28 Current Sense Amplifier

28.1 Features

Main Features

- Programmable gain settings: G = 10, 20, 40, 60
- Differential input voltage: ± 1.5V / G
- Wide common mode input range ± 2 V
- Low setting time < 1.4 µs

28.2 Introduction

The current sense amplifier in **Figure 227** can be used to measure near ground differential voltages via the 10-bit ADC. Its gain is digitally programmable through internal control registers.

Linear calibration has to be applied to achieve high gain accuracy, e.g. end-of-line calibration including the shunt resistor.

Figure 227 shows how the current sense amplifier can be used as a low-side current sense amplifier where the motor current is converted to a voltage by means of a shunt resistor R_{SH}. A differential amplifier input is used in order to eliminate measurement errors due to voltage drop across the stray resistance R_{Stray} and differences between the external and internal ground. If the voltage at one or both inputs is out of the operating range, the input circuit is overloaded and requires a certain specified **recovery time**.

In general, the external low pass filter should provide suppression of EMI.

The CSA is able to measure positive as well as negative currents through the shunt. Since the ADC1 only provides single-ended inputs the output of the CSA will be offset by Vzero. Vzero is 0.4 * VAREF, approx. 2V. In order to measure the real CSA output at 0A input the user has to perform an ADC1 Ch1 measurement with idealy 0A through the shunt, with **CTRL**.VZERO bit set to ‘0’. The desired gain has to be set before that. The offset might vary from one gain setting to another, therefore if the gain has been changed the offset measurement has to be repeated.

The bit **CTRL**.VZERO switches between the CSA output and the Vzero voltage reference, as displayed in **Figure 227**. The CSA is not ideal, it shows an input offset, therefore the Vzero voltage reference, if measured by the ADC1, may differ from the CSA output value at 0A current input by +/-~1mV * Gain.

28.2.1 Block Diagram

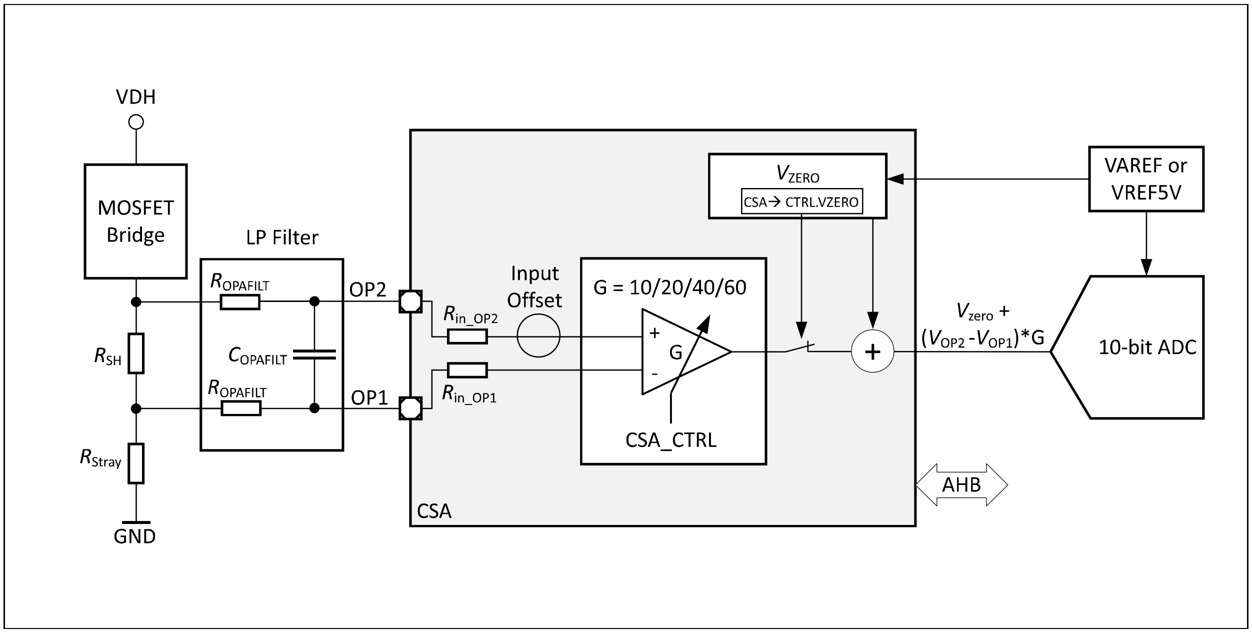

Figure 227 Simplified Application Diagram

28.2.2 Recommended Offset Calibration

In order to perform a correct offset calibration the complete path from shunt resistor throught the CSA to the ADC1 should be measured. For this purpose it should be ensured that there is no current flow (0A) through the shunt. The following list collects the steps to perform a recommended offset calibration:

- connect the CSA output to the ADC1 Channel 1 input by closing the switch, CSA->**CTRL**.VZERO=0
- set desired CSA gain, CSA->**CTRL**.GAIN=x
- ensure 0A current flowing through the shunt, therefore 0V differential voltage at the CSA input
- perform an ADC1 Channel 1 measurement, using the software mode, would be suitable
- the ADC1 Channel 1 digital output, **RES_OUT1**, holds the CSA output offset including the CSA input offset
- repeat the measurement for other CSA gain settings if needed

Note: By applying the recommended calibration procedure the violated output offset is compensated.

