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Microchip received ISO/TS-16949:2002 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company’s quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip’s quality system for the design and manufacture of development systems is ISO 9001:2000 certified.
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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
“DSXXXXXX”, where “XXXXXX” 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.
CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

### DOCUMENTATION CONVENTIONS

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

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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) at the following locations:

- http://www.microchip.com/appnotes/
- 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® C Compiler for PIC24 MCUs and dsPIC® 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.

MPLAB® 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.

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

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The Development Systems product group categories are:

• **Compilers** – The latest information on Microchip C compilers and other language tools. These include the MPLAB® C compiler; MPASM™ and MPLAB 16-bit assemblers; MPLINK™ and MPLAB 16-bit object linkers; and MPLIB™ and MPLAB 16-bit object libraries.
• **Emulators** – The latest information on the Microchip in-circuit emulator, MPLAB REAL ICE™
• **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® 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.
• **Programmers** – The latest information on Microchip programmers. These include the MPLAB PM3 device programmer and the PICkit™ 3 development programmers.
CUSTOMER SUPPORT

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- 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.
Chapter 1. Introduction

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)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power supply connected to J3</td>
<td>9</td>
<td>12</td>
<td>Vdc</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>12</td>
<td>12</td>
<td>Vdc</td>
</tr>
<tr>
<td>Peak Current</td>
<td>0.2</td>
<td>0.8</td>
<td>A</td>
</tr>
<tr>
<td>Power Rating</td>
<td>2.5</td>
<td>10</td>
<td>W</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Voltage</td>
<td>12</td>
<td>Vdc</td>
</tr>
<tr>
<td>Rated Torque</td>
<td>6</td>
<td>mNm</td>
</tr>
<tr>
<td>Rated Speed</td>
<td>1400</td>
<td>RPM</td>
</tr>
<tr>
<td>Rated Current</td>
<td>0.16</td>
<td>A</td>
</tr>
</tbody>
</table>

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)
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)
Chapter 2. Software Description

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).

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).

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.
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>
<thead>
<tr>
<th>Labels on the Motor Control Starter Kit Board</th>
<th>dsPIC33FJ16MC102</th>
<th>Description/Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pin Number</td>
<td>Pin Name</td>
</tr>
<tr>
<td>MOTOR_CURRENT</td>
<td>1</td>
<td>AN2/RP0/CN4/RB0</td>
</tr>
<tr>
<td>M1_V</td>
<td>2</td>
<td>AN3/RP1/CN5/RB1</td>
</tr>
<tr>
<td>M2_V</td>
<td>3</td>
<td>AN4/RP2/CN6/RB2</td>
</tr>
<tr>
<td>M3_V</td>
<td>4</td>
<td>AN5/RP3/CN7/RB3</td>
</tr>
<tr>
<td>GND</td>
<td>5</td>
<td>VSS</td>
</tr>
<tr>
<td>LED_1</td>
<td>6</td>
<td>OSC1/CLKI/CN30/RA2</td>
</tr>
<tr>
<td>PUSHBUTTON</td>
<td>7</td>
<td>OSC2/CLKO/CN29/RA3</td>
</tr>
<tr>
<td>ICSP_PGEC_TARGET</td>
<td>8</td>
<td>PGED3/RP4/CN1/RB4</td>
</tr>
<tr>
<td>ICSP_PGEC_TARGET</td>
<td>9</td>
<td>PGEC3/T1CK/CN0/RA4</td>
</tr>
<tr>
<td>+3.3V_TARGET</td>
<td>10</td>
<td>VDD</td>
</tr>
<tr>
<td>+3.3V_TARGET</td>
<td>11</td>
<td>FLTB1/RP5/CN27/RB5</td>
</tr>
<tr>
<td>FLT2</td>
<td>12</td>
<td>FLT2/AN0/CN0/RA0</td>
</tr>
<tr>
<td>LED_2</td>
<td>13</td>
<td>INT0/RP7/CN23/RB7</td>
</tr>
<tr>
<td>LED_3</td>
<td>14</td>
<td>TCK/RP8/CN22/RB8</td>
</tr>
<tr>
<td>GND</td>
<td>15</td>
<td>VSS</td>
</tr>
<tr>
<td>VCAP</td>
<td>16</td>
<td>VCAP</td>
</tr>
<tr>
<td>PWM1H3</td>
<td>17</td>
<td>PWM1H3/RP10/RB10</td>
</tr>
<tr>
<td>PWM1L3</td>
<td>18</td>
<td>PWM1L3/RP11/RB11</td>
</tr>
<tr>
<td>PWM1H2</td>
<td>19</td>
<td>PWM1H2/RP12/RB12</td>
</tr>
<tr>
<td>PWM1L2</td>
<td>20</td>
<td>PWM1L2/RP13/RB13</td>
</tr>
<tr>
<td>PWM1H1</td>
<td>21</td>
<td>PWM1H1/RP14/RB14</td>
</tr>
<tr>
<td>PWM1L1</td>
<td>22</td>
<td>PWM1L1/RP15/RB15</td>
</tr>
<tr>
<td>AGND</td>
<td>23</td>
<td>AVss</td>
</tr>
<tr>
<td>+3.3V_ANALOG</td>
<td>24</td>
<td>AVDD</td>
</tr>
<tr>
<td>ICSP_MCLR_VPP_TARGET</td>
<td>25</td>
<td>MCLR</td>
</tr>
<tr>
<td>SLIDER_A</td>
<td>26</td>
<td>PGED2/AN0/CN2/RA0</td>
</tr>
<tr>
<td>SLIDER_B</td>
<td>27</td>
<td>PGEC2/AN1/CN3/RA1</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Component</th>
<th>Label</th>
<th>Figure #</th>
<th>Item #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programmer/ Debugger Power LED</td>
<td>D2</td>
<td>1-1</td>
<td>10</td>
<td>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.</td>
</tr>
</tbody>
</table>

