MICROCHIP

Digital Power Starter Kit User's Guide

Note the following details of the code protection feature on Microchip devices:

• Microchip products meet the specification contained in their particular Microchip Data Sheet.

• Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.

• There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.

• Microchip is willing to work with the customer who is concerned about the integrity of their code.

• Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

QUALITY MANAGEMENT SYSTEM

CERTIFIED BY DNV

═ ISO/TS 16949 ═

Object of Declaration: Digital Power Starter Kit

EU Declaration of Conformity

Manufacturer: Microchip Technology Inc.
                     2355 W. Chandler Blvd.
                     Chandler, Arizona, 85224-6199
                     USA

This declaration of conformity is issued by the manufacturer.

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

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

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

For information regarding the exclusive, limited warranties applicable to Microchip products, please see Microchip's standard terms and conditions of sale, which are printed on our sales documentation and available at www.microchip.com.

Signed for and on behalf of Microchip Technology Inc. at Chandler, Arizona, USA

Derek Carlson
VP Development Tools

12-Sep-14
Date

Digital Power Starter Kit User's Guide

NOTES:

Safety Notice

The following safety notices and operating instructions should be adhered to in order to avoid a safety hazard. If in any doubt, consult your supplier.

DANGER – The Digital Power Starter Kit contains two resistive loads that are intended to dissipate power in the form of heat. Depending on the output power level, it is possible for the resistive load to become hot to the touch or to any surface in direct contact with the board.
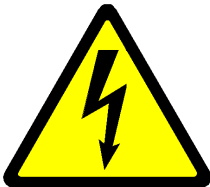
WARNING – The Digital Power Starter Kit should only be installed, operated, serviced or modified by qualified personnel. Any service or modification performed by the user is done at the user's own risk and voids all warranties.

CAUTION – Particular care should be taken during code development as unexpected voltage regulation behavior is possible. Ensure that the power supply connected to the Digital Power Starter Kit is properly protected against overcurrent event caused by code development.

General Notices:

• The Digital Power Starter Kit is intended for evaluation and development purposes, and should only be operated in a normal laboratory environment as defined by IEC 61010-1:2001.
• Clean with a dry cloth only.
• Operate flat on a bench away from any surface items that might come in contact with the board. Do not move during operation and avoid direct contact with the bottom layer of the board.
• The Digital Power Starter Kit should not be connected or operated if there is any apparent damage to the unit.

NOTES:

DIGITAL POWER STARTER KIT
USER'S GUIDE

Table of Contents

NOTES:

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 "DSXXXXXXXXA", where "XXXXXXXX" 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 preface contains general information that will be useful to know before using the Digital Power Starter Kit. Topics discussed in this preface include:

- Document Layout
- Conventions Used in this Guide
- Warranty Registration
- Recommended Reading
- The Microchip Web Site
- Development Systems Customer Change Notification Service
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

This user's guide provides an overview of the Digital Power Starter Kit. The document is organized as follows:

- **Chapter 1. "Introduction"** – This chapter introduces the Digital Power Starter Kit and provides a brief overview of its features.
- **Chapter 2. "Hardware"** – This chapter describes the board layout and the main components of the Digital Power Starter Kit.
- **Chapter 3. "Demonstration Program Operation"** – This chapter describes the demonstration software that is preloaded on the device that accompanies the Digital Power Starter Kit.
- **Appendix A. "Board Layout and Schematics"** – This appendix provides diagrams of the hardware layout, as well as schematic diagrams for the Digital Power Starter Kit.

Digital Power Starter Kit User's Guide

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 braces 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) { ... }`

WARRANTY REGISTRATION

Please complete the enclosed Warranty Registration Card and mail it promptly. Sending in the Warranty Registration Card entitles users to receive new product updates. Interim software releases are available at the Microchip web site.

Preface

RECOMMENDED READING

This user's guide describes how to use the Digital Power Starter Kit. The device-specific data sheets contain current information on programming the specific microcontroller or digital signal controller devices. The following Microchip documents are available and recommended as supplemental reference resources:

MPLAB® C Compiler for PIC24 MCUs and dsPIC® DSCs User's Guide (DS51284)

This comprehensive guide describes the usage, operation and features of Microchip's MPLAB C compiler (formerly MPLAB C30) for use with 16-bit devices.

MPLAB® X IDE User's Guide (DS50002027)

This document describes how to set up the MPLAB X IDE software and use it to create projects and program devices.

Readme Files

For the latest information on using the Digital Power Starter Kit board, read the `Readme.txt` text file in the Readme subdirectory of the MPLAB X IDE installation directory from the Digital Power Starter Kit code example. The Readme file contains updated information and known issues that may not be included in this user's guide.

dsPIC33 'GS' Data Sheet

Refer to these documents for detailed information on the dsPIC33 'GS' SMPS Digital Signal Controllers (DSCs). Reference information found in these data sheets includes:

- Device memory maps
- Device pinout and packaging details
- Device electrical specifications
- List of peripherals included on the devices

dsPIC33/PIC24 Family Reference Manual Sections

Family Reference Manual (FRM) sections are available, which explain the operation of the dsPIC® DSC and PIC® MCU family architecture and peripheral modules. The specifics of each device family are discussed in the individual family's device data sheet.

Microchip SMPS Resources

- AN1114 *"Switch Mode Power Supply (SMPS) Topologies (Part I)"* (DS01114)
- AN1207 *"Switch Mode Power Supply (SMPS) Topologies (Part II)"* (DS01207)
- TB062 *"Frequently Asked Questions (FAQs) About dsPIC® DSC SMPS Devices"* (DS93062)

To obtain any of these documents, visit the Microchip web site at www.microchip.com.

Digital Power Starter Kit User's Guide

THE MICROCHIP WEB SITE

Microchip provides online support via our web site at www.microchip.com. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **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

DEVELOPMENT SYSTEMS CUSTOMER CHANGE NOTIFICATION SERVICE

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, access the Microchip web site at www.microchip.com, click on Customer Change Notification and follow the registration instructions.

The Development Systems product group categories are:

- **Compilers** – The latest information on Microchip C compilers and other language tools. These include the MPLAB® XC compiler; MPASM™ and MPLAB 16-bit assemblers; MPLINK™ and MPLAB 16-bit object linkers; and MPLIB™ and MPLAB 16-bit object librarians.
- **Emulators** – The latest information on the Microchip MPLAB REAL ICE™ in-circuit emulator.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debugger, MPLAB ICD 3.
- **MPLAB X IDE** – The latest information on Microchip MPLAB X IDE, the Windows® Integrated Development Environment for development systems tools. This list is focused on the MPLAB X IDE, MPLAB SIM simulator, MPLAB X IDE project manager, and general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include the MPLAB PM3 device programmer and the PICkit™ 3 development programmer.

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 A (January 2015)

This is the initial released version of this document.

Revision B (May 2015)

Updated schematic in Figure A-3 that resides in **Appendix A. "Board Layout and Schematics"**.

Digital Power Starter Kit User's Guide

NOTES:

Chapter 1. Introduction

This chapter introduces the Digital Power Starter Kit and provides an overview of its features. The topics covered include:

- Overview
- Kit Contents
- Starter Kit Functionality and Features
- Electrical Specifications

1.1 OVERVIEW

Modern power supplies are becoming smaller, more efficient, more flexible and less expensive. These desirable enhancements have come about as Digital Signal Controllers (DSCs) are incorporated into Switch Mode Power Supply (SMPS) designs. The board provided in the kit is intended to introduce and demonstrate the capabilities and features of Microchip SMPS families of devices. The Digital Power Starter Kit features an on-board programmer/debugger, which eliminates the need for any additional programmer or hardware interface.

The software for the demonstration application that is preprogrammed into the on-board dsPIC33 'GS' Digital Signal Controller (DSC) is available for download from the Microchip web site at: http://www.microchip.com.

> **Note:** Refer to the Readme file provided with the Digital Power Starter Kit demonstration software for instructions on how to run the demonstration application. Refer to the Information Sheet that is provided with the starter kit package for additional resources and instructions on how to use the starter kit for programming and debugging application software.

1.2 KIT CONTENTS

The Digital Power Starter Kit contains the following:

- Digital Power Starter Kit Board
- 9V Power Supply
- USB Cable

> **Note:** If you are missing any part of the kit, contact a Microchip sales office for assistance. A list of worldwide Microchip offices for sales and service is provided at the end of this document.

1.3   STARTER KIT FUNCTIONALITY AND FEATURES

The Digital Power Starter Kit is a Switch Mode Power Supply (SMPS) board that consists of one independent DC/DC synchronous Buck converter and one independent DC/DC Boost converter. Figure 1-1 illustrates a high-level block diagram of the Digital Power Starter Kit.

