

Lamp Inrush Current Computation Tool for Optimal eXtreme Switch Usage

1 Introduction

This application note describes the transient overcurrent protection for the Generation III eXtreme Switch family of devices, when used with automotive lighting applications.

For example, the 10XS3435 is one in a family of devices designed for low-voltage automotive lighting applications. Its four low $R_{DS(ON)}$ MOSFETs (dual 10 m Ω and dual 35 m Ω) can control four separate 55 W/28 W bulbs, and/or Xenon modules, and/or LEDs.

Programming, control and diagnostics is accomplished using a 16-bit SPI interface. Its output with selectable slew-rate, improves electromagnetic compatibility (EMC) behavior. Additionally, each output are controlled through SPI for pulse-width modulation (PWM). The 10XS3435 allows the user to program via the SPI the fault current trip levels and the duration of acceptable lamp inrush. The device has a Fail-safe mode to provide safe functionality of the outputs in case of MCU damage. For feature information, refer to the device data sheets.

Freescale analog ICs are manufactured using the SMARTMOS process, a combinational BiCMOS manufacturing flow that integrates precision analog, power functions and dense CMOS logic together on a single cost-effective die.

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Lamp Switching

Freescall Semiconductor has developed a new family of optimized mixed analog/power devices, containing several high side MOSFETs, fulfilling the aforementioned requirements. Several drivers are available to control front lamps (max 65 W), rear lights (max 27 W) and 5.0 W loads including LEDs, as presented in [Table 1](#).

Table 1. Freescall Smart Power Switches for Lighting Application (Front and Rear)

Application in Car:	Low & High Beam, Fog Lights	Low & High Beam, Fog Lights	Stop, Flasher, Back Drive Lights	Stop, Flasher, Back Drive Lights
Type of Lamp:	H1, H3, H4, H7, H9	Xenon-HID	P27W, P21W, P21W+R10W, P21W+R5W	LED Arrays
Quad 15 mΩ (MC15XS3400)	√	√	√	√
Dual 10/12 mΩ (MC10XS3412)	√	√	√	√
Dual 10/35 mΩ (MC10XS3435)	√	√	√	√
Quad 35 mΩ (MC35XS3400)			√	√
Dual 10/25 mΩ (MC10XS3425)	√	√	√	√
Dual 7.0 mΩ (MC07XS3200)	√	√	√	√
Dual 6/17 mΩ (MC06XS3417)	√	√	√	√
Quad 9.0 mΩ (MC09XS3400)	√	√	√	√
Triple 6/Dual 17 mΩ (MC06XS3517)	√	√	√	√

2 Lamp Switching

Before an incandescent or halogen lamp is turned on, the filament temperature and resistance are initially very low. At turn-on, the temperature of the filament starts rising from the ambient temperature.

The low initial resistance causes large inrush current into a lamp, which can be more than 10 times the nominal current. The solid-state switch should allow this inrush current to flow in the wiring harness, but only for a specified time (<100 msec). Once the lamp is fully on, its steady-state current depends on the supplied voltage.

When a lamp is driven in PWM mode, the duty-cycle signal has to be defined in order to keep the lamp's supply voltage at the desired reference RMS voltage. Because of PWMing, the filament can not be heated as rapidly as in the normal ON mode since the supplied electrical power is reduced. The slower heating rate in PWM mode increases the inrush time as compared to the normal ON mode, as Presented In [Figure 1](#).

