Introducing FETtec SFOC: A New Standard in Motor Control

Overview of FETtec SFOC

FETtec SFOC (Simplified Field Oriented Control) is an innovative approach to control brushless three-phase motors, enhancing efficiency, lowering current and torque ripple, and improving response times. With FETtec SFOC, users can experience up to a **13% increase in efficiency** and up to a **30% boost in acceleration**, alongside other benefits such as stronger sensorless motor startups, reduced noise, and smoother motor operation.

Benefits for FPV Pilots and Industry

- **Enhanced Efficiency:** Up to 13% increase in efficiency means longer flight times with less battery drain, crucial for racing, freestyle sessions or extended operations.
- **Accelerated Performance:** Up to 30% faster acceleration provides a competitive edge, delivering swift responses for dynamic maneuvers in various applications.
- **Reliable Motor Startups:** The stronger sensorless startup ensures consistent and dependable motor engagement.
- **Reduced Noise:** Lower electrical noise translates to less interference, crucial for maintaining a clear video signal.
- **Smoother Operation:** A quieter and smoother running motor enhances the overall flying experience and reduces acoustic signatures for stealth operations in noise-sensitive environments. It also contributes to less wear and longer service life.

The Evolution of ESC Technology

The journey of electronic speed controller (ESC) technology in drones and other applications has been marked by significant advancements, each step bringing us closer to achieving optimal motor control efficiency and performance. Understanding this evolution provides insights into the technological milestones that have shaped today's state-of-the-art system: FETtec SFOC, which brings forth the culmination of efficiency and performance improvements over previous technologies.

Block Commutation: The Classic Approach

Block commutation is the simplest form of motor control with a straightforward on-off phase sequence for motor rotation.

Pros:

- Its simplicity makes it easy to implement and reliable for basic applications.
- Generally exhibits lower PWM switching losses, advantageous in various operational conditions, and eliminates the need for PWM at full throttle.

Cons:

- It is the least efficient method on motors with sinusoidal BEMF, as phases are open/disabled 33% of the time, not generating torque.
- The sharp transitions in current lead to torque and current ripple, reducing smoothness in motor operation.
- Demagnetization losses occur, where energy stored in the motor's coils discharges inefficiently, creating heat and potentially high RF noise.

Sinusoidal Commutation: The Efficient Advance

Sinusoidal commutation represents an advancement over block commutation by supplying current to the motor's phases in a sinusoidal pattern, matching the motor's BEMF waveform more naturally

Pros:

- It offers higher efficiency compared to block commutation.
- The motor operates with lower torque and current ripple, providing smoother operation.
- There are no demagnetization losses.

Cons:

- Sinusoidal commutation leads to higher switching losses due to continuous PWM across all transistors.
- Reduced maximum power output compared to block commutation.

Space Vector Modulation (SVM): The Integrated Technique

SVM ESC technology integrates the benefits of both block and sinusoidal commutation, optimizing efficiency and power delivery.

Pros:

- High efficiency and good phase current supply.
- Low torque ripple and current ripple, with no demagnetization.
- Enables full power delivery to the motor.

Cons:

- Higher switching losses than block commutation, though less than sinusoidal commutation.

FETtec's previous ESC firmware already utilized SVM with 16% phase interruptions for BEMF reading, while the new SFOC approach enables uninterrupted SVM, thus improving efficiency and control.

Sensorless Field Oriented Control (FOC): The Ideal but Complex Solution

Sensorless FOC offers efficient motor control by maintaining an ideal sinusoidal current supply without needing to switch off any phase. It aligns the current precisely with the motor's magnetic field for optimal efficiency.

Pros:

- Maximizes efficiency in motor control.
- Ensures smooth operation and precise control.

Cons:

- It requires complex observers and detailed motor models for accurate rotor position tracking.
- The computational demand limits its use, mostly to 100-200k e-RPM, not enough for higher speed motors used in drones.

FETtec SFOC: The Pinnacle of ESC Technology

FETtec's SFOC technology addresses these challenges by simplifying the computations required in conventional FOC. This approach allows even basic microcontrollers to manage motors effectively at speeds above 400k e-RPM, pushing the boundaries of what's possible in drone motor control.

