Low-Voltage Motor Drive Operation with a Smart Gate Driver

Introduction

Low voltage operation is a crucial consideration for motor drive system design. Motor drivers operate in harsh applications, many of which have inconsistent loads and operating conditions. For example, battery powered hand tools have frequent changes in load which create changes in power delivery from the battery to the motor. In these situations, the motor may experience transient periods of low voltage. The battery supplied system experiences a high load and the voltage from the battery will drop as the device tries to draw more current. This voltage drop may cause the device to trigger undervoltage lockout (UVLO) and stop operating. Some gate drivers, such as TI's Smart Gate Drivers, can avoid problems of low voltage dropouts with minor modification to maintain consistent operation during transient periods of low voltage.

Undervoltage Lockout (UVLO)

Undervoltage lockout is one of many safety features employed in TI motor driver solutions. Motor drivers require a certain amount of input voltage to operate properly. If a certain voltage is not met, the functionality and performance of the device can be unknown, making it difficult to predict the system's behavior. Some examples of the detrimental effects include logic functions generating the wrong control signals and incorrect gate switching, both which could damage the device and the system. UVLO protection is included to protect against the negative effects of supply drop-out and disconnection. Whenever the on-chip monitor detects the voltage level is below the operable threshold, the device outputs are disabled and the device performs a controlled shut down, reporting a fault condition. Using the earlier situation as an example, if a high load causes a voltage drop, UVLO can trigger and protect the device from erroneous operation.

Modified Circuit to Improve Low-Voltage Operation

By using a simple diode in series with the driver supply pin, the device can be operational for transient durations when a voltage drop occurs or if the supply is momentarily disconnected. The diode will allow energy to be stored in the VM capacitor which can hold up the device supply in the case of battery droop and avoid triggering UVLO. (see Figure 1). This modification can easily be used in gate drivers that implement a VDRAIN pin.

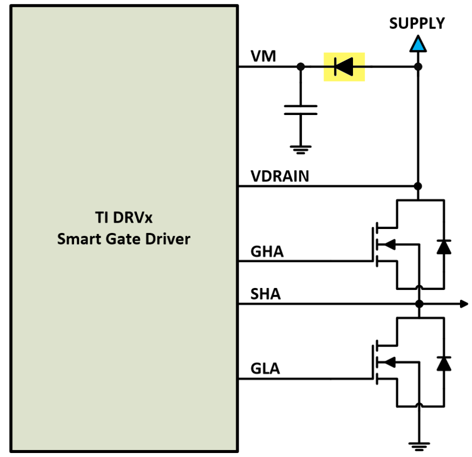

Figure 1. Modified Circuit with Diode

VDS Monitors and VDRAIN

TI Smart Gate Drivers implement adjustable VDS voltage monitors used to detect short-circuit and overcurrent events on the external power MOSFETs. These monitors will trigger a fault if the VDS trip point is reached. The high-side MOSFET monitors measure the voltage between the VDRAIN and SHx pins. A VDRAIN pin ensures the sense line for the overcurrent monitors and the power supply stay separate and prevents the overcurrent monitor triggering inaccurately due to measuring the incorrect voltage difference across the switch. Some gate drivers do not integrate a VDRAIN pin. These types of devices use the gate driver power pin (VM for example) as the reference for the VDS monitor. These devices will not be operable using this modified circuit because it will cause the overcurrent monitor to trip incorrectly.

Transient Operation Time

An estimate can be made of the transient time that the device can stay on despite the battery voltage falling below UVLO by using basic charge and current relationships.

$$I_{avg} = Q_G \times f_{PWM} \times n \quad (1)$$

$$I_{TOT} = I_Q + I_{avg} + I_{internal} \quad (2)$$

$$dt = C\frac{(V_{NOM} - V_{UVLO})}{I_{TOT}} \quad (3)$$

The transient time *dt* is the time that the capacitor will discharge from nominal voltage to the UVLO threshold voltage. The difference between these two voltages is denoted by $V_{NOM} – V_{UVLO}$. The total current, I_{TOT}, is the sum of the given internal device quiescent current plus the total average current drawn from the FETs that are switching. Additionally, the total current may also include the current from the internal clamping diodes within the device which activate when the high side V_{GS} exceed a certain voltage level. The number of FETs switching is denoted by *n* which varies by system. In sinusoidal systems, there are typically six FETs switching at once whereas for trapezoidal systems, two are switching in brake mode and one in coast.

