Application Brief

High-Efficiency , Code-Free Sensorless BLDC Motor Drives for Scalable Systems

Code-Free Sensorless Control of BLDC Motors

Development of a sensorless end usable motor control algorithm for brushless DC (BLDC) or permanent magnet synchronous motor (PMSM) can be complex and time consuming. There can be different challenges, including the reliable motor starting in all scenarios without backspin, on-the-fly catch of initial motor spin in either direction, accurate sensing of motor current and voltages for the reliable estimation of motor position. Other challenges include the variation of motor parameters, controlled motor stopping, faster acceleration and deceleration, ultra-high speed, built-in protection against motor lock, over current and short circuit, and so on. This process can be difficult and requires longer development and test time. The MCT8329A code-free sensorless trapezoidal control three phase gate driver helps designers accelerate a design, tune motors for improved performance without writing code, and enables scalable, high efficiency, low-noise, robust motor control.

MCT8329A for a Powerful, Compact, and Highly Efficient Drive

For applications such as vacuum cleaners and blowers, a high-speed operation can reduce the size of the system and provides powerful suction or air flow. However, controlling a BLDC motor using sensorless methods at ultra-high speeds can be challenging and can result in lower efficiency due to improper motor commutations.

The MCT8329A device integrates multiple techniques to achieve improved efficiency across operating speeds.

1. **Hybrid Commutation Scheme**: The MCT8329A device integrates a hybrid commutation, where the commutation instant is determined by using back-EMF integration at low-medium speeds and by using built-in precision comparators (BEMF zero crossing) at higher speeds. The algorithm automatically transitions between back-EMF integration and comparator-based commutation depending on the motor speed. The built-in comparator based commutation enable high efficient ultra-high speed more than 3 kHz (more than 180 kRPM for a 2-pole motor) motor electrical frequency. Figure 1 shows more than 3 kHz operation of MCT8329A illustrating proper commutation giving optimum motor current.

   Figure 2 shows initial speed detection at 3 kHz motor speed and on-the-fly catch to closed loop commutation.

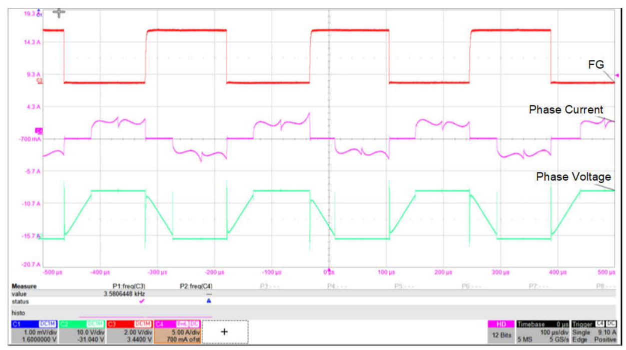

Figure 1. Motor Speed More Than 3 kHz with MCT8329A

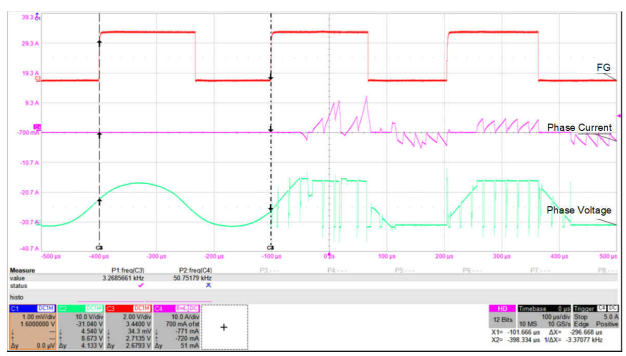

Figure 2. On-The-Fly Catch at 3 kHz Initial Speed using MCT8329A

2. **Lead-Lag Control**: To achieve optimized efficiency, the drive state of the motor must be controlled so that the motor phase current is aligned with the motor BEMF voltage. For motors with high saliency, a slight advance or delay of motor current compared to back EMF can provide increased torque output and increased efficiency. The MCT8329A integrates lead-lag angle control (-20° lead and 30° lag) to maximize efficiency and torque output.

3. **Mixed PWM Modulation**: The traditional commutation of BLDC motor uses high side modulation where the high side power switch is switched at PWM frequency at the target duty cycle for 120 ° electrical period. The low side power switch is kept on continuously for 120° electrical period. The other approach can be low side modulation. In either case, there can be current in the floating phase winding while the other phases are switching, as shown in Figure 3. This can reduce the effective torque, and increase the torque ripple, which results in additional power loss and can cause unequal distribution of losses between the high side and low side switches. This results in reduced torque delivery at lower duty cycles.

