

# ZSSC3281

## Dual Channel Resistive Sensor Signal Conditioner IC

The ZSSC3281 is a dual path sensor signal conditioning IC (SSC) for highly accurate amplification, digitization, and sensor-specific correction of sensor signals. The ZSSC3281 is suitable for bridge and half-bridge sensors, as well as external voltage-source element and single-element sensors (for example, Pt100 and external temperature sensor diodes) powered by an on-chip current source. Digital compensation of the sensor offset, sensitivity, temperature drift, and non-linearity is accomplished via a 32-bit ARM M3 based math core running a correction algorithm with calibration coefficients stored in a non-volatile, reprogrammable memory. The programmable, integrated sensor front-end allows optimally applying various sensors for a broad range of applications.

The ZSSC3281 provides measurement value readouts and programming capabilities via an I2C, SPI, or one-wire interface (OWI). Absolute and ratiometric voltage, current-loop, or interrupt outputs are supported by the ZSSC3281.

## Applications

- Calibrated, continuously operating sensors with digital interface and/or analog output: (absolute or ratiometric) voltage or current loop output
- Enables smart, digital sensors for energy-efficient solutions
- (Dual/Diff.) pressure, flow and level sensing
- Industrial applications; for example, process/factory automation
- Consumer / white goods, for example, HVAC, weight scales
- Medical applications, for example, blood pressure, continuous smart health monitors

## Features

- Digital communication and calibration interfaces:
  - SPI up to 12MHz
  - I2C (Standard, Fast, Fast+) and I3C SDR
  - One-wire-interface (OWI), up to 100kBit/s
- Accommodates nearly all resistive bridge sensor types (signal spans from 1mV/V up to 500mV/V)
- Supports different sensor element configurations:
  - Resistive bridge or half-bridge
  - Resistive divider string
  - Voltage source
- On-chip temperature sensor
- External temperature sensing supported, for example, sensor-bridge as temperature detector, external diode, etc.
- Programmable 16-bit digital-to-analog-converter and output (supporting “True-0Volt”-output):
  - (0V to 1V) or (0V to 5V) absolute voltage output
  - VDD-ratiometric voltage output
  - 4mA to 20mA current-loop output supported
  - 0V to 10V absolute-voltage output supported
- Wide operational temperature and supply range
- On-chip voltage regulators for sensor supply, and IC operation item Support for extra regulation by external transistor, for example, JFET (especially for industrial supply voltages 5.5VDC)
- Programmable sensor-signal-conditioning math core
- Reprogrammable, nonvolatile memory (NVM)
- On-chip diagnostics:
  - Sensor connection
  - AFE self-test
  - Memory integrity

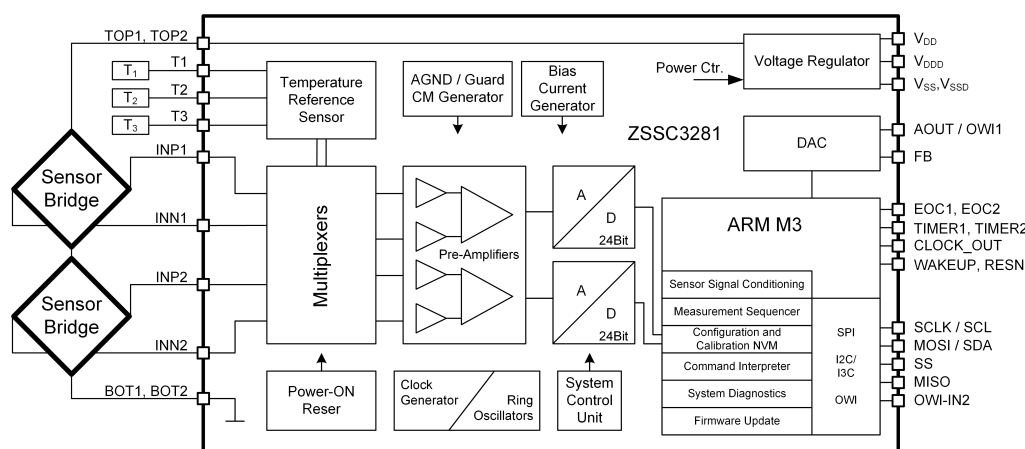


Figure 1: Typical Application Diagram

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# 1 Overview

## 1.1 Block Diagram

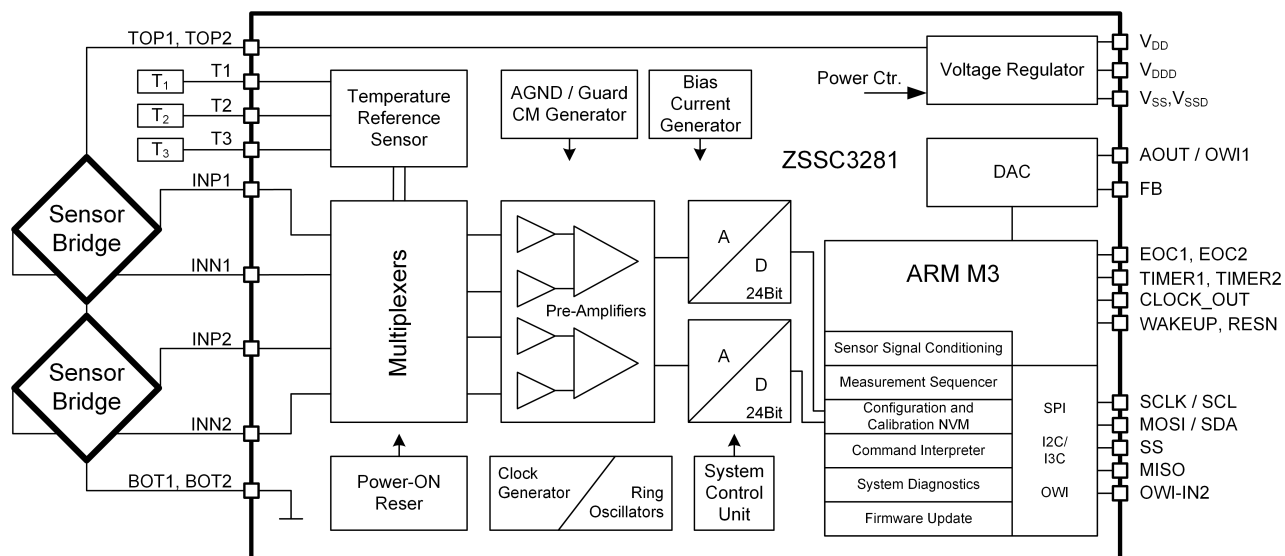
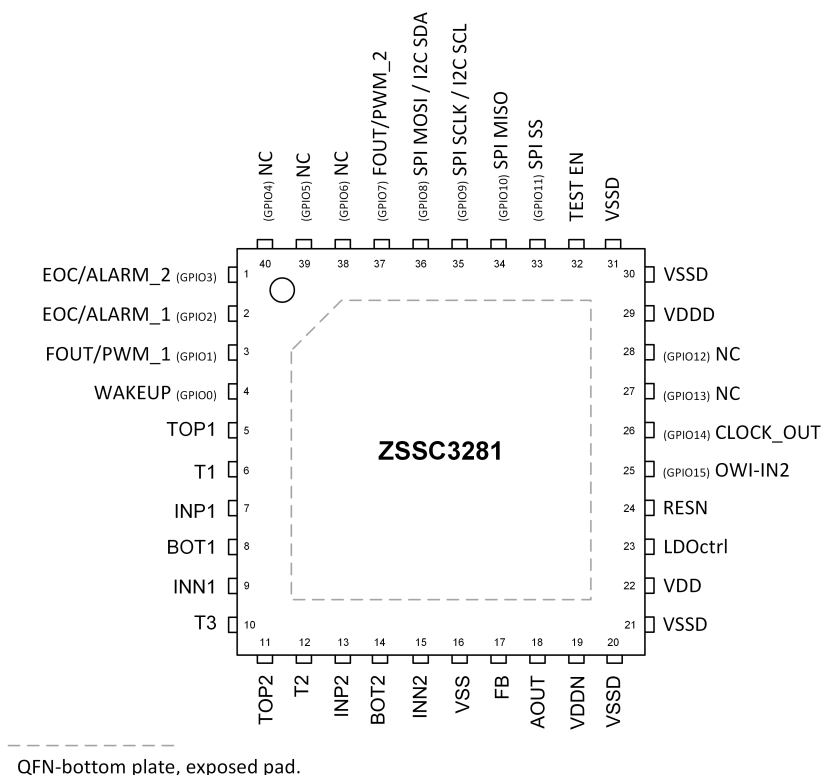


Figure 2: Block Diagram

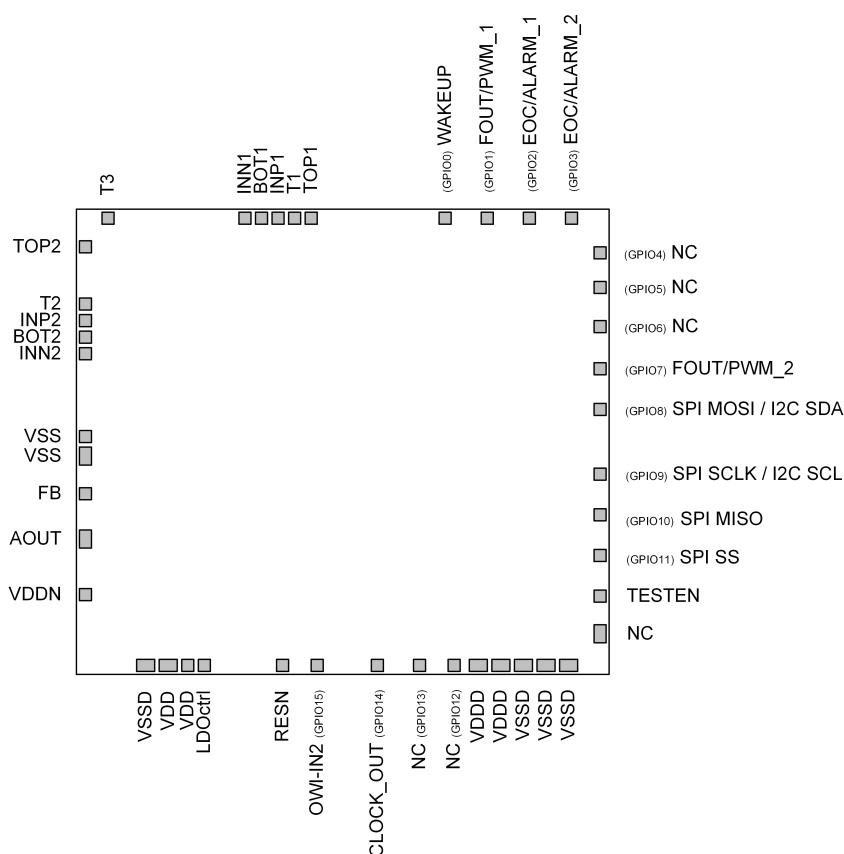
## 1.2 Ordering Information

Orderable Part Number	Description and Package	MSL Rating	Carrier Type	Temperature
ZSSC3281CI1B	DICE on 304μm unsawn wafer no inking		Wafer Box	-40 to 125°C
ZSSC3281CI5B	DICE on 304μm unsawn wafer with inking		Wafer Box	-40 to 125°C
ZSSC3281CI5C	DICE on 304μm sawn on frame wafer with inking		Wafer Box	-40 to 125°C
ZSSC3281CI1D-ES	DICE on 304μm wafer no inking, only engineering samples		Waffel Pack	-40 to 125°C
ZSSC3281CI3R	5 x 5 mm2 NDG40S1 (40-VFQFPN)	MSL1	13 inch Reel	-40 to 125°C
ZSSC3281CI8R	5 x 5 mm2 WLCSP	MSL1	13 inch Reel	-40 to 125°C
ZSSC3281KIT	Modular ZSSC3281 SSC Evaluation Kit including three interconnecting boards, five ZSSC3281 VFPQFN samples, and cable. Software is available for download on <a href="http://www.renesas.com/ZSSC3281">www.renesas.com/ZSSC3281</a> .			

### 1.3 Pin Configuration



### Figure 3: Pin Layout QFN40



**Figure 4: Pad Layout on Die**

## 1.4 Pin Descriptions

QFN40 Pin Number	Name	Type	Description
1	EOC/ALARM_2	Digital Input/Output	GPIO3: mapped to EOC2 function
2	EOC/ALARM_1	Digital Input/Output	GPIO2: mapped to EOC1 function
3	PWM/FOUT_1	Digital Input/Output	GPIO1: mapped to TIMER2 function
4	WAKEUP	Digital Input/Output	GPIO0: mapped to WAKEUP function
5	TOP1	Analog Input/Output	Positive sensor (bridge 1) supply or sensor-signal input
6	T1	Analog Input/Output	External temperature sensor
7	INP1	Analog Input/Output	Positive sensor (bridge 1) signal
8	BOT1	Analog Input/Output	Sensor (bridge 1) ground or sensor-signal input
9	INN1	Analog Input/Output	Negative sensor (bridge 1) signal
10	T3	Analog Input/Output	External temperature sensor 3
11	TOP2	Analog Input/Output	Positive sensor (bridge 2) supply or sensor-signal input
12	T2	Analog Input/Output	External temperature sensor 2
13	INP2	Analog Input/Output	Positive sensor (bridge 2) signal
14	BOT2	Analog Input/Output	Sensor (bridge 2) ground or sensor-signal input
15	INN2	Analog Input/Output	Negative sensor (bridge 2) signal
16	VSS	Ground	Power supply ground
17	FB	Analog Output	Current-loop application feedback output (level below VSS). No connection if not used.
18	AOUT/OWI	Analog Output Digital Input/Output	Analog smart-sensor output signal and/or OWI interface input/output line.
19	VDDN	Analog Output	Negative voltage output, charge pump buffer cap
20	VSSD	Ground	Digital power supply ground
21	VSSD	Ground	Digital power supply ground
22	VDD	Supply	Power supply
23	LDOctrl	Analog Output	Control output (reference signal) for (optional) external regulator / supply control loop
24	RESN	Digital Input	Digital IC reset (low active); internal pull-up
25	OWI-IN2	Digital Input/Output	GPIO15: mapped to OWI-IN2 function
26	CLOCK_OUT	Digital Input/Output	GPIO14: mapped to CLOCK_OUT function
27	N.C.	Digital Input/Output	GPIO13: Renesas internal use only. Debug interface
28	N.C.	Digital Input/Output	GPIO12: Renesas internal use only. Debug interface
29	VDDD	analog I/O	Buffer cap connection for internal VDDD
30	VSSD	Ground	Digital power supply ground
31	VSSD	Ground	Digital power supply ground
32	TESTEN	–	Renesas internal use only. Connect to VSSD
33	SPI SS	Digital Input/Output	GPIO11: mapped to SPI SS
34	SPI MISO	Digital Input/Output	GPIO10: mapped to SPI MISO
35	SPI SCLK / I2C SCL	Digital Input/Output	GPIO9: mapped to SPI SCLK / I2C SCL
36	SPI MOSI / I2C SDA	Digital Input/Output	GPIO8: mapped to SPI MOSI / I2C SDA
37	PWM/FOUT_2	Digital Input/Output	GPIO7: mapped to TIMER 1
38	N.C.	Digital Input/Output	GPIO6: not mapped
39	N.C.	Digital Input/Output	GPIO5: not mapped
40	N.C.	Digital Input/Output	GPIO4: not mapped
	Exposed PAD	-	QFN-bottom plate, Die-bottom/substrate. Connect to VSS, PAD connection used for heat dissipation and enhanced EMC robustness.

## 2 Specifications

### 2.1 Absolute Maximum Ratings

Symbol	Parameter	Conditions	Minimum	Maximum	Units
$T_J$	Junction temperature			135	°C
$T_S$	Storage temperature		-45	150	°C
	ESD: Human Body Model Tested per JS-001-2017	Pins: INPx, INNx, TOPx, BOTx, Tx, VDDD		2000	V
		Pins: GPIOx, VDD, VDDN, VSS, VSSD, LDOctrl, AOUT/OWI, FB, RESN, NC		4000	V
	ESD: Charged Device Model Tested per JS-002-2014	All Pins		750	V
	Latch-up	Tested per JESD78E; Class 2, Level A	-100	+100	mA
$V_{DD\_max}$	Maximum allowed for voltage supply	Referenced to VSS	-0.3	6.5	V
$V_{IF\_max}$	Voltage at digital I/O	Referenced to VSSD	-0.3	5.5	V
$V_{FB\_max}$	Voltage at FB pin	2-wire Current Loop Mode	-2	2	V

**WARNING:** Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions can adversely impact product reliability and result in failures not covered by warranty.

### 2.2 Thermal Information

Symbol	Parameter	Conditions	Typical	Units
$\theta_{JA}$	Theta JA	40Ld 5×5 QFN Package, 0 m/s air flow	25.8	°C/W
		40Ld 5×5 QFN Package, 1 m/s air flow	22.4	°C/W
		40Ld 5×5 QFN Package, 2 m/s air flow	20.8	°C/W
$\theta_{JB}$	Theta JB	40Ld 5×5 QFN Package	1.3	°C/W
$\theta_{JC}$	Theta JC	40Ld 5×5 QFN Package	24.4	°C/W

### 2.3 Recommended Operating Conditions

Symbol	Parameter	Minimum	Typical	Maximum	Units
$V_{DD}$	Power supply voltage	1.8			
	Flash write/erase	2.7		5.5	V
	With optional "True-0V" at analog output	2.7			
$T_J$	Junction temperature (depending on the ordered device, see subsection 1.2 for details.)	-40		125	°C
$C_{VDD}$	External capacitance between VDD and VSS, without external supply transistor regulation	10 -20%		22 +20%	μF
	External capacitance between VDD and VSS, with (optional) external supply transistor regulation	10 -20%		10 +20%	
$C_{V3D}$	External capacitance between VDDD and VSS	1 -20%		1 +20%	μF
$C_{VDDN}$	External capacitance between VDDN and VSS, with optional "True-0V" at analog output	1 -20%		1 +20%	μF
$C_{TOP\_EMC}$	Recommended, external capacitance between TOP and VSS for electro-magnetic immunity (EMI)	0	6.8	8	nF
$C_{AOUT\_EMC}$	Recommended, external capacitance between AOUT versus VDD and VSS for EMI suppression <sup>1</sup>	0	22	33	nF
$I_{Sensor}$	Load current through external sensor element <sup>2</sup>	0.005	0.5	2	mA
$V_{DioDrop}$	External temperature diode and RTD input range, drop over external element referenced to T1, T2, T3 pin	0.2		1.2	V
$V_{Sens\_in}$	Absolute sensor signal input level, INN, INP pins	0.2		1.2	V
$I_{max\_AOUT\_V}$	Maximum current load at AOUT pin for voltage outputs	0	5		mA
$S_{RVDD\_POR}$	Recommended VDD rise slew rate for power-on-reset (POR)	1.5			V/ms
$I_{max\_GPIO}$	Maximum overall GPIO driver strength			120	mA

<sup>1</sup> For applications with OWI interface or analog voltage-output.

<sup>2</sup> With ratiometric sensor supply configuration, for example, a ratiometric bridge or bridge as temperature sensor with internal or external temperature sensitive resistor

## 2.4 Electrical Specifications

All parameter values are valid only under operating conditions specified in subsection 2.3 All voltages are referenced to VSS.

**Table 1: IC Supply**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$I_{IC}$	Current consumption, active mode: • low power (current loop)	Excluding connected sensor elements (external LDO enabled)		3.3	3.5	mA
	• high power (depending on settings)			8	15	
$V_{DD,LDO}$	VDD generated with external depletion NMOS	Programmable in 4 steps: • 3V	2.85	3	3.15	V
		• 4V	3.80	4	4.20	
		• 5V	4.75	5	5.25	
		• 5.25V	5.00	5.25	5.50	
VDDA	Internally generated analog supply		1.6	1.65	1.85	V

**Table 2: Sensor Supply**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
TOP	Sensor bias voltage in ratiometric supply mode	Ratiometric sensor voltage supply		VDDA		V
$I_{bias\_TOP}$	Sensor bias current used in Source Mode	Programmable in 10 steps: 0μA, 5μA, 10μA, 20μA, 40μA, 80μA, 100μA, 160μA, 200μA, 500μA	0		500	μA
$I_{biasN\_BOT}$	Sensor current used in sink mode	Programmable in 2 steps: 20μA, 100μA	20		100	μA
$I_{ERR}$	Relative bias current ( $I_{bias\_TOP}$ and $I_{biasN\_BOT}$ ) error	Overall	-10		10	%
		Over-temperature	-1		1	
$R_{TH}, R_{TL}$	TOP/BOT bias resistor	Programmable in 12 steps: open, 1.33kΩ, 2kΩ, 4kΩ, 8kΩ, 10kΩ, 14kΩ, 18kΩ, 20kΩ, 24kΩ, 28kΩ, 40kΩ	1.3		40	kΩ
$dR_{TH}, dR_{TL}$	TOP/BOT bias resistor process variation		-30		30	%
TK of $R_{TH}, R_{TL}$	TOP/BOT bias resistor temperature variation	T = -55°C to 125°C			1.3	%

**Table 3: Analog-to-Digital Converter (ADC, A2D)**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$r_{ADC}$	Resolution		10	16	24	Bit
$V_{ADCmid}$ (AGND)	Differential ADC input Common Mode	With internal regulator supplying TOP pin, typical: $V_{TOP}/2 = 875mV$ (=PGA output Common Mode level)		0.5		$V_{TOP}$
$\Delta_{ADC,c}$	Differential input offset shift	Sensor signal offset versus maximum sensor signal. Programmable in 8 steps.	0		7/8	$V_{shift}/V_{fs}$
ENOB <sup>1</sup>	Effective number of bits, $3\sigma_{Noise}$ based	Gain = 1.32, $r_{ADC} = 24$ bit, no oversampling		17		Bit
		Gain = 28, $r_{ADC} = 16$ bit, no oversampling		12		Bit
		Gain = 495, $r_{ADC} = 24$ bit, no oversampling		11		Bit

<sup>1</sup>  $ENOB = LOG_2 \left( \frac{2^{r_{ADC}}}{3\sigma_{Noise}} \right)$  with for example,  $r_{ADC}$  [Bit] = 24.

Table 4: Digital-to-Analog Converter (DAC) and Analog Output

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
VDD	VDD operating range	AOUT modes using 1V buffer	1.8		5.5	V
		AOUT modes using VDD buffer	2.7		5.5	
t <sub>AOUTsettle</sub>	Time between digital value applied at DAC and voltage at VOUT	10% to 90% input step: V <sub>AOUT</sub> at 90% of final value			100	μs
V <sub>OUT_START</sub>	Voltage at AOUT during startup			0		V
V <sub>AOUT</sub>	Output voltage at pin AOUT	Ratiometric Voltage Mode (VDD Buffer)	0		VDD	V
		1V absolute Voltage Mode (1V Buffer)	0		1	
		3V absolute Voltage Mode (VDD Buffer)	0		3.1 <sup>1</sup>	
		5V absolute Voltage Mode (VDD Buffer)	0		5 <sup>2</sup>	
		10V absolute Voltage Mode (VDD Buffer)	0		5 <sup>2</sup>	
I <sub>OUTMAX</sub>	Short current limit at pin AOUT	<ul style="list-style-type: none"> <li>AOUT modes using VDD Buffer</li> <li>Short to VDD or VSS</li> <li>Programmable in 4 steps</li> </ul>	3	5	9	mA
			8	12	20	
			13	19	25	
			18	25	32	
C <sub>load</sub>	Load capacitance at AOUT	2-Wire Current Loop Mode			2	nF
		All other modes (for example, cap for EMC: 33nF, ECU load: 10nF)	10 <sup>3</sup>		50	
r <sub>DAC</sub>	Resolution			16		Bit

<sup>1</sup> VDD must be ≥ 3.5V

<sup>2</sup> VDD must be ≥ 5.25V

<sup>3</sup> If Power-Ground Loss detection is enabled, ensure a minimum of 10nF capacitance is connected to AOUT.

Table 5: Programmable-Gain Amplifier (PGA)

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
G <sub>amp</sub>	Gain	120 steps	1.32		495	V/V
G <sub>err</sub>	Gain error	Referenced to nominal gain: Gain = 1.32 to 5	-2.5	0	-2.5	%
		Gain = 6 to 125	-5		5	
		Gain = 126 to 495	-10		10	
G <sub>errTemp</sub>	Gain error over-temperature	Sensors with temperature compensation do not require calibration over varying temperature ranges.	-0.2		0.2	%
V <sub>CMin</sub>	Supported input Common Mode		0.2	0.5	0.7	V <sub>TOP</sub>
V <sub>ioffsc</sub>	Differential input offset shift	Programmable in 30 steps: Gain1 ≤ 223	-28.1	0	28.1	mV
		Gain1 = 275	-22.5	0	22.5	



Table 6: Sensor Signal Conditioning (SSC) Performance

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$f_{SSCout}$	Output (update) rate	<ul style="list-style-type: none"> <li>3 measurements: signal+, signal-, diagnosis</li> <li><math>r_{ADC} = 16\text{bit}</math></li> <li>SSC-corrected digital output</li> </ul>		1.3		kHz
		<ul style="list-style-type: none"> <li>3 measurements: signal+, signal-, diagnosis</li> <li><math>r_{ADC} = 14\text{bit}</math></li> <li>SSC-corrected digital output</li> </ul>		2.245		kHz
		<ul style="list-style-type: none"> <li>2 measurements: signal+, diagnosis</li> <li><math>r_{ADC} = 14\text{bit}</math></li> <li>SSC-corrected digital output</li> </ul>		3.36		kHz
$t_{stepresp}$	Step response	<ul style="list-style-type: none"> <li>3 measurements: signal+, signal-, diagnosis</li> <li><math>r_{ADC} = 16\text{bit}</math></li> <li>SSC-corrected digital output</li> </ul>		1.38		ms
		<ul style="list-style-type: none"> <li>3 measurements: signal+, signal-, diagnosis</li> <li><math>r_{ADC} = 14\text{bit}</math></li> <li>SSC-corrected digital output</li> </ul>		0.84		ms

Table 7: Analog Inputs

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$V_{INP1}$ , $V_{INN1}$ , $V_{INP2}$ , $V_{INN2}$	Absolute sensor input	Voltages at INPx and INNx pin; resulting minimum/maximum differential voltages: $-800\text{mV} < V_{INDiff} < 800\text{mV}$	0.2		1.2	V
$V_{TEXT}$	External temperature diode or RTD input range	At T1, T2, T3 pin (see Table 2 and ExtTempBrdgIBias for available configuration options)	0.3		1.2	V
$R_{SENSOR}$	External sensor (bridge) resistance	TOP = 1.65V	0.825		60	k $\Omega$
		2-wire Current Loop Mode	3.3		60	k $\Omega$
$ V_{DIFFin} $	Differential input signal range	Referenced to sensor supply ( $V_{DDA_{int}}$ )			800	mV

Table 8: Diagnostics

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$R_{open}$	Broken sensor: values $>R_{open}$ set a failure flag	<ul style="list-style-type: none"> <li>• INP1 vs. INN1</li> <li>• INP2 vs. INN2</li> </ul> <b>Note:</b> INN is drawn to VSS! This is not applicable in sensor configuration with one bridge at both frontends!	100	120	150	k $\Omega$
$R_{short}$	Shorted sensor: values $<R_{short}$ set a failure flag	<ul style="list-style-type: none"> <li>• INP1 vs. INN1</li> <li>• INP2 vs. INN2</li> <li>• INP1 vs. INP2</li> <li>• INP2 vs. INN1</li> </ul>	120		220	$\Omega$
$I_{leak}$	Sensor leakage check	Sensor leakage current from INP/INN to VSS: values $>I_{leak}$ set a failure flag	0.8	1	2	$\mu$ A
$V_{common}$	Sensor Common Mode check (measurement $V_{INP} - V_{AGND}$ , $V_{INN} - V_{AGND}$ )	Detects sensor connection failure: <ul style="list-style-type: none"> <li>• open TOP or BOT</li> <li>• short INP or INN to TOP or BOT</li> </ul>	0.4		0.6	$V_{TOP}$
$V_{drift}$	AFE gain check, run measurement with dedicated gain, compare with stored values	Input value from RDAC is applied				
$V_{RDAC}$	RDAC differential output voltage	VDDAx = 1.65V: <ul style="list-style-type: none"> <li>• S = 00</li> </ul>		2		mV
		<ul style="list-style-type: none"> <li>• S = 01</li> </ul>		10		
		<ul style="list-style-type: none"> <li>• S = 10</li> </ul>		100		
		<ul style="list-style-type: none"> <li>• S = 11</li> </ul>		200		
$R_{T\_OPEN}$	T1, T2, T3 connection check: open	Broken Tx sensor: values $>R_{T\_OPEN}$ set a failure flag and can be configured in 3 level <b>Note:</b> INN is drawn to VSS! This is not applicable in sensor configuration with one bridge at both frontends!	1.6	2	3	M $\Omega$
			0.4	0.5	0.6	
			0.07	0.1	0.13	
$t_{T\_OPEN}$	Diagnosis time; depends on $C_{ts}$ and $R_{T\_OPEN}$	Time from diagnose enable to valid output	0.1		10	ms
$R_{T\_SHORT}$	T1, T2, T3 connection check: short to TOP, BOT, INP, INN	Shorted Tx sensor: values $<R_{T\_SHORT}$ set a failure flag: <ul style="list-style-type: none"> <li>• configuration for Pt1000</li> </ul>	320	500	650	$\Omega$
VDD	<ul style="list-style-type: none"> <li>• Programmed (expected) VDD level</li> <li>• VDD drop below the programmed level signalizes a VDD drop</li> </ul>	Programmable in 6 steps: 2.2V, 2.7V, 3V, 4V, 5V, 5.25V	2.2		5.25	V
$V_{dropVDD}$	Voltage level, where the VDD drop is detected		70	85	95	%VDD
VDDD <sub>BOD</sub>	VDDD brown out detection	VDDD $<$ VDDD <sub>BOD</sub> set a failure flag	67	90	97.5	%VDDD
$V_{LOSS}$	Power/ground loss with respect to AOUT	<ul style="list-style-type: none"> <li>• <math>V_{AOUT} - VDD &gt; V_{LOSS}</math></li> <li>• <math>V_{AOUT} - VSS &lt; V_{LOSS}</math></li> </ul>		0.2		V

Table 9: Power-Up

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$t_{STA1}$	Startup time	VDD ramp up to interface communication			5	ms
$t_{STA2}$		VDD ramp up to analog operation; depends on the configuration used			5	ms
$t_{WUP1}$	Wake-up time	Sleep to Active State interface communication		2	10	$\mu$ s

Table 10: Oscillator

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$f_{CLK\_HF}$	Internal HF-oscillator frequency	At T=27°C	15.8	16	16.2	MHz
		Across temperature range	15		17	
$f_{CLK\_LF}$	Internal LF-oscillator frequency		25	32	41	kHz

Table 11: Internal Temperature Sensor

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$r_{Temp}$	Internal temperature sensor resolution	Differential output voltage		220		$\mu V/K$

Table 12: Digital IO Pins

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$V_{IL}$	Input low voltage	voltage level where the input is recognized as low level			30	% VDD
$V_{IH}$	Input high voltage	voltage level where the input is recognized as high level	70			% VDD
$V_{Ihys}$	Input hysteresis		10		35	% VDD
$V_{OL}$	Output low voltage				8	% VDD
$V_{OH}$	Output high voltage		92			% VDD
$I_{OL}$	Output drive low current	$V_{PAD} = V_{OL}$ : VDD = 1.7V	1		2.4	mA
		VDD = 2.6V	2.7		6.6	
		VDD = 5V	9		20	
$I_{OH}$	Output drive high current	$V_{PAD} = V_{OH}$ : VDD = 1.7V	1.2		2.3	mA
		VDD = 2.6V	3.2		6.4	
		VDD = 5V	10.9		20.2	
$I_{pullup}$	Weak pull-up current at pin RESN	$V_{PAD} = 0V$ : VDD = 1.7V	5		13	mA
		VDD = 2.6V	17		50	
		VDD = 5V	84		250	
$I_{pulldown}$	Weak pull-down current at pin WAKEUP	$V_{PAD} = VDD$ : VDD = 1.7V	5		11	mA
		VDD = 2.6V	17		35	
		VDD = 5V	80		160	

Table 13: Serial Interfaces

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$f_{C,SPI}$	SPI clock frequency				12	MHz
$f_{C,I2C}$	I2C clock frequency				1	MHz
$f_{C,I3C}$	I3C clock frequency				12	MHz
$C_{DOWI}$	OWI data rate		0.25		100	kBit/s

Table 14: Flash Memory

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$t_{PROG}$	NVM program time	Programming time for complete configuration and calibration page: $f_{CLK\_HF} = 16\text{MHz}$		360		ms
			-	740	-	
$n_{NVM}$	NVM endurance	Number of reprogramming cycles	20000			Numeric
$t_{RET,NVM}$	Data retention		10			Years

### 3 Basic System Configuration

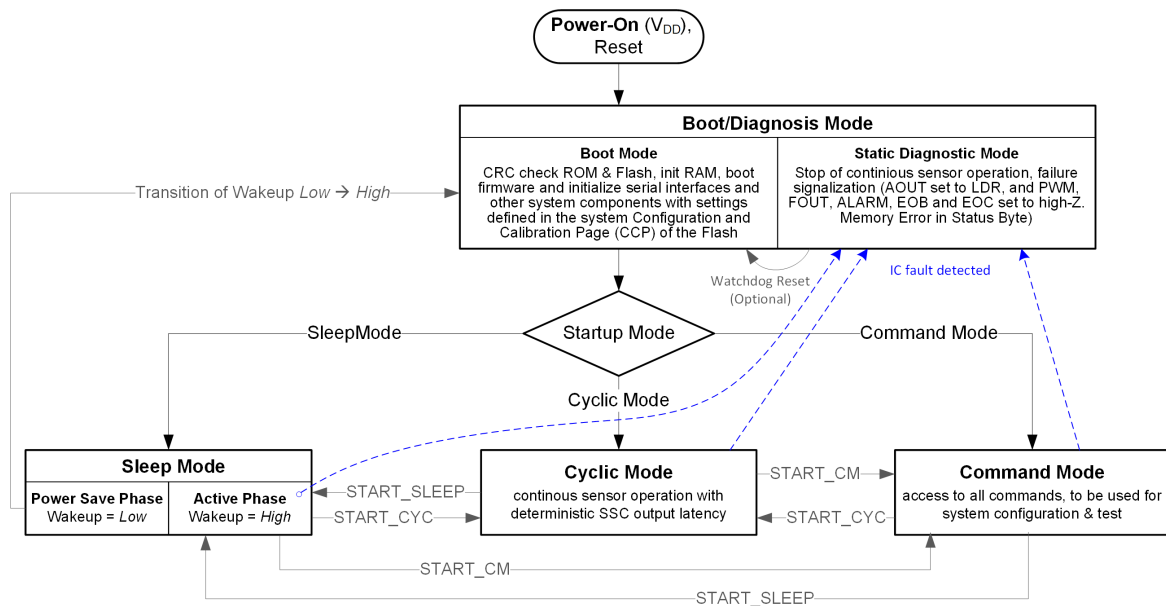
#### 3.1 System Modes/System Start

The ZSSC3281 can operate in three different main operating modes:

<b>Cyclic Mode</b>	This is the default mode for continuously operating sensors. In this mode autonomous, cyclically repeated sensor measurements are performed and related digital and/or analog output updates are provided. The cyclic sequences for sensor measurements and system diagnostic measurements are configurable and allow to define the output update rate of the conditioned sensor signals. Cyclic Mode supports only a subset of the defined serial interface commands to guarantee deterministic input-output behavior (especially latencies) and to prevent accidental interruption of the conditioned sensor data stream.
<b>Command Mode</b>	This is the most appropriate mode for evaluation, test, and calibration purposes. In this mode, all supported serial interface commands are available. Command Mode can be used for applications requiring re-occurring digital interaction on functions that are not available in Cyclic Mode or certain system configuration changes.
<b>Sleep Mode</b>	This is the default mode for non-continuously operating sensors. In this mode WAKEUP (GPIO0) pin controls the operation phase and the current consumption of ZSSC3281. Within the active phase of Sleep Mode, a subsets of serial interface commands are supported, new measurement can be started, and results can be gathered. During the power save phase no communication is possible and ZSSC3281 stays in power down phase to allow the lowest possible current consumption.

