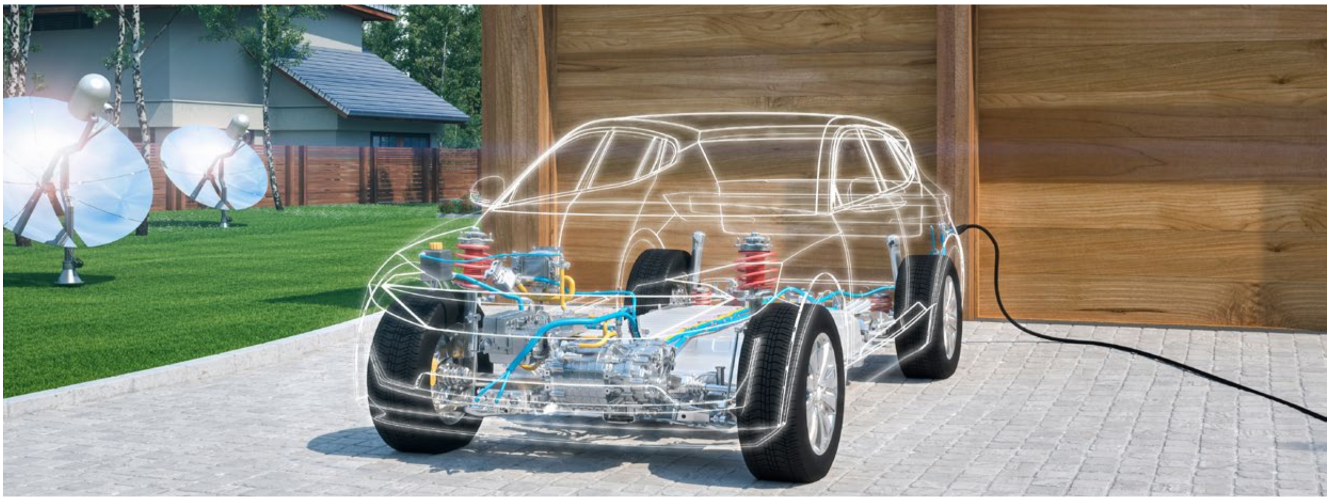
Gate drivers with dynamic gate strength improve EV performance



As a leading supplier of gate drivers for automotive EV traction inverters, NXP enables improvements in inverter efficiency, safety and vehicle performance. The GD3162's dynamic gate drive function delivers optimal switching performance for advanced power switch devices (e.g. SiC, GaN) over increasingly wide operating ranges. Dynamic gate strength on the GD3162 device boosts inverter efficiency, delivers a strong functional safety solution, and improves upon typical hardware design criteria to protect the power device.

The definitive features of an electric vehicle (EV) may be its battery and its electric traction motor, but these two necessitate the existence of a third element that is just as fundamental: traction inverters. A traction inverter is what makes it possible for an EV battery to work with an electric motor, converting DC power from the battery into AC power to drive the motor.

The EV market is now firmly established, but EV technology is far from fully mature. There are still improvements in EV performance, reliability and safety that are possible, and the automotive industry remains busy pursuing them. Significant attention has been focused on battery and motor technology, but a recent innovation in traction inverters is also consequential.

Gate drivers for traction inverters have recently been introduced that for the first time can toggle between multiple, preset current values in response to EV operating conditions; in other words, the gate drivers offer dynamic gate strength. One of the first examples is NXP's GD3162.

The ability to change the gate strength makes it possible for the inverter control algorithm to optimize the switching rate of the inverter's power device for the present condition on the motor. Examples include when the environmental temperature is very cold (which can affect the switching rate of the power device), or during regenerative braking (which can increase the bus voltage and cause device stress from overshoot), with vehicles that offer that feature.

The key benefit is that the overall efficiency of the EV is increased, but NXP's innovation also delivers a strong functional safety solution, while improving upon typical hardware design criteria to protect power devices.