Figure 228 displays the effective signal path for the recommended offset calibration.

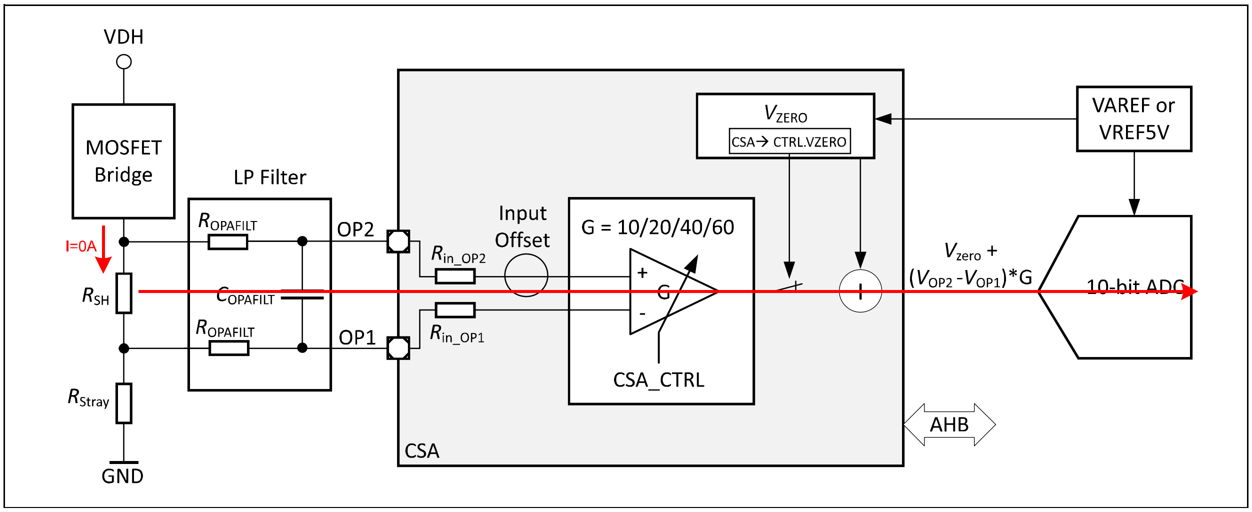

Figure 228 CSA simplified internal structure - offset calibration path

28.3 Functional Description

28.3.1 ADC Code Calculation

The differential input voltage V_{OP2} - V_{OP1} of the embedded Current Sense Amplifier (CSA) is converted to an ADC code by the following equation:

(33)

$$\text{ADC1out} = \text{floor}\left(\frac{V_{zero} + (V_{OP2} - V_{OP1}) * G}{V_{LSB}} \right)$$

wherein the parameter V_{OP1} *and* V_{OP2} are the voltages at the inputs of the amplifier and G is the configured gain. The CSA output voltage V_{CSAout} = (V_{OP2} - V_{OP1}) * G is centered around an offset voltage V_{Zero} which has the following dependency on the reference voltage V_{AREF} of ADC1:

(34)

$$V_{Zero} = 0.4 * V_{AREF}$$

The value of V_{AREF} is 5V @ 27 °C. V_{LSB} defined as follows:

(35)

$$V_{LSB} = \frac{V_{ref}}{1024}$$

28.4 Register Definition

The next chapter lists the configuration possibilities of the Current Sense Amplifier (CSA) which can be used for external current sensing.

Table 187 Amplifier Module Base Address List

Module	Base Address
CSA	48018000_H

The base address of the module is the same as for the measurement unit (MU) as the current sense amplifier is a sub-block of the MU.

Table 188 Register Overview

Register Short Name	Register Long Name	Offset Address	Reset Value
Register Definition			
CTRL	Operational Amplifier Control and Status	$0C_H$	$0000\ 0000_H$

The registers are addressed wordwise.

Operational Amplifier Control and Status

The following register consists of control and status bits. This Register is cleared by every reset.

The register is reset by RESET_TYPE_3.

CTRL **Offset** **Reset Value**

Operational Amplifier Control and Status **$0C_H$** **$0000\ 0000_H$**

31–16
Res
r

15–9	8	7–3	2–1	0
Res	VZERO	Res	GAIN	EN
r	rw	r	rw	rw

Field	Bits	Type	Description
Res	31:9	r	**Reserved** Always read as 0
VZERO	8	rw	**Current Sense Output Selection** 0_B **VOUT** CSA output connected to ADC1 Ch1 1_B **VZERO** voltage reference connected to ADC1 Ch1
Res	7:3	r	**Reserved** Always read as 0

Field	Bits	Type	Description
GAIN	2:1	rw	**Operational Amplifier Gain Setting** 00_B **10** Gain Factor 10 01_B **20** Gain Factor 20 10_B **40** Gain Factor 40 11_B **60** Gain Factor 60
EN	0	rw	**OPA Enable** 0_B **DISABLE** OPA switched off 1_B **ENABLE** OPA switched on