MICROCHIP

AN1208

Integrated Power Factor Correction (PFC) and Sensorless Field Oriented Control (FOC) System

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INTRODUCTION

In recent years, the motor control industry has been focusing on designing power efficient motor control drives for a wide variety of applications. The consumer demand for improved power quality standards is driving this trend. The power quality can be enhanced by implementing Power Factor Correction (PFC), and efficient control of a motor can be realized using Sensorless Field Oriented Control (FOC) techniques. The appliance industry often requires low-cost implementation of these algorithms. This can be achieved by integrating PFC and Sensorless FOC algorithms on a single Digital Signal Controller (DSC).

This application note describes the process of integrating two complex applications: PFC and Sensorless FOC. These applications are implemented on a Permanent Magnet Synchronous Motor (PMSM). In addition, this application note also describes the integration of the algorithms, lists the necessary hardware requirements, and provides the guidelines to optimize the development procedure.

The integrated solution is based on these application notes:

- AN1106, *Power Factor Correction in Power Conversion Applications Using the dsPIC DSC*
- AN1078, *Sensorless Field Oriented Control of PMSM Motors Using dsPIC30F or dsPIC33F Digital Signal Controllers*

The application note AN1106, describes the Power Factor Correction (PFC) method. The application note AN1078, describes the Sensorless Field Oriented Control (FOC) method. The detailed digital design and implementation techniques are provided in these application notes. This application note is an addendum to the above application notes.

The integrated application is implemented on the following families of dsPIC® DSC devices:

- dsPIC30F
- dsPIC33F

The low cost and high performance capabilities of the DSC, combined with a wide variety of power electronic peripherals such as the Analog-to-Digital Converter (ADC) and the Pulse Width Modulator (PWM), enable the digital design and the implementation of such a complex application to be simpler and easier.

Digital PFC and Motor Control

The majority of motor control systems often use PFC as the first stage of the system. Without an input PFC stage, the current drawn will have significant harmonic content due to the presence of switching elements of the inverter. In addition, since motor loads are highly inductive, the input currents will induce significant reactive power into the input system, thereby reducing overall efficiency of the system. A PFC stage which is a front-end converter of a motor control application, provides better output voltage regulation and reduces harmonic content of the input current drawn.The standard boost converter topology with average current mode control is the preferred method for implementing digital PFC in these applications.

The dual shunt Sensorless FOC method is a speed control technique that drives the PMSM motor. The Sensorless FOC technique overcomes restrictions placed on some applications that cannot deploy position or speed sensors. The speed and position of the PMSM motor are estimated by measuring phase currents. With a constant rotor magnetic field produced by a permanent magnet on the rotor, the PMSM is very efficient when used in appliances. When compared with induction motors, PMSM motors are more powerful for the same given size. They are also less noisy than DC motors, since brushes are not involved. Therefore, the PMSM motor is chosen for this application.

Why Use a Digital Signal Controller?

The dsPIC DSC devices are ideal for a variety of complex applications running multiple algorithms at different frequencies and using multiple peripherals to drive the various circuits. These applications (e.g., washing machines, refrigerators, and air conditioners) use various motor control peripherals to precisely control the speed of the motor at various operating loads. The integrated PFC and Sensorless FOC system uses the following peripherals:

- Pulse Width Modulator (PWM)
- Analog-to-Digital Converter (ADC)
- Quadrature Encoder Interface (QEI)

These peripherals offer the following major features:

- Multiple sources to trigger the ADC
- Input Conversion Capability up to 1 Msps rate
- Methods to simultaneous sample multiple analog channels
- Fault detection and handling capability
- Comprehensive single-cycle DSP instructions (e.g., `MAC`)

SYSTEM OVERVIEW

Figure 1 shows a block diagram of the integrated PFC and Sensorless FOC system.

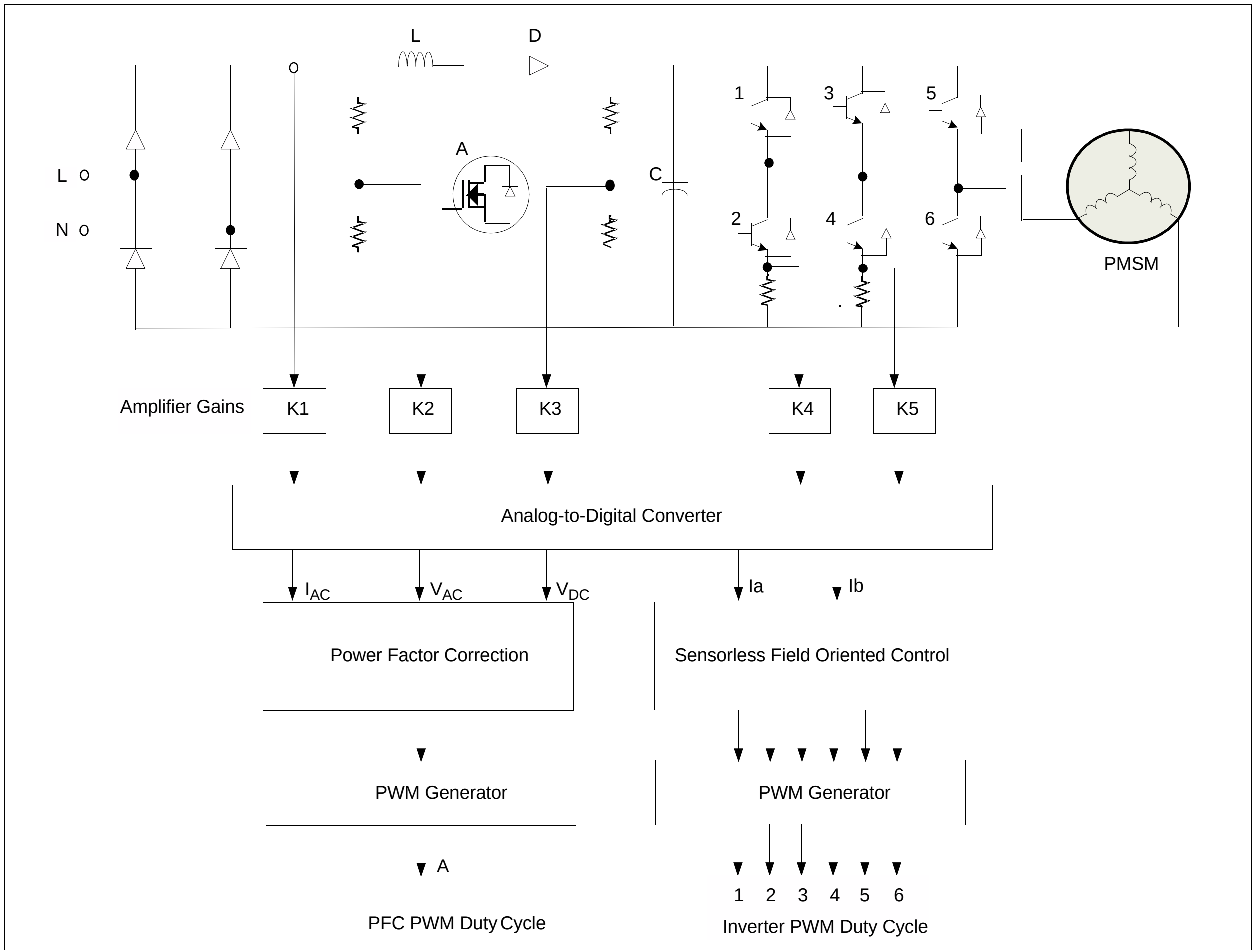
The first stage is a rectifier stage that converts the input line voltage into a rectified AC voltage. The rectified AC voltage is the input to the second stage, which is the boost converter stage.

During the second stage, the boost converter boosts the input voltage and shapes the inductor current similar to that of the rectified AC voltage. This is achieved by implementing digital power factor correction. The Average Current Mode Control method is used to implement PFC on a dsPIC DSC device. In this control method, the output DC voltage is controlled by varying the average value of the current amplitude signal. The current amplitude signal is calculated digitally.

The third and the final stage of the integrated system is a three-phase inverter stage that converts the DC voltage into a three-phase voltage. The converted three-phase voltage is the input to the PMSM motor. This stage is controlled by implementing the Sensorless FOC strategy on the dsPIC DSC device. The Sensorless FOC controls the stator currents flowing into the PMSM to meet the desired speed and torque requirements of the system. The position and speed information is estimated by executing mathematical operations on the dsPIC DSC.

