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**Motor Control Starter Kit  
User's Guide**

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# MOTOR CONTROL STARTER KIT USER'S GUIDE

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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](http://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 “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 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 you use the Motor Control Starter Kit. Items 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 document describes how to use one of the starter kits as a development tool to emulate and debug firmware on a target board. The document layout is as follows:

- **Chapter 1. “Introduction”** – This chapter provides a brief overview of the Motor Control Starter Kit.
- **Chapter 2. “Software Description”** – This chapter describes the software that is provided with the Motor Control Starter Kit.
- **Chapter 3. “Hardware”** – This chapter describes the Motor Control Starter Kit hardware.
- **Appendix A. “Layout, Schematics, and Bill of Materials”** – This appendix provides detailed schematics, board layout, and the bill of materials for the Motor Control Starter Kit.

# Motor Control Starter Kit User's Guide

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## 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
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
<b>Courier New font:</b>		
Plain Courier New	Sample source code	<code>#define START</code>
	Filenames	<code>autoexec.bat</code>
	File paths	<code>c:\mcc18\h</code>
	Keywords	<code>_asm, _endasm, static</code>
	Command-line options	<code>-Opa+, -Opa-</code>
	Bit values	<code>0, 1</code>
	Constants	<code>0xFF, 'A'</code>
Italic Courier New	A variable argument	<i>file.o</i> , where <i>file</i> can be any valid filename
Square brackets [ ]	Optional arguments	<code>mcc18 [options] file [options]</code>
Curly brackets and pipe character: {   }	Choice of mutually exclusive arguments; an OR selection	<code>errorlevel {0 1}</code>
Ellipses...	Replaces repeated text	<code>var_name [, var_name...]</code>
	Represents code supplied by user	<code>void main (void) { ... }</code>

## WARRANTY REGISTRATION

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

## RECOMMENDED READING

This user's guide describes how to use the Motor Control Starter Kit. The following are available and recommended as supplemental reference resources.

### BLDC Motor Control Resources

- AN1160 *"Sensorless BLDC motor control using a Majority Function"*
- AN901 *"Using the dsPIC30F for Sensorless BLDC Control"*
- AN885 *"Brushless DC (BLDC) Motor Fundamentals"*
- AN857 *"Brushless DC Motor Control Made Easy"*
- Web Seminar – *"Sensorless BLDC Motor Control Using a Majority Function"*

### mTouch Resources

- AN1250 *"Microchip CTMU for Capacitive Touch Applications"*
- Web Seminar – *"Introduction to mTouch™ Capacitive Touch Sensing"*

You can obtain these reference documents as well as other related documents from your nearest Microchip sales office (listed in the back of this document) or by downloading them from the Microchip web site ([www.microchip.com](http://www.microchip.com)) at the following locations:

- <http://www.microchip.com/appnotes/>
- <http://techtrain.microchip.com/webseminars/QuickList.aspx>
- <http://www.microchip.com/motor/>
- <http://www.microchip.com/mtouch/>

### dsPIC33FJ16GP101/102 and dsPIC33FJ16MC101/102 Data Sheet (DS70652)

Refer to this document for detailed information on this family of dsPIC33F General Purpose and Motor Control Digital Signal Controllers (DSC). Reference information found in this data sheet includes:

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

### dsPIC33F/PIC24H Family Reference Manual Sections

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

### dsPIC33F/PIC24H Flash Programming Specification (DS70152)

Refer to this document for information on instruction sets and firmware development. This document may be obtained from the Microchip web site or your local sales office.

## MPLAB<sup>®</sup> C Compiler for PIC24 MCUs and dsPIC<sup>®</sup> DSCs User's Guide (DS51284)

This document details the use of Microchip's MPLAB C Compiler for PIC24 MCUs and dsPIC DSC devices to develop an application. The MPLAB C Compiler is a GNU-based language tool, based on source code from the Free Software Foundation (FSF). For more information about the FSF, visit [www.fsf.org](http://www.fsf.org).

## MPLAB<sup>®</sup> IDE User's Guide (DS51519)

This document describes how to use the MPLAB IDE Integrated Development Environment (IDE), as well as the MPLAB project manager, MPLAB editor and MPLAB SIM simulator. Use these development tools to help you develop and debug application code.

## THE MICROCHIP WEB SITE

Microchip provides online support via our web site at [www.microchip.com](http://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

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To register, access the Microchip web site at [www.microchip.com](http://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<sup>®</sup> C compiler; MPASM<sup>™</sup> and MPLAB 16-bit assemblers; MPLINK<sup>™</sup> and MPLAB 16-bit object linkers; and MPLIB<sup>™</sup> and MPLAB 16-bit object librarians.
- **Emulators** – The latest information on the Microchip in-circuit emulator, MPLAB REAL ICE<sup>™</sup>
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debugger, MPLAB ICD 3.
- **MPLAB IDE** – The latest information on Microchip MPLAB IDE, the Windows<sup>®</sup> Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB SIM simulator, MPLAB IDE Project Manager and general editing and debugging features.
- **Programmiers** – The latest information on Microchip programmers. These include the MPLAB PM3 device programmer and the PICkit<sup>™</sup> 3 development programmers.

## 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://www.microchip.com/support>

## DOCUMENT REVISION HISTORY

### Revision A (June 2011)

This is the initial released version of the document.

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# MOTOR CONTROL STARTER KIT USER'S GUIDE

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## Chapter 1. Introduction

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Thank you for purchasing a Motor Control Starter Kit from Microchip Technology. The board provided in the kit is intended to introduce and demonstrate the capabilities and features of the low-cost 16-bit Motor Control and mTouch™ families of devices. In addition, the Motor Control Starter Kit includes an on-board programmer/debugger, which eliminates the need for an additional programmer or hardware interface.

This chapter introduces the Motor Control Starter Kit and provides an overview of its features. Topics covered include:

- [Kit Contents](#)
- [Electrical Specifications](#)
- [Starter Kit Functionality and Features](#)

The software for the demonstration application that is preprogrammed into the on-board dsPIC33F Digital Signal Controller (DSC) is available for download from the Microchip web site at: <http://www.microchip.com>.

All project files have been included so that the code may be used directly to restore the dsPIC33F DSC on the starter kit to its original state (i.e., if the sample device has been reprogrammed with another program) or so you can use the demonstration code as a platform for further experiment and evaluation.

**Note:** Refer to the Readme file provided with the Motor Control 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.

### 1.1 KIT CONTENTS

The Motor Control Starter Kit contains the following:

- Motor Control Starter Kit Board
- BLDC motor
- 9V power supply
- USB cable

**Note:** If you are missing any part of a 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.

## 1.2 ELECTRICAL SPECIFICATIONS

**TABLE 1-1: DC INPUT RATING (J3)**

Parameter	Typical	Maximum	Unit
Power supply connected to J3	9	12	VDC

**TABLE 1-2: DC OUTPUT RATING (J5)**

Parameter	Typical	Maximum	Unit
Voltage	12	12	VDC
Peak Current	0.2	0.8	A
Power Rating	2.5	10	W

**TABLE 1-3: BLDC MOTOR (SHINANO DR-29312) MANUFACTURER SPECIFICATIONS**

Parameter	Value	Unit
Rated Voltage	12	VDC
Rated Torque	6	mNm
Rated Speed	1400	RPM
Rated Current	0.16	A

## 1.3 STARTER KIT FUNCTIONALITY AND FEATURES

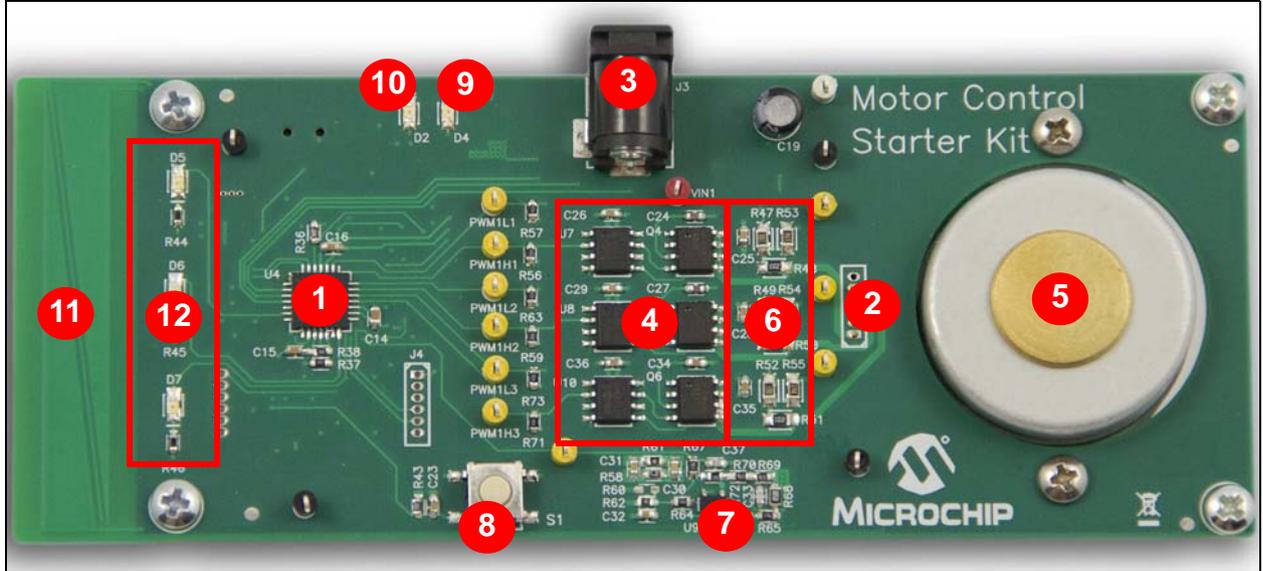
This section describes the top and bottom board layout assembly of the Motor Control Starter Kit.