ZSSC3281 provides a fourth operation mode which is not a user accessible operation mode:

<b>Boot/Diagnosis Mode</b>	<p><b>Boot Mode:</b> this is immediately active after power-on or reset of ZSSC3281, while the firmware is still in boot-up phase and the Command Interpreter is not functional yet. The serial interfaces are only partly operational in Boot/Diagnosis Mode to allow an external host to read the system status for ZSSC3281. Write access and command execution is not supported.</p> <p><b>Diagnosis Mode:</b> this indicates the Static Diagnostic Mode (SDM) of the firmware and it is reached if the system self-supervision detects either of the following system faults that could lead to unreliable or unpredictable behavior of the IC:</p> <ul style="list-style-type: none"> <li>• 2 bit SRAM failures</li> <li>• Internal ARM faults (bus failures, ALU failures, memory or command failures)</li> <li>• CRC failures of CCP page</li> <li>• First time that watchdog triggers</li> </ul> <p>In the SDM mode the autonomous, cyclically repeated sensor measurements running in Cyclic Mode are stopped and the analog output is set to LDR, digital outputs (PWM, FOUT, ALARM) are set to high-Z, and CLOCK_OUT remains active. Leaving SDM is possible via watchdog reset or power cycle. Within SDM, the operation mode and the memory error flag inside the status flag is set supporting the detection of Boot or Diagnosis Mode.</p>
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**Figure 5: Main Operating Modes**

After power-on (reset) the ZSSC3281 always enters the programmed System Startup Mode (GUI path: Configure\System Control\System Startup) as soon as the firmware boot process is finished.

Each of the three operating modes can be set up as the default startup mode. Changing the ZSSC3281 to another operating mode is possible via the mode change and start commands: START\_CM, START\_CYC and START\_SLEEP (see subsection 10.5 for details).

The ZSSC3281 supports three different types of digital interfaces: I2C/I3C, SPI, and OWI. All three interface types are available in the different main operating modes if they were enabled via GUI.

## 3.2 System Clocks

### 3.2.1 Internal Oscillators and Specifications

ZSSC3281 is equipped with two internal oscillators:

- Calibrated, first order temperature compensated 16MHz system clock oscillator
- Un-calibrated, first order temperature compensated 32kHz ultra low power oscillator

### 3.2.2 Main System Clock

The Main System Clock, which drives the ARM MCU, the memories (ROM, Flash, SRAM), and the peripherals is derived from the internal System Clock Oscillator. By default, the oscillator frequency (16MHz) is directly applied across the entire system without further down division. Hardware and software driven clock gating are applied to maintain a low power consumption.

For applications where power consumption of ZSSC3281 is a concern, the Main System Clock can be reduced by choosing a system clock source divider other than the value of div1. The maximum divider factor can be 16 (div16), which sets the Main System Clock to 1MHz.

The system clock divider can be changed via GUI field: Configure\PowerSupply and Oscillator\System Clock Source Divider.

If the ZSSC3281 is operated in a 2-Wire Current Loop setup (and respective GUI configurations are made) a reduction of the Main System Clock to 1 MHz is mandatory to meet the maximum system current consumption specification (<4mA) over the entire temperature range. In this case the 'System Clock Source Divider' is not selectable by the user.

### 3.2.3 Always-On Clock

The 32kHz always-on clock is used by the System Management Unit to control the power-up-sequence of the ZSSC3281 device, as well as by the internal watchdog and the low speed timer.

## 3.3 System Reset

The ZSSC3281 becomes reset at following scenarios:

- Power On Reset      Voltage at VDD or VDDD is below limits as specified in subsection 2.4.
- External Reset      RESN Pin of ZSSC3281 is set to LOW.
- Self-Reset      Self supervision via system diagnosis detected a critical system state and sets system in safe reset state.

**Table 15: VDDD Power-On-Reset Specifications**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$V_{\text{riseVDDD}}$	reset release voltage	VDDD level where reset is released	1.35		1.8	V
$V_{\text{fallVDDD}}$	reset voltage	VDDD level where reset is generated	1.1		1.6	V
$V_{\text{hysVDDD}}$	reset hysteresis voltage		50		500	mV

## 4 Analog Front End (AFE)

### 4.1 AFE Signal Path

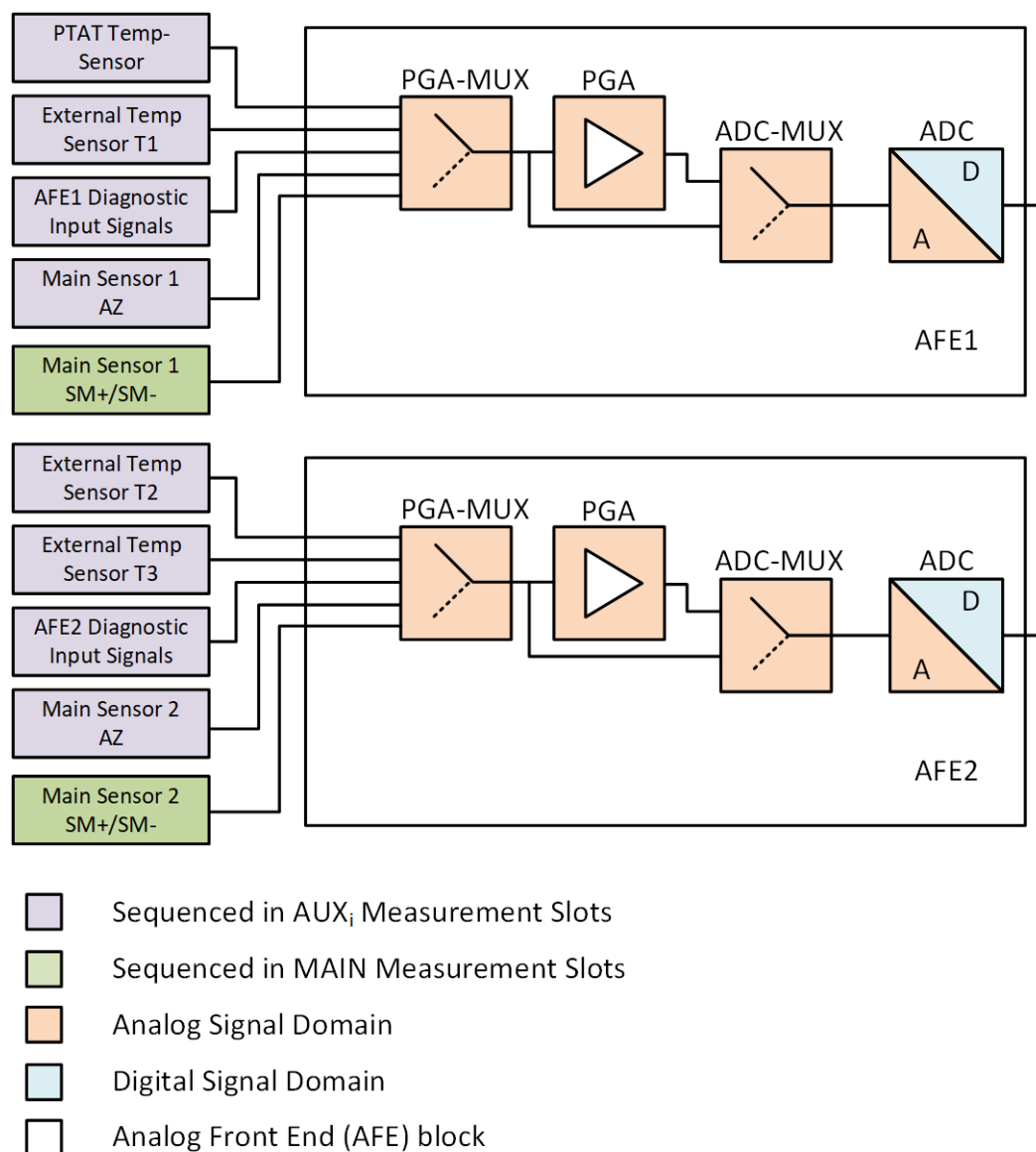


Figure 6: Block Diagram Analog Front End

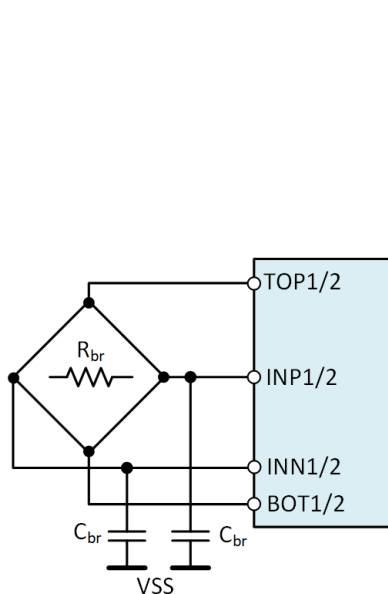
### 4.2 Resistive Bridge Sensors

Table 16: Resistive Bridge Parameters

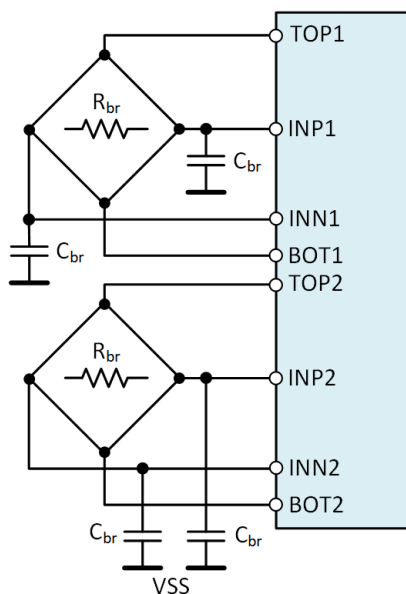
Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
R <sub>br</sub>	Bridge resistor	Constant Voltage Mode	0.825		60	kΩ
		Constant Current Mode	0.1			
C <sub>br</sub>	Bridge capacitance, depends on the required resolution: $\tau = R_{br} \times C_{br}$ defines the settle time.	Filter capacitance C <sub>br</sub> between INN <sub>x</sub> /INP <sub>x</sub> and VSS		1		nF
V <sub>sig</sub>	Signal span	mV/V is related to the bridge supply			500	mV/V
V <sub>off</sub>	Signal offset	For example: V <sub>sig</sub> = 1mV allows V <sub>off</sub> = 20mV			2000	% off V <sub>sig</sub>
					20	1/ V <sub>sig</sub>

### Table 17: Resistive Bridge Application Configurations

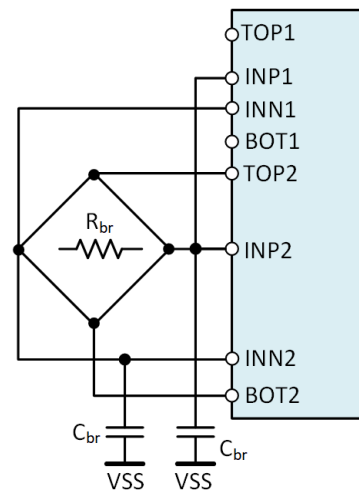
Type #	Application Case	AFE1	AFE2	Comment
1	One resistive sensor	Resistive sensor 1	-	
2	Two resistive sensors	Resistive sensor 1	Resistive sensor 2	Not available with 2-wire current loop operation
3	One resistive sensor at both inputs	Resistive sensor 1 (normal speed)	Resistive sensor 1 (low speed)	Not available with 2-wire current loop operation



### Figure 7: Bridge Sensor Type 1



### Figure 8: Bridge Sensor Type 2

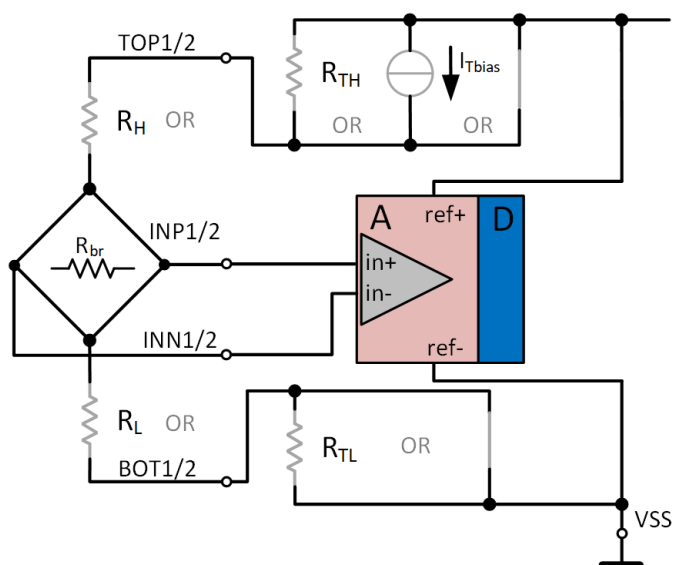


### Figure 9: Bridge Sensor Type 3

In single bridge applications shown in Figure 7 the resistive bridge can be connected to either AFE1 or AFE2 depending on the PCB layout requirements.

The resistive bridge can be sourced either in Constant Voltage mode (V-source) or in Constant Current mode (I-source).

**Note:** Constant Current mode requires a low bridge resistance for optimal performance.



Legend:

Gray components: can be activated “either-or” via the GUI.

### Figure 10: Resistive Bridge Bias Configurations



In Constant Current mode the bridge output must be set within the common input range of the PGA. This can be done with a low side external resistor  $R_L$  or with the internal resistor  $R_{TL}$ . The current that is supplied to the bridge must be adjusted to the bridge resistance. To align with the common input range of the PGA, adjust the  $R_L$  or the internal  $R_{TL}$  as needed.

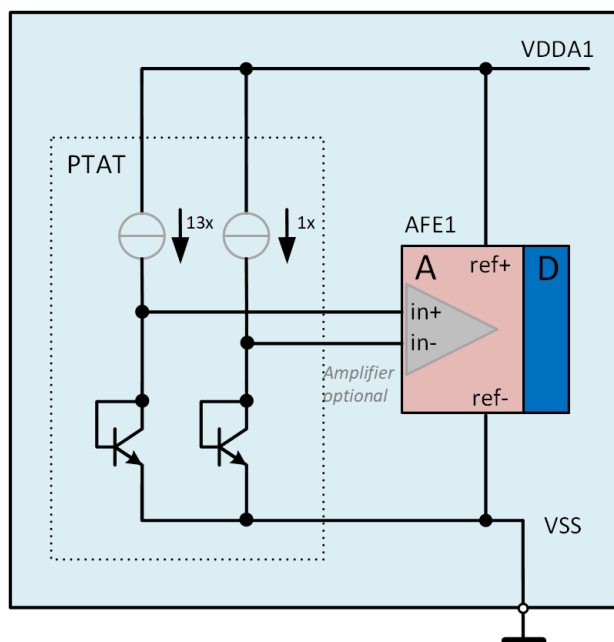
In Constant Voltage mode the bridge current can be reduced by inserting the internal high and low side resistors  $R_{TH}$ ,  $R_{TL}$  or by adding external resistors  $R_H$  and  $R_L$ .

**Table 18: Resistive Bridge Supply Parameters**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$V_{TOP1/2}$	Output voltage at TOP1/2			VDDA		V
$I_{load}$	Load current	In Constant Voltage mode defined by bridge resistance			2	mA
$I_{Rbr\_bias}$	Current out of TOP1/2	In Constant Current mode adjustable via <i>BmBrdgIBias</i>	5		500	$\mu$ A
$C_{TOP\_BOT}$	Load capacitance				2.2	nF
$R_{TH}$ , $R_{TL}$	Bias resistor		1.3		40	k $\Omega$

## 4.3 Auxiliary Temperature Sensor Inputs

### 4.3.1 Internal PTAT Temperature Sensor



**Figure 11: PTAT Sensor Configuration**

**Table 19: Internal PTAT Parameters**

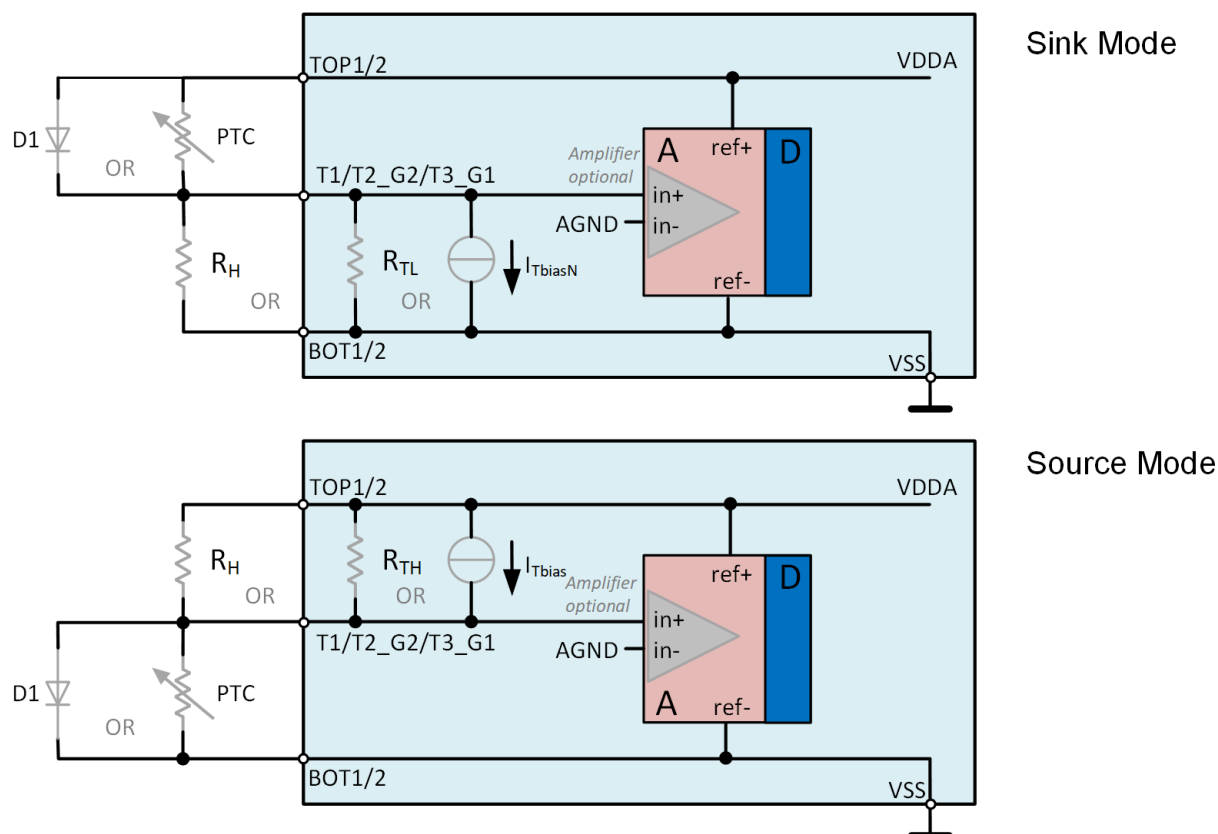
Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$T_{meas}$	Measurement range		-55		125	$^{\circ}$ C
$E_T$	Measurement error	Calibrated	-5		5	K
$ADC_{res}$	Resolution	Programmable ADC resolution	10		15	bit
$T_{res}$	Effective resolution	$\pm 1.5\sigma$	2			LSB/ $^{\circ}$ C
$S$	Sensitivity	Differential output voltage	218		230	$\mu$ V/K

### 4.3.2 External Temperature Sensors

Three different external sensor types can be used to measure the temperature of the main sensor or a media temperature in the auxiliary signal path of the AFEs:

- PTC
- Diode
- TC Bridge Sensor

The PTC and Diode Sensors can be supplied either in Sink Mode or in Source Mode as shown in Figure 12. The gray marked components can be activated “either-or” via the GUI. The AGND potential is at  $VDDA/2$ .

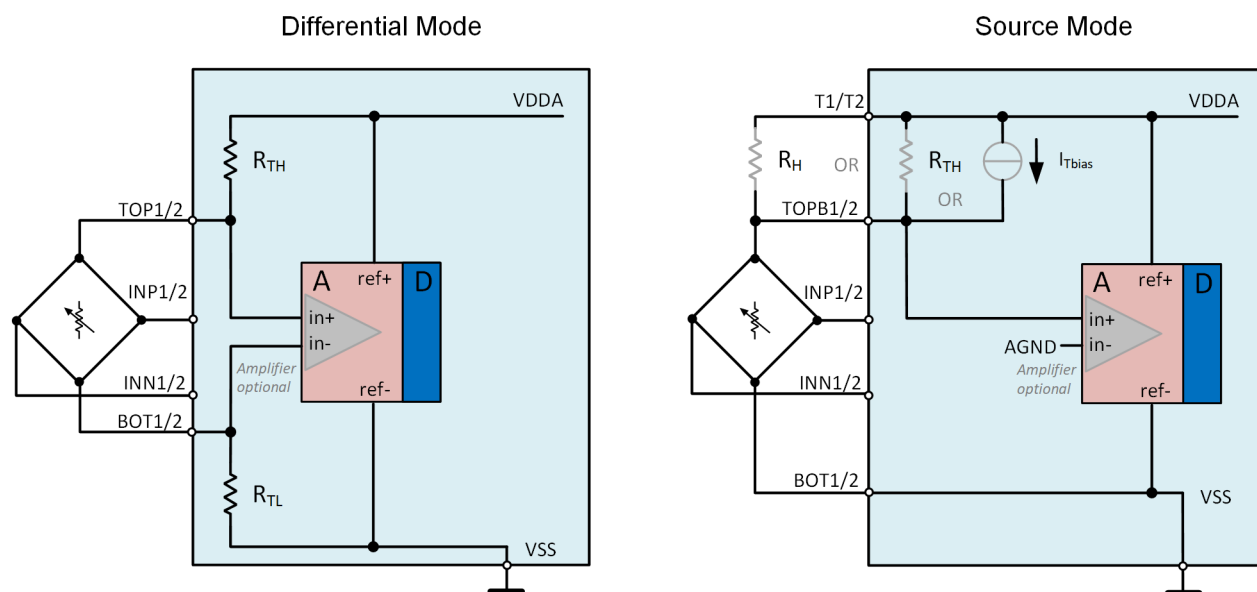


Legend:

Gray components: can be activated “either-or” via the GUI. The AGND potential is at  $VDDA/2$ .

**Figure 12: PTC, Diode Sensor Bias Configurations**

TC Bridge Sensor configurations can be supplied in Differential Mode or Source Mode as shown in Figure 13.



Legend:

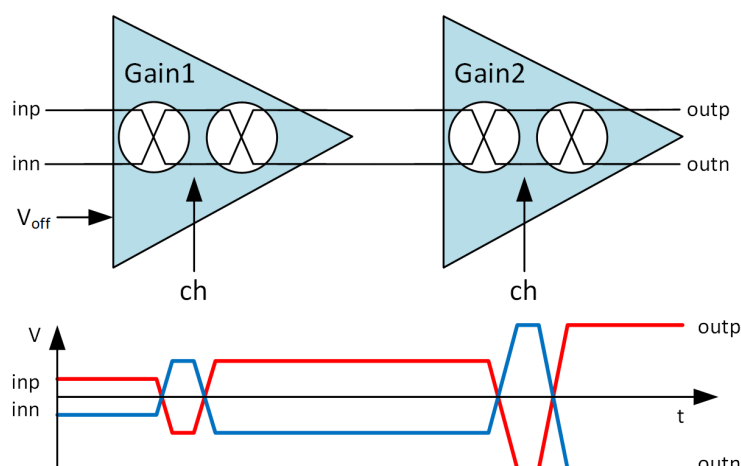
Gray components: can be activated "either-or" via the GUI. The AGND potential is at  $V_{DDA}/2$ .

**Figure 13: TC Bridge Sensor Bias Configurations**

**Table 20: External Temperature Sensor Parameters**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$R_{\text{sensor}}$	Sensor resistance (PTC/TC Bridge Sensor)		50		1M	$\Omega$
$ADC_{\text{res}}$	ADC resolution	Programmable ADC resolution	10		15	bit
ENOB	Effective resolution	$\pm 1.5\sigma$	14			bit

#### 4.4 Programmable Gain Amplifier (PGA)



**Figure 14: PGA Architecture**

The first amplifier (Gain1) has a built in PGA offset compensation (auto-zero) that is refreshed at the beginning of every measurement. The second stage has no offset compensation. The second stage amplifier offset is present at the PGA output with offset  $\times$  Gain2. Both PGA amplifier stages have built-in chopper functionality to suppress  $1/f$  noise.

The gain settings that can be selectively programmed for both PGA stages are listed in Table 21.

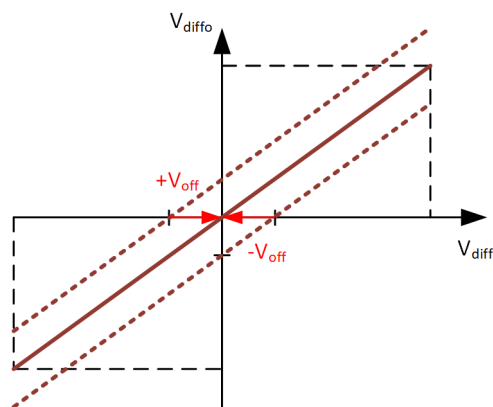
**Table 21: PGA Gain Steps**

Gain1	Gain2
1.2	1.1
2	1.2
4	1.3
5.97	1.4
11.9	1.5
19.8	1.6
29.6	1.7
39.2	1.8
58.1	
76.6	
112	
143	
187	
223	
275	

If bridge sensors show noticeable DC offsets (that is offset from 0) in their differential output voltage, it restricts the maximum PGA gain that can be applied without causing saturation. To compensate this, the PGA can be programmed to shift the input signal by an offset voltage, as shown in the Figure 15. The default shift is 0mV, and the offset can be adjusted in 15 steps in both positive and negative directions, see Table 21 and Table 22. This PGA offset shift function is available only for PGA Gain values of 11.9 or higher.

**Table 22: PGA Input Offset Compensation Steps**

$11.9 \leq \text{Gain1} \leq 223$ [mV]	Gain1 = 275 [mV]
0	0
$\pm 1.9$	$\pm 1.5$
$\pm 3.8$	$\pm 3$
$\pm 5.6$	$\pm 4.5$
$\pm 7.5$	$\pm 6$
$\pm 9.4$	$\pm 7.5$
$\pm 11.3$	$\pm 9$
$\pm 13.1$	$\pm 10.5$
$\pm 15$	$\pm 12$
$\pm 16.9$	$\pm 13.5$
$\pm 18.8$	$\pm 15$
$\pm 20.6$	$\pm 16.5$
$\pm 22.5$	$\pm 18$
$\pm 24.4$	$\pm 19.5$
$\pm 26.3$	$\pm 21$
$\pm 28.1$	$\pm 22.5$



**Figure 15: PGA Input Offset Compensation**

PGA gain and the Input Offset Compensation value can be programmed separately for the two main bridge sensors and for the three external auxiliary temperature sensors that can be connected to the ZSSC3281. The PGA Input Offset Compensation feature is limited to SM+/SM- and SM+ sequencer configurations which are described in subsection 4.6.

Table 23: PGA Parameters

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
Gain	Total PGA gain	Programmable in 15/8 steps: • stage1: 15 steps, 1.2 to 275 • stage2: 8 steps, 1.1 to 1.8	1.32		495	V/V
V <sub>cmi</sub>	Input Common Mode voltage			VDDA/2		V
BW <sub>PGA</sub>	Bandwidth			5		kHz
t <sub>az_PGA</sub>	Auto-zero time		10			μs
f <sub>ch_PGA</sub>	Chopper frequency			100		kHz

## 4.5 Analog-to-Digital Converter (ADC)

An incremental delta-sigma analog-to-digital converter (ADC) is used to digitize the PGA signal. To allow optimizing the trade-off between conversion time and resolution, the resolution can be programmed from 10-bit to 24-bit. The ADC processes differential input signals around its input Common Mode level VDDA/2. Table 24 lists the ADC resolution, signal ranges, conversion times for a single analog-to-digital conversion and VDDA = 1.65V.

