AN3959
Rev. 2.0, 6/2012

Repetitive Short-circuit Performances

For the MC15XS3400D, MC35XS3400D, and MC10XS3435D

1 Introduction

This application note relates the robustness of the Generation III, eXtreme Switch family of devices in the event of a repetitive short-circuit condition.

For example, the 15XS3400D is one in a family of devices designed for low-voltage automotive lighting applications. Its four low $R_{DS(ON)}$ MOSFETs (quad 15 mΩ) 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 15XS3400D allows the user to program via the SPI, the fault current trip levels and duration of acceptable lamp inrush. The device has Fail-safe mode to provide safe functionality of the outputs in case of MCU damaged.

For feature information, refer to the device’s Data Sheet.

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2 Short-circuit Protections

Those devices include four self-protected high side switches 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 100 Hz and address the dimming application (day running light).

For example, the 15XS3400D proposes two different over-load protection features:

- latched over-current protection,
- severe short-circuit protection.

Those protections are preferred to conventional current limitations, to minimize the thermal overstress within the device in case of an overload condition. 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 Over-current Protection

The transient over-current profile is adjustable to account for the variability in the bulb characteristics and the energy associated with the expected wire harness current capability. The device 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 over-current profile allows protecting the application in case of the lamp is driven in the PWM mode as well. Figure 1 shows an example for an H1 lamp.

Those transient over-currents are configurable using a SPI communication between an external micro-controller 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.

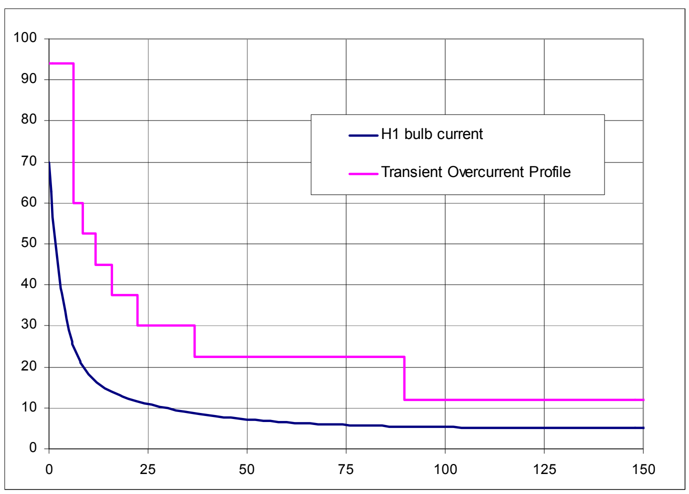

Figure 1. Transient Over-current Profile Example for the 10/12/15m Ohms Outputs

2.2 Severe Short-circuit Protection

In addition to latched over-current protection, a severe short-circuit detection is available during lamp switching to immediately turn off the output. 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 the 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.

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

a) Terminal short-circuit of 20 mΩ (R_{SHORT})
b) Load short-circuit of 100 mΩ
c) Overload condition exceeding the nominal current (i.e. 40 A DC)

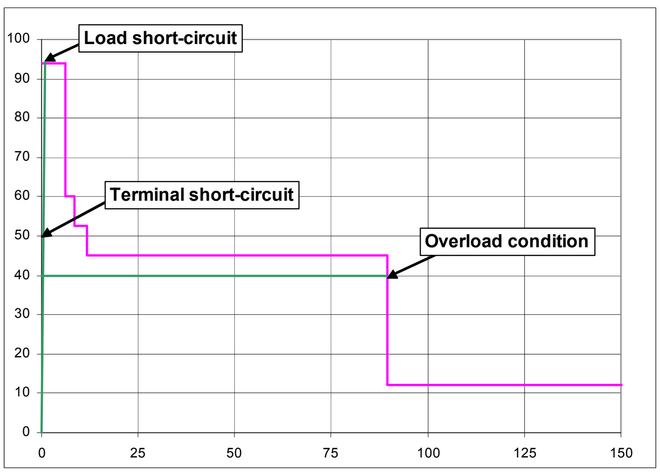

Figure 2. Short-circuit Conditions

Figure 3 describes the hardware test setup used with L_{SUPPLY} = 4.4 µH, R_{SUPPLY} = 10mΩ, and L_{SHORT} = 4.4 µH

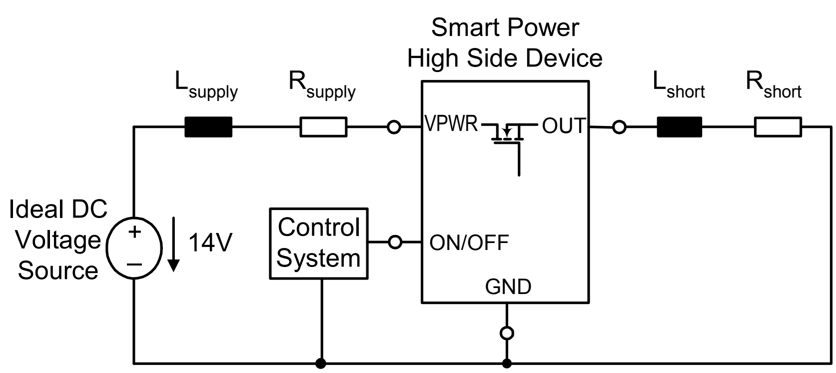

Figure 3. Short-circuit Test Setup

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 each device at 85 °C of ambient temperature. 10 engineering samples were used per test.