Advantages of FETtec SFOC:

- Simplifies the complexity of sensorless FOC calculations, allowing for high-speed application in a cost-effective manner.
- Delivers performance close to sensorless FOC with the added benefit of being suitable for cost and size-sensitive applications.
- Brings high precision to a broader range of motor types, enhancing versatility and bridging the gap between the precision of BLDC and PMSM motors, making it a versatile solution for various drone types.

FETtec's SFOC represents a significant leap in drone ESC technology, bridging the gap between efficiency and practicality, redefining the standards of motor control.

Glossary

- **BEMF** stands for Back Electromotive Force. Essential in electric motor operation, BEMF refers to the voltage generated by the rotor's movement within the stator's magnetic field. In sensorless systems, it is one of the methods used to deduce the rotor's position—vital for the timing of motor control commutation. However, it is not the sole method; others like High-Frequency Injection (HFI) are also employed for rotor position tracking without physical sensors. Effective BEMF management or alternative methods like HFI is crucial for precise motor control, necessary for various high-performance applications.

- **e-RPM** or electrical revolutions per minute, is a term used to describe the speed of an electric motor in terms of the number of electrical cycles its electronic speed controller (ESC) completes in one minute. This metric is particularly relevant for brushless motors, like those found in FPV drones and various electric vehicles.

  Unlike the mechanical RPM, which indicates the actual rotational speed of the motor's rotor (how many times it physically spins around in a minute), e-RPM focuses on the electrical aspect. In brushless motors, for each mechanical revolution, there are multiple electrical commutations or cycles. These electrical cycles are necessary for the ESC to energize the motor windings in the correct sequence to produce motion. The e-RPM is thus higher than the mechanical rpm, especially in motors with a high number of pole pairs.

  In contrast, the KV rating of a motor is a specification that indicates the motor's speed in relation to the voltage supplied to it, under no-load conditions. It tells you how many revolutions per minute (RPM) the motor will theoretically turn for each volt of electricity supplied. For example, a 1000 KV motor will spin at 1000 rpm for every volt applied. This rating is independent of the motor's load and purely a characteristic of the motor itself.

  Therefore, while e-RPM is a measure of the ESC's electrical output frequency to the motor, the KV rating is a fixed property of the motor that defines its speed potential per volt. The difference between the two is crucial in applications where precise motor control is necessary, such as in FPV drones, where both the responsiveness of the ESC (reflected in e-RPM) and the inherent speed capability of the motor (indicated by KV rating) are key factors in performance.

- **Switching Losses** refer to a type of power loss that occurs in electronic components like transistors (including MOSFETs) when they switch states between on and off. These losses are especially relevant in devices like ESCs for FPV drones, where the transistors switch on and off rapidly to control motor speed.

  When a transistor switches from the off state to the on state or vice versa, it doesn't change states instantaneously. During the transition period, the transistor is neither fully on nor fully off. It's in a state where both voltage across it and current through it are significant. Since power loss is the product of voltage and current ($P = V \times I$), this transitional state results in power being dissipated as heat.

  The two main components of switching losses are:

  Turn-on Loss: When the transistor begins to turn on, the voltage across it starts to drop, but the current through it has not yet reached its maximum level. This period of partial conduction results in power loss.

  Turn-off Loss: Similarly, when the transistor turns off, the current through it begins to decrease while the voltage across it rises. Until the transistor is fully off, there is a period where both current and voltage are present, leading to power loss.

  In an ESC, which switches the current to the motor windings at high frequencies (often in the kilohertz range), these switching losses can be significant. The faster the switching frequency, the more often these losses occur, potentially leading to higher total power loss and more heat generation. This is why efficient switching and heat management are crucial in ESC design, especially for high-performance applications like FPV drones where both efficiency and minimizing weight (including cooling mechanisms) are important.

  Reducing switching losses is a key goal in ESC development, achieved through design choices such as selecting MOSFETs with faster switching capabilities, optimizing the drive voltage for the gates of the MOSFETs, and fine-tuning the PWM algorithms.