Freescale Semiconductor
Application Note

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Output Current Sensing

for the MC35XS3400 eXtreme Switch Device

1 Introduction

This application note relates to the output current sensing of 3rd generation Quad 35 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 28 W bulbs 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 highly accurate and timely information regarding the status each lamp. Digital diagnostics are reported to the MCU using a 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 by the device's CSNS pin. So, the current of a 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 the module level.

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

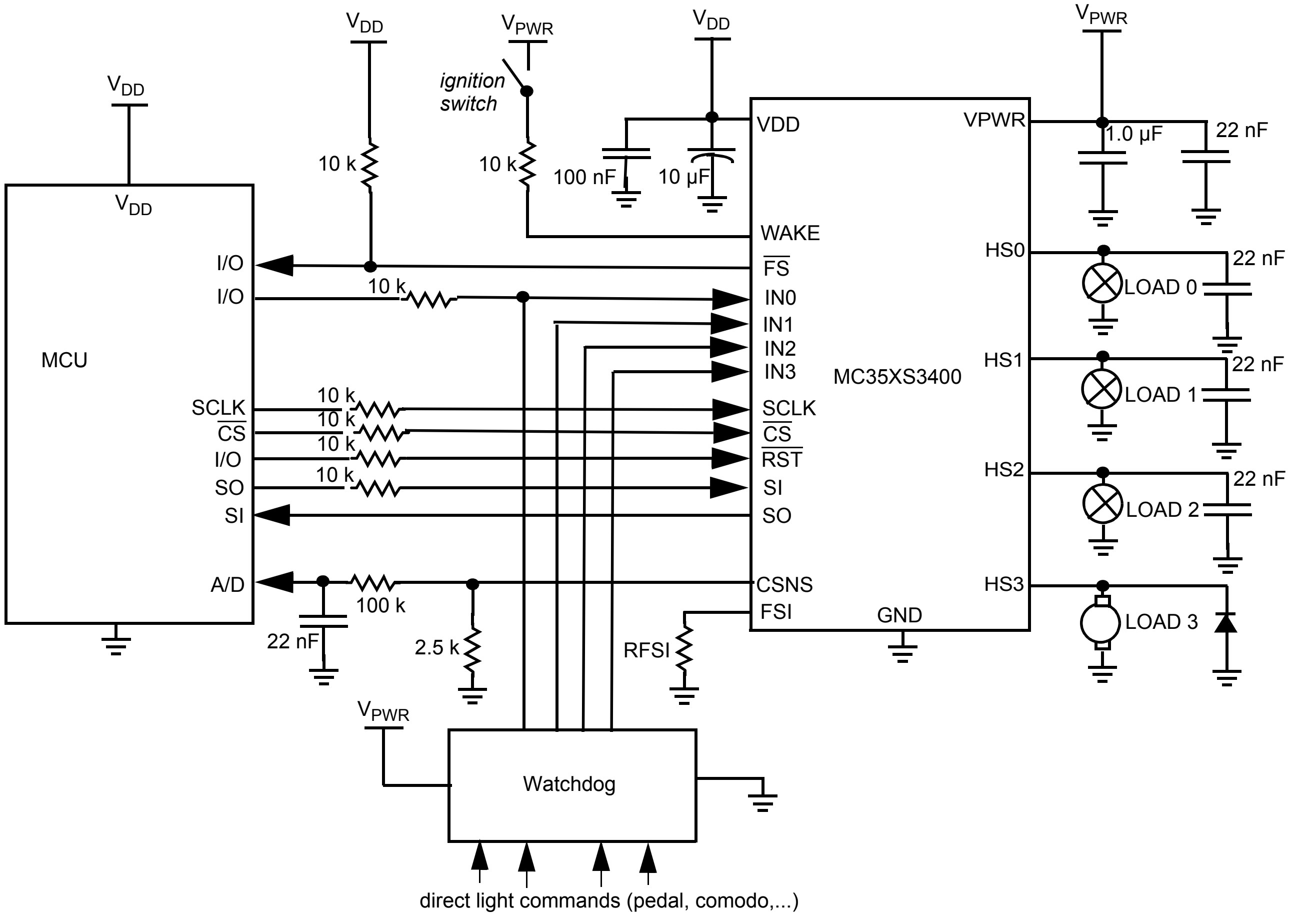


Figure 1. Typical Application Diagram

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 the inrush phase.

Figure 2 presents the appropriate current sense ratio.

