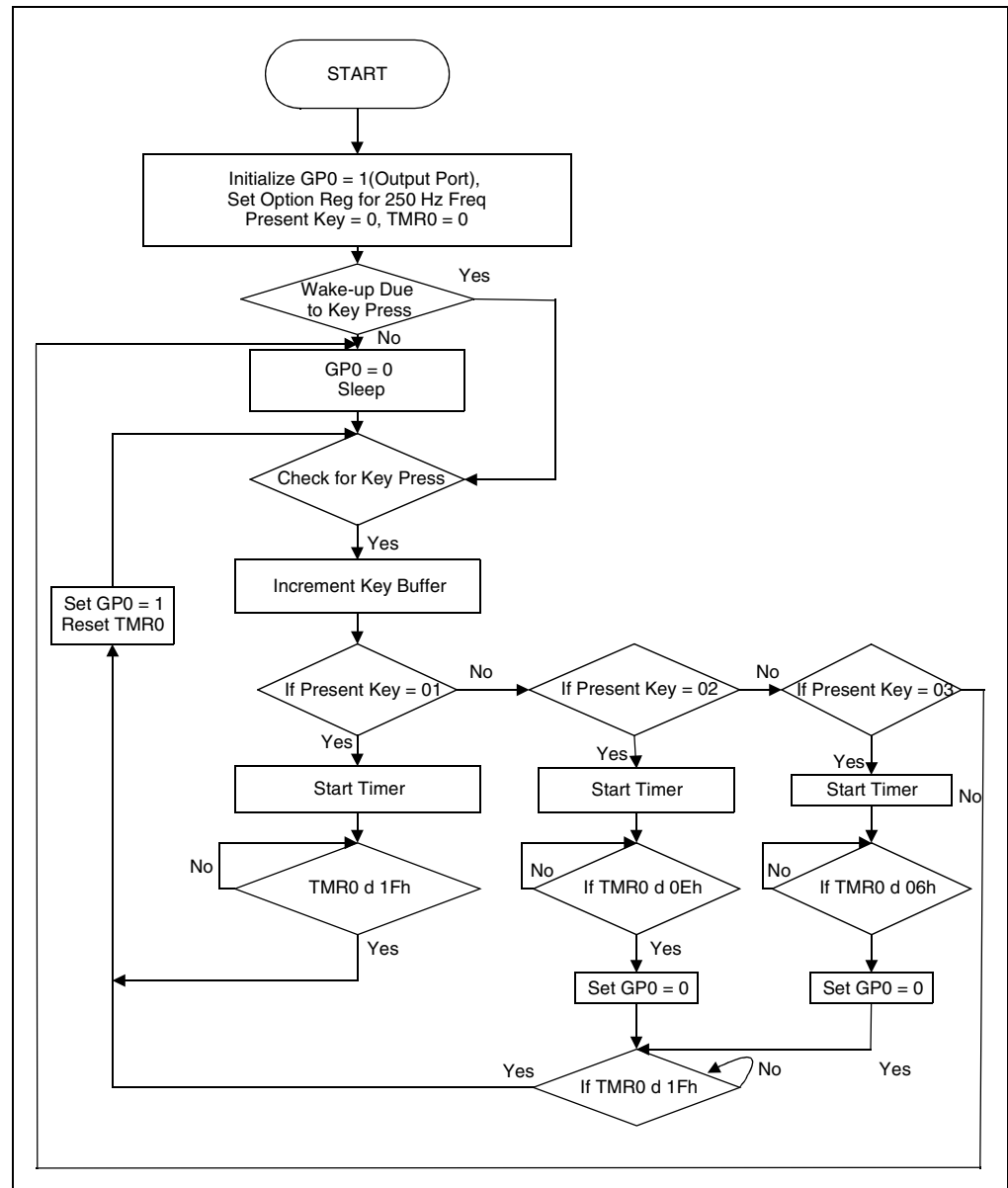
Qty	Reference	Description	Manufacturer	Part Number
1	CIN	CAP 47UF 6.3V CERAMIC X5R 1210	Panasonic - ECG	ECJ-4YB0J476M
1	COUT	CAP CER 1UF 50V X7R 10% 1206	TDK Corporation	C3216X7R1H105K
2	C1, C2	CAP .10UF 50V CERAMIC X7R 1206	Yageo America	CC1206KRX7R9BB104
1	D1	MBRS2040LT3	ON Semiconductors	MBRS2040LT3
1	F1	PolySwitch Resettable Fuses	Raychem® Corp.	MINISMD110
1	J1	CONN HEADER 5POS .100 VERT TIN	Molex	22-03-2051
1	L1	INDUCTOR SHIELD DUAL 3.3UH SMD	Coiltronics	DRQ74-3R3
9	LED1, LED2, LED3, LED4, LED5, LED6, LED7, LED8, LED9	LED 5mm Blue/Waterclear Lens	LED Shop	OBWC5.5000-A
1	Q1	FDN337N	Fairchild	FDN337N
2	R1, R2	RES 47.5K OHM 1/10W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF4752V
1	R3	Resistor 1MOhm 1% 0805 Package	Panasonic - ECG	ERJ-6ENF1004V
1	R4	RES 80.6 OHM 1/8W 1% 1206 SMD	Panasonic - ECG	ERJ-8ENF80R6V
1	S1	Momentary Tact Switches	E-Switch Inc	TL3301NF260QG
4	TP1, TP2, TP3, TP4	SMT Test Point	Keystone Electronics®	5016
1	U1	PIC10F202 6-pin SOT-23	Microchip Technology Inc	PIC10F202T-I/OT
1	U2	MCP1650 8-pin MSOP	Microchip Technology Inc	MCP1650S-E/MS
1	VIN	3 AA Plastic Battery Holder	Keystone Electronics®	2464

NOTES:

## Appendix C. Demo Board Firmware

### C.1 DEVICE FIRMWARE

For the latest version of the MCP1650 Multiple White LED Demo Board firmware, visit the Microchip web site at [www.microchip.com](http://www.microchip.com).



**FIGURE C-1:** Firmware Flowchart – Page 1.





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