The integrated system uses five compensators to implement PFC and Sensorless FOC technique. The PFC technique uses two compensators to control the voltage and current control loops, and the Sensorless FOC technique uses three compensators to control the speed control loop, torque control loop, and flux control loop. All of the compensators are realized by implementing Proportional-Integral (PI) controllers.

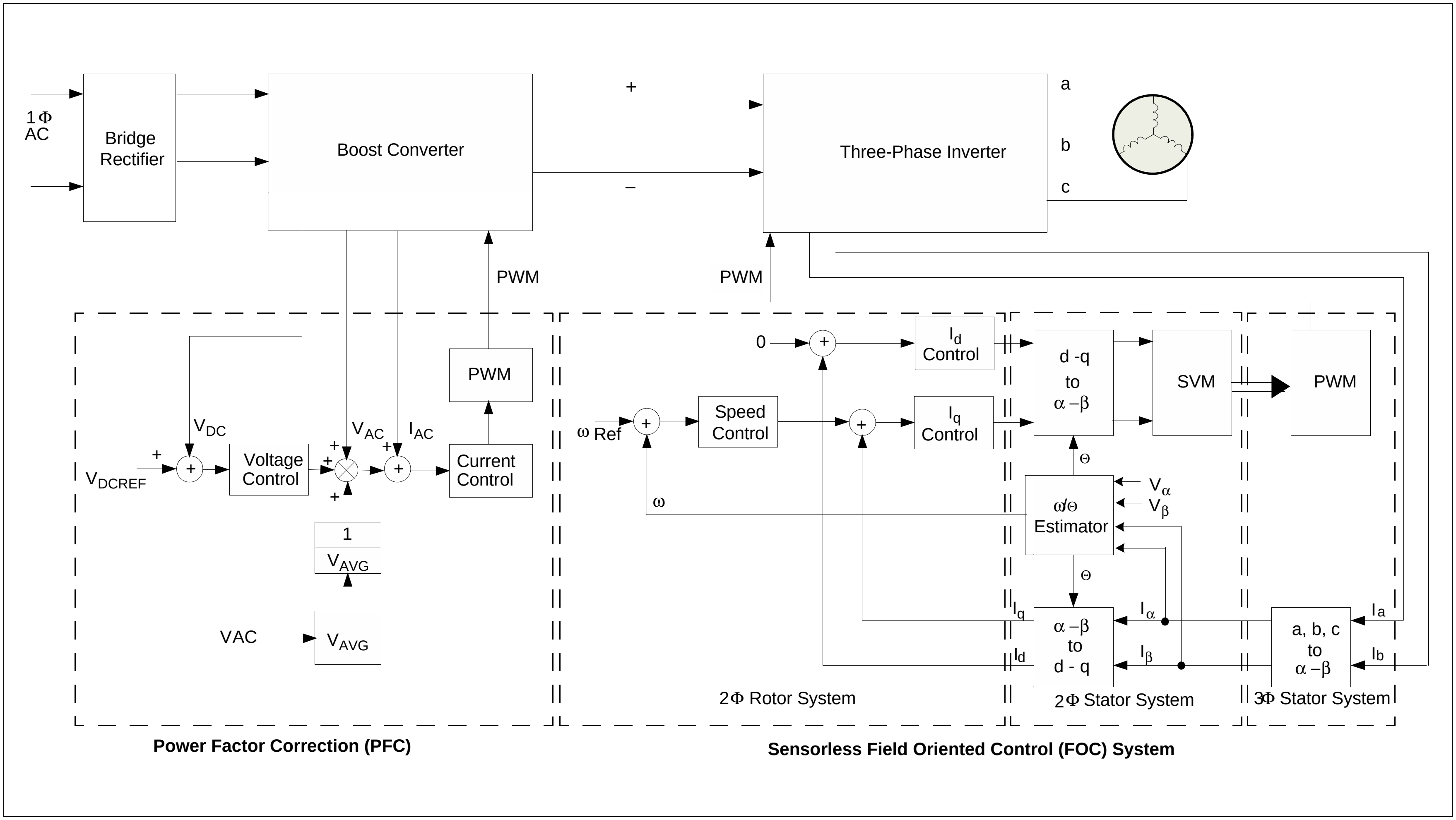
FIGURE 1: INTEGRATED PFC AND SENSORLESS FOC SYSTEM BLOCK DIAGRAM



A NOVEL APPROACH FOR DIGITAL IMPLEMENTATION OF PFC AND SENSORLESS FOC ALGORITHMS

Figure 2 shows a block diagram of the PFC and Sensorless FOC control loops implemented digitally using the dsPIC DSC device.

FIGURE 2: DIGITAL PFC AND SENSORLESS FOC BLOCK DIAGRAM



Digital Power Factor Correction

The inductor current (I_{AC}), input rectified AC voltage (V_{AC}), and DC Output Voltage (V_{DC}) are used as feedback signals to implement the digital PFC. These signals are scaled by hardware gains and are input to the analog channels of the ADC module**.**

The PFC algorithm uses three control loops: the voltage control loop, current control loop, and the voltage feed forward control loop.

The voltage compensator uses the reference voltage and actual output voltage as inputs to compute the error and compensate for the variations in output voltage. The output voltage is controlled by varying the average value of the current amplitude signal.

The current amplitude signal is calculated digitally by computing the product of the rectified input voltage, the voltage error compensator output, and the voltage feed-forward compensator output.

The rectified input voltage is multiplied to enable the current signal to have the same shape as the input voltage waveshape. The current signal should match the rectified voltage as closely as possible to have a high power factor.

The voltage feed-forward compensator is essential for maintaining a constant output power for a given load because it compensates for variations in the input voltage. Once the current signal is computed, it is fed to the current compensator. The output of the current compensator determines the duty cycle of the PWM pulses. The boost converter can be driven either by the Output Compare module or the PWM module.

Refer to application note AN1106, *Power Factor Correction in Power Conversion Applications Using the dsPIC® DSC* (DS01106), for information about the system design and digital implementations of this control method.

Sensorless Field Oriented Control

The phase currents, I_a and I_b, are used as feedback signals to implement the Sensorless FOC technique. The third phase current, I_c, is calculated digitally. The three-phase currents are first converted to a two-phase stator system by using Clarke transformation before being converted to a two-phase rotor system by using Park transformation. This conversion provides two computed current components: I_d and I_q. The magnetizing flux is a function of the current I_d and the rotor torque is a function of the current I_q.

A position estimator estimates the rotor position and speed information. The motor model uses voltages and currents to estimate the position. The motor model essentially has a position observer to indirectly derive the rotor position. The PMSM model is based on a DC motor model.

After the speed is determined by mathematical estimation, the error between the desired speed and the estimated speed is fed to the speed compensator. The speed compensator produces an output that acts as a reference to the I_q compensator. For a permanent magnet motor, the reference to the I_d compensator is zero value. The PI controllers for I_q and I_d compensate errors in the torque and flux, thereby producing V_d and V_q as the output signals respectively.

The Inverse Park transformation and Space Vector Modulation (SVM) techniques are applied to generate the duty cycle for the Insulated Gate Bipolar Transistors (IGBTs).The motor control PWM module is used to generate PWM pulses.

Refer to application note AN1078, *Sensorless Field Oriented Control of PMSM Motors* (DS01078), for information about how to design, implement, and tune the compensator.

The implementation details and the hardware configuration details required to develop the integrated system are discussed in the following sections.

INTEGRATED PFC AND SENSORLESS FOC IMPLEMENTATION ON A dsPIC DSC DEVICE

The following control parameters and routine are used, when the integrated system is implemented by using a dsPIC30F or dsPIC33F device:

- PFC PWM frequency: 80 kHz
- FOC PWM frequency: 8 kHz
- PFC Control loop frequency: 40 kHz
- FOC Control loop: 8 kHz
- Point of execution for PFC routine: ADC ISR
- Point of execution for FOC routines: PWM ISR
- Trigger Source to the ADC: Timer

Figure 3 shows the timing diagram of the integrated PFC and Sensorless FOC system. Figure 4 through Figure 6 shows the state flow diagram of the integrated system.

