AN4269
Rev. 1.0, 8/2011

eXtreme Switch

Diagnostic, Protection Features, and Limitations

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1 Introduction

The purpose of this document is to provide an overview of the diagnostic features offered in our eXtreme Switch family, specifically for our Generation 3 Quad high side drive devices (MC10XS3412D, MC15XS3400D, MC10XS3435D and MC35XS3400D). A description of the diagnostic functionality, including it's limitations (especially at very low or very high duty cycles), will be further developed.

This document is thought to extend on what the data sheet already states, so consider the data sheet as initial information. The values to be presented in graphs, and throughout the document, do not replace the parameters already specified in our documentation. They are mainly to highlight how certain parameters behave with changes in temperature and supply voltage.

Contents

2 Diagnostic and Protection Features

Table 1 summarizes the diagnostic features offered within the extreme Switch family, which is further explained in each of the sub-sections.

Table 1. eXtreme Switch Diagnostic and Protection Duty Cycle Limitations

Diagnostic and protection features.	Low duty cycle limitation	High duty cycle limitation
Open load ON	3.4%	100%
Open load OFF	0%	86%
Short-circuit to V_{BATT}	0%	96%
Short-circuit to GND	3.4%	100%
Current sensing	3.4%	100%
Temperature feedback	0%	100%
Under-voltage	0%	100%
Over-voltage	0%	100%

This table applies for:

- Bulb loads (200 Hz) with default slew rate selection
- LED
- loads (400 Hz) with fast slew rate selection
- with a 22 nF decoupling cap on the output
- 11 V $\leq V_{PWR} \leq$ 18 V
- -40 to 125 °C ambient temperature

In case of a 100 Hz switching frequency (bulb load), the diagnostic limitations are reduced by half of what is considered in Table 1 for 200 Hz. For example, the Open load ON low duty cycle limitation of 3.4% at 200 Hz, would actually be 1.7% low duty cycle limitation at 100 Hz, since both represent the same amount of detection time.

2.1 Open Load in ON State (for Bulbs)

The internal mechanism used to detect an open load condition operates basically by monitoring the amount of current flowing through the high side switch. When it is configured for regular bulbs, the threshold would be at a typical 300 mA value. This detection circuitry integrates a typical 4.0 μs filter, to properly recognize an open load condition in the ON state. Due to the output transition from OFF to ON, it is not possible to detect an open load condition for a short output pulse (low duty cycle). In this case, the open load in OFF state diagnosis can be used to report this fault.

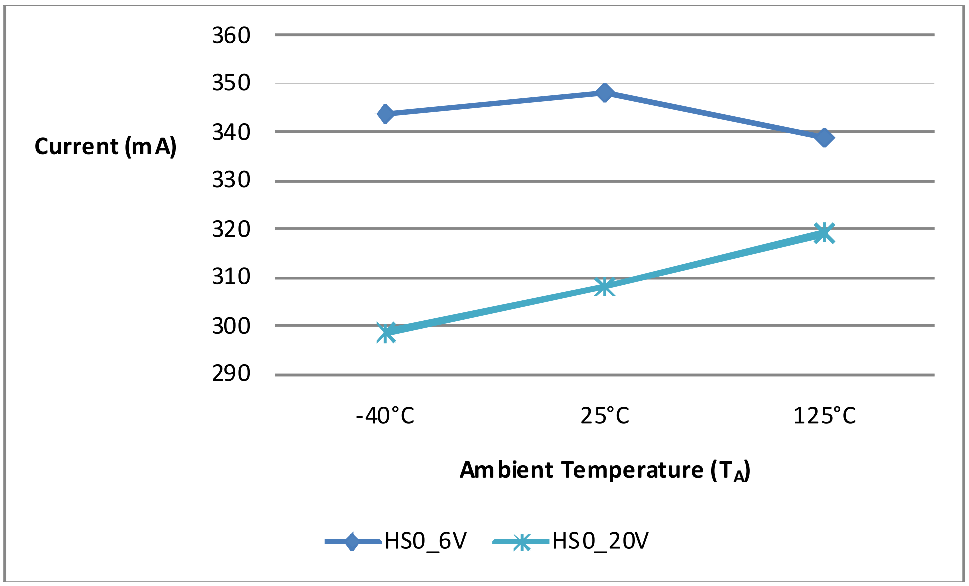

Figure 1. “Bulb” Open Load Current Threshold Variation in the ON State Across Supply Voltage and Temperature

