Smart Gate Drive

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In many motor drive designs, gate drivers to control power MOSFETs and drive current in electric motors. A gate driver needs to be flexible enough to drive a wide variety of external MOSFETs for different system applications and power levels. Rather than using different external components for different applications, TI accomplishes this through Smart Gate Drive technology. Smart Gate Drive technology was developed to make designer's jobs easier by providing the ability to adjust the MOSFET slew rate, optimize switching loss and EMI performance, automatically generating a closed-loop dead-time, and provide additional protection features for the power MOSFETs and motor system. All of these features are incorporated into the gate driver itself without the need for external components, saving cost and board space. Continue reading to learn more about the features and benefits of Smart Gate Drive technology.

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1 Introduction

Smart Gate Drive technology offers a combination of protection features and gate-drive configurability to improve design simplicity, reduce the number of external components, and bring a new level of intelligence to motor systems.

2 Smart Gate Drive Technology Features

2.1 Flexible Slew Rate Control

The gate drive current controls the slew rate and therefore how quickly a MOSFET is turned on or off. The turn on and off speed plays an important role in the overall thermal and EMI performance of a system. Traditional gate drivers require external resistors and diodes placed on the board to control the slew rate. Designers must figure out the best balance between the MOSFET switching speed and EMI emissions when choosing the external components. Once the board is built, the slew rate is set and can no longer be changed adjusted easily. As shown in Figure 1, up to 4 external components are needed per MOSFET, increasing the board size and adding cost. The R_{source} and R_{sink} resistors limit the current between the gate driver and MOSFET gate. The diode provides a path for the rise and fall slew rate to be individually adjusted. $R_{pulldown}$ ensures that the MOSFET remains disabled when the gate driver is inactive. When using these external components, their values are fixed, and the slew rates cannot be adjusted without physically replacing all of these components for each MOSFET.

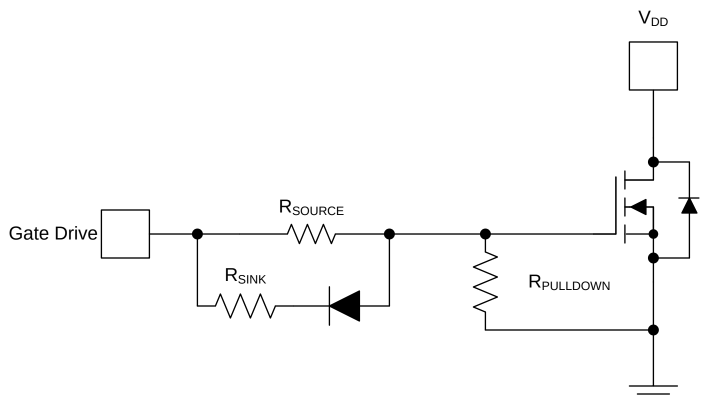

Figure 1. Traditional Components Between Gate Driver and MOSFET

With Smart Gate Drive, these external components are no longer needed. Gate drivers with Smart Gate Drive technology have multiple internal switches as shown in Figure 2 to adjust and control the drive and sink current, otherwise known as IDRIVE. This adjustability provides designers the flexibility to choose the gate drive strength to meet their EMI and performance requirements. With a simple SPI command, designers can easily adjust the slew rate as desired for their system. In addition, by eliminating the need for extra external components, Smart Gate Drive products can save substantial board space and cost. Since each MOSFET requires up to 4 external components, up to 24 components can be eliminated from the board with three phase motor designs. See the 48V/500W Three-phase Inverter with Smart Gate Driver Reference Design as a design example using Smart Gate Drive products.