FIGURE 3: TIMING DIAGRAM

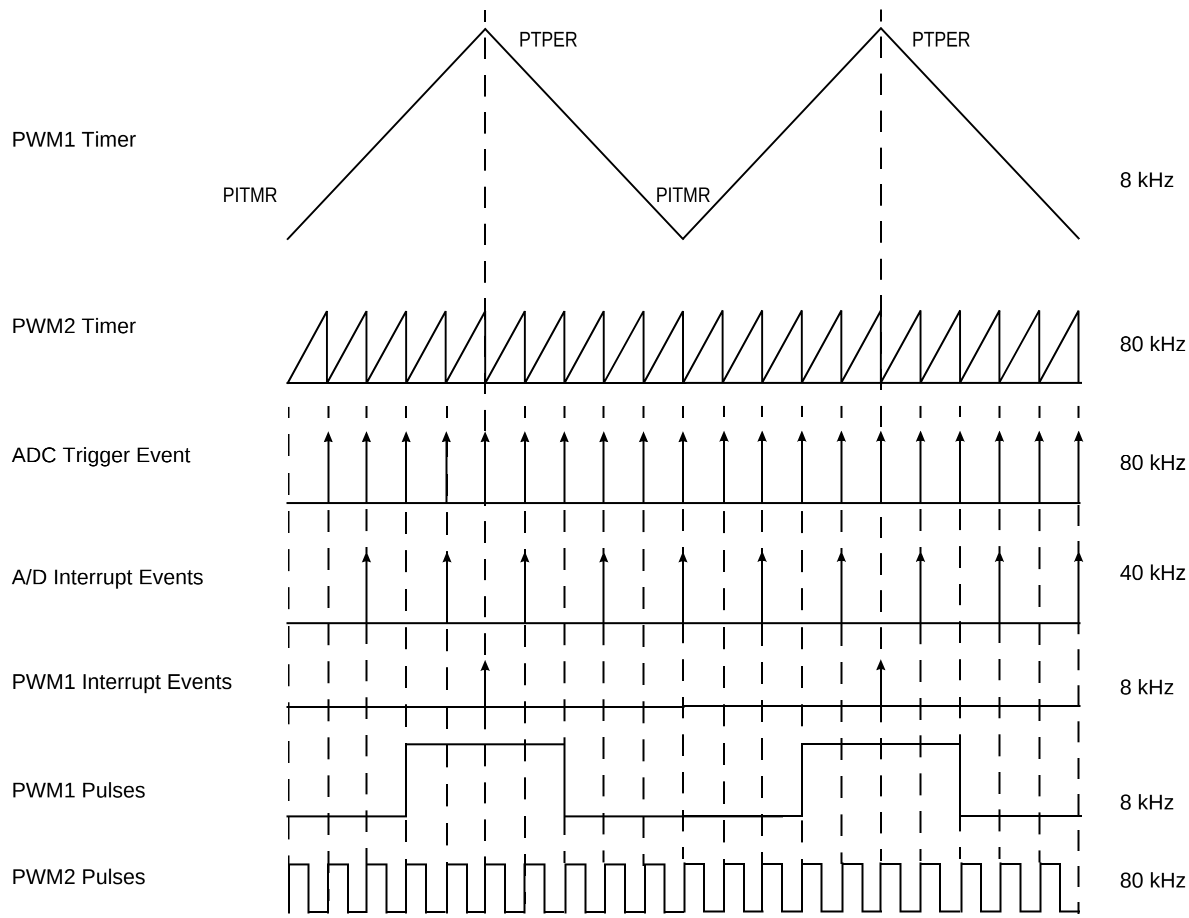


FIGURE 4: STATE FLOW DIAGRAM OF INTEGRATED SYSTEM

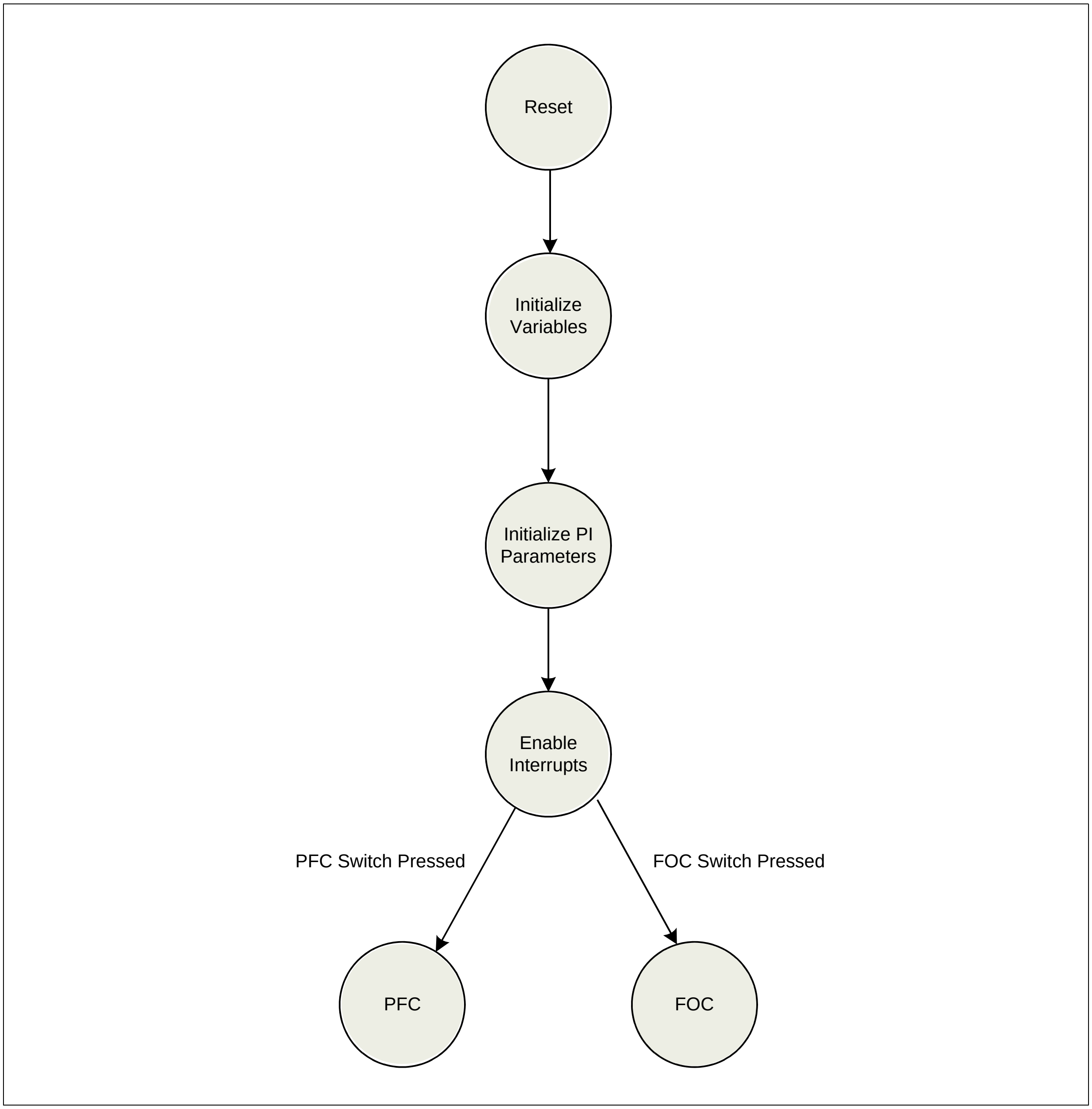


FIGURE 5: STATE FLOW DIAGRAM OF DIGITAL PFC

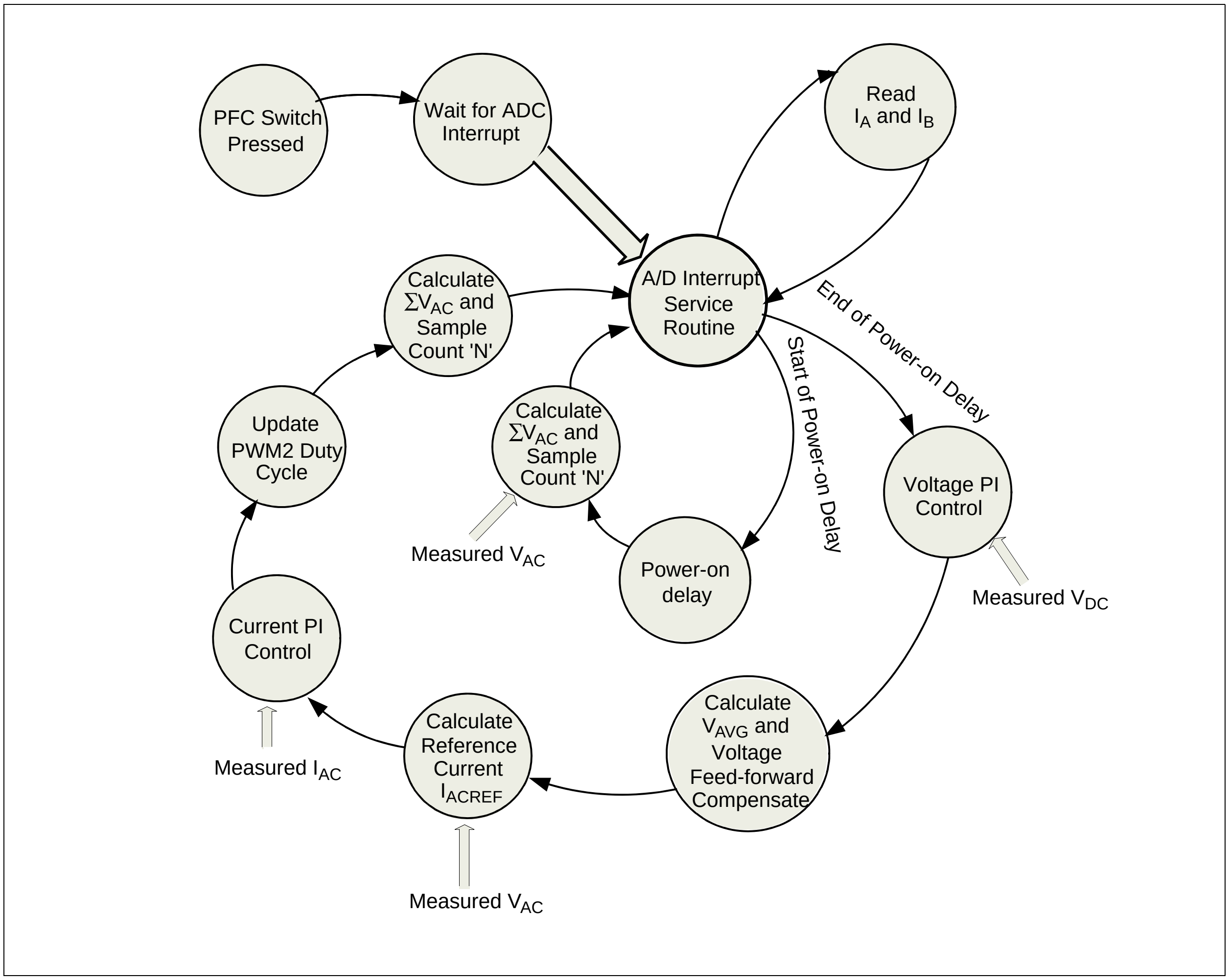