2.2 Open Load in ON State (for LEDs)

In the case of an open load when the ON state diagnostic is configured for LEDs, the detection threshold is reduced to a typical 5.0 mA value. The detection concept (patented) is based on initiating a controlled turn-off of the power MOSFET, together with a “weak” pull-up of the output (a current source circuit is only activated for a short period of time, typically 150 µs, while in the ON state). The behavior of the output voltage, compared to the gate voltage of the power MOSFET, is evaluated during this time. If the output voltage is higher than the gate voltage during this short period, it is recognized as an open load in the ON state condition.

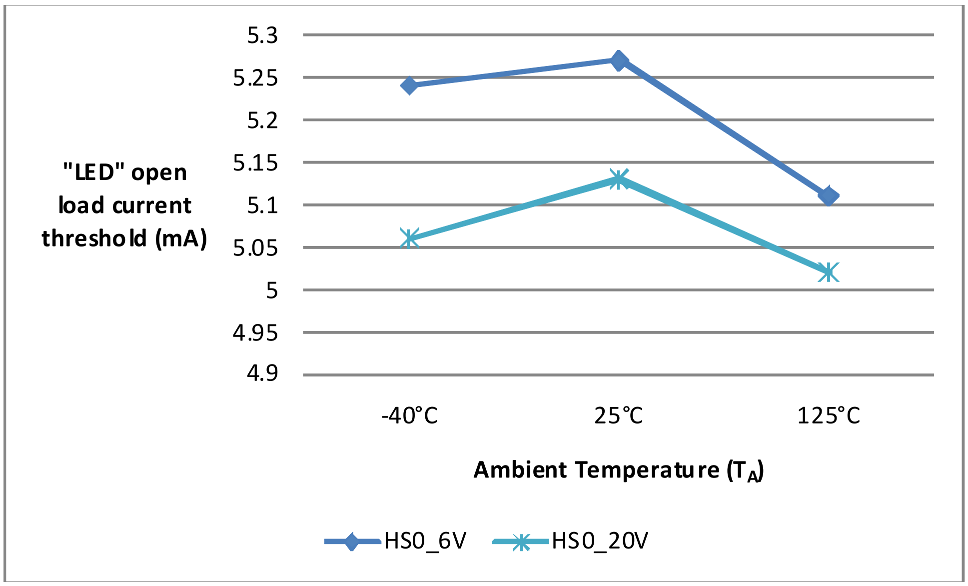

Figure 2. “LED” Open load in the ON State Current Threshold Variation Across Supply Voltage and Temperature

2.3 Open Load in OFF State

This diagnostic operates differently from the previous two open load ON diagnostic features. When the detection principle used is to allow a very small current (550 μA typical) to flow through the load, just enough to pull the voltage at the output up for a very short period of time, during this time, the voltage is measured. If the voltage is below a pre-defined 2.3 V typical threshold, this condition is identified as an open load condition. To perform this diagnosis mechanism, a certain amount of time is required, thus limiting the diagnostic capabilities at very high duty cycles.

Figure 3 and Figure 4 are shown as a reference to illustrate the behavior of the threshold and the source current variations at different temperatures and supply voltages. These graphs represent the average value of tests performed in one lot of devices.