Table 1. Cycle Number Passed Before Failure for Load Short-circuit

Device (output)	Grade	Cycle Number Passed Before 1st Failure
MC15XS3400D (15mΩ/channel)	D	36257
MC10XS3435D (10mΩ/channel)	C	142043
MC10XS3435D (35mΩ/channel)	C	136824
MC10XS3435B (10mΩ/channel)	C	108915
MC10XS3435D (35mΩ/channel)	D	51884
MC35XS3400D (35mΩ/channel)	D	89512

5 Weibull Plots

Each test with device going into a failure mode has been stopped after 5/10. Figure 4 describes the cumulative failure over the number of passed cycles. Frechet predictive law with 95% confidence level is used to define the number of cycles to failure, down to 10PPM (1e-5).

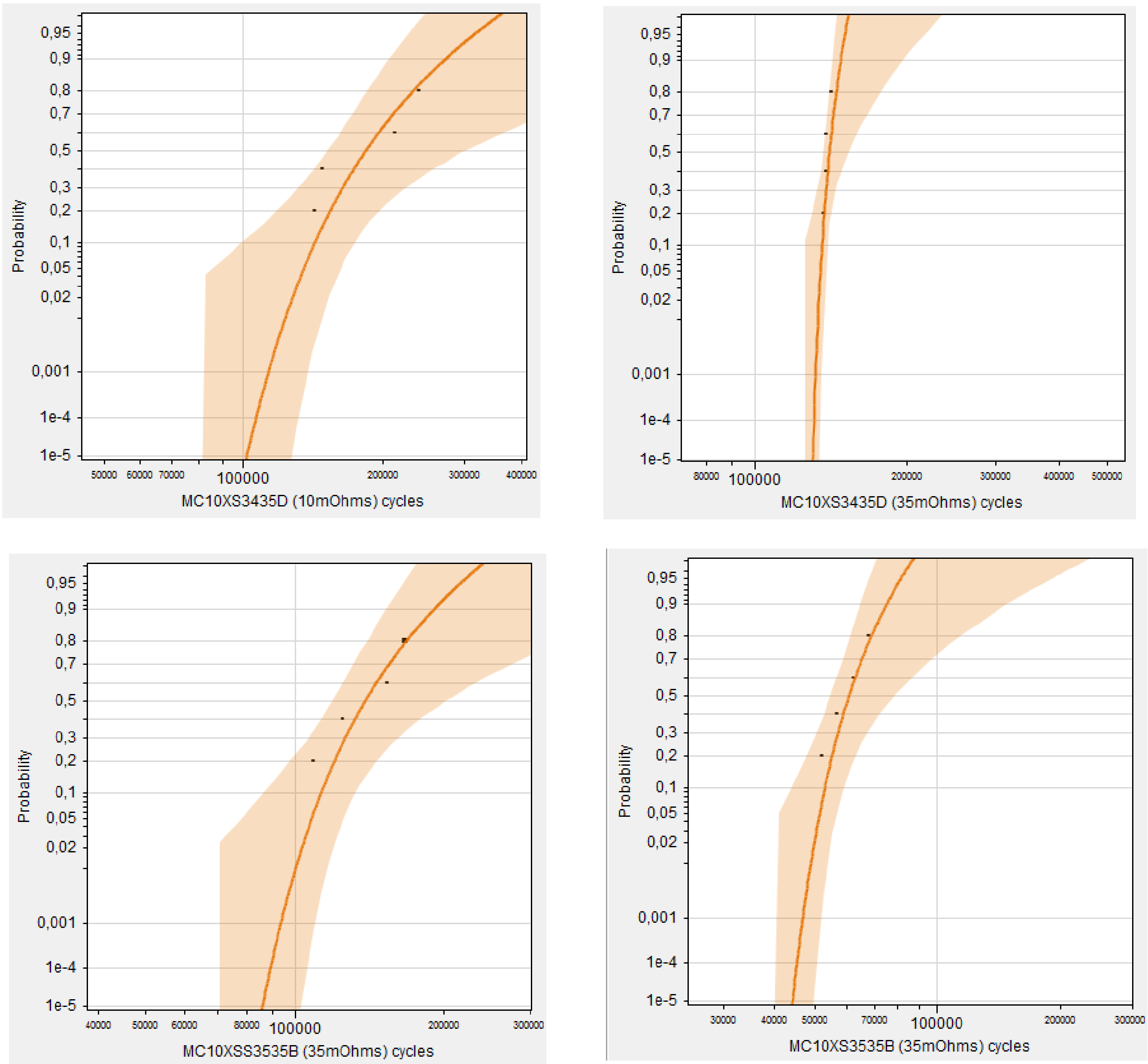

Figure 4. Cumulative Failures per Passed Cycles

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Document Number: AN3959
Rev. 2.0
6/2012