### 1.3.1 Top Assembly

The top assembly of the board includes these key features, as indicated in [Figure 1-1](#):

1. Microchip dsPIC33FJ16MC102 DSC (U4)
2. Motor connector (J5)
3. 9V power connector (J3)
4. 3-phase inverter
5. BLDC motor
6. BEMF feedback
7. Current feedback
8. Push button (S1)
9. Power LED (D4)
10. Programmer/debugger power LED (D2)
11. Capacitive slider
12. User LEDs (D5, D6, D7)

**FIGURE 1-1: MOTOR CONTROL STARTER KIT BOARD (TOP)**

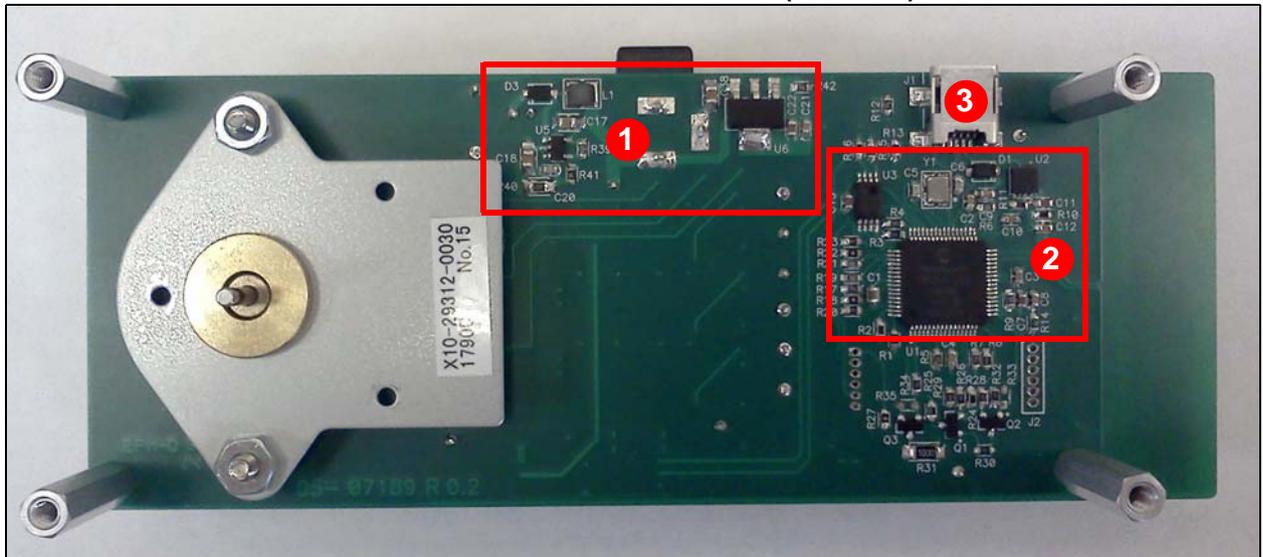


### 1.3.2 Bottom Assembly

The bottom assembly of the board includes these key features, as indicated in [Figure 1-2](#):

1. Power supply regulators
2. On-board programmer/debugger
3. Programmer/debugger USB connector (J1)

**FIGURE 1-2: MOTOR CONTROL STARTER KIT BOARD (BOTTOM)**



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## Chapter 2. Software Description

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The starter kit tutorial application demonstrates how to successfully integrate a noise sensitive mTouch application within a standard Motor Control environment.

This chapter contains the following topics:

- [Motor Control Application](#)
- [mTouch Capacitive Slider Application](#)
- [Integrating Motor Control and mTouch](#)

### 2.1 MOTOR CONTROL APPLICATION

The motor control software and hardware on this starter kit are based on the algorithm described in the application note, AN1160 “*Sensorless BLDC Control with Back-EMF Filtering Using a Majority Function*”, which is available from the Microchip website ([www.microchip.com](http://www.microchip.com)).

The main difference from the standard AN1160 software is the way the overcurrent fault functionality is implemented. The dsPIC33FJ16MC102 DSC features an internal analog comparator, which allows instant detection of an overcurrent condition and immediate hardware shutdown of the PWM outputs. The overcurrent level can be easily set in software, thus making the solution much more flexible and adaptable to a wide range of motors.

The motor current that passes through a shunt, is amplified by an operational amplifier and is available as input on an analog pin of the dsPIC33FJ16MC102 DSC. The analog input can be configured in software both as a comparator input and as an ADC input. Reading the current with the ADC module offers the possibility of implementing more complex control algorithms, such as the single shunt.

To close the Fault detection loop, the comparator output is wired externally to the PWM Fault input. As soon as the current exceeds the level set in software, the comparator will toggle its output and the PWM will be shut down immediately, without waiting for the next clock pulse to occur.

### 2.2 mTouch CAPACITIVE SLIDER APPLICATION

The capacitive slider on the Motor Control Starter Kit is implemented based on the application note, AN1250 “*Microchip CTMU for Capacitive Touch Applications*”. For detailed information on mTouch sliders and buttons, and the CTMU module, refer to this document, which is available from the Microchip website ([www.microchip.com](http://www.microchip.com)).

A two-channel capacitive slider is implemented on the Motor Control Starter Kit. Each channel is connected to an analog input on the dsPIC33FJ16MC102 DSC. The CTMU module charges each channel's capacitance with a fixed current for a certain amount of time. The capacitance of each channel depends on the position of the user's finger over the slider, and it is at its higher value when the slider is not touched. After the fixed charging time has elapsed, the CTMU module stops charging the capacitors and triggers the ADC to start sampling and converting the voltage on each capacitor to a numerical value.

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The numerical value for each channel is filtered to remove noise, and then, based on predefined thresholds, the position of the user's finger on the slider is determined. Movements over the slider can also be detected by monitoring both channels over a period of time.

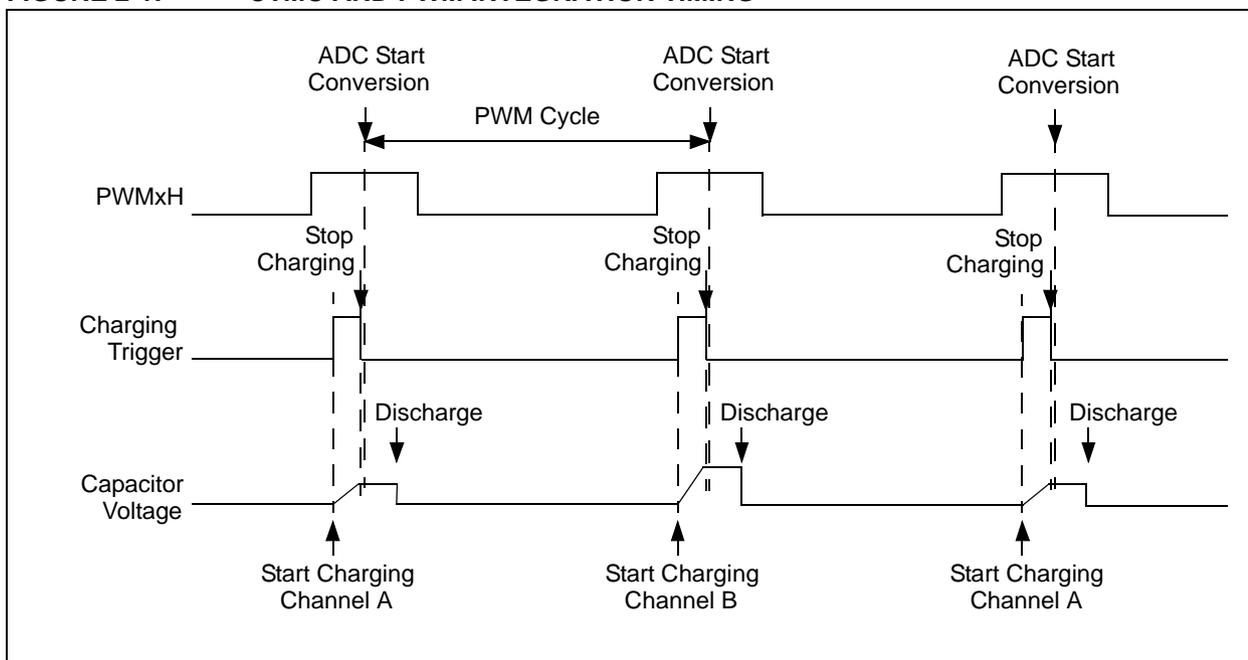
## 2.3 INTEGRATING MOTOR CONTROL AND mTouch

The dsPIC33FJ16MC102 DSC runs at a maximum of 16 MHz, and has sufficient resources to run the Motor Control Starter Kit demonstration application, including the motor control and the mTouch features.

Capacitive touch applications require a noise free environment, which is not the case of motor control applications where MOSFETs turn on and off continuously, generating noise spikes on the power supply levels. In such an environment, it is important to take the capacitive slider measurements at a time when no MOSFETs are switching. This is achieved by reducing the capacitance charging time to a minimum, by increasing the charging current, and synchronizing it to the PWM cycle.

The ADC module of the dsPIC33FJ16MC102 DSC allows simultaneous sampling of four different analog channels. Because three channels are needed for the BEMF feedback from the motor's phases, one channel remains available for the CTMU module. Both of the slider's channels are sampled and converted alternatively on subsequent PWM cycles, as shown in [Figure 2-1](#).

**FIGURE 2-1: CTMU AND PWM INTEGRATION TIMING**



The CTMU module uses a trigger to start and stop charging of the slider's capacitors. The trigger is configured in such a way that the ADC starts conversion a few nanoseconds after the capacitor has stopped charging. This ensures that no PWM switching occurs while sampling the voltage on the capacitor.

However, avoiding the PWM switching events in the charging period is also important. This is easily achieved in this configuration since the duty cycle is usually much larger than the capacitor charging time. After the ADC completes converting all four channels, three BEMF signals and one of the capacitors, the ADC interrupt is triggered and the capacitor is discharged to allow charging another one in the next cycle.