   The MCT8329A device integrates a mixed modulation scheme where the floating phase current can be eliminated as shown in Figure 4, resulting in improved torque, efficiency, and equal distribution of losses.

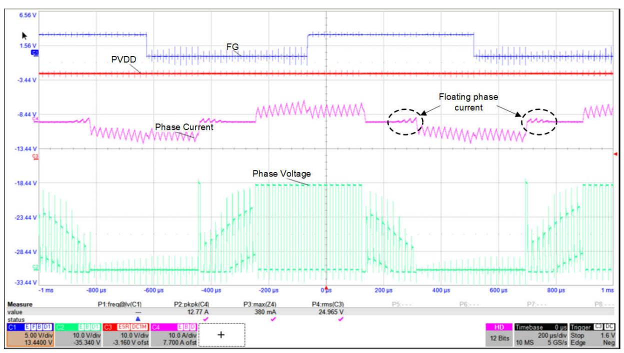

Figure 3. High Side PWM Modulation

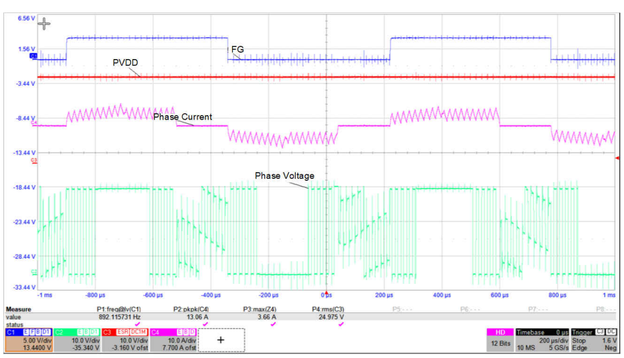

Figure 4. Mixed PWM Modulation

4. **Dynamic Voltage Scaling and Dynamic Degauss**: The MCT8329A device integrates techniques to improve the accuracy of motor commutation instant. The dynamic voltage scaling for back EMF sensing comparators optimizes the voltage sense resolution across a wide range of operating voltage. The dynamic degauss feature (or adjustable degauss window) allows the user to tune the back EMF sensing window until the commutating phase current reaches zero to eliminate false back EMF sensing.

Quiet BLDC Motor Operation

For home, office, or commercial uses, lower noise is a prime requirement in motor drive applications. The MCT8329A provides advanced sensorless trapezoidal control techniques with additional 150° modulation to reduce BLDC motor noise by 2-4% compared to conventional 120° trapezoidal control designs.

Figure 5 shows the phase current for a high speed (1 kHz electrical) vacuum cleaner low inductance motor in 150° commutation.

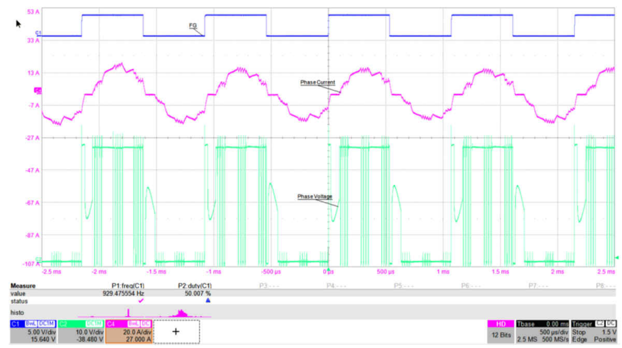

Figure 5. High Speed Operation of a Vacuum Cleaner Motor with 150° Modulation

Scalability to Achieve up to 100% Development Reuse

Development of a single platform across multiple end applications helps reduce production cost, improve inventory management, lower design effort and enable faster release to market. The MCT8329A device enables scalability across voltage, power, and motor control algorithms.

1. **Scalability across voltage**: The MCT8329A driver supports operating voltage from 4.5 V to 60 V that can support single PCB design for different application voltages such as 5 V, 12 V, 18 V, 24 V, 36 V and so on by scaling the external MOSFETs and capacitors. The integrated gate driver architecture of bootstrap with charge pumps helps to achieve 100 % duty cycle support and a VGS of more than 8 V for external MOSFETs (even at 5-V DC supply voltage) and provides sufficient gate-to-source voltage for a standard MOSFET.
2. **Scalability across power**: The gate drivers in the MCT8329A device can provide up to 1 A source and 2 A sink current for the external MOSFETs, help to drive applications that require power levels more than 1 kW, and allows the designer to create a single platform across application

power levels by changing the on-state resistance (R_{DS_ON}) of the external MOSFET by properly sizing the sense resistor and the bulk capacitor and adjusting the gain of integrated current sense amplifier.

