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GS001

Getting Started with BLDC Motors and dsPIC30F Devices

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INTRODUCTION

As a means of reducing high energy and maintenance costs in motor control applications, BLDC motors are seeing a resurgence in applications where efficiency and reliability are important. The dsPIC30F motor control devices are ideally suited to drive and control a wide range of BLDC motor types, in a large number of applications. Microchip has developed a number of solutions using the dsPIC30F and BLDC motors. This document will help you select an appropriate solution for your BLDC motor application.

BLDC MOTOR BASICS

DC brush motors have a permanent magnet on the stator with the motor winding on the rotor. During rotation, the current in the windings is reversed using mechanical carbon brushes and a commutator located on the rotor. The BLDC motor has permanent magnets on the rotor with the electrical windings on the stator. The first obvious advantage of the BLDC motor is the elimination of the mechanical commutator and brushes, which significantly improves mechanical reliability. The commutator and brushes in DC motors also give rise to sparking, so eliminating these components means that BLDC motors can operate in a harsh environment. The I^2R heat losses in the windings of a BLDC motor are now on the stator and can be dissipated very easily. Consequently, efficiency of the BLDC motor is vastly improved.

There are, however, some challenges when spinning a BLDC motor. Firstly, a revolving electrical field has to be created in the windings, which also has to be well aligned with the magnetic field on the rotor. The efficiency of the BLDC motor depends largely on the alignment of the revolving electrical field to the magnetic field on the rotor. To sense the magnetic field, Hall sensors are normally used. Based on the signal presented by the Hall sensors, the windings are appropriately excited. As the speed of the rotor increases, however, there is a certain amount of lag between the voltage excitation and the current effect on the windings due to the inductance of the windings. To overcome this lag, the voltage is initiated a little in advance. This phenomenon is known as phase

advance and is implemented mainly in software at high speeds of rotation. The result of phase advance is better efficiency in the BLDC motor operation.
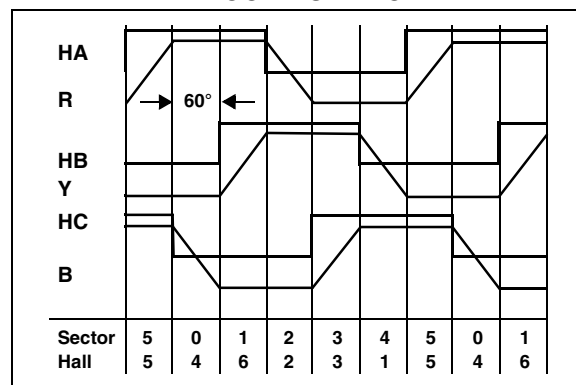
Sensored BLDC Motor Control

When driving a BLDC motor, it is important to know the position of the magnetic rotor with reference to the stator. Most commonly, Hall effect sensors are used to generate feedback on the rotor position. This type of control is called sensored BLDC motor control. Most BLDC motors have three windings. Based on the position of the magnetic rotor, two windings are energized at a given time with each phase conducting for 120 electrical revolution degrees, resulting in six distinct combinations of energization. This type of drive is called "trapezoidal" or "six-step commutation".

SIX-STEP COMMUTATION

Figure 1 depicts a typical six-step commutation scheme with the Hall sensor output overlay. Six-step commutation offers a simple, yet efficient, method of driving a BLDC motor. Hall A (HA), Hall B (HB) and Hall C (HC) sense the position of the rotor with respect to the windings, R, Y and B. Depending on the Hall sensor reading from 1 to 6, an appropriate pair of windings is driven high and low with the third winding not driven. Each 360 degree electrical cycle is broken down to six 60 degree electrical sectors, in which one winding is driven high, a second is driven low and the third is not driven. Example: In Hall position 6 or sector 1, the R winding is driven high while the B winding is driven low and the Y winding is not driven. By reading the Hall sensors, the six-step commutation algorithm can very easily be implemented in software.

