Freescale Semiconductor
Application Note

AN3848
Rev. 1.0, 4/2009

Output Current Sensing

for the MC15XS3400 eXtreme Switch Device

1 Introduction

This application note relates to the output current sensing of 3rd generation Quad 15 mΩ device.

This application note presents the current sensing accuracy and the practical implementation of a calibration procedure to improve it.

Contents

2 Scope

This device is designed for low-voltage automotive lighting applications. Its four low $R_{DS(ON)}$ MOSFETs can control four separate 55 W / 28 W bulbs, Xenon or LEDs, or other type of loads.

Programming, control, and diagnostics are accomplished using a 16-bit SPI interface. The programmable slew-rate of each output makes it easier to satisfy electromagnetic compatibility (EMC) requirements. Additionally, each output can be controlled by an internal PWM modulated clock signal instead of an external clock.

This IC's diagnostic features are essential to ensuring its safety, and they provide the microcontroller (MCU) with very highly accurate and timely information regarding the status each lamp. Digital diagnostics are reported to the MCU using an SPI communication, and an analog feedback signal provides current and temperature data to one of the MCU's A/D inputs. For example, a current proportional to the selected output's load current is provided at the device's CSNS pin. The current of bulb can be fully supervised in real time by the MCU. The purpose of this application note is to quantify the current sensing tolerance, with and without calibration at module level.

Figure 1 shows a typical application diagram using this type of quad high side device.