The Digital Power Starter Kit provides closed-loop Peak Current Mode control using a 2-Pole, 2-Zero (2P2Z) compensator implemented in software to maintain the desired output voltage level of Peak Current Mode (PkCM) control. The dsPIC$^®$ DSC device provides the necessary memory and peripherals for ADC conversion, PWM generation, analog comparison and general purpose I/O, preventing the need to perform these functions in external circuitry.

SMPS dsPIC DSC devices are specifically designed to provide low-cost and efficient control for a wide range of power supply topologies. The specialized peripherals facilitate closed-loop feedback control of Switch Mode Power Supplies, providing communication for remote monitoring and supervisory control.

The dsPIC33 'GS' family of devices provides the following features:

- Integrated program and data memory on a single chip
- Ultra-fast interrupt response time with interrupt priority logic
- High-Speed ADC with multiple Sample-and-Hold (S&H) circuits.
- High-resolution PWM generators, specially designed to support different power topologies
- High-speed analog comparators for control loop implementation and system protection
- On-chip system communications (I^{2}C™/SPI/UART)
- On-chip fast RC oscillator for lower system cost

FIGURE 1-1: DIGITAL POWER STARTER KIT SYSTEM DIAGRAM
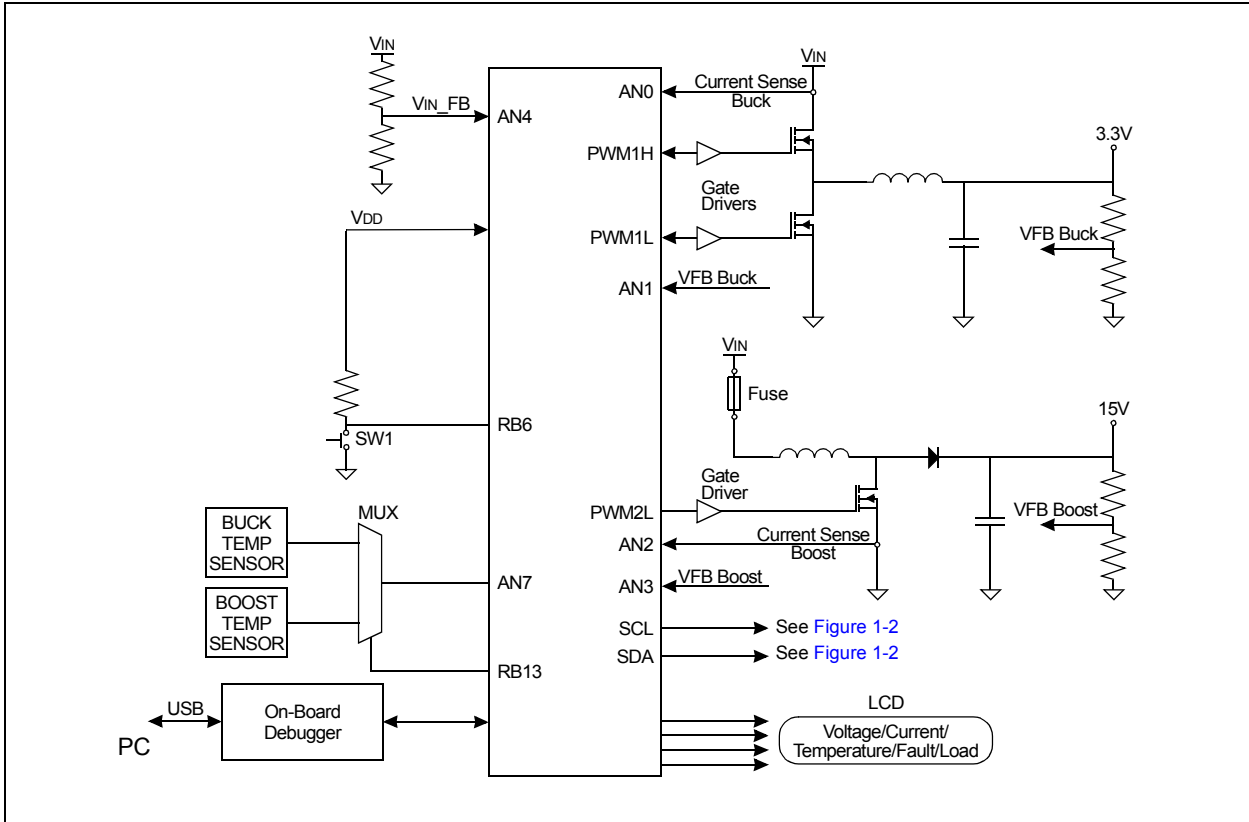
FIGURE 1-2: BUCK/BOOST RESISTIVE INTERNAL LOAD CONFIGURATION OPTION

Note 1: R1 = 22Ω
R2 = R3 = 8.7Ω

R4 = 450Ω
R5 = R6 = 180Ω

2: When both converters are programmed to their nominal values of 3.3V and 15V, and all internal loads are enabled, each converter is loaded with 3W.
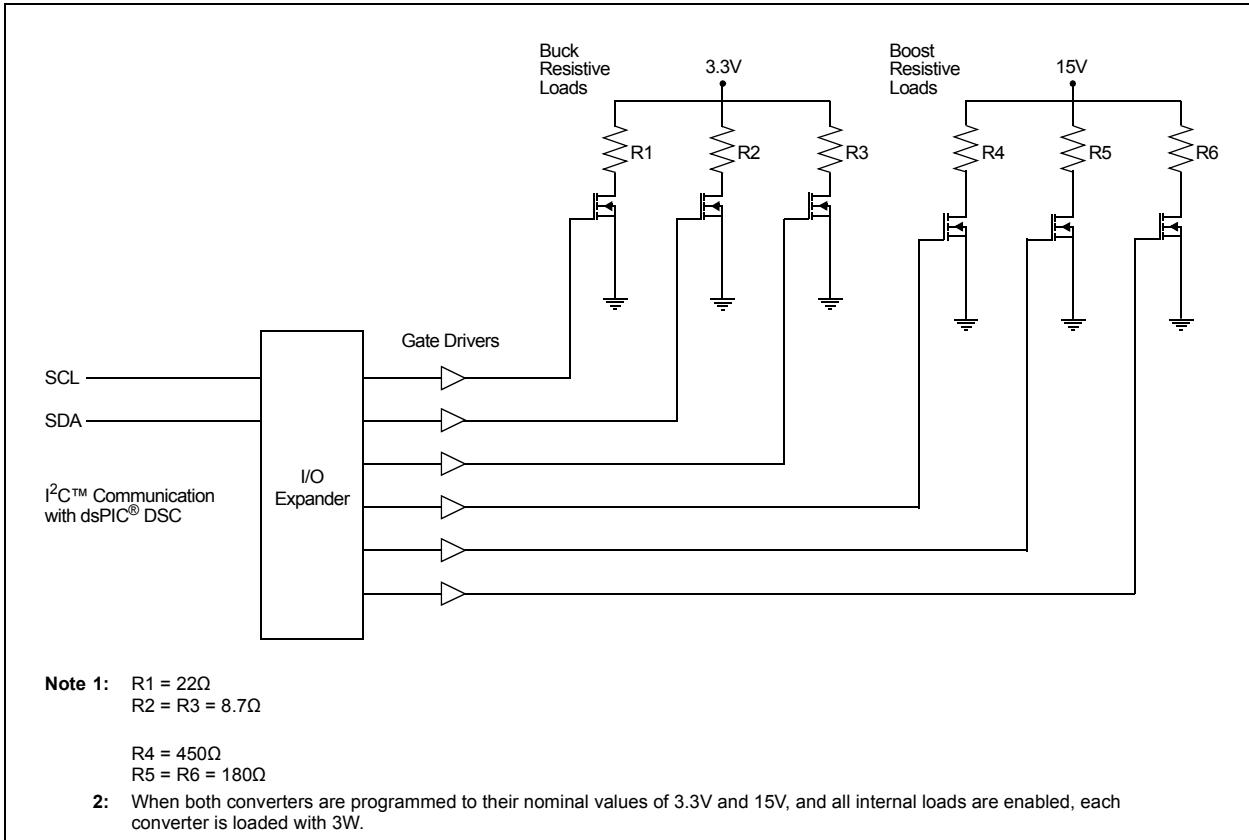
1.3.1 Power Stages

- One Boost converter power stage
- One synchronous Buck converter power stage

1.3.2 Display

- Voltage, current, temperature, internal load setting and converter status (enabled/disabled)

1.3.3 Converter Loads

- Buck 3W configurable resistive load
- Boost 3W configurable resistive load

1.3.4 Additional Features

- Two on-board temperature sensors, located near the resistive loads of each converter; this enables the user to program a temperature protection limit
- Input voltage sense, used to detect under/overvoltage conditions
- Connector for PICkit™ 3 Programmer/Debugger (J3)
- LED power-on indicator (D1)
- Load indication LEDs
- LCD used to display voltage, internal load, temperature and Fault conditions