FIGURE 1:   **TYPICAL SIX-STEP COMMUTATION**

Sector	5	0	1	2	3	4	5	0	1
Hall	5	4	6	2	3	1	5	4	6

DRIVING SENSORED BLDC MOTORS WITH A SINUSOIDAL VOLTAGE

When it is rotated like a generator, a BLDC motor creates a sinusoidal voltage output (120 degrees apart) in all three phase windings. So the "natural" drivers for a BLDC motor are three sinusoidal voltages at 120 degrees apart. The six-step commutation normally works very efficiently in most BLDC applications. However, in some applications, the DC switching of the PWM drive voltage used in six-step commutation some-times causes a phenomenon known as torque ripple. Torque ripple typically manifests as a low-frequency rumble in some systems.

An alternative to the six-step method is to feed a PWM driven sine wave to the three phases (at 120 degrees apart) using a Space Vector Modulation (SVM) technique. This method is just as efficient as six-step commutation and delivers uniform torque to the load. Microchip is developing an application note on this technique.
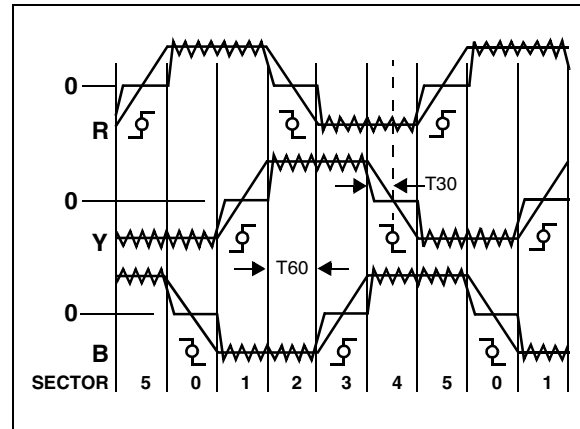
Sensorless BLDC Motor Control

Sensors add cost to a BLDC motor application. Also, sensors need to be adjusted during the manufacturing process. In quite a few applications, however, the need to find the exact position of the rotor is not necessary. Fan blowers and compressor motors are typical appli-cations which run at a constant or limited speed range. In these applications, the back EMF detected on the third unexcited winding can be used to switch the PWM commutation of the motor windings.

Figure 2 shows a typical sensorless commutation diagram. In this method, the back EMF voltage on the winding that is not driven in each sector is monitored. When this voltage crosses the imaginary "half-point" or "zero-crossing" line, zero crossing is detected. The algorithm now knows that it is in the center of the sector and has 30 electrical degrees remaining to do the next commutation. The time taken for each sector (60 degrees) is known as, say T60. When the zero-crossing point is detected, a timer is loaded with half the value of T60. When this timer times out, an interrupt is generated and the next winding commutation is implemented. This method of control is called sensorless control of a BLDC motor.

For example, in Sector 1, the Y winding is monitored for zero crossing. When that transition occurs, the timer is loaded with half the T60 time in a timer. When that timer times out, the windings are commutated as described earlier. That is, Y is driven high, B is kept at low and R is not driven.

Microchip has developed two application notes on sensorless BLDC control: *AN901, "Using the dsPIC30F for Sensoreless BLDC Control"* and *AN992, "Sensorless BLDC Motor Control Using dsPIC30F2010"*.

FIGURE 2: **TYPICAL SENSORLESS COMMUTATION**

dsPIC30F APPLICATION NOTES

The following are some applications notes on BLDC motor control with the dsPIC30F that will help you jump start your BLDC motor control project

AN957, "Sensored BLDC Motor Control Using dsPIC30F2010"

This application note describes a simple open and closed-loop solution to control a sensored BLDC motor using a 28-pin dsPIC30F2010. The solution described uses the six-step commutation method described above to rotate and control the sensored BLDC motor.

The hardware platform used is the PICDEM™ MC LV Board. With minor modifications, this application note can be used with any other hardware platform from Microchip (see the following section on motor control boards). The firmware, with minor modifications, can also be used with any motor control dsPIC30F device.

The dsPIC30F2010 is ideally suited for this application due to on-chip availability of the motor control PWM, Hall sensor and QEI input modules and the ability of the DSP engine to compute multiple PID control loops.

