Technical Article

Simple BLDC Motor Spinning 101, Part 2: Sensored v. Sensorless Motor Control

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It has been a while since I posted part 1 of this simple brushless DC (BLDC) motor spinning 101 blog series, in which I talked about the five key priorities when designing a BLDC motor-control system: efficiency, noise, flexibility, dependability and cost. Now it's time to take a look at common three-phase BLDC motor-control approaches from a few different angles. Let's start with sensored vs. sensorless motor control.

Unlike a brushed DC motor – where the control approach could be as simple as direct drive with a battery – without the brush, a BLDC motor has to find an alternative for motor commutation. The first idea that came to engineers' minds was to leverage sensors. There are different ways of categorizing these sensors, and I see them as two types:

- **Resolver and/or optical encoder (**Figure 1**).** These sensing components measure motor rotor angles with very high resolution, enabling precise position/speed control and high efficiency. On the other hand, both are expensive (especially resolvers) and need additional data conversion/processing in the system, which further increases system cost. As a result, these sensors are more common in specific industrial and automotive applications that require high-performance/high-precision motor control.

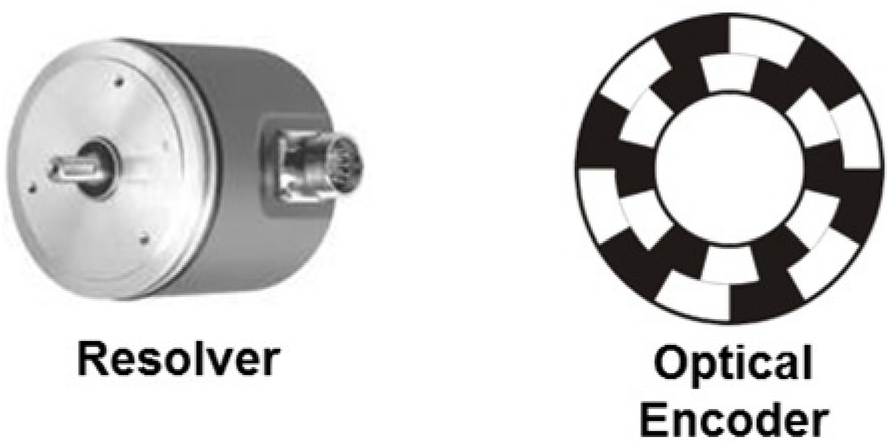

Figure 1. Resolver / Optical Encoder

- **Hall-effect sensing element/integrated circuit (IC) (**Figure 2**).** These magnetic-field-sensing devices based on the Hall effect can signal a change in magnetic field polarity, which you can leverage for motor commutation. By nature, a BLDC control system based on Hall-effect sensors doesn't provide the highest resolution, but the relatively low cost of Hall-effect sensors compared to resolvers and optical encoders often makes it a cost-effective, "good enough option." This is the most common sensor choice when very high precision is not the most critical application requirement.

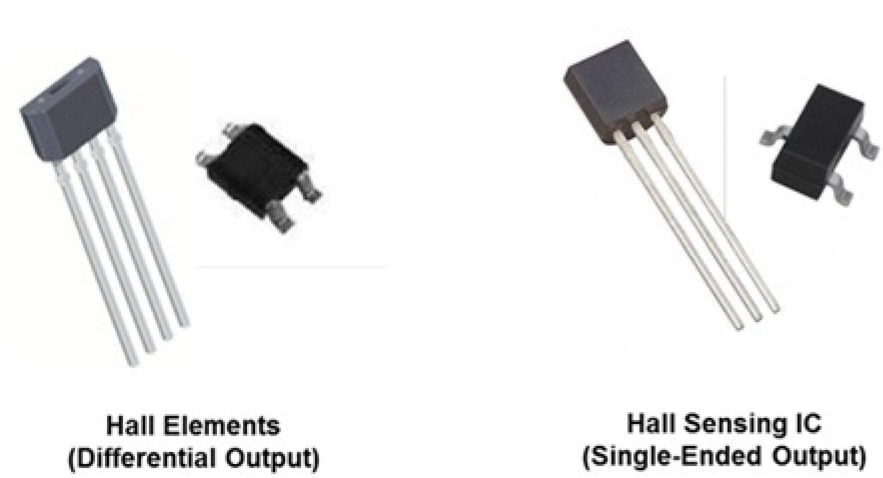

Figure 2. Hall-effect Sensing Element/Integrated Circuit (IC)

Hall-effect sensors do a decent job spinning motors, especially when load conditions vary drastically, to enable dependable motor operation. However, motor control engineers are not perfectly happy with them for three main reasons:

- The amount of effort involved in the motor manufacturing process, including Hall-effect sensor placements, sealing and connections, and wiring the Hall signals out from the motor.
- The sensors and wires could wear out in the application.
- Even though the cost is lower than resolvers/optical encoders, Hall-effect sensors still add cost to the system, not only for the sensor itself but for the whole Hall sensor board. It also has the potential to add a change-in-mechanical-design cost to the motor.

Thus, there's a need for a "sensorless" solution, with which motor control engineers can solve all of these issues by getting rid of Hall-effect sensors in their motors. Typical sensorless motor control approaches include:

- **Position estimation** through the back electromotive force (BEMF) of a spinning motor (Figure 3). Given the nature of a motor, the BEMF is proportional to the product of magnetic field and motor speed, whereas motor position is a function of magnetic field. So with BEMF, you can know and control both the position and speed of a BLDC motor without the need for Hall-effect sensors. Challenges include how to get BEMF information and what to do if the motor speed is zero (that is, there is no BEMF information). I will briefly discuss these topics in my next post.

Figure 3. Example of the BEMF Voltage of a "Trapezoidal" BLDC Motor

- **Field-oriented control (FOC).** FOC does not necessarily mean sensorless because you can see resolvers/ encoders from time to time in an FOC system for servo applications. But as far as spinning a motor goes, FOC doesn't need sensors to do the job. I won't try to completely explain FOC in one paragraph of a blog post – it's really a bigger topic that involves things like vector control and Clarke/Park transformations. But I would like to focus on why people want to spend time on FOC. Compared to other sensorless approaches, FOC provides smooth motion at low speeds and efficient operation at high speeds, which is a highly flexible and dependable operation that the BEMF approach cannot easily achieve. And it should come as no surprise that implementing an FOC system requires very powerful microcontrollers, so the system cost is higher.

Do you feel I'm missing anything about sensored/sensorless BLDC motor control? Feel free to share your thoughts in the comments section below. In my next post, I'll discuss BLDC motor-control approaches from a different angle and talk about trapezoidal and sinusoidal-control algorithms.

Additional Resources

- Download a white paper with more on sensorless control.
- Read more about applications for Hall sensors.
- Watch a video to learn more about a reference design for brushless motors for power tool application.
- Watch a video to view the correct sequence for commutating a three phase brushless DC motor.