It is up to the auto manufacturer to choose how to take advantage of the efficiency improvements but, for example, the OEM can use the improvement to increase the vehicle's range by a modest but measurable amount.

Gate drivers

An EV's traction inverter must deliver high power levels that vary from 80 kilowatts to over 200 kW, withstand high temperatures, and be lightweight.

Gate drivers in traction inverters drive the inverter's power devices, traditionally silicon IGBTs but increasingly silicon carbide (SiC) MOSFETs. Power devices are the switches that convert DC power from the battery into AC power for the motor.

An EV's traction inverter typically incorporates six discrete gate driver ICs and six power devices, two of each for each phase in a three-phase AC motor (see Figure 1). The gate drivers – including the gate strength commands – are typically managed by the traction inverter's microcontroller.

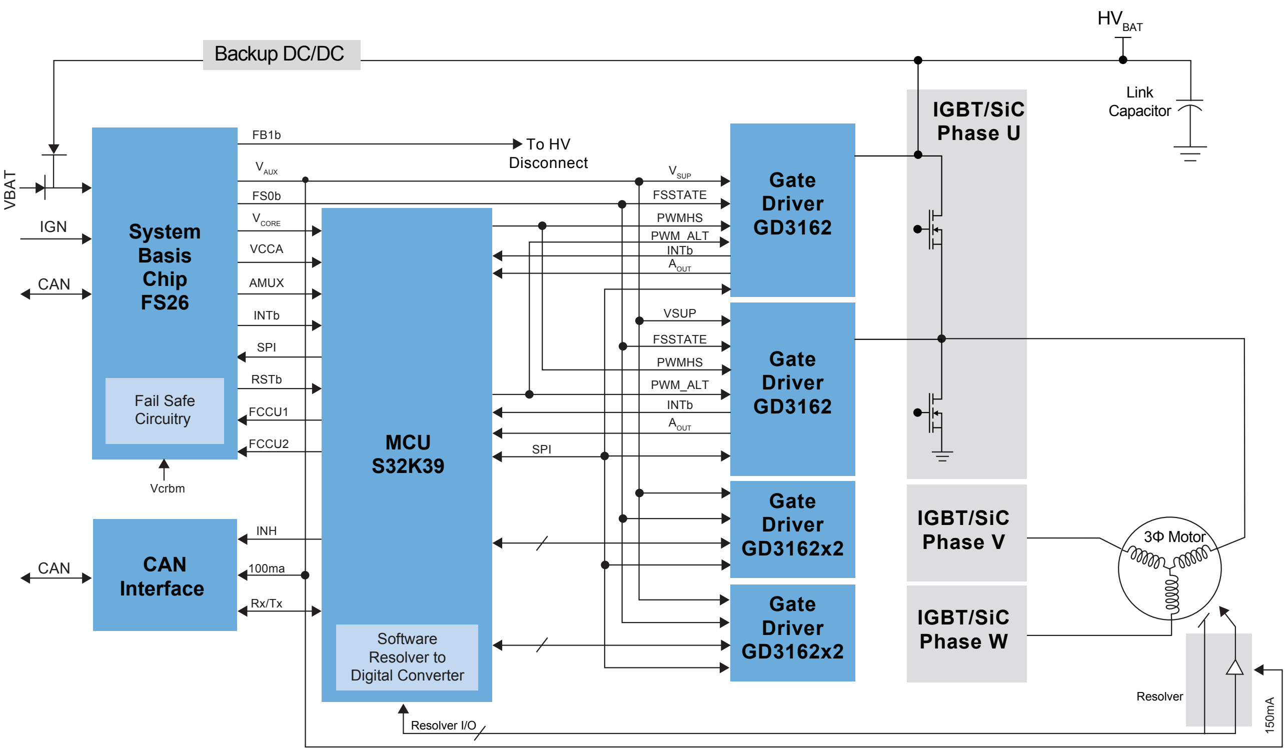


Figure 1: A sample schematic of a traction inverter for an EV. Six separate gate driver ICs are commonly used, two for each phase of a typical three-phase AC motor. The gate driver directly drives the power device — an IGBT or silicon carbide (SiC) MOSFET, which switches DC power from the battery to AC power for the motor. Gate drivers typically set the switching rate at a single specific value. A gate driver with dynamic gate strength, however, can vary the switching rate in response to motor conditions.