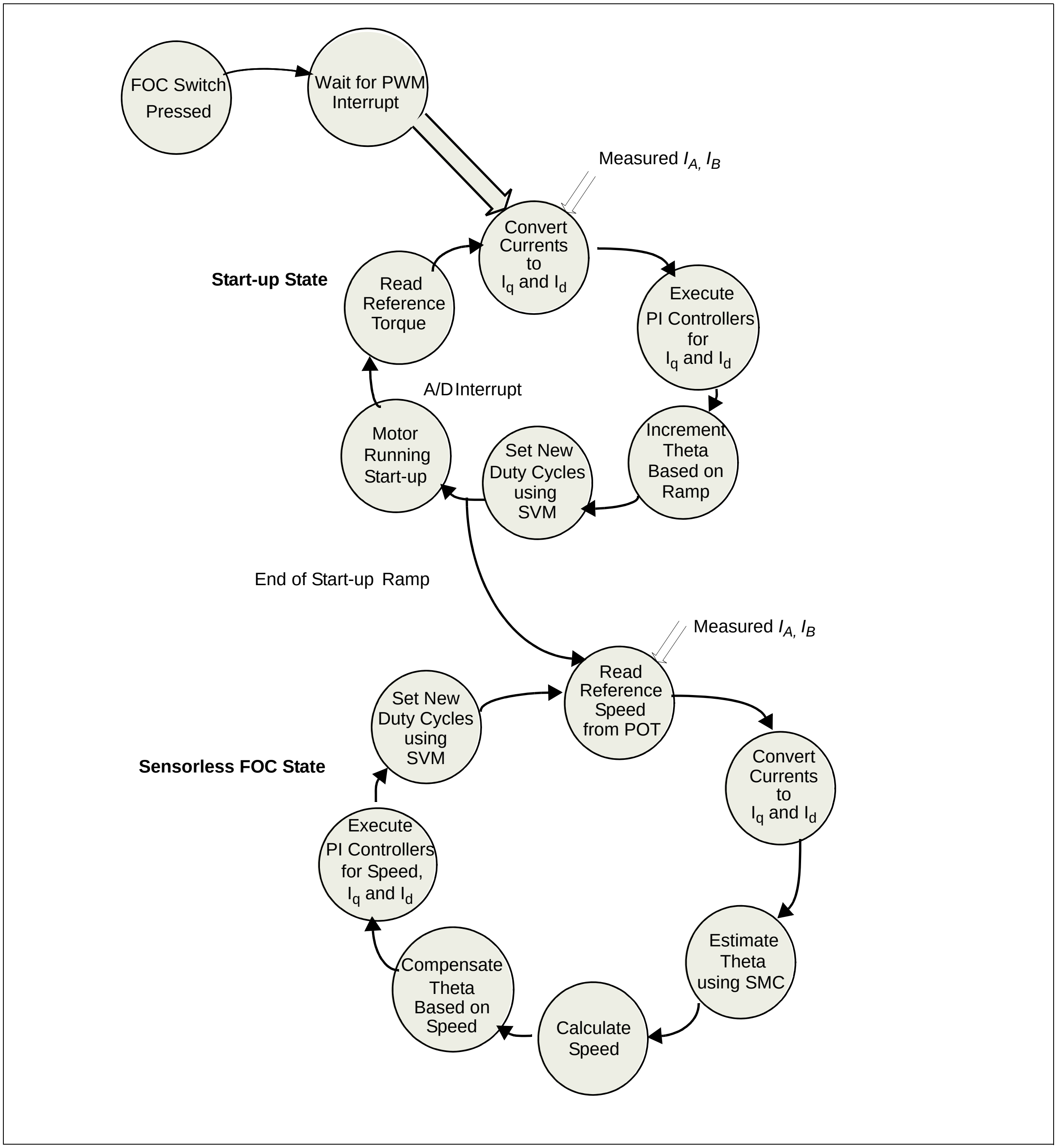


FIGURE 6: STATE FLOW DIAGRAM OF SENSORLESS FOC



IMPLEMENTATION ON A dsPIC30F6010A DEVICE

This section describes the following topics:

- ADC Configuration Details
- Hardware Setup
- Hardware Setup
- System Execution Procedure