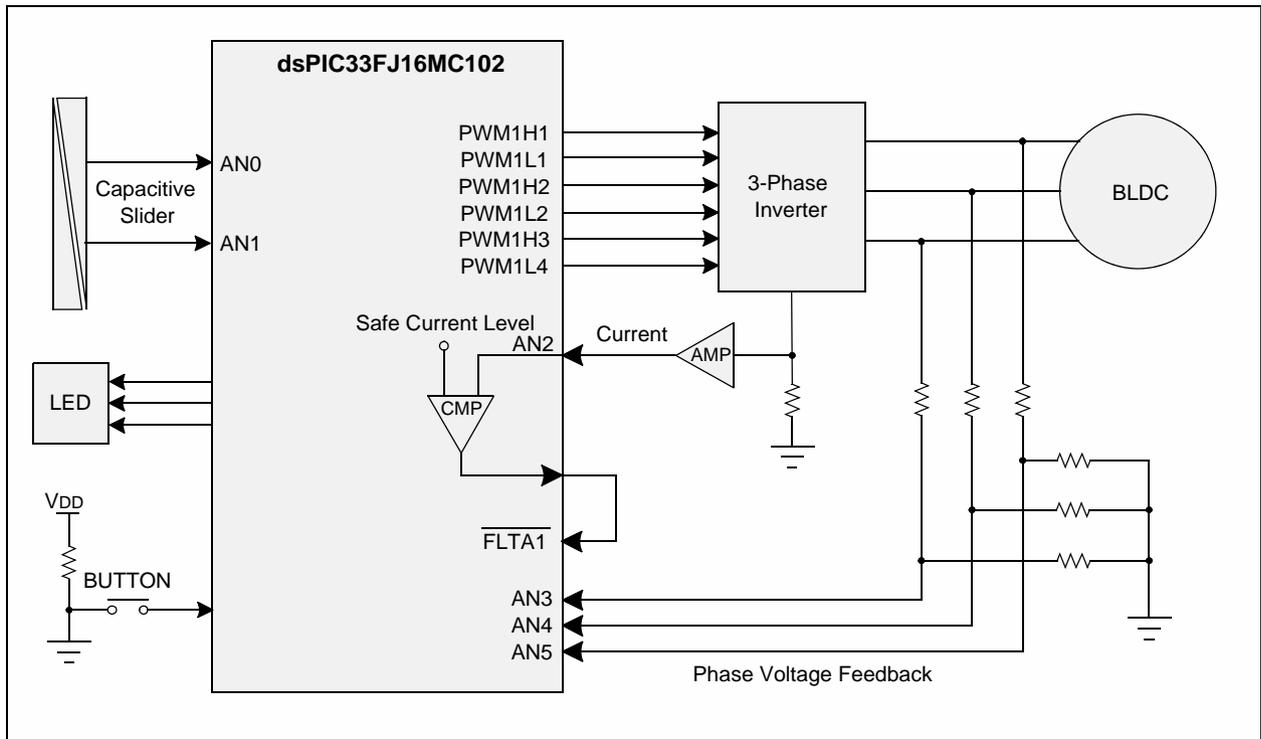
**Chapter 3. Hardware**

This chapter describes the hardware for the Motor Control Starter Kit and includes the following topics:

- [Programmer/Debugger](#)
- [Signal Configuration](#)
- [Programmer/Debugger Components](#)
- [Application Components](#)
- [Board Connectors](#)
- [Indicators and Human Interfaces](#)

Figure 3-1 shows a high-level block diagram, which details the main functions of the starter kit.

**FIGURE 3-1: MOTOR CONTROL STARTER KIT SYSTEM DIAGRAM**



The application side of the starter kit is centered on the dsPIC33FJ16MC102 DSC, which requires very little additional hardware to perform its tasks. The Motor Control Starter Kit is preprogrammed with an application featuring integrated motor control and mTouch functionality. The motor control application algorithm is based on the application note AN1160 “Sensorless BLDC Control with Back-EMF Filtering Using a Majority Function”.

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The powerful PWM module allows easy control over the 3-phase BLDC motor. The PWM module features three complementary output pairs, hardware Fault shutdown, programmable dead time, among others. A standard 3-phase inverter is used to interface the device and the motor.

Three ADC channels provide information of the motor's BEMF by reading the voltage on the motor windings. Three resistor networks scale the voltage in the range needed by the ADC module.

A single-shunt topology is featured on this starter kit, which can be used for overcurrent protection or for a single-shunt control algorithm.

The dsPIC33FJ16MC102 DSC also features three analog comparators. One internal comparator is used to trigger the Fault function of the PWM module if an overcurrent. The advantage of the internal comparator is that different software thresholds can be used to implement overcurrent conditions on different motors.

The demonstration application accepts user inputs from two sources: the capacitive slider, and the push button (S1). The device's CTMU module works together with the A/D Converter to sample and convert both the channels of the capacitive slider. Three user LEDs are also available for various display combinations.

The 9V power supply provided with the kit is sufficient for running the demonstration application in Stand-alone mode. In Debug mode, both the 9V power supply and the USB connection must be used.

## 3.1 PROGRAMMER/DEBUGGER

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

## 3.2 SIGNAL CONFIGURATION

Table 3-1 provides a full list of the dsPIC33FJ16MC102 DSC connections to the starter kit's signals, and a brief functional description of the pins used in the demonstration application.

**TABLE 3-1: dsPIC33FJ16MC102 DSC CONFIGURATION DETAILS**

Labels on the Motor Control Starter Kit Board	dsPIC33FJ16MC102		Description/Function
	Pin Number	Pin Name	
MOTOR_CURRENT	1	AN2/RP0/CN4/RB0	Analog and comparator input.
M1_V	2	AN3/RP1/CN5/RB1	Analog Phase 1 voltage.
M2_V	3	AN4/RP2/CN6/RB2	Analog Phase 2 voltage.
M3_V	4	AN5/RP3/CN7/RB3	Analog Phase 3 voltage.
GND	5	Vss	Ground.
LED_1	6	OSC1/CLKI/CN30/RA2	User-programmable LED.
PUSHBUTTON	7	OSC2/CLKO/CN29/RA3	S1 push button.
ICSP_PGED_TARGET	8	PGED3/RP4/CN1/RB4	Data I/O pin for programming/ debugging communication channel 3.
ICSP_PGEC_TARGET	9	PGEC3/T1CK/CN0/RA4	Clock input pin for programming/ debugging communication channel 3.
+3.3V_TARGET	10	VDD	Positive supply for peripheral logic and I/O pins.
+3.3V_TARGET	11	FLTB1/RP5/CN27/RB5	PWM Fault B input pulled high.
FLTA1	12	FLTA1/RP6/CN24/RB6	PWM Fault A input.
FLTA1	13	INT0/RP7/CN23/RB7	Comparator output.
LED_2	14	TCK/RP8/CN22/RB8	User-programmable LED.
LED_3	15	TDO/RP9/CN21/RB9	User-programmable LED.
GND	16	Vss	Ground reference for logic and I/O pins.
VCAP	17	VCAP	CPU logic filter capacitor connection.
PWM1H3	18	PWM1H3/RP10/RB10	PWM output.
PWM1L3	19	PWM1L3/RP11/RB11	PWM output.
PWM1H2	20	PWM1H2/RP12/RB12	PWM output.
PWM1L2	21	PWM1L2/RP13/RB13	PWM output.
PWM1H1	22	PWM1H1/RP14/RB14	PWM output.
PWM1L1	23	PWM1L1/RP15/RB15	PWM output.
AGND	24	AVss	Ground reference for analog modules. For devices without this pin, this signal is connected to Vss internally.
+3.3V_ANALOG	25	AVDD	Positive supply for analog modules. This pin must be connected at all times. For devices without this pin, this signal is connected to VDD internally.
ICSP_MCLR_VPP_TARGET	26	MCLR	Master Clear (Reset) input.
SLIDER_A	27	PGED2/AN0/CN2/RA0	Analog input from slider.
SLIDER_B	28	PGEC2/AN1/CN3/RA1	Analog input from slider.

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## 3.3 PROGRAMMER/DEBUGGER COMPONENTS

Table 3-2 describes the programmer/debugger components that are available on the Motor Control Starter Kit (see Figure 1-1 and Figure 1-2 for component locations).

**TABLE 3-2: PROGRAMMER/DEBUGGER COMPONENTS**

Component	Label	Figure #	Item #	Description
<b>Top Assembly Component</b>				
Programmer/Debugger Power LED	D2	1-1	10	When lit, indicates that power is being supplied to the PIC24FJ256GB106 MCU via the USB and the target MCU may be set to operate in Debug mode.
<b>Bottom Assembly Components</b>				
On-board Programmer/Debugger	N/A	1-2	2	Controls the programming/debugging operations of the target dsPIC33FJ16MC102 DSC.
Programmer/Debugger USB Connector	J1	1-2	3	Provides system power and bidirectional communication between the host PC and starter kit.

## 3.4 APPLICATION COMPONENTS

Table 3-3 describes the application components that are available on the Motor Control Starter Kit (see Figure 1-1 and Figure 1-2 for component locations).

**TABLE 3-3: APPLICATION COMPONENTS**

Component	Label	Figure #	Item #	Description
<b>Top Assembly Components</b>				
dsPIC33FJ16MC102 DSC	U4	1-1	1	Provides the processing power for the demonstration applications and application development on the starter kit. The MCU features 16 Kbytes of Flash program memory and 1 Kbyte of RAM. The demonstration application uses the MCU's on-chip FRC oscillator with PLL as a clock source.
Motor Connector	J5	1-1	2	The BLDC Motor is connected to the starter kit board via a 6-pin connector. The three phases of the motor are connected to pins 1, 2, and 3 while the other pins are left unconnected.
9V Power Connector	J3	1-1	3	A 9V power supply powers the dsPIC33FJ16MC102 DSC and the motor control circuitry on the starter kit. To operate the starter kit, connect the power supply provided with the starter kit (AC162039) to J3.
3-Phase Inverter	N/A	1-1	4	Microchip's TC4428 dual MOSFET drivers provide the interface between the low-voltage control side, the dsPIC33FJ16MC102 DSC, and the power side of the application (i.e., MOSFETs). These drivers provide the MOSFETs with current as well as the proper voltage, inverting the high-side PWM to drive the P-channel MOSFET, while keeping the delay time equal to the N-channel MOSFET. The 3-phase inverter features three half-bridges implemented with dual N- and P-Channel MOSFETs. While the MOSFETs are capable of driving higher currents, the 10W power supply limits the maximum current to approximately 800 mA. At this power level, there is no need for an external heat sink.
BLDC Motor	N/A	1-1	5	A 3-phase BLDC motor is provided with the Motor Control Starter Kit (Shinano DR-29312). The motor specifications are provided in Table 1-3 of Chapter 1. "Introduction".