1.3.5 Starter Kit Power

- +9V power connector (J2) supplies power to the Digital Power Starter Kit
- USB connection jack (J5) supplies power/connection to the on-board programmer/debugger
- Buck and Boost converters are both operated in Peak Current Mode (default), but can also be reprogrammed to operate in Average Current or Voltage Current Control mode; this requires minor hardware changes to the current sense and slope compensation circuits

> **Note:** Average Current mode control requires the following changes:
>
> Buck Converter:
> R5 – DNP
> R14 – DNP
> C26 – 0 Ohm
>
> Boost Converter:
> R7 – DNP
> R13 – DNP
> R62 – 0 Ohm
> C20 – 0 Ohm

1.4 ELECTRICAL SPECIFICATIONS

TABLE 1-1: DC INPUT RATING (J2)

Parameter	Minimum	Typical	Maximum	Unit
Voltage	7.0	9	11	V
Current	—	1.3	—	A

TABLE 1-2: BUCK CONVERTER ELECTRICAL SPECIFICATIONS

Parameter	Minimum	Typical	Maximum	Unit
Output Voltage (default programmed)	—	3.3	—	V
Output Voltage (programmable range)[1]	2.4	—	3.8	V
Output Voltage Ripple	—	50	—	mV (pk-pk)
Output Current	—	—	2.5	A
Load Regulation: V_{OUT} = 3.3V, I_{OUT} = 0.02 – 1.51A, V_{IN} = 9V	—	50	—	mV/A
Switching Frequency	—	350	—	kHz
Output Power	—	3[1]	5[2]	W

Note 1: Maximum power of resistive loads should not exceed 3W.

2: Ensure that 5W maximum is never exceeded, regardless of the output voltage and current.

TABLE 1-3: BOOST CONVERTER ELECTRICAL SPECIFICATIONS

Parameter	Minimum	Typical	Maximum	Unit
Output Voltage (default programmed)	—	15	—	V
Output Voltage (programmable range)[1]	13.4	—	17.8	V
Output Voltage Ripple	—	100	—	mV (pk-pk)
Output Current	—	—	0.37	A
Load Regulation: V_{OUT} = 15V, I_{OUT} = 0.02 – 0.33A, V_{IN} = 9V	—	50	—	mV/A
Switching Frequency	—	350	—	kHz
Output Power	—	3[1]	5[2]	W

Note 1: Maximum power of resistive loads should not exceed 3W.

2: Ensure that 5W maximum is never exceeded, regardless of the output voltage and current.

Digital Power Starter Kit User's Guide

NOTES:

Chapter 2. Hardware

This chapter describes the hardware components of the Digital Power Starter Kit.

Topics covered include:

- Top Assembly
- Signal Configuration
- Application Components
- Board Connectors
- Indicators and Human Interfaces
- Test Points
- Power Rating of Converter Stages
- Programmer/Debugger

2.1   TOP ASSEMBLY

The top and bottom assembly of the board is shown in Figure 2-1 and Figure 2-2. Table 2-1 and Table 2-2 provide a description of the components.

FIGURE 2-1:   DIGITAL POWER STARTER KIT (TOP VIEW)
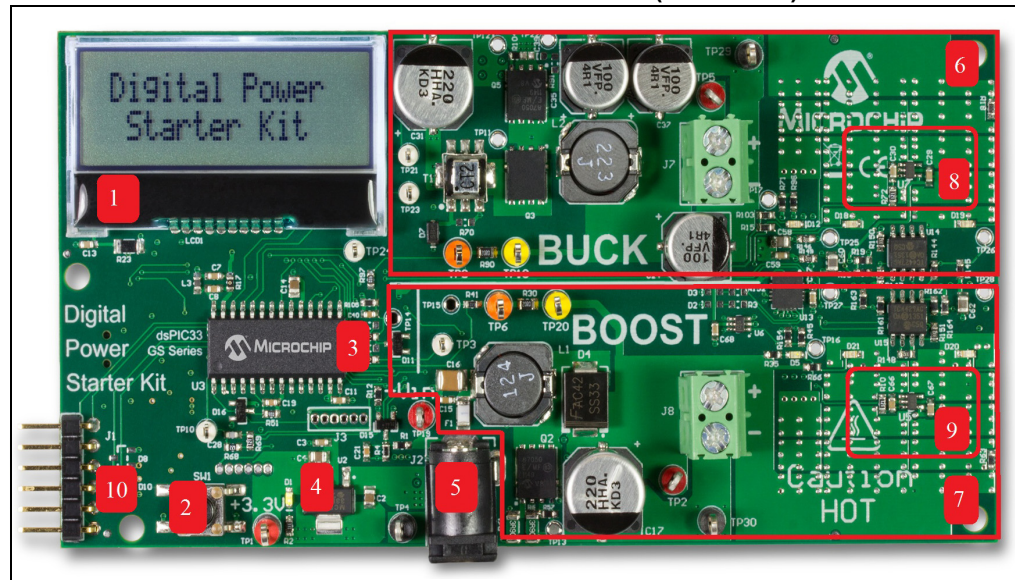
Digital Power Starter Kit User's Guide

TABLE 2-1: DIGITAL POWER STARTER KIT COMPONENTS (TOP VIEW)

Number	Description
1	2x16 Character LCD
2	Push Button (SW1)
3	dsPIC33 'GS' Digital Signal Controller (DSC) (U3)
4	Voltage Regulator (3.3V)
5	9V Power Connector (J2)
6	Buck Converter Stage
7	Boost Converter Stage
8	Buck Temperature Sensor
9	Boost Temperature Sensor
10	PICkit™ 3 Programmer/Debugger

FIGURE 2-2: DIGITAL POWER STARTER KIT (BOTTOM VIEW)
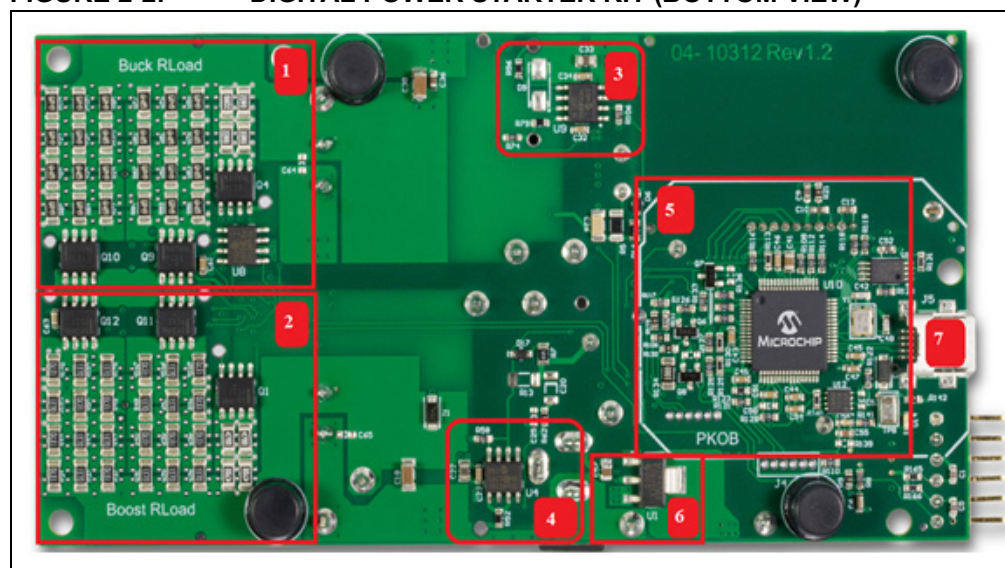
TABLE 2-2: DIGITAL POWER STARTER KIT COMPONENTS (BOTTOM VIEW)

Number	Description
1	Buck Load
2	Boost Load
3	Buck PWM Drive Circuit
4	Boost PWM Drive Circuit
5	On-Board PKOB Programmer/Debugger Circuit
6	Voltage Regulator (+5V)
7	Programmer/Debugger USB Connector (J5)

2.2 SIGNAL CONFIGURATION

Table 2-3 provides a full list of the dsPIC33 'GS' DSC connections and a brief functional description of the pins used in the Digital Power Starter Kit.