Table 24: ADC Configuration Parameters

ADC Resolution [Bits]	Full Scale Input Voltage V <sub>fs</sub> [V]	LSB Size V <sub>LSB</sub> [μV]	Conversion Time, Typical, T <sub>Conv</sub> [μs]	Conversion Rate, Typical, F <sub>Conv</sub> [kHz]
10	±1.418	2768.638	32.54	30.73
11	±1.425	1391.718	43.75	22.86
12	±1.431	698.499	59.59	16.78
13	±1.434	350.189	81.99	12.20
14	±1.437	175.428	113.68	8.80
15	±1.439	87.832	158.49	6.31
16	±1.440	43.958	221.86	4.51
17	±1.441	21.994	311.48	3.21
18	±1.442	11.002	438.22	2.28
19	±1.443	5.503	617.46	1.62
20	±1.443	2.752	870.94	1.15
21	±1.443	1.376	1229.41	0.81
22	±1.443	0.688	1736.38	0.58
23	±1.443	0.344	2453.33	0.41
24	±1.444	0.172	3467.25	0.29

The ADC can perform an additional offset shift (independent of the PGA shifting) to adapt input signals with offsets to the ADC input range. Enabling the offset shift causes the ADC to perform an additional amplification of the ADC's input signal by factor ×2. This must be considered for a correct PGA configuration setup.

The ADC offset shift feature is limited to SM+/SM- and SM+ sequencer configurations which are described in subsection 4.6.

The shift values in Table 25 are related to the input voltages at INP, INN:

- Full scale differential input voltage:  $V_{INdiff\_fs} = \frac{V_{fs}}{Gain}$
- Differential input shift voltage:  $V_{INdiff\_shift}$
- Maximum, minimum differential input voltage:  $V_{INdiff\_max}$  ,  $V_{INdiff\_min}$

Table 25: ADC Input Offset Shift Steps

PGA Polarity	ADC Shift Enable	ADC Gain	ADC Shift	$V_{INDIFF\_shift}/V_{INDIFF\_fs}$	$V_{INDIFF\_min}/V_{INDIFF\_fs}$	$V_{INDIFF\_max}/V_{INDIFF\_fs}$
Positive	0	x1	0	No shift	-1	+1
Negative			0	No shift	+1	-1
Positive	1	x2	1	7/8	-1/16	+15/16
			2	6/8	-2/16	+14/16
			3	5/8	-3/16	+13/16
			4	4/8	-4/16	+12/16
			5	3/8	-5/16	+11/16
			6	2/8	-6/16	+10/16
			7	1/8	-7/16	+9/16
			0	No shift	-1/2	+1/2
Negative			0	No shift	+1/2	-1/2
			1	1/8	-9/16	+7/16
			2	2/8	-10/16	+6/16
			3	3/8	-11/16	+5/16
			4	4/8	-12/16	+4/16
			5	5/8	-13/16	+3/16
			6	6/8	-14/16	+2/16
			7	7/8	-15/16	+1/16

## 4.6 AFE Sequencer

The measurement flow, especially the frequency of main bridge measurements vs. auxiliary measurements can be configured by the user. Once started by the ARM MCU, the measurement flow runs autonomously controlled by the AFE. The AFE Sequencer state machine ensures predictable measurement timing in the continuous cyclic operation of ZSSC3281.

The AFE sequencer carries out AFE measurements based on a measurement slot mechanism. There can be up to eight measurement slots assigned per AFE, which form a single measurement cycle. A measurement cycle can be executed only once (for example, initiated by a dedicated command request) or continuously cycled in Cyclic Mode operation of ZSSC3281.

Each of the measurement slots inside AFE1 or AFE2 can be individually configured for the following measurement types:

- Sensor Measurement (SM+): bridge inputs INP/INN directly converted (non-inverted)
- Sensor Measurement (SM-): bridge inputs INP/INN flipped (inverted)
- Auxiliary Measurement (aux<sub>i</sub>): cycles through the auxiliary measurement vector

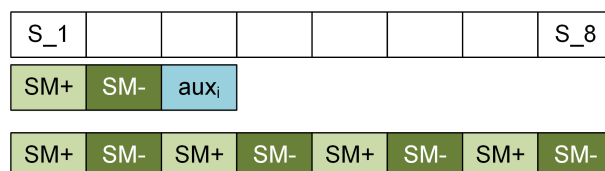


Figure 16: Measurement Slot Configuration with Two Example Configurations

The actual number of measurement slots per measurement cycle can be defined by the user between 1 and 8. The hardware allows to configure any combination, but not all combinations lead to reasonable measurement schemes. The GUI supports the user in selecting proper measurement schemes. Figure 16 shows two example configurations. The measurement schemes are explained in further detail in subsubsection 4.6.3, 4.6.4, and 4.6.5.

Auxiliary measurements usually have lower response time requirements than measurements on the main sensor bridge. The auxiliary measurements are therefore cycled orthogonal to the main loop of the sequencer. Activated

auxiliary measurements become listed in the so called auxiliary measurement vector. The vector index 'i' gets increased after each executed aux<sub>i</sub> slot and starts over after the entire set of active measurements was completed. The configuration options of auxiliary measurements are further detailed in subsubsection 4.6.2.

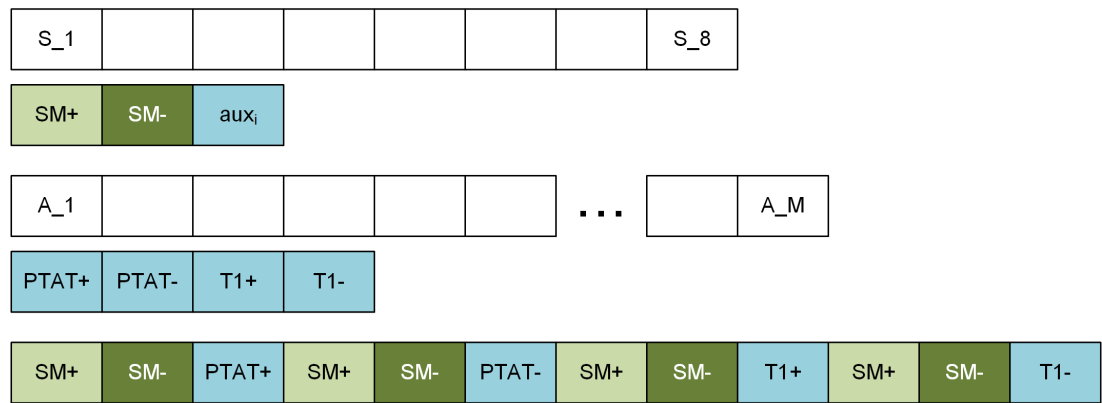


Figure 17: Auxiliary Measurement Configuration, and Corresponding Measurement Flow

Figure 17 illustrates the sequencer operation with an example configuration using 4 auxiliary measurements. During the 3rd measurement (configured as aux<sub>i</sub>), the first enabled auxiliary measurement is executed ("PTAT", internal temperature sensor). After the measurement sequence (SM+/SM-/aux<sub>i</sub>) is executed again in the next measurement slot, the next enabled auxiliary measurement is executed ("T1", external temperature sensor). Similarly, "Bridge1 open" and "Bridge1 short" diagnostics measurements are carried out in following measurement slots. During the 5th execution of the measurement sequence, the PTAT auxiliary measurement is carried out again.

4.6.1 Bridge Sensor Measurement Configuration

The main bridge sensor signals can be measured in three ways:

- SM+/SM- (or SM-/SM+) measurement
- SM+/AZ measurement (SM+ and auto-zero measurement)
- SM+ without AUX\_AZ measurement

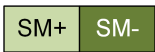


Figure 18: SM+/SM- (or SM-/SM+) Measurement



Figure 19: SM+/AZ Measurement

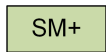


Figure 20: SM+ without AZ Measurement

Configurations in Figure 18 and Figure 19 provide digital offset compensation of the entire signal path in the analog front end. The configuration in Figure 20 only provides analog offset compensation in the first stage of the PGA. The offsets of the second PGA stage and the ADC offset are not compensated.

In the SM+/SM- configuration, the bridge inputs INP/INN are first converted straight forward in the SM+ measurement slot and second with an internally flipped INP/INN input signal in SM- slot. For the SM+/AZ configuration, the second measurement (AZ) is performed without applied input signal. INP/INN become disconnected from the sensor and internally shorted for AZ measurements.

Since signal integration time in SM+/SM- configuration is twice as long as in in the SM+/AZ configuration (same ADC resolution settings assumed), the SM+/SM- configuration achieves approx. 0.5 bit better noise performance than the SM+/AZ configuration. The longer input signal integration time of the SM+/SM- configuration leads to an increased output update rate and step response as described in subsubsection 4.6.3 and subsubsection 4.6.4.

The auto-zero measurement (AZ) belongs to the group of auxiliary measurements and is cycled less often if either of the following options appears:

- further auxiliary measurements are enabled in the auxiliary measurement vector described in subsubsection 4.6.2
- accelerated bridge measurements are enabled as described in subsubsection 4.6.5

Since the offset in the internal signal path varies rather slowly, the auto-zero compensation remains very accurate even for a long auxiliary measurement vector.

Because SM- needs to be configured and most sensor applications also require other auxiliary measurements, the assignment of the AZ measurement to the group of auxiliary measurements helps to reduce the worst case step response on the main bridge sensor.

The lowest step response is achieved with the “SM+ only” configuration shown in Figure 20 if no other auxiliary measurements are needed for the desired sensor application.

The input settling time of each measurement task also affects the overall measurement time, including the output update rate and worst-case response. This settling is required depending on the output resistance of the external sensors, respective capacitive loads on the signal lines and the ADC resolution selected by the user. The input settling time is always inserted before an ADC conversion starts and can be configured in the GUI for main bridge measurements via `Configure\AFE\Bridge\SetTime [μs]` and for auxiliary temperature measurements via `Configure\AFE\Temperature\SetTime [μs]`.

Considering achievable measurement latencies and noise performance, configuration shown in Figure 18 is better when higher ADC resolutions are required or for sensor configurations with fast input settling, while configuration shown in Figure 19 and Figure 20 are preferable when lower ADC resolutions become selected or for sensor configurations requiring long input settling times (bridge settling time has a considerable impact on the timing budget).

## 4.6.2 Auxiliary Measurement Configuration

The supported auxiliary measurements are:

- Auto-zero for internal signal path
- Temperature on sensor input T1
- Temperature on sensor input T2
- Temperature on sensor input T3
- Internal PTAT
- AFE diagnostic checks
  - Sensor connection checks for all external sensors (Short to TOPx pin or BOTx pin and Open)
  - Bridge signal range check
  - AFE gain and offset drift supervision via internal reference DAC

They can be activated in the GUI via tabs `Configure\AFE\Sequencer`, `Configure\AFE\Temperature Selection` and `Diagnostic\Sensor\AFE`.

## 4.6.3 Timings with SM+/SM- Configuration

As described in subsubsection 4.6.1, sensor configurations with fast input settling or applications requiring higher ADC resolutions are better served with the SM+/SM- scheme for the main bridge measurement. For the step response consideration the following application example is used:

- Sensor Measurement (non-inverted)
- Sensor Measurement (inverted)
- Auxiliary Measurement (for example, for sensor temperature)

**Note:** SM+ and SM- can be exchanged yielding to the same result.

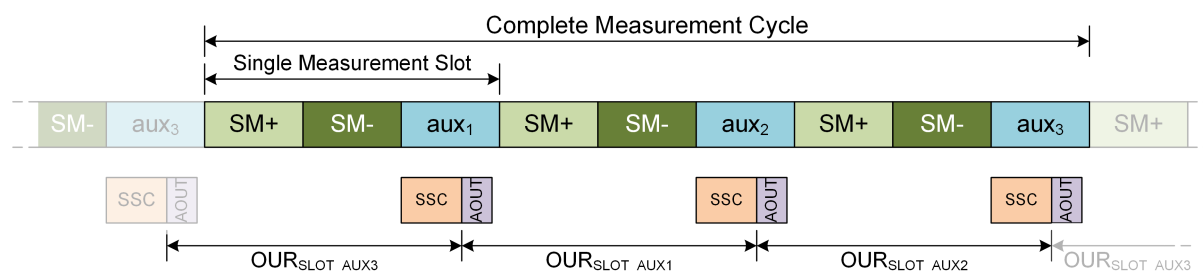


**Figure 21: SM+/SM- Configuration**

For SM+/SM- configuration, the measurement cycle and output update rate is shown in Figure 22 for an example involving three enabled auxiliary measurement tasks. After the final main measurement task is completed, the firmware



starts data processing as detailed in section 5 and section 6. The conditioned output signal is then recorded into the output registers.

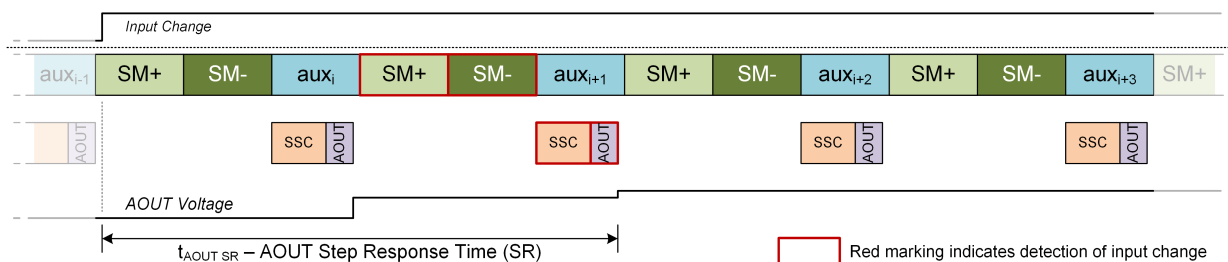


**Figure 22: SM+/SM- Measurement Cycle and Output Update Rate**

For SM+/SM- configuration the worst-case step response is shown in Figure 23 and consists of:

- 4 sensor ADC-conversion times (duration depending on selected ADC resolution)
- 1 auxiliary conversion time (fixed duration, based on longest auxiliary conversion timing)
- 1 SSC calculation

Additionally, there is a delay depending on the selected interface, such as the settling time at AOUT for all analog output options. In a worst-case scenario, be aware that intermediate results can occur because input changes and data readout are asynchronous to the ongoing internal measurement cycle.



**Figure 23: SM+/SM- Step Response**

#### 4.6.4 Deterministic Input Step Response with SM+/AZ Configuration

Since the SM+/SM- configuration samples the input signal twice as long as the SM+/AZ configuration and it suffers a noticeable timing overhead for sensor configurations with slow sensor input signal settling, a second SM+/AZ measurement scheme with deterministic step response times is available. For the step response consideration, the following application example is used:

- Sensor measurement (non-inverted)
- Auxiliary measurement (for example, for sensor path auto-zero and/or sensor temperature) within the auxiliary measurement vector



Figure 24: SM+/AZ Configuration

For SM+/SM- configuration, the measurement cycle and output update rate is shown in Figure 22 for an example involving three enabled auxiliary measurement tasks. After the final main measurement task is completed, the firmware starts data processing as detailed in section 5 and section 6. The conditioned output signal is then recorded into the output registers.

Assuming equal ADC resolution settings for the SM+/SM- configuration as described in subsubsection 4.6.3 and the SM+/AZ configuration described in this section, the worst case step response is shorter by two sensor AD-conversion times in case of the SM+/AZ setup. The auxiliary measurement duration in the SM+/AZ setup may become slightly longer than for the SM+/SM- configuration, since it is determined by the AZ measurement time if the selected resolution of the main bridge is larger than the resolutions of all other active auxiliary measurements. This is because the resolution of the AZ measurement is set by the resolution of the SM+ measurement and the longest measurement of the auxiliary measurement vector determines the duration of the aux<sub>i</sub> slot(s)

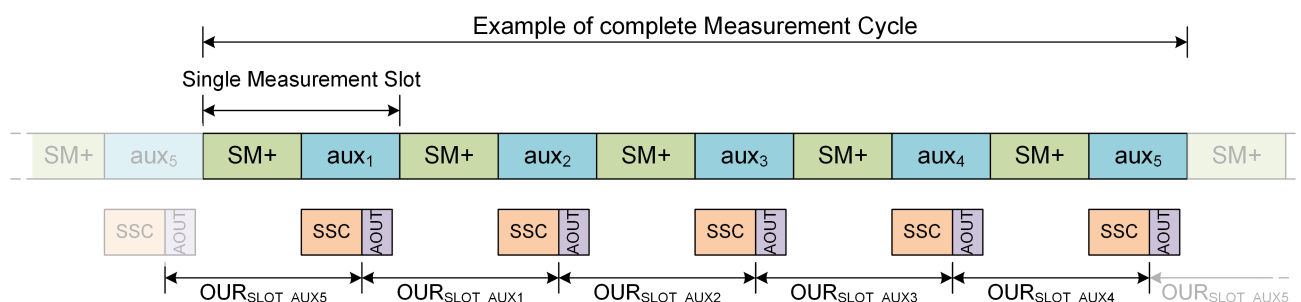


Figure 25: SM+/AZ Measurement Cycle and Output Update Rate

As shown in Figure 26, the worst-case latency consists of:

- 2 sensor AD-conversion times (duration depending on selected ADC resolution)
- 1 auxiliary conversion time (fixed duration, based on longest auxiliary conversion timing)
- 1 SSC calculation

Additionally, there is a delay depending on the selected interface, such as the settling time at AOUT for all analog output options. In a worst-case scenario, be aware that intermediate results can occur because input changes and data readout are asynchronous to the ongoing internal measurement cycle.

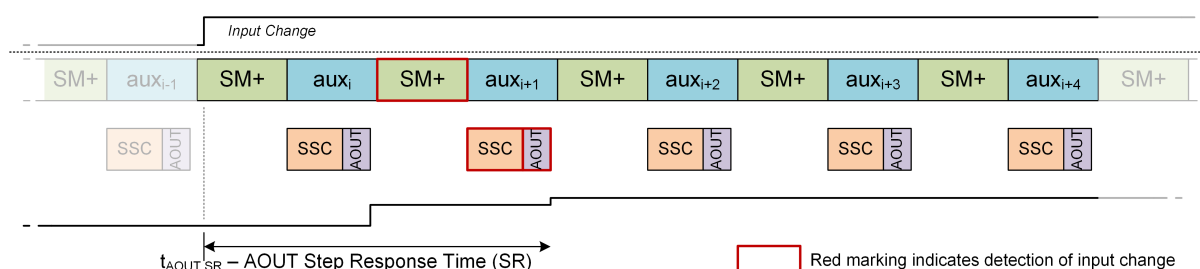


Figure 26: Measurement Flow and Latency for SM+/AZ Configuration

#### 4.6.5 Accelerated Bridge Measurements with Sparsely Inserted Auxiliary Measurements

For applications which focus on highest conversion rates at the bridge sensor input but do not require a deterministic maximum input to output latency of the corrected sensor signal, auxiliary measurements can be sparsely inserted to occur only after a certain number of measurement sequences were executed by the AFE sequencer. This way, auxiliary measurements become executed even more seldom, giving the main sensor bridge measurements priority.

The AFE sequencer can be configured such that an  $aux_i$  measurement is only executed (inserted) after every  $P_x$  measurement sequence.  $P$  can be selected as 2, 4, or 8. Figure 27 shows an example of a measurement flow with  $P = 2$  while Figure 28 uses  $P = 8$  where  $aux_i$  measurements are executed after eighth measurement sequences.

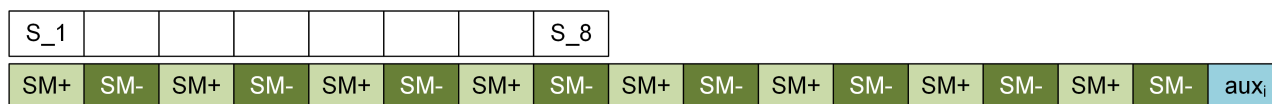


Figure 27: Auxiliary Measurement Executed after Every Second Measurement Cycle

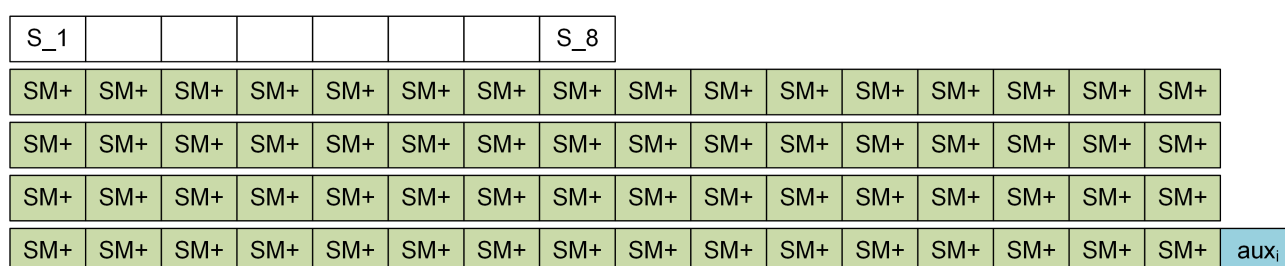


Figure 28: Sequencer Setup for Highest Update Rate on Bridge Sensor

For the SM+/SM- measurement sequencer use case, the output update rate is shown in Figure 29. The complete measurement cycle concludes after the final auxiliary measurement task is completed. Once the SM+ main measurement task is finished, the firmware starts data processing as detailed in section 5 and section 6. Since auxiliary measurement tasks are only inserted after every 2nd, 4th, or 8th measurement sequence, the output update rate varies accordingly. This explanation also applies when using only the SM+/AZ measurement sequencer.

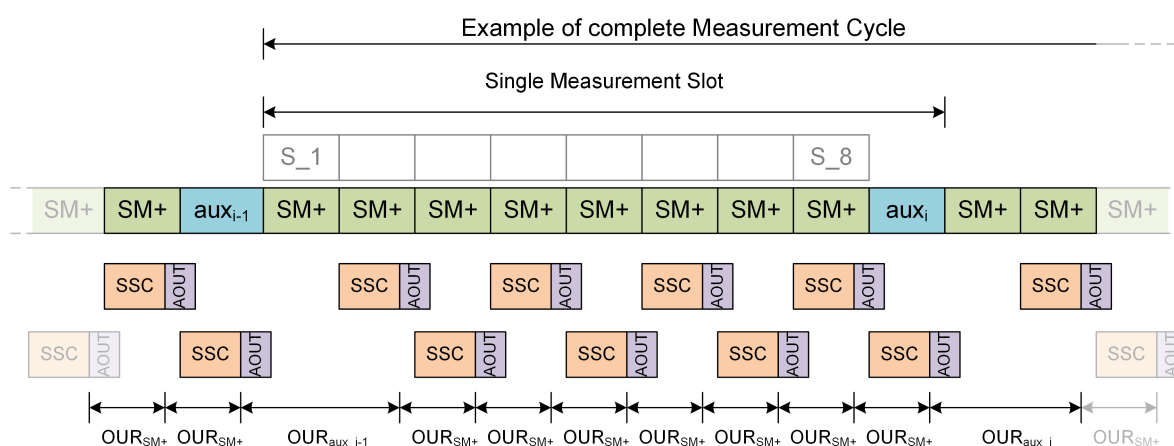


Figure 29: SM+ Accelerated Measurement Cycle and Output Update Rate

The worst-case step response primarily depends on the selected AFE sequencer mode as the following:

- SM+/SM- configuration: refer to Figure 23 and description for step response in subsection 4.6.3
- SM+/AZ configuration: refer to Figure 26 and description for step response in subsection 4.6.4

## 4.7 AFE Dual Speed Mode

The AFE Dual Speed Mode operation is intended for single bridge sensor applications that require a fast transient step response combined with a high resolution steady state signal at analog and serial interface outputs. It can be activated in the GUI via Configure\AFE\Sequencer\AFE Selection and Configurability\Dual speed AFE with AOUT.

In AFE Dual Speed Mode the sensor bridge is measured by both frontends (AFE1 and AFE2) in parallel, see Figure 30 for the required schematic. AFE Dual Speed Mode allows the operation of one external temperature sensor (T1) or the internal temperature sensor (PTAT).

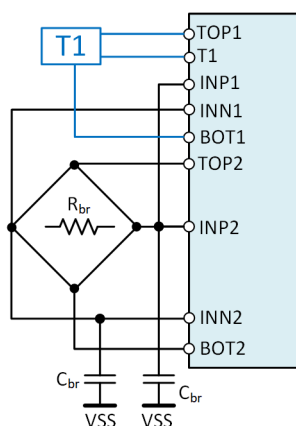


Figure 30: Schematic in AFE Dual Speed Mode

The fast reaction of the bridge sensor input is achieved through AFE1, which runs at low resolution (10 bit) and highest update rate. AFE2 runs on high resolution (SM+/SM- sequencer, 16bit) and a slower update rate according to Table 26. Figure 31 illustrates the sequence of AFE1 and AFE2 measurements.

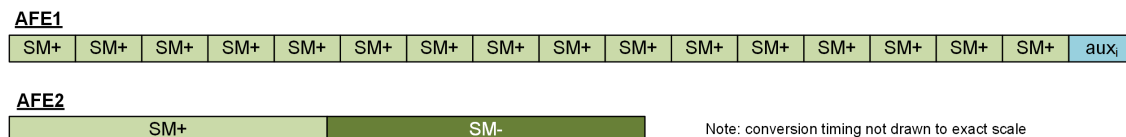


Figure 31: Sequencer Illustration for AFE1 and AFE2

Table 26: ADC Configuration Parameters for Dual Speed Mode

ADC Resolution [Bits]	Full Scale Input Voltage $V_{fs}$ [V]	LSB Size $V_{LSB}$ [ $\mu$ V]	Conversion Time, Typical, $T_{Conv}$ [ $\mu$ s]	Conversion Rate, Typical, $F_{Conv}$ [kHz]
10	$\pm 1.418$	2768.638	32.54	30.73
16	$\pm 1.440$	43.958	887.44	1.13

A digital algorithm decides whether the SSC conditioned results of AFE1 or AFE2 are forwarded to the outputs. By default, the more precise data of AFE2 is forwarded. As soon as a significant signal step occurs at the bridge sensor inputs, the algorithm switches from the slower AFE2 to the fast AFE1. After the transition to AFE1, the outputs follow the AFE1 results with its speed, accuracy, and noise properties.

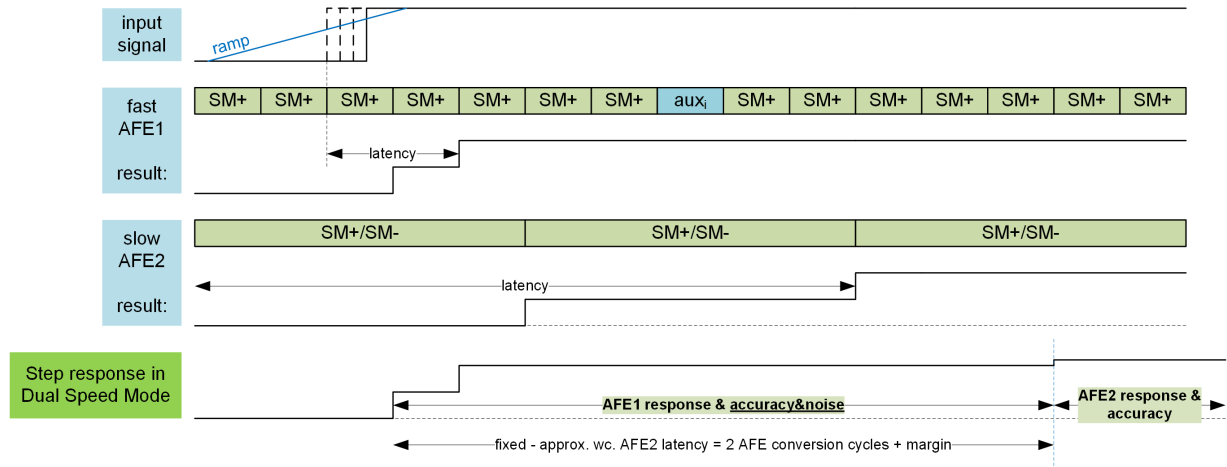
AFE1 stays active for at least the duration of approximately two slow AFE2 conversions. If no further significant input signal variation is detected within this time, the algorithm switches back from AFE1 to AFE2. See Figure 32 for a graphical explanation of the algorithm.

An input step is detected if the signal difference between AFE1 and AFE2 crosses Threshold 1 (can be setup via GUI Configure\AFE\Sequencer\Dual Speed AFE with AOUT). Once an input step was detected and outputs were switched to AFE1, a count down timer is started to let AFE1 process a number of approximately 60 samples. The actual sample number is between 57 and 61, depending on the configured AFE2 bridge settling time and is automatically calculated by the GUI. Once the count down timer expired, the outputs are switched back from AFE1 to AFE2 if no further step was detected.

To judge the signal variation after the initial step detection, all new AFE1 measurement results are compared against an AFE1 reference result that was stored at the preceding threshold crossing. A further step is detected when the

comparison difference is larger than Threshold 2 (can also be setup via GUI). In this case a new AFE1 reference value is stored and the count down timer is reset which causes another approximately 60 samples from AFE1.

The algorithm detects signal changes which span over multiple AFE1 conversions see Figure 32, it compares the current measurement result with a reference value from several conversion periods back in time. The user can modify the dynamic behavior of the algorithm by modifying the Threshold 1 and Threshold 2 settings.



**Figure 32: Step Response in Dual Speed Mode for a Significant Single Input Step**

The AFE Dual Speed Mode is available for following SSC outputs:

- all Analog Output (AOUT) Modes with exception of 2-wire current loop mode
- all Serial interface outputs

AFE Dual Speed Mode is not available for:

- 2-wire current loop operation
- PMW/FOUT output modes
- Signal Post processing features: EOC, ALARM, Output Filtering.
- AFE diagnosis features

The dynamic Sensor Bridge configuration is fixed to:

- AFE1: 10bit, SM+ only
- AFE2: 16bit, SM+/SM-
- The aux<sub>i</sub> cycle in the sequencer becomes automatically activated if T1 or PTAT are selected. If no temperature sensor is selected, the aux<sub>i</sub> cycle shown in Figure 31 is removed.

With the dynamic AFE configuration setup a worst case input step latency of 0.35ms is achievable at AOUT. The precise signal settles maximum 5ms after stable input signal.

## 5 Sensor Signal Conditioning

### 5.1 Signal Conditioning Data Path

Figure 33 illustrates the sensor signal conditioning flow that is applied for AFE output data to compensate for offset, gain, non-linearity, and temperature effects and to calculate the conditioned data for further output processing. See subsection 5.2 to subsection 5.6 for more information on the basis mathematical subfunctions.

The signal path from conditioned data to individual output signals is described in section 6.

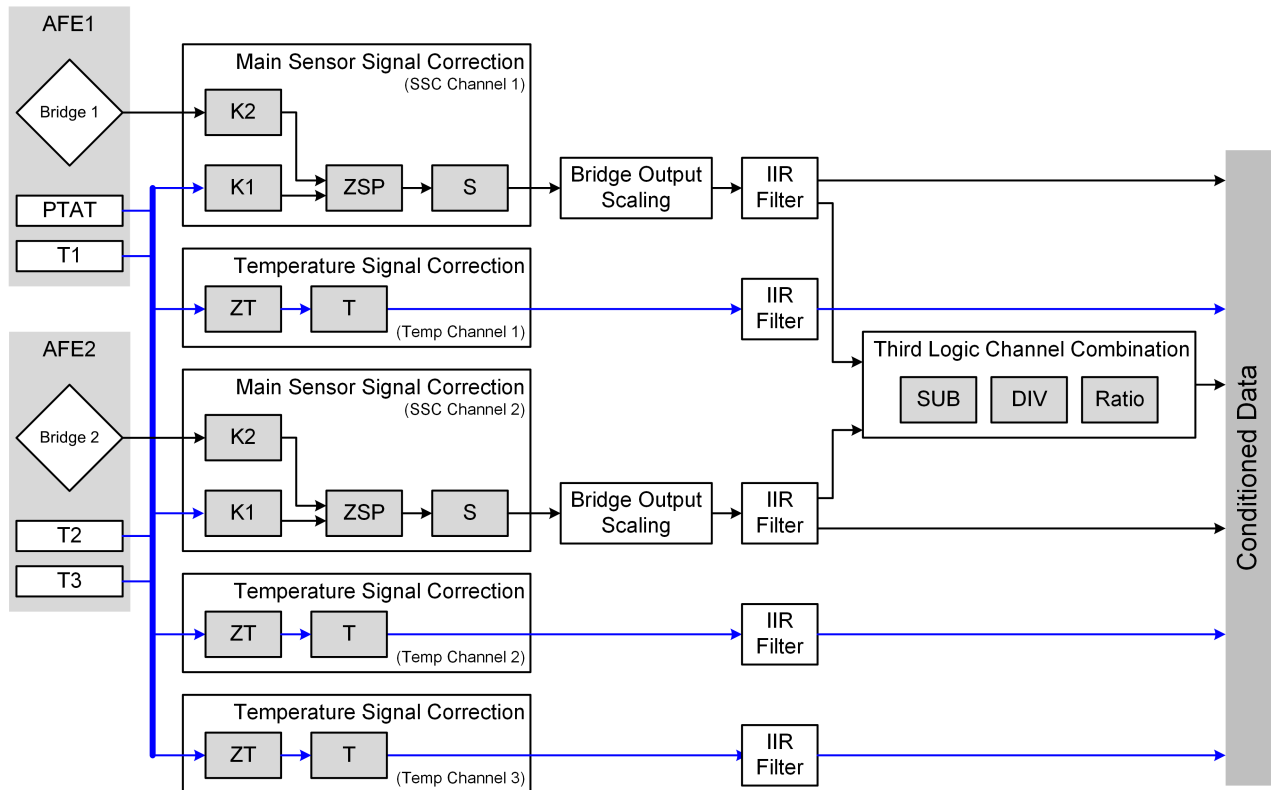


Figure 33: Sensor Signal Flow Chart from Input to Conditioned Data

### 5.2 Main Sensor Signal Correction

ZSSC3281 supports basic second-order compensation of sensor nonlinearities. The following basic SSC math options are available:

- Sensor signal correction
  - SOT Curve-0: Parabolic compensation curve
  - SOT Curve-1: S-shaped compensation curve
- Temperature signal correction

The parabolic compensation is recommended for most sensor types. The applied SSC math option can be selected in the GUI through the field Calibration\Curve.