Bottom Assembly Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Label</th>
<th>Figure #</th>
<th>Item #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-board Programmer/ Debugger</td>
<td>N/A</td>
<td>1-2</td>
<td>2</td>
<td>Controls the programming/debugging operations of the target dsPIC33FJ16MC102 DSC.</td>
</tr>
<tr>
<td>Programmer/ Debugger USB Connector</td>
<td>J1</td>
<td>1-2</td>
<td>3</td>
<td>Provides system power and bidirectional communication between the host PC and starter kit.</td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>Component</th>
<th>Label</th>
<th>Figure #</th>
<th>Item #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dsPIC33FJ16MC102 DSC</td>
<td>U4</td>
<td>1-1</td>
<td>1</td>
<td>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.</td>
</tr>
<tr>
<td>Motor Connector</td>
<td>J5</td>
<td>1-1</td>
<td>2</td>
<td>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.</td>
</tr>
<tr>
<td>9V Power Connector</td>
<td>J3</td>
<td>1-1</td>
<td>3</td>
<td>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.</td>
</tr>
<tr>
<td>3-Phase Inverter</td>
<td>N/A</td>
<td>1-1</td>
<td>4</td>
<td>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.</td>
</tr>
</tbody>
</table>
| 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”.

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### TABLE 3-4: BOARD CONNECTORS

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1</td>
<td>mini-B USB connection between the on-board programmer/debugger and the host computer.</td>
</tr>
<tr>
<td>J2</td>
<td>ICSP™ programmer interface connector for programming the PIC24FJ256GB106 MCU USB-to-UART bridge.</td>
</tr>
<tr>
<td>J3</td>
<td>9V board power input.</td>
</tr>
<tr>
<td>J4</td>
<td>ICSP programmer interface connector for programming the dsPIC33FJ16MC102 DSC.</td>
</tr>
<tr>
<td>J5</td>
<td>BLDC motor connector.</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Label</th>
<th>Hardware Element Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Push button, which is connected to a port pin. When momentarily pressed, the switch connects the respective port pin to Ground.</td>
</tr>
<tr>
<td>D2</td>
<td>USB bus indicator, which indicates that the device is connected to the USB bus and the programmer/debugger is powered.</td>
</tr>
<tr>
<td>D4</td>
<td>Power-on status LED, which indicates that the board is powered by the 9V supply.</td>
</tr>
<tr>
<td>D5-D7</td>
<td>User-programmable LED’s. Each LED is connected to a port pin. When the corresponding port pin is set high, the LED is lit.</td>
</tr>
<tr>
<td>Slider A-B</td>
<td>Two-channel capacitive slider. Each channel is connected to an analog input pin.</td>
</tr>
</tbody>
</table>

