AN4208
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Output Current Sensing

for the MC10XS3535 & MC35XS3500 eXtreme Switch Devices

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1 Introduction

This application note pertains to the output current sensing of 3rd generation Penta device.

AN4208 presents the current sensing accuracy for 10 mOhm and 35 mOhm channels and the practical implementation of a calibration procedure to improve it. This document is based on statistical analysis covering 96.2% of produced parts.

Contents

2 Scope

This device is designed for low-voltage automotive lighting applications. Its five 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 precise and timely information regarding the status each lamp. Digital diagnostics are reported to the MCU using 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 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 penta high side device.

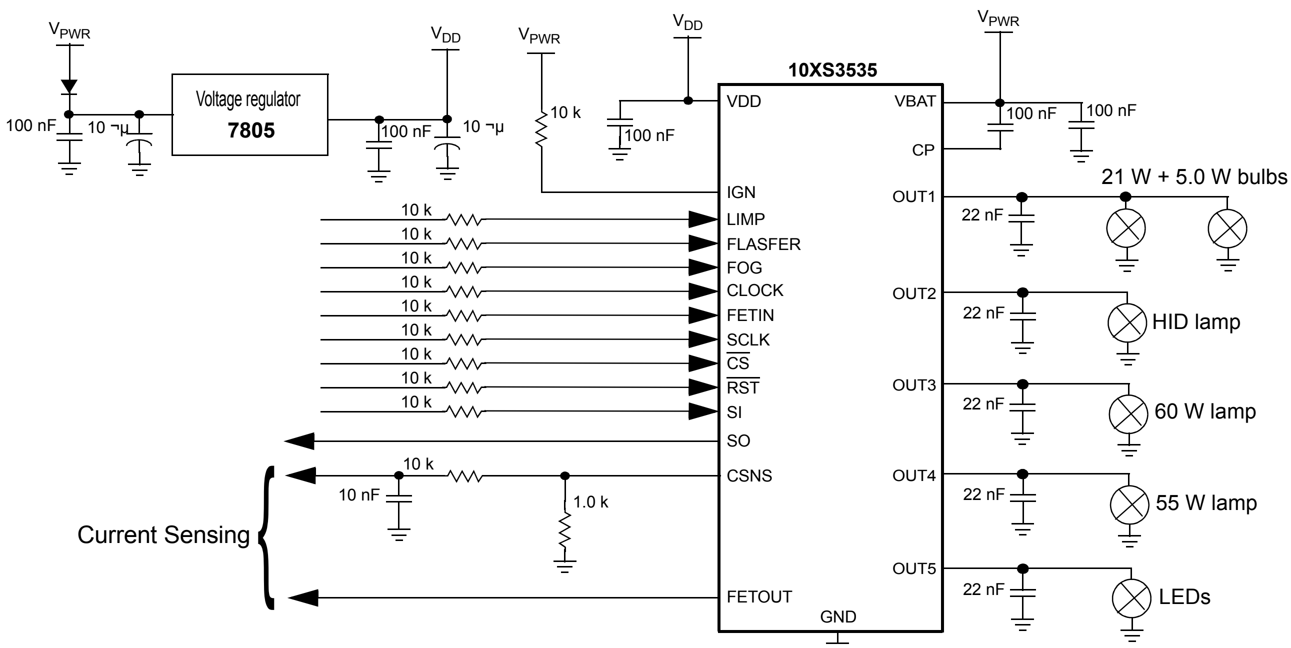

Figure 1. Typical Application Diagram

3 Selectable Current Sensing Overview

The current sensing ratio can be adjusted according to the intended lamp wattage and operation mode. The default setting allows monitoring of the nominal lamp current. The full-scale range (FSR) can be reduced by a factor of 25%, thanks to the “LED Control” SPI bit, to monitor low output current as mentioned in Figure 2 and in Table 1. The minimum output current reported in CSNS is called $I_{MIN(CSNS)}$