AN901, "Using the dsPIC30F for Sensorless BLDC Control"

This application note describes how to implement sensorless control of a BLDC motor using the back EMF detection technique mentioned above. The back EMF voltage is attenuated and fed to the ADC inputs of the dsPIC® Digital Signal Controller (DSC). The high-speed ADC is then used to detect the zero crossing. This technique provides a very efficient control method for starting and running a sensorless BLDC motor with a minimum of components. The hardware used is a dsPICDEM™ MC1 Motor Control Development Board used in conjunction with either a dsPICDEM MC1L 3-Phase Low-Voltage Power module or a dsPICDEM MC1H 3-Phase High-Voltage Power module.

A dsPIC30F6010 device is used on the MC1 board in this application. The application note describes in detail how to start and run a sensorless BLDC motor. The control method, however, is general enough to work with any BLDC motor available in the market. Details are provided to assist you in configuring the 45 parameters needed to start and run the BLDC motor. All 45 of these user parameters can be set using the LCD and push buttons available on the MC1 development board.

The firmware supports four different control modes and two starting modes. The hardware drive section is connected via a 37-pin D-type connector to either a high-voltage or low-voltage power module, which allows for BLDC motors that can operate in the voltage range from 10 to 400 VDC. The firmware can also be modified to work with any motor control dsPIC30F device.

The dsPIC30F6010 is ideally suited for this application because it includes on-chip motor control PWM, Hall sensor and QEI input modules, along with a fast ADC required to sample the back EMF and detect zero crossing. A powerful DSP engine is available to compute multiple PID control loops.

AN992, "Sensorless BDLC Motor Control Using dsPIC30F2010"

This application note takes the application described in AN901 one step further and provides a low-cost, yet efficient, implementation on the smallest dsPIC30F motor control device available, namely the 28-pin dsPIC30F2010 with 12 Kbytes of program memory and 512 bytes of RAM. The hardware is simplified and uses the stand-alone PICDEM™ MC LV board as the hardware platform.

Because the PICDEM MC LV board has no LCD and the dsPIC30F2010 has limited I/O, the 45 user parameters are set using a PC via the serial port and a HyperTerminal link.

The PICDEM MC LV only supports voltages from 10 to 40 VDC, hence, only low-voltage BLDC motors are able to run on this board. However, the technique used in this application can be extrapolated. If higher voltage and current drivers are provided to support higher voltage and current, then a similar, but modified hardware can be used to run BLDC motors from 40V to 400V DC.

The dsPIC30F2010 is ideally suited for this application. It includes on-chip motor control PWM, Hall sensor and QEI input modules, along with a fast ADC to sample the back EMF and detect zero crossing. A powerful DSP engine is available to compute multiple PID control loops.

dsPIC30F HARDWARE MODULES TO CONTROL BLDC MOTORS

Micorchip offers a number of hardware tools to help you implement your own BLDC motor control solution.

FIGURE 3:   PICDEM™ MC LV BOARD
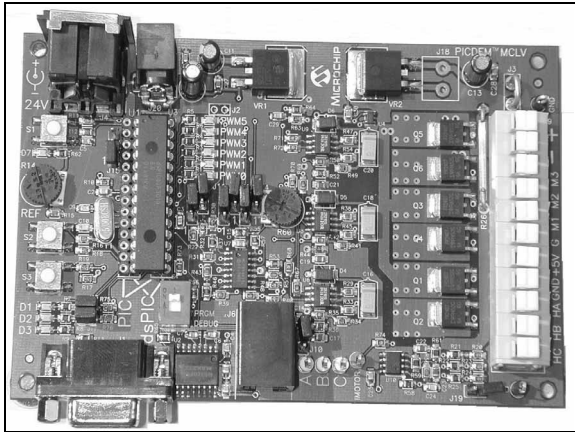
PICDEM MC LV Board

This board offers a self-contained, low-voltage platform (Figure 3) that supports all 28-pin motor control dsPIC30F devices, including the dsPIC30F2010, dsPIC30F3010 and the dsPIC30F4012. Hardware support for sensored, as well as sensorless, BLDC motors is available on this board. The factory shipped board supports a motor voltage of 24V; however, the hardware can support voltages from 10V to 40V at motor currents of up to 4 Amps.