The available SSC capabilities for SOT Curve-0 and SOT Curve-1 are described in Table 27, Table 28, and Table 29. The used equation terms are as follows:

		Valid Input Range
<i>S</i>	Corrected sensor reading output via I2C, OWI, or SPI	0x0 to 0xFFFFF
<i>S_Raw</i>	Raw sensor reading from ADC (after AZ correction, depends on Afe1SmConfig)	-(0x7FFFFF) to 0x7FFFFF
<i>Gain_S</i>	Sensor gain term	-(0x7FFFFF) to 0x7FFFFF
<i>Offset_S</i>	Sensor offset term	-(0x7FFFFF) to 0x7FFFFF
<i>Tcg</i>	Temperature coefficient gain term	-(0x7FFFFF) to 0x7FFFFF
<i>Tco</i>	Temperature coefficient offset term	-(0x7FFFFF) to 0x7FFFFF
<i>T_Raw</i>	Raw temperature reading (after AZ correction)	-(0x7FFFFF) to 0x7FFFFF
<i>SOT_tcg</i>	Second-order term for <i>Tcg</i> non-linearity	-(0x7FFFFF) to 0x7FFFFF
<i>SOT_tco</i>	Second-order term for <i>Tco</i> non-linearity	-(0x7FFFFF) to 0x7FFFFF
<i>SOT_sens</i>	Second-order term for sensor non-linearity	-(0x7FFFFF) to 0x7FFFFF
<i>SENS_shift</i>	Post-calibration, post-assembly offset shift	-(0x7FFFFF) to 0x7FFFFF
...	Absolute value	
[...] <sup>ul</sup> / <sub>ll</sub>	Bound/saturation number range from <i>ll</i> to <i>ul</i> , overflow and/or underflow is reported as saturation in the Status Byte	

All raw data and compensation coefficients supplied to the formulas are required in 24-bit data format shown in Table 27 and Table 28.

**Table 27: Data Format of Raw ADC Readings**

Bit Number	23	22	21	20	...	2	1	0
Meaning, Weighting	$-2^0$	$2^{-1}$	$2^{-2}$	$2^{-3}$	...	$2^{-21}$	$2^{-22}$	$2^{-23}$

**Table 28: Data Format of 24-bit SSC Coefficients**

Bit Number	23	22	21	20	...	2	1	0
Meaning, Weighting	0 = positive 1 = negative	$2^{-1}$	$2^{-2}$	$2^{-3}$	...	$2^{-21}$	$2^{-22}$	$2^{-23}$

The compensated result data is supplied in 24-bit data format as shown in Table 29.

**Table 29: Data Format of Corrected SSC Results (*S* and *T*)**

Bit Number	23	22	21	20	...	2	1	0
Meaning, Weighting	$2^0$	$2^{-1}$	$2^{-2}$	$2^{-3}$	...	$2^{-21}$	$2^{-22}$	$2^{-23}$

### 5.2.1 Pre-calculation

Simplified:

$$K_1 = 2^{23} + \frac{T\_Raw}{2^{23}} \times \left( \frac{4 \times SOT\_tcg}{2^{23}} \times T\_Raw + 4 \times Tcg \right) \quad (1)$$

$$K_2 = 4 \times Offset\_S + S\_Raw + \frac{T\_Raw}{2^{23}} \times \left( \frac{4 \times SOT\_tco}{2^{23}} \times T\_Raw + 4 \times Tco \right) \quad (2)$$

Complete:

$$K_1 = \left[ 2^{23} + \left[ \frac{T\_Raw}{2^{23}} \times \left[ \left[ \frac{SOT\_tcg}{2^{21}} \times T\_Raw \right]_{-2^{25}}^{2^{25}-1} + 4 \times Tcg \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} \quad (3)$$

$$K_2 = \left[ 4 \times Offset\_S + \left[ S\_Raw + \left[ \frac{T\_Raw}{2^{23}} \times \left[ \left[ \frac{SOT\_tco}{2^{21}} \times T\_Raw \right]_{-2^{25}}^{2^{25}-1} + 4 \times Tco \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} \quad (4)$$

### 5.2.2 SOT Curve-0 (Parabolic Compensation)

Simplified:

$$Z_{SP} = \frac{4 \times Gain\_S}{2^{23}} \times \frac{K_1}{2^{23}} \times K_2 + 2^{23} \quad (5)$$

$$S = \frac{Z_{SP}}{2^{23}} \times \left( \frac{4 \times SOT\_sens}{2^{23}} \times Z_{SP} + 2^{23} \right) + SENS\_shift \quad (6)$$

**Note:**  $Z_{SP}$  and  $S$  are delimited to positive number range.

Complete:

$$Z_{SP} = \left[ \left[ \frac{Gain\_S}{2^{21}} \times \left[ \frac{K_1}{2^{23}} \times K_2 \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} + 2^{23} \right]_0^{2^{25}-1} \quad (7)$$

$$S = \left[ \left[ \frac{Z_{SP}}{2^{23}} \times \left[ \left[ \frac{SOT\_sens}{2^{21}} \times Z_{SP} \right]_{-2^{25}}^{2^{25}-1} + 2^{23} \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} + SENS\_shift \right]_0^{2^{24}-1} \quad (8)$$

### 5.2.3 SOT Curve-1 (S-shaped Compensation)

Simplified:

$$Z_{SS} = \frac{4 \times Gain\_S}{2^{23}} \times \frac{K_1}{2^{23}} \times K_2 \quad (9)$$

**Note:**  $K_1$  and  $K_2$  according to Equation 3 and Equation 4.

$$S = \frac{Z_{SS}}{2^{23}} \times \left( \frac{4 \times SOT\_sens}{2^{23}} \times |Z_{SS}| + 2^{23} \right) + 2^{23} + SENS\_shift \quad (10)$$

**Note:**  $S$  is delimited to positive number range.

Complete:

$$Z_{SS} = \left[ \frac{Gain\_S}{2^{21}} \times \left[ \frac{K_1}{2^{23}} \times K_2 \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} \quad (11)$$

$$S = \left[ \left[ \left[ \frac{Z_{SS}}{2^{23}} \times \left[ \left[ \frac{SOT\_sens}{2^{21}} \times |Z_{SS}| \right]_{-2^{25}}^{2^{25}-1} + 2^{23} \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} + 2^{23} \right]_{-2^{25}}^{2^{25}-1} + SENS\_shift \right]_0^{2^{24}-1} \quad (12)$$



### 5.3 Temperature Signal Correction

Temperature is measured either internally by the ZSSC3281, through an additional external element, or by means of a combination of ZSSC3281 internal and external temperature sensing capabilities. Temperature correction contains both linear gain and offset terms as well as a second-order term to correct for any nonlinearities. For temperature, second-order compensation is always parabolic.

The correction equation terms are as follows:

		Valid Input Range
$T$	Corrected temperature sensor reading output via digital interface	0x0 to 0xFFFFF
$T\_Raw$	Raw temperature reading after AZ correction	-(0x7FFFFF) to 0x7FFFFF
$Gain\_T$	Gain coefficient for temperature	-(0x7FFFFF) to 0x7FFFFF
$Offset\_T$	Offset coefficient for temperature	-(0x7FFFFF) to 0x7FFFFF
$SOT\_T$	Second-order term for temperature source nonlinearity	-(0x7FFFFF) to 0x7FFFFF
$T\_shift$	Shift for post-calibration/post-assembly offset compensation	-(0x7FFFFF) to 0x7FFFFF

The correction formula is best represented as a two-step process as follows:

Simplified:

$$Z_T = \frac{4 \times Gain\_T}{2^{23}} \times (T\_Raw + 4 \times Offset\_T) + 2^{23} \quad (13)$$

$$T = \frac{Z_T}{2^{23}} \times \left( \frac{4 \times SOT\_T}{2^{23}} \times Z_T + 2^{23} \right) \quad (14)$$

**Note:**  $Z_T$  and  $T$  are delimited to positive number range.

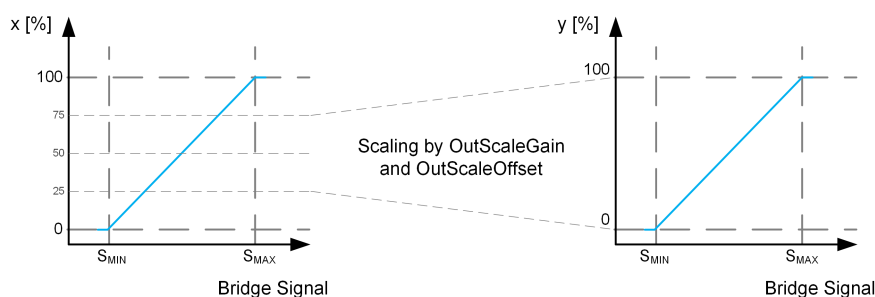
Complete:

$$Z_T = \left[ \left[ \frac{Gain\_T}{2^{21}} \times [T\_Raw + 4 \times Offset\_T]_{-2^{25}}^{2^{25}-1} + 2^{23} \right]_{-2^{25}}^{2^{25}-1} \right]_{0}^{2^{25}-1} \quad (15)$$

$$T = \left[ \left[ \frac{Z_T}{2^{23}} \times \left[ \left[ \frac{SOT\_T}{2^{21}} \times Z_T \right]_{-2^{25}}^{2^{25}-1} + 2^{23} \right]_{-2^{25}}^{2^{25}-1} + T\_shift \right]_{-2^{25}}^{2^{25}-1} \right]_{0}^{2^{24}-1} \quad (16)$$

## 5.4 Bridge Output Scaling

ZSSC3281 offers a linear rescaling function to amplify or compress a partial region of the sensor input range to the desired signal output range. Figure 34 illustrates the rescaling on an example where the 25% to 75% calibrated signal input range is mapped to the output range of 0% to 100%. The feature is intended for customers who need to separate product derivatives after a common sensor calibration step.



**Figure 34: Example: Bridge Output Scaling Function for Scaling 25% - 75%, to final 0% - 100%**

The rescaling feature applies the following formula to the SSC conditioned outputs of the main bridge sensor:

$$y = \left[ \frac{8 \times OutScaleGain}{2^{23}} \times (x + 8 \times OutScaleOffset) \right]_0^{2^{24}-1} \quad (17)$$

The Coefficients *OutScaleGain* and *OutScaleOffset* are stored in the CCP (Configuration and Calibration Page) of ZSSC3281 in signed magnitude format. According to Table 30 *OutScaleGain* is limited to a maximum gain of 4 and the *OutScaleOffset* can vary from -1.5 to 0 related to the SSC result number range 0 to ~2.

**Table 30: Examples for Bridge Output Scaling**

Input Relative – x [%]		OutScaleGain		OutScaleOffset		Output Relative – y [%]	
		real	CCP Content (Decimal)	real	CCP Content (Decimal)		
0	50.0	2.000	2097152	0.0	0	0	100
0	33.3	3.003	3148876	0.0	0	0	100
0	25.0	4.000	4194304	0.0	0	0	100
25	50.0	4.000	4194304	-0.5	-524288	0	100
25	75.0	2.000	2097152	-0.5	-524288	0	100
50	100.0	2.000	2097152	-1.0	-1048576	0	100
75	100.0	4.000	4194304	-1.5	-1572864	0	100

Table 31 lists the mapping of CCP register content to output scaling coefficients.

**Table 31: Data Format of Output Scaling Coefficients in CCP**

Bit Number	23	22	21	20	19	...	1	0
Meaning, Weighting	0 = positive 1 = negative	2 <sup>2</sup>	2 <sup>1</sup>	2 <sup>0</sup>	2 <sup>-1</sup>	...	2 <sup>-19</sup>	2 <sup>-20</sup>

The GUI supports the calculation of *OutScaleGain* and *OutScaleOffset* based on provided relative input and output range specifications (can be configured on the GUI tab Configure\Output Scaling).

## 5.5 IIR Filter

The conditioned outputs of the two main sensor bridge channels CH1 and CH2 and the conditioned outputs of the temperature channels TCh1 to TCh3 can be low pass filtered for noise reduction. Each channel is equipped with an independent configurable IIR Filter. The mathematical filter description is as follows:

$$y_0 = x_0 \quad (18)$$

$$y_i = x_{i-1} + \frac{(x_i - y_{i-1}) \times Diff}{Avg} \quad (19)$$

where:

$$Diff = FiltDiff + 1 \quad (20)$$

$$Avg = 2^{FiltAvg} \quad (21)$$

*FiltDiff* and *FiltAvg* represent the filter coefficients which are stored as unsigned 3-bit values per filter channel in *lirFiltCoeffReg* inside the CCP of ZSSC3281. They are determined by the GUI (Configure\Filter) depending on the filter Tau selections made by the user. For a stable system, the  $Diff \leq Avg$  must be ensured.

The filter Tau can be calculated by:

$$\frac{Diff}{Avg} = \alpha \approx \frac{1}{\tau_{dig}} = \frac{\Delta T}{\tau_{ana}} \quad (22)$$

$$\tau_{dig} = -\frac{1}{\ln(1 - \alpha)} \quad (23)$$

$\tau_{dig}$  is given in number of digital samples.

## 5.6 Third Logic Channel Combination

The potentially pre-scaled and filtered two main sensor bridge channels Ch1 and Ch2 of ZSSC3281 can be mathematically combined to calculate the output of a third logic channel Ch3. Channel Ch3 is only available in the synchronized AFE mode which is enabled via the GUI menu Configure\AFE\Sequencer\AFE Selection and Configurability\selection: "AFE1+AFE2, config equally".

The calculation result on Ch3 is available through serial interface read out only. The digital output format is signed 32-bit (two's complement), see Table 32. Outputting the Ch3 result at AOUT is possible for subtraction and ratio only. Division is readable via digital interfaces only.

The Third Logic Channel (TLC) can be configured via the GUI menu Configure\TLC menu.

Following mathematical operations are available:

- Subtraction: (Ch1 – Ch2) or (Ch2 – Ch1)
- Division: (Ch1 / Ch2) or (Ch2 / Ch1)
- Ratio: If Ch1 == Ch2 then Ch3 = 1  
Else if Ch1 < Ch2 then Ch3 = Ch1 / Ch2  
Else Ch3 = 2 – (Ch2 / Ch1)

**Note:** Division calculation can lead to math saturation, which is not suppressed by firmware.

Calibration of the sensor channels Ch1 and Ch2 must still be done independently applying the single channel calibration routines.

**Table 32: Data Format of Logic Output Channel Ch3 at Serial Interface**

Bit Number	31	30	29	...	24	23	22	21	...	2	1	0
Meaning, Weighting	$-2^8$	$2^7$	$2^6$	...	$2^1$	$2^0$	$2^{-1}$	$2^{-2}$	...	$2^{-21}$	$2^{-22}$	$2^{-23}$

## 6 Post Processing Options for Conditioned Sensor Signals

### 6.1 Signal Post Processing Flow Chart

Figure 35 illustrates the signal flow from conditioned data to individual output signals. All basis mathematical sub-functions are described within the subsection 6.5 to subsection 6.6.

The signal path from AFE output data to conditioned data is described in subsection 5.2.

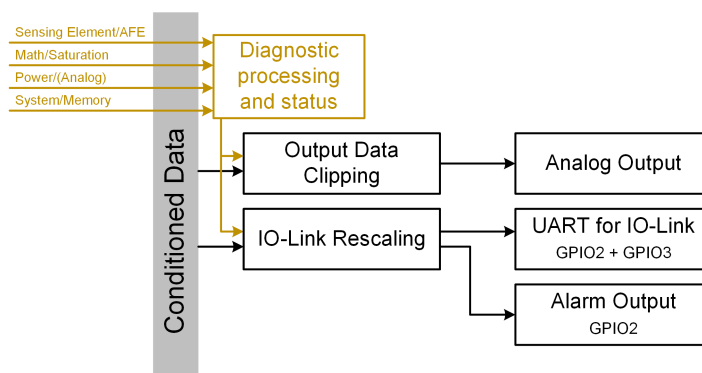


Figure 35: Sensor Signal Flow Chart from Input to Output

### 6.2 LSB Zeroing

All internal calculations are performed with higher precision than the selected ADC resolution, and the output results on digital interfaces are normalized for all channels except SSC CH3 (Third Logic Channel) before providing on the digital interfaces as defined by:

$$DigitalOutputValue = ConditionedData AND (2^{ADCResolution} - 1) \quad (24)$$

### 6.3 SSC Process Image

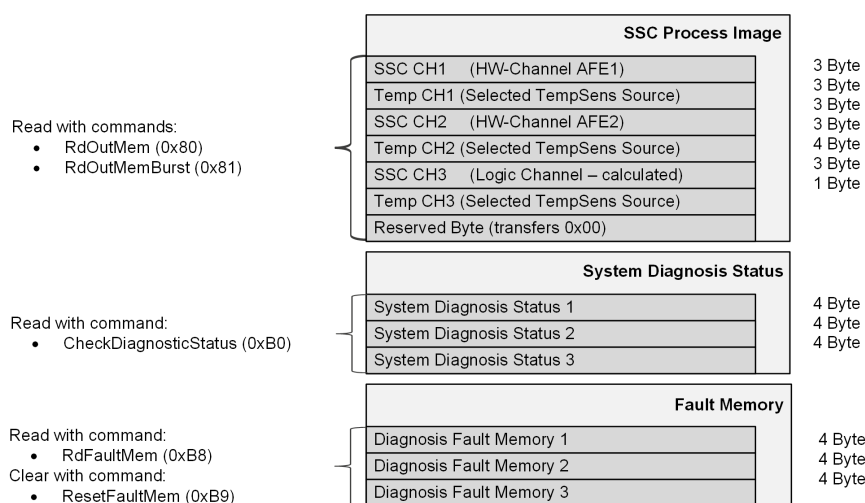


Figure 36: SSC Process Image, System Diagnosis Status and Fault Memory Map

ZSSC3281 handles all continuous process data communication with a host system through memory interfaces called SSC Process Image, System Diagnosis Status, and Fault Memory.

The data in the SSC Process Image is updated as soon as respective AFE measurements are completed, and the related sensor signal conditioning operations are carried out. It always reflects the most up-to-date known status of the connected sensor system. The SSC Process Image holds data of both main sensor, three temperature signals and for the third logic channel.

Status informations from all activated system diagnosis checks are contained inside the System Diagnosis Status and the Fault Memory which allows the host system to check for the source of system failure states that were reported in the Status Byte of a previously received command response. The structure of the system diagnosis status words is described in subsection 7.2.

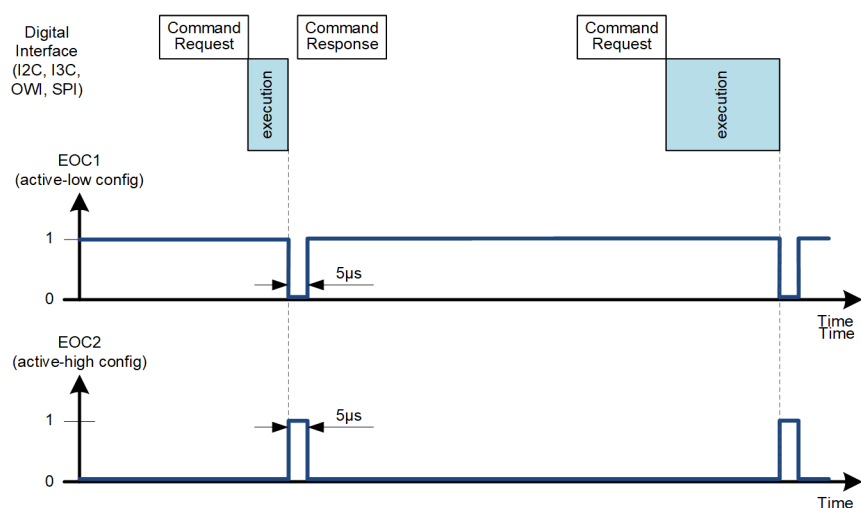
## 6.4 EOB/EOC/Alarm Functions

The Pins EOC/ALARM 1 (GPIO2) and EOC/ALARM 2 (GPIO3) can be configured to operate either as an end-of-busy (EOB) in Command and Sleep Mode, or end-of-conversion (EOC) transducer or as a configurable switch/alarm transducer for the respective SSC conditioned outputs of the main bridge sensors in Cyclic Mode.

To support different external logic, the global setting for polarity of the EOB/EOC/ALARM outputs can be configured as active high or active low (can be setup via GUI Configure\EOC/ALARM\Output Polarity).

### 6.4.1 EOB Function

The end-of-busy (EOB) function can be enabled as an additional functionality within Command Mode and Sleep Mode (setup via GUI Configure\System Control) to allow upper MCUs receiving interrupt signals after finishing ZSSC3281's internal command execution. If EOB is enabled, a short signal pulse of approximately 5 $\mu$ s wide (see Figure 37) is generated on enabled EOC pins.

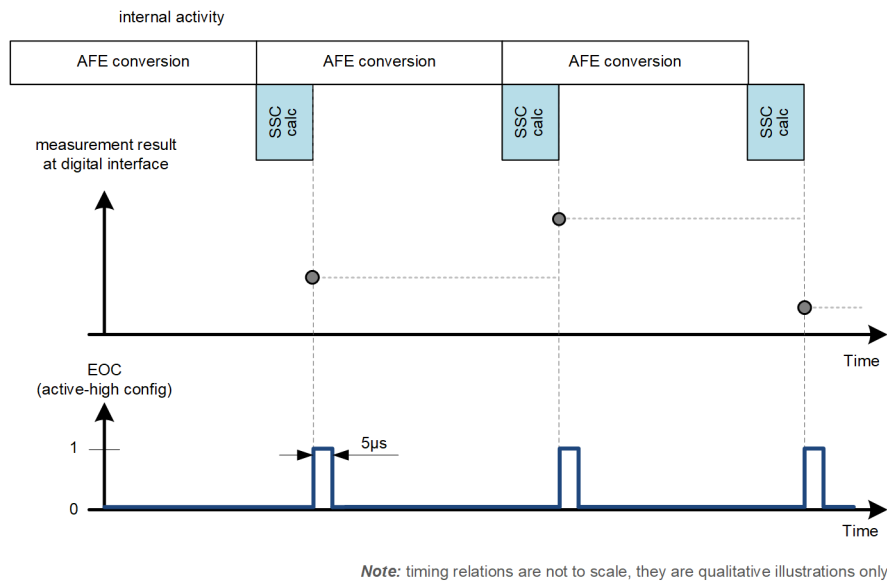


*Note: timing relations are not to scale, they are qualitative illustrations only*

**Figure 37: EOB Behavior - Signalization of End-of-Busy**

### 6.4.2 EOC Function

If the EOC output mode is active (can be setup via GUI Configure\EOC\ALARM\Selected Mode\EOC), an EOC event is signaled at the GPIO pin as soon as a new SSC-corrected measurement result of the bridge sensor is available for read out by the host system. The EOC signal pulse is approximately 5µs wide (see Figure 38).



**Figure 38: EOC Behavior - Signalization of End-of-Conversion**

**Note:** The EOC Output Mode is not available in AFE Dual Speed Mode PWM/FOUT Mode

### 6.4.3 ALARM Function

If the ALARM output mode is active (can be setup via GUI Configure\EOC\ALARM\Selected Mode\Alarm) further configuration options exist:

- Single threshold comparison vs. Window comparison
- Range definition for ALARM (above/below vs. inside/outside)
- Hysteresis setting
- Persistence setting

Figure 39 shows the ALARM output signaling in the possible four different modes. The dotted black lines reflect the behavior for zero hysteresis, while the dotted blue lines take a configured threshold hysteresis into account.

The lower charts of Figure 39 feature a special signal transient example. If the measurement result jumps from one sample to another from above the upper to below the lower alarm threshold (or vice versa), the alarm state remains the same since the logic conditions of the Window comparison mode permit this.

The configured hysteresis value (GUI tab Configure\EOC\ALARM\Hysteresis) defines the hysteresis half width or “offset”. The total hysteresis width is effectively twice the configured hysteresis value.

The ALARM persistence can be set between 0 and 255. A persistence value >0 requires the signal to remain above or below the threshold for the selected number of consecutive pulses before the ALARM output state is changed. The value of 0 effectively disables the persistence feature and the logic checks for a single occurrence of the threshold condition only.

If AFE1 and AFE2 are running asynchronously, the EOC/ALARM outputs are also evaluated independently after the SSC operation was completed. In case of synchronous setup, the evaluations happen at about the same time but AFE1 is evaluated first.

The alarm thresholds and hysteresis values are stored in the respective CCP registers using the data format as shown in Table 33.

Table 33: Data Format of Alarm Thresholds and Hysteresis

Bit-Number:	23	22	21	20	...	2	1	0
Meaning, Weighting	20	$2^1$	$2^2$	$2^3$	...	$2^{21}$	$2^{22}$	$2^{23}$

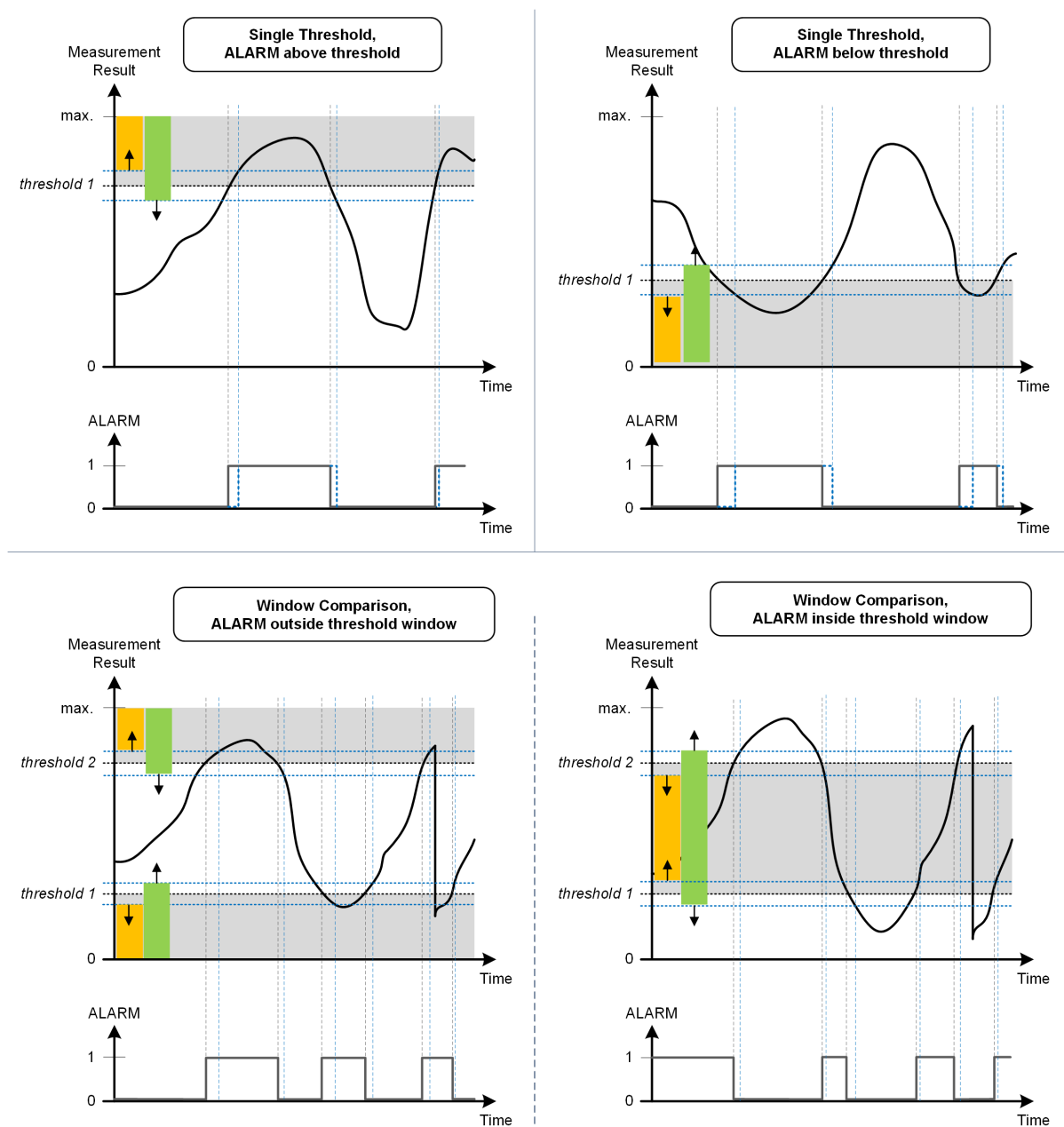


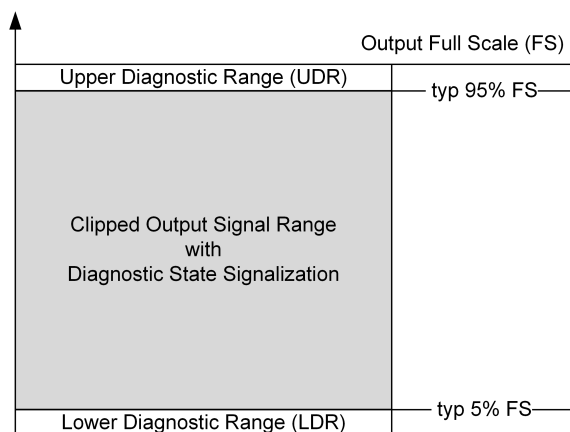
Figure 39: Behaviour of ALARM Feature in Four Different Modes

## 6.5 Output Data Clipping

The signaling of a diagnosis failure state can also be activated on the analog output AOUT via the GUI tab Diagnostic\General. If the signalization of Diagnostic State at AOUT is enabled, discovered diagnostic failure states can be either mapped to the Upper or the Lower Diagnostic Range (UDR and LDR) of the output span (GUI tab Diagnostic\Sensor\AFE).

The boundaries of the upper and lower diagnostic ranges are configurable via the GUI tab Configure\Output Pre-process. They are typically set to 5% and 95% of the full scale output level but can be modified to the application needs.

To prevent false interpretation of very large or very low output signals, the conditioned data is clipped according to Figure 40 to fit into the remaining output range between UDR and LDR before it is forwarded to the AOUT output.



**Figure 40: AOUT Output Ranges with Active Diagnostic State Signalization**

- Note:** There is no rescaling of the conditioned data performed at this stage.  
If rescaling of the conditioned data to the clipped output signal range is required, use the Bridge Output Scaling feature (see subsection 5.4) or use different target values during the SSC calibration process.
- Note:** UDR has higher priority than LDR.  
Each sensor and AFE diagnostic feature described in subsection 7.1 assigns individually UDR or LDR which requires an internal prioritization in case of multiple malfunctions detected.

