

Turning to Integrated Driver Electronics for BLDCs

Brushless DC motors (BLDCs) achieve commutation electronically by utilizing a permanent-magnet rotor, wound stator, and rotor-position sensing scheme instead of a mechanical commutator or brushes found in brush-type DC motor designs. With brush wear or arcing eliminated and as a result of other factors influencing brushless motor performance, BLDCs can achieve rapid acceleration and high speed, generate less audible noise and less electromagnetic interference, and promote long life with low maintenance. These features make BLDCs ideal to drive devices such as computer hard/floppy disks, fans, pumps, and countless other end-products in a wide range of industries.

Despite advantages, BLDCs have presented their own challenges in terms of technology, design, and capabilities. Typically, complex and bulky cabling has been required between motor and amplifier to attach discrete logic components “outside” the motor frame, which have added undesired size, weight, and cost. Traditionally expensive rare-earth magnets and rotor-position sensors further contributed to higher manufacturing costs. And, due to inherent limitations in chip technology, more chips were required in earlier years to achieve desired logic control functions.

With the latest advances in driver electronics that now can be integrated by a motor manufacturer directly into brushless motor designs, BLDCs are evolving rapidly to become faster, smaller, more versatile, more controllable and more cost-effective.

The Process of Electronic Commutation

Brushless DC motors produce torque through the interaction of two magnetic forces (the “field” and the armature). In permanent-magnet motors, because the field force is generated by magnets, the controlling electronics need only regulate the electromagnetic field in the armature. Once the motor starts to turn, however, current has to be changed in the armature to keep it moving. The process of switching the current as the motor rotates is known as *commutation*.

In a closed-loop 3-phase BLDC, electronic commutation generally works this way: The motor’s rotor consists of a steel shaft with permanent magnets or a magnetic ring fixed around the circumference. As the rotor turns, the shaft’s poles pass each of three Hall-effect sensors (usually mounted in or around the stator structure), where they sense the polarity of the permanent magnet field in the air gap. These sensors read the motor’s rotor position and enable the amplifier to switch the three winding phases on and off in the proper sequence to produce rotary motion.

The switching is accomplished as the sensors generate signals to a control chip (or “commutation chip”), which recognizes the rotor’s position and simultaneously provides signals into six “states” and outputs these signals to six solid-state power switches, which then steer current into the windings, keep the winding currents in sync with the rotor, and cause the motor to turn.

Virtually every component comprising driver electronics in BLDCs has undergone dramatic transformation, especially in the past five years. The advancements have enabled design-savvy motor manufacturers to take advantage of the latest technology and move to the next level: *designing and mounting integrated driver control electronics inside the motor frame*.

By taking advantage of integrated driver control electronics, users need no longer perform complicated hookups between motor and amplifier to attach components; motor size and weight are unaffected (remaining as compact as possible and often allowing direct replacement of existing brush-based assemblies); and fewer electronic components become necessary (delivering cost-effective economies during production and efficiencies during motor operation).

The boards serving as a platform for this newest generation of driver electronics can be designed in a circular shape for mounting easily inside a motor’s frame or configured for mounting in the “standard” encoder housing. These advanced driver electronics provide a capability to convert a multi-wire motor into a simple two-wire (single polarity) brushless DC motor with open loop speed control in voltages from 12v to 48v and currents from 8 amps to 10 amps, depending on windings used. (Dual polarity and bidirectional motors with a 3 amp limit also can be engineered.)

Technological Strides in Components

While the ability to integrate driver electronics into BLDCs owes much to a motor manufacturer's design engineering expertise, technological strides in the various system components have brought more alternatives and flexibility to motor designers.

For example, **control (or commutation) chips** have become smaller, denser, more intelligent, more feature-packed, and otherwise enhanced. They have been developed in a wide range of variations to meet functional requirements.

Occupying significantly less real estate, one single chip can now perform standard functions (on/off, direction, brake, and speed control) accomplished in the past by multiple chips. In addition, a series of **advanced support chips** designed into an assembly can serve to extend power supply range; convert analog to digital (or digital to analog); enable electrical interface; allow for linking to computer and/or communications systems; and govern temperature control and current limits, among other desired functions.