A serial port is available to communicate with an external source. An MPLAB® ICD 2 In-Circuit Debugger connection is available for programming and debugging purposes. A potentiometer is available for speed control, along with two switches for start/stop control.

On-board power drivers support direct drive to the BLDC motor. A low-side power resistor supplies current and Fault feedback to the dsPIC DSC. The "*PICDEM™ MC LV Development Board User's Guide*" (DS51554) provides details on the use of this board.

dsPICDEM MC1 Motor Control Development Board

The dsPICDEM MC1 Motor Control Development Board (Figure 4), is a general purpose development board that uses a dsPIC30F6010 to control a wide range of motor control applications, including sensored and sensorless BLDC motors. Serial RS-232 and CAN ports are supported, along with an ICD 2 In-Circuit Debugger connection for programming and debugging purposes.

A two-lines by 20-character LCD is used along with four LEDs for display purposes. Four push buttons and two potentiometers are available for data entry and feedback. Spare analog and digital pins are made available on two header banks.

No drivers are available on the board, so the MC1 board must be connected to an external drive system. A 37-pin D-type connector is used to connect the MC1 board to a dsPICDEM MC1H 3-Phase High-Voltage module (Figure 5) or dsPICDEM MC1L 3-Phase Low-Voltage module (Figure 6). The D-type connector connects to external circuitry via opto isolators, thus allowing for a safe, electrically isolated drive to high voltage (400 VDC).

The dsPICDEM MC1 Motor Control Development Board can be used with a dsPICDEM MC1H 3-Phase High-Voltage Power module to drive a high-voltage BLDC motor. Refer to the "*dsPICDEM™ MC1 Motor Control Development Board User's Guide*" (DS70098) for full details on the capabilities and functions available on this board.

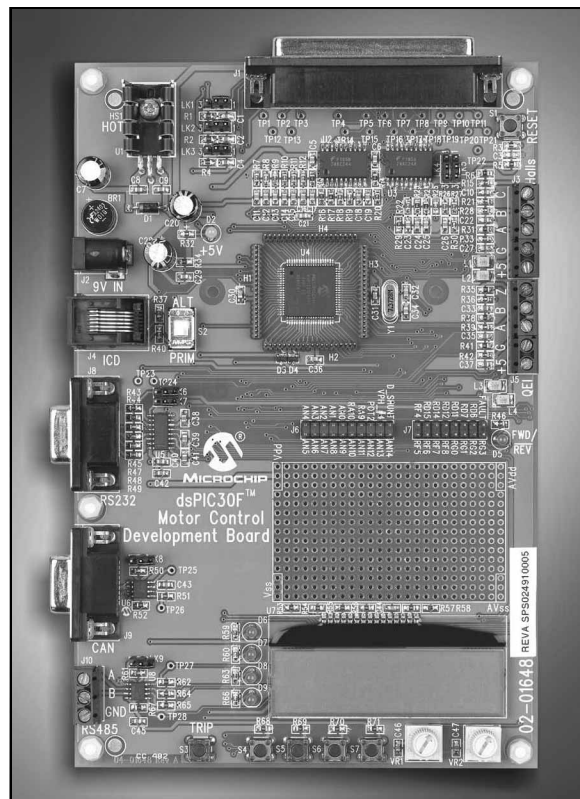**FIGURE 4:   dsPICDEM™ MC1 MOTOR CONTROL DEVELOPMENT BOARD**

FIGURE 5: **dsPICDEM™ MC1H 3-PHASE HV MODULE**

dsPICDEM MC1H 3-Phase High-Voltage Power Module

The high-voltage module (Figure 5) connects to an MC1 board to form a high-voltage BLDC motor control system. The dsPICDEM MC1H 3-Phase High-Voltage Power module offers high-voltage isolation, as well as Fault, overcurrent and overvoltage protection. Each phase is monitored with fast current sensors and a robust latching network to disable the outputs in case any Fault condition occurs. This protection is necessary during code development and prevents accidental destruction of the drive circuitry due to inadvertent software issues.