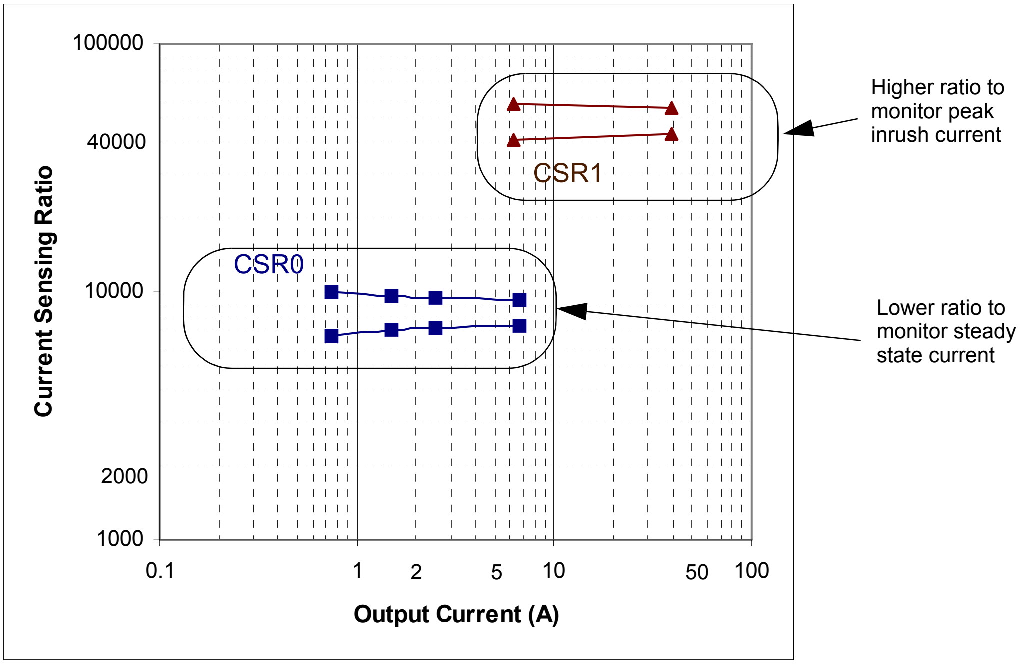


Figure 2. Current Sense Ratio in Function to Output Current Range

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].

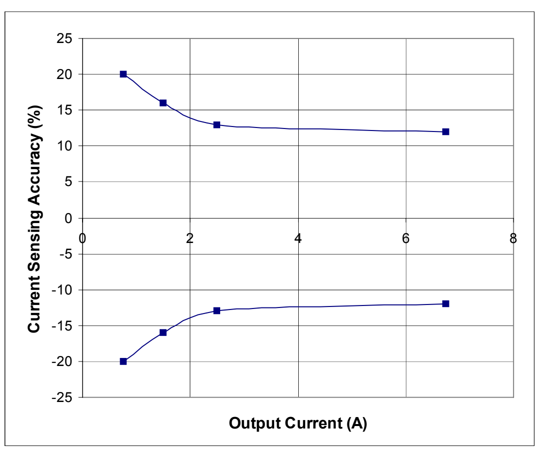


Figure 3. CSR0 Current Sense Variation

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 remove variation at other conditions.

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

Table 1 summarizes the accuracy at 1.0 A output current. There is a possibility of using the analog temperature feedback feature of the device to distinguish low a temperature range (-40°C to +25°C) and a high temperature range (+25°C to +125°C).

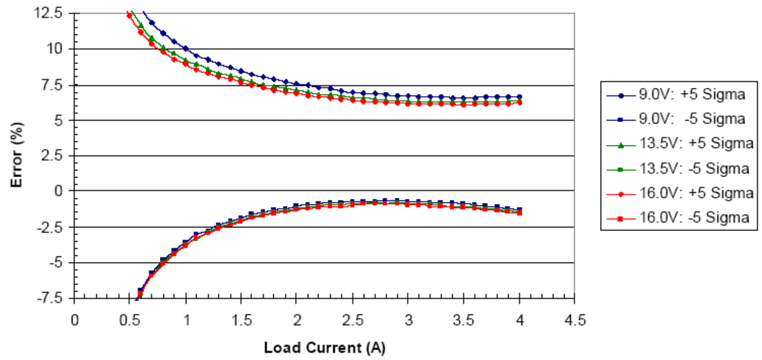
Table 1. Current Recopy Accuracy at 1.0 A Output Current

Without Calibration	With Calibration at 85°C only		
	Two Calibration Points		
from -40degC to 125degC	at -40degC	at 25degC	at 125degC
+17%, -17%	+10%, -3.0%	+6.0%, -2.4%	+3.0%, -3.5%

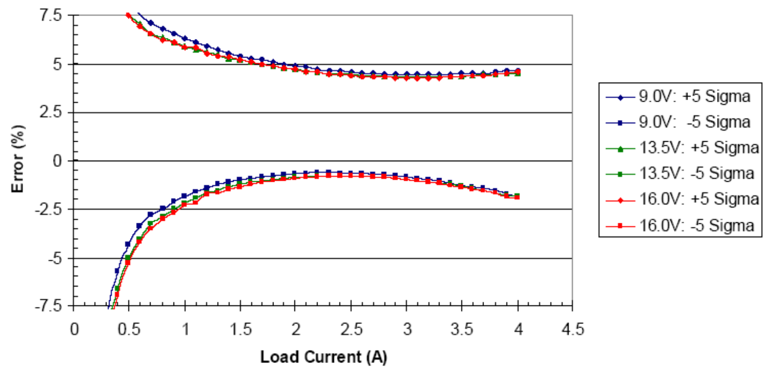
Note: Those results do not take into account the errors in the MCU and external sense resistor connected to the CSNS terminal.