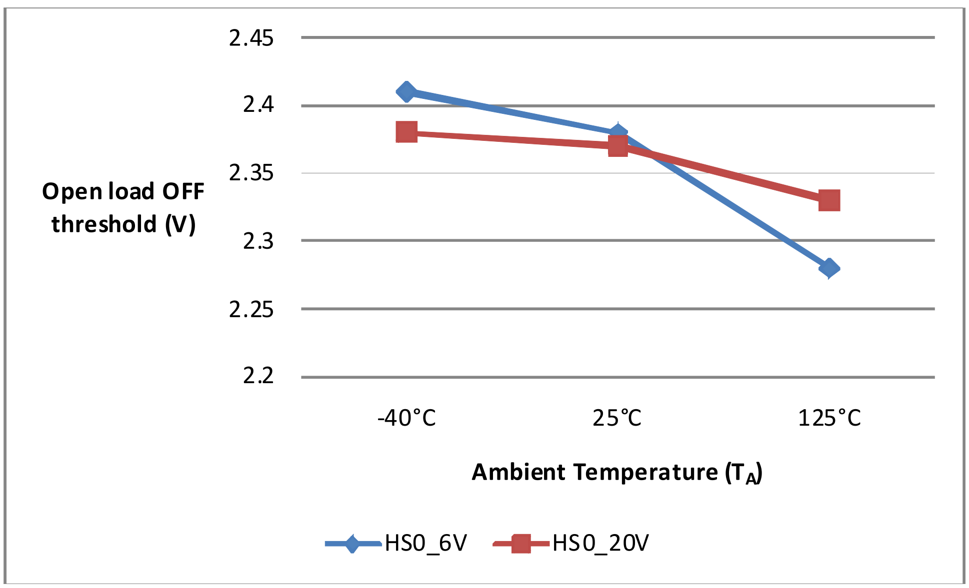

Figure 3. Open Load in the OFF State Threshold Variation Due to Temperature and Supply Voltage

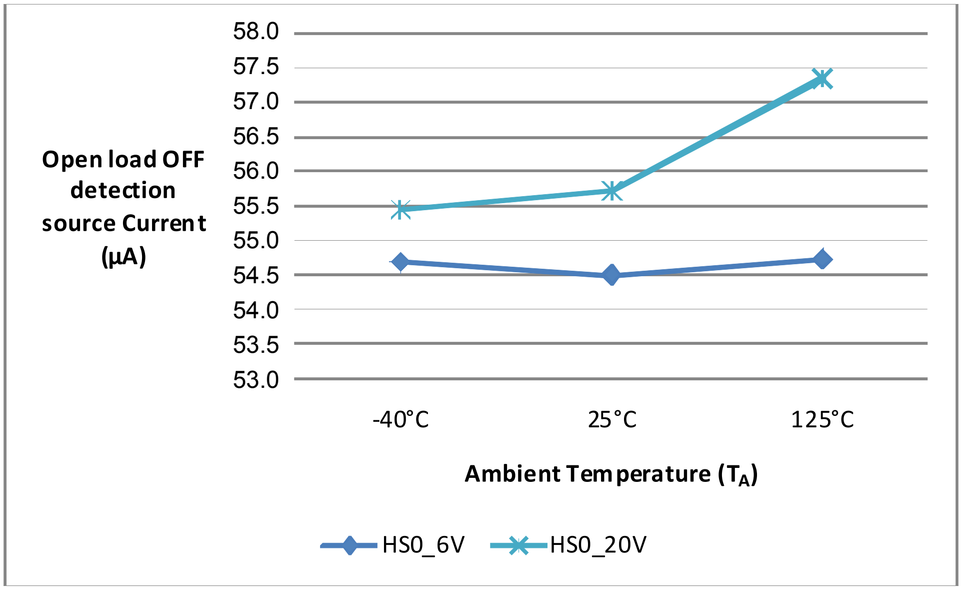

Figure 4. Open Load in the OFF State Detection Source Current Variation Due to Temperature and Supply Voltage

2.4 Short-circuit to V_{BATT}

To detect this condition, the voltage at the output is monitored in the OFF state. If the voltage is higher than the pre-defined $V_{OSD(THRES)}$ threshold voltage, the output is reported to be a short-circuit to V_{BATT}. Since this measurement is done in the OFF state, the output needs to remain in this state for a short time to be able to perform this diagnostic measurement. By using this feature, it is possible to distinguish between a short-circuit to V_{BATT} and an open load in the OFF state.

Figure 5 shows in more detail how the $V_{OSD(THRES)}$) typical value varies with temperature and supply voltage on each of the different outputs.