## 6.6 FOUT Oscillator Compensation

Frequency output requires a stable base frequency. The internal oscillator provides the base frequency for frequency modulation (see subsection 9.1). To minimize the resulting temperature drift, it can be compensated via internal PTAT temperature sensor by the following compensation mathematics:

$x$	Corrected sensor signal selected for Frequency Output	Valid Input Range
$y$	Temperature compensated output signal for Frequency Output	0x0 to 0xFFFFFFFF
$T_{RawPTAT}$	Raw temperature reading of PTAT (after AZ correction)	0x0 to 0xFFFFFFFF
$Fm_{SOT}$	Second-order term for frequency modulation	-(0x7FFFFFFF) to 0x7FFFFFFF
$Fm_{Gain}$	Gain term for frequency modulation	-(0x7FFFFFFF) to 0x7FFFFFFF
$Fm_{Offset}$	Offset term for frequency modulation	-(0x7FFFFFFF) to 0x7FFFFFFF

- Note:** The compensation mathematics requires enabling the internal PTAT temperature measurement within the AUX measurements.

All raw data and compensation coefficients supplied to the formulas are required in the 24-bit data format described in Table 21, Table 22, Table 23, and Equation 25.

**Table 34: Data Format of Raw ADC Readings**

Bit-Number:	23	22	21	20	...	2	1	0
Meaning, Weighting	$2^0$	$2^{-1}$	$2^{-2}$	$2^{-3}$	...	$2^{-21}$	$2^{-22}$	$2^{-23}$

**Table 35: Data Format of Corrected SSC Result**

Bit-Number:	23	22	21	20	...	2	1	0
Meaning, Weighting	$2^0$	$2^{-1}$	$2^{-2}$	$2^{-3}$	...	$2^{-21}$	$2^{-22}$	$2^{-23}$

**Table 36: Data Format of 32-bit SSC Coefficients**

Bit-Number:	23	22	21	20	...	2	1	0
Meaning, Weighting	$2^0$	$2^{-1}$	$2^{-2}$	$2^{-3}$	...	$2^{-28}$	$2^{-29}$	$2^{-30}$

$$y = [x \times (4 \times Fm_{SOT} \times T_{RawPTAT}^2 + Fm_{Gain} \times T_{RawPtat} + Fm_{Offset})]_0^{2^{32}-1} \quad (25)$$



## 7 Sensor and System Diagnosis

The ZSSC3281 sensor and system diagnosis function can detect several false conditions on externally connected sensors and monitor long term gain and offset drifts of the analog front end. This makes ZSSC3281 well suited for sensing applications that require increased system reliability as well as for predictive maintenance supervision done by the host system.

### 7.1 Sensor and AFE Diagnostic Features

The supported sensor and AFE diagnostic features are summarized in Table 37.

**Table 37: Sensor and AFE Diagnosis Functions**

Monitored Input or Component	Failure Category	Failure Condition <sup>1</sup>
Main sensor bridge 1	INP or INN open	INP to INN resistance >125kΩ
	INP or INN shorted	INP to INN resistance <170Ω
Main sensor bridge 2	INP or INN open	INP to INN resistance >125kΩ
	INP or INN shorted	INP to INN resistance <170Ω
Temperature sensor T1	Short to Top (TOP)	T1 to TOP resistance <500Ω
	Short to Bottom (BOT)	T1 to BOT resistance <500Ω
	Open	T1 resistance >2MΩ, 500kΩ, 100kΩ
Temperature sensor T2	Short to Top (TOP)	T2 to TOP resistance <500Ω
	Short to Bottom (BOT)	T2 to BOT resistance <500Ω
	Open	T2 resistance >2MΩ, 500kΩ, 100kΩ
Temperature sensor T3	Short to Top (TOP)	T3 to TOP resistance <500Ω
	Short to Bottom (BOT)	T3 to BOT resistance <500Ω
	Open	T3 resistance >2MΩ, 500kΩ, 100kΩ
AFE1	Gain Drift	Gain check deviates by provided percentage from previously stored reference value
	Offset Drift	Offset check deviates by provided permillage from previously stored reference value
AFE2	Gain Drift	Gain check deviates by provided percentage from previously stored reference value
	Offset Drift	Offset check deviates by provided permillage from previously stored reference value

<sup>1</sup> Typical values. Further specifications are provided in subsection 2.4.

For all active sensor inputs and AFEs, the checks can be enabled selectively on the GUI tab Diagnostic\Sensor\AFE.

The AFE gain drift check employs an internally connected resistive DAC to create itself a defined input signal. The internal DAC can generate four different input voltages: 2mV, 10mV, 100mV, 200mV. The GUI proposes the most suitable setting based on other configurations made for the AFE. The selected voltage level is stored in the CCP.

In order to make proper use of the long-term AFE gain and offset drift checks, a device dependent reference value must be acquired and stored during the sensor calibration process. The GUI supports this via the 'Get' button which is located in front of the GainRef and OffsetRef fields.

To run individual tests for sensor and AFE diagnosis features, use the 0xB4 command. This command triggers a single measurement that returns a pass or fail result, as shown in Table 38. A full update of all enabled sensor checks can be executed using the 0xB2 command.

**Table 38: 0xB4 - Self Diagnostic Measurement Command**

Command Code	Description	Return
0xB4 followed by 0x0XYY	<b>Self-Diagnostic Measure</b> for AFE1 and AFE2 <ul style="list-style-type: none"> <li>0x0X <ul style="list-style-type: none"> <li>AFE1: 0x00</li> <li>AFE2: 0x01</li> </ul> </li> <li>0xYY - see below</li> </ul>	2 Bytes
0xYY	Measurement	Return
0x05	External temperature sensor, T1, check short to top	0b0000_0000_0000_000X
0x06	External temperature sensor, T1, check short to bottom	0b0000_0000_0000_000X
0x07	External temperature sensor, T1, check open	0b0000_0000_0000_000X
0x0A	External temperature sensor, T2, check short to top	0b0000_0000_0000_000X
0x0B	External temperature sensor, T2, check short to bottom	0b0000_0000_0000_000X
0x0C	External temperature sensor, T2, check open	0b0000_0000_0000_000X
0x0F	External temperature sensor, T3 (pin GUARD), check short to top	0b0000_0000_0000_000X
0x10	External temperature sensor, T3 (pin GUARD), check short to bottom	0b0000_0000_0000_000X
0x11	External temperature sensor, T3 (pin GUARD), check open	0b0000_0000_0000_000X
0x1B	Main bridge sensor connection check open	0b0000_0000_0000_000X
0x1C	Main bridge sensor connection check short	0b0000_0000_0000_000X
0x27	Offset drift (calculated diagnosis result)	0b0000_0000_0000_000X
0x28	Gain drift (calculated diagnosis result)	0b0000_0000_0000_000X

## 7.2 Sensor and System Diagnosis Status

All individual sensor and AFE diagnosis features are able to set an individual bit inside a fault memory.

Since the SSC Process Image data is continuously updated as soon as new measurement data becomes available, it may happen that diagnosis faults disappear before the host has read them via the CheckDiagnosticStatus command 0xB0.

To allow system failure detection at a later point in time, ZSSC3281 additionally stores all appeared system diagnosis failures in a separate volatile fault memory. The fault memory has the same organization as the system Diagnosis Status Memory and becomes cleared only via ClearFaultMem (0xB9) command or a system reset. The fault memory can be read via RdFaultMem (0xB8) command.

Reading the fault memory or diagnosis status memory returns three words as shown in Table 39, Table 40, and Table 41. The complete fault memory or diagnosis status memory can be updated using the 0xB2 command.

Diagnoses detailed in Table 39 and Table 40 trigger the sensor fault bit within the status byte.

Similarly, diagnoses described in Table 41 set the saturation bit within the status byte.

The status byte is fully described in subsection 10.1.1.

Table 39: Fault Memory - Word 0 - Bits 31:0

Bits	Description	Bits	Description
31 : 25	Reserved	11	AFE2 sensor signal range check: INP2
24	AFE2 temperature sensor shorted connection check T3 to BOT shorted: $R < R_{T\_SHORT}$	10	AFE2 sensor leakage check: INN2 to VSS
23	AFE2 temperature sensor shorted connection check T3 to TOP shorted: $R < R_{T\_SHORT}$	9	AFE2 sensor leakage check: INP2 to VSS
22	AFE2 temperature sensor broken connection check T3 open: $R > R_{T\_OPEN}$	8	AFE2 sensor shorted connection check → INP2 – INN2 shorted: $R < R_{short}$
21	AFE2 temperature sensor shorted connection check T2 to BOT shorted: $R < R_{T\_SHORT}$	7	AFE2 sensor broken connection check → INP2 or INN2 open: $R > R_{broken}$
20	AFE2 temperature sensor shorted connection check T2 to TOP shorted: $R < R_{T\_SHORT}$	6	AFE1 sensor signal range check: INN1
19	AFE2 temperature sensor broken connection check T2 open: $R > R_{T\_OPEN}$	5	AFE1 sensor signal range check: INP1
18	AFE1 temperature sensor shorted connection check T1 to BOT shorted: $R < R_{T\_SHORT}$	4	AFE1 sensor leakage check: INN1 to VSS
17	AFE1 temperature sensor shorted connection check T1 to TOP shorted: $R < R_{T\_SHORT}$	3	AFE1 sensor leakage check: INP1 to VSS
16	AFE1 temperature sensor broken connection check T1 open: $R > R_{T\_OPEN}$	2	AFE1 sensor shorted connection check → INP1 – INN1 shorted: $R < R_{short}$
15 : 13	Reserved	1	AFE1 sensor broken connection check → INP1 or INN1 open: $R > R_{open}$
12	AFE2 sensor signal range check: INN2	0	Reserved

Table 40: Fault Memory - Word 1 - Bits 31:0

Bits	Description
31 : 4	Reserved
3	AFE2 Offset Drift
2	AFE2 Gain Drift
1	AFE1 Offset Drift
0	AFE1 Gain Drift

Table 41: Fault Memory - Word 2 - Bits 31:0

Bits	Description
31 : 6	Reserved
5	SSC calculation unit OR raw output data saturation channel 3, temperature sensor data
4	SSC calculation unit channel 3, bridge sensor data
3	SSC calculation unit OR raw output data saturation channel 2, temperature sensor data
2	SSC calculation unit OR raw output data saturation channel 2, bridge sensor data
1	SSC calculation unit OR raw output data saturation channel 1, temperature sensor data
0	SSC calculation unit OR raw output data saturation channel 1, bridge sensor data

## 8 Analog Output

The conditioned and post processed output data of one of the following channels can be made available as analog output signal at the Analog Output AOOUT

- Bridge Sensor Channel 1
- Bridge Sensor Channel 2
- Third Logic Channel
- Temperature Channel 1
- Temperature Channel 2
- Temperature Channel 3

Depending on the configuration of the Analog Output Driver, two different output modes, (absolute voltage output and current mode output) are supported.

### 8.1 Analog Output Driver

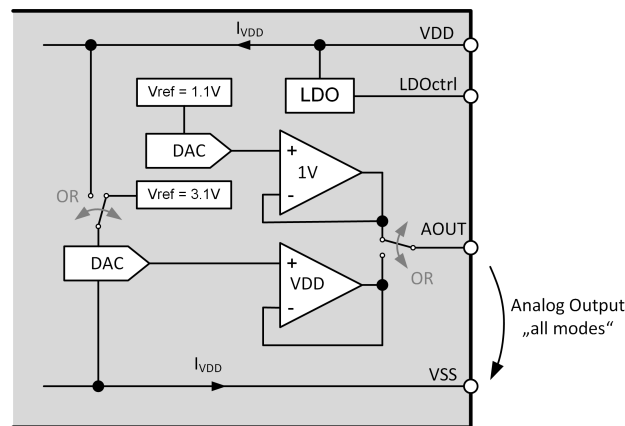


Figure 41: Block Schematic AOUT Driver

The Analog Output Driver contains two separate output buffers, one for a full-scale voltage of 1V and another one for full scale voltages ranging up to VDD. The following functional assignments apply:

- 1V buffer
  - 1V absolute Voltage Mode
  - 2-wire current loop mode
  - 3-wire current loop mode
- VDD buffer
  - Ratiometric Voltage Mode
  - 3V absolute Voltage Mode
  - 5V absolute Voltage Mode
  - 10V absolute Voltage Mode

The VDD buffer offers a programmable output current limiting function which is not available for the 1V buffer. The VDD buffer requires the VDD to be in the range between 2.7V and 5.5V for proper operation.

### 8.2 Negative Voltage Generation for AOOUT

To support True-0V signals on the Analog Output (AOOUT), ZSSC3281 provides an option to externally supply a negative voltage rail for the AOOUT buffer at VDDN. VDDN supply specifications are shown in Table 42. The external circuitry must ensure to not generate a VDDN voltage of less than -0.5V to prevent latchup conditions for the internal circuitry.

The negative VDDN voltage can also be generated by an internal charge pump circuit. The internal charge pump can be activated through GUI field: Configure\AOUT\VDDN Charge Pump. The field Configure\AOUT\VDDN Load allows to set a maximum current that the internal charge pump can supply.

The activation of the internal charge pump at VDDN considerably increases the power consumption of ZSSC3281 and needs to be carefully considered in applications where current consumption of the sensor device (sensor + ZSSC3281) is a critical parameter. The VDDN charge pump can only be used for  $VDD \geq 2.7V$ .

If no True-0V signals are required at AOUT, the user must disable the VDDN charge pump in the GUI and directly connect VDDN with VSS on PCB level.

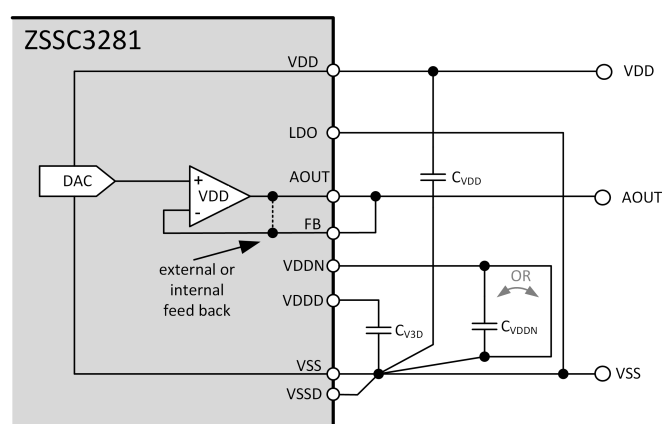
The charge pump function is only available for all AOUT Operation Modes with Voltage Output. The charge pump circuit requires an external buffer capacitor  $C_{VDDN}$  and a Schottky Diode to work properly.

**Table 42: Parameter Negative Voltage for AOUT**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$VDD_{CP}$	VDD operating range of internal charge pump		2.7		5.5	V
$VDDN$	Negative voltage supply for analog output (AOUT)	Internally generated, requires activation of VDDN charge pump		$V_{ExtSchottky}$		V
		Externally supplied	0	-0.3V	-0.5V	V
$I_{VDDN}$	Available charge pump load current	Programmable in 4 steps.			0.5	mA
					1	
					3	
					5	
$I_{VDD}$	Additional charge pump current consumption at VDD	0.5mA load current	0.5	4.5	5	mA
		1.0mA load current	1	9	10	
		3.0mA load current	3	15.5	17	
		5.0mA load current	5	25	30	
$C_{VDDN}$	Buffer capacitance at pin VDDN			1		$\mu F$
$V_{FW-Schottky}$	Forward voltage of external Schottky diode			0.3	0.5	V

## 8.3 Analog Output Configuration

### 8.3.1 Ratiometric Voltage Mode



**Figure 42: Ratiometric Output Mode Configuration at AOUT**

The SSC output can be ratiometric mapped to 0 to VDD range with the application circuit shown in Figure 42 and activation of the Ratiometric Voltage Mode in the GUI via Configure\AOUT\Operation Mode\Ratiometric Voltage. In Ratiometric Output Mode the reference voltage for the AOUT DAC is identical to the VDD level.

### 8.3.2 5V Absolute Voltage Mode

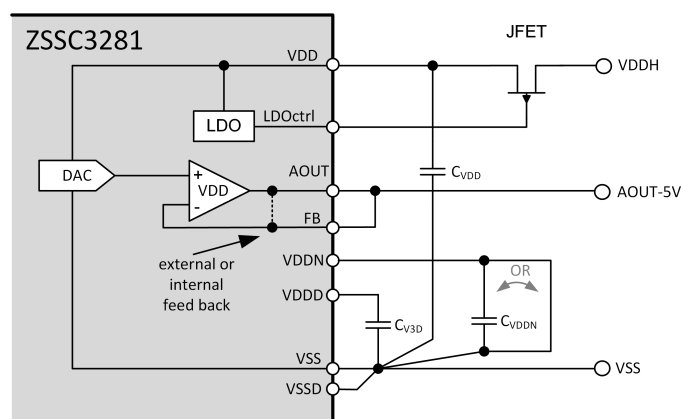


Figure 43: 5V Absolute Output Voltage Configuration at AOUT

The SSC output can be mapped to 0V to 5V voltage range with the application circuit shown in Figure 43 and activation of the 5V Absolute Voltage Mode in the GUI via Configure\AOUT\Operation Mode\Absolute Voltage 0V – 5V. This AOUT mode requires the external regulator supply configuration to be active in the GUI with the regulated VDD set to 5.25V.

The applied reference voltage for the AOUT DAC is directly derived from VDD through a digital factory calibration coefficient.

### 8.3.3 10V Absolute Voltage Mode

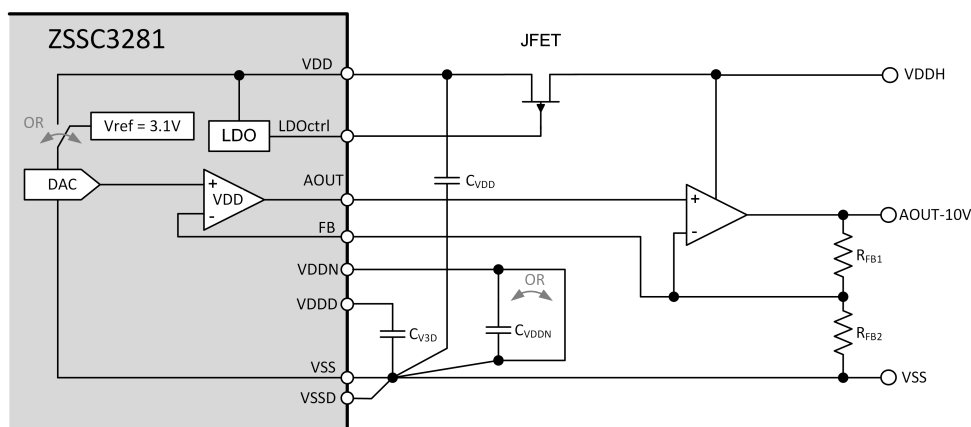


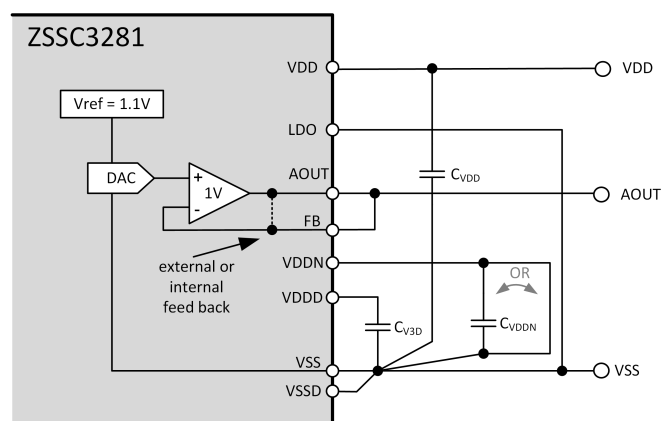
Figure 44: 10V Absolute Output Voltage Configuration at AOUT

The SSC output can be mapped to a 0V to 10V voltage range using the application circuit shown in Figure 44 and activating the 10V Absolute Voltage Mode in the GUI under Configure\AOUT\Operation Mode\Absolute Voltage 0V – 10V. For this mode, the DAC reference can be selected as either the internal 3.1V or VDD reference. When using the VDD reference, this AOUT mode requires the external regulator supply configuration to be active in the GUI, with the regulated VDD set to 5.25V.

The reference voltage applied to the AOUT DAC is directly derived from VDD through a digital factory calibration coefficient. To achieve a 0V to 10V output signal, the VDD or 3.1V absolute voltage output can be scaled to higher voltages using an external operational amplifier. For improved voltage accuracy, connect the Feedback Pin FB to the inverting input of the external operational amplifier that is offset compensated. The calculation for the external voltage amplification factor is as follows:

$$A = \frac{R_{FB1} + R_{FB2}}{R_{FB2}} \quad (26)$$

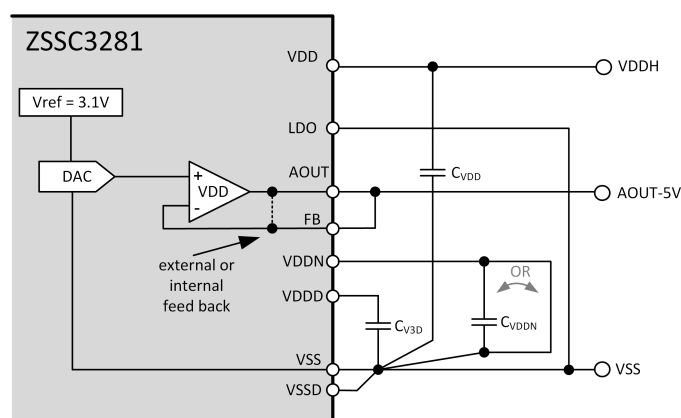
### 8.3.4 1V Absolute Voltage Mode



**Figure 45: 1V Absolute Output Voltage Configuration at AOUT**

The SSC output can be mapped to 0V to 1V voltage range with the application circuit shown in Figure 45 and activation of the 1V Absolute Voltage Mode in the GUI via Configure\AOUT\Operation Mode\Absolute Voltage 0V – 1V. The applied reference voltage for the AOUT DAC is generated from an internal factory calibrated bandgap source.

### 8.3.5 3V Absolute Voltage Mode



**Figure 46: 3V Absolute Output Voltage Configuration at AOUT**

The SSC output can be mapped to a 0V to 3V voltage range using the application circuit shown in Figure 46 and by activating the 3V Absolute Voltage Mode. The reference voltage applied to the AOUT DAC is sourced from an internal factory-calibrated bandgap.

## 8.3.6 2-Wire Current Loop Mode

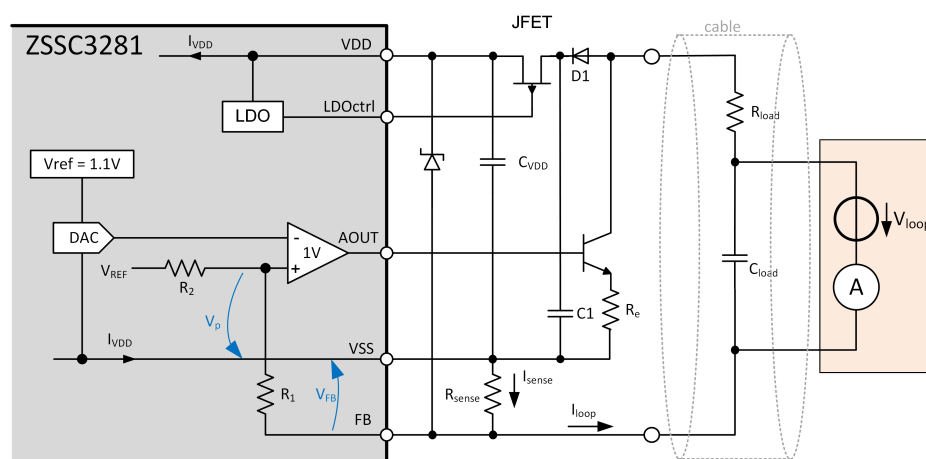


Figure 47: 2-Wire Current Loop Configuration at AOUT

Table 43: External Components in 2-Wire Current Loop Mode

Symbol	Parameter	Min	Typ	Max	Unit
$R_{sense}$	Feedback resistor		42		$\Omega$
$R_e$	Emitter resistor		150		$\Omega$
$T_1$	Bipolar Transistor	For example, BCX56-16			

The ZSSC3281 can be operated in two wire current loop configuration as shown in Figure 47. It requires the activation of 2-Wire Current Loop Mode in the GUI via Configure\AOUT\Operation Mode\2-Wire Current Loop. Because the signal current is typically expected to range from 4mA to 20mA on the 2-wire cable, the total operating current of the ZSSC3281 IC and the connected resistive bridges must stay below 4.0mA. To achieve this, the clock frequency of ZSSC3281 needs to be reduced to 1MHz, which impacts input to output signal latency and selectable AFE resolutions. 2-Wire Current Loop Mode also requires the activation of the external JFET pre-regulator. This, as well as the system clock frequency reduction are ensured by the GUI when 2-Wire Current Loop is selected at AOUT tab.

Besides production calibrated parameters of ZSSC3281, the value of the external resistor  $R_{sense}$  also determines the available min/max signal current range on the cable. To compensate for tolerances of  $R_{sense}$ , the GUI offers a post calibration option to calibrate the current loop current to the required absolute accuracy. The function recalculates the default CCP parameters 'CL2\_Offset' and 'CL2\_Delta' based on the entered  $R_{sense}$  (typical value), required and measured  $I_{min}$  and  $I_{max}$  values. To activate the optimized values, a Write Memory operation needs to be triggered by the user. 'CL2\_Offset' and 'CL2\_Delta' determine the swing of the AOUT voltage to cover the 4mA to 20mA current output signal.

The user can select the signal which shall be mapped to the 2-Wire Current Loop output via the drop-down menu Configure\AOUT\AOUT Pin Mapping.



## 8.3.7 3-Wire Current Loop Mode

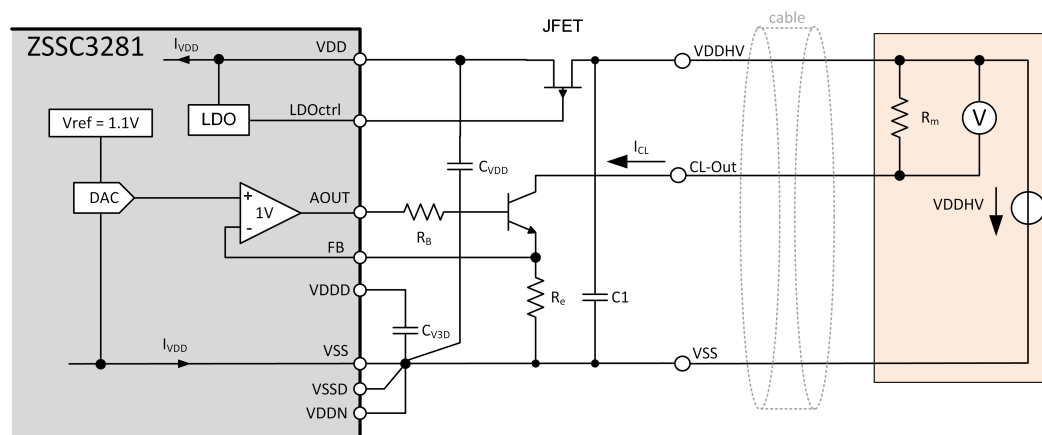


Figure 48: 3-wire NPN Current Loop Configuration at AOUT

Table 44: External Components in 3-Wire Current Loop Mode

Symbol	Parameter	Minimum	Typical	Maximum	Units
$R_e$	Emitter resistor		43		$\Omega$
$R_b$	Base resistor		4700		$\Omega$
$T_1$	Bipolar Transistor	for example BCX56-16			n.a.

The SSC output can be mapped to an input current at CL-Out in the application circuit shown in Figure 48 and by activation of the 3-Wire Current Loop Mode in the GUI via Configure\AOUT\Operation Mode\3-Wire Current Loop.

The signal current at CL-Out is typically required to range from 4mA to 20mA. The available min/max signal current range at CL-Out depends on the actual value of the external emitter resistor  $R_e$ .

To compensate for tolerances of  $R_e$ , the GUI offers a post calibration option to calibrate the current loop current to the required absolute accuracy. The function recalculates the default CCP parameters 'CL3\_Offset' and 'CL3\_Delta' based on the entered  $R_e$  (typical value), required and measured  $I_{min}$  and  $I_{max}$  values. To activate the optimized values, a Write Memory operation needs to be triggered by the user. 'CL3\_Offset' and 'CL3\_Delta' determine the swing of the AOUT voltage to cover the 4mA to 20mA current output signal.

The user can select the signal to map to the 3-Wire Current Loop output via the drop-down menu Configure\AOUT\AOUT Pin Mapping.

## 9 Digital Outputs/Output Modulation

The conditioned and post processed output data of two of the following channels can be made available as modulated digital output signal at the pins FOUT/PWM\_1 (GPIO1) and FOUT/PWM\_2 (GPIO7)

- Bridge Sensor Channel 1
- Bridge Sensor Channel 2
- Third Logic Channel
- Temperature Channel 1
- Temperature Channel 2
- Temperature Channel 3

The channel assignment to the output pins and the type of output modulation can be selected in the GUI via Configure\DOUT tab. There will be two types of output modulation supported:

- Frequency Modulation
- Pulse Width Modulation

### 9.1 Frequency Modulation

The minimum and maximum frequencies of the frequency modulation output can be configured via GUI on the Configure\DOUT tab. The frequency accuracy of the Frequency Modulation Output is determined by the frequency accuracy of the internal oscillator. Compensation mathematics for temperature drift of the oscillator is described in subsection 6.6.

**Table 45: FOUT Parameters**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
FOUT <sub>MIN</sub>	Minimum output frequency		100		255	Hz
FOUT <sub>MAX</sub>	Maximum output frequency		1000		10000	Hz
FOUT <sub>ERR</sub>	Frequency error	FOUT feature operated with non-compensated internal oscillator clock	-5%		5%	

### 9.2 Pulse Width Modulation

PWM can be enabled and configured via GUI on the Configure\DOUT tab. PWM base frequency can be adjusted according to Table 46.

**Table 46: PWM Parameters**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
PWM <sub>BaseFreq</sub>	PWM Base Frequency	Stepsize: 500Hz in range 0.5kHz to 15kHz	0.2	0.5	15	kHz

## 10 Digital Interfaces

### 10.1 Serial Interfaces

For sensor data read out, ZSSC3281 supports three digital interface protocols in slave mode operation:

- I2C/I3C
- SPI
- OWI (One-Wire-Interface)

Digital slave interfaces do not initiate data communication with the master system themselves but have to quickly react on arbitrary received read/write requests from the master.

To maintain short response times in continuous Cyclic Mode operation, ZSSC3281 is equipped with a dedicated DMA controller, which can read the content of the SSC Process Image (see subsection 6.3) without interaction of the ARM MCU.

The DMA controller supports one active digital interface at the time. After reset, the DMA controller activates and locks the serial interface for further communication that first received a valid telegram. A telegram is valid if:

- the address match was pass for I2C/I3C or OWI and the first 8-bit of telegram data were received
- the Slave Select (SS) was activated for SPI and first 8-bit of telegram data were received on MOSI

As soon as one of the three interfaces was locked by DMA controller, potential data streams from the other interfaces are blocked. A different interface can only be selected after reset of ZSSC3281.

#### 10.1.1 Command / Response Format

All three interfaces operate on the same command request and response format. The number of data bytes which need to follow the command byte in the command request or are returned after the Status Byte in command response, assuming the command execution was completed, is specific to the command code.

**Table 47: Command Request Format**

Command	Command Byte								Data Bytes
	7	6	5	4	3	2	1	0	
Valid Command	8-bit command								[Data Bytes]

**Table 48: I2C Command Response Format**

Command	Command Byte								Data Bytes
	7	6	5	4	3	2	1	0	
Previously received command in execution, response pending, New command not accepted, retry later	Telegram Error Flag	Power Supply OK	Busy Flag	1	SSC Mode 00: Command Mode 01: Cyclic Mode 10: Sleep Mode 11: Boot/Diagnosis Mode	Memory Error	Sensor Connection Fault	Saturation <sup>1</sup>	NONE
Command successfully processed				0					[Data Bytes]

<sup>1</sup> Cleared before each command execution except for 0x80 and 0x81 Read Output Memory commands, 0xA8 Start Sleep Mode command, and 0xA9 Start Command Mode.

A list of supported command codes, the number of command and response data bytes and the command function description can be found in subsection 10.5.

If a command is still processed by the ZSSC3281 when the response read starts, the BusyFlag of the Status Byte is set and no response data is returned. The response data stream only contains a repeated Status Byte until the transaction is ended. The BusyFlag within the Status Byte changes as soon as the command execution is completed.

### 10.1.2 Advanced Error Response

Beside the command and response format there is an option for an advanced error response. This option can be enabled in the GUI at the tab Configure\System Control and supports failure detection during communication with ZSSC3281.