**TABLE 3-3: APPLICATION COMPONENTS (CONTINUED)**

Component	Label	Figure #	Item #	Description
<b>Top Assembly Components</b>				
BEMF Feedback	N/A	1-1	6	A six resistor network consisting in three voltage dividers is connected to the motor windings to measure the BEMF of the motor, providing the feedback needed for driving the motor in sensorless mode. Based on the ADC measurements, the motor virtual neutral point is reconstructed in software. The resistor values are chosen taking into consideration the maximum BEMF voltage on the motor terminals and the maximum voltage allowed on the ADC input pins.
Current Feedback	N/A	1-1	7	A single-shunt topology has been implemented on this starter kit, featuring a 0.5Ω shunt. One MCP6021 operational amplifier provides the current input to the ADC channel at a resolution of 2.5V/A, with no offset. A 1.67V offset can be configured by populating R60 and R62 with 10 KΩ resistors.
Push Button	S1	1-1	8	This simple push button can be used as an input to the device. When the button is pressed, the corresponding port pin is low.
Power LED	D4	1-1	9	When lit, indicates that power is being supplied to the dsPIC33FJ16MC102 DSC from the 3.3V regulator.
Capacitive Slider	N/A	1-1	11	The capacitive slider is an integral part of the board's top layer. The application responds to capacitive changes induced by direct contact with the user by monitoring each of the slider pads with the device's integrated CTMU module.
User-programmable LEDs	D5, D6, D7	1-1	12	Three user-programmable LEDs are available for the application. The LEDs are lit when their corresponding port pins are set high.
<b>Bottom Assembly Component</b>				
Power Supply Regulators	N/A	1-2	1	Two power regulators are included in the application side of this starter kit, converting the 9V input to voltages appropriate for the other starter kit components. A 3.3V regulator provides the power for the dsPIC33FJ16MC102 DSC, feedback circuitry, user LEDs and push button. The maximum power of this regulator is 0.5W.  The second regulator provides 12V for powering the three-phase inverter and driving the BLDC motor. The maximum of this regulator is 10W.

## 3.5 BOARD CONNECTORS

Table 3-4 describes the hardware connections available on the Motor Control Starter Kit (see Figure 1-1 and Figure 1-2 for component locations).

**TABLE 3-4: BOARD CONNECTORS**

Label	Description
J1	mini-B USB connection between the on-board programmer/debugger and the host computer.
J2	ICSP™ programmer interface connector for programming the PIC24FJ256GB106 MCU USB-to-UART bridge.
J3	9V board power input.
J4	ICSP programmer interface connector for programming the dsPIC33FJ16MC102 DSC.
J5	BLDC motor connector.

# Motor Control Starter Kit User's Guide

## 3.6 INDICATORS AND HUMAN INTERFACES

Table 3-5 describes the user interaction interfaces available on the starter kit (see Figure 1-1 and Figure 1-2 for component locations).

**TABLE 3-5: INDICATORS AND HUMAN INTERFACES**

Label	Hardware Element Description
S1	Push button, which is connected to a port pin. When momentarily pressed, the switch connects the respective port pin to Ground.
D2	USB bus indicator, which indicates that the device is connected to the USB bus and the programmer/debugger is powered.
D4	Power-on status LED, which indicates that the board is powered by the 9V supply.
D5-D7	User-programmable LED's. Each LED is connected to a port pin. When the corresponding port pin is set high, the LED is lit.
Slider A-B	Two-channel capacitive slider. Each channel is connected to an analog input pin.

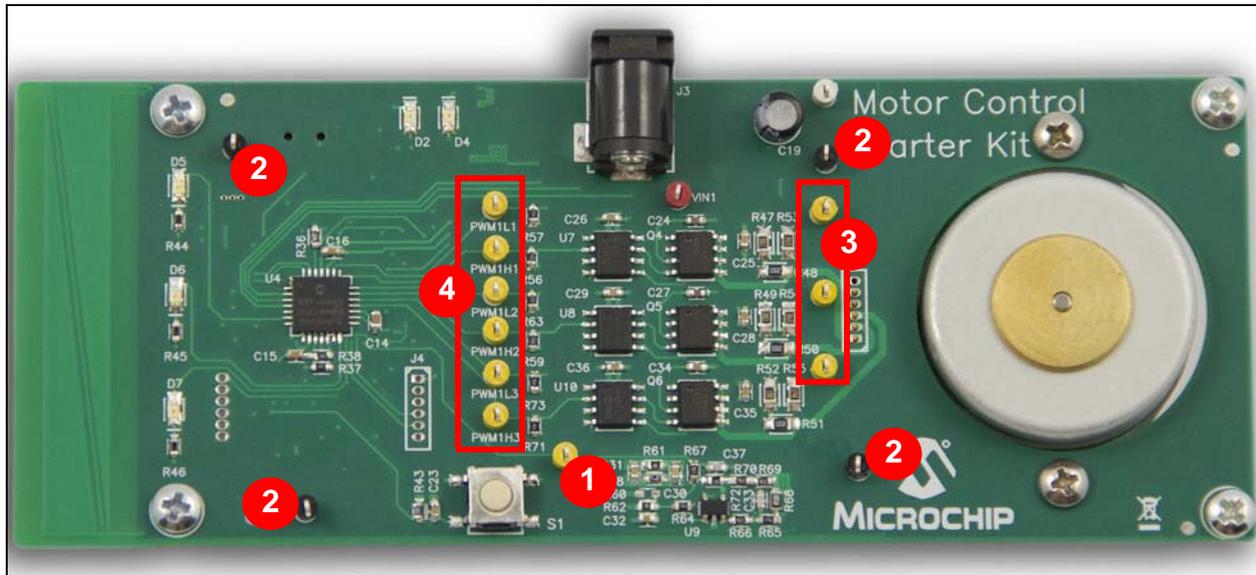
## 3.7 TEST POINTS

Table 3-6 describes the test points that are available on the starter kit (see Figure 3-2 for test point locations).

**TABLE 3-6: TEST POINTS**

Test Point	Item #	Description
MOTOR_CURRENT	1	Motor current feedback (2.5 V/A).
GND	2	Four board Ground test points.
M1_V, M2_V, M3_V	3	Phase 1, Phase 2, and Phase 3 BEMF voltage feedback (148 mV/V).
PWM1Hx/PWM1Lx	4	Three complementary PWM pairs.

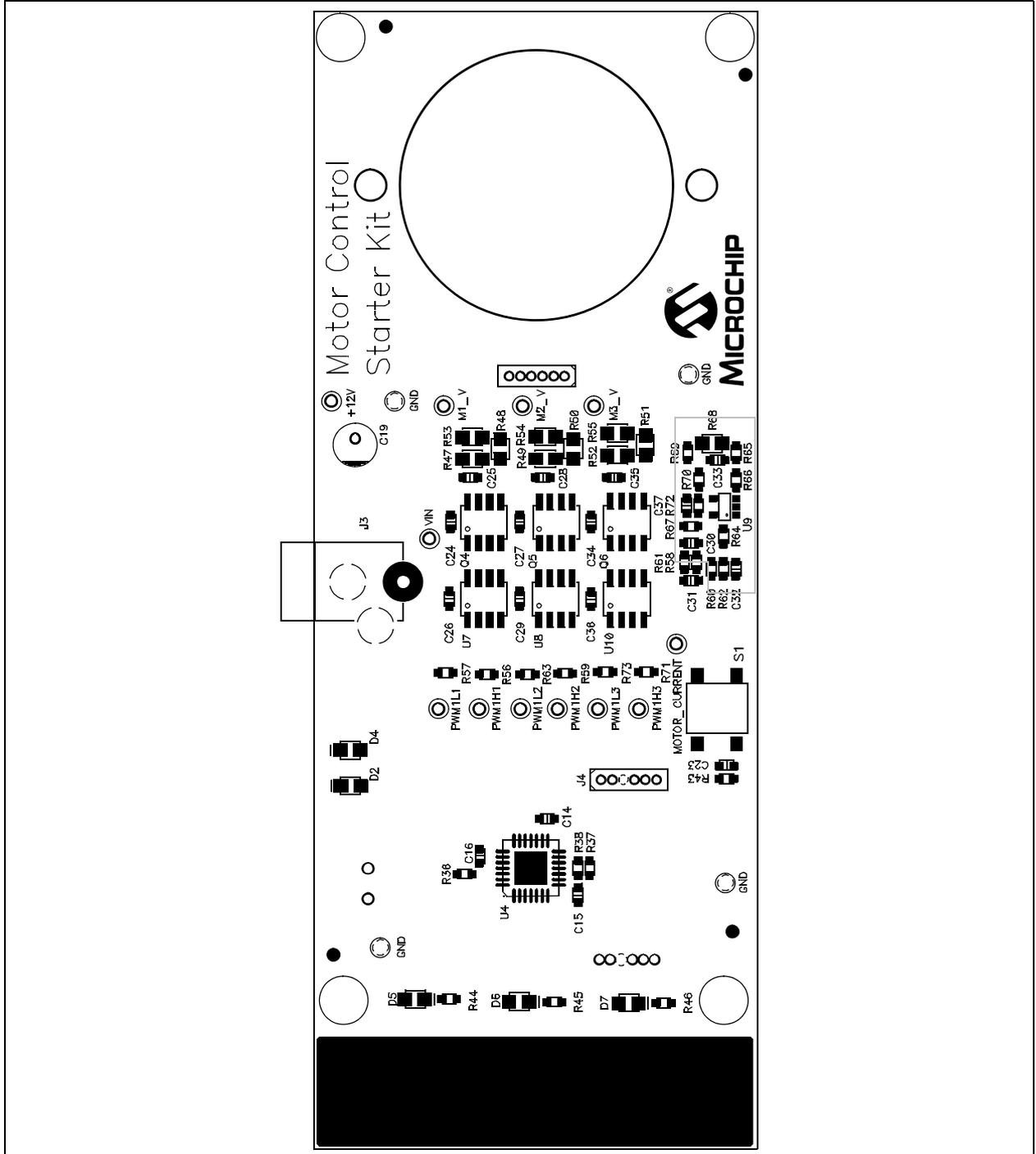
**FIGURE 3-2: MOTOR CONTROL STARTER KIT BOARD TEST POINT LOCATIONS**