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

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)
A.2 DEBUGGER HARDWARE SCHEMATICS

FIGURE A-3: POWER DISTRIBUTION/SWITCHING

POWER DISTRIBUTION / SWITCHING

USB INTERFACE (BUS POWERED)

Debugger Circuit

+3.3V

MCP1727
+3.3 V LDO regulator

D2
Green

USB INTERFACE
(CORE POWERED)

USB MINI-B

J1

+3.3V

D1
MBR0520L

R12
330R

C9
2.2uF

C10
0.1uF

C11
2.2uF

C12
0.01uF

R11
200K

R10
0.01uF

R12
330R

D2
Green

USB_MINI-B

1
VUSB

2
USB_D+

3
USB_D-

4
USB_ID

5
GND

GND1

2.2uF

Power Good

Debugger Circuit

POWER_GOOD_PICKIT3

ICSP_MCLR_VPP_TARGET

ICSP_PGEC_TARGET

ICSP_PGED_TARGET

Debugger Circuit
A.3 APPLICATION SCHEMATICS

FIGURE A-4: TARGET POWER

![Target Power Schematic](image1)

FIGURE A-5: MOTOR SOCKET

![Motor Socket Schematic](image2)
FIGURE A-6: dsPIC33FJ16MC102 DIGITAL SIGNAL CONTROLLER

- Internal connection for comparator using PPS

---

Layout, Schematics, and Bill of Materials
FIGURE A-11: USER-PROGRAMMABLE LEDs

LED_1
D5
RED
R44
470R

LED_2
D6
RED
R45
470R

LED_3
D7
RED
R46
470R
### A.4 BILL OF MATERIALS (BOM)

