

NXP Repetitive short-circuit performances

For the MC15XS3400C

1 Introduction

This application note describes the robustness of the 15XS3400C device under repetitive short-circuit conditions.

The 15XS3400C is one in a family of devices designed for low-voltage automotive lighting applications. Its four low $R_{DS(on)}$ MOSFETs (quad 15 m Ω) can control four separate 55 W / 28 W bulbs, and/or Xenon modules, and/or LEDs.

Programming, control, and diagnostics are accomplished using a 16-bit SPI interface. Its output with selectable slew-rate improves electromagnetic compatibility (EMC) behavior. Additionally, each output has its own parallel input or SPI control for pulse-width modulation (PWM) control if desired. The 15XS3400C allows the user to program via the SPI, the fault current trip levels and duration of acceptable lamp inrush. The device has a Fail-safe mode that allows outputs to function safely if the MCU is damaged.

For feature information, refer to the device data sheet for the 15XS3400C.

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2 Short-circuit protections

The 15XS3400C device includes four self-protected high side switches with $15\text{ m}\Omega$ $R_{DS(on)}$ and extended diagnostics, in order to detect bulb outage and short-circuit fault conditions. Moreover, this device incorporates a pulse width modulation control module, to improve lamp lifetime with bulb power regulation at no less than 100Hz and address the dimming application (day running light).

The 15XS3400C offers two different over-load protection features:

- latched overcurrent protection
- severe short-circuit protection

These protections are preferable to conventional current limitations because they minimize thermal overstress within the device when an overload occurs. The delta (T) is drastically reduced to a value which does not affect the device's reliability. Moreover, the availability of the lighting is guaranteed by the limited auto-retry feature (15 retries).

2.1 Latched overcurrent protection

The transient overcurrent profile is adjustable to account for the variability in the bulb characteristics and the energy associated with the expected wire harness current capability. The 15XS3400C incorporates multiple configurable inrush profiles to address halogen lamps like H1, H3, H4, H7 and H9, incandescent bulbs like P27W, P21W and P21W+R5W, and Xenon-HID modules. Coupled to a modulation control module, the transient overcurrent profile protects the application if the lamp is driven in the PWM mode as well. Figure 1 shows an example for an H1 lamp.

Transient overcurrents are configurable using an SPI communication link between an external microcontroller and the device. Two OCHI thresholds are available to sustain inrush current and four OCLO current levels allow optimizing cable gage in the steady state.

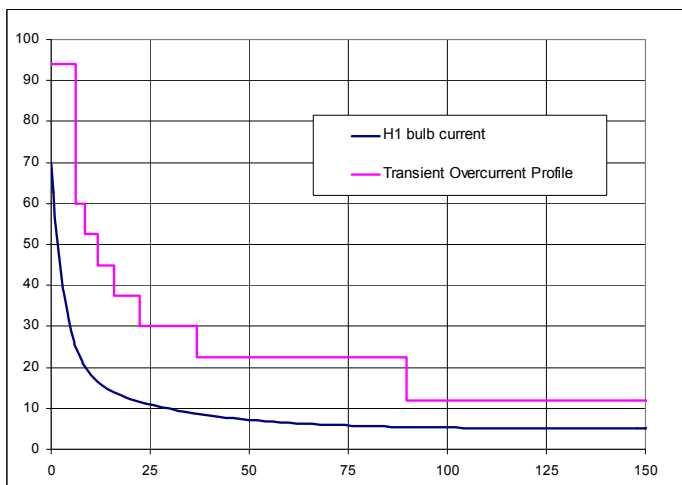


Figure 1. Transient overcurrent profile example

2.2 Severe short-circuit protection

In addition to latched overcurrent protection, a severe short-circuit detection feature immediately turns off the output if a short-circuit is detected during lamp switching. Without this feature, the junction temperature will likely be high because the high-side MOSFET is not yet in the $R_{DS(on)}$ state.

Both short-circuit conditions can be distinguished with SPI fault reports.

3 Repetitive short-circuit test setup

The repetitive short-circuit tests have been performed in accordance with Chapter 12 of AEC-Q100 specification published by the Automotive Electronics Council. The goal is to force the device to switch “on” and “off” cyclically in a short-circuit condition in order to accelerate silicon fatigue.

Some test cases are defined in the AEC specification:

- Hot Repetitive Short-circuit Test: an infinite “on” command,
- Cold Repetitive Short-circuit Test-Short Pulse: a repetitive turn-on command of 10 ms periods,
- Cold Repetitive Short-circuit Test-Long Pulse: a repetitive turn-on command of 300 ms periods.