**Appendix A. Layout, Schematics, and Bill of Materials**

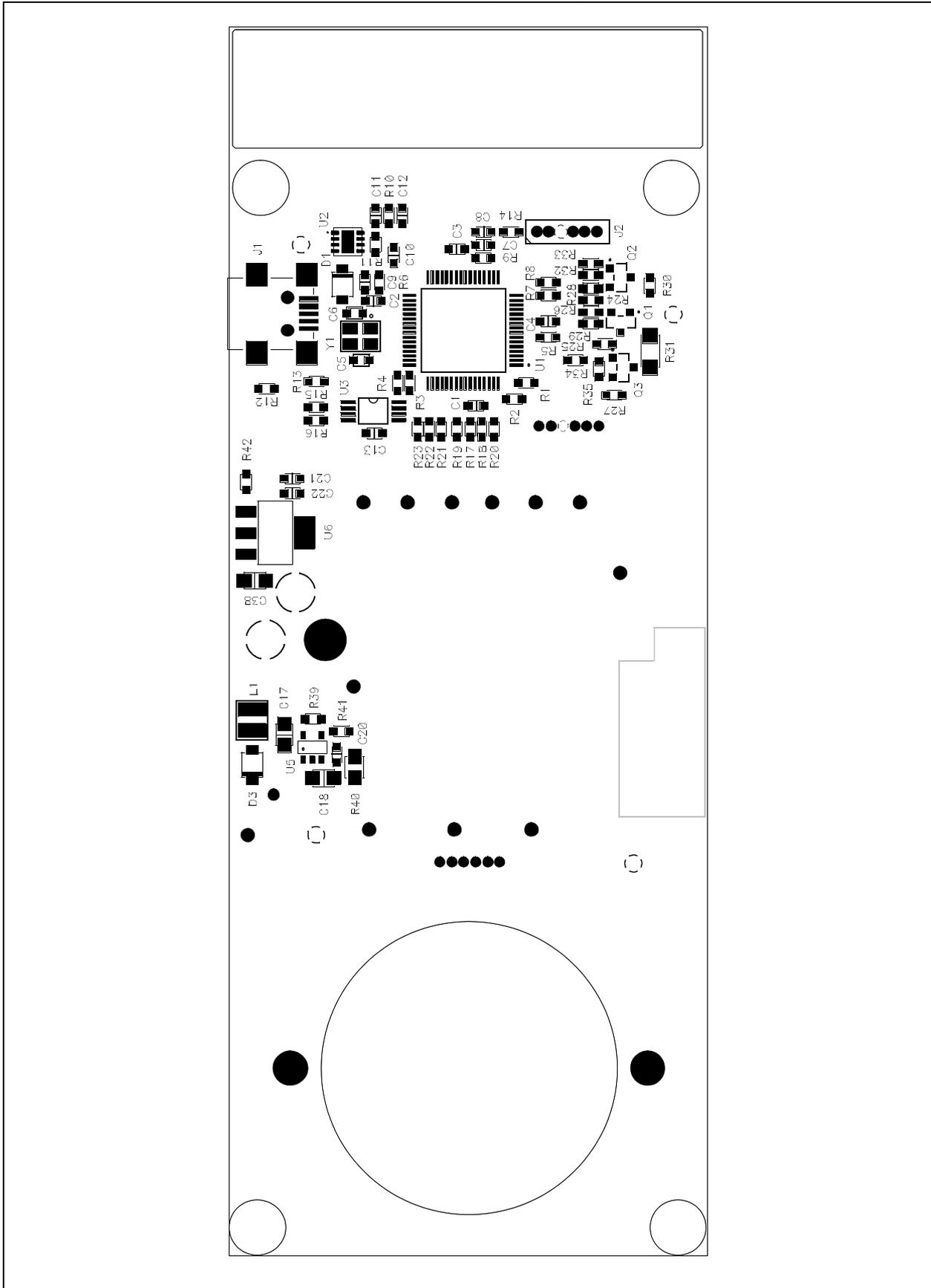
**A.1 STARTER KIT BOARD LAYOUT**

**FIGURE A-1: STARTER KIT BOARD LAYOUT (TOP)**



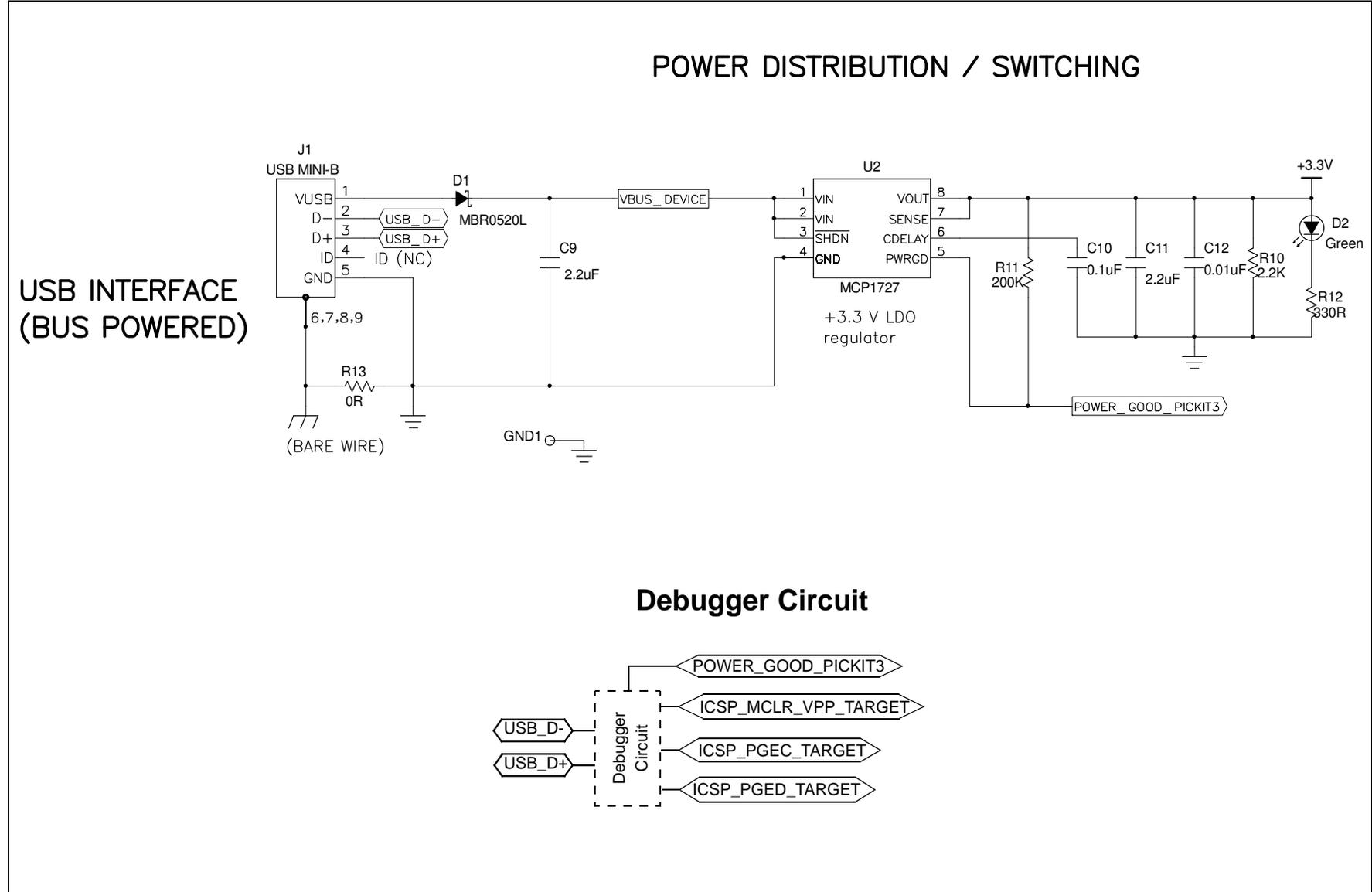
# Motor Control Starter Kit User's Guide

FIGURE A-2: STARTER KIT BOARD LAYOUT (BOTTOM)



