

Inductive Switching for Dual 24 and 36 V High-side Switch Families

1 Introduction

This application note describes the behavior of the SMARTMOS Dual 24 – 36 V high-side switch devices ([Table 1](#)), at switch OFF when driving inductive loads.

These intelligent high-side switches are designed to be used in 24 V systems such as trucks and busses (XS4200). They can be used in industrial (XSD200) and 12 V applications as well. The low $R_{DS(on)}$ channels can control incandescent lamps, LEDs, solenoids, or DC motors. Control, device configuration, and diagnostics are performed through a 16-bit SPI interface, allowing easy integration into existing applications. For a complete feature description, refer to the individual data sheets.

Contents

1	Introduction	1
2	24 and 36 V eXtreme Switch Inductive Switching	
2.1	Clamped Inductive Switching (CIS)	2
2.2	Inductive Switching with External Clamp > -2.0 V	3
2.3	Inductive Switching with External Clamp < -2.0 V	3
3	References	5
4	Revision History	6

Table 1. eXtreme Switch Core

XS4200 Family	XSD200 Family
MC06XS4200	MC06XSD200
MC10XS4200	MC10XSD200
MC20XS4200	MC16XSD200

2 24 and 36 V eXtreme Switch Inductive Switching

This paragraph explains dual high-side switch behavior during turn off, when the output is connected to an inductive load.

2.1 Clamped Inductive Switching (CIS)

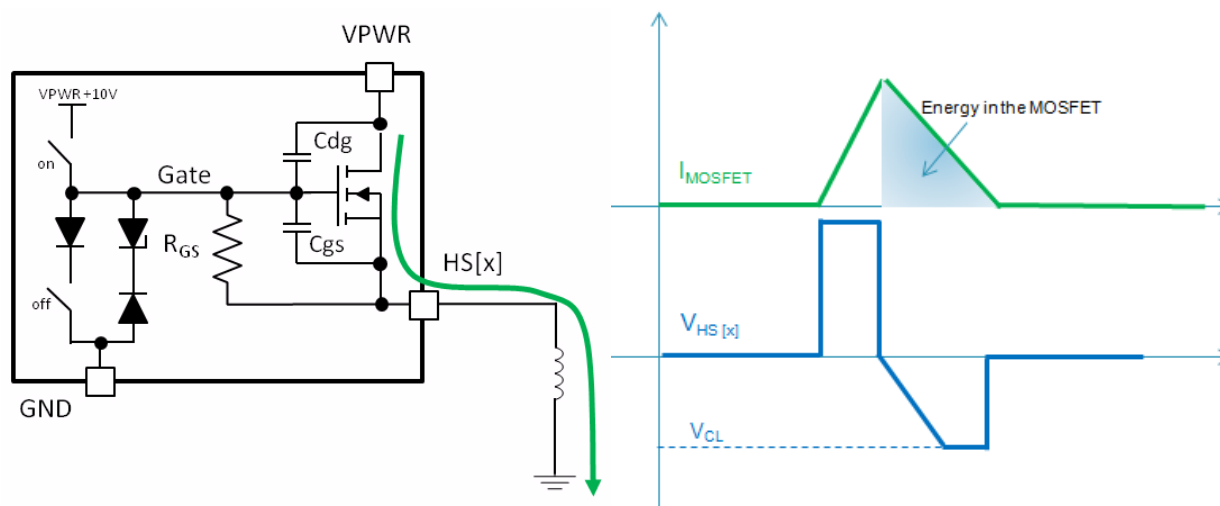


Figure 1. XS4200 and XSD200 Clamped Inductive Switching Schematic

When turning off high-side switches on inductive loads, inductance polarity inverts and device output goes below ground to continue driving current. In the case of the 24 and 36 V eXtreme switch devices, the resulting negative voltage clamps to V_{CL} (negative output voltage protection) via the internal clamping circuitry. This kind of inductive switching with no freewheeling diode is called the Clamped Inductive Switching (CIS).

Load current is demagnetized by the internal power MOSFET only. The maximum load energy that can be drained is limited by device energy capability E_{CL} .

The energy dissipated in the MOSFET (E_{CL}) during turn off depends on the load energy (E_{load}), on the power supply voltage and on the negative output voltage protection V_{CL} . A simplified expression of E_{CL} is given here:

$$E_{CL} = E_{load} * (1 + V_{PWR}/|V_{CL}|) = L * I^2/2 * (1 + V_{PWR}/|V_{CL}|)$$

Knowing that the energy dissipated in the MOSFET is higher than the load energy is important to consider when designing the module.

However, for loads with $L > 20\mu\text{H}$, it is highly recommended to use a freewheeling diode.

2.2 Inductive Switching with External Clamp > -2.0 V

When turning off 24 and 36 V eXtreme switches on inductive loads >20 μH , using a freewheeling diode to drain the load current is highly recommended.

Special care should be taken when designing the freewheeling path. As long as the output voltage of the device (V_{HS}) is greater than -2.0 V (equivalent to the difference of the internal MOSFET threshold voltage with the forward voltage of the diode in gate driver clamping circuitry), current will flow through the freewheeling path.

However, if the output voltage goes below -2.0 V, expect different behavior.