ADC Configuration Details

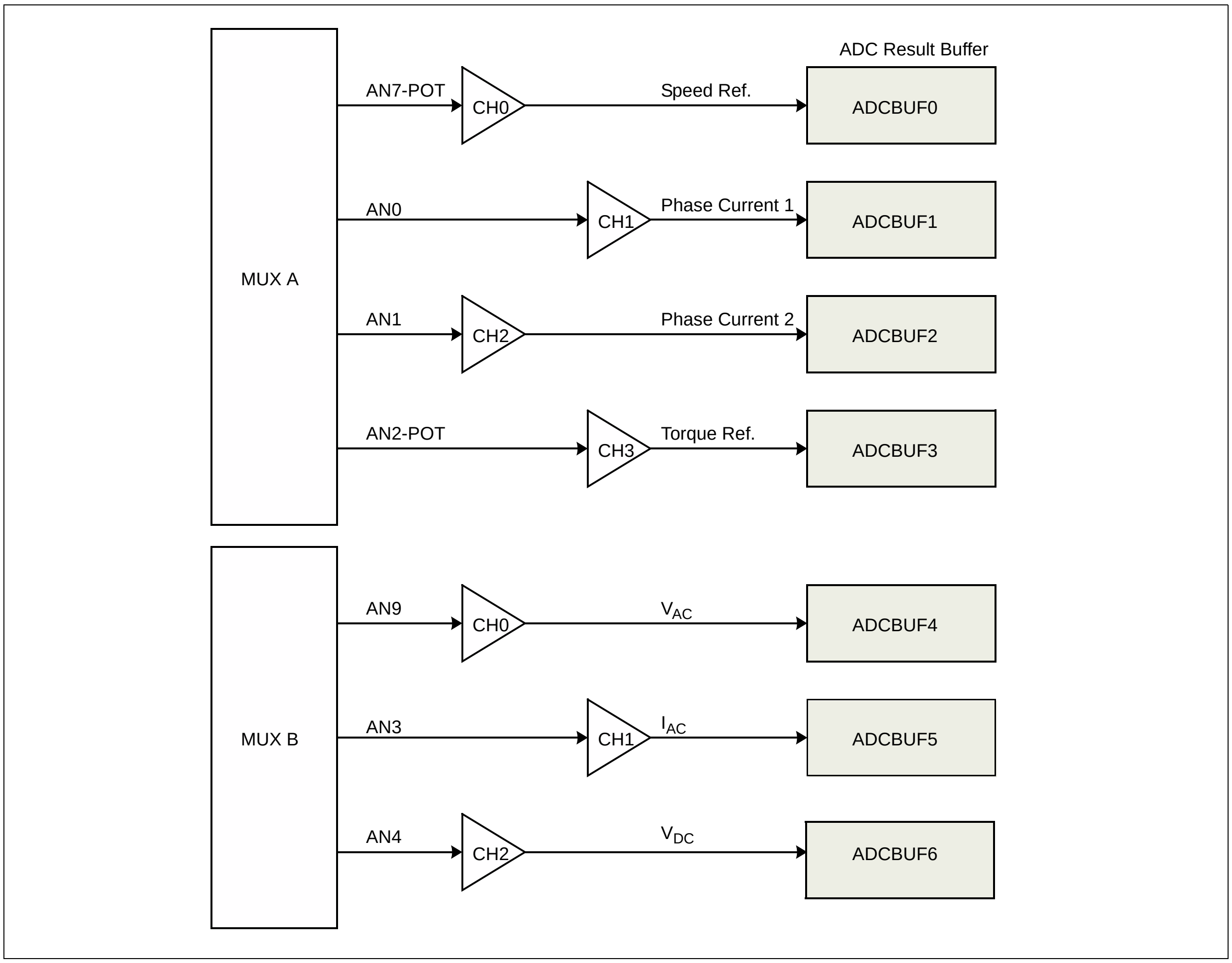
Figure 7 shows the connections between the various analog inputs and the analog channels of the ADC module. It also shows the resulting buffer locations where the digital results are stored.

Development Resources

To develop and test the integrated algorithm, the following software and hardware tools are required:

- Hardware Tools:
  - dsPICDEM™ MC1H 3-Phase High Voltage Power Module (P/N: DM300021)
  - dsPICDEM™ MC1 Motor Control Development Board (P/N: DM300020)
  - dsPIC30F6010A digital signal controller (P/N: MA300015)
  - PMSM motor
  - MPLAB® REAL ICE™ Debugger/Programmer
  - 220V, 50 Hz AC power source
  - 9V DC power supply
- Software Tools:
  - MPLAB IDE - Version 7.61 (or later)
  - C30 Compiler Version 3.01 (or later)

FIGURE 7: ADC CONFIGURATION



Hardware Setup

CONFIGURING THE dsPICDEM MC1 MOTOR CONTROL DEVELOPMENT BOARD

The following steps outline the procedure to set up the the dsPICDEM MC1 Development Board:

1. Remove the following components:
   - R36 and C33 located on the AN3 line
   - R39 and C35 located on the AN5 line
   - R42 and C37 located on the AN4 line
2. Connect analog channel AN3 to analog channel AN6.
3. Connect analog channel AN4 to analog channel AN11.
4. Connect analog channel AN2 to VR1 on the J6 connector.

ACCESSING THE HIGH VOLTAGE POWER MODULE

Before removing the lid, the following procedure should be rigidly followed:

1. Turn off all power to the system.
2. Wait a minimum of 3 minutes so that the internal discharge circuit has reduced the DC bus voltage to a safe level. The red LED bus voltage indicator visible through the top ventilation holes *should not* be lit.
3. Verify with a voltmeter that discharge has taken place by checking the potential between the plus (+) and minus (–) DC terminals of the 7-pin output connector before proceeding. The voltage should be less than 10V before proceeding to the next step.

> **WARNING:** If the voltage is more than 10V, repeat steps 2 and 3 until the voltage level is less than 10V. The system is only safe to work on if the voltage is less than 10V. Failure to heed this warning could result in bodily harm.

4. Remove all cables from the system.
5. Remove the screws fixing the lid to the chassis and heat sink on the top and bottom.
6. Slide the lid forward while holding the unit by the heat sink.
7. After the board is out of the housing, modify the power module as described in the next section.

CONFIGURING THE dsPICDEM MC1H HIGH VOLTAGE POWER MODULE

The following steps outline the procedure to set up the the board:

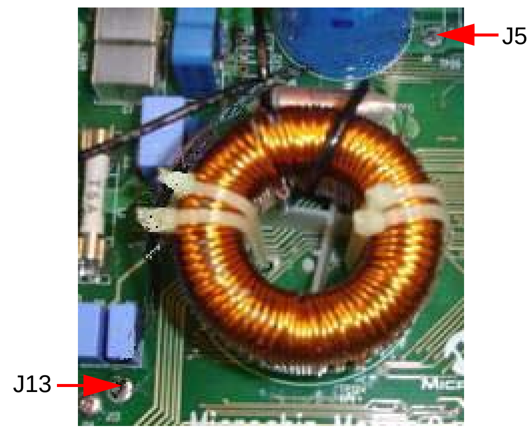
1. Solder a high-current jumper wire (AWG 18 minimum) between J5 and J13, as shown in Figure 8.

FIGURE 8: ESTABLISH COMMON POWER AND DIGITAL SIGNAL GROUND

Because shunt resistors are used to sense current from the motor, power and digital signals must use the same ground.

Solder a high-current jumper wire (AWG 18 minimum) between J5 and J13.

BEFORE



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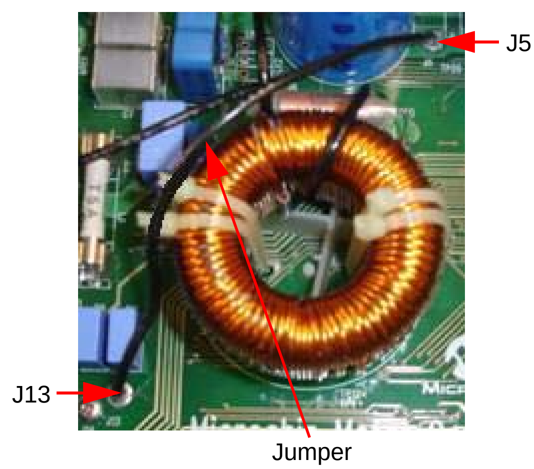


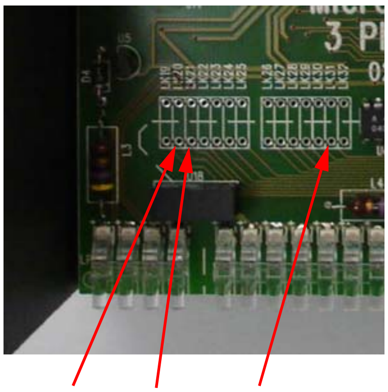
2. Connect LK30 to the BUS_SENSE terminal by using a signal wire.
3. Place 5.6 kOhm resistors on links LK20, LK21, and LK31, as shown in Figure 9.

FIGURE 9: INSTALL FEEDBACK CURRENT SELECTION RESISTORS

To obtain feedback current, the circuit links must be completed.

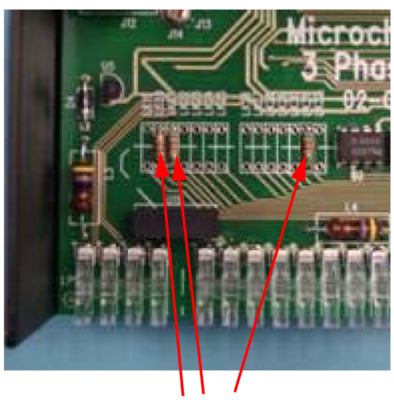
To activate the current feedback for this application, populate links LK20, LK21, and LK31 with 5.6 kΩ resistors.

BEFORE



LK20, LK21, and LK31 Links

AFTER



5.6 kΩ Shunt Resistors

4. Remove the LK2 jumper connection and place a link on jumper LK1.
5. Place jumper LK4 in the 1-2 position.
6. Place jumpers on link LK5 through LK12.