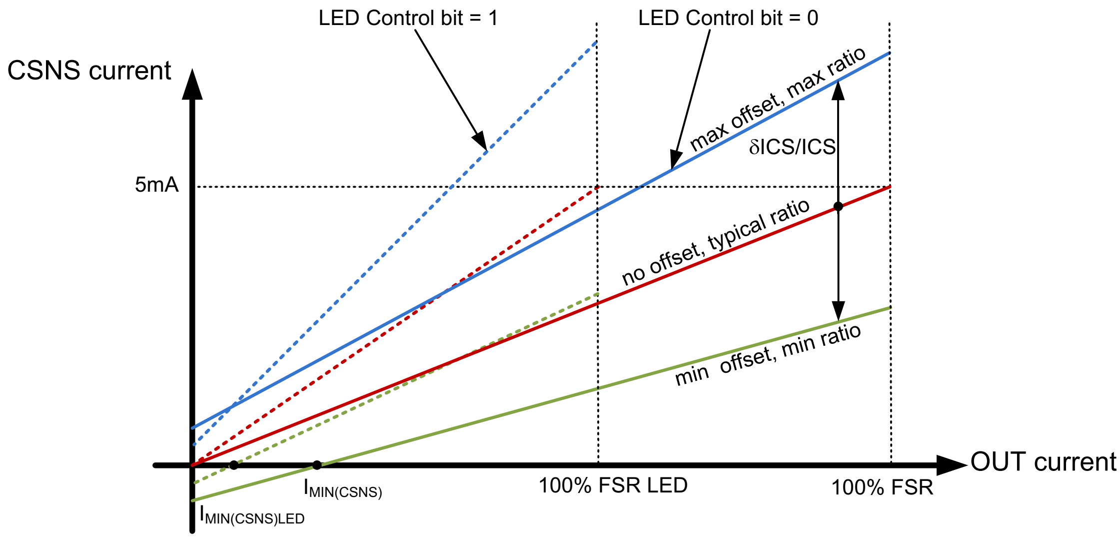

Figure 2. Current Sense Versus Load Current

Table 1. Area of Output Current Sensing

Under All Conditions	Minimum, $I_{CSNS(MIN)}$	Maximum
10 mOhms Channel	250 mA with LED Control bit=0	21.9 A (Xenon) 12.5 A or 12.7 A (Lamp)
	140 mA with LED Control bit=1	3.5 A
35 mOhms Channel	65 mA with LED Control bit=0	5.7 A
	40 mA with LED Control bit=1	1.6 A

Figure 3 describes the absolute precision of the current sense, as a function of the output current for the ambient temperature range [-40 °C, 125 °C], battery voltage range [10 V, 16 V], and both selectable full-scale ranges.

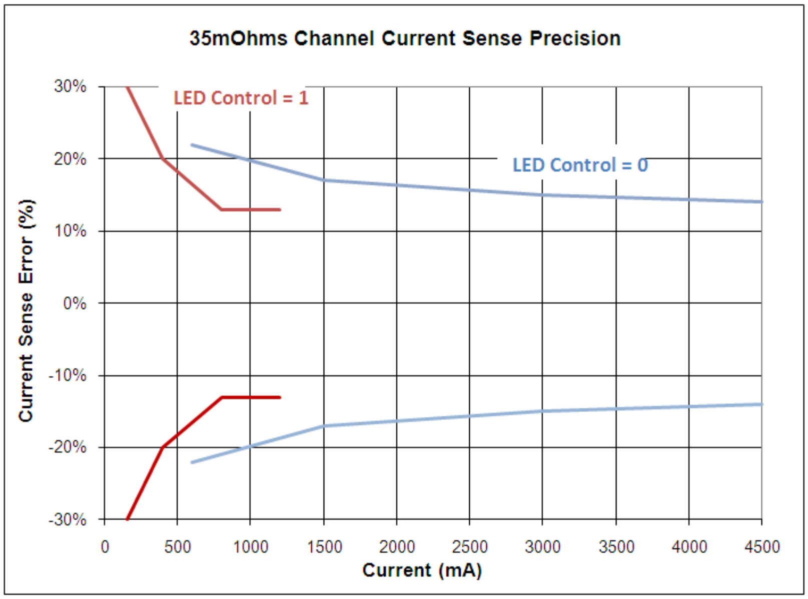

Figure 3. Current Sense Precision in Function to the Output Current Range

The accuracy of current sensing (δICS/ICS) depends on the following contributors:

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

This application note does not consider the errors in the MCU and the external sense resistor connected to CSNS pin.

