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CE003

Driving a BLDC with Sinusoidal Voltages Using dsPIC30F

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INTRODUCTION

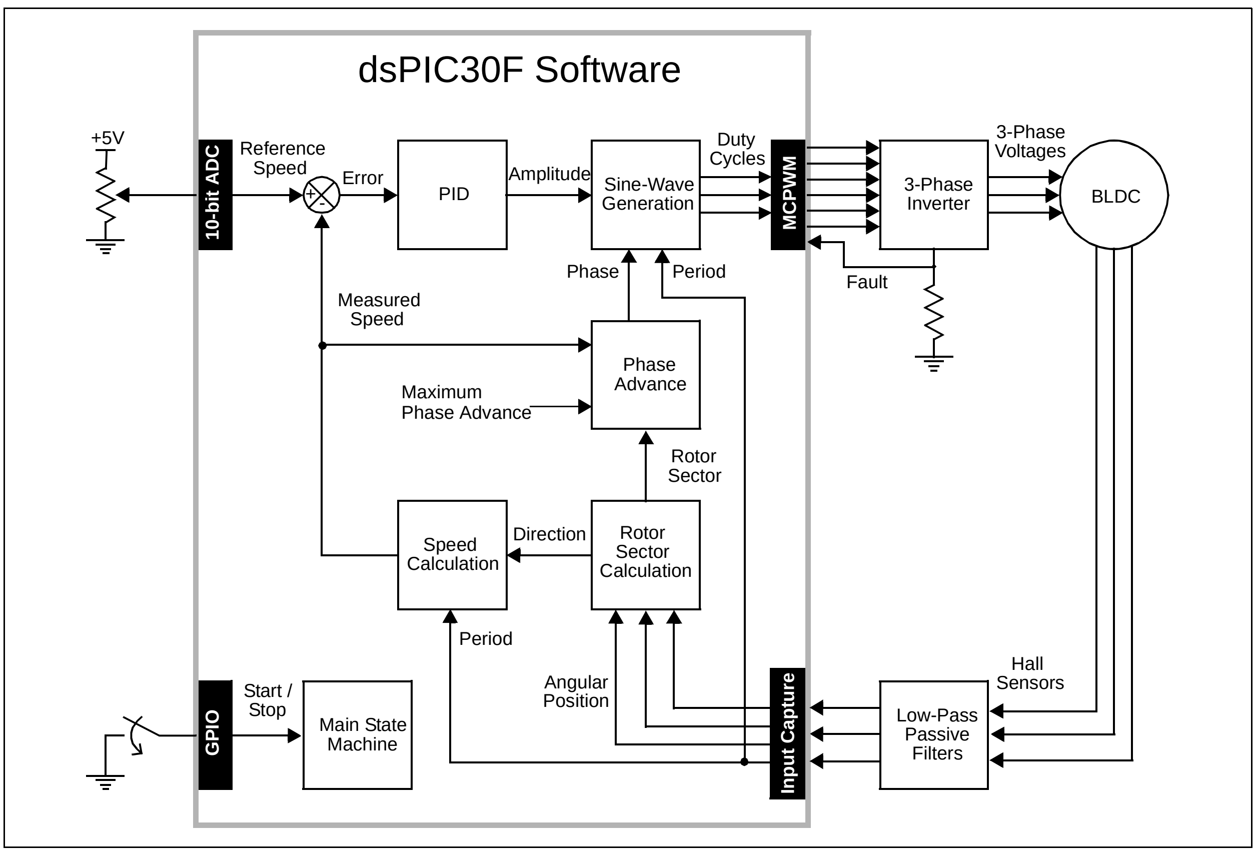
In BLDC motor applications where audible noise and torque ripple are issues, driving the motor with three-phase sine waves instead of 6-step voltages is a desirable approach. This document describes application software that enables the dsPIC30F digital signal controller to efficiently and robustly drive a BLDC motor with sinusoidal voltages.

The dsPIC30F Motor Control devices include peripheral modules that are well suited for this application. The Motor Control PWM (MCPWM), 10-bit A/D Converter (ADC), input capture and general purpose I/O modules provide essential functionality that facilitate software control. The use of software algorithms for such functions as PID closed-loop control, and the elimination of external PWM generators and expensive current sensing devices not only increases efficiency but ultimately reduces overall application cost.

OVERVIEW

Figure 1 is a block diagram representation of the application software. The application runs closed-loop based on the difference between the desired speed and actual speed. The speed set point is established by the voltage value of an external potentiometer. Actual speed is measured from signals from Hall effect sensors. Proportional, integral and derivative interpretations of the speed error determine the amplitude of the voltage sine wave, which in turn controls the motor speed.

FIGURE 1: SOFTWARE FOR SINUSOIDAL CONTROL OF A BLDC MOTOR



CODE EXAMPLE

The code for this application is contained in the zip file that accompanies this document.

Main Initialization

The motor is started and stopped by an external switch, which is monitored by a general purpose I/O pin. When a start signal is sensed, all the variables are initialized and the peripherals are enabled.