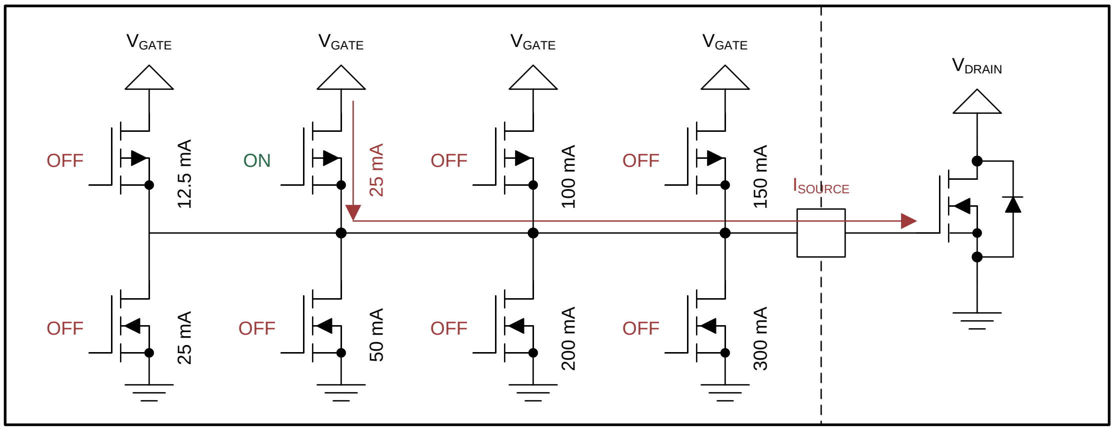

Figure 2. IDRIVE Settings, Programable Slew Rates

2.2 *Closed-Loop Dead Time*

Dead time is the period between when one MOSFET in a half bridge is turned off and its opposite MOSFET in the half bridge is turned on. This is also commonly referred to as cross-current or cross-conduction prevention. It is very important to make sure that both MOSFETs are not on simultaneously, which would cause a low impedance path from the supply to ground known as a shoot-through condition. Shoot through can damage the MOSFETs, so it must be prevented.

Normally, dead time is inserted by delaying the turn on signal by an amount of time to give the driver plenty of time to turn off one MOSFET before turning on the other. The downside with this approach is the system has no real awareness of whether the MOSFET is on or off. If the inserted dead time is too short, the driver may complete the dead time and turn on the opposing MOSFET before the deactivating MOSFET is completely turned off. To cover all possible cases, system designers must add a significantly long enough dead time to cover any worst case scenario. A long dead time will reduce the efficiency of the motor driver due to the diode conduction losses while all of the MOSFETs are off. Smart Gate Drive simplifies dead-time insertion through intelligent monitoring. Smart Gate Drive products monitor the gate voltage of all MOSFETs to ensure that one MOSFET is disabled before turning on the opposite MOSFET in the half bridge. By monitoring the gate voltage, the dead time is controlled as a closed loop. As shown in Figure 3, Smart Gate Drivers will insert an optimal period of dead time once the MOSFET is turned off before turning on the other FET in the half bridge compared to traditional gate drivers where a long period of dead time is applied at the input to hopefully accommodate for the worst case scenario. This closed loop scheme provides better assurance that shoot-through events will not happen.

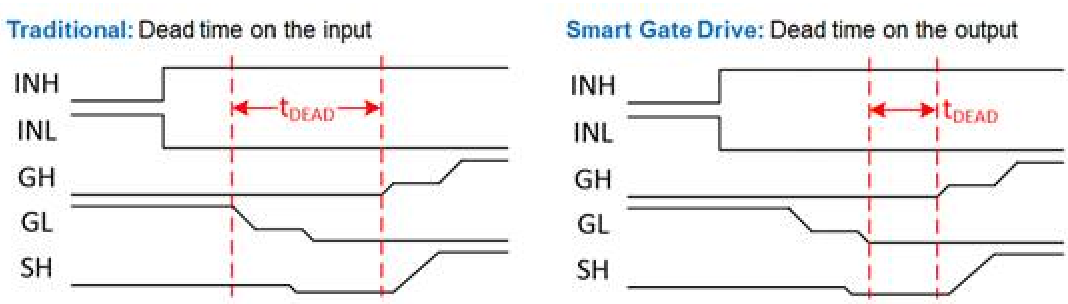

Figure 3. Traditional Dead Time Compared to Smart Gate Drive Dead Time

2.3 MOSFET Gate Fault Protection with Smart Fault Response

The ability to monitor the state of external MOSFETs can have a big advantage in understanding if the MOSFETS and the motor are operating as expected. As mentioned previously, Smart Gate Drive products monitor the MOSFET gate voltage continuously as shown in Figure 3.

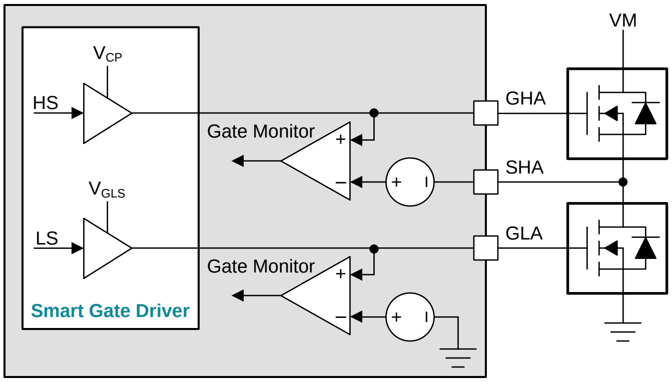

Figure 4. Smart Gate Drive Gate Monitor

Not only does this help with cross-current protection through closed-loop dead time insertion, but the monitor checks if the MOSFETs are operating as expected. If a MOSFET is being turned off or on by the gate driver and the MOSFET gate voltage does not actually change, the gate driver will report a gate drive fault indicate that there is something wrong with the MOSFETs. This sort of event can be caused by damaged MOSFETs or board-level pin shorts. Traditional gate drivers cannot detect these faults, and continuing to drive current into a damaged system may result in additional component damage or fire. Smart Gate Drivers can intelligently detect these situations, report the condition, and perform a controlled shut down.