4 Calibration Practice

With a calibration strategy, the precision can be improved significantly. One calibration point at 25 °C allows for removal of the device-to-device effect. For lamp diagnostic or partial open-load detection, the calibrated part precision at 50% FSR goes down to ±5.8%, over a 20 to 75% FSR, an over-voltage of 10 to 16 V, and a temperature range -40 to 125 °C, as illustrated in Figure 4. Moreover, calibration points can also help to partially remove offset error at low output current.

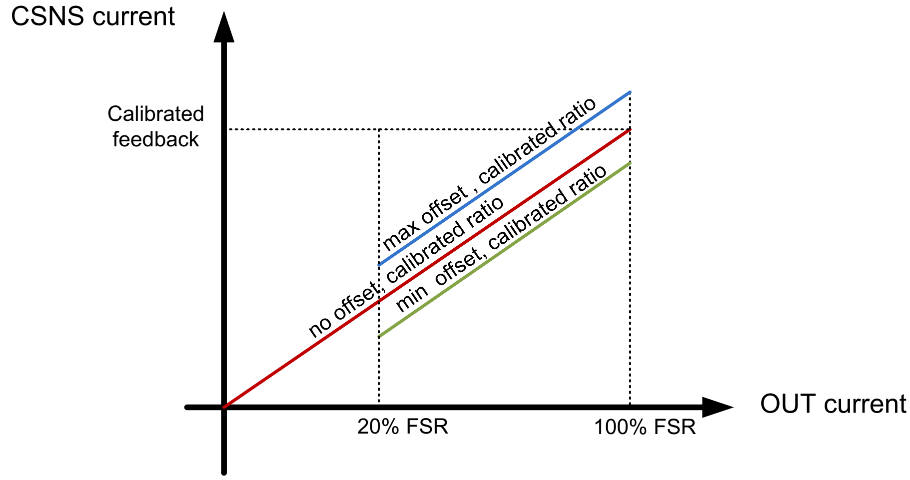

Figure 4. Calibrated Current Sense (50% FSR @ 25 °C) Versus Load Current

Figure 5 presents the precision when calibration is done at each current level, at 25 °C and 13.5 V.

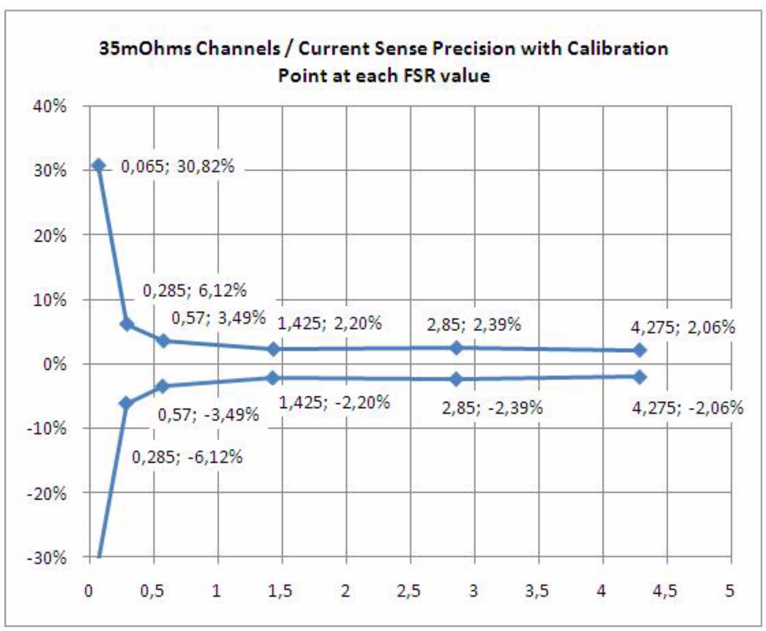

Figure 5. Current Sense Precision for Lamp with One Calibrated Point at 25 °C per Current Level

To diagnose LEDs or an ultra-low open-load event, it is recommended to use LED control bit to a logic [1], as described in Figure 6