Reference-Speed Measurement

In closed-loop operation, the operator of the system sets a desired speed, and the system compensates the voltage fed to the motor to get the actual speed. In the first part of the closed loop, the desired speed is read from an external potentiometer by the A/D converter. The A/D converter establishes a software value called `Reference Speed`.

Period Measurement

The second part of the closed-loop system is the measured speed, which is used to either increase or decrease the output voltage of the motor depending on the calculated error between the desired speed (set point) and the measured speed. The application assumes that the motor uses Hall effect sensors to detect rotor position. The signals from the Hall effect sensors are conditioned by low-pass passive filters to produce pulses that can be measured by the input capture module. One of the Hall effect sensors is used to determine the `Period`, which must be known for two reasons: first, to calculate the speed of the motor for the closed-loop controller, and second, to keep the sine wave phase locked to the angular position of the rotor. The logic states of the three Hall effect sensors determine the angular position of the rotor.

Rotor Sector Calculation

The angular position measurements are evaluated to generate an output value defined as `Rotor Sector`. This value is used in phase advance calculations.

Also, angular position measurements are compared with their last measured value to determine direction of rotation of the motor. Direction is used in the speed calculation.

Speed Calculation

The speed calculation uses the period measurement from the input capture module and the direction value from the rotor sector calculation to calculate the speed of the motor in a signed format. In this calculation, a constant value is divided by the period measurement, then a sign is added to indicate the direction of rotation of the motor. The result of this calculation is the measured speed value used to determine the speed error.

PID Speed Control

The measured speed is subtracted from the reference speed to determine the speed error, which determines if the motor must speed up or slow down. To ensure smooth operation of the motor, the error value is parsed into proportional, integral and derivative components to produce a composite output that is used to compensate for the speed error.

The output of the PID speed control calculations is a voltage value defined as `Amplitude`. The `Amplitude` value is used to generate the sine waves that drive the motor.

Phase Advance Calculation

A phase advance calculation is used in this application to increase the speed range of the motor. Without phase advance, the sine waves are in phase with the Hall effect sensor signals. With phase advance, the sine waves are shifted by an angle while maintaining the same period as the Hall effect sensors.

The algorithm used to calculate phase advance uses three values: `Measured Speed`, `Phase` and a constant. The constant (`MAX_PH_ADV_DEG`) determines the maximum amount of phase shift in electrical degrees (from 0 to 60°).

The `Measured Speed` value is the result of the speed calculation. The `Phase` value is retrieved from a table that contains values corresponding to each phase of the sine waves for each rotor sector (with no phase advance), as measured by the Hall effect sensors.

First, the current `Phase` value is retrieved from the table. Then the `Measured Speed` is multiplied by the phase advance constant, and this product is added to the `Phase` value from the table. The result of the calculation is the `Phase` value that drives the sine-wave generation.

Sine-Wave Generation

Sine-wave generation uses the values of `Amplitude`, `Phase` and `Period` to generate three-phase sine waves. These sine-wave outputs are the corresponding duty cycles, which are fed to the duty cycle registers in the MCPWM module. The MCPWM module converts the duty cycle inputs into modulated square waves, which drive an external inverter. The inductance of the motor windings will filter the current from the PWM output voltages.

Sine-Wave Modulation Calculation

The MCPWM module converts the three duty cycle inputs from the Sine-Wave Generator into six sine-wave modulated square-wave signals. The modulated square waves drive the transistors of an external inverter, which generates the drive voltage for the motor.

An external limit comparator generates a Fault signal if an overcurrent occurs. This Fault signal instructs the MCPWM module to shut down all its outputs automatically to protect the external hardware.

SOFTWARE AND DEVELOPMENT TOOLS

The workspace for this example application was created using MPLAB® IDE v7.2. All source code in the project is written in C. Source-level comments are provided to facilitate understanding of the source code. The example MPLAB IDE workspace is configured for a dsPIC30F4012 device, but it is easily reconfigured for any dsPIC30F device with a 10-bit A/D converter.

The project/workspace assumes that a 5 MHz crystal provides device clocking. Additional oscillator plus PLL options have been configured in source code to operate the device at a throughput of 20 MIPS. All Microchip software tools and dsPIC30F documentation described in this document can be downloaded from:

http://www.microchip.com

The hardware used for this application is the PICDEM™ MC LV Development Board. The *PICDEM™ MC LV Development Board User's Guide* (DS51554) provides details on the use of this board. You can order the board from the Microchip web site with the reference number DM183021. The motor used for development was from the Hurst Manufacturing NT Dynamo™ standard range of products. A Hurst motor can be ordered from the Microchip web site with the reference number AC300020.

SUMMARY

This code example document describes a representative project that implements a sinusoidal control of a BLDC motor using peripherals dedicated to motor control applications. Also, the DSP engine of the dsPIC digital signal controller was used to perform algorithms such as a PID control loop. Operational aspects are described in source-level comments in each file.

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