Motor Applications for Small Appliances

Using BLDC motors in small home appliances

Introduction

Brushless motors are more efficient at converting electricity into mechanical power than brushed motors. Lack of a commutator allows for reduced complexity and maintenance, as well as lower electromagnetic interference. Brushless motors can develop high torque with a good speed response and can be easily controlled by an MCU. They can also operate in a very wide speed range to enable fine motion control and hold torque when stationary.

Brushless motors have come to dominate many applications, namely hard drives, CD/DVD players, pumps, fans, robotic vacuum cleaners, coffee machines, mixers, hairdryers, bread cutters and spindle drives in adjustable or variable speed applications. They are also a popular motor choice for helping to increase battery life for model aircraft, remote control (RC) cars and portable power tools.

Application Requirements

Each application has very specific requirements. Though it's not easy to cover all solutions through a single example, Freescale offers many application reference designs and/or demo software which can be easily reconfigured according to application-specific needs.

Figure 1: BLDC Motor Cross Section

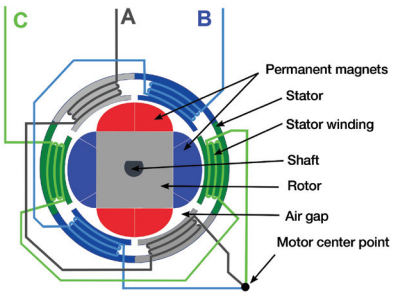
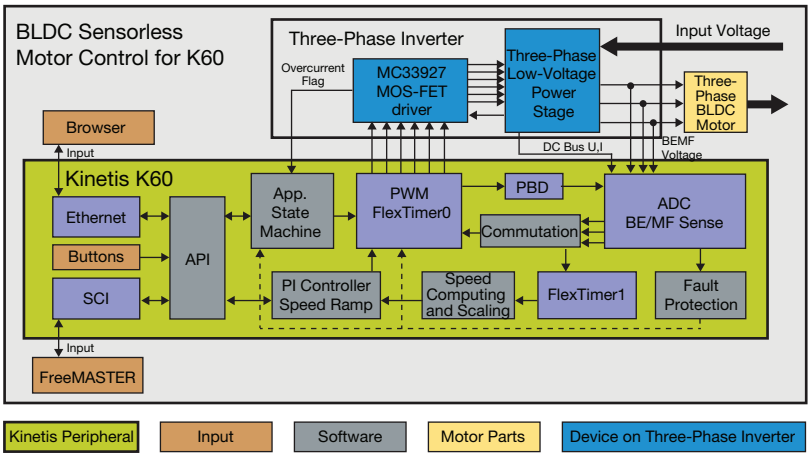


Figure 2: Freescale Kinetis BLDC Sensorless Reference Design Block Diagram



High Efficiency

Brushless motors are used in place of various types of AC motors. The most significant reason to switch to a brushless motor is the dramatic reduction in power required to operate them versus a typical AC motor. Some devices use brushless motors in order to increase overall system efficiency and achieve a higher efficiency class according to the European Union energy label. In small, battery-powered devices, improving drive efficiency also helps to lengthen battery life.

Speed Variability and Speed Control

In addition to the brushless motor's higher efficiency, certain home appliance devices use brushless motors because the built-in MCU allows for programmability, variable-speed and/or load modulation with enough precision. A robotic vacuum cleaner is a typical example of when MCU speed control is needed. It enables bi-directional operation with fast torque response and low noise. RC toys and vacuum cleaners also utilize very high-speed operation.

Low Price, High Quality

Small appliances are usually produced in very large volumes, therefore one of the most important requirements is cost effectiveness. Cost-effective control topology with BLDC motors allows for lower device prices while maintaining the quality of the product.

Additional price reduction can be achieved by removing the position sensor. For more information on this option, see the related small appliance articles in this edition of *Beyond Bits*.

High Reliability

Reliability is an important aspect of brushless motors, as they contain a minimal number of mechanical parts: no commutator, no slip rings, and no winding on rotary parts. The most important parts of the drive are

the inverter and controller design. Therefore, it is necessary to pay attention to good hardware design with reliable software.

Communication

As the MCU is part of the whole design, it is possible to use it to increase system intelligence and value. Adding a modern user interface, special features or connectivity will improve system value with minimal expense. Hardware can be dramatically reduced by using the right MCU.

Dimensions and Weight

High output power, low weight and small form factors are desirable for RC planes, helicopters and electric hand tools. This is one reason that BLDC motors have displaced other types of motors and combustion engines.

Application Concept

The system consists of hardware and software tools for controlling this type of motor.

Hardware consists of:

- Three-phase inverter
- MCU board
- User interface

Software consists of:

- PWM generation control
- Rotor position measurement
- User interface
- Fault control
- Current limitation
- Speed controller

The controller must control the rotor rotation, therefore, the controller requires some information to determine the rotor's orientation/position (relative to the stator). Some designs may use Hall effect sensors or an encoder to directly measure the rotor's position. Others measure the back EMF in the unpowered coils to infer the rotor position, eliminating the need for Hall effect sensors. This technique is known as sensorless BEMF control.

Figure 3: MCU Selection for Specific Applications

Application Example	Application Requirements	Devices	Tools
Robot vacuum cleaner	High	Kinetis K series MCUs based on the ARM® core, DSC family 56F82xx, 56F83xx, 56F84xx	Hardware and software tools, motor control drivers and algorithms, FreeMASTER, Processor Expert
Coffee machines, RC planes	Mid	S12X, DSC family 56F80xx, 56F81xx	
Toys, mixers, fans	Low	RS08, HCS08, HC08, Kinetis L	

The back EMF sensing technique is based on the fact that only two phases of a brushless DC motor are energized at one time. The third phase is a non-fed phase that can be used to sense the back EMF voltage.

The whole system according to the user interface input and feedback signals, generates three-phase PWM output signals for the motor inverter.

For the sensorless BLDC application example, it is necessary to sense the following parameters during the application run:

- DC bus voltage
- DC bus current
- Phase A, B, C back EMF voltages

The commutation time and period are calculated from these measured parameters. To manage these tasks, the Freescale processor must have rich features of timers, ADC converters and PWM to ADC synchronization modules. The processor must also contain special control registers with hardware and software triggers which can make six-step control very easy.

Implementation of Freescale MCUs

Freescale offers several 8-, 16- and 32-bit MCU families that are perfectly adapted to the requirements of modern industrial and household applications, combining high performance and low cost.

Freescale MQX™ software solutions offer a straightforward API with a modular architecture that is scalable to fit most requirements, making it simple to fine tune custom applications. The combination of market-proven Freescale MQX software solutions and the silicon portfolio provides a streamlined and powerful platform as a comprehensive source for hardware, software, tools and service needs.

Freescale Enablement

More information about Freescale Kinetis MCUs based on the ARM core, DSCs and S08 MCUs can be found at **freescale.com/Kinetis**, **freescale.com/DSC** and **freescale.com/S08**.

More information about Freescale modular hardware development platform and motor control solutions can be found at **freescale.com/Tower** and **freescale.com/motorcontrol**.

The FreeMASTER runtime debugging tool and CodeWarrior integrated development environment (IDE) studio are integral parts of motor control application development. To learn more, visit **freescale.com/FreeMASTER** and **freescale.com/CodeWarrior**.

Several design reference manuals on the topic of sensorless BLDC control, including DRM135, DRM078, DRM086, DRM128 and DRM117, as well as application notes such as AN4142, AN4376, AN4254 and AN1914, are available at **freescale.com**.

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