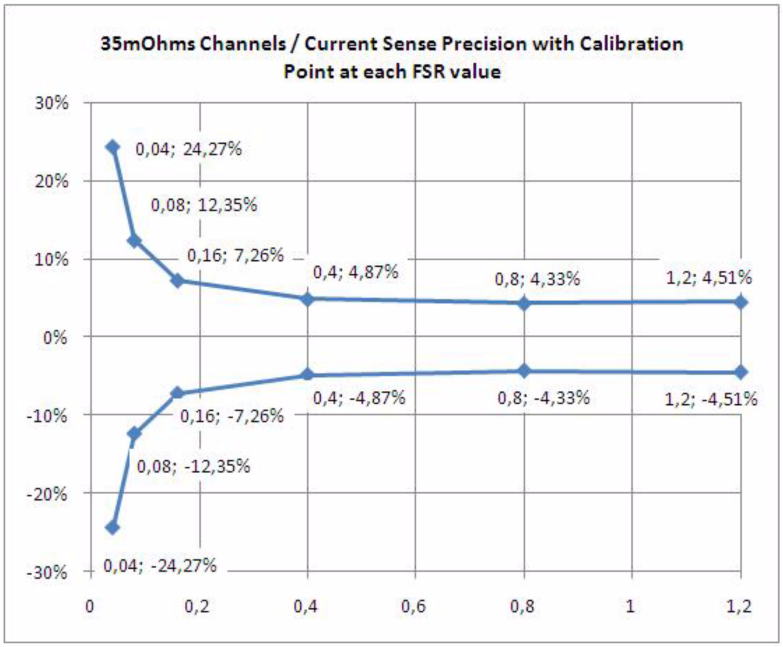

Figure 6. Current Sense Precision for LED with One Calibrated Point at 25 °C per Current Level

5 Calibration Pratice for the 10 mOhm Channel

Figure 7, Figure 8, and Figure 9 summarize the precision when a calibration is done at each current level, at 25 °C and 13.5 V.

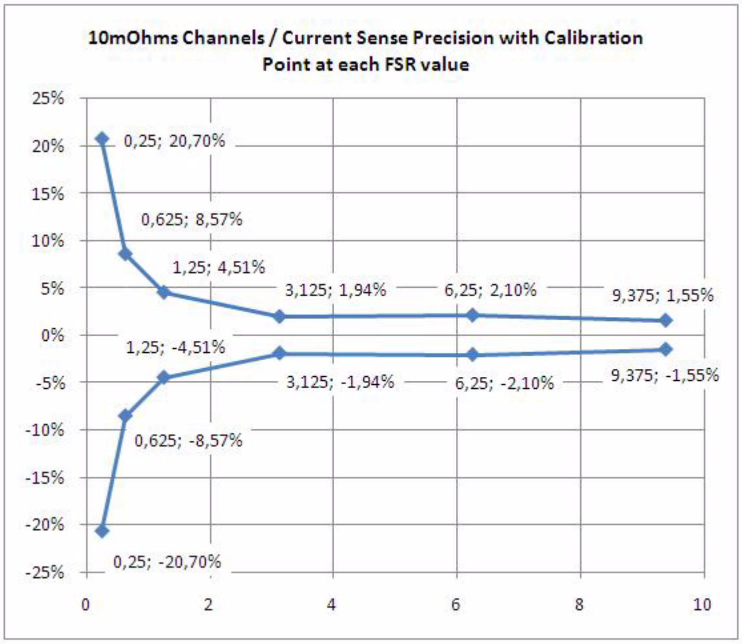

Figure 7. Current Sense Precision with One Calibrated Point at 25 °C per Current Level