If this feature is enabled, it will replace the Status Byte with an Error Response Byte in case that a command error as shown in Table 49 was detected. This Error Response Byte will be repeated continuously as long as the host requests data. By this replacement it can easily be detected if a command error was detected since the MSB of the error response byte is set. MSB is cleared in case of a normal Status Byte.

**Table 49: Command Response Format**

Command Status	Error Response Byte (MSB always set)	
	Error Code	Interpretation of Error Code
Command unknown in Cyclic Mode	0x80	Not Successful
Command failed or not known Command		
Command CRC Byte aborted/missing (if protocol CRC was enabled)	0x90	Incomplete Command CRC failed
Expected Data CRC Byte aborted/missing (only possible if protocol CRC was enabled)		Incomplete
Mandatory data aborted		
Command CRC failed (only possible if protocol CRC was enabled)	0x82	CRC Error
Data CRC failed (only possible if protocol CRC was enabled)		
Command not authorized	0xA0	Not Authorized
Mandatory data not in range	0xB0	Argument Error

## 10.2 I2C/I3C

ZSSC3281 supports I2C communication in StandardMode, FastMode, FastMode+, and it supports high speed communication in I3C Single Data Rate (SDR) Mode on I2C SCL and I2C SDA pins. The I2C/I3C interface is listening to receive a telegram after system startup or system reset as long as the SPI Slave Select (pin SPI SS) signal is not active.

I2C/I3C communication mode is selected and locked after I2C/I3C address match was pass and the first 8-bit of telegram data were received.

The interface settings, and a selection whether to use the traditional I2C or the advanced I3C communication mode, can be made in the GUI at the tab Configure\Serial Interfaces in section I2C/I3C.

I3C is an MIPI standard <https://www.mipi.org/specifications/i3c-sensor-specification> which is based on the traditional I2C protocol but extends the physical layer and the protocol layer towards higher communication speeds and improved management of the slave communication parameters by the I3C master. It allows In-Band Interrupts through which an I3C slave can signal an interrupt request to the I3C master via the SCL/SDA lines. Inband Interrupts are not supported by ZSSC3281.

**Table 50: I2C/I3C Interface Parameter**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
SlvAddr	I2C slave address	ZSSC3281 delivery default		0x3C		
	Static I3C address					
f <sub>SCL</sub>	Interface clock	I2C Mode	0.1		1.0	MHz
		I3C Mode	0.1		12.5	MHz
D <sub>I2C</sub>	Duty cycle		33	–	50	%

Timing and protocol details of the I2C communication in Standard Mode, Fast Mode, and Fast Mode+ are given in I2C-Bus Specification, Rev.6, UM10204. SCL Clock Stretching is not supported by ZSSC3281.

In I2C/I3C Mode, each Command Request follows the structure shown in Figure 49. Only the number of Data Bytes needed by the command must be sent.

## Command Request (I2C/I3C Write)

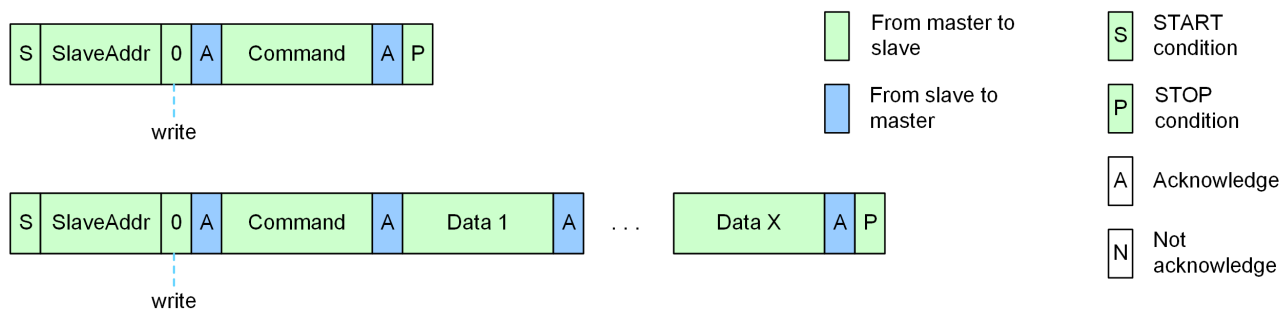


Figure 49: I2C/I3C Command Request

The different options for a response request are shown in Figure 50.

## Read Data (I2C/I3C Read)

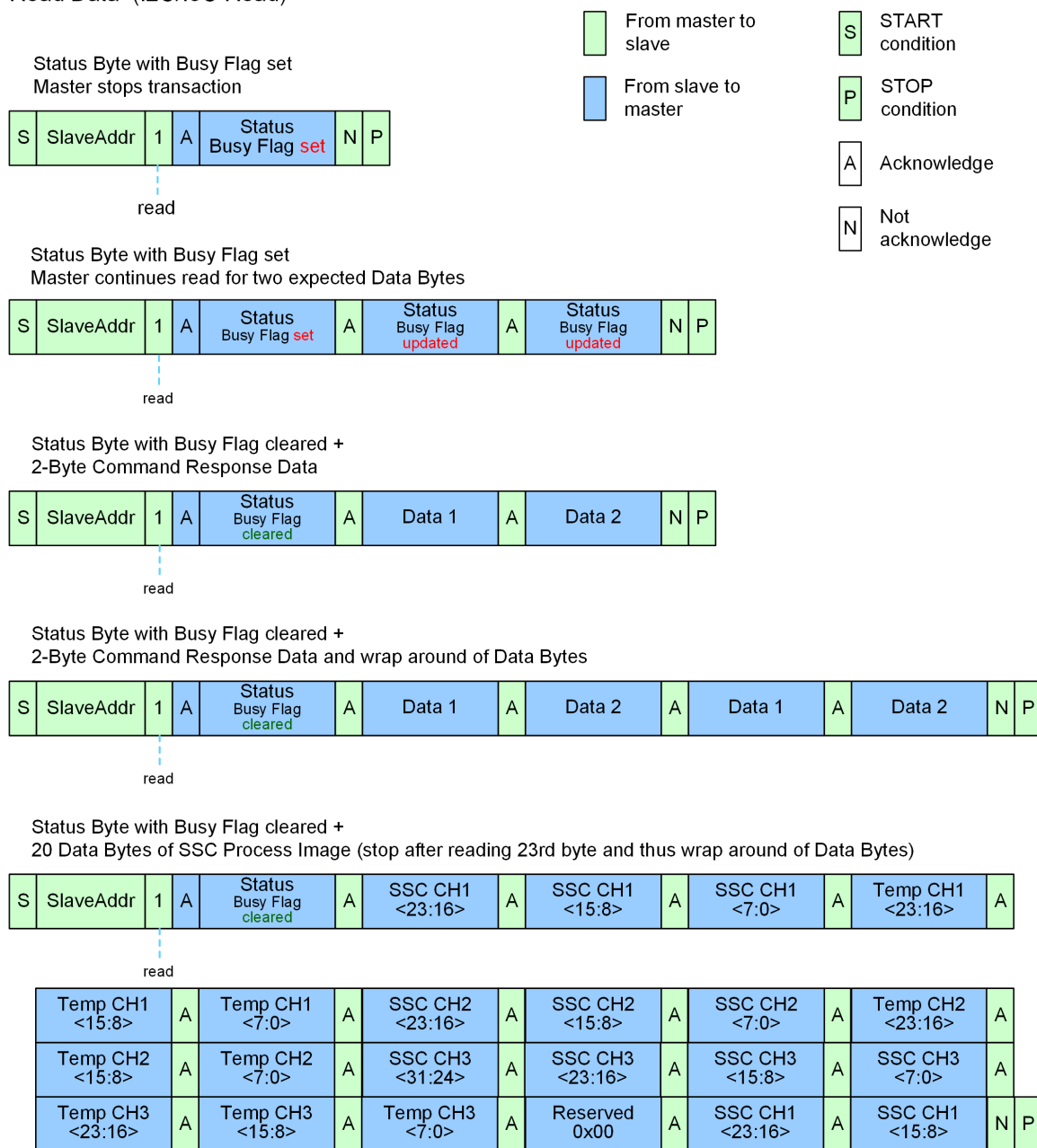


Figure 50: I2C/I3C Response Request

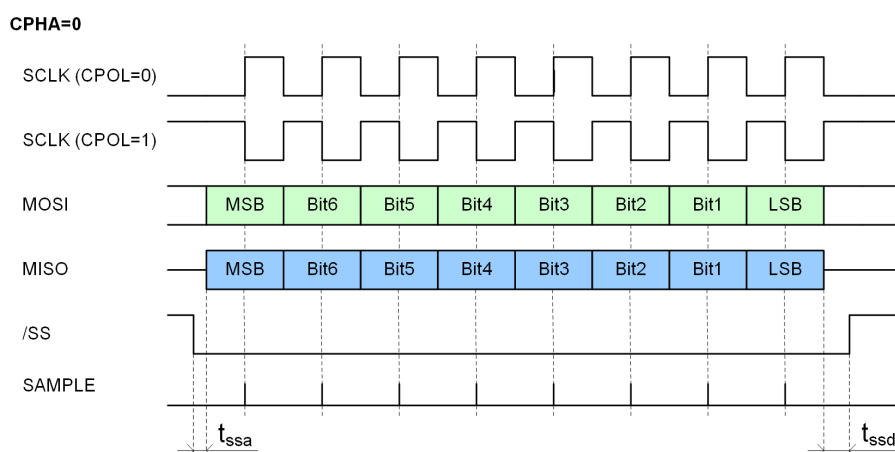
### 10.3 SPI

ZSSC3281 supports SPI communication on the SPI SCLK, SPI MOSI, and SPI MISO pins if the SPI slave select signal is active at the SPI SS pin and no other serial interface was locked yet after reset or power-on.

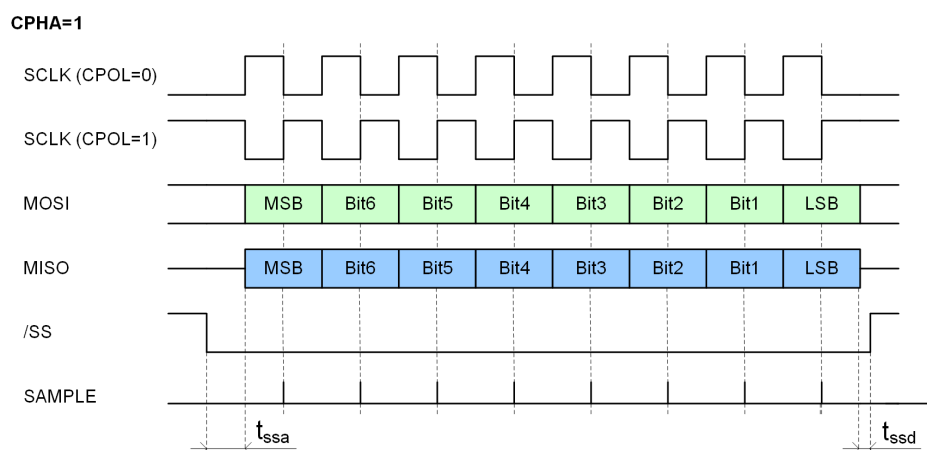
An active SPI SS signal connects the SPI SCLK and SPI MOSI pins to the SPI slave interface at the DMA controller and disconnects the I2C/I3C slave. As soon as the first 8-bit of data received on MOSI line, the SPI interface is locked as communication interface until the next reset or power-on of the ZSSC3281.

The polarity of the SPI slave select signal is active low by delivery default. It can be changed to active high at the Serial Interfaces tab of the GUI Configure\Serial Interfaces\SPI Slave Select Polarity. The polarity and the phase of the SPI clock can be changed via 'CPHA' and 'CPOL' selection fields at the same GUI tab.

The different combinations of polarity and phase are illustrated in Figure 51 and Figure 52. See Table Table 51 for the timing parameters.



**Figure 51: SPI Configuration CPHA=0**



**Figure 52: SPI Configuration CPHA=1**

Table 51: SPI Interface Parameter

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$f_{SCLK}$	Interface clock		0.05	1	12	MHz
$D_{SPI}$	Duty cycle		40	50	60	%
$SR_{SPI}$	Input rising and falling edge slew rate		0.26		1	V/ns
$t_{ssa}$	Delay time between SS-activation edge and first edge of SLCK, MOSI or MISO	"Typical" is for $f_{SCLK} \leq 3\text{MHz}$ operation	62.5			ns
$t_{ssd}$	Delay time between SS-deactivation edge and last edge of SLCK, MOSI or MISO			50		ns
$t_{ss}$	Delay between SS-deactivation edge of last command and of SS-activation edge for next command		10			$\mu\text{s}$

In SPI Mode, each command request follows the structure shown in Figure 54. Only the number of data bytes needed by the command must be sent.

A SPI transaction is started with activation of SPI SS and it is ended with deactivation of SPI SS. A new command request can only be sent at the start of a new transaction, which begins after SPI SS changed from inactive to active state.

#### Command Request

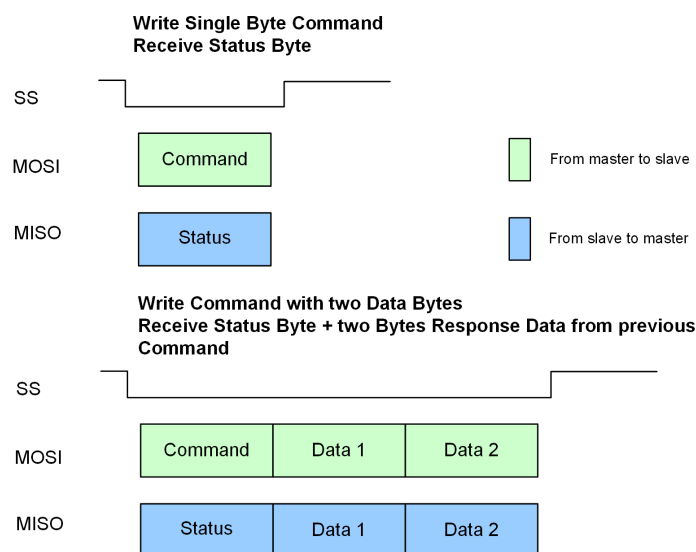
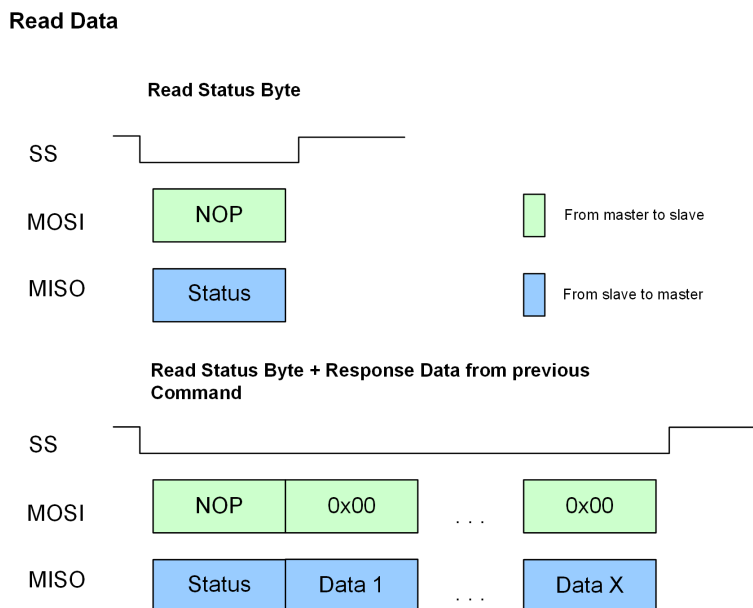


Figure 53: SPI Command Request

In contrast to the I2C/I3C interface the SPI interface supports full duplex communication. Hence, a new command request can already be sent on the MOSI line while response data from the previous command request is returned on the MISO line. According to Figure 53 and Figure 54 ZSSC3281 always responds with Status Byte, even at the very first reading.

If the response data from the previous call is read without triggering a new command request in parallel, the NOP command must be sent on the MOSI line in the first telegram byte of the transaction as shown in Figure 54.



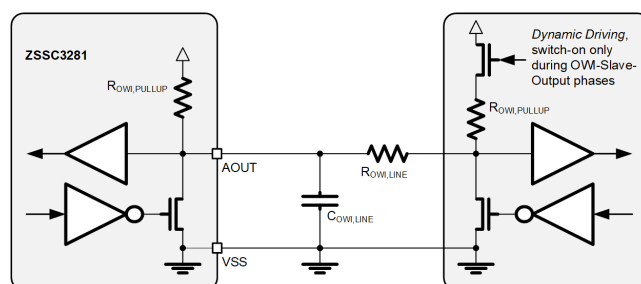
### Figure 54: SPI Read Data

## 10.4 One-Wire-Interface

ZSSC3281 employs a one-wire digital interface (OWI) concept. The communication principle of the OWI interface is derived from the I2C protocol.

An advantage of the OWI is that it enables “end of line” calibration, no additional pins are required to digitally calibrate a finished assembly sensor module. Although the OWI is integrated mainly for calibration, it can also be used to read out the calibrated sensor signal continuously or retrieve diagnostic detail information.

The OWI driver and the OWI receiver are usually connected both to the analog output signal pin AOUT. The mode switching at AOUT between Analog Output Mode and OWI Communication Mode is controlled via different selectable OWI operation modes that are described in subsubsection 10.4.1.



**Figure 55: General Block Schematic of the OWI Interface**

Some Analog Output configurations, like 2-Wire and 3-Wire Current Loop Mode and the 10V Absolute Voltage Mode require a second OWI input pin (OWI-IN2) because the external AOUT circuitry does not allow to drive a digital signal from an external OWI master into the AOUT pin. A respective application schematic is provided in subsection 13.3 and subsection 13.4.

The OWI protocol is defined as follows:

Idle state	During inactivity of the bus, the OWI line is pulled up to the supply voltage VDD by an external resistor.
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Start condition	When the OWI line is in idle mode, a low pulse with a minimum width of $t_{OWI,START} \geq 10\mu s$ and then a return to high indicates a start condition. Every request must be initiated by a start condition sent by a master. A master can generate a start condition only when the OWI line is in idle mode.
-----------------	---



Stop condition	A constant level at the OWI line (no transition from low to high or from high to low) for at least twice the period of the last transmitted valid bit indicates a stop condition. Without considering the last bit-time, a stop condition is generated with a constant level at the OWI line for at least 20ms. The master finishes a transmission by changing back to the high level (idle mode). Every command must be closed by a stop condition to start the processing of the command. The master must interrupt a sending slave after it has completed a data request by clamping the OWI line to the low level for generating a stop condition.
Valid data	Data is transmitted in bytes (8 bits) starting with the most significant bit (MSB). Transmitted bits are recognized after a start condition at every transition from low to high at the OWI line. The value of the transmitted bit depends on the duty ratio between the high phase and high/low period (bit period, $t_{OWI,BIT}$ in Table 53). A duty ratio greater than 1/8 and less than 3/8 is detected as 0; a duty ratio greater than 5/8 and less than 7/8 is detected as 1. The bit period of consecutive bits must not increase to more than 1.5 times the previous bit period or decrease to less than half of the previous bit period because a stop condition is detected in this case.
Write operation	During transmission from master to slave (WRITE), the address byte including a set data direction bit (0 for WRITE) is followed by a command byte and, depending on the transmitted command, by an optional number of data bytes. The internal ARM MCU evaluates the received command and processes the requested routine. Figure 56 illustrates the writing of a command with two data bytes and a command without data bytes.

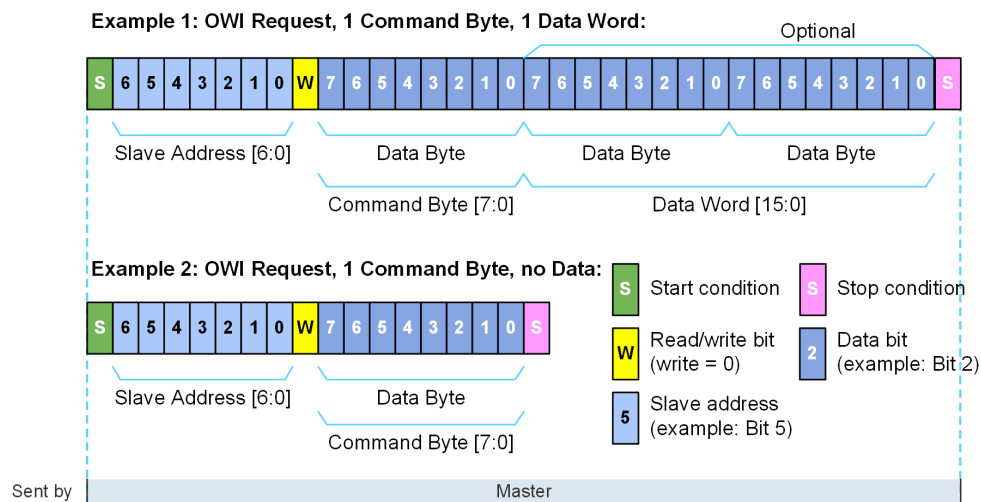


Figure 56: OWI Write Operation/Command Request

## Read operation

After a data read request from the master to the slave (matching address byte and data direction bit = 1 for READ), the slave answers by sending data from the interface output registers. The master must generate a stop condition after receiving the requested data (see Figure 57). The data in the output registers is sent continuously until a stop condition is detected. After transmitting all available data, the slave starts repeating the data. The data of an ongoing OWI transaction is fixed. It does not get updated with newly available conditioned results. To receive new output data a new OWI read transaction must be started.

## Example: OWI Read Operation, Status Byte (+n) Data Bytes\*:

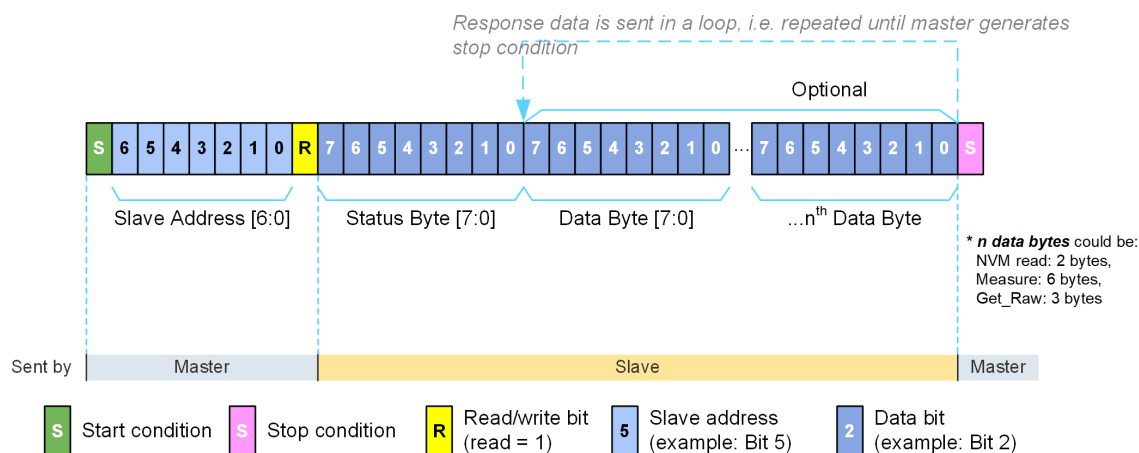


Figure 57: OWI Read Operation

The length of the OWI-line and the size of ROWI,PULL (if it is statically connected to AOUT), and consequently the resistive and capacitive loads, influence the maximum possible interface speed and minimum bit period. Additional capacitance on the OWI1 (AOUT) line can improve RF disturbance robustness und harsh EMC conditions. Table 52 shows practical OWI interface dimensioning examples and the resulting maximum signal frequencies (minimum possible bit periods).

The ZSSC3281's OWI interface properties and timing capabilities are given in Table 53.

Table 52: OWI Dimensioning Examples

		ROWI,PULL (+ ROWI,LOAD)				
		1.8 kΩ	2.5 kΩ	3.3 kΩ	5.5 kΩ	10.0 kΩ
COWI,LOAD	1nF	20μs	20μs	21μs	35μs	63μs
	10nF	113μs	157μs	207μs	345μs	628μs
	22nF	249μs	345μs	456μs	760μs	1381μs
	33nF	373μs	518μs	684μs	1140μs	2070μs
	44nF	497μs	691μs	912μs	1520μs	2762μs
	51nF	576μs	801μs	1057μs	1760μs	3205μs

<sup>1</sup> Examples are shown with statically connected ROWI,PULL, and with minimum bit period: tOWI,BIT.

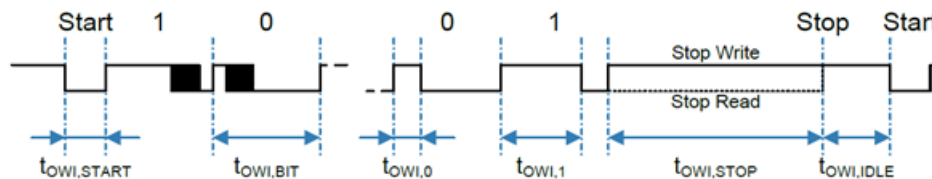


Figure 58: OWI Telegram

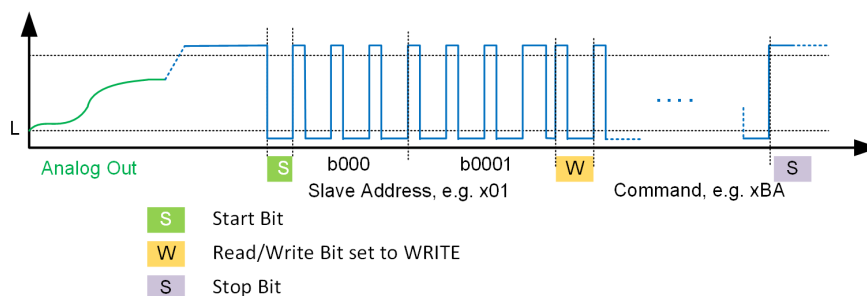


Figure 59: Typical OWI Communication on AOUT in Voltage Out Mode

Table 53: OWI Timing Parameters

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
$t_{OWI,WINDOW}$	OWI-Startup "Listening" Window	Time after power-on in which the OWI can be enabled by a valid OWI-Start-Condition and command				ms
		OWI Window Mode		400		
		OWI Analog Mode		200		
$t_{OWI,IDLE}$	Bus free time between start and stop condition		1	30		us
$t_{OWI,START}$	Hold time start condition		10			us
$t_{OWI,BIT}$	Bit time		10	40	4000	us
$t_{OWI,0}$	Duty ratio bit '0'		0.125	0.25	0.375	$t_{OWI,BIT}$
$t_{OWI,1}$	Duty ratio bit '1'		0.625	0.75	0.875	$t_{OWI,BIT}$
$t_{OWI,BIT\_DEV}$	Bit time deviation	Tolerated variation of Bit time from bit to bit	0.55	1.0	1.45	$t_{OWI,BIT}$
$t_{OWI,STOP}$	Hold time stop condition	$t_{OWI,BIT\_L}$ is the bit time of the last valid bit	1.5	2.5		$t_{OWI,BIT\_L}$
$C_{OWI,LOAD}$	Capacitive load at OWI line		–	2.2	50	nF
$R_{OWI,PULL}$	Pull-up resistance – master		0.3	0.47	3.3	k $\Omega$
$R_{OWI,LOAD}$	Resistive OWI line load		20	0.01 x $R_{OWI,PULL}$	–	$\Omega$

An enabled OWI interface is checked after power-on or reset of ZSSC3281 for incoming telegrams. The OWI interface is locked by DMA controller for further communication if it is the first which received a telegram with a matching slave address and at least 8bit of telegram data. The OWI communication mode can only be left by power-on or reset of the ZSSC3281.

### 10.4.1 OWI operation modes

The ZSSC3281 allows utilization of the OWI interface in different application configurations. The respective configuration settings can be made in the GUI via Configure\Serial Interfaces\OWI Mode.

OWI Disable/OWI Off	This mode deactivates the OWI interface. For example, this could be applied in cases when an analog-output smart sensor is configured and calibrated using the OWI interface and the OWI is not available for end user access after calibration and final setup/programming.
OWI Digital (no analog output)	In this mode AOUT does not provide any analog outputs and is only used as OWI pin. There is no startup window limitation for activation of the OWI interface, but if the ZSSC3281 was started in Command Mode or Sleep Mode and no OWI Startup (0xBA) command was received within a window time of 200ms, the system state machine automatically moves to Cyclic Mode.
OWI Window	<p>The OWI Window Mode is not intended to be used in end applications but useful to run with calibration line due to easier access to OWI communication. The OWI Window Mode disables the analog output signal driving at AOUT after power-on or reset of ZSSC3281 for a startup window time of <math>2 \times 200\text{ms}</math>. During the first 200ms window ZSSC3281 listens on OWI-IN1 (=AOUT) for incoming OWI telegrams. As soon as it receives an OWI Startup (0xBA) command on OWI-IN1 it locks the AOUT channel for OWI communication. The OWI channel can only be locked if the I2C/I3C and SPI channels remained silent and do not lock the interface first.</p> <p>If no OWI Startup command was received during the first 200ms startup window, a second 200ms window is started and ZSSC3281 listens on OWI-IN2 for incoming OWI telegrams. If it detects an OWI Startup (0xBA) command within the second 200ms startup window, it locks the OWI channel to the OWI-IN2 + AOUT communication path.</p> <p>If no OWI Startup command was received even during the second 200ms startup window, the OWI interface is disabled automatically and the AOUT resumes to its configured analog output function. OWI Window Mode is the factory default OWI mode for AOUT.</p>
OWI Analog Voltage	<p>The OWI Analog Voltage mode allows to start OWI communication even while the configured voltage output function is already active on AOUT. During a startup window of 200ms after power-on or reset ZSSC3281 listens on OWI-IN1 for incoming OWI telegrams. As soon as it receives an OWI Startup (0xBA) command on OWI-IN1 it locks the AOUT channel for OWI communication.</p> <p>The difference to the OWI Window Mode is, that the OWI master has to overdrive the analog output voltage signal at AOUT. To prevent self-locking of the OWI channel without external overdrive from the OWI master (for example, if the conditioned analog output waveform at AOUT matches an OWI telegram by accident), the OWI slave also checks for the occurrence of at least one overdrive drive condition at AOUT (either short to VSS or short to VDD) before it releases a received OWI telegram to the DMA Controller.</p> <p>If no OWI Startup command was received during the 200ms startup window, the OWI interface is disabled automatically and the AOUT remains in its configured analog output function. OWI activation is not possible until new power-on or reset of ZSSC3281.</p>

## 10.5 Command Interpreter

The availability of commands in Table 54 depends on the active main operating mode (Command or Cyclic Mode) and the current connection mode.

Some commands require an additional argument for successful command execution. If an argument error or missing argument appears, the current command is not executed and a failure is indicated in the extended error response.