## A.2 DEBUGGER HARDWARE SCHEMATICS

FIGURE A-3: POWER DISTRIBUTION/SWITCHING



# Motor Control Starter Kit User's Guide

## A.3 APPLICATION SCHEMATICS

FIGURE A-4: TARGET POWER

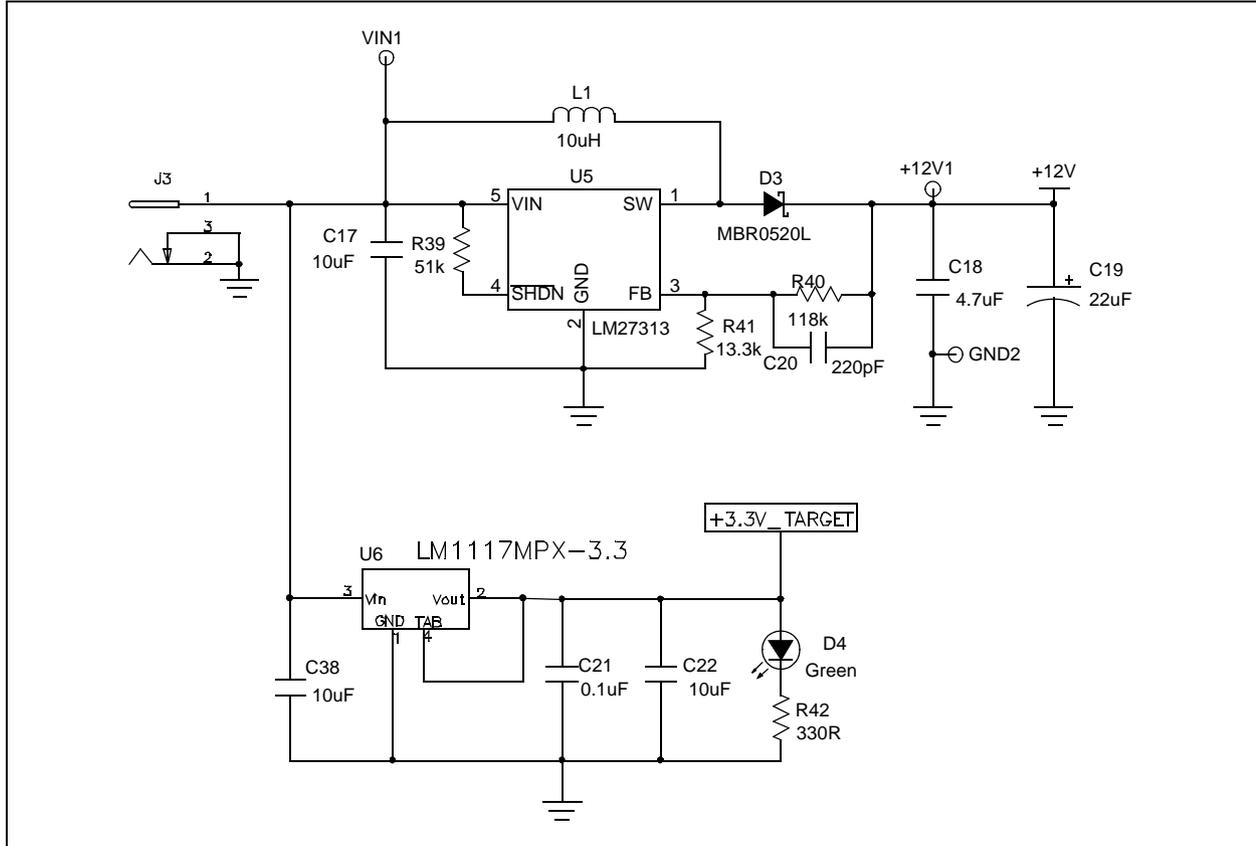


FIGURE A-5: MOTOR SOCKET

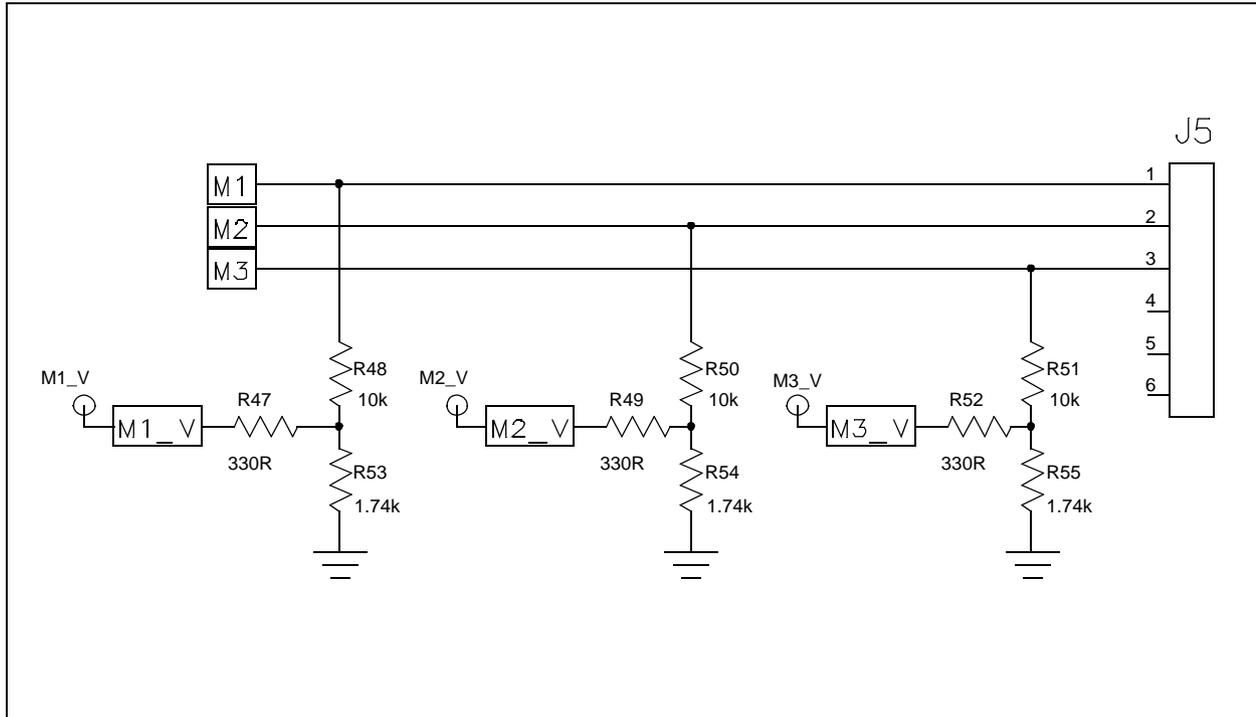


FIGURE A-6: dsPIC33FJ16MC102 DIGITAL SIGNAL CONTROLLER

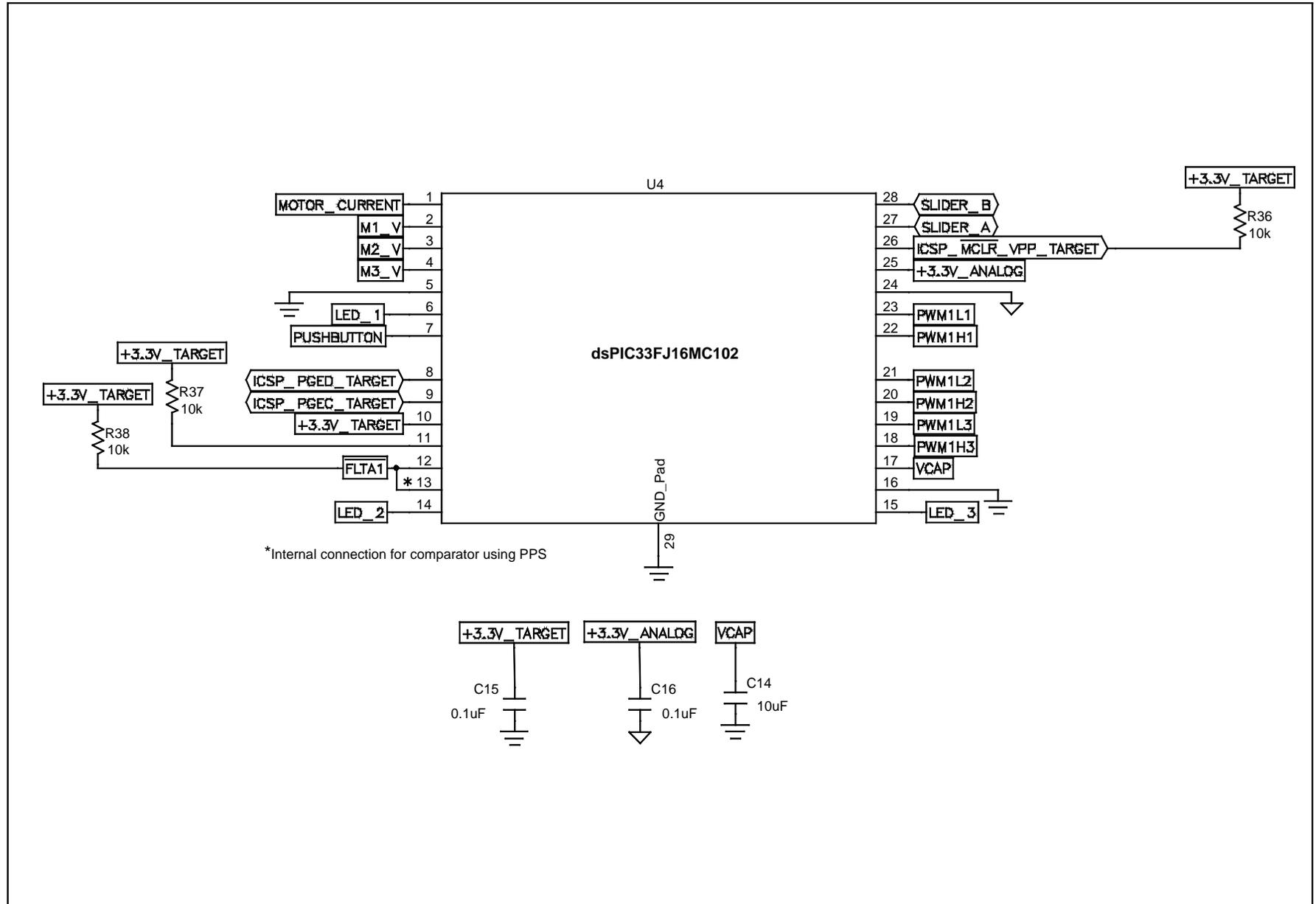
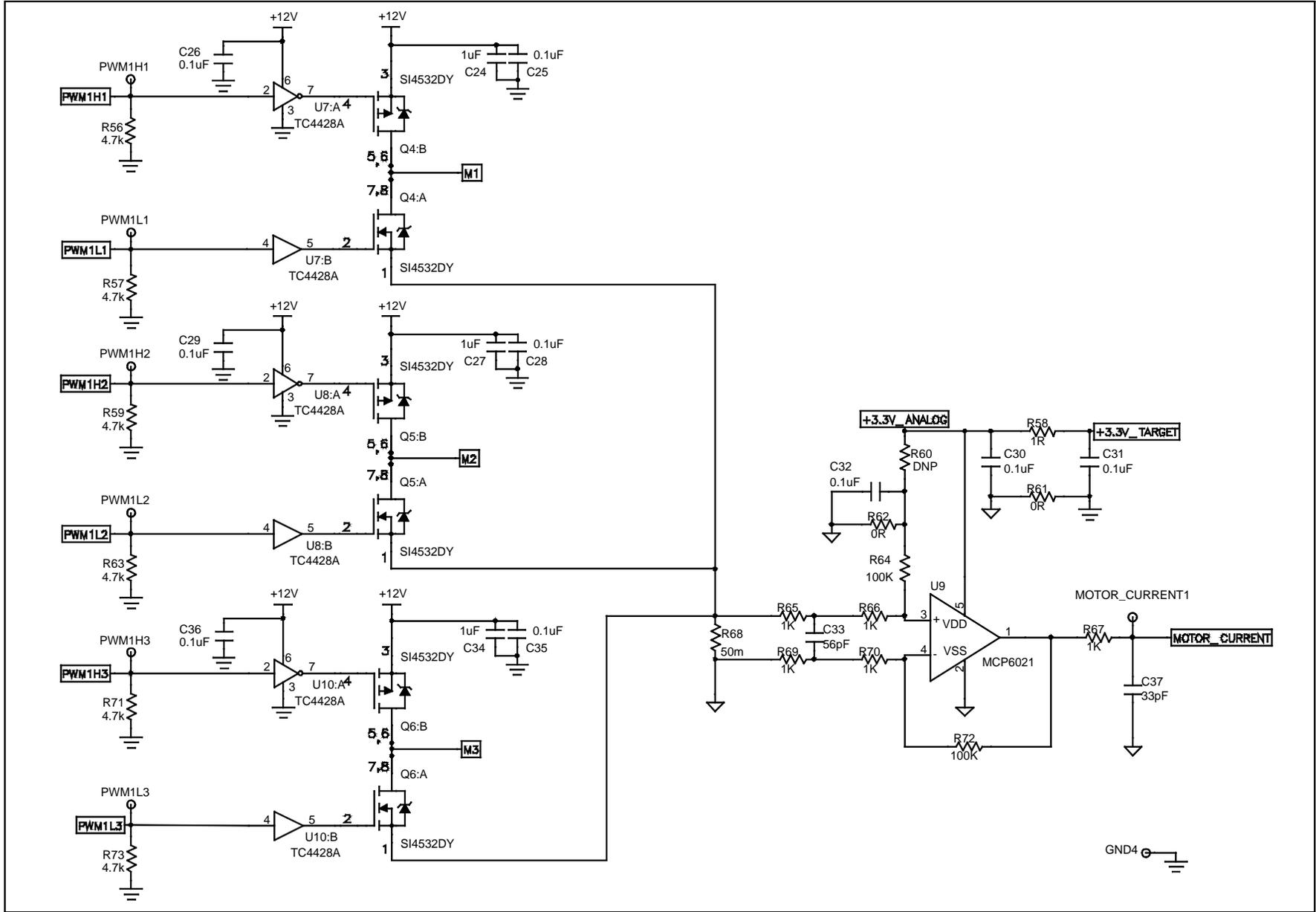