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

<table>
<thead>
<tr>
<th>Qty</th>
<th>Reference</th>
<th>Description</th>
<th>Manufacturer</th>
<th>Manufacturer Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C12</td>
<td>CAP CER 10000PF 16V 10% X7R 0603</td>
<td>Murata</td>
<td>GRM186R71C103KA01D</td>
</tr>
<tr>
<td>18</td>
<td>C2, C3, C4, C8, C10, C15, C16, C21, C23, C25, C26, C28, C29, C30, C31, C32, C35, C36</td>
<td>CAP .10UF 16V CERAMIC X7R 0603</td>
<td>Yageo</td>
<td>CC0603KRX7R7BB104</td>
</tr>
<tr>
<td>5</td>
<td>C7, C13, C24, C27, C34</td>
<td>CAP 1.0UF 16V CERAMIC X7R 0805</td>
<td>Kemet</td>
<td>C0805C105K4RACTU</td>
</tr>
<tr>
<td>2</td>
<td>C9, C11</td>
<td>CAP CER 2.2UF 16V X5R 0603</td>
<td>TDK</td>
<td>C1608X5R1C225K</td>
</tr>
<tr>
<td>3</td>
<td>C1, C14, C22</td>
<td>CAP CER 10UF 6.3V Y5V 0603</td>
<td>TDK</td>
<td>C1608Y5V0J106Z</td>
</tr>
<tr>
<td>1</td>
<td>C37</td>
<td>CAP CER 33PF 50V 5% C0G 0603</td>
<td>Murata</td>
<td>GCM1885C1H330JA16D</td>
</tr>
<tr>
<td>2</td>
<td>C33</td>
<td>CAP CER 56PF 50V 5% C0G 0603</td>
<td>Murata</td>
<td>GRM1885C1H560JA01D</td>
</tr>
<tr>
<td>1</td>
<td>C20</td>
<td>CAP CER 220PF 50V C0G 5% 0603</td>
<td>TDK</td>
<td>C1608C0G1H221J</td>
</tr>
<tr>
<td>1</td>
<td>C18</td>
<td>CAP CER 4.7UF 25V Y5V 0805</td>
<td>TDK</td>
<td>C2012Y5V1E475Z</td>
</tr>
<tr>
<td>2</td>
<td>C17, C38</td>
<td>CAP CER 10UF 16V Y5V 0805</td>
<td>TDK</td>
<td>C2012Y5V1C106Z</td>
</tr>
<tr>
<td>2</td>
<td>C5, C6</td>
<td>CAP CER 8.0PF 50V C0G 0603</td>
<td>TDK</td>
<td>C1608C0G1H080D</td>
</tr>
<tr>
<td>1</td>
<td>C19</td>
<td>22UF 25V MINI ALUM ELECT (KA)</td>
<td>Panasonic-ECG</td>
<td>ECE-A1EKA220</td>
</tr>
<tr>
<td>1</td>
<td>J3</td>
<td>CONN PWR JACK 2.5X5.5MM HIGH CUR</td>
<td>Cui Inc.</td>
<td>PJ-102BH</td>
</tr>
<tr>
<td>1</td>
<td>J1</td>
<td>CONN RECEPT MINI USB2.0 5POS</td>
<td>Hirose</td>
<td>UX60-MB-5ST</td>
</tr>
<tr>
<td>1</td>
<td>Y1</td>
<td>CRYSTAL 12.000000 MHZ SMD 8PF</td>
<td>NDK</td>
<td>NX3225SA-12.000000MHZ</td>
</tr>
<tr>
<td>2</td>
<td>D1, D3</td>
<td>DIODE SCHOTTKY 0.5A 20V SOD-123</td>
<td>Fairchild</td>
<td>MBR0520L</td>
</tr>
<tr>
<td>1</td>
<td>L1</td>
<td>10uH power inductor</td>
<td>Coil Craft</td>
<td>ME3220-103</td>
</tr>
<tr>
<td>2</td>
<td>D2, D4</td>
<td>LED ALINGAP GRN CLEAR 0805 SMD</td>
<td>Dialight</td>
<td>598-8170-107F</td>
</tr>
<tr>
<td>3</td>
<td>D5, D6, D7</td>
<td>LED ALINGAP RED-ORN CLR 0805 SMD</td>
<td>Dialight</td>
<td>598-8120-107F</td>
</tr>
<tr>
<td>6</td>
<td>R13, R18, R22, R27, R61, R62</td>
<td>RES 0.0 OHM 1/10W 0603 SMD</td>
<td>Stackpole</td>
<td>RMCF0603ZT0R00</td>
</tr>
<tr>
<td>6</td>
<td>R7, R65, R66,R67,R69,R70</td>
<td>RES 1K OHM 1/10W 1% 0603 SMD</td>
<td>Stackpole</td>
<td>RMCF 1/16 1K 1% R</td>
</tr>
<tr>
<td>1</td>
<td>R58</td>
<td>RESISTOR 1.0 OHM 1/10W 1% 0603</td>
<td>Panasonic-ECG</td>
<td>ERJ-3RQF1R0V</td>
</tr>
<tr>
<td>2</td>
<td>R10, R16</td>
<td>RES 2.20K OHM 1/10W 1% 063 SMD</td>
<td>Panasonic-ECG</td>
<td>ERJ-3KEKF2201V</td>
</tr>
<tr>
<td>2</td>
<td>R28, R29</td>
<td>RES 2.21K OHM 1/10W 1% 063 SMD</td>
<td>Stackpole</td>
<td>CF 1/16 2.21K 1% R</td>
</tr>
<tr>
<td>1</td>
<td>R8</td>
<td>RES 3.16K OHM 1/10W 1% 063 SMD</td>
<td>Stackpole</td>
<td>RMCF0603FT3K16</td>
</tr>
<tr>
<td>1</td>
<td>R24</td>
<td>RES 3.92K OHM 1/10W 1% 063 SMD</td>
<td>Panasonic-ECG</td>
<td>ERJ-3KEKF3921V</td>
</tr>
<tr>
<td>8</td>
<td>R20, R23, R56, R57, R59, R63, R71, R73</td>
<td>RES 4.70K OHM 25W 1% 063 SMD</td>
<td>Vishay</td>
<td>CRCW06034K70FKEAHP</td>
</tr>
<tr>
<td>14</td>
<td>R1, R3, R4, R9, R14, R15, R26, R30, R32, R34, R36, R37, R38, R43</td>
<td>RES 10.0K OHM 1/10W 1% 063 SMD</td>
<td>Vishay</td>
<td>CRCW060310K0FKEA</td>
</tr>
<tr>
<td>1</td>
<td>R68</td>
<td>RES 0.5 OHM 1/4W 1% 0805 SMD</td>
<td>Stackpole</td>
<td>CSR0805FKR500</td>
</tr>
<tr>
<td>1</td>
<td>R41</td>
<td>RES 13.3K OHM 1/10W 1% 063 SMD</td>
<td>Stackpole</td>
<td>RMCF0603FT13K3</td>
</tr>
<tr>
<td>1</td>
<td>R39</td>
<td>RES 51.0K OHM 1/10W 1% 063 SMD</td>
<td>Yageo</td>
<td>RC0603FR-0751KL</td>
</tr>
<tr>
<td>3</td>
<td>R25, R64, R72</td>
<td>RES 100K OHM .25W 1% 063 SMD</td>
<td>Vishay</td>
<td>CRCW060310KFKEAHP</td>
</tr>
<tr>
<td>1</td>
<td>R6</td>
<td>RES 100 OHM 1/10W 1% 063 SMD</td>
<td>Panasonic-ECG</td>
<td>ERJ-3KEKF1000V</td>
</tr>
<tr>
<td>2</td>
<td>R2, R11</td>
<td>RES 200K OHM 1/10W 1% 063 SMD</td>
<td>Panasonic-ECG</td>
<td>ERJ-3KEKF2003V</td>
</tr>
<tr>
<td>6</td>
<td>R5, R12, R17, R19, R21, R42</td>
<td>RES 330 OHM 1/10W 1% 063 SMD</td>
<td>Stackpole</td>
<td>RMCF0603FT330R</td>
</tr>
<tr>
<td>3</td>
<td>R44, R45, R46</td>
<td>RES 470 OHM 1/10W 1% 063 SMD</td>
<td>Panasonic-ECG</td>
<td>ERJ-3KEFK4700V</td>
</tr>
</tbody>
</table>
### TABLE A-1: MOTOR CONTROL STARTER KIT BILL OF MATERIALS (BOM) (CONTINUED)