Table 54: Command List

Command Code (Byte)	Return (after Status Byte)	Description	Command Available in		
			Command Mode	Cyclic Mode	Bootloader
0x80	20-byte SCC data	<b>Read output memory</b> Reads content of output memory which contains following information: <ul style="list-style-type: none"> <li>• Conditioned Bridge Sensor1 (24-bit)</li> <li>• Conditioned Temperature Channel1 (24-bit)</li> <li>• Conditioned Sensor2 (24-bit)</li> <li>• Conditioned Temperature Channel2 (24-bit)</li> <li>• Logic Bridge Sensor Channel3 (32-bit)</li> <li>• Conditioned Temperature Channel3 (24-bit)</li> <li>• Reserved byte (0x00) (8-bit)</li> </ul> <b>Note:</b> <ul style="list-style-type: none"> <li>• If more than 20 data bytes are read by the host, the response data rolls over.</li> <li>• In Command Mode or Sleep Mode the last valid output data is provided.</li> </ul>	Yes	Yes <sup>3</sup>	Yes
0x81 followed by data 0xXXYY	0xYY bytes	<b>Read output memory burst</b> Reads content of output memory in burst mode: <ul style="list-style-type: none"> <li>• 0xXX selects the byte in output memory which is read first</li> <li>• 0xYY defines the number of bytes which is read from output memory</li> </ul> <b>Note:</b> If more than 0xYY data bytes are read by the host, the response data rolls over. In Command Mode or Sleep Mode the last valid output data is provided.	Yes	Yes <sup>3</sup>	Yes
0x82 followed by 0xXX + 0xWW	0xWW × 4 bytes	<b>Read configuration data in burst</b> Reads content of Configuration and Calibration Page (CCP) in burst mode: <ul style="list-style-type: none"> <li>• 0xXX selects the 32-bit word in CCP which is read first</li> <li>• 0xWW defines the number of words which is read from output memory</li> </ul> <b>Note:</b> Maximum supported 0xWW is 0x20		Yes <sup>3</sup>	
0x83 followed by data 0xXXWW	–	<b>(Over-) Write configuration data in burst<sup>1</sup></b> Writes content of Configuration and Calibration Page (CCP) in burst mode into Shadow RAM: <ul style="list-style-type: none"> <li>• 0xXX selects the word in CCP which is written first</li> <li>• 0xWW defines the number of words which is written in output memory</li> </ul> <b>Note:</b> Maximum supported 0xWW is 0x20		Yes <sup>3</sup>	
0x84 followed by 0xXX + 0xWW	0xWW × 4 bytes	<b>Read device info data in burst</b> Reads device info data in burst mode : <ul style="list-style-type: none"> <li>• 0xXX selects the word in InfoPage which is read first</li> <li>• 0xWW defines the number of words which is read from output memory</li> </ul> <b>Note:</b> Maximum supported 0xXX is 0x1F <b>Note:</b> Maximum supported 0xWW is 0x20 <b>Note:</b> If 0xXX + 0xWW is > 0x20, the command fails.		Yes <sup>3</sup>	
0x88	–	<b>Copy CCP RAM shadow to flash</b> Programs Configuration and Calibration Page in flash with content from Shadow RAM		Yes <sup>3</sup>	
0x89	4 bytes (CCP version with PID)	<b>Read expected CCP Version</b>		Yes <sup>3</sup>	
0x8A	2 bytes	<b>Read chip revision</b> Returns 0x0001		Yes <sup>3</sup>	
0x8B	3 bytes (Bootloader Version)	<b>Read IAP Version</b> Returns 0x010000		Yes <sup>3</sup>	
0x8C	No answer is returned (Execution jumps directly to the FW update routines)	<b>Start firmware update</b> Triggers Firmware update procedure.		Yes <sup>3</sup>	
0x8D	n.a. (Device is immediately restarted)	<b>Restart the Device</b>		Yes <sup>3</sup>	

Continued on next page

Table 54: Command List (Continued)

Command Code (Byte)	Return (after Status Byte)	Description	Command Available in		
			Command Mode	Cyclic Mode	Bootloader
0x8E	3 bytes (APP Firmware Version)	<b>Read RCA Firmware Version</b> Returns 0x01040000D5B7DAC5		Yes <sup>3</sup>	
0xA2	3 bytes raw data	<b>Raw sensor measurement AFE1</b> <sup>2</sup> Returns unconditioned raw data of Bridge Sensor1	Yes	Yes <sup>3</sup>	
A0x3	3 bytes raw data	<b>Raw sensor measurement AFE2</b> <sup>2</sup> Returns unconditioned raw data of Bridge Sensor2	Yes	Yes <sup>3</sup>	
0xA4	3 bytes raw data	<b>Raw temperature measurement Sensor1</b> <sup>2</sup> Returns unconditioned temperature data for Temperature Channel 1	Yes	Yes <sup>3</sup>	
0xA5	3 bytes raw data	<b>Raw temperature measurement Sensor2</b> <sup>2</sup> Returns unconditioned temperature data for Temperature Channel 2	Yes	Yes <sup>3</sup>	
0xA7 followed by 0xXX + 0xYY	20 bytes (Raw data)	<b>Snapshot calibration all sensors</b> <sup>2</sup> Returns unconditioned raw sensor and temperature data of all AFE channels that are activated in CCP. Other auxiliary measurement tasks will be excluded within the execution of this command. <ul style="list-style-type: none"> <li>• 0xXX minimum average count for AFE1 data</li> <li>• 0xYY minimum average count for AFE2 data</li> </ul> 0xXX and 0xYY must be in range 1 to 32 (=0x20). "Minimum average count" defines the minimal amount of executed measurement task within one measurement cycle. Typically, those are single temperature or auto-zero measurement tasks. Thus, main measurements like SM+ and SM- might be executed more often. The output data format is as follows: <ul style="list-style-type: none"> <li>• Raw Data Bridge Sensor1 (24 bit)</li> <li>• Raw Data Temperature Channel1 (24 bit)</li> <li>• Raw Data Bridge Sensor2 (24 bit)</li> <li>• Raw Data Temperature Channel2 (24 bit)</li> <li>• 0x00000000 (4 bytes 0x0) (32 bit)</li> <li>• Raw Data Temperature Channel3 (24 bit)</li> <li>• 0x00 (1 byte 0x0) (8 bit)</li> </ul>	Yes	Yes <sup>3</sup>	
0xA8	–	<b>START_SLEEP</b> Exit Command Mode or Cyclic Mode and transition to Sleep Mode	Yes	Yes <sup>3</sup>	Yes
0xA9	–	<b>Start Command Mode</b> Exit Cyclic Mode and transition to Command Mode	Yes	Yes <sup>3</sup>	Yes
0xAA followed by data 0xXXYY	20 bytes SSC data (Fully corrected sensor measurement data plus corrected temperature data)	<b>Snapshot measurement all sensors</b> <sup>2</sup> Returns conditioned sensor and temperature data of all AFE channels that are activated in CCP. <ul style="list-style-type: none"> <li>• 0xXX minimum average count for AFE1 data</li> <li>• 0xYY minimum average count for AFE2 data</li> </ul> 0xXX and 0xYY must be in range 1 to 32 (=0x20). The output data format is as follows: <ul style="list-style-type: none"> <li>• Bridge Sensor1 (24-bit)</li> <li>• Temperature Channel1 (24-bit)</li> <li>• Bridge Sensor2 (24-bit)</li> <li>• Temperature Channel2 (24-bit)</li> <li>• Third Logic Channel Combination (4 bytes 0x0) (32-bit)</li> <li>• Temperature Channel3 (24-bit)</li> <li>• Reserved byte (0x00) (8-bit)</li> </ul>	Yes	Yes <sup>3</sup>	
0xAB	-	<b>Start Cyclic Mode</b> Enter Cyclic Mode based on configuration in Shadow RAM: continuous measurement cycles, SSC corrections, and automatic, continuous digital and/or analog output updates	Yes	Yes <sup>3</sup>	
0xB0	12 bytes diagnostic result data	<b>Read diagnosis status</b> Responds with the detailed diagnosis status (see subsection 7.2)	Yes	Yes <sup>3</sup>	

Continued on next page

Table 54: Command List (Continued)

Command Code (Byte)	Return (after Status Byte)	Description	Command Available in		
			Command Mode	Cyclic Mode	Bootloader
0xB1	–	<b>Reset diagnosis status</b> Resets the contents of the diagnosis status register to 0x00	Yes	Yes <sup>3</sup>	
0xB2 followed by data (0x0000 to 0xFFFF)	-	<b>Update diagnosis status</b> Executes all activated sensor and system diagnosis checks <b>Note:</b> If a measurement cycle is running concurrently, the diagnostic update happens after completion of the measurement cycle and SSC calculations.		Yes <sup>3</sup>	
0xB3 followed by data (0x0000 to 0xFFFF)	-	<b>Direct DAC Stimulus</b> Set the DAC output register with the data in the command and enable/output the respective analog signal through AOUT (according to the AOUT_setup) <b>Note:</b> The DAC output can be switched off by the RESN pin, POR, or a change in the main operating mode	Yes	Yes <sup>3</sup>	
0xB4 followed by 0x0X + 0xYY	2 bytes	<b>Self-diagnostic measure</b> for AFE1 and AFE2 Parameter 0x0X: • AFE1: 0x00 • AFE2: 0x01 • Parameter 0xYY See description in Table 38		Yes <sup>3</sup>	
0xB5 followed by 0xXX 0xYY 0xYY 0xYY	n.a.	<b>Direct linear stimulus of analog output path</b> Stimulates the output path, linear relation between input data and pin output. Parameter 0xXX - Output Selection: • 0: reserved • 1: AOUT • 2: reserved • 3: reserved Parameter 0xYYYYYY – Output Value: • 24bit data value for output, unsigned integer (as SSC value format) • assigned output is static (the output can be switched off by the RESN pin, POR, or a change in the main operating mode) <b>Note:</b> The following workflow for the given command must be ensured: • Start Command Mode (0xA9) • Set Direct linear stimulus of output path (0xB5) • Reset the device	Yes	Yes <sup>3</sup>	
0xB8	12 bytes (diagnostic result data)	<b>Read fault memory</b> Responds with the detailed fault-memory status (see subsection 7.2)		Yes <sup>3</sup>	
0xB9	n.a.	<b>Reset fault memory</b> Resets the contents of the fault memory to 0x0		Yes <sup>3</sup>	
0xBA	–	<b>Startup OWI</b> Initialization command to enter OWI interface operation; only valid for OWI (see subsubsection 10.4.1)		Yes <sup>3</sup>	Yes
0xFF	Status followed by last output buffer data	<b>NOP</b> Output of read results; only valid for SPI	Yes	Yes <sup>3</sup>	Yes

<sup>1</sup> The Overwrite CCP data command 0x83 can be used to optimize evaluation and test routine execution time for analog front-end setup or to configure measurement setups without changing the ZSSC3281's Flash content. Without adding command 0x88 the changes made by 0x83 command are lost after reset of ZSSC3281 reset via the RESN pin or Power On Reset.

<sup>2</sup> These commands can be used to conduct a measurement with or without SSC conditioning, e.g., during the smart sensor calibration procedure. No digital correction is performed on the measurement result except for the Snapshot measurement all sensors (0xAA) command. The setup and configuration for the raw measurement is the content in the shadow registers that can be pre-loaded (automatically loaded during power-on) from the Flash or by means of the Overwrite command 0x83.

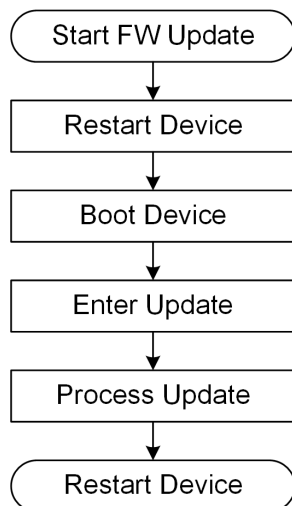
Use Oversample measurements to obtain noise-minimized measurement results in Sleep or Command Mode. With higher oversampling factors, the command execution time increases proportionally.

<sup>3</sup> Command is also available after entering Command Mode from Static Diagnostic Mode (SDM).

## 11 Firmware Update

ZSSC3281 offers a firmware update function via the serial I2C interface for Renesas provided code (RCA code).

Figure 60 shows the high-level firmware flow. Initiating the firmware update is done by a “start firmware update” command in command mode. This command stores a command sequence in a dedicated register and performs a reset of the device. Due to the required command sequence, the device starts to the update procedure during system boot and performs the firmware update.



**Figure 60: High-level Firmware Update Flow**

A firmware update is meant to be executed exclusively via the ZSSC3281 GUI. It can be initiated at the FW Update Tab, where the respective new firmware file can be selected, and the update process can be triggered.



## 12 Configuration and Calibration Page (CCP) Memory Map

This section describes the details and usage of single bitfields of CCP memory. The bitfields have two possible access attributes:

- **Reserved:** contains data that is set by Renesas and must not be changed from its default value.
- **Read/Write:** programmable with proper Read/Write access. By default all bitfields can be assumed as read and writeable. Thus an empty access information indicates an read and writeable bitfield.

### 12.1 Serial Interfaces

#### 12.1.1 0x00 – IfbParamCfg

Address : 0x00		Register Name : IfbParamCfg		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:5	Reserved	0x0		Reserved
4		0x0	BypassCmdInterp	Bypass of IFB Command Interpreter in Cyclic Mode 0x0 : Inactive 0x1 : Active
3	Reserved	0x0		Reserved
2		0x0	EnErrResp	Extended Error Response Mode in Serial Communication 0x0 : Inactive 0x1 : Active
1		0x0	EnCrc	CRC Checking of Serial Interface Communication 0x0 : Disabled 0x1 : Enabled

#### 12.1.2 0x01 – I3cslvRegCtrl

Address : 0x01		Register Name : I3cslvRegCtrl		Default: 0x000000C0
Bits	Access	Default	Field Name	Description
31:8	Reserved	0x0		Reserved
7		0x1	Model2c	Operation Mode of I2C/I3C Interface 0x0 : I3C Mode 0x1 : I2C Mode
6		0x1	Enable	I2C/I3C Interface Activation 0x0 : Disabled 0x1 : Enabled
5:4	Reserved	0x0		Reserved
3:0		0x0	Instanceld	I3C Instance ID 4bit hex value

#### 12.1.3 0x02 – I3cslvRegStatAddrCtrl

Address : 0x02		Register Name : I3cslvRegStatAddrCtrl		Default: 0x0000003C
Bits	Access	Default	Field Name	Description
31:17	Reserved	0x0		Reserved
16		0x0	PinSel	I2C Address Selection via Pins
15:7	Reserved	0x0		Reserved
6:0		0x3C	Addr	I2C/I3C Static Slave Address 7bit hex value

## 12.1.4 0x03 – I3cslvInBandIrqSupport

Address : 0x03		Register Name : I3cslvInBandIrqSupport		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:1	Reserved	0x0		Reserved
0		0x0	InBandIrq	I2C/I3C Inband Interrupt Support 0x0 : Disabled 0x1 : Enabled

## 12.1.5 0x04 – SpislvParamCfg

Address : 0x04		Register Name : SpislvParamCfg		Default: 0x00000001
Bits	Access	Default	Field Name	Description
31:4	Reserved	0x0		Reserved
3		0x0	SsPolar	SPI Slave Select Polarity 0x0 : Active Low 0x1 : Active High
2		0x0	ClockPolar	SPI Clock Polarity 0x0 : CPOL =0; Default Low 0x1 : CPOL=1; Default High
1		0x0	ClockPhase	ISPI Clock Phase 0x0 : CPHA=0 0x1 : CPHA=1
0		0x1	Enable	SPI Interface Activation 0x0 : Disabled 0x1 : Enabled

## 12.1.6 0x05 – OwislvCtrReg

Address : 0x05		Register Name : OwislvCtrReg		Default: 0x00000008
Bits	Access	Default	Field Name	Description
31:8	Reserved	0x0		Reserved
7		0x0	OutPolarBit	OWI-OUT Output Polarity 0x0 : Active Low 0x1 : Active High
6		0x0	In2PolarBit	OWI-IN2 Input Polarity 0x0 : Active Low 0x1 : Active High
5		0x0	In1PolarBit	OWI-IN1 Input Polarity 0x0 : Active Low 0x1 : Active High
4	Reserved	0x0		Reserved
3		0x1	SlvAddrEn	OWI Slave Address Checking 0x0 : Disabled 0x1 : Enabled
2		0x0	FammAddrEn	Family address enable
1		0x0	FixedLenEn	Apply fixed bit length as defined in register <b>OwislvFixedlenReg</b> for transmission instead of the bit length measured for the last received bit. 0x0 : Disabled 0x1 : Enabled

## 12.1.7 0x06 – OwislvSlvaddrReg

Address : 0x06		Register Name : OwislvSlvaddrReg		Default: 0x00000028
Bits	Access	Default	Field Name	Description
31:7	Reserved	0x0		Reserved
6:0		0x28	SlvAddr	OWI Static Slave Address 7bit hex value

## 12.1.8 0x07 – OwislVFixedlenReg

Address : 0x07		Register Name : OwislVFixedlenReg		Default: 0x00000140
Bits	Access	Default	Field Name	Description
31:16	Reserved	0x0		Reserved
15:0		0x140	FixedLen	Bit length of a single OWI bit in 8MHz clock cycles, relevant only if <b>OwislVCtrReg.FixedLenEn = 1</b> 16bit hex value

## 12.1.9 0x08 – OwiModeParam

Address : 0x08		Register Name : OwiModeParam		Default: 0x00000001
Bits	Access	Default	Field Name	Description
31:3	Reserved	0x0		Reserved
2:0		0x1	OwislVMode	OWI Slave Operation Mode 0x0 : Off 0x1 : Window 0x2 : Digital 0x3 : Analog5V 0x4 : Analog10V 0x5 : AnalogCL2 0x6 : AnalogCL3 <b>Note:</b> Window as operation mode is not intended to be used in end application.

## 12.1.10 0x09 – CntCommParam

Address : 0x09		Register Name : CntCommParam		Default: 0x0000000A
Bits	Access	Default	Field Name	Description
31:0		0xA	CntCommParam	Internal parameter of ZSSC3281 Firmware. <b>Must not be changed.</b>

## 12.1.11 0x0A – CommParamCrc

Address : 0x0A		Register Name : CommParamCrc		Default: 0x685AD4EB
Bits	Access	Default	Field Name	Description
31:0		0x685AD4EB	CommParamCrc	Internal parameter of ZSSC3281 Firmware. <b>Must not be changed.</b>

## 12.2 Clocks

## 12.2.1 0x0B – MiscctrlParamCfg.Clkout

Address : 0x0B		Register Name : MiscctrlParamCfg.Clkout		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:2	Reserved	0x0		Reserved
1:0		0x0	Clkoutmode	Clock Output Signal at CLK_OUT Pin (GPIO14) 0x0 : Inactive 0x1 : Internal High Speed Clock (16MHz) 0x2 : Internal Low Speed Clock (32kHz) 0x3 : Main System Clock depends on setting in Register <b>MiscctrlParamCfg.Divfclk</b>

## 12.2.2 0x0C – MiscctrlParamCfg.Divafeaout

Address : 0x0C		Register Name : MiscctrlParamCfg.Divafeaout		Default: 0x00000008
Bits	Access	Default	Field Name	Description
31:6	Reserved	0x0		Reserved
5		0x0	Afe2LowSpeedMode	AFE2 clock speed with respect to AFE1 0x0 : Normal (equal) Speed 0x1 : Quarter Speed
4:2		0x2	FreqDivClkAout	Clock Divider HighSpeedClock to AFE Clock 0x0 : div1 (16MHz AOUT clock) 0x1 : div2 (8MHz AOUT clock) 0x2 : div4 (4MHz AOUT clock) 0x3 : div8 (2MHz AOUT clock) 0x4 : div16 (1MHz AOUT clock)
1:0		0x0	FreqDivClkAfe	Clock Divider HighSpeedClock to AFE Clock 0x0 : div4 (4MHz AFE clock) 0x1 : div8 (2MHz AFE clock) 0x2 : div16 (1MHz AFE clock)

## 12.2.3 0x0D – MiscctrlParamCfg.Divfclk

Address : 0x0D		Register Name : MiscctrlParamCfg.Divfclk		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:3	Reserved	0x0		Reserved
2:0		0x0	Divfclk	Clock Divider HighSpeedClock to AFE Clock 0x0 : div1 (16MHz AOUT clock) 0x1 : div2 (8MHz AOUT clock) 0x2 : div4 (4MHz AOUT clock) 0x3 : div8 (2MHz AOUT clock) 0x4 : div16 (1MHz AOUT clock)

## 12.2.4 0x0E – SmuParamCfg.Anacfg

Address : 0x0E		Register Name : SmuParamCfg.Anacfg		Default: 0x00000108
Bits	Access	Default	Field Name	Description
31:9	Reserved	0x0		Reserved
8:4		0x10	ExtldoVolt	External JFET LDO Voltage if SmuParamCfg.Anacfg.ExtldoDisable set to enabled 0x02 : 3.00V 0x04 : 4.00V 0x08 : 5.00V 0x10 : 5.25V
3		0x1	PgLossDetect	Power-Ground Loss Activation 0x0 : Enabled 0x1 : Disabled
2:1	Reserved	0x0		Reserved
0		0x0	ExtldoDisable	External JFET LDO Activation 0x0 : Enabled 0x1 : Disabled

## 12.2.5 0x0F – SmuParamCfg.ExtClkCfg

Address : 0x0F		Register Name : SmuParamCfg.ExtClkCfg		Default: 0x00271030
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:8		0x2710	WaitTime	
7	Reserved	0x0		Reserved
6:4		0x3	StartupTime	
3	Reserved	0x0		Reserved
2		0x0	Type	External Clock Type 0x0 : Clock
1		0x0	EnExtclk	External Clock Input Activation 0x0 : Disabled

## 12.2.6 0x10 – AfeBaseCfgParam

Address : 0x10		Register Name : AfeBaseCfgParam		Default: 0x00000003
Bits	Access	Default	Field Name	Description
31:24		0x0	AfeSyncStatus	AFE1 / AFE2 Synchronization 0x0 : Asynchronous measurement 0x1 : Synchronized measurement
23:16		0x0	Afe2SmConfig	AFE2 Sequencer Configuration 0x0 : SM- and SM+ 0x1 : SM+ and AUX_AZ 0x2 : SM+ only 0x3 : No Main Sensor-Bridge Measurement
15:8		0x0	Afe1SmConfig	AFE1 Sequencer Configuration 0x0 : SM- and SM+ 0x1 : SM+ and AUX_AZ 0x2 : SM+ only 0x3 : No Main Sensor-Bridge Measurement
7:0		0x3	AfeActive	AFE Activation configuration 0x0 : None 0x1 : AFE1 only 0x2 : AFE2 only 0x3 : AFE1 and AFE2 0x7 : DualSpeed

## 12.2.7 0x11 – AfeBaseCfgParam.AfeDsCfg.Reg1

Address : 0x11		Register Name : AfeBaseCfgParam.AfeDsCfg.Reg1		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24		0x0	ConvCnt	Internal Dual Speed Mode parameter - Must not be changed.
23:0		0x0	Thresh1	Dual Speed Mode Threshold 1

## 12.2.8 0x12 – AfeBaseCfgParam.AfeDsCfg.Reg2

Address : 0x12		Register Name : AfeBaseCfgParam.AfeDsCfg.Reg2		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	Thresh2	Dual Speed Mode Threshold 2

## 12.3 Basic AFE Setup

### 12.3.1 0x13 – Bm1Cfg1

Address : 0x13		Register Name : Bm1Cfg1		Default: 0x04000655
Bits	Access	Default	Field Name	Description
31		0x0	BmType	Sensor Type 0x0 : Resistive Bridge 0x1 : Thermopile / Thermocouple
30	Reserved	0x0	BmTestDac	Reserved, must remain 0
29	Reserved	0x0	BmTest	Reserved, must remain 0
28:26		0x1	BmAdcMux	ADC Input MUX Setting 0x0 : ADC inputs shorted to AGND 0x1 : ADC input connected to PGA 0x2 : ADC input connected to input (Gain = 1, PGA bypassed)
25:22		0x0	BmBrdgRtl	Rtl resistor, applicable if BmBrdgType = 1 0x0 : Open    0x4 : 8000Ω    0x8 : 20000Ω 0x1 : 1333Ω    0x5 : 10000Ω    0x9 : 24000Ω 0x2 : 2000Ω    0x6 : 14000Ω    0xA : 28000Ω 0x3 : 4000Ω    0x7 : 18000Ω    0xB : 40000Ω
21:18		0x0	BmBrdgRth	Rth resistor, applicable if BmBrdgType = 1 0x0 : Open    0x4 : 8000Ω    0x8 : 20000Ω 0x1 : 1333Ω    0x5 : 10000Ω    0x9 : 24000Ω 0x2 : 2000Ω    0x6 : 14000Ω    0xA : 28000Ω 0x3 : 4000Ω    0x7 : 18000Ω    0xB : 40000Ω
17:16		0x0	BmSetTime	Bridge Settling Time before ADC conversion starts 0x0 : 20μs    0x1 : 40μs    0x2 : 60μs    0x3 : 80μs
15		0x0	BmBrdgType	Bridge Supply via TOPx, BOTx 0x0 : Voltage Source 0x1 : Resistor or Current Source
14:12		0x0	BmAdcShift	ADC Shift $V_{Shift} / V_{fs}$ 0x0 : 0    0x2 : 0.250    0x4 : 0.500    0x6 : 0.750 0x1 : 0.125    0x3 : 0.375    0x5 : 0.625    0x7 : 0.875
11:8		0x6	BmAdcReso	ADC Resolution 0x0 : 10 Bit    0x4 : 14 Bit    0x8 : 18 Bit    0xC : 22 Bit 0x1 : 11 Bit    0x5 : 15 Bit    0x9 : 19 Bit    0xD : 23 Bit 0x2 : 12 Bit    0x6 : 16 Bit    0xA : 20 Bit    0xE : 24 Bit 0x3 : 13 Bit    0x7 : 17 Bit    0xB : 21 Bit
7		0x0	BmPgaPolarity	PGA Polarity 0x0 : Positive 0x1 : Negative
6:4		0x5	BmPgaGain2	PGA2 Gain 0x0 : 1.1    0x2 : 1.3    0x4 : 1.5    0x6 : 1.7 0x1 : 1.2    0x3 : 1.4    0x5 : 1.6    0x7 : 1.8
3:0		0x5	BmPgaGain1	PGA1 Gain 0x0 : 1.2    0x3 : 5.97    0x6 : 29.6    0x9 : 76.6    0xC : 187 0x1 : 2    0x4 : 11.9    0x7 : 39.2    0xA : 112    0xD : 223 0x2 : 4    0x5 : 19.8    0x8 : 58.1    0xB : 143    0xE : 275

## 12.3.2 0x14 – Bm1Cfg2

Address : 0x14		Register Name : Bm1Cfg2		Default: 0x00000210	
Bits	Access	Default	Field Name	Description	
31:15	Reserved	0x0		Reserved	
14		0x0	BmSetPerm	Enables permanent bridge supply	
13:12		0x0	BmSetTimeMult	Bridge settling time multiplier	
11:10		0x0	BmBias	AFE Bias Current Setting 0x0 : normal operation 0x3 : reduced AFE bias current	
9		0x1	BmAdcEnShift	ADC Shift & Gain ×2 Enable, activates <b>BmAdcShift</b> setting 0x0 : ADC Gain ×1, ADC Shift disabled 0x3 : ADC Gain ×2, ADC Shift enabled	
8:5		0x0	BmBrdglBias	Sensor Supply Current, applicable if BmBrdgType = 1 0x0 : Open/Off    0x4 : 40μA    0x8 : 200μA 0x1 : 5μA        0x5 : 80μA    0x9 : 500μA 0x2 : 10μA       0x6 : 100μA 0x3 : 20μA       0x7 : 160μA	
4:0		0x10	BmPgaOffset	PGA Offset Shift 0x1 : -1.9mV    0x10 : 0mV 0x2 : -3.8mV    0x11 : 1.9mV 0x3 : -5.6mV    0x12 : 3.8mV 0x4 : -7.5mV    0x13 : 5.6mV 0x5 : -9.4mV    0x14 : 7.5mV 0x6 : -11.3mV   0x15 : 9.4mV 0x7 : -13.1mV   0x16 : 11.3mV 0x8 : -15.0mV   0x17 : 13.1mV 0x9 : -16.9mV   0x18 : 15.0mV 0xA : -18.8mV   0x19 : 16.9mV 0xB : -20.6mV   0x1A : 18.8mV 0xC : -22.5mV   0x1B : 20.6mV 0xD : -24.4mV   0x1C : 22.5mV 0xE : -26.2mV   0x1D : 24.4mV 0xF : -28.1mV   0x1E : 26.2mV 0x1F : 28.1mV	

## 12.3.3 0x15 – Bm2Cfg1

Address : 0x15		Register Name : Bm2Cfg1		Default: 0x04000656
Bits	Access	Default	Field Name	Description
31		0x0	BmType	Sensor Type 0x0 : Resistive Bridge 0x1 : Thermopile / Thermocouple
30	Reserved	0x0	BmTestDac	Reserved, must remain 0
29	Reserved	0x0	BmTest	Reserved, must remain 0
28:26		0x1	BmAdcMux	ADC Input MUX Setting 0x0 : ADC inputs shorted to AGND 0x1 : ADC input connected to PGA 0x2 : ADC input connected to input (Gain = 1, PGA bypassed)
25:22		0x0	BmBrdgRtl	Rtl resistor, applicable if BmBrdgType = 1 0x0 : Open    0x4 : 8000Ω    0x8 : 20000Ω 0x1 : 1333Ω    0x5 : 10000Ω    0x9 : 24000Ω 0x2 : 2000Ω    0x6 : 14000Ω    0xA : 28000Ω 0x3 : 4000Ω    0x7 : 18000Ω    0xB : 40000Ω
21:18		0x0	BmBrdgRth	Rth resistor, applicable if BmBrdgType = 1 0x0 : Open    0x4 : 8000Ω    0x8 : 20000Ω 0x1 : 1333Ω    0x5 : 10000Ω    0x9 : 24000Ω 0x2 : 2000Ω    0x6 : 14000Ω    0xA : 28000Ω 0x3 : 4000Ω    0x7 : 18000Ω    0xB : 40000Ω
17:16		0x0	BmSetTime	Bridge Settling Time before ADC conversion starts 0x0 : 20μs    0x1 : 40μs    0x2 : 60μs    0x3 : 80μs
15		0x0	BmBrdgType	Bridge Supply via TOPx, BOTx 0x0 : Voltage Source 0x1 : Resistor or Current Source
14:12		0x0	BmAdcShift	ADC Shift $V_{\text{Shift}} / V_{\text{fs}}$ 0x0 : 0    0x2 : 0.250    0x4 : 0.500    0x6 : 0.750 0x1 : 0.125    0x3 : 0.375    0x5 : 0.625    0x7 : 0.875
11:8		0x6	BmAdcReso	ADC Resolution 0x0 : 10 Bit    0x4 : 14 Bit    0x8 : 18 Bit    0xC : 22 Bit 0x1 : 11 Bit    0x5 : 15 Bit    0x9 : 19 Bit    0xD : 23 Bit 0x2 : 12 Bit    0x6 : 16 Bit    0xA : 20 Bit    0xE : 24 Bit 0x3 : 13 Bit    0x7 : 17 Bit    0xB : 21 Bit
7		0x0	BmPgaPolarity	PGA Polarity 0x0 : Positive 0x1 : Negative
6:4		0x5	BmPgaGain2	PGA2 Gain 0x0 : 1.1    0x2 : 1.3    0x4 : 1.5    0x6 : 1.7 0x1 : 1.2    0x3 : 1.4    0x5 : 1.6    0x7 : 1.8
3:0		0x6	BmPgaGain1	PGA1 Gain 0x0 : 1.2    0x3 : 5.97    0x6 : 29.6    0x9 : 76.6    0xC : 187 0x1 : 2    0x4 : 11.9    0x7 : 39.2    0xA : 112    0xD : 223 0x2 : 4    0x5 : 19.8    0x8 : 58.1    0xB : 143    0xE : 275



## 12.3.4 0x16 – Bm2Cfg2

Address : 0x16		Register Name : Bm2Cfg2		Default: 0x00000210	
Bits	Access	Default	Field Name	Description	
31:15	Reserved	0x0		Reserved	
14		0x0	BmSetPerm	Enables permanent bridge supply	
13:12		0x0	BmSetTimeMult	Bridge settling time multiplier	
11:10		0x0	BmBias	AFE Bias Current Setting 0x0 : normal operation 0x3 : reduced AFE bias current	
9		0x1	BmAdcEnShift	ADC Shift & Gain ×2 Enable, activates <b>BmAdcShift</b> setting 0x0 : ADC Gain ×1, ADC Shift disabled 0x3 : ADC Gain ×2, ADC Shift enabled	
8:5		0x0	BmBrdglBias	Sensor Supply Current, applicable if BmBrdgType = 1 0x0 : Open/Off    0x4 : 40μA    0x8 : 200μA 0x1 : 5μA        0x5 : 80μA     0x9 : 500μA 0x2 : 10μA       0x6 : 100μA 0x3 : 20μA       0x7 : 160μA	
4:0		0x10	BmPgaOffset	PGA Offset Shift 0x1 : -1.9mV    0x10 : 0mV 0x2 : -3.8mV    0x11 : 1.9mV 0x3 : -5.6mV    0x12 : 3.8mV 0x4 : -7.5mV    0x13 : 5.6mV 0x5 : -9.4mV    0x14 : 7.5mV 0x6 : -11.3mV   0x15 : 9.4mV 0x7 : -13.1mV   0x16 : 11.3mV 0x8 : -15.0mV   0x17 : 13.1mV 0x9 : -16.9mV   0x18 : 15.0mV 0xA : -18.8mV   0x19 : 16.9mV 0xB : -20.6mV   0x1A : 18.8mV 0xC : -22.5mV   0x1B : 20.6mV 0xD : -24.4mV   0x1C : 22.5mV 0xE : -26.2mV   0x1D : 24.4mV 0xF : -28.1mV   0x1E : 26.2mV 0x1F : 28.1mV	