TABLE 2-3: dsPIC33 'GS' CONFIGURATION DETAILS

Digital Power Starter Kit Signal Label	Pin #	Device Pin Function	Description/Function
ICSP_MCLR_VPP_Target	1	$\overline{\text{MCLR}}$	Master Clear (Reset) Input
CS_BUCK	2	AN0	Analog – Buck Current Sense
VFB_BUCK	3	AN1	Analog – Buck Voltage Feedback
CS_BOOST	4	AN2	Analog – Boost Current Sense
VFB_BOOST	5	AN3	Analog – Boost Voltage Feedback
VIN_FB	6	AN4	Analog – Input Voltage Feedback
LCD_CLOCK	7	RB10	Clock to LCD Device
—	8	V$_{SS}$	Ground
LCD_DATA	9	RB1	Data to LCD Device
TEMP_SENSE	10	AN7	Analog – Temperature Sensor
PGD2	11	PGD2	Data I/O Pin for Programming/ Debugging Communication Channel 2
PGC2	12	PGC2	Clock Input Pin for Programming/ Debugging Communication Channel 2
—	13	V$_{DD}$	Positive Supply for Peripheral Logic and I/O Pins
SW	14	RB8	SW1 Push Button
LCD_RESET	15	RB15	LCD Active-Low Reset Signal
LCD_RSELECT	16	RB5	LCD Register Select Signal
SCL	17	SCL1	LCD Serial Clock
SDA	18	SDA1	LCD Data
—	19	V$_{SS}$	Ground
—	20	V$_{CAP}$	CPU Logic Filter Capacitor Connection
LCD_CSB	21	RB11	Active-Low LCD Chip Select Signal
GPIO1	22	RB12	General Purpose I/O
GPIO2	23	RB13	General Purpose I/O
PWM2L	24	PWM2L	Boost PWM Drive Signal
PWM1H	25	PWM1H	Buck Converter High Drive Signal
PWM1L	26	PWM1L	Buck Converter Low Drive Signal
—	27	AV$_{SS}$	Analog Ground
—	28	AV$_{DD}$	Analog Positive Supply

2.3 APPLICATION COMPONENTS

Table 2-4 describes the application components that are available on the Digital Power Starter Kit (see Figure 2-1 and Figure 2-2 for component locations).

TABLE 2-4: APPLICATION COMPONENTS

Component	Label	Description
Top Assembly Components (see Figure 2-1)		
dsPIC33 'GS'	U3	Provides the processing power for the demonstration applications and application development on the starter kit.
3.3V Voltage Regulator	U2	Voltage regulator (3.3V) provides power to the dsPIC33, LCD, I/O expander device, push button and temperature sensors.
9V Power Connector	J2	A 9V power supply powers the on-board 5V regulator, and loads the MOSFET drivers, as well, to the Buck and Boost DC/DC converters on the starter kit.
Buck Converter Stage	BUCK	Step-down converter with three on-board resistive selectable loads.
Boost Converter Stage	BOOST	Step-up converter with three on-board resistive selectable loads.
Buck/Boost Converter Temperature Sensor	U7/U5	The temperature sensor is strategically placed near the Buck/Boost load resistors. They are intended to provide the board temperature to the DSC and to disable all of the Buck/Boost resistive loads if the temperature exceeds the set limit.
Bottom Assembly Components (see Figure 2-2)		
Buck Resistive Load	BUCK RLOAD	3.6 Ohm resistive load (3W max).
Boost Resistive Load	BOOST RLOAD	75 Ohm resistive load (3W max).
Buck PWM Drive Circuit	U9	Dual high-speed power FET drivers used to turn on/off the Buck resistive loads.
Boost PWM Drive Circuit	U4	Dual high-speed power FET drivers used to turn on/off the Boost resistive loads.
On-Board Programmer/ Debugger	PKOB	Controls the programming/debugging operations of the target dsPIC33.
5V Voltage Regulator	U1	Voltage regulator (5V) provides power to the 3.3V regulator and to the Buck stage gate driver (U9).
Programmer/Debugger USB Connector	J5	Provides power to the programmer/debugger and bidirectional communication between the host PC and starter kit.

2.4   BOARD CONNECTORS

Table 2-5 describes the hardware connections available on the Digital Power Starter Kit (see Figure 2-1 and Figure 2-2 for component locations).

TABLE 2-5:   HARDWARE CONNECTIONS

Label	Hardware Element Description
J1	Connector for PICkit™ Programmer/Debugger.
J2	9V power supply.
J5	Mini-USB connector provides bidirectional communication between the host PC and the on-board programmer/debugger.

2.5   INDICATORS AND HUMAN INTERFACES

Table 2-6 describes the user interfaces available on the starter kit.

TABLE 2-6:   INDICATORS AND HUMAN INTERFACES

| Label	Hardware Element Description
D1	Power-on status LED, which indicates that the Digital Power Starter Kit is powered by the 9V supply.
D14	USB bus indicator, which indicates that the device is connected to the USB bus and the programmer/debugger is powered.
D12, D18, D19	Buck converter load LEDs. See schematic for details.
D5, D20, D21	Boost converter load LEDs. See schematic for details.

2.6   TEST POINTS

Table 2-7 describes the test points that are available on the Digital Power Starter Kit. See Figure 2-3 for test point locations.

TABLE 2-7:   TEST POINTS

Test Point	Description
TP1	+3.3V Regulator Output Voltage
TP2	+15V Boost Voltage Output Voltage
TP3	CS_BOOST (White)
TP4	Ground
TP5	+3.3V Buck Voltage Output
TP6	Boost Converter Bode Test Point (Orange)
TP7	N/A
TP8	+3.3V_PKOB
TP9	Buck Converter Bode Test Point (Orange)
TP10	CS_BUCK
TP11	Buck Converter High-Side MOSFET Gate Signal Test Point
TP12	Buck Converter Low-Side MOSFET Gate Signal Test Point
TP13	Boost Converter MOSFET Gate Signal Test Point
TP14	VFB_BUCK
TP15	VFB_BOOST
TP16	Boost 0.5W Load MOSFET Gate Signal Test Point
TP17	Buck 0.5W Load MOSFET Gate Signal Test Point
TP18	Buck Converter Bode Test Point (Yellow)
TP19	+9V DPSK Board Input Voltage
TP20	Boost Converter Bode Test Point (Yellow)
TP21	Buck PWM1L Gate Drive Signal (White)
TP22	Buck Converter Switch Node Test Point
TP23	Buck PWM1H Gate Drive Signal (White)
TP24	Boost PWM2L Gate Drive Signal (White)
TP25	First Buck 1.25W Load MOSFET Gate Signal Test Point
TP26	Second Buck 1.25W Load MOSFET Gate Signal Test Point
TP27	First Boost 1.25W Load MOSFET Gate Signal Test Point
TP28	Second Boost 1.25W Load MOSFET Gate Signal Test Point
TP29	GND
TP30	GND

FIGURE 2-3: **DIGITAL POWER STARTER KIT TEST POINT LOCATIONS**
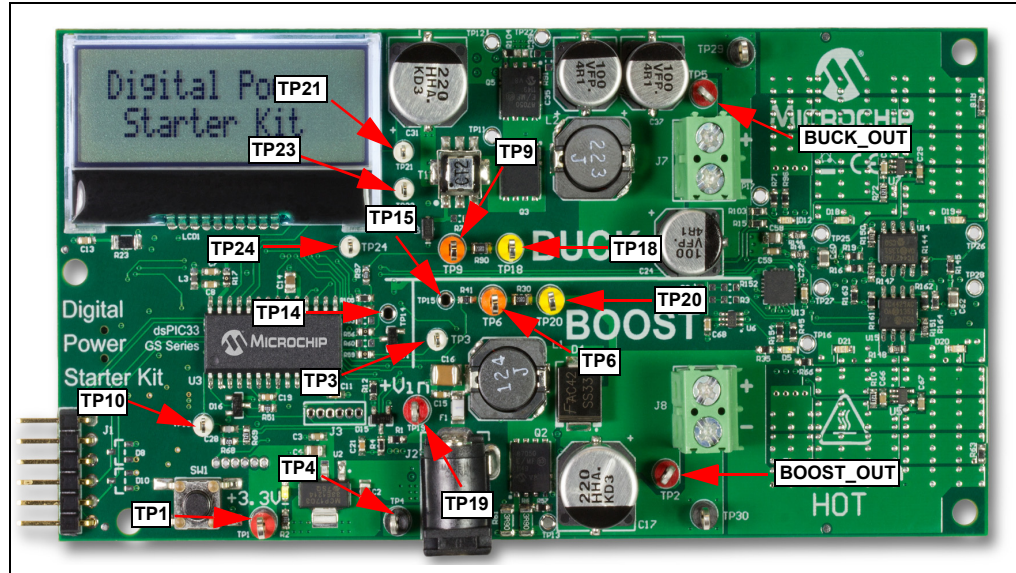
Digital Power Starter Kit User's Guide

## 2.7   POWER RATING OF CONVERTER STAGES

The Digital Power Starter Kit is designed to be a self-contained power supply with each converter having three on-board resistive loads. Each converter includes one resistive 0.5W load and two resistive 1.25W loads for a total of 3W when the converters are programmed to their nominal output voltages only. See Figure 1-2 for more details on hardware configuration.