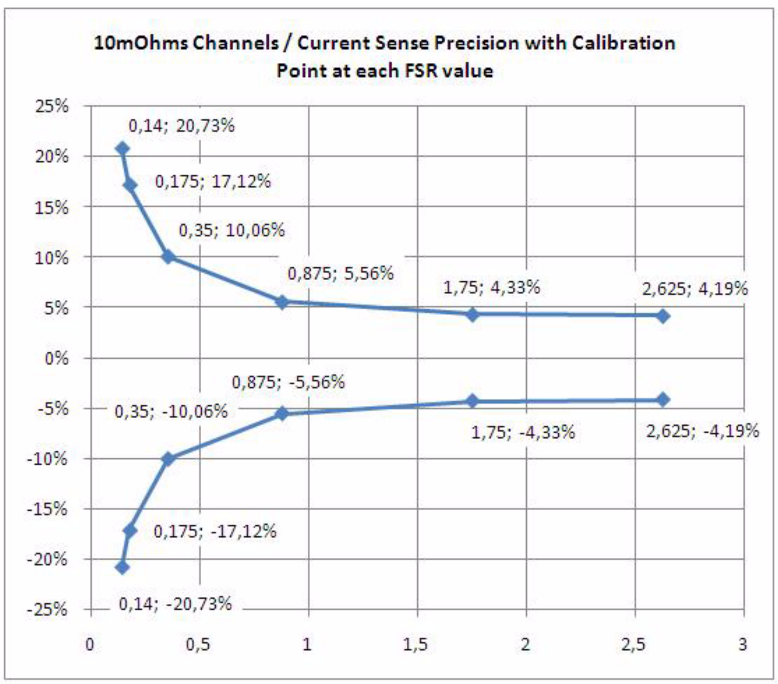

Figure 8. Current Sense Precision for LED Mode with One Calibrated Point at 25 °C per Current Level

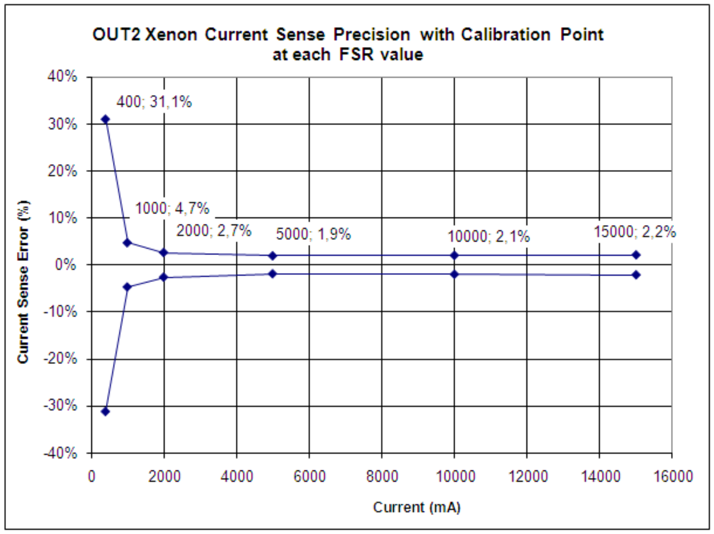

Figure 9. Current Sense Precision for OUT2 Xenon Mode with One Calibrated Point at 25 °C per Current Level

6 MCU Current Sense Monitoring

6.1 Current Sense Response Time

Figure 10 describes the dynamic response of the current sensing function:

- a typical 175 μsec ($t_{DLY(ON)} + t_{CSNS(VAL)}$), after the turn-on command coming from rising edge of $\overline{CS}$, the current recopy is within ±5.0% of the final value, regardless of the battery voltage and output current values,
- the CSNS output typically lags 10 μsec ($t_{CSNS(SET)}$) behind the actual selected output current.