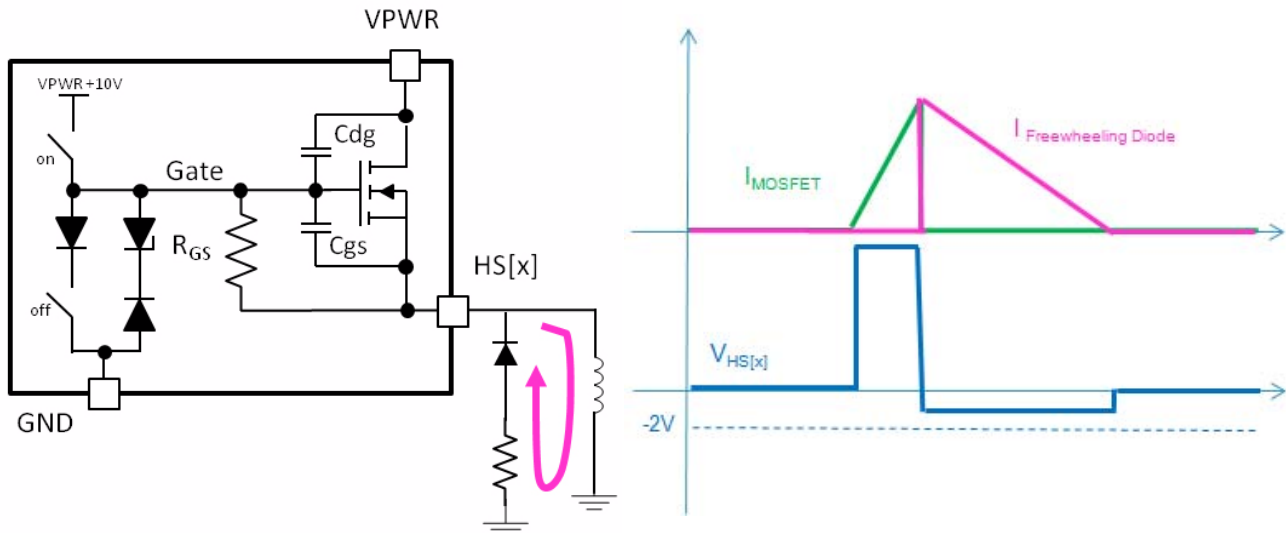


Figure 2. XS4200 and XSD200 Inductive Switching with a Freewheeling Diode where $V_{\text{HS}} > -2.0 \text{ V}$

2.3 Inductive Switching with External Clamp < -2.0 V

For high inductive loads, it is tempting to pull the device output down to help discharge the load more rapidly. Using additional devices in the freewheeling circuitry may allow this faster load demagnetization, but this can lead to higher energy through the MOSFET.

When extra voltage is added in the freewheeling path, such as $V_{\text{HS}} < -2.0 \text{ V}$, the output voltage drops and the gate source voltage of the power die increases, creating a current path through the MOSFET. In this case, during turn off, load current is shared between the power MOSFET and the freewheeling circuitry. Special care should be taken when choosing components for the external circuitry, to limit energy in the power device to its maximum rating, indicated in the datasheet as E_{CL} .

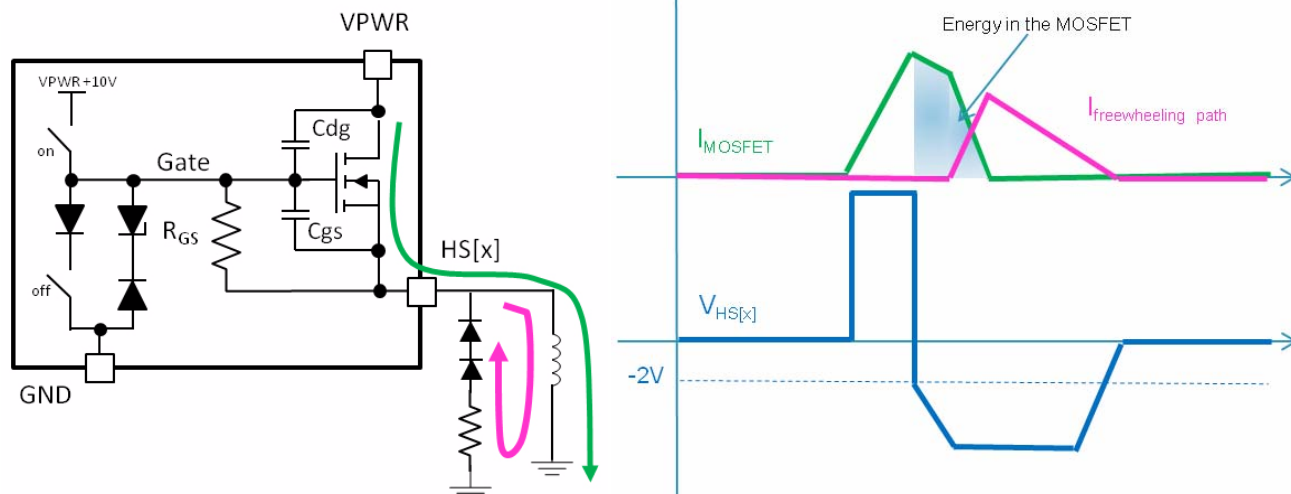


Figure 3. XS4200 and XSD200 Inductive Switching with a Freewheeling Path where $V_{HS} < -2.0 V$

3 References

Document Number and Description		URL
MC06XS4200	Dual 24 V High-side Switch (6.0 mΩ) Data Sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC06XS4200.pdf
MC10XS4200	Dual 24 V High-side Switch (10 mΩ) Data Sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC10XS4200.pdf
MC20XS4200	Dual 24 V High-side Switch (20 mΩ) Data Sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC20XS4200.pdf
MC06XSD200	Dual 36 V High-side Switch (6.0 mΩ) Data Sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC06XSD200.pdf
MC10XSD200	Dual 36 V High-side Switch (10 mΩ) Data Sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC10XSD200.pdf
MC16XSD200	Dual 36 V High-side Switch (16 mΩ) Data Sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC16XSD200.pdf

4 Revision History

Revision	Date	Description of Changes
1.0	2/2014	Initial release

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