Two calibration points at 85°C were 0.7 A and 2.0 A for V_{PWR} = 13.5 V:

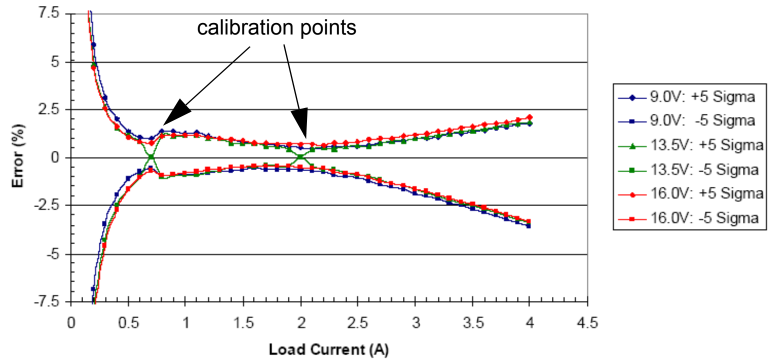
T_A = -40°C



T_A = 25°C



T_A = 85°C



T_A = 125°C

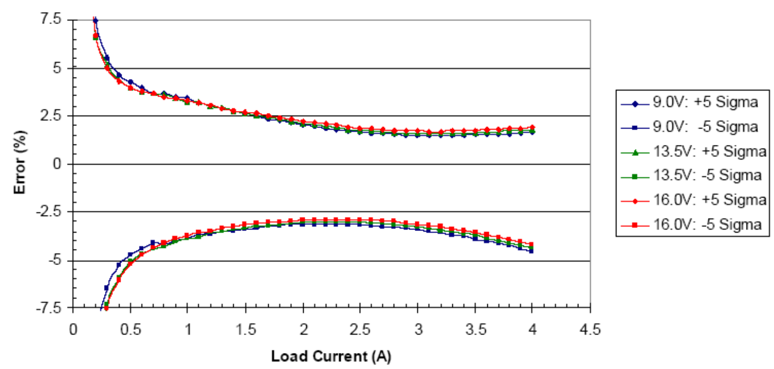


Figure 4. Calibrated CSR0 Current Sense Variation

5 MCU Current Sense Monitoring

5.1 Current Sense Response Time

Figure 5 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,
- The CSNS output typically lags 5.0µsec ($t_{CSNS(SET)}$) behind the actual selected output current.

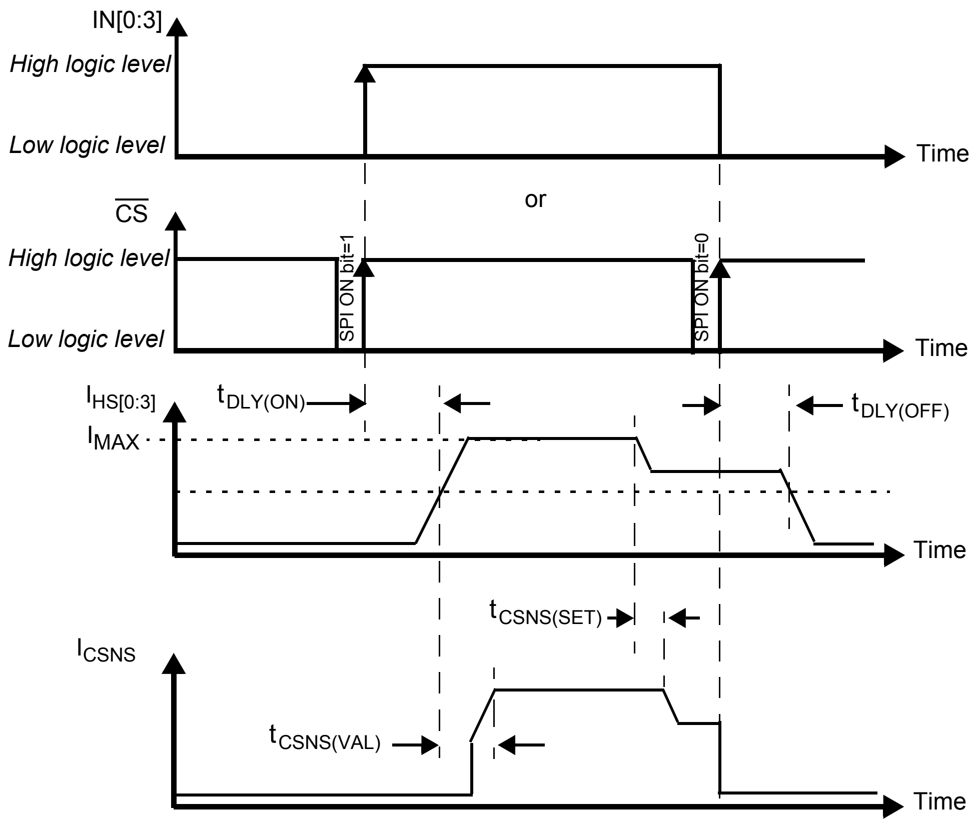


Figure 5. Current Sensing Time Delays

The current recopy transient response fulfils to 3.0% duty cycle of 200 Hz PWM output switching, with the 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 in 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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