System Execution Procedure

Complete the following steps to execute the integrated PFC and Sensorless FOC algorithm that controls the motor:

1. Launch the MPLAB software and open the program.
2. Run the algorithm.
3. Apply AC input voltage to the dsPICDEM MC1H High Voltage Power module.
4. Make sure VR2, the Speed Reference POT, is in its minimum position and VR1, the Initial Torque Reference POT, is set between the 0% and 25% position.
5. Start the motor by pressing the S4 switch.

   The motor starts in Open Loop mode and ramps up the speed until it is equal to 900 rpm, and then makes a transition from Open Loop mode to Closed Loop mode.
6. When the motor enters Closed Loop mode and stabilizes, start the PFC calculations by pressing the S7 switch.

   The DC bus voltage boosts from its initial value based on the amplitude of the applied AC input voltage.
7. Change values of the VR2 POT to operate the motor at a different speed.
8. Stop the motor by pressing the S4 switch.

IMPLEMENTATION ON A dsPIC33FJ12MC202 DEVICE

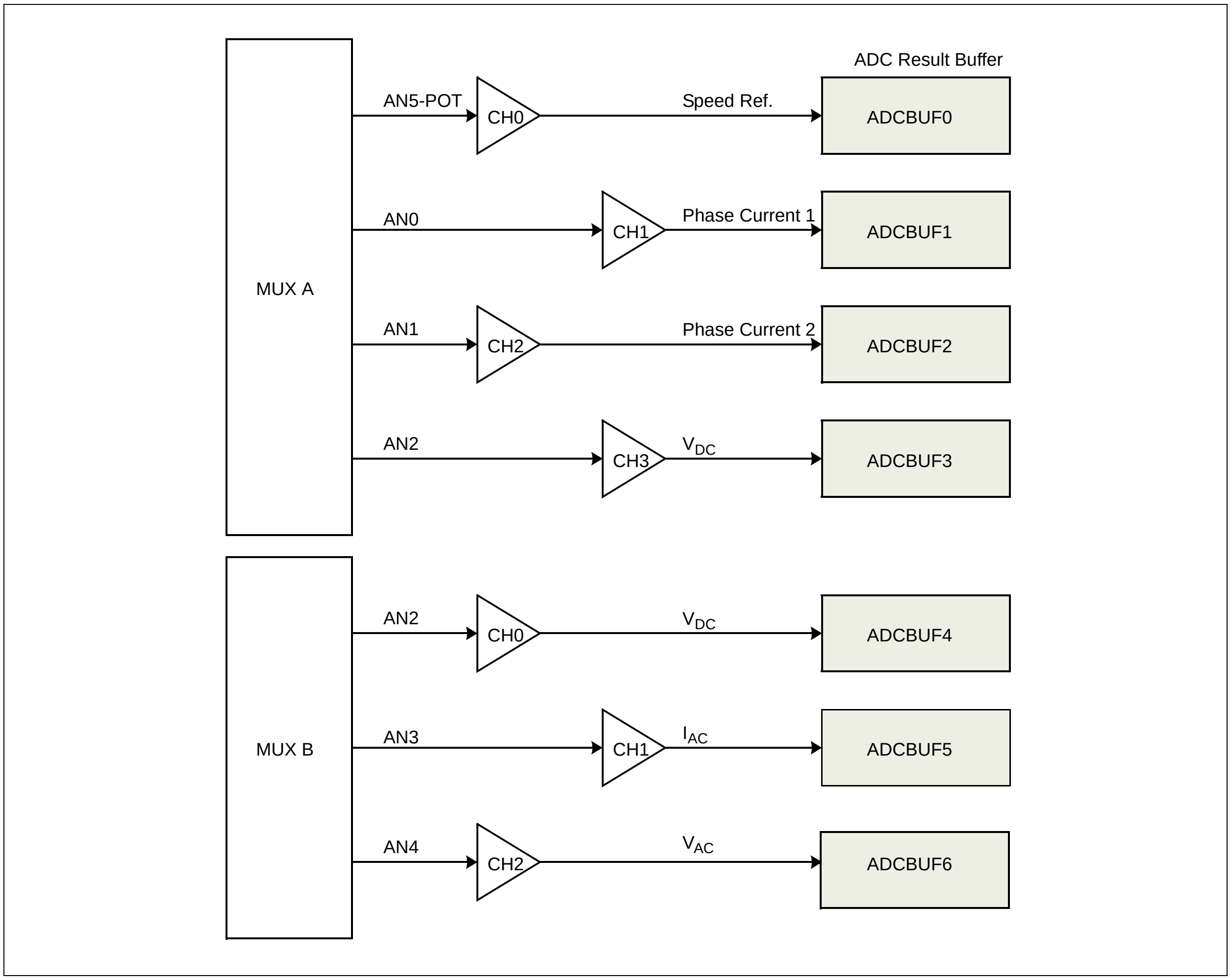
This section describes the following topics:

- ADC Configuration Details
- dsPIC33FJ12MC202 Pin Allocation
- Development Resources
- Hardware Setup
- Interconnecting the Hardware
- System Execution Procedure

ADC Configuration Details

Figure 10 shows the connections between the various analog inputs and the analog channels of the ADC module. It also shows the resulting buffer location where the digital results are stored.

FIGURE 10: ADC CONFIGURATION



dsPIC33FJ12MC202 Pin Allocation

Since the dsPIC33FJ12MC202 device is an I/O remappable device, the functionality for each pin can be defined by the user. Table 1 lists the different pins and the functionality assigned to the pin.

TABLE 1: PIN FUNCTIONALITY

No.	NAME	FUNCTIONALITY
1	AN2	VDC
2	AN3	IAC
3	AN4	VAC
4	AN5	Speed Reference (POT)
5	VSS	Ground
6	RA2	Primary Oscillator Line
7	RA3	Primary Oscillator Line
8	PGD/EMUD3	Debug Data Line
9	PGC/EMUC3	Debug Clock Line
10	VDD	Device Supply
11	RB5	Fault Input Signal
12	RB6	Switch 1 - Motor On/Off
13	RB7	Switch 2 - PFC On/Off
14	PWM2H1	PFC MOSFET Fire
15	RB9	Fault Reset/PWM Enable
16	VSS	Digital Ground
17	VDDCORE	Device Supply
18	PWM1H3	Inverter IGBT3 High Fire
19	PWM1L3	Inverter IGBT3 Low Fire
20	PWM1H2	Inverter IGBT2 High Fire
21	PWM1L2	Inverter IGBT2 Low Fire
22	PWM1H1	Inverter IGBT1 High Fire
23	PWM1L1	Inverter IGBT1 Low Fire
24	AVSS	Analog Ground
25	AVDD	Device Supply
26	$\overline{\text{MCLR}}$	Reset/Clear
27	AN0	Phase A Current
28	AN1	Phase B Current

Development Resources

To develop and test the PFC application, the following hardware and software development tools are required:

- Hardware Tools:
  - dsPICDEM MC1H 3-Phase High Voltage Power Module (P/N: DM300021)
  - Explorer 16 Development Board (P/N: DM240001)
  - Motor Control Interface PICtail Plus Daughter Board (P/N: AC164128)
  - dsPIC33FJ12MC202 Plug-in Module (P/N: MA330014)
  - 9V DC power supply
  - Variable AC power supply (0-220V)
  - PMSM motor
  - MPLAB ICD 2 Debugger/Programmer
- Software Tools:
  - MPLAB IDE - Version 8.00.04 (or later)
  - C30 - Version 3.01 (or later)

Hardware Setup

ACCESSING THE HIGH VOLTAGE POWER MODULE

Before removing the lid, the following procedure should be rigidly followed:

1. Turn off all power to the system.
2. Wait a minimum of 3 minutes so that the internal discharge circuit has reduced the DC bus voltage to a safe level. The red LED bus voltage indicator visible through the top ventilation holes *should not* be lit.
3. Verify with a voltmeter that discharge has taken place by checking the potential between the plus (+) and minus (–) DC terminals of the 7-pin output connector before proceeding. The voltage should be less than 10V before proceeding to the next step.

> **WARNING:** If the voltage is more than 10V, repeat steps 2 and 3 until the voltage level is less than 10V. The system is only safe to work on if the voltage is less than 10V. Failure to heed this warning could result in bodily harm.

4. Remove all cables from the system.
5. Remove the screws fixing the lid to the chassis and heat sink on the top and bottom.
6. Slide the lid forward while holding the unit by the heat sink.
7. After the board is out of the housing, modify the power module as described in the next section.