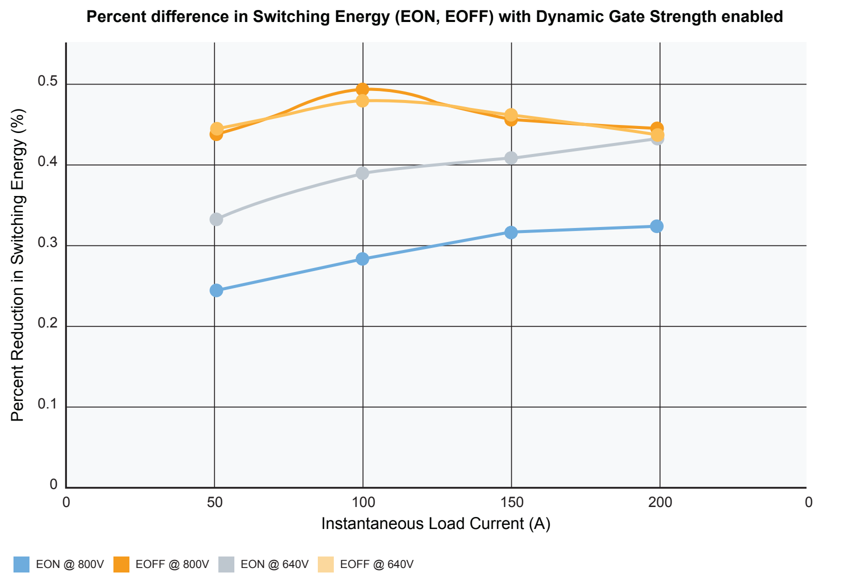


Figure 2: A comparison of EON/EOFF at range of currents. (Source: NXP)

Resistors are included to reliably limit peak current to charge or discharge the gate(s). Traditionally, the specific value has been fixed to protect against worst-case overvoltage, leaving potential energy savings on the table at more nominal conditions.

Dynamic gate strength

But the ability to change the speed at which the gate turns on or off has many potentially advantageous effects on the power device itself as well as on the motor.

Power switches are well-characterized, but vehicles encounter any number of conditions that affect electrical performance of the power switches. A partial list includes changes in motor current, the battery/bus voltage, and power device temperature.

Tuning the gate drive current is the means of modulating the switching event (energy) for the specific condition, which is invaluable for maximizing efficiency in all conditions (Figure 2).

The performance of the inverter (and therefore of the vehicle as a whole) could be more efficient if the switching behavior can be selected based on driving conditions – if dynamic gate strength were an option.

NXP affords this option by integrating additional pins in its gate drivers. The NXP GD3162 gate driver has two pins for turn-on and two for turn-off paths, which may be independently articulated. It offers the choice between outputs of up to roughly 10 amps, or up to roughly 20 A, along with the third option of using the two together to provide up to roughly 30 A.

Why "roughly"? As a practical matter, the OEM or system designer is likely to want to include a power-limiting resistor to limit the current so that the values are something less than 10 A, 20 A, or 30 A, based on the OEM's preferences and other system constraints.

The gate strength can be controlled by digital input pins or SPI command (figure 3). Either way, customers can choose to drive their power devices as hard as they want. With such a wide range of possible currents to drive the gate with, the GD3162 is even capable of driving multiple devices or die in parallel.

The desired gate strength can be commanded and executed in real-time as the motor is spinning with the GD3162.