> **Note:**   The output voltages should not be programmed to exceed their nominal values when using the on-board resistive loads as this can cause the resistive loads to exceed their power handling capabilities, leading to potential damage of the board.

2.7.1   Buck Converter

The Buck converter stage is rated for a maximum of 5W. However, the maximum on-board configurable resistive load is 3W. The output voltage and output current should remain within its Safe Operating Area (SOA) to avoid damage to the board, as shown in the graph in Figure 2-4. The output voltage of the Buck converter (BUCK_Out) can be programmed from a 2.4V to 3.84V output, with a default programmed voltage of 3.3V. The hardware gain, $3.16k/(3.16k + 1k + 20)$, of the voltage feedback from the BUCK_Out is provided by the resistor divider network, R97 and R105. Additionally, a 20 Ohm resistor, R90, for bode plot measurements is also in series with the feedback network. The hardware gain of the current feedback is provided by the current transformer (T1) with turns ratio (1:125) and burden resistor, R69.

FIGURE 2-4:   **BUCK CONVERTER SOA CURVE**
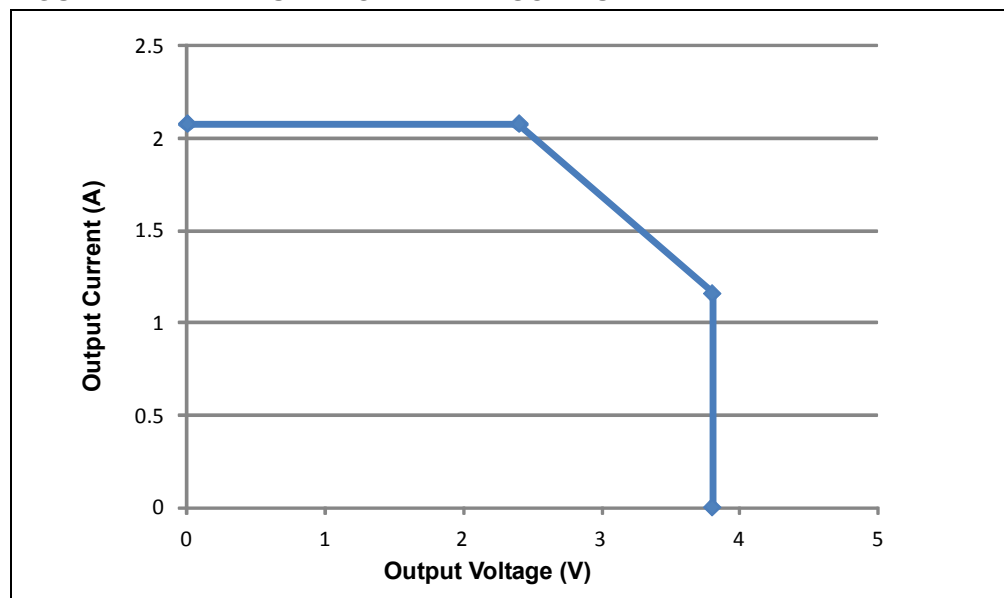
2.7.2   Boost Converter

The Boost converter stage is rated for a maximum of 5W. However, the maximum on-board configurable resistive load is 3W. The output voltage and output current should remain within the Boost converter Safe Operating Area (SOA) to avoid damage to the board, as shown in the graph in Figure 2-5. The output voltage of the Boost converter (BOOST_Out) can be programmed from a 13.4V to 17.8V output, with a default programmed voltage of 15V. The hardware gain, $1k/(1k + 5.1k + 20)$, of the voltage feedback from the BOOST_Out is provided by the resistor divider network of R41 and R51. Additionally, a 20 Ohm resistor, R30, for bode plot measurements is also in series with the feedback network. The hardware gain of the current feedback is provided by the current sense resistors, R6 and R61.

FIGURE 2-5:   BOOST CONVERTER SOA CURVE
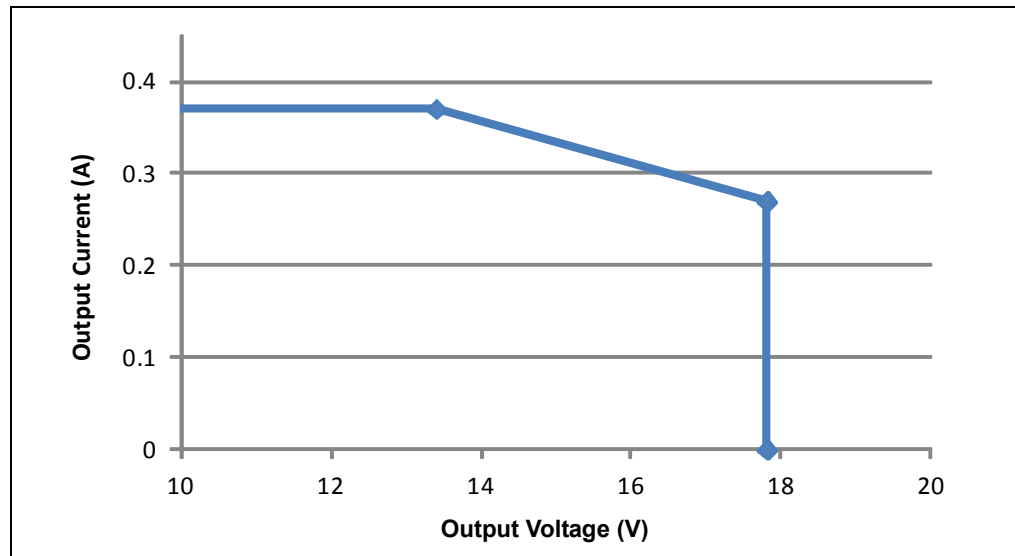
2.8   PROGRAMMER/DEBUGGER

The Digital Power Starter Kit includes an on-board programmer/debugger circuit that provides connectivity over USB. This circuit is hard-wired to the dsPIC® DSC device to provide ICSP™ debugging/programming capability.

TABLE 2-8:   PROGRAMMER/DEBUGGER COMPONENTS

Component	Label	Description
On-Board Programmer/ Debugger	N/A	Controls the programming/debugging operations of the target dsPIC33 'GS' DSC.
Programmer/Debugger USB Connector	J5	Provides power to the programmer/debugger, and bidirectional communication between the host PC and the Digital Power Starter Kit.

NOTES:

Chapter 3. Demonstration Program Operation

The dsPIC33 'GS' on the Digital Power Starter Kit is preprogrammed with Peak Current Mode control application software that illustrates simultaneous 2-Pole, 2-Zero (2P2Z) compensator control of the output voltage for the two DC/DC converter circuits. This code can be downloaded from the Microchip web site (www.microchip.com).

This section covers the following topics:

- Program Demonstration
- Code Demonstration
- Other Code Examples

3.1   PROGRAM DEMONSTRATION

The demonstration program provides simultaneous closed-loop control of the output voltage for both DC/DC converter stages of the Digital Power Starter Kit.

The 2P2Z control loop controls the Buck converter output voltage to 3.3V and the Boost converter output voltage to 15V.

The 2P2Z control scheme consists of the following parameters:

- Reference – Desired set point for the output voltage
- Error – Calculation of (Reference – Feedback). This is the value the compensator acts upon
- System Plant – This is the converter being controlled
- Output – Either the output voltage or current
- Feedback – The measured output signal level

Please refer to **Section 3.2.4 "2P2Z SW Control Compensator"** for further details. The demonstration program requires no manual preparation except to connect 9V to the J2 connector.