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

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**Table A-1:** Motor Control Starter Kit Bill of Materials (BOM) (Continued)
## 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](http://www.microchip.com/support)
Web Address: [www.microchip.com](http://www.microchip.com)

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  - Fax: 678-957-1455

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  - Fax: 774-760-0088

- **Chicago**
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  - Tel: 630-285-0071
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  - Tel: 216-447-0464
  - Fax: 216-447-0643

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  - Tel: 972-818-7423
  - Fax: 972-818-2924

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  - Tel: 248-538-2250
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  - Fax: 317-773-5453

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  - Tel: 949-462-9529
  - Fax: 949-462-9608

- **Santa Clara**
  - Santa Clara, CA
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  - Fax: 408-961-6445

- **Toronto**
  - Mississauga, Ontario, Canada
  - Tel: 905-673-0699
  - Fax: 905-673-6509

### ASIA/PACIFIC

**Asia Pacific Office**
Suits 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon
Hong Kong
Tel: 852-2401-1200
Fax: 852-2401-3431

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

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

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

- **China - Hangzhou**
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  - Fax: 86-571-2819-3189

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  - Fax: 852-2401-3431

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  - Fax: 86-25-8473-2470

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  - Fax: 86-755-8203-1760

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  - Fax: 86-27-5980-5118

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

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  - Tel: 86-592-2388135
  - Fax: 86-592-2388130

- **China - Zhuhai**
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  - Fax: 86-756-3210049

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  - Fax: 91-80-3090-4123

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  - Fax: 91-11-4160-8632

- **India - Pune**
  - Tel: 91-20-2566-1512
  - Fax: 91-20-2566-1513

- **Japan**
  - **Japan - Yokohama**
    - Tel: 81-45-471-6166
    - Fax: 81-45-471-6122

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

- **Singapore**
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  - Fax: 65-6334-8850

- **Taiwan**
  - **Taiwan - Hsin Chu**
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    - Fax: 886-3-6578-370

- **Taiwan - Kaohsiung**
  - Tel: 886-7-213-7830
  - Fax: 886-7-330-9305

- **Taiwan - Taipei**
  - Tel: 886-2-2500-6610
  - Fax: 886-2-2508-0102

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

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  - Fax: 43-7422-2244-393

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  - Fax: 45-4485-2829

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  - Fax: 33-1-69-30-90-79

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  - Fax: 49-89-627-144-44

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  - Fax: 39-0331-466781

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  - Fax: 31-416-690340

**Spain**
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  - Fax: 34-91-708-08-91

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  - Tel: 44-118-921-5869
  - Fax: 44-118-921-5820

**05/02/11**