MODIFYING THE dsPICDEM HIGH VOLTAGE POWER MODULE

The following steps outline the procedure to set up the the board:

1. Solder a high-current jumper wire (AWG 18 minimum) between J5 and J13, as shown in Figure 11.

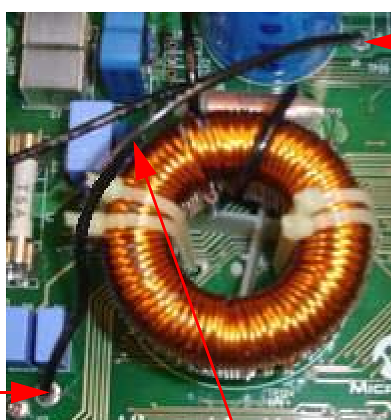
FIGURE 11: ESTABLISH COMMON POWER AND DIGITAL SIGNAL GROUND

Because shunt resistors are used to sense current from the motor, power and digital signals must use the same ground.

Solder a high-current jumper wire (AWG 18 minimum) between J5 and J13.

BEFORE

AFTER



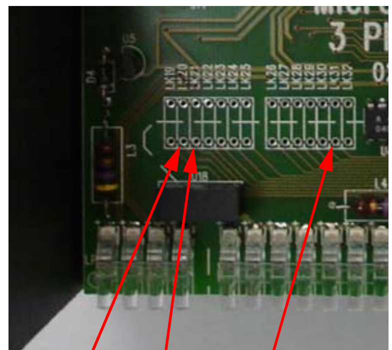
2. Replace resistor R15 with a 390 kOhm resistor.
3. Replace resistor R13 with a 158 kOhm resistor.
4. Connect LK30 to the BUS_SENSE terminal by using a signal wire.
5. Place 5.6 kOhm resistors on links LK20, LK21, and LK31, as shown in Figure 12.

FIGURE 12: INSTALL FEEDBACK CURRENT SELECTION RESISTORS

To obtain feedback current, the circuit links must be completed.

To activate the current feedback for this application, populate links LK20, LK21, and LK31 with 5.6 kΩ resistors.

BEFORE



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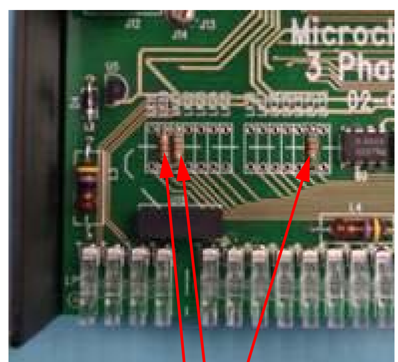


6. Remove the LK2 jumper connection and place a link on jumper LK1.
7. Place jumper LK4 in the 1-2 position.
8. Place jumpers on link LK5 through LK12.

SETTING UP THE EXPLORER 16 BOARD

The following steps outline the procedure to set up the the board:

1. Place jumper J7 in the PIC24 position.
2. Switch S2 to the PIM position.
3. Remove the LCD connections. Some LCDs have internal pull-up resistors; therefore, it is recommended to remove the LCD.

CONFIGURING AND SETTING THE MOTOR CONTROL INTERFACE PICtail PLUS DAUGHTER BOARD

Use these steps to configure and set up the board:

1. On jumper J4, connect Pin 1 to Pin 2.
2. On jumper J10, connect Pin 2 to Pin 3.
3. On jumper J11, connect Pin 2 to Pin 3.
4. Place Jumper J27.

CONFIGURING THE dsPIC33FJ12MC202 PLUG-IN MODULE

The following steps outline the procedure to set up the the board:

1. Connect RP1 to pin 34.
2. Connect RP2 to pin 33.
3. Connect RP3 to pin 20.
4. Connect RP5 to pin 18.
5. Connect RP6 to pin 83.
6. Connect RP7 to pin 92.
7. Connect RP8 to pin 84.
8. Place the following zero ohm resistors:

   R12, R13, R14, R15, R16, R17, R18, R19, R20, R24, and R25.
9. Remove the following zero ohm resistors:

   R5, R6, R7, R8, R9, R10, R11, R21, R22, R23, R26, R27, R28, R29, R30, R31, R32, and R33.

Interconnecting the Hardware

To set up the system, complete the following steps:

1. Configure the hardware properly. Refer to **"Hardware Setup"** for more information on hardware modifications.
2. Place the dsPIC33FJ12MC202 PIM on the Explorer 16 Development Board.
3. Connect the Explorer 16 Development Board to the Motor Control Interface PICtail Plus Daughter Board by using the 120-pin connector.
4. Connect the Motor Control Interface PICtail Plus Daughter Board to the dsPICDEM High Voltage Power Module by using the 37-pin connector.
5. Connect the 9V DC power supply to the Explorer 16 Development Board.
6. Connect the variable AC supply to the dsPICDEM MC1 3-Phase High Voltage Power Module.
7. Power on the 9V supply.
8. Power on the input AC supply.

System Execution Procedure

Complete the following steps to execute the algorithm on a dsPIC33F DSC device:

1. Launch the MPLAB software and open the program.
2. Build All and Flash the device. Make sure the Debug option is selected in MPLAB IDE.
3. Run the algorithm.
4. Apply an AC input voltage to the dsPICDEM MC1 3-Phase High Voltage Power Module.
5. Make sure R6, the Speed Reference POT on the Explorer 16 Development Board, is in its minimum position (CCW).
6. Start the motor by pressing the S3 switch.

   The motor starts in Open Loop mode and ramps up the speed until it is equal to 900 rpm, and then makes a transition from Open Loop mode to Closed Loop mode.
7. When the motor enters the Closed Loop mode and stabilizes, start the PFC calculations by pressing the S5 switch.
8. The DC bus voltage boosts from its initial value based on the amplitude of the applied AC input voltage.
9. Change values of the R6 POT to operate the motor at a different speed.
10. Stop the motor by pressing the S3 switch.

LABORATORY TEST RESULTS AND WAVEFORMS

Figure 13 and Figure 14 show the waveforms for the input current, R phase current, and Y phase current when executing the integrated application. This information aids in validating the PFC and Sensorless FOC implementation on a dsPIC DSC device.