FIGURE 3-1:   PEAK CURRENT MODE CONTROL LOOP BLOCK DIAGRAM
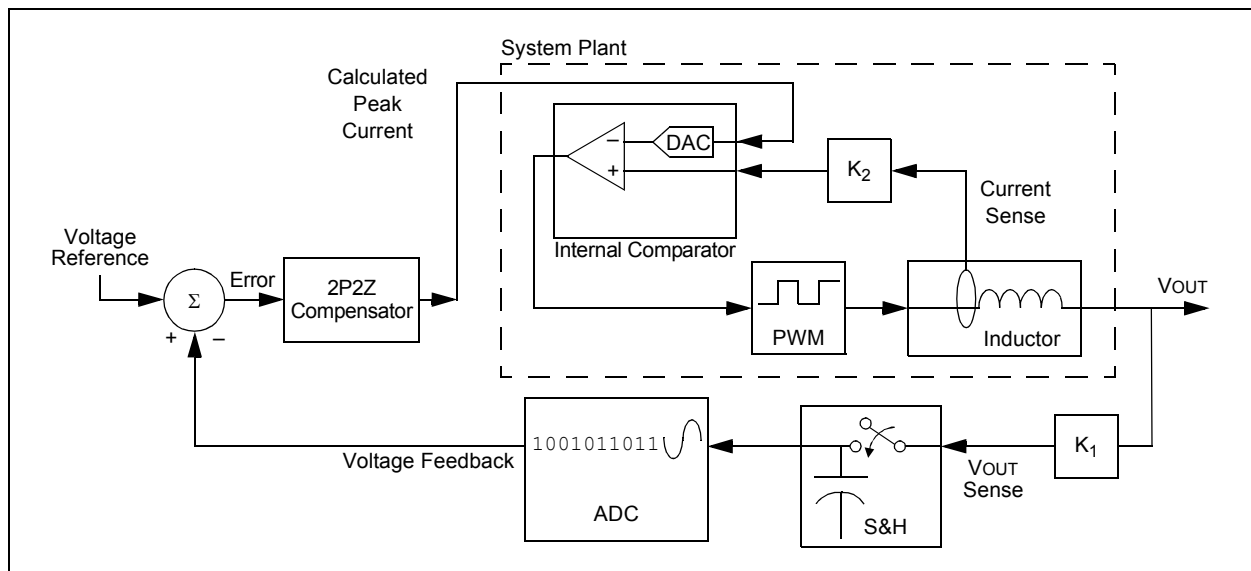
Digital Power Starter Kit User's Guide

FIGURE 3-2: **SMPS DEMONSTRATION PROGRAM FLOW CHART**

```
                          ┌─────────┐
                          │  Start  │
                          └─────────┘
                               │
                               ▼
        ┌──────────────────────────────────────┐
        │ Initialization Routines:             │
        │                                       │
        │ • Peripherals – ADC, PWM, Timers, GPIO,│
        │   LCD, etc.                           │
        │ • Variables – Buck/Boost Compensator  │
        │   Coefficient Initializations, Data   │
        │   Buffers                             │
        │ • Interrupts – ADC, Timers            │
        │ • Set Soft Start Flag                 │
        │ • Initialize I²C™ Module and          │
        │   Initialize Load Configuration       │
        │   (static/dynamic)                    │
        └──────────────────────────────────────┘
                               │
```
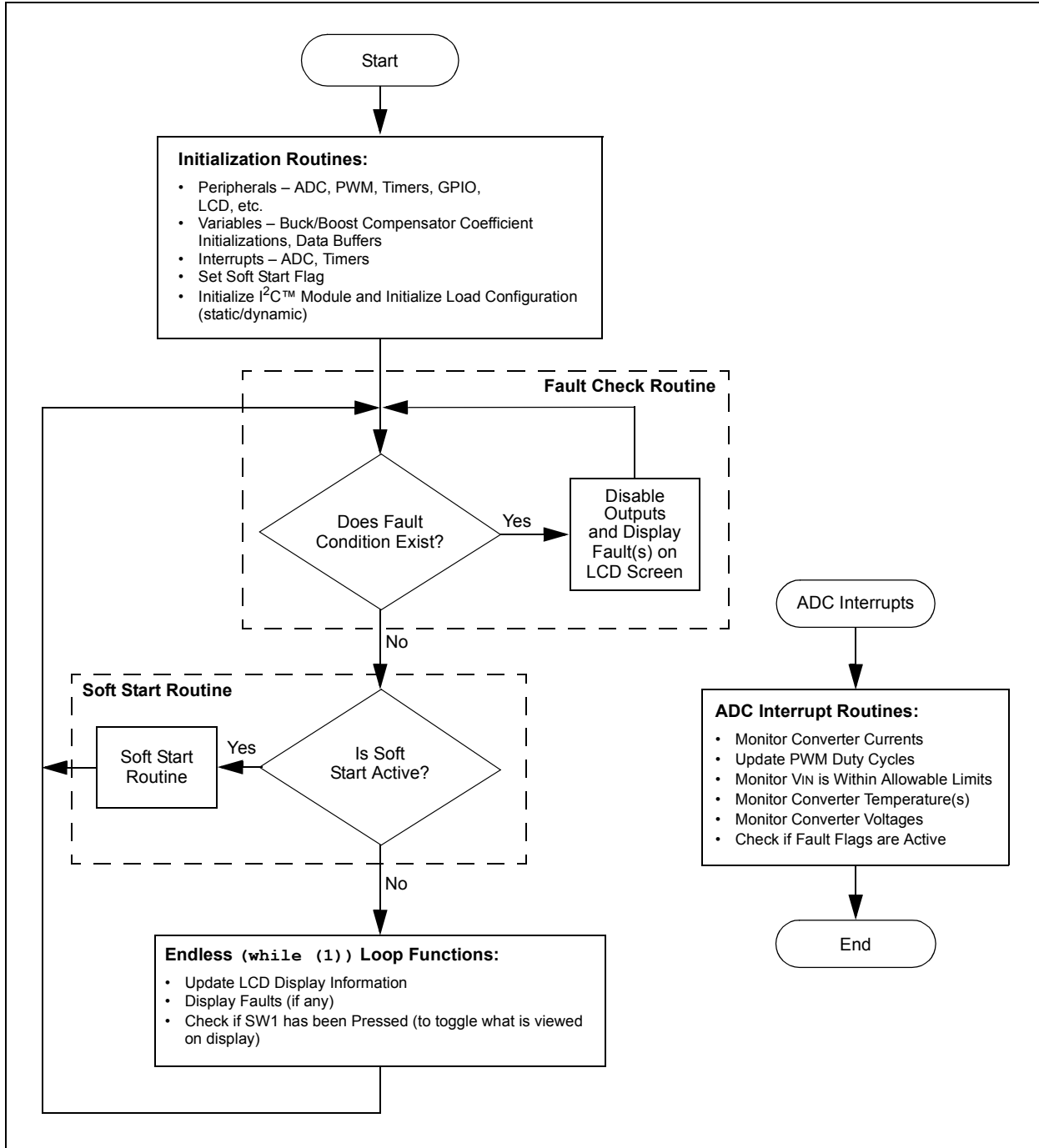
Fault Check Routine

Does Fault Condition Exist? — Yes → Disable Outputs and Display Fault(s) on LCD Screen

No

Soft Start Routine

Is Soft Start Active? — Yes → Soft Start Routine

No

Endless `(while (1))` Loop Functions:

- Update LCD Display Information
- Display Faults (if any)
- Check if SW1 has been Pressed (to toggle what is viewed on display)

ADC Interrupts

ADC Interrupt Routines:

- Monitor Converter Currents
- Update PWM Duty Cycles
- Monitor V$_{IN}$ is Within Allowable Limits
- Monitor Converter Temperature(s)
- Monitor Converter Voltages
- Check if Fault Flags are Active

End

3.2   CODE DEMONSTRATION

3.2.1   System Initialization

When power is applied to the board, the program starts by executing the following system initialization routines:

- Peripherals – The required peripherals (PWM, ADC, Comparators, I^{2}C™ module, Timers and GPIO) are configured and enabled.
- Interrupts – Include ADC(s), Timer(s), I^{2}C and comparator(s) interrupts.
- Loads – Can be configured for either Static mode or Dynamic mode. If Dynamic mode is selected, a switching frequency can be configured in application SW.

3.2.2   Fault Check

The program checks for any Faults that might have occurred during program operation. The Fault checks include the following:

- Input Over/Undervoltage
- Buck/Boost Converter Overtemperature
- Buck/Boost Soft Start

If any of the listed Faults occur, the corresponding Fault will be shown on the LCD display. The corresponding PWM signals and loads are disabled until the Fault condition has been cleared. Fault checks are dispersed throughout all the interrupts. If no Fault condition is detected, the program proceeds.

3.2.3   Soft Start

The Soft Start routine ramps up the output voltage in a closed-loop fashion until it is at the programmed output voltage value. This routine ensures that the output does not overshoot the desired voltage.

3.2.4   2P2Z SW Control Compensator

The 2-Pole, 2-Zero (2P2Z) controller implemented in SW is the digital implementation of the Analog Type II controller. This filter maintains regulation of the output voltage and ensures stability during different line/load conditions. This controller requires three feedback errors, multiplied by their associated coefficients, plus the two latest controller output values, multiplied by their associated coefficients, along the delay line to provide proper compensation of the power converter. The coefficients are determined externally using simulation tools.

Reference the `smps_2p2z_dspic.s` library and `smps_control.h` header files in the DPSK software package for further implementation details.

3.2.5   System `While (1)` Loop

The LCD refresh functions are called within the system Idle routine. The routine refreshes the LCD screen based on both user input (SW1) and converter feedback (Fault flags/V$_{IN}$ measurement/converter output voltage). All Fault display updates are performed in the system Idle loop routine, as well as the toggling of the displayed measurements as the results of pressing SW1.