Control and support chips will continue to evolve and more features will become standard even as chips become smaller. While the expected proliferation of chip functions and choices may tend to make the chip-selection process more involved or complicated, a motor application will suggest relevant features. At the outset, several factors are best considered before choosing a control chip: *voltage range, current rating, and speed/torque requirements*. (A knowledgeable motor manufacturer can provide technical guidance to help match a chip's features with application requirements and custom-design the motor accordingly.)

Commutation sensor systems continue to play a major role in BLDC system function and performance. **Hall-effect sensors** remain the most widely used method. This cost-effective sensing system has matured since introduction in the late 1970s.

In earlier versions of Hall sensors, their location in the stator structure represented a potential drawback: the location of the angular position sensors subjected them to stator temperature conditions at times severe in high-performance applications. Severe winding temperatures during peak-load conditions would affect sensor switching performance and, in turn, limit system performance. (As an alternative, sensors could be located away from the immediate stator structure and use a separate magnet for angular sensing. However, while not subject to the potentially severe operating conditions, this configuration failed to compensate for armature reaction problems.)

Hall sensor technology has resolved the location/stator temperature issue. Today's silicon sensors can perform optimally in winding temperature ranges from -40°C . up to 150°C . The newest Hall sensors also are highly sensitive and can be positioned closer to the rotor if magnets are relatively weak.

Other alternatives for an angular position sensing system can include **electro-optical switches (optical encoders)**, most commonly a combination of light emitting diode (LED) and a phototransistor. A shutter mechanism controls light transmission between the transistor and the sensor. The sensor voltages can be processed to supply logic signals to the controller. This system lends itself to the generation of precise angular encoding signals and is often specified where greater resolution is desired.

Sensorless drives represent one of the newer methods to achieve commutation in BLDCs, although applications for these are relatively limited. (Some sensorless drives even remain configured to generate phase, or position, information from an external pick-up coil or Hall-effect sensor, as required in such applications as monitoring the position of the tape in VCR scanner head motor drives.)

Other components can be added for more functions, such as **Pulse-width modulation (PWM)** to control the speed of the BLDC. The speed control is made possible because the logic circuitry is already in place capable of switching the appropriate transistors on and off.

For high-performance applications, **DC analog output tachometers** can be incorporated in the motor design to provide velocity feedback for speed-control purposes or to close the loop in a servo system for added stability. Digital-type tachometers can be used successfully if the controlled motor speed range is in a region where the pulse rate is high enough to provide a sufficient servo bandwidth after the required filtering following D/A conversion. (However, when servo control is required over a wide range of speeds, down to a stop position, then rate information is required over the entire range and a digital tachometer would prove insufficient for system operation.)

Looking Ahead

While the basic design of BLDCs will probably change little in the years ahead, advances in driver electronics and in making motors "smarter" will continue to evolve as an outgrowth of enhanced technology and design expertise. Among the anticipated developments:

- Smaller control chips will be embedded with more standard, "intelligence" features.

- Sophisticated support chips will promote complex motion-positioning applications.
- Chips will be able to “communicate” with each other to a greater degree for enhanced programmable motion control.
- Advancements will impact favorably on precise motion-control applications in the semiconductor and other manufacturing industries (promoting robotics and pick-and-place tasks).
- Motor power capabilities will grow.

In addition, an increasing use of digital signal processors (DSPs) to control motors suggests that motor control will broaden its focus from hardware to software. End-users will clearly have many more motor options at their disposal.

It will be the particular application demands for a motor that will establish how the motor is designed and which components are best engaged. Viewed from this perspective, the role of the experienced motor manufacturer is expanding even as technology evolves to offer OEMs the latest design and production expertise for desired motor performance.

This technical article was prepared by the engineering team at Haydon Kerk Pittman Motion Solutions, a leader in motion technologies. Complex custom and ready-to-ship standard lead screw assemblies are made at USA facilities with a full range of onsite capabilities including designing, engineering and manufacturing.