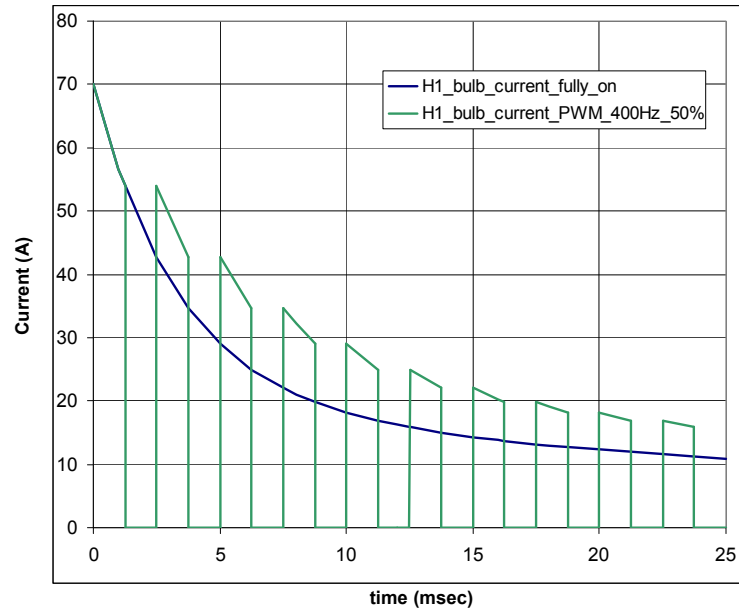


Figure 1. H1-55 w Halogen Lamp Inrush Current - Cold Temperature and for 16 V of Battery

The eXtreme Switch Generation III devices incorporate an auto-PWM module in order to simplify PWMing operation, reduce Microcontroller Unit (MCU) requirements and reduce required Printed Component Board (PCB) area. So, the MCU of lighting module must send only the duty-cycle through a SPI and the SMARTMOS device will drive the lamps in standalone. The linearity of duty-cycle is guaranteed from 5.0% to 95% at 200 Hz and 400 Hz with a resolution better than 1.0%. Furthermore, this feature can be used to address dimming application, such as daytime running lamps.

3 Short-circuit Protections

These devices operate either fully on or fully off. They never enter a “current limited” mode in which the device is partially on and limiting current in the linear mode, which is a very high power dissipation state.

The eXtreme Switch Generation III output latches off when an over-current is detected. This protection method is preferred over the conventional current limitation method because it minimizes the thermal stress within the device during an over-load condition. The junction temperature rise 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 in case the MCU is damaged.

Thanks to latched over-current protection, the device sustains successfully several thousands cycles of short-circuit, as presented in the AN3569.

4 Automotive Lighting Application

4.1 System Partitioning Overview

For a vehicle using a centralized lighting module, the length of cable between the Electronic Components Unit (ECU) and each lamp can reach several meters. The latched over-current circuitry protects the application in case the MOSFET current is higher than the defined current.

Automotive Lighting Application

[Figure 2](#) shows the application diagram for bulb protection with PWM, and this configuration is used in this study. The MCU senses the supply voltage and controls the output power by using the PWM manner when the supply voltage exceeds threshold voltage. This voltage threshold is commonly 13.2 V.

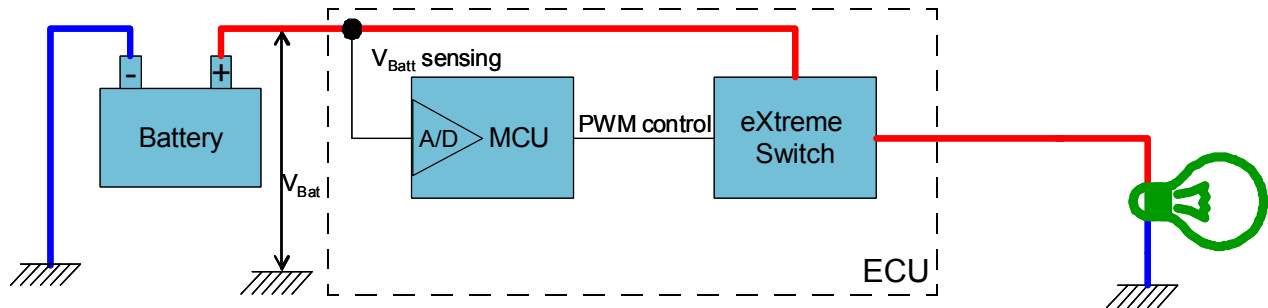


Figure 2. Typical Automotive Lighting Application

To compute the maximum lamp current, the following circuit resistances shall be taken into account:

- Wire harnesses: battery to ECU, ECU to lamp and lamp to vehicle ground
- ECU connectors
- PCB traces
- eXtreme switch $R_{DS(ON)}$
- Bulb including connector and socket

4.2 Maximum Lamp Inrush Current

For automobile stop lights, it is mandatory to guarantee the availability of the light in severe conditions. The lamp inrush current will be maximum at cold temperature and high battery voltage.