Select gate strength by SPI or GPIO pins

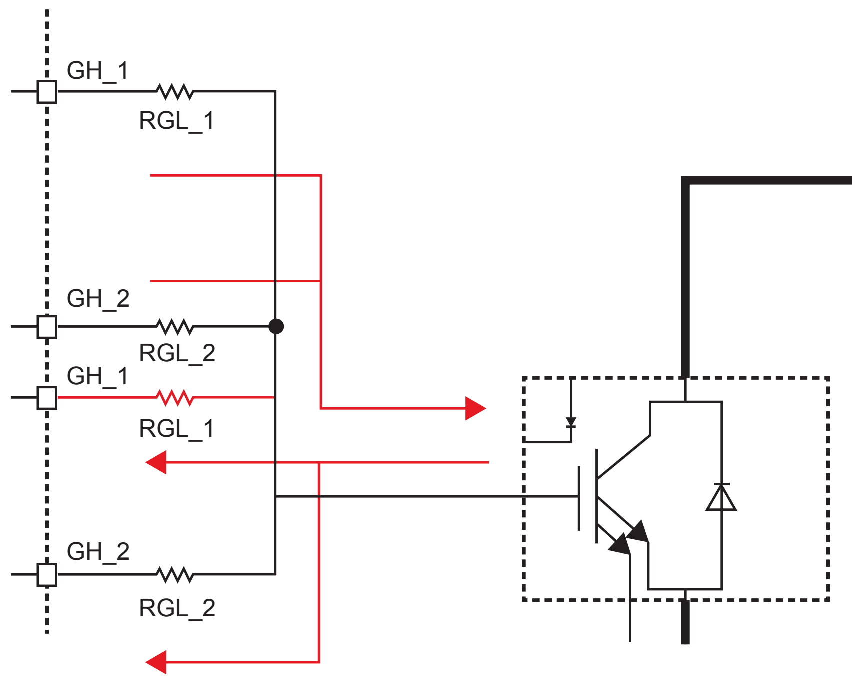


Figure 3: This application diagram of the GD3162 includes two separate turn-on and turn-off resistors. Gate strength can be selected by SPI command or via GPIO pins.

Efficiency

Power devices can be damaged by excessive voltage stress. Also, even though automotive electronics are rated to operate across wide temperature ranges, whenever it is possible to limit the thermal load on automotive ICs, including increasingly advanced gate drivers, it remains advisable to do so.

The design of the gate drive resistor typically starts by examining the worst-case conditions (e.g., max load, max voltage). The goal is to have sufficient resistance to provide protection when those conditions occur.

That does indeed minimize potential damage, but worst-case conditions are inherently atypical. Adding a gate driver that offers dynamic gate strength, such as the NXP GD3162, creates the option to operate at gate strength settings that emphasize more typical (lighter) conditions.

The system continuously evaluates multiple system factors (current, voltage, temperature, etc.), and always controls the gate strength, operating at one setting the OEM designates as optimal for typical conditions, automatically changing to settings more suitable to atypical conditions when they occur, and then dynamically reverting when conditions return to typical.

The GD3162 provides to the system integrator more control as to how best to protect the power device. The associated boost in efficiency in modes more suited to typical operation can be significant.

As the gate driver performs more efficiently, cooling requirements are eased. System designers should consequently be able to employ a smaller cooling system, which would mean a size and weight reduction for the inverter as a whole. Reducing overall vehicle size and weight of course can ultimately have a positive effect on range.