2.4 Strong and Passive Pull Down Protection

Unintentional MOSFET turn-on is a dangerous event when a MOSFET that is supposed to be turned off is accidentally switched on. This may cause shoot through if the high-side MOSFET is already on. The MOSFET can be switched on through noise coupling onto the gate of the MOSFET, the most common way that this can happen is through the gate-to-drain capacitance of the MOSFET. When the high-side MOSFET turns on, the switching node (the trace between the high-side and low-side MOSFETs) will slew from low to high. This rising edge is coupled to the low-side MOSFET gate through this gate-to-drain capacitance. This effect can also be called dV/dt turn-on since the speed of the slewing directly effects the amount of coupling. If this coupling effect is strong enough and the gate voltage is pulled high enough, the low-side MOSFET can turn on causing shoot-through. Smart Gate Drivers help prevent these issues by integrating a strong pull down, which is an automatic current sink to ensure MOSFETs stay off. This strong pull down is used specifically when one MOSFET is turning on; the opposing MOSFET is held off using this strong current.

When the system is powered off, the Smart Gate Driver employs passive pulldowns to keep the MOSFETs off when the system is supposed to be off.

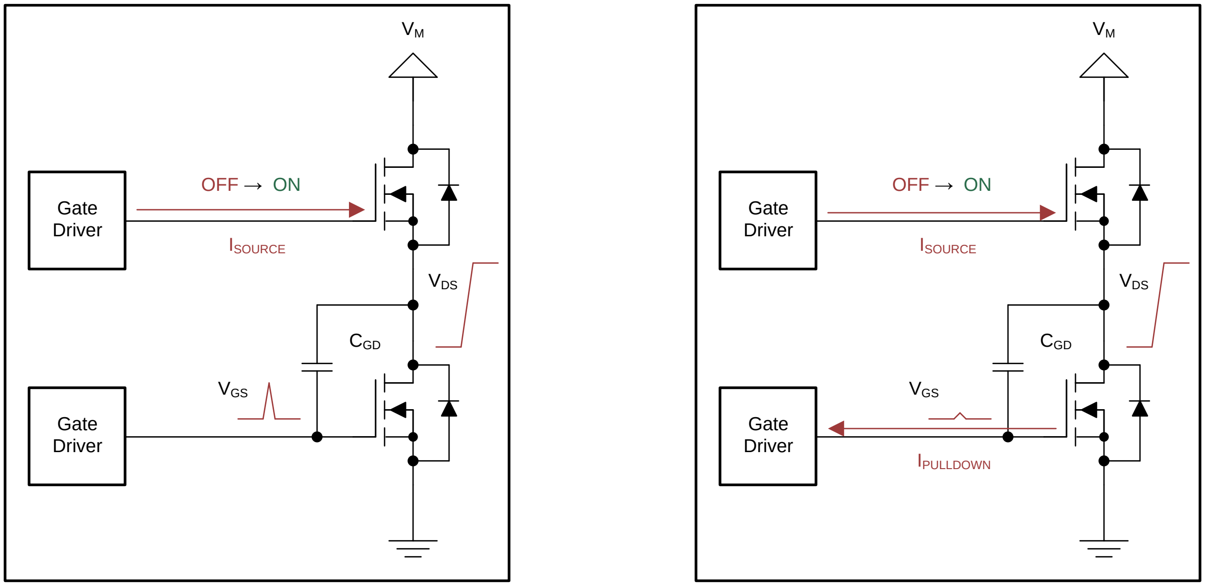

Figure 5. dV/dt Example

3 Summary

TI's Smart Gate Drive brings motor drives to a new level with its enhanced flexibility, ease of use, performance, and protection features. Not only does it save cost by reducing external components and board space, but it also provides designs with unparalleled protection and gate drive current configurability. For more information on Smart Gate Drive, visit our Motor Driver Technology page.

4 References

- Understanding IDRIVE and TDRIVE in TI Smart Gate Drivers
- Reduce Motor Drive BOM and PCB Area with TI Smart Gate Drive
- Motor Drive Protection With TI Smart Gate Drive
- Reducing EMI Radiated Emissions with TI Smart Gate Drive

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