3. **Scalability across motor control**: The MCT8329A device integrates 120º and 150º commutation, configurable PWM switching frequencies, and PWM modulation schemes to select the control as per application need.

Fast Real Time Control System Response

There are many applications that require fast acceleration or deceleration of motor. Applications such as CPAP machines and automotive fuel pumps must decelerate and accelerate within few tens of milliseconds. A vacuum cleaner must accelerate to full speed within couple of seconds for improved user experience. A fast acceleration or deceleration poses system challenges including a loss of sync for sensorless motor control, pumping energy back to the DC bus, which increases DC bus voltage that can require higher rated capacitor or higher rating of downstream devices.

The MCT8329A delivers real-time responses by providing fast, reliable, and safe operation for fast start up and acceleration to full speed and fast stop. With the patented fast deceleration technology in the MCT8329A driver, it is now possible to achieve up to 50% faster deceleration than traditional motor control techniques. The MCT8329A stops the motor without pumping energy back into the battery, which protects the motor system from damage. Figure 6 shows the deceleration of a CPAP motor from 33 kRPM to 3.3 kRPM within 130 ms.

The MCT8329A device integrates reliable fast start up methods with independently configurable start up and open loop setting and with automatic open loop to closed loop hand-off, the user can achieve faster start up time, such as 35 ms start up time from stationary to full speed (270 Hz) in an automotive fuel pump application, as shown in Figure 7. Figure 8 shows acceleration to full speed of 1.2 kHz (72 kRPM) in a vacuum cleaner motor within 1.5 seconds using the MCT8329A driver.

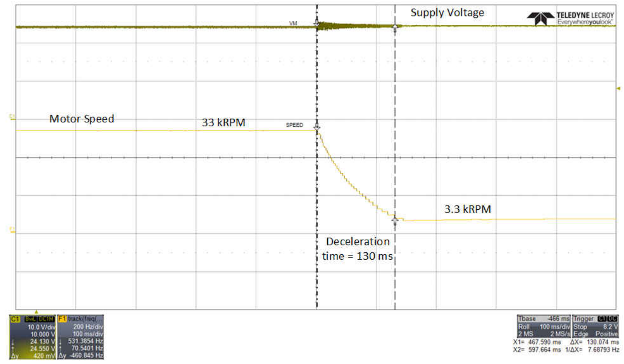

Figure 6. Fast Deceleration with a CPAP Motor using MCT8329A

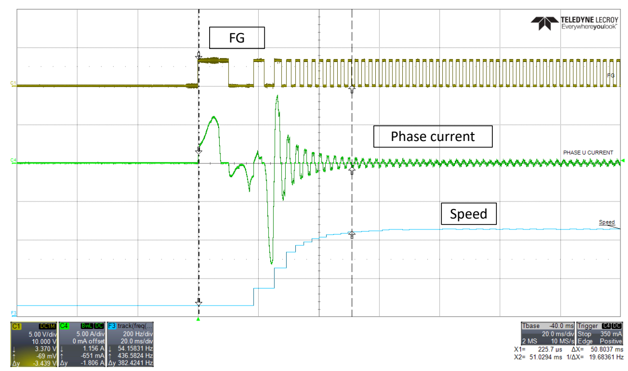

Figure 7. Fast Acceleration with a Fuel Pump Motor using MCT8329A

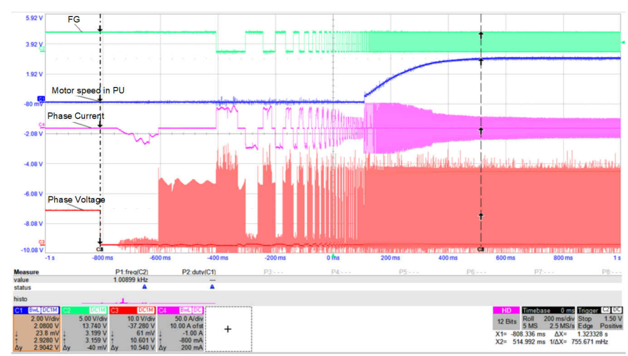

Figure 8. Fast Acceleration with a Vacuum Cleaner Motor using MCT8329A

Conclusion

The MCT8329A driver can help design the next generation of high speed powerful vacuum cleaners, garden leaf blowers, or other BLDC applications by enabling a scalable, ultra-high-speed, efficient and fast responding platform design.

References

1. Texas Instruments, *MCT8329A High Speed Sensorless Trapezoidal Control Three-phase BLDC Gate Driver*, data sheet.