FIGURE A-7: MOTOR CONTROL LOGIC



# Layout, Schematics, and Bill of Materials

FIGURE A-8: CAPACITIVE TOUCH SLIDER

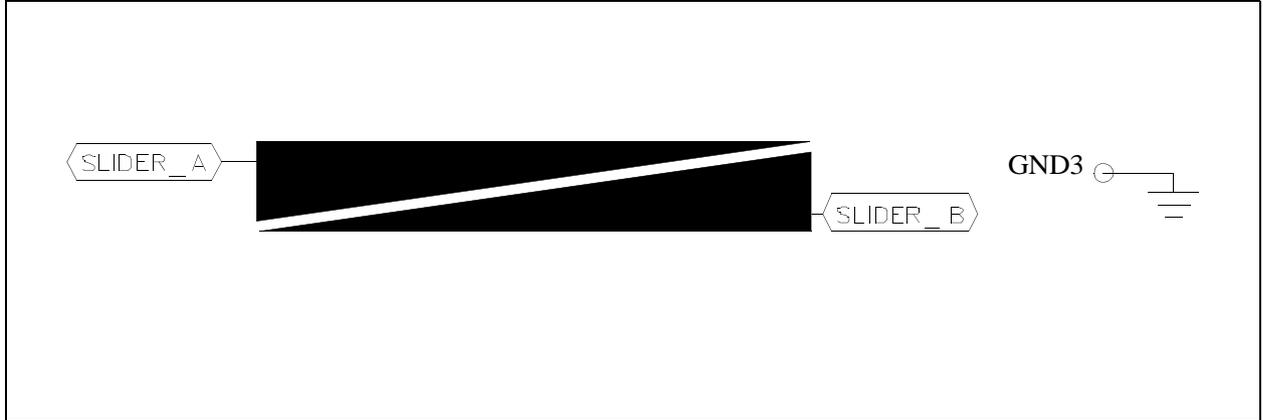


FIGURE A-9: PUSH BUTTON

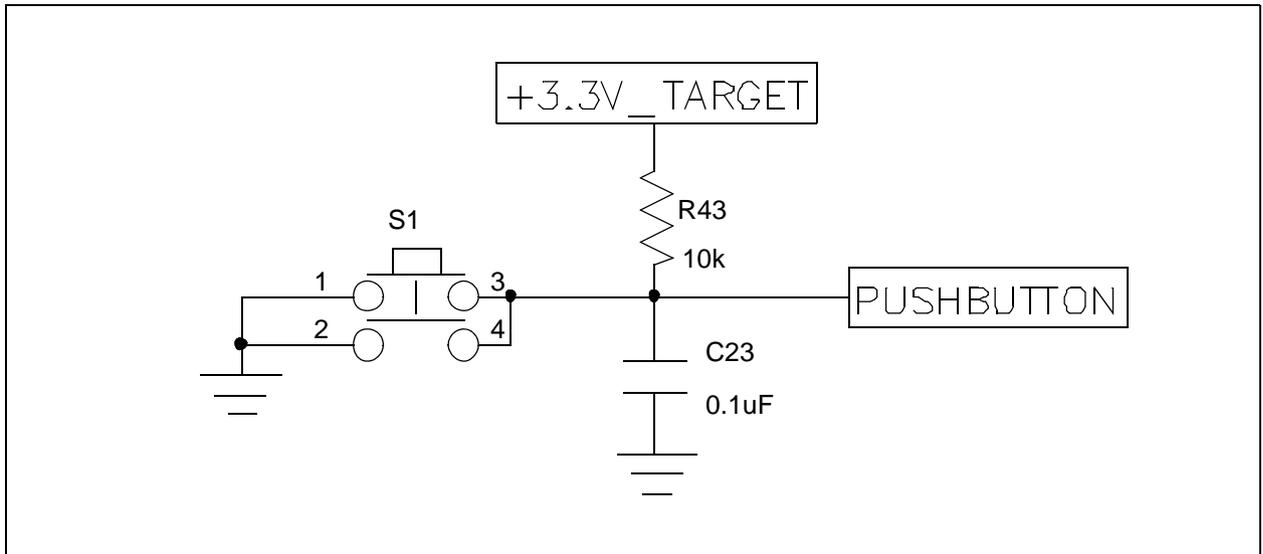
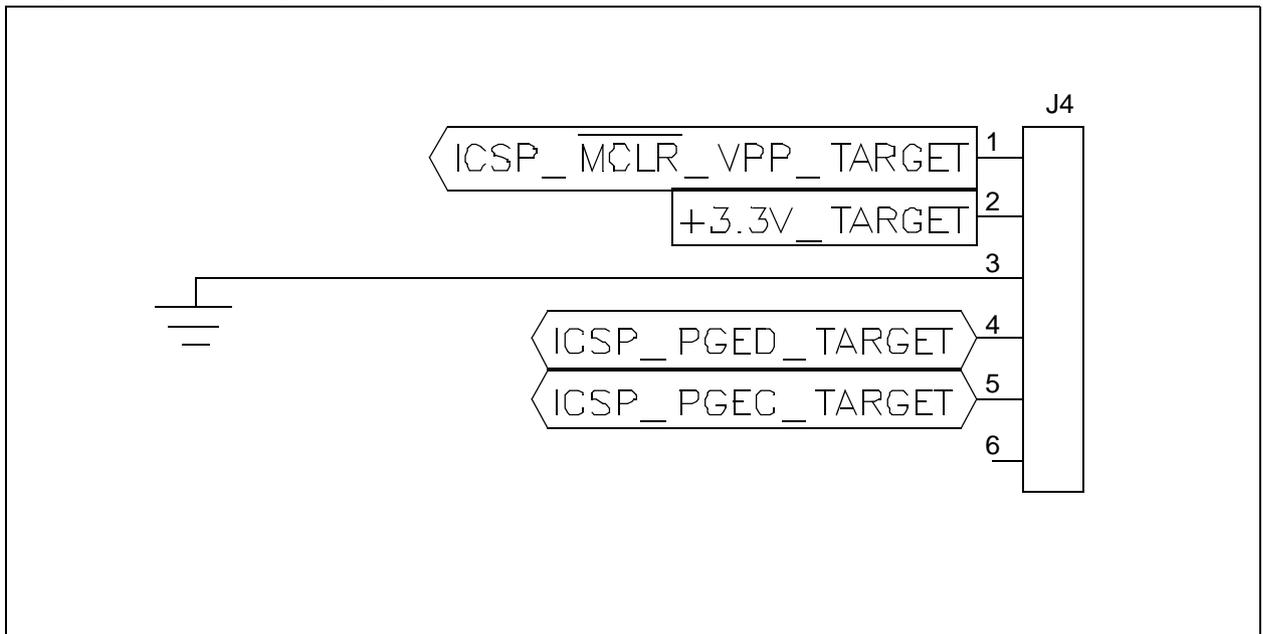
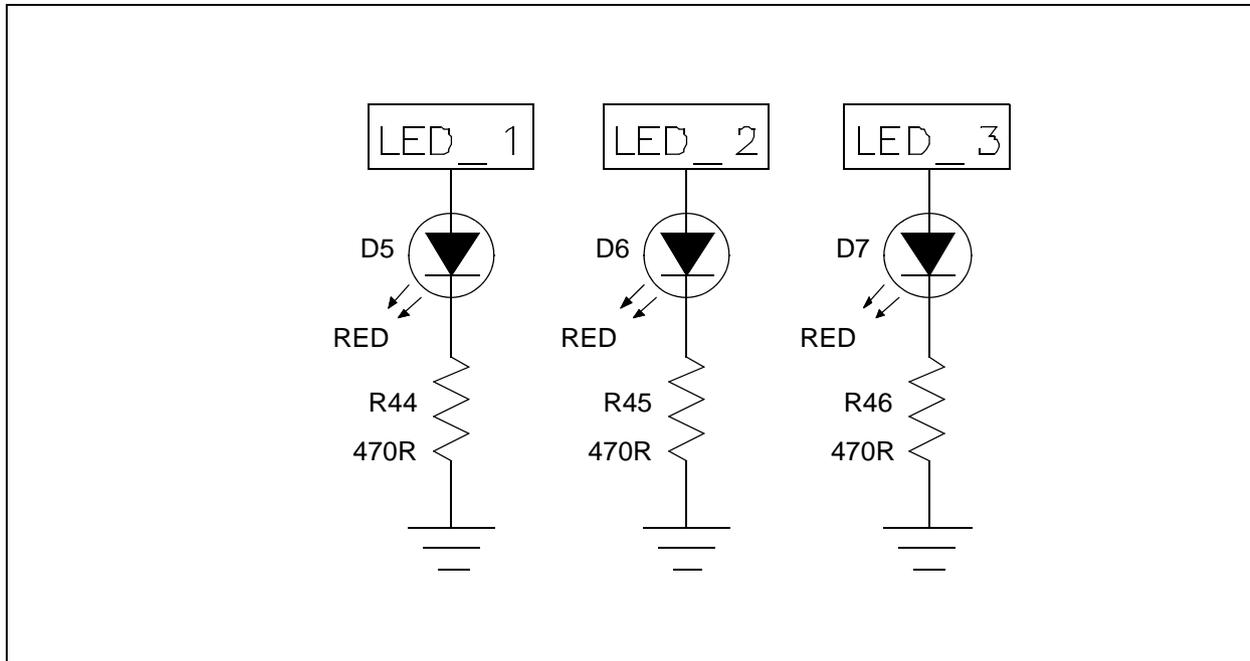