FIGURE 13: INPUT CURRENT AND MOTOR PHASE CURRENT WAVEFORMS

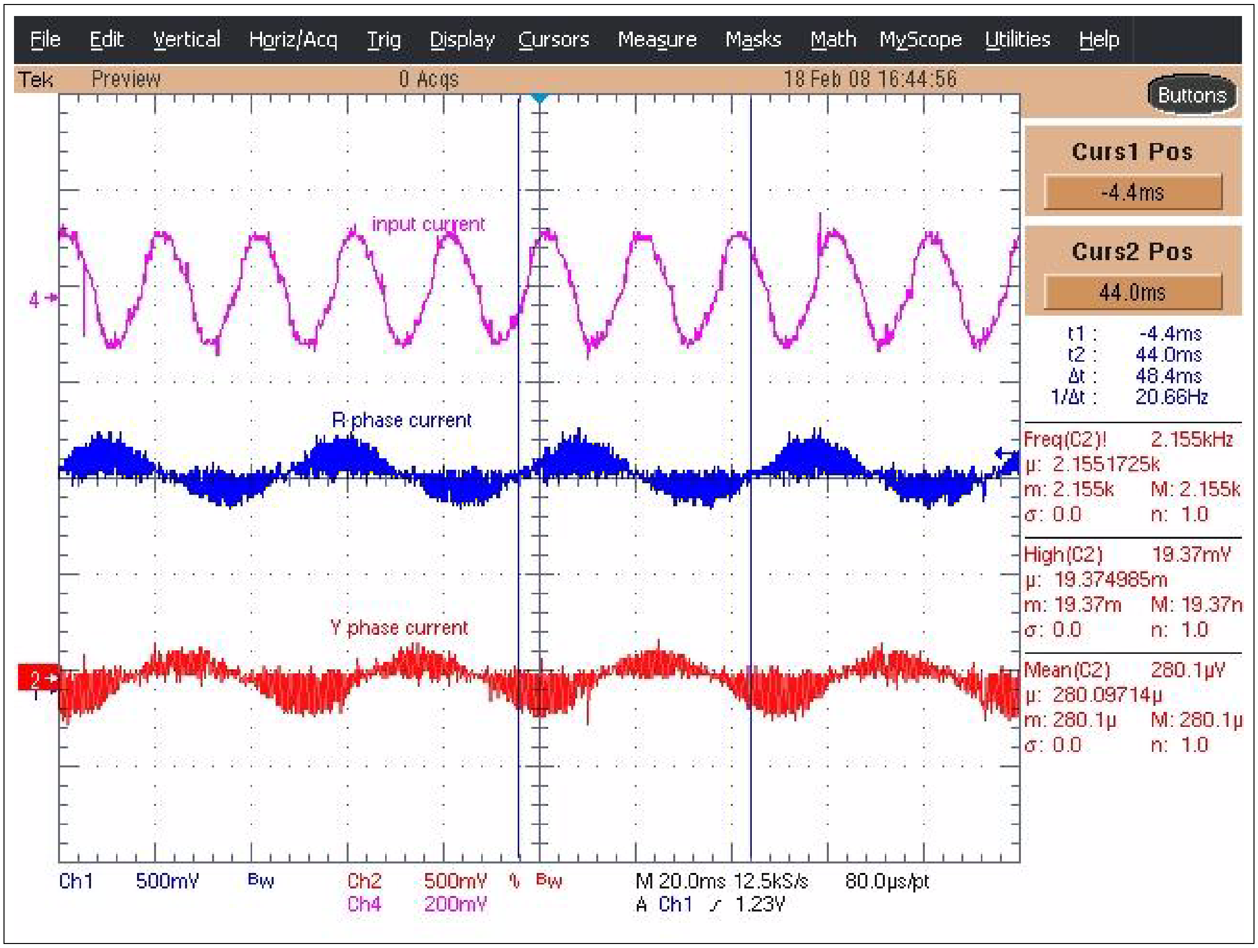
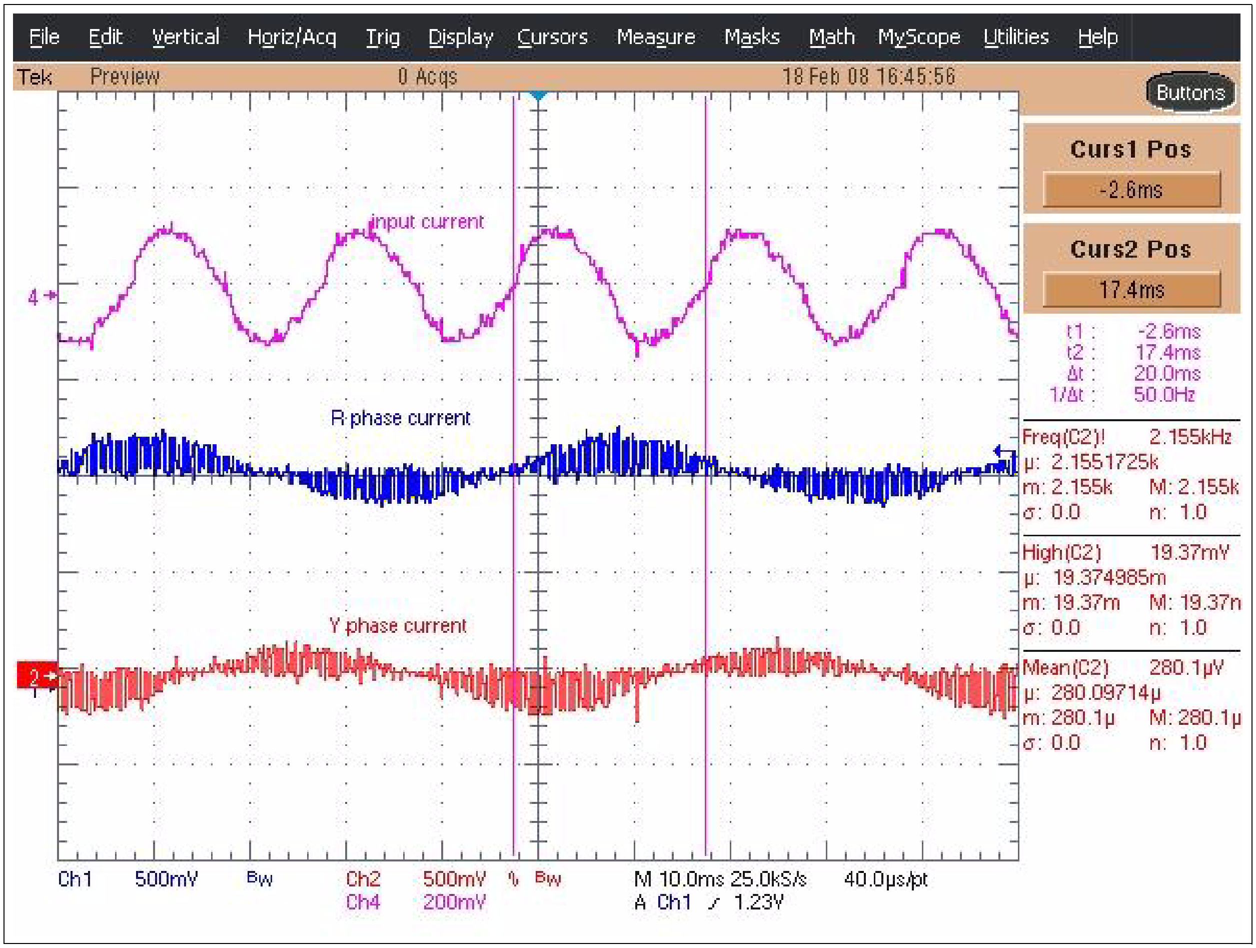


FIGURE 14: EXPANDED INPUT AND MOTOR PHASE CURRENT WAVEFORMS



CONCLUSION

Considering the consumer demand for increased efficiency and growing desires for environmental standards, designers are always looking out for new algorithms that can be used to develop low-cost, power efficient motor control systems.

The dsPIC DSC device's high processing power and peripheral-rich platform enable the implementation of complex algorithms on a single chip. The Sensorless FOC process uses three control loops to compensate the current and the speed. The PFC process uses two control loops to compensate the input current and output voltage. All of these compensators use a PI controller to compensate for variations in these parameters, which requires very high processing power and finer control of the system. The dsPIC DSC devices are best suited to handle the above requirements because of the high resolution, good processing speed, availability of advanced analog peripherals, and the variety of instructions that support these functions.

Microchip has various resources to assist you in developing this integrated system. Contact your local Microchip sales office if you would like further support.

REFERENCES

Several application notes have been published by Microchip Technology, which describe the use of dsPIC DSC devices for motor control applications.

- **For ACIM control see**:
  - AN984, *An Introduction to AC Induction Motor Control Using the dsPIC30F MCU* (DS00984)
  - AN908, *Using the dsPIC30F for Vector Control of an ACIM* (DS00908)
  - GS004, *Driving an ACIM with the dsPIC DSC MCPWM Module* (DS93004)
  - AN1162*, Sensorless Field Oriented Control (FOC) of an AC Induction Motor (ACIM)* (DS01162)
  - AN1206, *Sensorless Field Oriented Control (FOC) of an AC Induction Motor (ACIM) Using Field Weakening* (DS01206)
- **For BLDC motor control see**:
  - AN901, *Using the dsPIC30F for Sensorless BLDC Control* (DS00901)
  - AN957, *Sensored BLDC Motor Control Using dsPIC30F2010* (DS00957)
  - AN992, *Sensorless BLDC Motor Control Using dsPIC30F2010* (DS00992)
  - AN1083*, Sensorless BLDC Control with Back-EMF Filtering* (DS01083)
  - AN1160, *Sensorless BLDC Control with Back-EMF Filtering Using a Majority Function* (DS01160)
- **For PMSM control see**:
  - AN1017, *Sinusoidal Control of PMSM Motors with dsPIC30F DSC* (DS01017)
  - AN1078*, Sensorless Field Oriented Control of PMSM Motors* (DS01078)
- **For Power Control see**:
  - AN1106*, Power Factor Correction in Power Conversion Applications Using the dsPIC DSC* (DS01106)
- **For information on the dsPICDEM MC1 Motor Control Development Board see**:
  - *dsPICDEM MC1 Motor Control Development Board User's Guide* (DS70098)
  - *dsPICDEM MC1H 3-Phase High Voltage Power Module User's Guide* (DS70096)
  - *dsPICDEM MC1L 3-Phase Low Voltage Power Module User's Guide* (DS70097)
  - *Explorer 16 Development Board User's Guide* (DS51589)
  - *Motor Control Interface PICtail Plus Daughter Board User's Guide* (DS51674)

These documents are available on the Microchip web site (www.microchip.com).

APPENDIX A: SOURCE CODE

All of the software covered in this application note is available as a single WinZip archive file. This archive can be downloaded from the Microchip corporate Web site at:

www.microchip.com

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