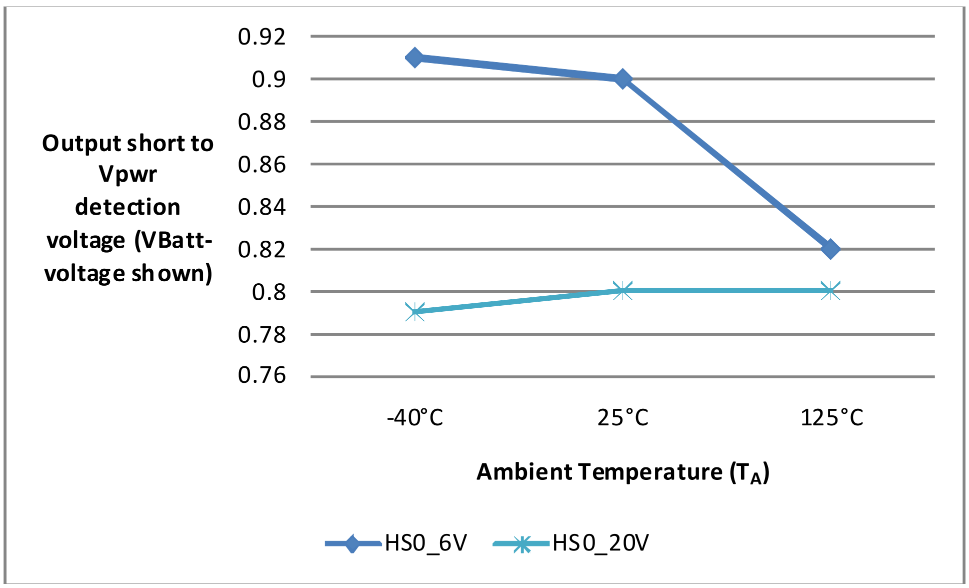

Figure 5. $V_{OSD(THRES)}$ Variation Due to Ambient Temperature and Supply Voltage Variations

The voltage shown in Figure 5 is the voltage difference between V_{BATT} and the output.

2.5 Short-circuit to GND

Detecting a short-circuit to GND is done by monitoring the high side MOSFET current. This information is used to detect both a severe short-circuit condition or an overload of the high side switch. This detection circuitry has a typical time filter of 3.0 μs, meaning that the output needs to be turned ON for a minimum duration for this condition to be detected.

2.5.1 Severe Short-circuit to GND

During the OFF to ON transition of the output, the load impedance is compared to an internal reference. Where the impedance is smaller than the internal reference, the output is turned OFF without allowing the current to reach it’s maximum possible level. In this way, the thermal stress inside the device is minimized.

This R_{SHORT} value is guaranteed by design.

The duration of the OFF to ON transition depends on the characteristics of the short-circuit (inductance, resistance, and ground shift).

2.5.2 Overload Current on the High Side MOSFET

The current monitored through the high side switch is compared with a level that changes according to a selected over-current protection profile, and also with the amount of time the load has been turned ON. This is explained in more detail in the application note AN4049.

2.6 Current Sensing

The current sensing functionality is explained in more detail in the AN3848 (MC15XS3400) and the AN3853 (MC35XS3400) application notes.

2.7 Temperature feedback

In addition to the temperature sensors located on each of the different power MOSFETs, these devices contain an additional temperature sensor, located on the “control die” and positioned on top of the main ground terminal. This temperature is accessible to be read through the CSNS pin. Different from the behavior of the current sense feedback, a proportional current to the load current comes out of the CSNS pin. For temperature feedback, the output is a voltage that can be directly read by an A/D pin from the MCU.

2.8 Under-voltage Detection

These devices contain a monitoring circuit for the supply voltage. If this voltage drops below a pre-defined 3.85 V typical threshold, due to a long input line and severe-short circuit condition, the outputs are automatically turned OFF before reaching the over-current level. The outputs are automatically latched-OFF, in cases of an under-voltage condition.

Figure 6 shows the variation of the under-voltage threshold and it’s behavior vs. temperature.