The high-voltage module rectifies a single-phase wall input voltage of 110 VAC to generate a DC bus voltage of 165 VDC. Alternatively, it can also rectify an input wall voltage of 220 VAC to get a DC bus voltage of 330 VDC. This DC bus voltage is then converted to drive a 3-phase motor.

The hardware can be used to drive ACIM and BLDC motors. For complete details on the features and capabilities of this module, refer to the "*dsPICDEM™ MC1H 3-Phase High-Voltage Power Module User's Guide*" (DS70096).

FIGURE 6: **dsPICDEM™ MC1L 3-PHASE LV MODULE**

dsPICDEM MC1L 3-Phase Low-Voltage Power Module

The low-voltage module (Figure 6) connects to an MC1 board to form a low-voltage BLDC motor control system. The dsPICDEM MC1L 3-Phase Low-Voltage Power module offers voltage isolation, along with Fault, overcurrent and overvoltage protection. Each phase is monitored with fast current sensors and a robust latching network to disable the outputs in case any Fault condition occurs. This protection is necessary during code development and prevents accidental destruction of the drive circuitry due to inadvertent software issues.

DC voltage is supplied externally from a power supply. This DC bus voltage is then converted to drive a 3-phase motor.

The hardware can drive 3-phase low-voltage BLDC motors. For more details on the features and capabilities of this module, refer to the "*dsPICDEM™ MC1L 3-Phase Low-Voltage Power Module User's Guide*" (DS70097).

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DIFFERENT dsPIC30F BASED HARDWARE PLATFORMS FOR BLDC MOTOR CONTROL

You can use the Selection Summary (Table 1) to select different Microchip hardware platforms for specific application needs. Note that although there are a limited number of dsPIC DSC devices supported on a given hardware platform, you can build a daughter board based on the motor control dsPIC30F device needed for your application and plug it into the available socket or header pins on the PICDEM MC LV or MC1 development boards.

TABLE 1: SELECTION SUMMARY

BLDC Motor Type	Operating Voltage Range (VDC)	Power Range (Watts)	Application Note	Hardware Platform Recommendations	Supported dsPIC30F Devices
Sensored	10 to 40	50 to 200	AN957	PICDEM™ MC LV	dsPIC30F2010 dsPIC30F3010 dsPIC30F4012
Sensored	40 to 400	Up to 800	AN957	MC1 and High-Voltage Power module	dsPIC30F6010
Sensored	10 to 48	Up to 600	AN957	MC1 and Low-Voltage Power module	dsPIC30F6010
Sensorless	10 to 40		AN992	PICDEM MC LV	dsPIC30F2010 dsPIC30F3010 dsPIC30F4012
Sensorless	40 to 400	Up to 800	AN901	MC1 and High-Voltage Power module	dsPIC30F6010
Sensorless	10 to 48	Up to 600	AN901	MC1 with Low-Voltage Power module	dsPIC30F6010
Sensorless	40 to 400	As per user's design	AN992	PICDEM MC LV (user modified for high voltage)	dsPIC30F2010 dsPIC30F3010 dsPIC30F4012

ORDERING INFORMATION AND NUMBERS

PICDEM™ MC LV Development Board: DM183021

Power Supply (optional): AC002013

Motor with cables: AC300020

"PICDEM™ MC LV Development Board User's Guide" (DS51554)

dsPICDEM™ MC1 Motor Control Development Board: DM300020

"dsPICDEM™ MC1 Motor Control Development Board User's Guide" (DS70098)

dsPICDEM™ MC1H 3-Phase High-Voltage Power Module: DM300021

"dsPICDEM™ MC1H 3-Phase High-Voltage Power Module User's Guide" (DS70096)

dsPICDEM™ MC1L 3-Phase Low-Voltage Power Module: DM300022

"dsPICDEM™ MC1L 3-Phase Low-Voltage Power Module User's Guide" (DS70097)

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