Application Brief

DRV8334 Gate Drive Features and Benefits

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Introduction

The DRV8334 offers various gate drive features that are configurable over SPI to help solve challenges related to dead-time reduction, EMI, inductive spiking, and power loss reduction. Efficiently switching MOSFETs is key to reducing MOSFET switching losses, however, measures must also be taken to mitigate ringing that can occur on the gate and source during MOSFET switching. This application brief discusses the features of TI's DRV8334 integrated gate-drive technology and how this can be used to solve various design challenges.

VDS Slew Rate Control

VDS slew rate control (IDRIVE) is a feature offered in many of TI's BLDC motor driver devices. VDS Slew Rate Control provides the ability to adjust the strength of the gate current from the driver by selecting the desired setting. This allows you to be able to adjust the gate drive sink and source current to change the MOSFET switching speed based on the parameters of your particular MOSFET. This helps to optimize the balance between EMI and switching speed. For motor drivers that have a fixed gate current, external gate resistors are needed to slow down the gate current to achieve the desired MOSFET switching speed. VDS slew rate control can help reduce external components by up to 24 components since the source and sink current is configurable over SPI and an internal gate to source passive pulldown is integrated into the device. Most drivers with VDS slew rate control have SPI configuration available, allowing the gate current to be adjusted dynamically without having to make any hardware changes. This helps reduce design time and improves ease of use and scalability.

DRV8334 Gate Drive Features

The features offered in the DRV8334 includes increased gate current granularity (45 steps), adjustable gate current duration, a turnoff pre-discharge feature that provides the ability to use a higher gate current to more quickly discharge the gate voltage until the miller plateau is reached during PWM operation, and a fault soft turnoff feature to reduce inductive spiking when shutting down the driver in case of a fault.

Increased Levels of Gate Current Granularity

For previous devices, the devices with the most amount of granularity for gate current offered 16 different gate currents (IDRIVE settings) for the sink current and 16 different IDRIVE settings for the source current. For the DRV8334, there are 45 different IDRIVE settings for the sink gate current and 45 different IDRIVE settings for the source gate current. One of the benefits of the increased gate current granularity is that it allows for better fine tuning of the gate current to find a more optimal tradeoff between EMI and switching losses. This also reduces the possibility of needing a gate resistor to tune the gate current to achieve a current in between two settings.

Another feature of this device is that the source and sink gate current can be set to as low as 0.75mA for driving small Qgd MOSFETs, and it is also capable of setting a source gate current of up to 1000mA and a sink current of up to 2000mA to be able to drive larger Qgd MOSFETs as well as parallel MOSFETs.

36 steps of gate current adjustability are available between 0.75mA and 247mA, which provides an impressive level of granularity especially at the lower gate currents. This is especially important for low Qgd MOSFETs, where a little bit of change in the gate current can result in a significant change in the MOSFET slew rate.

How Can I Determine Which IDRIVE Setting to Use?

The critical region for MOSFET switching is the region when the drain-source voltage (VDS) voltage slews, since this is the largest contributor to EMI during MOSFET switching. There is a tradeoff on how fast the MOSFET VDS voltage switches and how much EMI is acceptable to have in your system.

Understanding your target MOSFET VDS slew rate is helpful in determining which IDRIVE setting can be used starting out. It is generally preferred to target a slower gate drive current and then increase it if the EMI is good.

If the target MOSFET VDS turn on time is 300ns and the target MOSFET VDS turn off time is 150ns, then you can approximate the IDRIVE strength needed to achieve that VDS slew time by taking the MOSFET Qgd and dividing it by the MOSFET VDS slew time. Qgd is the MOSFET Qgd charge and T_{VDS_SLEW} is the VDS switching time.

$$\mathrm{IDRIVE} = \frac{\mathrm{Qgd}}{T_{\mathrm{VDS\_SLEW}}} = \frac{5.6\mathrm{nC}}{300\mathrm{ns}} = 18.7\mathrm{mA} \quad (1)$$

Note that the calculated IDRIVE value may not be exactly the same as one of the available settings, but you can choose the closest setting that is available (18mA in this case).

Adjustable IDRIVE Duration

The DRV8334 allows you to configure the duration for which the IDRIVE current is applied during MOSFET switching. This is done by configuring the TDRVP and TDRVN bits over SPI. After the TDRVP or TDRVN time expires, then the driver switches over to a hold current of either 500mA/1000mA pullup/pulldown current or 260mA/260mA IHOLD pullup/pulldown current depending on the register configuration for the IHOLD_SEL bit.

This adjustable gate current duration allows for more optimization so that the driver can provide the desired gate current through the miller plateau and then switch over to an IHOLD current once the miller plateau has completed. TDRVP is the time that the MOSFET VDS slew current is applied for MOSFET turnon, and TDRVN is the time that the MOSFET VDS slew current is applied for the MOSFET turnoff. TDRVP and TDRVN can be selected so that the source and sink gate current continues for the complete duration of the miller plateau. If TDRVP or TRVN is set too short, then this can result in the driver switching over to the IHOLD current before the VDS of the MOSFET has finished slewing, which can lead to higher EMI due to potentially stronger IHOLD current compared to the IDRVN and IDRVP current. If TDRVN is properly set, then after the completion of the miller plateau, the discharge time of the MOSFET gate node can be shortened with the strong IHOLD current. This helps reduce dead time and improve switching losses.