FIGURE A-10: ICSP TARGET



# Motor Control Starter Kit User's Guide

FIGURE A-11: USER-PROGRAMMABLE LEDs



# Layout, Schematics, and Bill of Materials

## A.4 BILL OF MATERIALS (BOM)

TABLE A-1: MOTOR CONTROL STARTER KIT BILL OF MATERIALS (BOM)

Qty.	Reference	Description	Manufacturer	Manufacturer Part Number
1	C12	CAP CER 10000PF 16V 10% X7R 0603	Murata	GRM188R71C103KA01D
18	C2, C3, C4, C8, C10, C15, C16, C21, C23, C25, C26, C28, C29, C30, C31, C32, C35, C36	CAP .10UF 16V CERAMIC X7R 0603	Yageo	CC0603KRX7R7BB104
5	C7, C13, C24, C27, C34	CAP 1.0UF 16V CERAMIC X7R 0805	Kemet	C0805C105K4RACTU
2	C9, C11	CAP CER 2.2UF 16V X5R 0603	TDK	C1608X5R1C225K
3	C1, C14, C22	CAP CER 10UF 6.3V Y5V 0603	TDK	C1608Y5V0J106Z
1	C37	CAP CER 33PF 50V 5% C0G 0603	Murata	GCM1885C1H330JA16D
1	C33	CAP CER 56PF 50V 5% C0G 0603	Murata	GRM1885C1H560JA01D
1	C20	CAP CER 220PF 50V C0G 5% 0603	TDK	C1608C0G1H221J
1	C18	CAP CER 4.7UF 25V Y5V 0805	TDK	C2012Y5V1E475Z
2	C17, C38	CAP CER 10UF 16V Y5V 0805	TDK	C2012Y5V1C106Z
2	C5, C6	CAP CER 8.0PF 50V C0G 0603	TDK	C1608C0G1H080D
1	C19	22UF 25V MINI ALUM ELECT (KA)	Panasonic-ECG	ECE-A1EKA220
1	J3	CONN PWR JACK 2.5X5.5MM HIGH CUR	Cui Inc.	PJ-102BH
1	J1	CONN RECEIPT MINI USB2.0 5POS	Hirose	UX60-MB-5ST
1	Y1	CRYSTAL 12.000000 MHZ SMD 8PF	NDK	NX3225SA-12.000000MHZ
2	D1, D3	DIODE SCHOTTKY 0.5A 20V SOD-123	Fairchild	MBR0520L
1	L1	10uH power inductor	Coil Craft	ME3220-103
2	D2, D4	LED ALINGAP GRN CLEAR 0805 SMD	Dialight	598-8170-107F
3	D5, D6, D7	LED ALINGAP RED-ORN CLR 0805 SMD	Dialight	598-8120-107F
6	R13, R18, R22, R27, R61, R62	RES 0.0 OHM 1/10W 0603 SMD	Stackpole	RMCF0603ZTOR00
6	R7, R65, R66, R67, R69, R70	RES 1K OHM 1/10W 1% 0603 SMD	Stackpole	RMCF 1/16 1K 1% R
1	R58	RESISTOR 1.0 OHM 1/10W 1% 0603	Panasonic-ECG	ERJ-3RQF1R0V
2	R10, R16	RES 2.20K OHM 1/10W 1% 0603 SMD	Panasonic-ECG	ERJ-3EKF2201V
2	R28, R29	RES 2.21K OHM 1/10W 1% 0603 SMD	Stackpole	CF 1/16 2.21K 1% R
1	R8	RES 3.16K OHM 1/10W 1% 0603 SMD	Stackpole	RMCF0603FT3K16
1	R24	RES 3.92K OHM 1/10W 1% 0603 SMD	Panasonic-ECG	ERJ-3EKF3921V
8	R20, R23, R56, R57, R59, R63, R71, R73	RES 4.70K OHM .25W 1% 0603 SMD	Vishay	CRCW06034K70FKEAHP
14	R1, R3, R4, R9, R14, R15, R26, R30, R32, R34, R36, R37, R38, R43	RES 10.0K OHM 1/10W 1% 0603 SMD	Vishay	CRCW060310K0FKEA
1	R68	RES 0.5 OHM 1/4W 1% 0805 SMD	Stackpole	CSR0805FKR500
1	R41	RES 13.3K OHM 1/10W 1% 0603 SMD	Stackpole	RMCF0603FT13K3
1	R39	RES 51.0K OHM 1/10W 1% 0603 SMD	Yageo	RC0603FR-0751KL
3	R25, R64, R72	RES 100K OHM .25W 1% 0603 SMD	Vishay	CRCW0603100KFKEAHP
1	R6	RES 100 OHM 1/10W 1% 0603 SMD	Panasonic-ECG	ERJ-3EKF1000V
2	R2, R11	RES 200K OHM 1/10W 1% 0603 SMD	Panasonic-ECG	ERJ-3EKF2003V
6	R5, R12, R17, R19, R21, R42	RES 330 OHM 1/10W 1% 0603 SMD	Stackpole	RMCF0603FT330R
3	R44, R45, R46	RES 470 OHM 1/10W 1% 0603 SMD	Panasonic-ECG	ERJ-3EKF4700V

# Motor Control Starter Kit User's Guide

**TABLE A-1: MOTOR CONTROL STARTER KIT BILL OF MATERIALS (BOM) (CONTINUED)**

Qty.	Reference	Description	Manufacturer	Manufacturer Part Number
3	R53,R54, R55	RES 1.74K OHM 1/8W 1% 0805 SMD	Rohm semi	MCR10EZPF1741
3	R48, R50, R51	RES 10K OHM 1/8W 1% 0805 SMD	Stackpole	RMCF0805FT10K0
1	R40	RES 118K OHM 1/8W 1% 0805 SMD	Rohm	MCR10EZPF1183
3	R47, R49, R52	RES 330 OHM 1/8W 1% 0805 SMD	Rohm	MCR10EZPF3300
1	R31	RES 100 OHM 1/4W 1% 1206 SMD	Vishay	CRCW1206100RFKEA
1	R33	DNP	—	—
1	R35	DNP	—	—
1	R60	DNP	—	—
1	S1	SWITCH TACT 6MM 160GF H=4.3MM	Omron	B3S-1000P
1	Q1	TRANS PNP 40V 300MW SMD SOT23-3	Diodes Inc.	MMBT3906-7-F
2	Q2, Q3	TRANSISTOR GP NPN AMP SOT-23	Fairchild	MMBT3904
1	U1	IC PIC MCU FLASH 256K 64-TQFP	Microchip	PIC24FJ256GB106-I/PT
1	U2	IC REG LDO 1.5A 3.3V 8DFN	Microchip	MCP1727-3302E/MF
1	U3	IC EEPROM 256KBIT 10MHZ 8TSSOP	Microchip	25LC256-I/ST
1	U4	dsPIC33FJ16MC102	Microchip	
1	U5	IC CONV BOOST SW 1.6MHZ SOT23-5	National	3XMF/NOPB
1	U6	IC REG LDO 800MA 3.3V SOT-223	National	LM1117MPX-3.3/NOPB
3	U7, U8, U10	IC MOSFET DVR 1.5A DUAL HS 8SOIC	Microchip	TC4428AEOA
1	U9	IC OPAMP 2.5V R-R I/O SOT23-5	Microchip	MCP6021T-E/OT
3	Q4, Q5, Q6	MOSFET N/P-CH DUAL 30V SO-8	Fairchild	SI4532DY
4	GND1, GND2, GND3, GND4	TEST POINT PC MINI .040"D BLACK	Keystone	5001
1	VIN	TEST POINT PC MINI .040"D RED	Keystone	5000
1	+12V	TEST POINT PC MINI .040"D WHITE	Keystone	5002
10	M1_V, M2_V, M3_V, MOTOR_CURRENT, PWM1L1, PWM1H1, PWM1L2, PWM1H2, PWM1L3, PWM1H3	TEST POINT PC MINI .040"D YELLOW	Keystone	5004
4	—	STANDOFF HEX .750"L 4-40THR NYL	Keystone	1902D
4	—	SCREW MACH PHIL 4-40X1/4 NYLON	Keystone	NY PMS 440 0025 PH
2	—	SCREW MACH PHIL 4-40X1/2 NYLON	B&F	NY PMS 440 0050 PH
2	—	NUT HEX 4-40 NYLON	B&F	NY HN 440
2	—	SPACER NYLON #4 SCREW 3/16"	Bivar Inc.	9908-187
1	—	Motor (NDR-TH_0.05-1X6)	ShinanoKenshi	DR-29312-026

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**NOTES:**



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