Complete Turn Off vs Momentary Turn Off

A DRV832x device with Smart Gate Driver technology drives a motor and uses a diode at VM to implement the low voltage operation method. Figure 2 displays what occurs when power is suddenly removed from the system (for example to 0 V). With this configuration, the driver remains operational for a little over 1.6 ms. The gate driver is clamping the gate drive voltage on the high-side FETs to 16 V using internal gate clamps. There is a VGS enhancement of about 10 V (on a VM of 0 V) right before the DRV832x triggers UVLO.

- FETs: CSD18540Q5B QG = 41 nC
- PWM: 25 kHz
- VM = 12 V > 0 V
- Trap Control

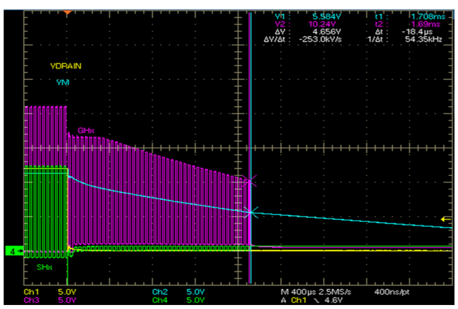

Figure 2. Complete Turn Off With Diode

Figure 3 displays what occurs when the supply is suddenly removed (for example to 0 V) and then reconnected after 1 ms. The driver continues to run but the motor stops in this test.

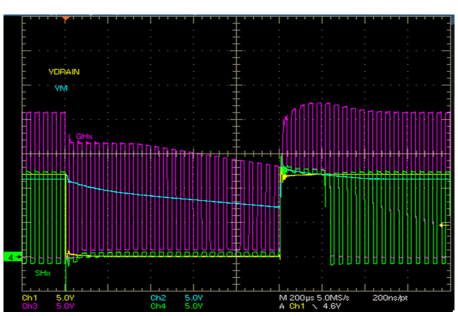

Figure 3. Momentary Turn Off With Diode

Figure 4 shows a DRV832x device tested with a diode and repeated voltage drops with an off time of about 0.9 ms. The driver continues to run and the motor continuously spins. Without the diode, the driver does not operate.

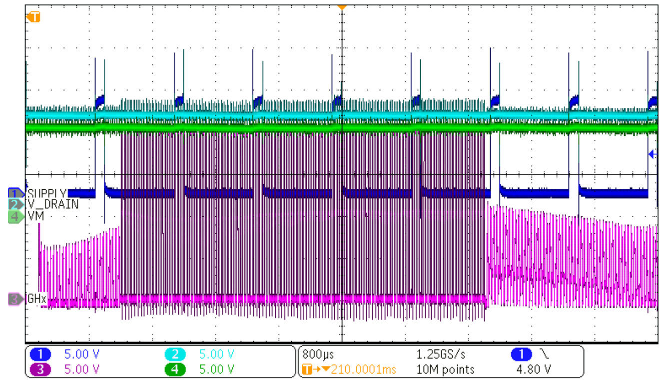

Figure 4. Recurring Voltage Drops with Diode

Conclusion

Reliability is a key factor in systems that involve motors. With minimal components, the motor drive system can be improved and optimized for many applications. Having features that ensure the system operates consistently and efficiently brings a lot of value for the system designer. TI's BLDC motor drivers with Smart Gate Drive provide this reliability, as well as improved efficiency, protection, and optimization features.

Related Links

- BLDC Motor Driver Portfolio
- Understanding IDRIVE and TDRIVE in TI Smart Gate Drivers
- Reduce Motor Drive BOM and PCB Area with TI Smart Gate Drive
- Six weird ways to design with a brushless-DC driver

Devices Featuring Smart Gate Drive Technology
DRV8343-Q1
DRV8353, DRV8353R, DRV8350, DRV8350R
DRV8323, DRV8323R, DRV8320, DRV8320R
DRV8306
DRV8304
DRV8305-Q1
DRV8305

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265