3.3 OTHER CODE EXAMPLES

There are several other SMPS code examples available on the Microchip web site. Refer to the Readme files located in each code example folder for details on what each code example demonstrates. Check the Microchip web site (www.microchip.com/SMPS) for the latest updates to the code examples and for additional code examples.
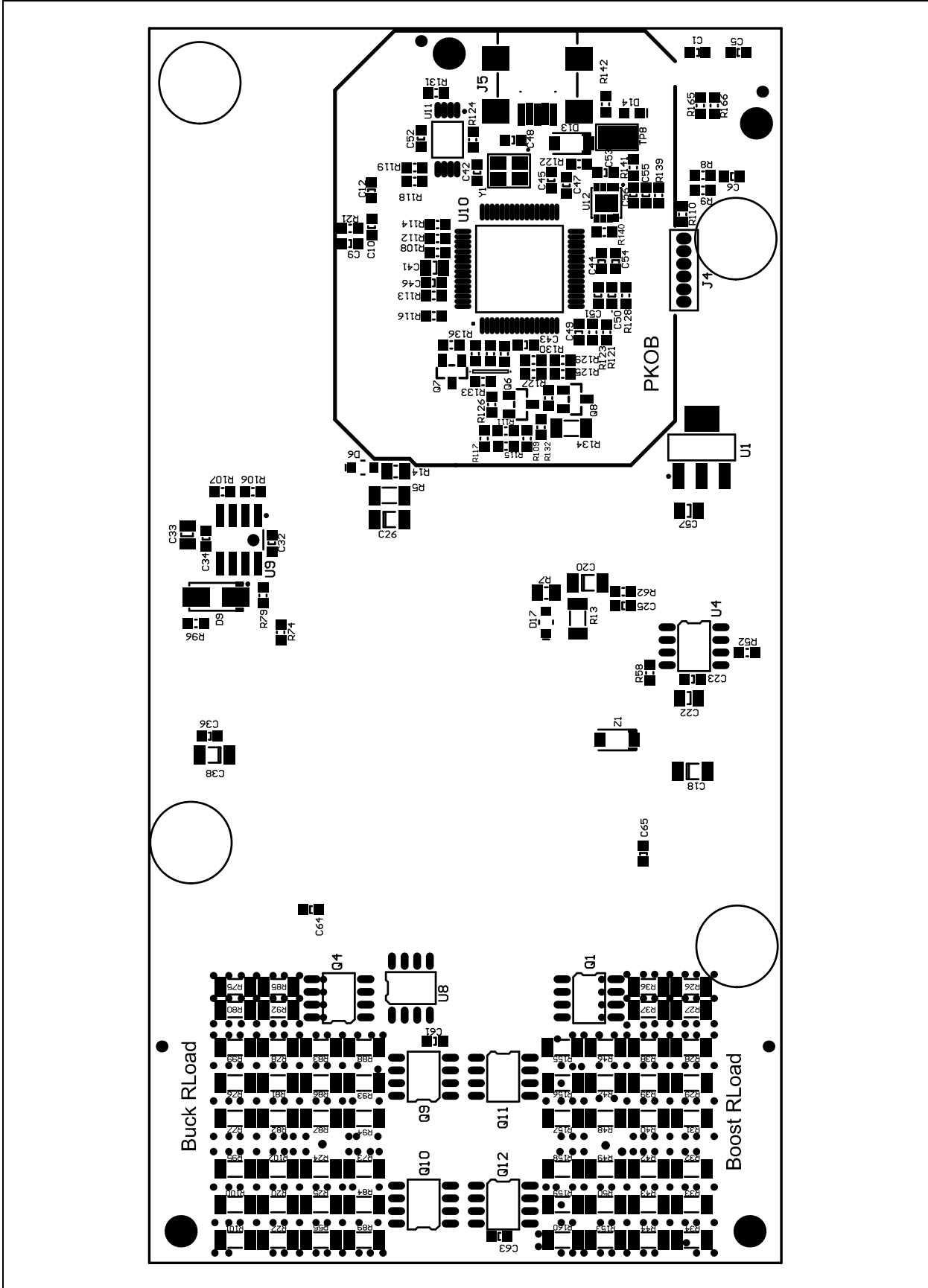
Appendix A. Board Layout and Schematics
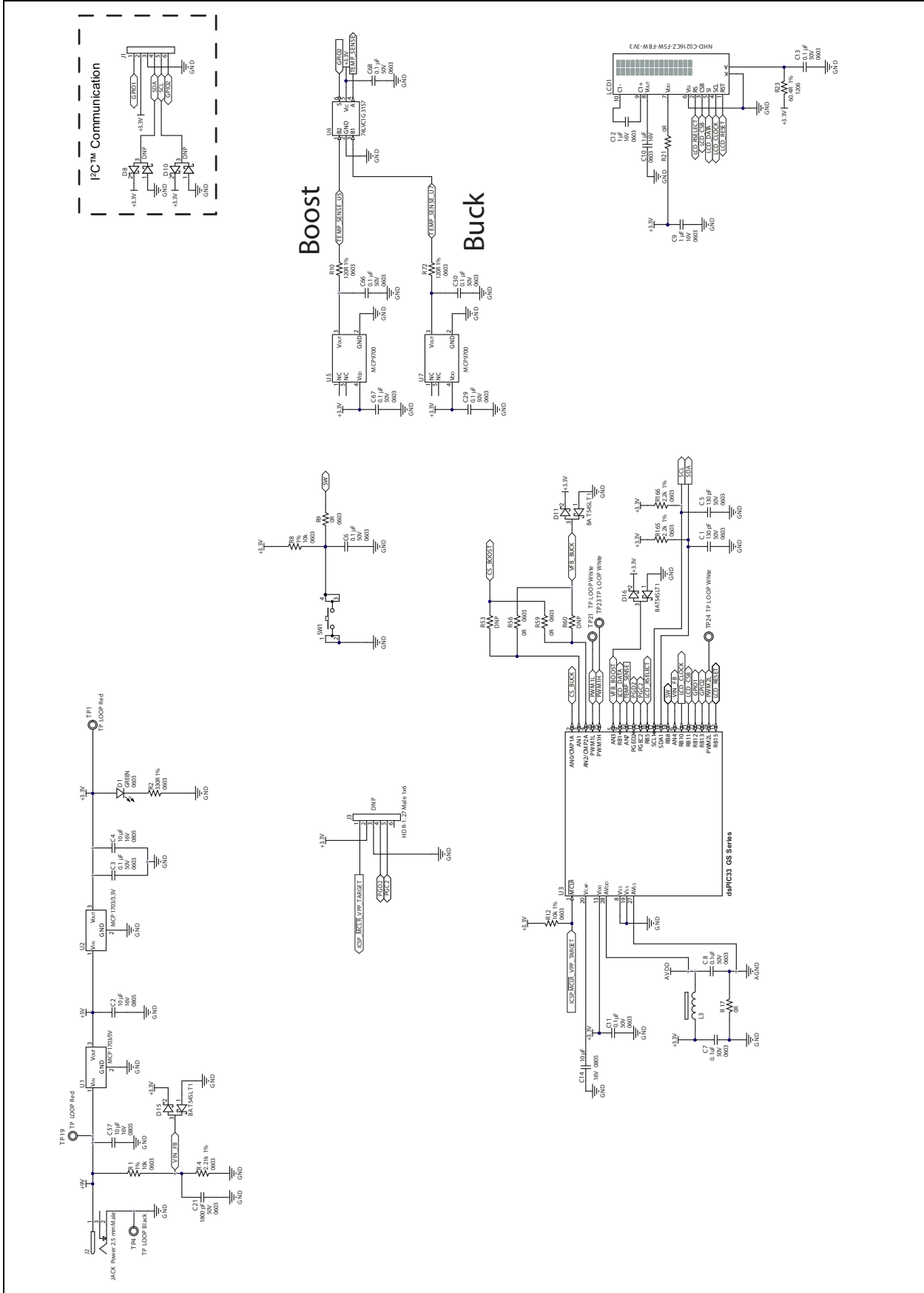
FIGURE A-1: DIGITAL POWER STARTER KIT LAYOUT (TOP)
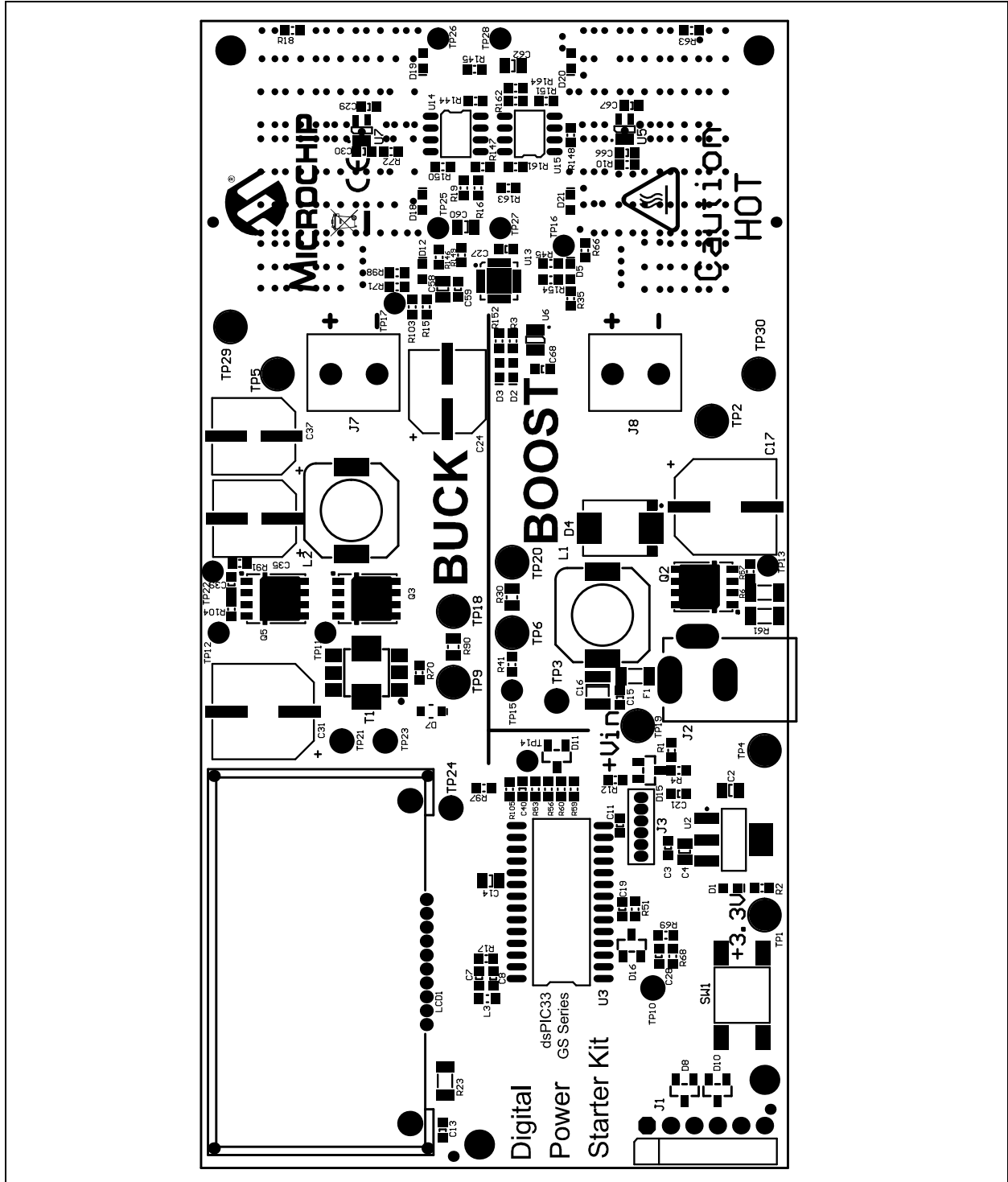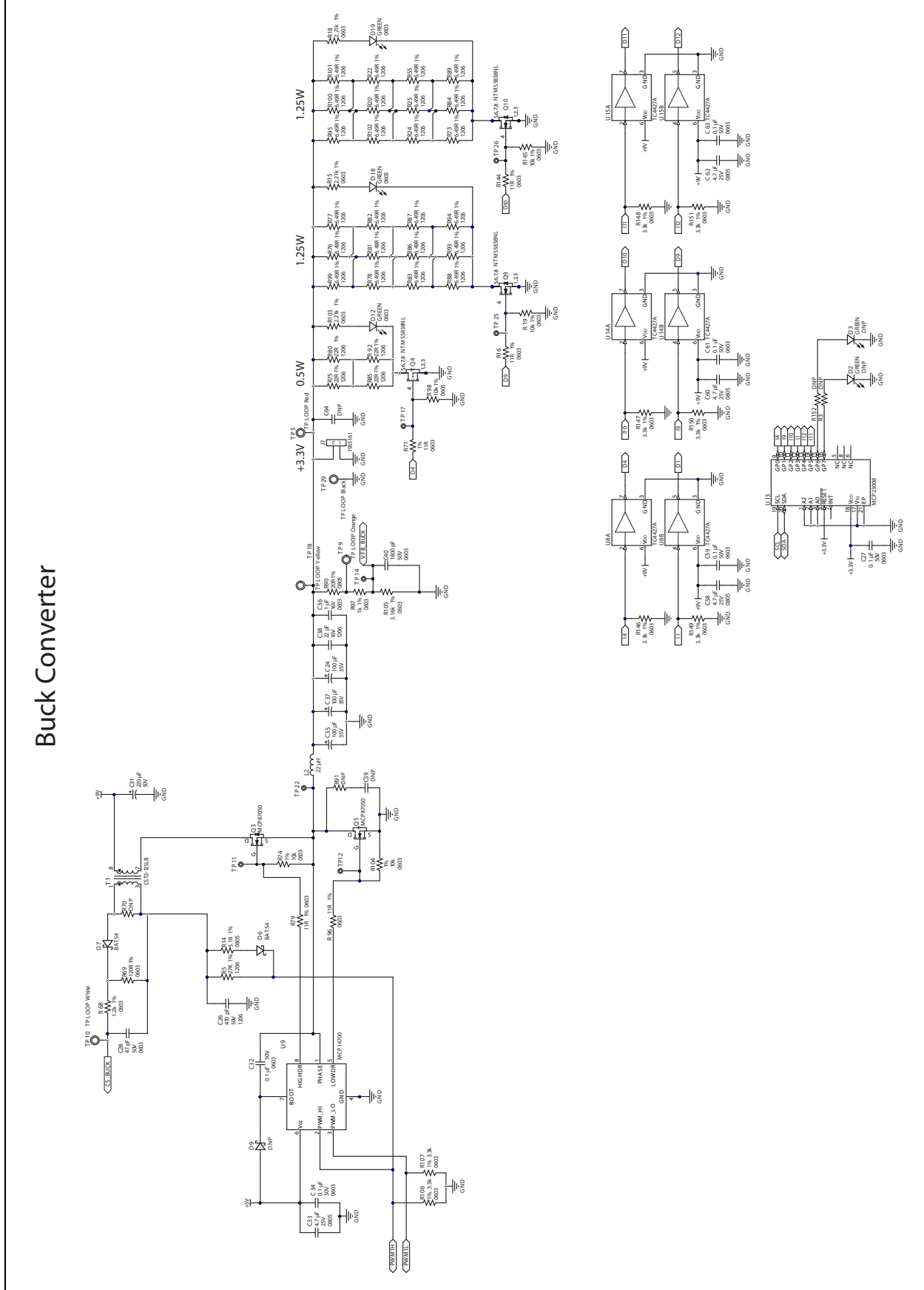
FIGURE A-2:   DIGITAL POWER STARTER KIT LAYOUT (BOTTOM)