These tests have been performed for difference short-circuit conditions, activating each overload protection feature as described in Figure 2:

- Terminal short-circuit of 20 mΩ (R_{short}) - 8 °C delta (T) estimated,
- Load short-circuit of 100 mΩ - 60 °C delta (T) estimated,
- Overload condition exceeding the nominal current (i.e. 40 A DC) - 75 °C delta (T) estimated.

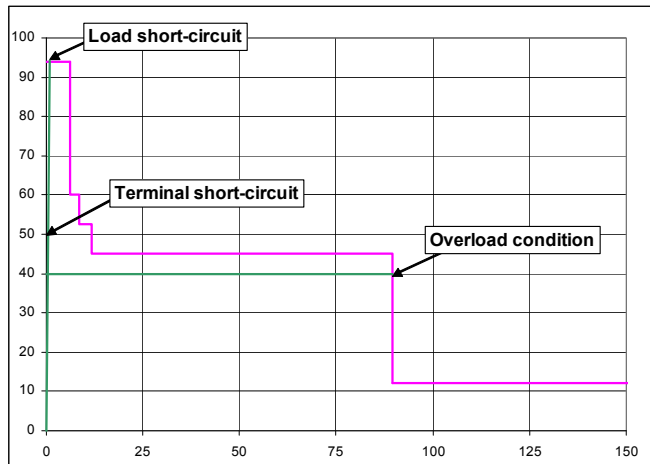


Figure 2. Short-circuit conditions

Figure 3 describes the hardware test setup used with $L_{supply} = 4 \mu\text{H}$, $R_{supply} = 10 \text{ m}\Omega$, and $L_{short} = 3 \mu\text{H}$

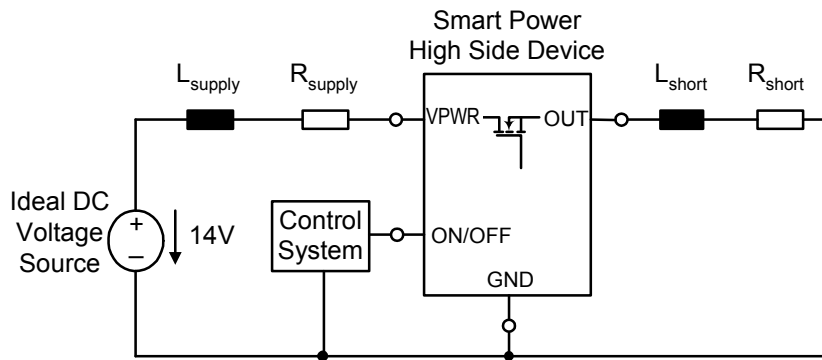


Figure 3. Short-circuit test setup

The test escape condition was severe part damage (i.e. destruction).

4 Repetitive short-circuit test results

Table 1 presents the summary of repetitive test results for the MC15XS3400C. 10 engineering samples were used per test.

Table 1. Test results summary

Test name	Ambient temperature	Cycle definition	OCHI level configured	Fault detected	Number of cycles passed before the first failure
Load short-circuit	-40 °C	ON 10 ms OFF 990 ms	OCHI1	Latched overcurrent for 90 A at 250 µsec	1 M cycles drain / source shorted together
Load short-circuit	+40 °C	ON 10 ms OFF 990 ms	OCHI1	Latched overcurrent for 90 A at 250 µsec	382 k cycles drain / source shorted together
Load short-circuit	+85 °C	ON 10 ms OFF 990 ms	OCHI1	Latched overcurrent for 90 A at 250 µsec	73 k cycles drain / source shorted together
Load short-circuit	+85 °C	ON 10 ms OFF 990 ms	OCHI2	Latched overcurrent for 65 A at 250 µsec	> 1.2 M cycles
Overload	+40 °C	ON 900 ms OFF 9 s	OCHI1	Latched overcurrent for 40 A at 95 msec	> 1 M cycles
Terminal short-circuit	+85 °C	ON 1 ms OFF 99 ms	OCHI1	Latched severe short-circuit for 40 A at 100 µsec	> 1 M cycles

The load short-circuit at hot temperature is the worst case.

5 Revision history

Revision	Date	Description of changes
2.0	9/2009	<ul style="list-style-type: none">Initial release
3.0	4/2015	<ul style="list-style-type: none">No technical changes. Revised back page. Updated document properties.
	7/2016	<ul style="list-style-type: none">Updated NXP document form and style

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