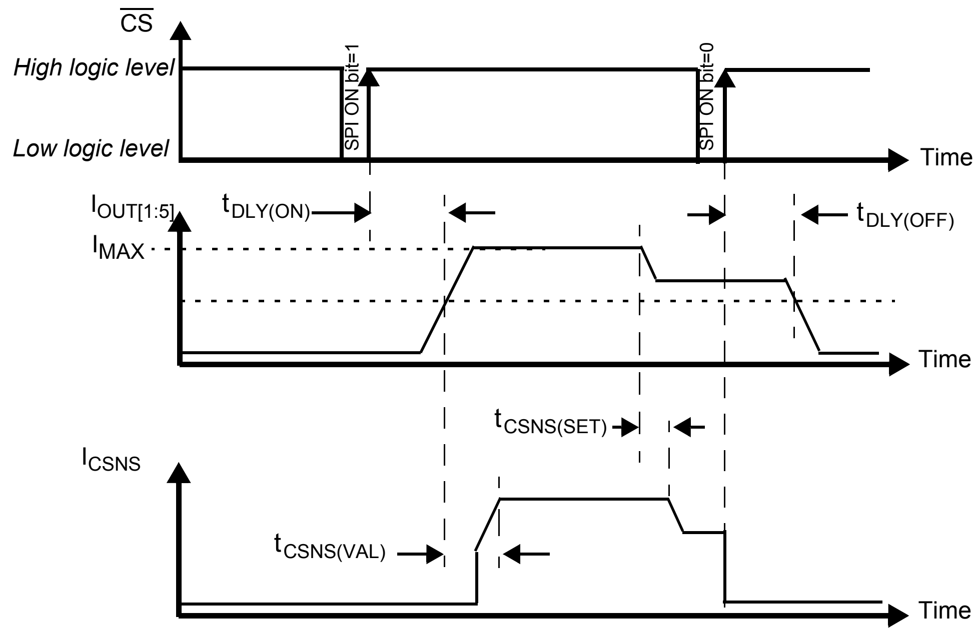

Figure 10. Current Sensing Time Delays

The current recopy transient response fulfils to a 5.5% duty-cycle of 200 Hz PWM output switching with a default slew-rate (5.5% duty-cycle for 400 Hz PWM frequency with a fast slew-rate selected).

6.2 Synchronization of MCU Analog-to-Digital Conversion

The current sense monitoring may be synchronized, if OUT6 is not used. The current sense monitoring can be synchronized with a rising edge of the FETOUT pin ($t_{CSNS(SYNC)}$), if the “CSNS SYNC” SPI bit is set to a logic [1].

As presented in Figure 11, connection of the FETOUT pin to an MCU input pin, allows the MCU to sample the CSNS pin during a valid time slot.

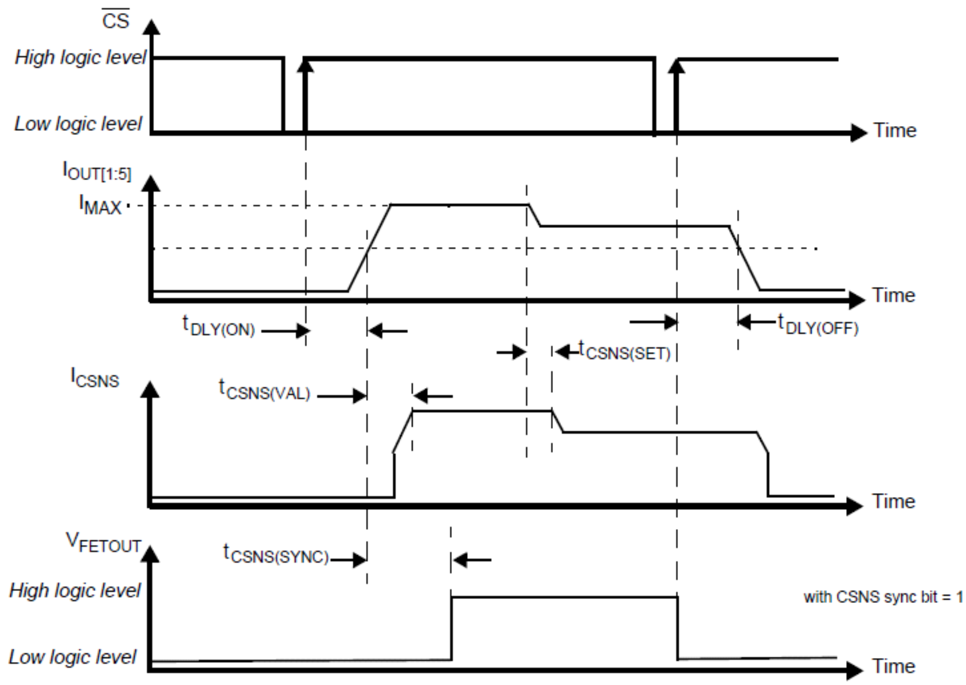

Figure 11. Current Sensing Synchronization with Digital Signal Called FETOUT

Since this falling edge is generated at the end of this time slot, upon a switch-off command, this feature may be used to implement maximum current control.

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