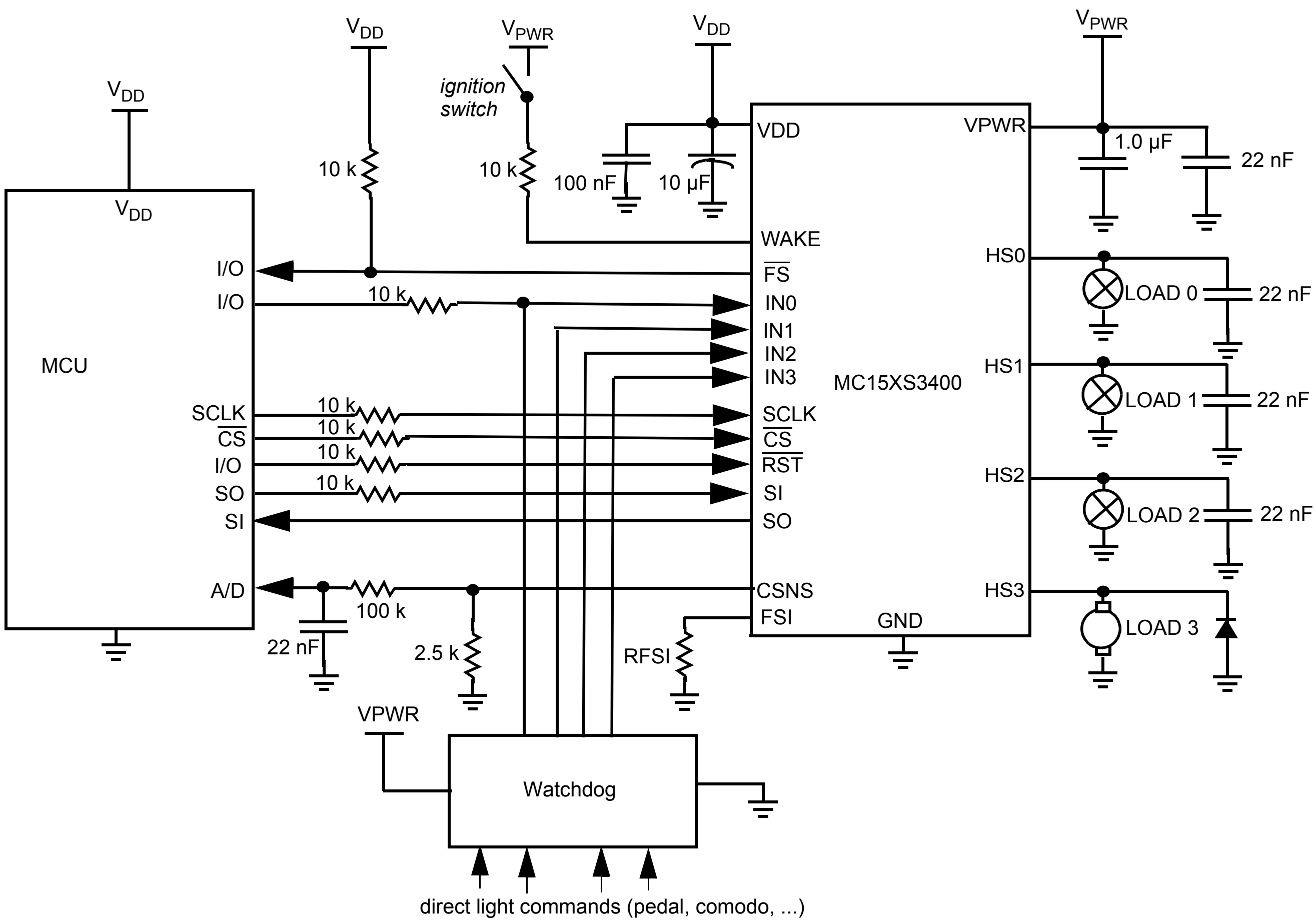


Figure 1. Typical Application Diagram

3 Selectable Current Sensing Overview

The current sensing ratio can be adjusted according to the intended lamp wattage and operation mode. For example, the CSR0 and CSR1 ratios can be used to monitor the lamp current respectively during the steady state and in inrush phase.

The Figure 2 presents the appropriate current sense ratio.

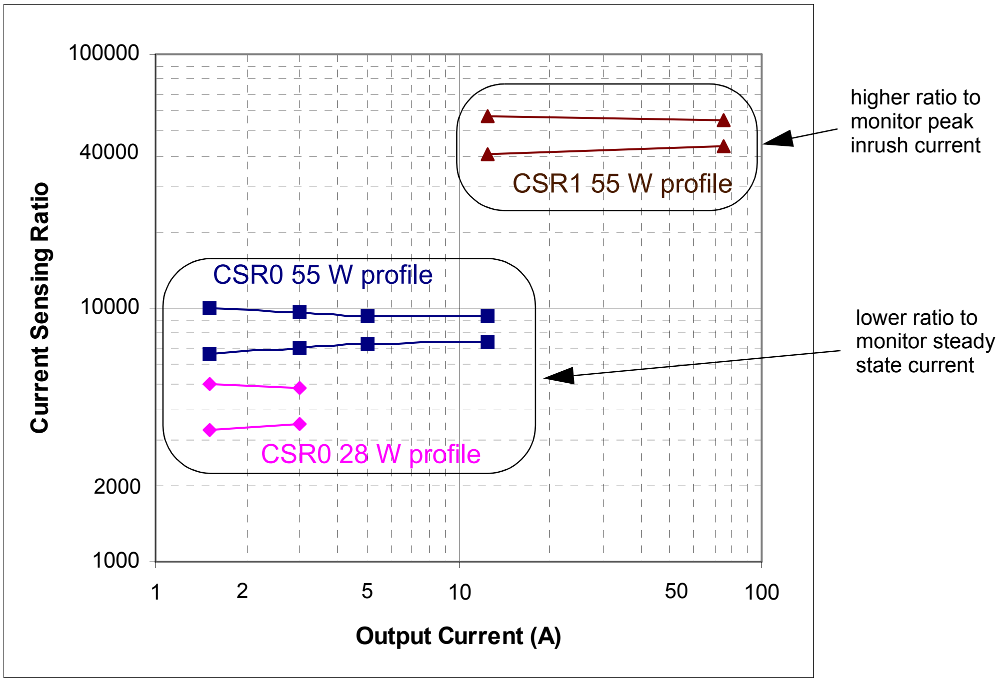


Figure 2. Current Sense Ratio in function to Output Current Range

The Figure 3 describes the accuracy of the current sense as a function of the output current for the ambient temperature range [-40°C, 125°C] and battery voltage range [6.0 V, 20 V].