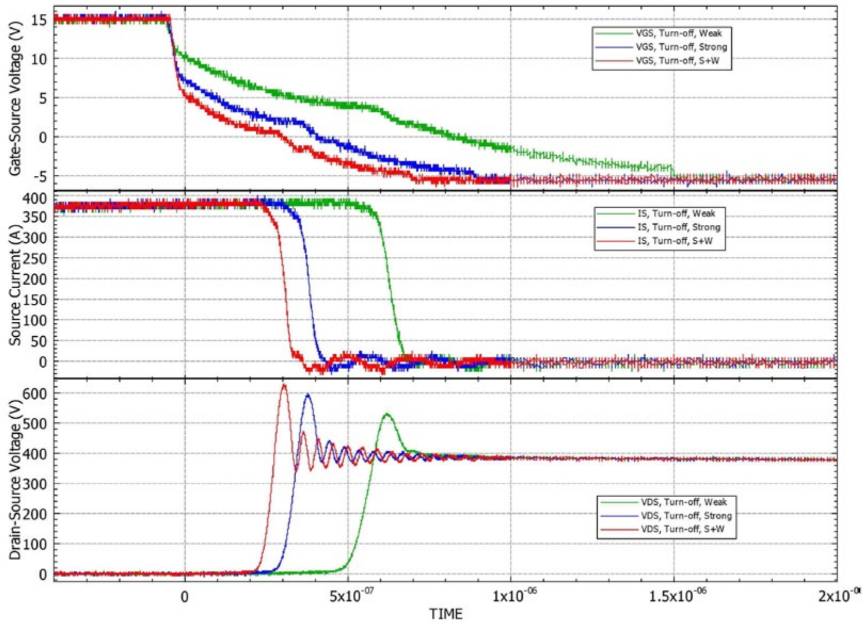


Figure 4: A comparison of switching event at high gate strength vs. low gate strength. GD3162 has the ability to affect the gate strength from the high-voltage side, via the ISEN/COMP pin.

Safety and reliability

Traction inverters are a safety-critical application, and typically carry ASIL D requirements. Gate driver ICs must contribute to the functional safety goals of the traction inverter. The GD3162 is rated ASIL C/D, and meets the requirements of automotive applications, being fully AEC-Q100 grade 1 qualified.

The GD3162 uses two pins for turn-on and off, protecting against single-point failures in the gate drive resistor. The device also reports the commanded and received gate strength, protecting against latent failures or a real-time breakdown in the gate strength command.

NXP traction inverter solutions

The GD3162 is an advanced, galvanically-isolated, single-channel gate driver designed to drive the latest SiC and IGBT modules for traction inverters in battery EVs, hybrid EVs, and others (xEV).

The GD3162 offers an adjustable dynamic gate strength drive feature with powerful efficiency and safety benefits. In addition, advanced programmable protection features are autonomously managed as faults and the status of the power device and gate driver are reported via the interrupt pins and SPI.

The GD3162 is designed for high-functional safety integrity level systems (ASIL C/D) and meets the stringent requirements of automotive applications, being fully AEC-Q100 grade 1 qualified.

NXP's EV traction inverter system solution features multicore lockstep MCUs, safety SBCs, CAN, Ethernet PHY and high-voltage gate drivers to control power conversion to the traction motor with high efficiency and reliability.

NXP's system solution delivers a rich set of motor control software packages to accompany the optimized hardware.

The EV traction inverter system also provides precise control, monitoring and protection of high-power switches for energy efficiency and reliability. The system gives accurate and efficient motor speed and torque control and enables ASIL D compliance with ISO 26262 requirements.

To support customers in their traction inverter development and reduce time to market, NXP offers an easy-to-use EV Power Inverter Control Reference Platform with system enablement software. These design platforms include schematics, BoMs, layout files and safety documentation for use with either IGBTs or SiC MOSFET modules.

The GD3162 can be fully explored using the FRDMGD3162HBIEVM evaluation board (EVB). Users can evaluate different resistor values by changing the component on the EVB, and then test the various effects of the gate strength through the GD3162.

Summary

The innovation of a gate driver IC, the GD3162 with dynamic gate strength gives automotive OEMs an exciting new option to improve traction inverters. The dynamic gate drive function delivers optimal switching performance for advanced power switch devices (e.g. SiC, GaN) over increasingly wide operating ranges. Dynamic gate strength on the GD3162 boosts inverter efficiency, delivers a strong functional safety solution, and improves upon typical hardware design criteria to protect the power device.

Additional resources

Gate Driver with dynamic gate voltage (GD3162) product page

Gate Driver with dynamic gate voltage (GD3162) fact sheet (PDF)

Evaluation kit product page

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