A Microsoft Excel tool, eXtremesw_AN4049_tools_CALC.xls (CALC.xls), has been created to calculate the maximum lamp inrush current, as well as the potential circuit overcurrent. The two tools contained in the CALC.xls tools file allows the circuit designer to select the type of lamp and enter the other circuit parameters. Three temperature areas are defined: wire harnesses, eXtreme switch and lamp levels. This tools takes into account possible lamp-to-lamp variations. The graphical user interface (GUI) is shown in [Figure 3](#) and can be found in the inrush dashboard tab in the CALC.xls tool.

USER INPUTS				
Battery	Voltage		16	V
	Rds(on) @ 25°C		10	mOhms
eXtreme Switch	OCHI level		78	A
	Junction Temp		-40	degC
Board	Total Traces		4.0	mOhms
Wire harness	Battery line	section	1.5	mm ²
		length	1	m
	Load line	section	0.5	mm ²
		length	1	m
	Connectors		4	mOhms
	Ambient Temp		-40	degC
Lamp	Type		H4-55W	
	Initial Ambient Temp		-40	degC
	Socket		5.0	mOhms

RESULTS		
Estimated Lamp Inrush Current	73.7	A
Safety Margin over OCHI selection	5.5%	

Figure 3. GUI to Estimate the Lamp Inrush Current

Using this tool (CALC.xls), the maximum inrush current can be compared to the minimum latched overcurrent threshold, prior to the design and implementation of the PCB layout, (see [Figure 4](#)). Also refer to the Inrush Curves tab in the CALC.xls tools file. If the computed inrush current is too close to the selected overcurrent level, you still has the possibility to improve the layout or change the device configuration. This avoids losing time in building up prototypes.

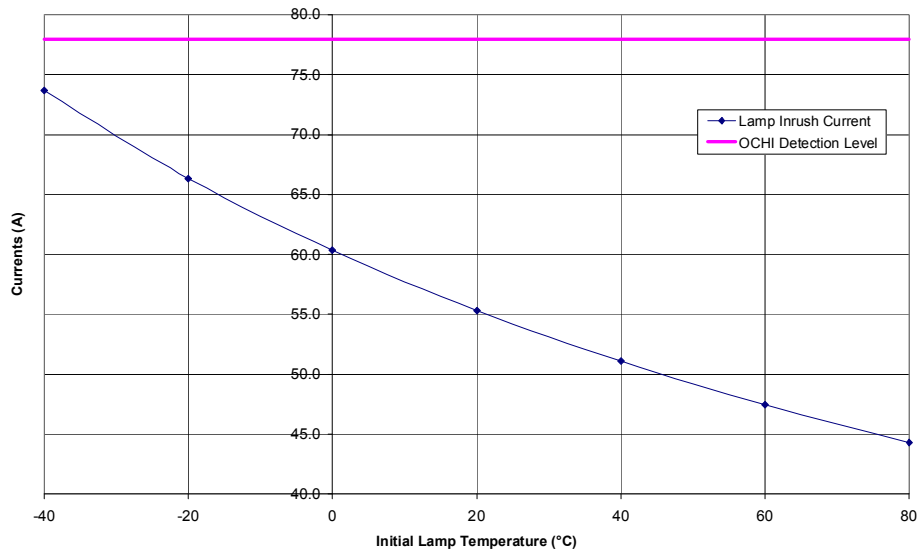


Figure 4. Estimate H4-55 W Lamp Inrush Current Over Initial Lamp Temperature

4.3 Transient Overcurrent Protection

Several transient overcurrent profiles are selectable by the MCU, using the SPI interface. To control halogen and incandescent lamps in fully-on and in PWM mode, [Figure 5](#) compares a profile for an H1-55 W lamp and the transient overcurrent protection. (Refer to the Overcurrent Profile tab in the CALC.xls tool file.)