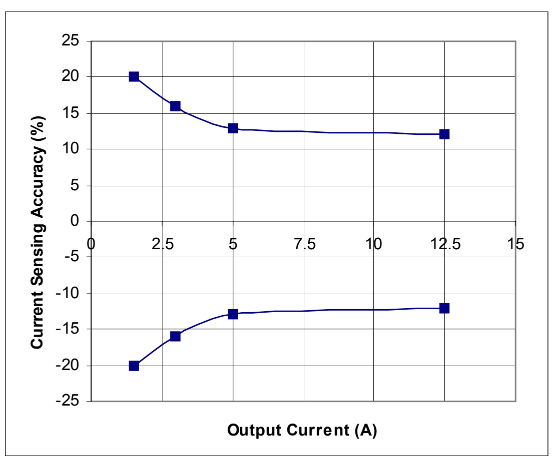


Figure 3. CSR0 Current Sense Variation with 55 W profile selected

Based on statistical data analysis performed on two production lots (initial testing only), the effect of each contributor has been demonstrated for:

1. device-to-device deviation due to manufacturing
2. ambient temperature drift
3. battery voltage range

4 Calibration Practice

Calibration at a single point removes the device-to-device error contribution for that condition. Multiple calibration points removes variation at the other conditions.

An experiment was done on low output current values. The relative CSR0 deviation based on only two or three calibration points per output has been performed on two production lots. Between each calibration point the linear regression has been used for measuring CSNS analog current feedback high precision. The Figure 4 and Figure 5 present the statistical results at 5 sigmas for battery voltage range from 9.0 V to 16 V.

The Table 1 summarizes the accuracy at 2.0 A output current. There is a possibility of using the analog temperature feedback feature of the device to distinguish low temperature range (-40°C to +25°C) and high temperature range (+25degC to +125degC).

Table 1. Current Recopy Accuracy at 2.0 A Output Current

without calibration	with calibration at 25degC only			
	Two calibration points		Three calibration points	
from -40degC to 125degC	at -40degC	from +25degC to +125degC	at -40degC	from +25degC to +125degC
+17%, -17%	+8.0%, -12%	+4.0%, -6.0%	+8.0%, -12%	+1.5%, -3.0%

Note: those results do not take into account the errors in the MCU and external sense resistor connected to CSNS terminal.

4.1 Two Calibration Points

Two points at 25°C were 0.7 A and 2.0 A for V_{PWR}=13.5 V:

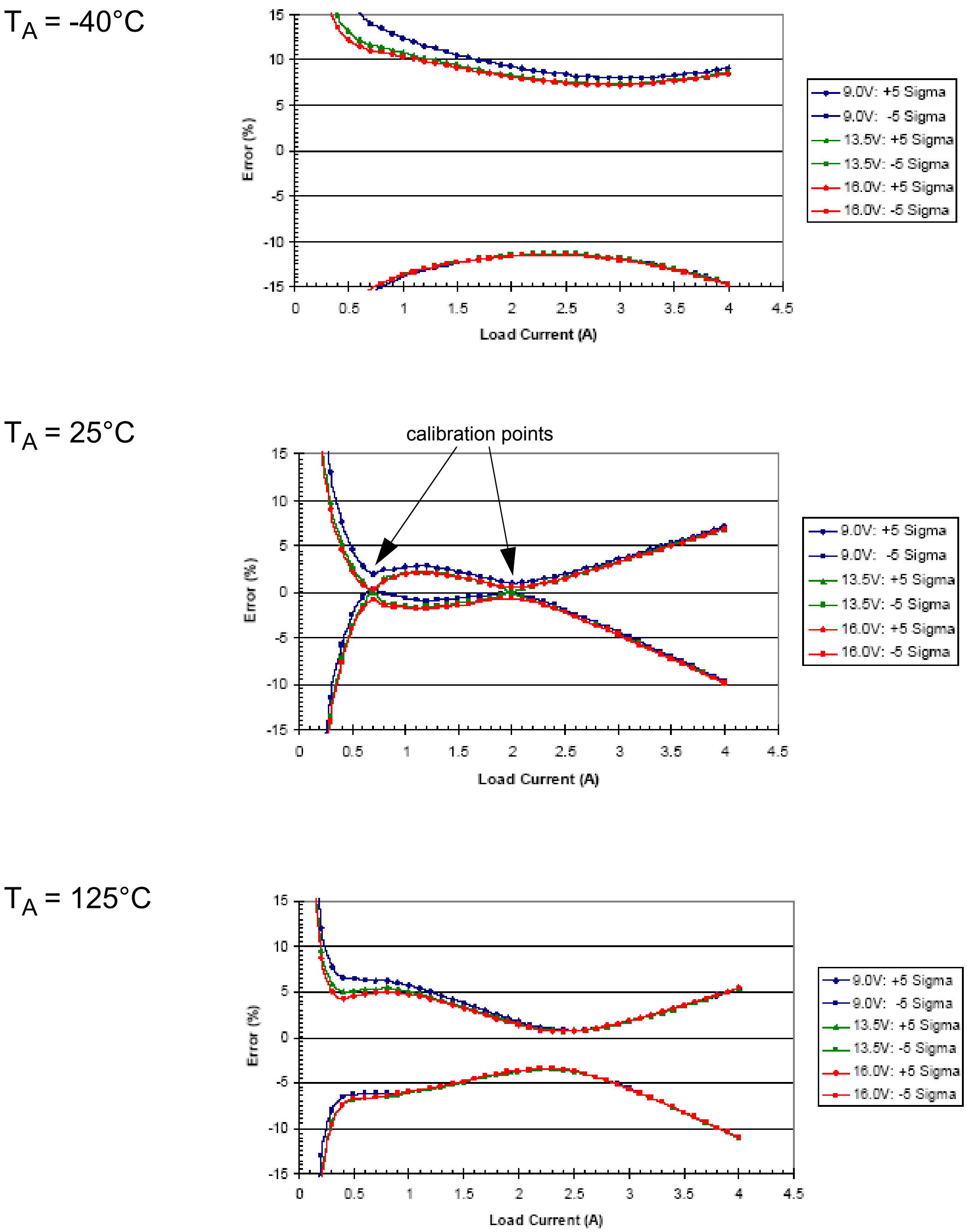
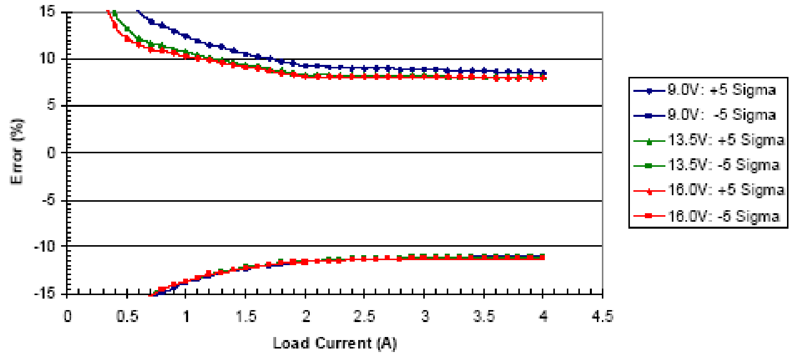