FIGURE A-3: **DIGITAL POWER STARTER KIT SCHEMATIC REV. 1.2**

Digital Power Starter Kit User's Guide

FIGURE A-4: **DIGITAL POWER STARTER KIT SCHEMATIC REV. 1.2 (BUCK CONVERTER)**

FIGURE A-5: DIGITAL POWER STARTER KIT SCHEMATIC REV. 1.2 (BOOST CONVERTER)

Boost Converter

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://www.microchip.com/
support
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Cleveland
Independence, OH
Tel: 216-447-0464
Fax: 216-447-0643

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110

Canada - Toronto
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon
Hong Kong
Tel: 852-2943-5100
Fax: 852-2401-3431

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing
Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Dongguan
Tel: 86-769-8702-9880

China - Hangzhou
Tel: 86-571-8792-8115
Fax: 86-571-8792-8116

China - Hong Kong SAR
Tel: 852-2943-5100
Fax: 852-2401-3431

China - Nanjing
Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai
Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8864-2200
Fax: 86-755-8203-1760

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

ASIA/PACIFIC

China - Xiamen
Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai
Tel: 86-756-3210040
Fax: 86-756-3210049

India - Bangalore
Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi
Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune
Tel: 91-20-3019-1500

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880- 3770
Fax: 81-3-6880-3771

Korea - Daegu
Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur
Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang
Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu
Tel: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7828

Taiwan - Taipei
Tel: 886-2-2508-8600
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Dusseldorf
Tel: 49-2129-3766400

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Pforzheim
Tel: 49-7231-424750

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Venice
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Poland - Warsaw
Tel: 48-22-3325737

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820

01/27/15

Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

[Microchip](#):
  [DM330017-2](#) [DM330017-1](#)