Turnoff Pre-Discharge Current

One key feature of the DRV8334 is the turnoff pre-discharge feature. This feature provides the ability to quickly discharge the MOSFET gate charge until the miller plateau is reached, and then slow down during the miller plateau of the MOSFET where the VDS voltage slews. This allows for a faster overall turnoff of the MOSFET while at the same time not compromising on EMI performance during the critical miller plateau region.

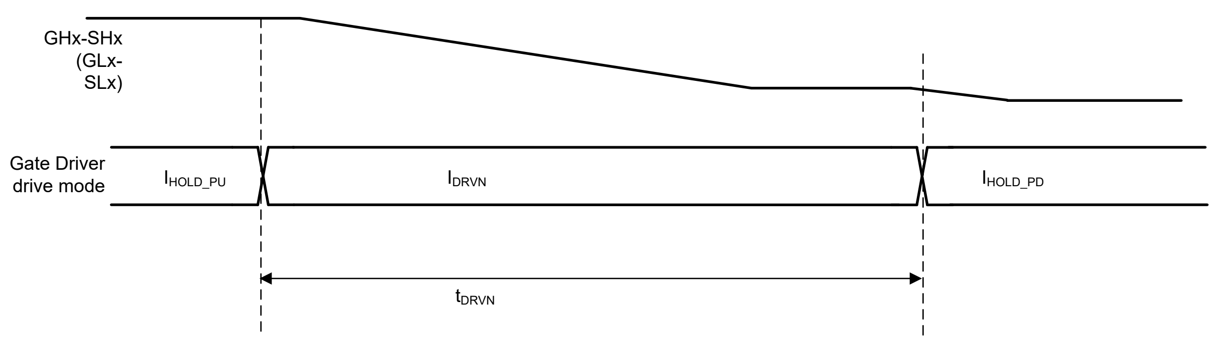

Figure 1. Gate Discharge Without Turnoff Pre-Discharge Enabled

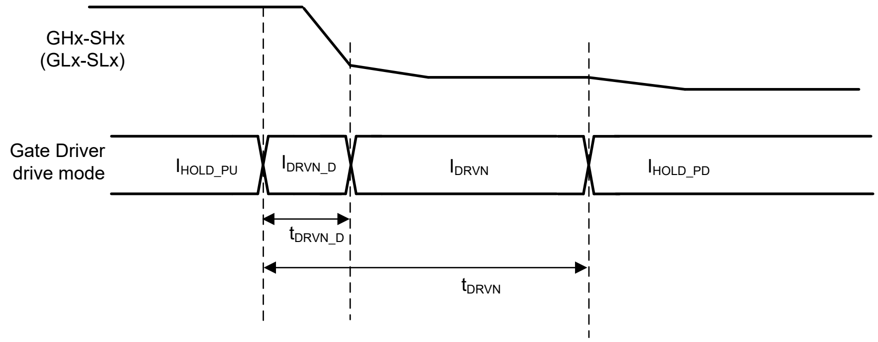

Figure 2. Gate Discharge With Turnoff Pre-Discharge Enabled

One benefit of this feature is that it allows for higher duty cycle operation since the overall turnoff time of the MOSFET is shorter. The switching of the MOSFETs as well as the bootstrap recharge time can be a limiting factor at high duty cycles, so reducing the switching time of the MOSFETs can improve performance.

Note

The device supports 100% duty cycle operation with the internal trickle charge pump.

A second benefit of the turnoff pre-discharge feature is that it helps reduce the time spent in the higher RDS(ON) region prior to the miller plateau during the MOSFET discharge, helping reduce switching losses. Turnoff pre-discharge works by configuring certain register settings to use a higher gate sink current for a configurable amount of time when turning off the MOSFET, and then once the time has expired the driver switches over to a lower gate drive current through the EMI-critical Miller plateau region.

How do I Configure my Turnoff Pre-Discharge Settings?

The turnoff pre-discharge current strength can be configured over SPI in the GD_CTRL3B register, and the duration of time for which the turnoff pre-discharge current is applied can be configured in the GD_CTRL2 register using the TDRVN_D. This duration of time needs to be long enough to allow the gate voltage to discharge as close as possible to the miller plateau, but it must be short enough to switch over to the regular discharge current before entering the miller plateau region. If the TDRVN_D is set too long, then this can result in the higher turnoff pre-discharge current being used to switch off the gate in the miller region, which can lead to higher EMI and ringing. It is better to start with a shorter TDRVN_D time and then increase it as needed, making sure that the transition from the turnoff pre-discharge current to the discharge current occurs before entering the miller plateau region.