Figure 4. Calibrated CSR0 Current Sense Variation with 55 W profile selected

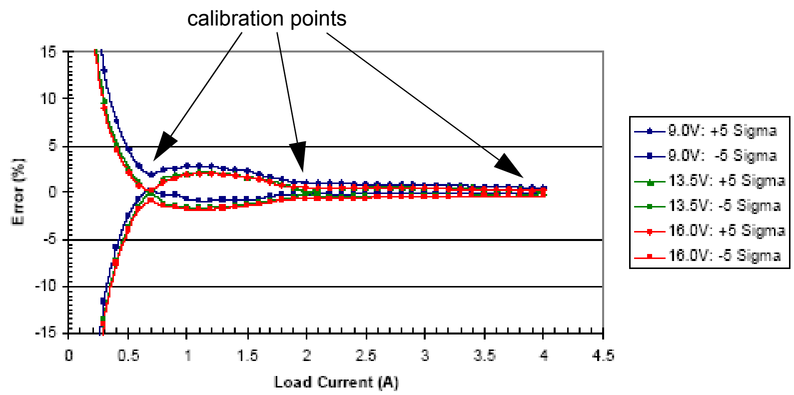
4.2 Three Calibration Points

Three points at 25°C were 0.7 A, 2.0 A and 4.0 A for V_{PWR}=13.5 V:

T_A = -40°C



T_A = 25°C



T_A = 125°C

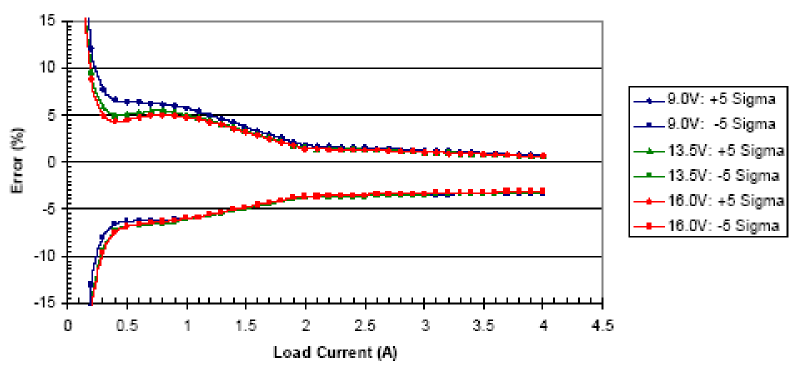


Figure 5. Calibrated CSR0 Current Sense Variation with 55 W profile selected

5 MCU Current Sense Monitoring

5.1 Current Sense Response Time

The Figure 6 describes the dynamic response of the current sensing function:

- 140 µsec typical ($t_{DLY(ON)}$ + $t_{CSNS(VAL)}$) after the turn-on command coming from the IN pin or SPI command, the current recopy is within +/-5% of the final value, whatever the battery voltage and the output current values are,
- the CSNS output typically lags 5.0 µsec ($t_{CSNS(SET)}$) behind the actual selected output current.

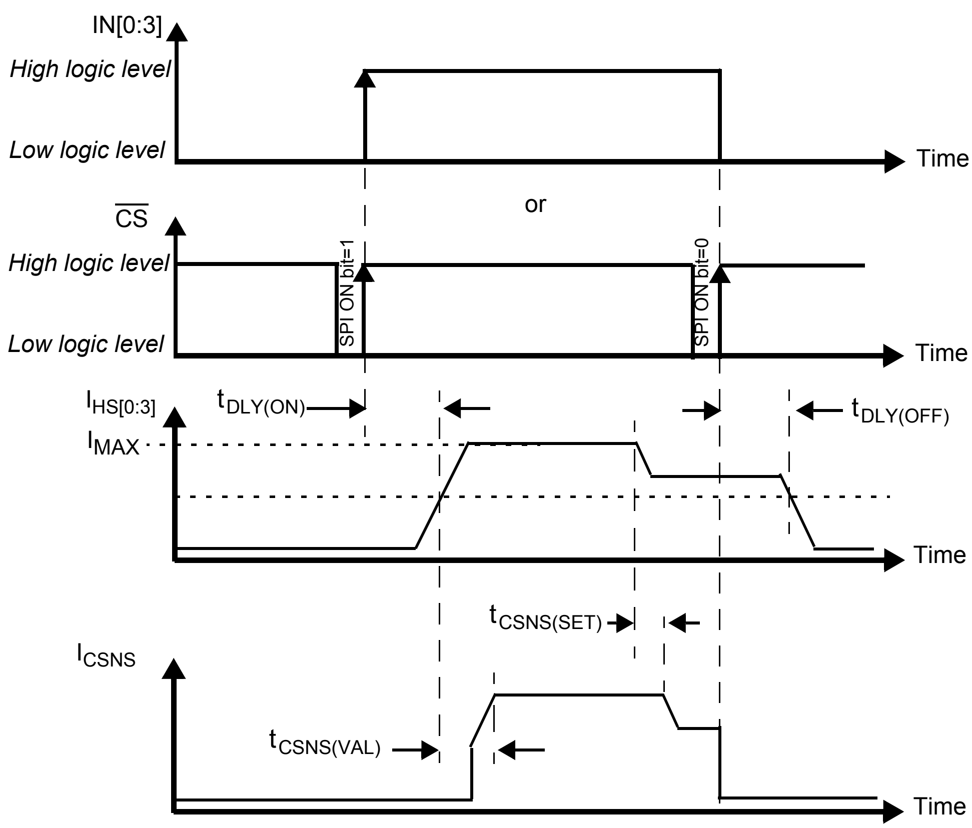


Figure 6. Current Sensing Time Delays

The current recopy transient response fulfils to 3.0% duty-cycle of a 200 Hz PWM output switching with a default slew-rate (4.0% duty-cycle for 400Hz PWM frequency with fast slew-rate selected).

5.2 Synchronization of MCU Analog-to-Digital Conversion

In many medium and high end microcontrollers, as the Freescale's MC9S12XE, the Analog-to-Digital (A/D) converter includes features combining interrupt generation and data acquisition.

Either an external control signal (ETRIGx) or the CSNS signal may used to trigger the A/D conversion, by first generating an interrupt and then sampling the analog value after the defined delay time. By using this feature, polling of the analog value at the CSNS pin can be avoided, thus alleviating microcontroller overhead and reducing average power consumption.

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AN3848
Rev. 1.0
4/2009

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