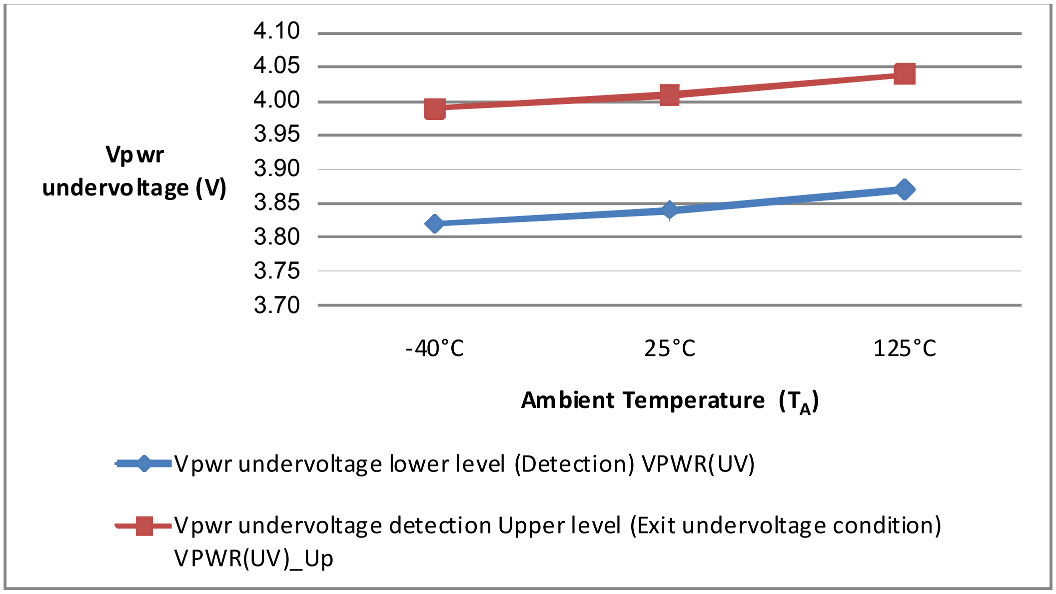

Figure 6. Under-voltage Detection Behavior Versus Temperature Variation.

2.9 Over-voltage Detection

If the supply voltage goes above a predefined 32 V typical threshold, the outputs are turned OFF. The outputs will remain OFF until the over-voltage condition is removed (considering the defined hysteresis of the detection circuit).

Figure 7 shows the variation of the over-voltage threshold and it's behavior vs. temperature.

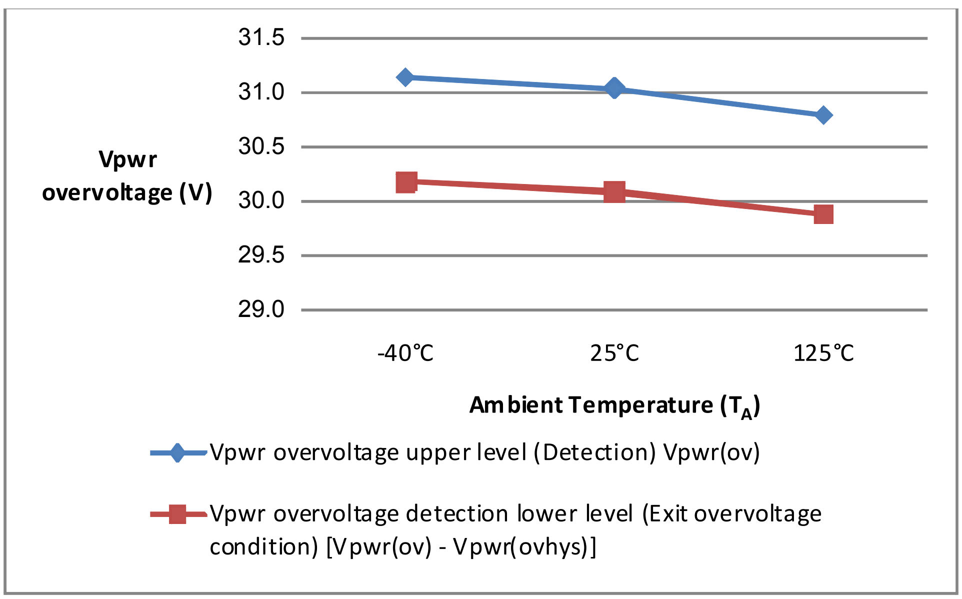

Figure 7. Over-voltage Detection Behavior Versus Temperature Variation

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AN4269
Rev. 1.0
8/2011