A rough calculation to select the appropriate TDRVN_D time is shown below:

Turnoff Pre-Discharge Current Setting	VDS Slew Rate Control Turnoff Current Setting	MOSFET Qg (Total MOSFET charge)	MOSFET Qgd (MOSFET gate to drain charge)	MOSFET Qgs (MOSFET gate to source charge)
247mA	88mA	180nC	34nC	78nC

$$\text{Turnoff pre−discharge time} = \frac{\text{amount of charge to discharge to reach miller plateau}}{\text{turnoff pre−discharge current}} \tag{2}$$

$$= \frac{\text{Qg} - \text{Qgd} - \text{Qgs}}{\text{pre−discharge current setting}} = \frac{180\text{nC} - 34\text{nC} - 78\text{nC}}{247\text{mA}} = 275\text{ns} \tag{3}$$

The turnoff pre-discharge time can be further adjusted as needed during testing, considering operation across voltage and temperature. Keep in mind that the MOSFET Qg is usually specified at 10V, however, the actual Qg is higher when the MOSFET VGS voltage is around 12V.

Fault Soft Turnoff

Fault soft turnoff is a feature of the DRV8334 that is used when a fault occurs. This feature is also available when the driver outputs are shut down when DRVOFF is pulled high. If a fault occurs that results in high motor current flowing through the shunt (possibly due to a shoot through condition), the high current can cause large inductive spikes on the low side source that can lead to abs max violations and possible component damage. In order to reduce these large voltage spikes, slowing down the switching off of the MOSFETs can reduce the severity of these large voltage spikes. The tradeoff of this is that switching off the MOSFETs slower means a longer time for there to be shoot through current before the MOSFETs are turned off. The DRV8334 has a feature which allows you to configure a lower gate drive sink current that is used when a fault response occurs. This provides a slower MOSFET turnoff time to reduce the severity of any inductive transients that can be caused due to high current through the shunt during a fault condition.

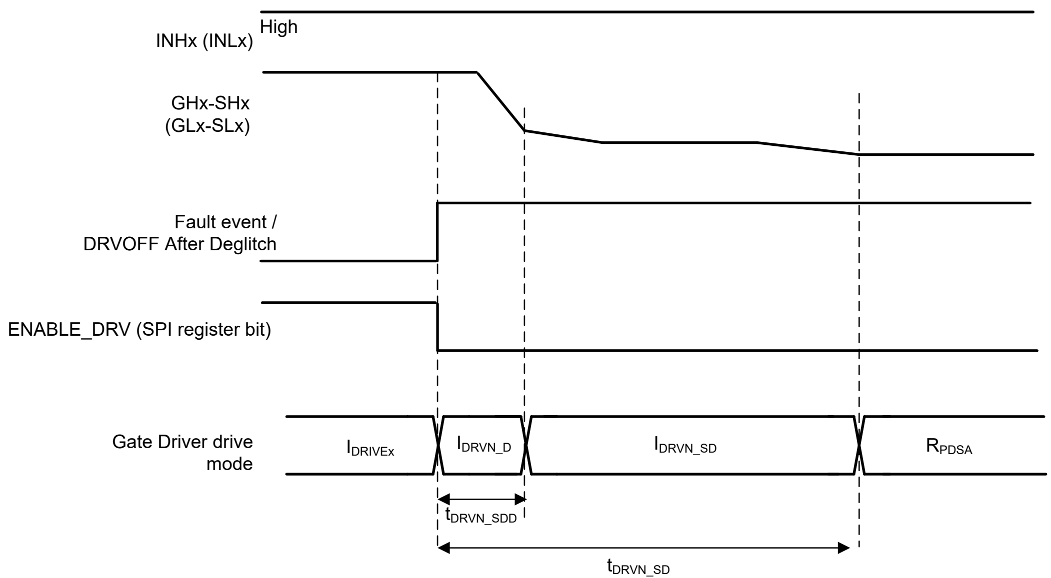

Figure 3. DRV8334 Fault Soft Turnoff

How do I configure my Fault Soft Turnoff?

The main setting to configure related to the fault soft turnoff feature is the soft turnoff current. This is the gate current used to turn off the MOSFET in the case of a motor driver fault. This is configured in the GD_CTRL3 register (0x21) under the IDRVN_SD setting.

Use the same equation as before where:

$$\mathrm{IDRIVE} = \frac{\mathrm{Qgd}}{\mathrm{T_{VDS\_SLEW}}} \tag{4}$$

The DRV8334 still has the turnoff pre-discharge feature that is used when going through the fault soft turnoff procedure. This allows for a faster discharge of the MOSFET gate charge until the miller plateau is reached before switching to a much lower current for slowly turning off the MOSFET during the region where the VDS voltage slews. The turnoff pre-discharge current used during the fault soft turnoff is the same current that is programmed in the GD_CTRL3B register (0x22), however there is the option of configuring a different duration of time for which that turnoff pre-discharge current is applied during a fault soft turnoff event. This can be configured in the GD_CTRL3 register using the TDRVN_SDD bits.

Summary

The integrated gate drive features for the DRV8334 allows the user to more precisely tune the switching profile of the MOSFET to provide more optimized switching that can reduce deadtime, improve switching power loss, improve EMI, and lower inductive spiking to provide a more robust motor driver solution.

Trademarks

All trademarks are the property of their respective owners.