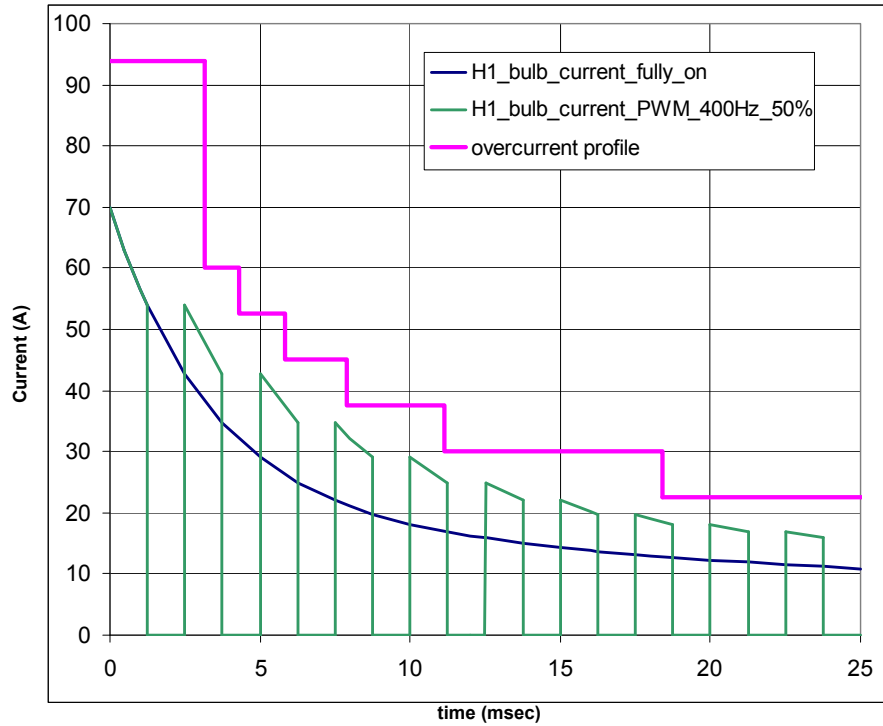


Figure 5. H1-55 W Lamp Inrush Current and Transient Overcurrent Profile

A Microsoft Excel Calculator (eXtremeSw_overcurrent_AN4049_Calc.xls) was also designed to help the software engineer to configure the MCU correctly.

5 References

Document Number and Description		URL
MC10XS3412	Data sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC10XS3412.pdf
MC15XS3400	Data sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC15XS3400.pdf
MC10XS3435	Data sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC10XS3435.pdf
MC35XS3400	Data sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC35XS3400.pdf
MC07XS3200	Data sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC07XS3200.pdf
MC10XS3425	Data sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC10XS3425.pdf
MC09XS3400	Data sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC09XS3400.pdf
MC06XS3417	Data sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC06XS3417.pdf
MC06XS3517	Data sheet	http://www.freescale.com/files/analog/doc/data_sheet/MC06XS3517.pdf
AN3569	Application Note	http://www.freescale.com/files/microcontrollers/doc/app_note/AN3569.pdf
eXtremesw_AN4049_tools_CALC.xls	Calculator	http://cache.freescale.com/files/analog/software/app_software/calculators/eXtremeSw_AN4049_tools_CALC.xls?fpsp=1
Freescale.com Support Pages		URL
MC10XS3412 Product Summary Page		http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=MC10XS3412
MC15XS3400 Product Summary Page		http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=MC15XS3400
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Analog Home Page		http://www.freescale.com/analog
Automotive Home Page		http://www.freescale.com/automotive

6 Revision History

Revision	Date	Description of Changes
1.0		<ul style="list-style-type: none">• Initial Release
2.0		<ul style="list-style-type: none">• Added reference to CALC.xls tool
3.0		<ul style="list-style-type: none">• Added new high side switch products

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