## 12.4 External Temperature Sensor

### 12.4.1 0x17 – ExtTemp1Cfg1

Address : 0x17		Register Name : ExtTemp1Cfg1		Default: 0x0011C5F1				
Bits	Access	Default	Field Name	Description				
31:28	Reserved	0x0		Reserved				
27:24		0x0	ExtTempBrdgRtl	Rtl resistor, applicable if BmBrdgType = 1 0x0 : Open      0x4 : 8000Ω      0x8 : 20000Ω 0x1 : 1333Ω    0x5 : 10000Ω    0x9 : 24000Ω 0x2 : 2000Ω    0x6 : 14000Ω    0xA : 28000Ω 0x3 : 4000Ω    0x7 : 18000Ω    0xB : 40000Ω				
23:20		0x1	ExtTempBrdgRth	Rth resistor, applicable if BmBrdgType = 1 0x0 : Open      0x4 : 8000Ω      0x8 : 20000Ω 0x1 : 1333Ω    0x5 : 10000Ω    0x9 : 24000Ω 0x2 : 2000Ω    0x6 : 14000Ω    0xA : 28000Ω 0x3 : 4000Ω    0x7 : 18000Ω    0xB : 40000Ω				
19		0x0	ExtTempInput	External Temperature Sensor Input MUX 0x0 : Input connected to PGA 0x1 : Input connected to ADC				
18:15		0x3	ExtTempType	External Temperature Type 0x0 : Reserved 0x1 : Diode/NTC/PTC sink mode, internal bias 0x2 : Diode/NTC/PTC, external bias 0x3 : Diode/NTC/PTC source mode, internal bias 0x4 : Reserved 0x5 : Bridge single ended, internal bias 0x6 : Bridge single ended, external bias 0x7 : Bridge differential				
14:12		0x4	ExtTempAdcShift	ADC Shift $V_{Shift} / V_{fs}$ 0x0 : 0          0x2 : 0.250      0x4 : 0.500      0x6 : 0.750 0x1 : 0.125    0x3 : 0.375      0x5 : 0.625      0x7 : 0.875				
11:8		0x5	ExtTempAdcReso	ADC Resolution 0x0 : 10 Bit    0x2 : 12 Bit    0x4 : 14 Bit 0x1 : 11 Bit    0x3 : 13 Bit    0x5 : 15 Bit				
7		0x1	ExtTempPgaPolarity	PGA Polarity 0x0 : Positive 0x1 : Negative				
6:4		0x7	ExtTempPgaGain2	PGA2 Gain 0x0 : 1.1      0x2 : 1.3      0x4 : 1.5      0x6 : 1.7 0x1 : 1.2      0x3 : 1.4      0x5 : 1.6      0x7 : 1.8				
3:0		0x1	ExtTempPgaGain1	PGA1 Gain 0x0 : 1.2      0x3 : 5.97      0x6 : 29.6      0x9 : 76.6      0xC : 187 0x1 : 2        0x4 : 11.9      0x7 : 39.2      0xA : 112      0xD : 223 0x2 : 4        0x5 : 19.8      0x8 : 58.1      0xB : 143      0xE : 275				

## 12.4.2 0x18 – ExtTemp1Cfg2

Address : 0x18		Register Name : ExtTemp1Cfg2		Default: 0x00000210	
Bits	Access	Default	Field Name	Description	
31:14	Reserved	0x0		Reserved	
13:12		0x0	ExtTempSetTime	T1 Input Settling Time before ADC conversion starts 0x0 : 20μs   0x1 : 40μs   0x2 : 60μs   0x3 : 80μs	
11:10		0x0	ExtTempBias	AFE Bias Current Setting 0x0 : normal operation 0x3 : reduced AFE bias current	
9		0x1	ExtTempAdcEnShift	ADC Shift & Gain ×2 Enable, activates <b>BmAdcShift</b> setting 0x0 : ADC Gain ×1, ADC Shift disabled 0x3 : ADC Gain ×2, ADC Shift enabled	
8:5		0x0	ExtTempBrdglBias	Sensor Supply Current, applicable if BmBrdgType = 1 0x0 : Open/Off   0x4 : 40μA   0x8 : 200μA 0x1 : 5μA   0x5 : 80μA   0x9 : 500μA 0x2 : 10μA   0x6 : 100μA 0x3 : 20μA   0x7 : 160μA	
4:0		0x10	ExtTempPgaOffset	PGA Offset Shift 0x1 : -1.9mV   0x10 : 0mV 0x2 : -3.8mV   0x11 : 1.9mV 0x3 : -5.6mV   0x12 : 3.8mV 0x4 : -7.5mV   0x13 : 5.6mV 0x5 : -9.4mV   0x14 : 7.5mV 0x6 : -11.3mV   0x15 : 9.4mV 0x7 : -13.1mV   0x16 : 11.3mV 0x8 : -15.0mV   0x17 : 13.1mV 0x9 : -16.9mV   0x18 : 15.0mV 0xA : -18.8mV   0x19 : 16.9mV 0xB : -20.6mV   0x1A : 18.8mV 0xC : -22.5mV   0x1B : 20.6mV 0xD : -24.4mV   0x1C : 22.5mV 0xE : -26.2mV   0x1D : 24.4mV 0xF : -28.1mV   0x1E : 26.2mV 0x1F : 28.1mV	

## 12.4.3 0x19 – ExtTemp2Cfg1

Address : 0x19		Register Name :    ExtTemp2Cfg1		Default: 0x00118502					
Bits	Access	Default	Field Name	Description					
31:28	Reserved	0x0		Reserved					
27:24		0x0	ExtTempBrdgRtl	Rtl resistor, applicable if BmBrdgType = 1 0x0 : Open      0x4 : 8000Ω      0x8 : 20000Ω 0x1 : 1333Ω      0x5 : 10000Ω      0x9 : 24000Ω 0x2 : 2000Ω      0x6 : 14000Ω      0xA : 28000Ω 0x3 : 4000Ω      0x7 : 18000Ω      0xB : 40000Ω					
23:20		0x1	ExtTempBrdgRth	Rth resistor, applicable if BmBrdgType = 1 0x0 : Open      0x4 : 8000Ω      0x8 : 20000Ω 0x1 : 1333Ω      0x5 : 10000Ω      0x9 : 24000Ω 0x2 : 2000Ω      0x6 : 14000Ω      0xA : 28000Ω 0x3 : 4000Ω      0x7 : 18000Ω      0xB : 40000Ω					
19		0x0	ExtTempInput	External Temperature Sensor Input MUX 0x0 : Input connected to PGA 0x1 : Input connected to ADC					
18:15		0x3	ExtTempType	External Temperature Type 0x0 : Reserved 0x1 : Diode/NTC/PTC sink mode, internal bias 0x2 : Diode/NTC/PTC, external bias 0x3 : Diode/NTC/PTC source mode, internal bias 0x4 : Reserved 0x5 : Bridge single ended, internal bias 0x6 : Bridge single ended, external bias 0x7 : Bridge differential					
14:12		0x0	ExtTempAdcShift	ADC Shift $V_{Shift} / V_{fs}$ 0x0 : 0      0x2 : 0.250      0x4 : 0.500      0x6 : 0.750 0x1 : 0.125      0x3 : 0.375      0x5 : 0.625      0x7 : 0.875					
11:8		0x5	ExtTempAdcReso	ADC Resolution 0x0 : 10 Bit      0x2 : 12 Bit      0x4 : 14 Bit 0x1 : 11 Bit      0x3 : 13 Bit      0x5 : 15 Bit					
7		0x0	ExtTempPgaPolarity	PGA Polarity 0x0 : Positive 0x1 : Negative					
6:4		0x0	ExtTempPgaGain2	PGA2 Gain 0x0 : 1.1      0x2 : 1.3      0x4 : 1.5      0x6 : 1.7 0x1 : 1.2      0x3 : 1.4      0x5 : 1.6      0x7 : 1.8					
3:0		0x2	ExtTempPgaGain1	PGA1 Gain 0x0 : 1.2      0x3 : 5.97      0x6 : 29.6      0x9 : 76.6      0xC : 187 0x1 : 2      0x4 : 11.9      0x7 : 39.2      0xA : 112      0xD : 223 0x2 : 4      0x5 : 19.8      0x8 : 58.1      0xB : 143      0xE : 275					

## 12.4.4 0x1A – ExtTemp2Cfg2

Address : 0x1A		Register Name : ExtTemp2Cfg2		Default: 0x00000010	
Bits	Access	Default	Field Name	Description	
31:14	Reserved	0x0		Reserved	
13:12		0x0	ExtTempSetTime	T1 Input Settling Time before ADC conversion starts 0x0 : 20μs   0x1 : 40μs   0x2 : 60μs   0x3 : 80μs	
11:10		0x0	ExtTempBias	AFE Bias Current Setting 0x0 : normal operation 0x3 : reduced AFE bias current	
9		0x0	ExtTempAdcEnShift	ADC Shift & Gain ×2 Enable, activates <b>BmAdcShift</b> setting 0x0 : ADC Gain ×1, ADC Shift disabled 0x3 : ADC Gain ×2, ADC Shift enabled	
8:5		0x0	ExtTempBrdglBias	Sensor Supply Current, applicable if BmBrdgType = 1 0x0 : Open/Off   0x4 : 40μA   0x8 : 200μA 0x1 : 5μA   0x5 : 80μA   0x9 : 500μA 0x2 : 10μA   0x6 : 100μA 0x3 : 20μA   0x7 : 160μA	
4:0		0x10	ExtTempPgaOffset	PGA Offset Shift 0x1 : -1.9mV   0x10 : 0mV 0x2 : -3.8mV   0x11 : 1.9mV 0x3 : -5.6mV   0x12 : 3.8mV 0x4 : -7.5mV   0x13 : 5.6mV 0x5 : -9.4mV   0x14 : 7.5mV 0x6 : -11.3mV   0x15 : 9.4mV 0x7 : -13.1mV   0x16 : 11.3mV 0x8 : -15.0mV   0x17 : 13.1mV 0x9 : -16.9mV   0x18 : 15.0mV 0xA : -18.8mV   0x19 : 16.9mV 0xB : -20.6mV   0x1A : 18.8mV 0xC : -22.5mV   0x1B : 20.6mV 0xD : -24.4mV   0x1C : 22.5mV 0xE : -26.2mV   0x1D : 24.4mV 0xF : -28.1mV   0x1E : 26.2mV 0x1F : 28.1mV	

## 12.4.5 0x1B – ExtTemp3Cfg1

Address : 0x1B		Register Name : ExtTemp3Cfg1		Default: 0x00118502					
Bits	Access	Default	Field Name	Description					
31:28	Reserved	0x0		Reserved					
27:24		0x0	ExtTempBrdgRtl	Rtl resistor, applicable if BmBrdgType = 1 0x0 : Open      0x4 : 8000Ω      0x8 : 20000Ω 0x1 : 1333Ω      0x5 : 10000Ω      0x9 : 24000Ω 0x2 : 2000Ω      0x6 : 14000Ω      0xA : 28000Ω 0x3 : 4000Ω      0x7 : 18000Ω      0xB : 40000Ω					
23:20		0x1	ExtTempBrdgRth	Rth resistor, applicable if BmBrdgType = 1 0x0 : Open      0x4 : 8000Ω      0x8 : 20000Ω 0x1 : 1333Ω      0x5 : 10000Ω      0x9 : 24000Ω 0x2 : 2000Ω      0x6 : 14000Ω      0xA : 28000Ω 0x3 : 4000Ω      0x7 : 18000Ω      0xB : 40000Ω					
19		0x0	ExtTempInput	External Temperature Sensor Input MUX 0x0 : Input connected to PGA 0x1 : Input connected to ADC					
18:15		0x3	ExtTempType	External Temperature Type 0x0 : Reserved 0x1 : Diode/NTC/PTC sink mode, internal bias 0x2 : Diode/NTC/PTC, external bias 0x3 : Diode/NTC/PTC source mode, internal bias 0x4 : Reserved 0x5 : Bridge single ended, internal bias 0x6 : Bridge single ended, external bias 0x7 : Bridge differential					
14:12		0x0	ExtTempAdcShift	ADC Shift $V_{Shift} / V_{fs}$ 0x0 : 0      0x2 : 0.250      0x4 : 0.500      0x6 : 0.750 0x1 : 0.125      0x3 : 0.375      0x5 : 0.625      0x7 : 0.875					
11:8		0x5	ExtTempAdcReso	ADC Resolution 0x0 : 10 Bit      0x2 : 12 Bit      0x4 : 14 Bit 0x1 : 11 Bit      0x3 : 13 Bit      0x5 : 15 Bit					
7		0x0	ExtTempPgaPolarity	PGA Polarity 0x0 : Positive 0x1 : Negative					
6:4		0x0	ExtTempPgaGain2	PGA2 Gain 0x0 : 1.1      0x2 : 1.3      0x4 : 1.5      0x6 : 1.7 0x1 : 1.2      0x3 : 1.4      0x5 : 1.6      0x7 : 1.8					
3:0		0x2	ExtTempPgaGain1	PGA1 Gain 0x0 : 1.2      0x3 : 5.97      0x6 : 29.6      0x9 : 76.6      0xC : 187 0x1 : 2      0x4 : 11.9      0x7 : 39.2      0xA : 112      0xD : 223 0x2 : 4      0x5 : 19.8      0x8 : 58.1      0xB : 143      0xE : 275					

## 12.4.6 0x1C – ExtTemp3Cfg2

Address : 0x1C		Register Name : ExtTemp3Cfg2		Default: 0x00000010	
Bits	Access	Default	Field Name	Description	
31:14	Reserved	0x0		Reserved	
13:12		0x0	ExtTempSetTime	T1 Input Settling Time before ADC conversion starts 0x0 : 20μs   0x1 : 40μs   0x2 : 60μs   0x3 : 80μs	
11:10		0x0	ExtTempBias	AFE Bias Current Setting 0x0 : normal operation 0x3 : reduced AFE bias current	
9		0x0	ExtTempAdcEnShift	ADC Shift & Gain ×2 Enable, activates <b>BmAdcShift</b> setting 0x0 : ADC Gain ×1, ADC Shift disabled 0x3 : ADC Gain ×2, ADC Shift enabled	
8:5		0x0	ExtTempBrdglBias	Sensor Supply Current, applicable if BmBrdgType = 1 0x0 : Open/Off   0x4 : 40μA   0x8 : 200μA 0x1 : 5μA   0x5 : 80μA   0x9 : 500μA 0x2 : 10μA   0x6 : 100μA 0x3 : 20μA   0x7 : 160μA	
4:0		0x10	ExtTempPgaOffset	PGA Offset Shift 0x1 : -1.9mV   0x10 : 0mV 0x2 : -3.8mV   0x11 : 1.9mV 0x3 : -5.6mV   0x12 : 3.8mV 0x4 : -7.5mV   0x13 : 5.6mV 0x5 : -9.4mV   0x14 : 7.5mV 0x6 : -11.3mV   0x15 : 9.4mV 0x7 : -13.1mV   0x16 : 11.3mV 0x8 : -15.0mV   0x17 : 13.1mV 0x9 : -16.9mV   0x18 : 15.0mV 0xA : -18.8mV   0x19 : 16.9mV 0xB : -20.6mV   0x1A : 18.8mV 0xC : -22.5mV   0x1B : 20.6mV 0xD : -24.4mV   0x1C : 22.5mV 0xE : -26.2mV   0x1D : 24.4mV 0xF : -28.1mV   0x1E : 26.2mV 0x1F : 28.1mV	

## 12.4.7 0x1D – AfeRegsAna.CmConfig[0]

Address : 0x1D		Register Name : AfeRegsAna.CmConfig[0]		Default: 0x00000000	
Bits	Access	Default	Field Name	Description	
31:0		0x0	CmConfig[0]		

## 12.4.8 0x1E – AfeRegsAna.CmConfig[1]

Address : 0x1E		Register Name : AfeRegsAna.CmConfig[1]		Default: 0x00000000	
Bits	Access	Default	Field Name	Description	
31:0		0x0	CmConfig[1]		

## 12.4.9 0x1F – AfeRegsAna.CmConfig[2]

Address : 0x1F		Register Name : AfeRegsAna.CmConfig[2]		Default: 0x00000000	
Bits	Access	Default	Field Name	Description	
31:0		0x0	CmConfig[2]		

## 12.5 PTAT Sensor

### 12.5.1 0x20 – PtatCfg1

Address : 0x20		Register Name : PtatCfg1		Default: 0x0000F533				
Bits	Access	Default	Field Name	Description				
31:18	Reserved	0x0		Reserved				
17:15		0x1	AdcMux	ADC Input MUX Setting 0x1 : ADC input connected to PGA <sup>1</sup>				
14:12		0x7	AdcShift	ADC Shift V <sub>Shift</sub> / V <sub>fs</sub> 0x0 : 0      0x2 : 0.250      0x4 : 0.500      0x6 : 0.750 0x1 : 0.125      0x3 : 0.375      0x5 : 0.625      0x7 : 0.875 <sup>1</sup>				
11:8		0x5	AdcReso	ADC Resolution 0x0 : 10 Bit      0x2 : 12 Bit      0x4 : 14 Bit 0x1 : 11 Bit      0x3 : 13 Bit      0x5 : 15 Bit				
7		0x0	PgaPolarity	PGA Polarity 0x0 : Positive <sup>1</sup> 0x1 : Negative				
6:4		0x3	PgaGain2	PGA2 Gain 0x0 : 1.1      0x2 : 1.3      0x4 : 1.5      0x6 : 1.7 0x1 : 1.2      0x3 : 1.4 <sup>1</sup> 0x5 : 1.6      0x7 : 1.8				
3:0		0x3	PgaGain1	PGA1 Gain 0x0 : 1.2      0x3 : 5.97 <sup>1</sup> 0x6 : 29.6      0x9 : 76.6      0xC : 187 0x1 : 2      0x4 : 11.9      0x7 : 39.2      0xA : 112      0xD : 223 0x2 : 4      0x5 : 19.8      0x8 : 58.1      0xB : 143      0xE : 275				

<sup>1</sup> Renesas recommended

### 12.5.2 0x21 – PtatCfg2

Address : 0x21		Register Name : PtatCfg2		Default: 0x00000030	
Bits	Access	Default	Field Name	Description	
31:8	Reserved	0x0		Reserved	
7:6		0x0	Bias	AFE Bias Current Setting 0x0 : normal operation 0x3 : reduced AFE bias current	
5		0x1	AdcEnShift	ADC Shift & Gain ×2 Enable, activates <b>AdcShift</b> setting 0x0 : ADC Gain ×1, ADC Shift disabled 0x3 : ADC Gain ×2, ADC Shift enabled <sup>1</sup>	
4:0		0x10	PgaOffset	PGA Offset Shift  0x1 : -1.9mV      0x10 : 0mV <sup>1</sup> 0x2 : -3.8mV      0x11 : 1.9mV 0x3 : -5.6mV      0x12 : 3.8mV 0x4 : -7.5mV      0x13 : 5.6mV 0x5 : -9.4mV      0x14 : 7.5mV 0x6 : -11.3mV      0x15 : 9.4mV 0x7 : -13.1mV      0x16 : 11.3mV 0x8 : -15.0mV      0x17 : 13.1mV 0x9 : -16.9mV      0x18 : 15.0mV 0xA : -18.8mV      0x19 : 16.9mV 0xB : -20.6mV      0x1A : 18.8mV 0xC : -22.5mV      0x1B : 20.6mV 0xD : -24.4mV      0x1C : 22.5mV 0xE : -26.2mV      0x1D : 24.4mV 0xF : -28.1mV      0x1E : 26.2mV 0x1F : 28.1mV	

<sup>1</sup> Renesas recommended



## 12.6 AFE Sequencer

### 12.6.1 0x22 – Afe1MeasCfg1

Wrong setting of this parameter can corrupt firmware execution. Leave the computation of necessary setup for this register to the GUI.

Address : 0x22		Register Name : Afe1MeasCfg1		Default: 0x01020036
Bits	Access	Default	Field Name	Description
31		0x0	BurstModeSlot8	AFE DMA Burst Mode Data Transfer after Slot_x 0x0 : Disabled 0x1 : Enabled
30		0x0	BurstModeSlot7	
29		0x0	BurstModeSlot6	
28		0x0	BurstModeSlot5	
27		0x0	BurstModeSlot4	
26		0x0	BurstModeSlot3	
25		0x0	BurstModeSlot2	
24		0x1	BurstModeSlot1	
23		0x0	EocIrqSlot8	End of Conversion Interrupt after Slot_x 0x0 : Disabled 0x1 : Enabled
22		0x0	EocIrqSlot7	
21		0x0	EocIrqSlot6	
20		0x0	EocIrqSlot5	
19		0x0	EocIrqSlot4	
18		0x0	EocIrqSlot3	
17		0x1	EocIrqSlot2	
16		0x0	EocIrqSlot1	
15:14		0x0	MeasTypeSlot8	AFE Measurement Type for Slot_x 0x0 : None 0x1 : SM- 0x2 : SM+ 0x3 : AUX_i
13:12		0x0	MeasTypeSlot7	
11:10		0x0	MeasTypeSlot6	
9:8		0x0	MeasTypeSlot5	
7:6		0x0	MeasTypeSlot4	
5:4		0x3	MeasTypeSlot3	
3:2		0x1	MeasTypeSlot2	
1:0		0x2	MeasTypeSlot1	

## 12.6.2 0x23 – Afe1MeasCfg2

Wrong setting of this parameter can corrupt firmware execution. Leave the computation of necessary setup for this register to the GUI.

Address : 0x23		Register Name : Afe1MeasCfg2		Default: 0x00000013
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:8		0x0	AuxMaxTime	Maximum lenght of AUX_i measurement slots within a sequence 0x0000 ... 0xFFFF AFE clock cycles The parameter is calculated based on the relevant timing setups of all active AUX_i measurements to secure all AUX_i measurements have the same duration. This is mainly required for synchronized AFE operation.
7:6		0x0	AuxInsertRate	Insertion Rate of an AUX_i measurement in „Accelerated main measurement“ setup 0x0 : Disabled 0x1 : Every 2nd 0x2 : Every 4th 0x3 : Every 8th
5:4		0x1	CyclicMode	Sequencer Run Mode 0x0 : Single measurement 0x1 : Continuous cyclic measurement 0x2 : Discontinuous cyclic measurement, started by trigger
3:0		0x3	NrOfSlots	Number of active measurement slots 0x0 ... 0x8 selectable

## 12.6.3 0x24 – Afe1MeasCfg3

Wrong setting of this parameter can corrupt firmware execution. Leave the computation of necessary setup for this register to the GUI.

Address : 0x24		Register Name : Afe1MeasCfg3		Default: 0x00000018
Bits	Access	Default	Field Name	Description
31	Reserved	0x0	AuxMeasEnable0Aux32	Activation of Auxiliary measurements Bit 0 : Auto-zero (AZ) measurement on Sensor Bridge Bit 1 : PTAT Sensor S- Bit 2 : PTAT Sensor S+ Bit 3 : T1 Sensor S- Bit 4 : T1 Sensor S+ Bit 5 : T1 Sensor, check short to top Bit 6 : T1 Sensor, check short to bottom Bit 7 : T1 Sensor, check open Bit 8 : T2 Sensor S- Bit 9 : T2 Sensor S+ Bit 10 : T2 Sensor, check short to top Bit 11 : T2 Sensor, check short to bottom Bit 12 : T2 Sensor, check open Bit 13 : T3 Sensor S- Bit 14 : T3 Sensor S+ Bit 15 : T3 Sensor, check short to top Bit 16 : T3 Sensor, check short to bottom Bit 17 : T3 Sensor, check open Bit 18 : AFE gain diagnosis S+ Bit 19 : AFE gain diagnosis S- Bit 22 : AFE offset diagnosis Bit 27 : Bridge Sensor connection check, INP or INN open Bit 28 : Bridge Sensor connection check, INP and INN shorted
30	Reserved	0x0	AuxMeasEnable0Aux31	
29	Reserved	0x0	AuxMeasEnable0Aux30	
28		0x0	AuxMeasEnable0Aux29	
27		0x0	AuxMeasEnable0Aux28	
26		0x0	AuxMeasEnable0Aux27	
25		0x0	AuxMeasEnable0Aux26	
24		0x0	AuxMeasEnable0Aux25	
23		0x0	AuxMeasEnable0Aux24	
22		0x0	AuxMeasEnable0Aux23	
21		0x0	AuxMeasEnable0Aux22	
20		0x0	AuxMeasEnable0Aux21	
19		0x0	AuxMeasEnable0Aux20	
18		0x0	AuxMeasEnable0Aux19	
17		0x0	AuxMeasEnable0Aux18	
16		0x0	AuxMeasEnable0Aux17	
15		0x0	AuxMeasEnable0Aux16	
14		0x0	AuxMeasEnable0Aux15	
13		0x0	AuxMeasEnable0Aux14	
12		0x0	AuxMeasEnable0Aux13	
11		0x0	AuxMeasEnable0Aux12	
10		0x0	AuxMeasEnable0Aux11	
9		0x0	AuxMeasEnable0Aux10	
8		0x0	AuxMeasEnable0Aux9	
7		0x0	AuxMeasEnable0Aux8	
6		0x0	AuxMeasEnable0Aux7	
5		0x0	AuxMeasEnable0Aux6	
4		0x1	AuxMeasEnable0Aux5	
3		0x1	AuxMeasEnable0Aux4	
2		0x0	AuxMeasEnable0Aux3	
1		0x0	AuxMeasEnable0Aux2	
0		0x0	AuxMeasEnable0Aux1	
				All other bits reserved Bit Value Meaning 0 : Aux measurement Skipped 1 : Aux measurement Executed

## 12.6.4 0x25 – Afe1MeasCfg4

Wrong setting of this parameter can corrupt firmware execution. Leave the computation of necessary setup for this register to the GUI.

Address : 0x25		Register Name : Afe1MeasCfg4		Default: 0x00400000
Bits	Access	Default	Field Name	Description
31:25	Reserved	0x0		Reserved
24		0x0	SensBufDepth	Bridge Sensor data buffer depth in SRAM 0x0 : data buffer depth 1 0x1 : data buffer depth 8
23		0x0	IrqEnableEoauxaz	End of AZ Measurement 0x0 : IRQ disabled 0x1 : IRQ enabled
22		0x1	IrqEnableEoauxseq	End of Aux Sequence 0x0 : IRQ disabled 0x1 : IRQ enabled
21		0x0	IrqEnableEoauxins	End of Inserted AUX Measurement 0x0 : IRQ disabled 0x1 : IRQ enabled
20:5		0x0	IdleTime	In continuous cyclic measurement mode idle times up to 10ms can be asserted between two sequences. IdleTime represents a number of AFE clocks – 4MHz by default
4	Reserved	0x0	AuxMeasEnable1Aux37	Enable CVC diagnosis leak_2 S+
3	Reserved	0x0	AuxMeasEnable1Aux36	Enable CVC diagnosis leak_2 S-
2	Reserved	0x0	AuxMeasEnable1Aux35	Enable CVC diagnosis leak_1 S+
1	Reserved	0x0	AuxMeasEnable1Aux34	Enable CVC diagnosis leak_1 S-
0	Reserved	0x0	AuxMeasEnable1Aux33	Enable sensor leakage check P

### 12.6.5 0x26 – Afe2MeasCfg1

Wrong setting of this parameter can corrupt firmware execution. Leave the computation of necessary setup for this register to the GUI.

Address : 0x26		Register Name : Afe2MeasCfg1		Default: 0x01020036
Bits	Access	Default	Field Name	Description
31		0x0	BurstModeSlot8	AFE DMA Burst Mode Data Transfer after Slot_x 0x0 : Disabled 0x1 : Enabled
30		0x0	BurstModeSlot7	
29		0x0	BurstModeSlot6	
28		0x0	BurstModeSlot5	
27		0x0	BurstModeSlot4	
26		0x0	BurstModeSlot3	
25		0x0	BurstModeSlot2	
24		0x1	BurstModeSlot1	
23		0x0	EocIrqSlot8	End of Conversion Interrupt after Slot_x 0x0 : Disabled 0x1 : Enabled
22		0x0	EocIrqSlot7	
21		0x0	EocIrqSlot6	
20		0x0	EocIrqSlot5	
19		0x0	EocIrqSlot4	
18		0x0	EocIrqSlot3	
17		0x1	EocIrqSlot2	
16		0x0	EocIrqSlot1	
15:14		0x0	MeasTypeSlot8	AFE Measurement Type for Slot_x 0x0 : None 0x1 : SM- 0x2 : SM+ 0x3 : AUX_i
13:12		0x0	MeasTypeSlot7	
11:10		0x0	MeasTypeSlot6	
9:8		0x0	MeasTypeSlot5	
7:6		0x0	MeasTypeSlot4	
5:4		0x3	MeasTypeSlot3	
3:2		0x1	MeasTypeSlot2	
1:0		0x2	MeasTypeSlot1	

### 12.6.6 0x27 – Afe2MeasCfg2

Wrong setting of this parameter can corrupt firmware execution. Leave the computation of necessary setup for this register to the GUI.

Address : 0x27		Register Name : Afe2MeasCfg2		Default: 0x00000013
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:8		0x0	AuxMaxTime	Maximum lenght of AUX_i measurement slots within a sequence 0x0000 ... 0xFFFF AFE clock cycles The parameter is calculated based on the relevant timing setups of all active AUX_i measurements to secure all AUX_i measurements have the same duration. This is mainly required for synchronized AFE operation.
7:6		0x0	AuxInsertRate	Insertion Rate of an AUX_i measurement in „Accelerated main measurement“ setup 0x0 : Disabled 0x1 : Every 2nd 0x2 : Every 4th 0x3 : Every 8th
5:4		0x1	CyclicMode	Sequencer Run Mode 0x0 : Single measurement 0x1 : Continuous cyclic measurement 0x2 : Discontinuous cyclic measurement, started by trigger
3:0		0x3	NrOfSlots	Number of active measurement slots 0x0 ... 0x8 selectable

## 12.6.7 0x28 – Afe2MeasCfg3

Wrong setting of this parameter can corrupt firmware execution. Leave the computation of necessary setup for this register to the GUI.

Address : 0x28			Register Name : Afe2MeasCfg3		Default: 0x00000300
Bits	Access	Default	Field Name	Description	
31	Reserved	0x0	AuxMeasEnable0Aux32	Activation of Auxiliary measurements	
30	Reserved	0x0	AuxMeasEnable0Aux31	Bit 0 : Auto-zero (AZ) measurement on Sensor Bridge	
29	Reserved	0x0	AuxMeasEnable0Aux30	Bit 1 : PTAT Sensor S-	
28		0x0	AuxMeasEnable0Aux29	Bit 2 : PTAT Sensor S+	
27		0x0	AuxMeasEnable0Aux28	Bit 3 : T1 Sensor S-	
26		0x0	AuxMeasEnable0Aux27	Bit 4 : T1 Sensor S+	
25		0x0	AuxMeasEnable0Aux26	Bit 5 : T1 Sensor, check short to top	
24		0x0	AuxMeasEnable0Aux25	Bit 6 : T1 Sensor, check short to bottom	
23		0x0	AuxMeasEnable0Aux24	Bit 7 : T1 Sensor, check open	
22		0x0	AuxMeasEnable0Aux23	Bit 8 : T2 Sensor S-	
21		0x0	AuxMeasEnable0Aux22	Bit 9 : T2 Sensor S+	
20		0x0	AuxMeasEnable0Aux21	Bit 10 : T2 Sensor, check short to top	
19		0x0	AuxMeasEnable0Aux20	Bit 11 : T2 Sensor, check short to bottom	
18		0x0	AuxMeasEnable0Aux19	Bit 12 : T2 Sensor, check open	
17		0x0	AuxMeasEnable0Aux18	Bit 13 : T3 Sensor S-	
16		0x0	AuxMeasEnable0Aux17	Bit 14 : T3 Sensor S+	
15		0x0	AuxMeasEnable0Aux16	Bit 15 : T3 Sensor, check short to top	
14		0x0	AuxMeasEnable0Aux15	Bit 16 : T3 Sensor, check short to bottom	
13		0x0	AuxMeasEnable0Aux14	Bit 17 : T3 Sensor, check open	
12		0x0	AuxMeasEnable0Aux13	Bit 18 : AFE gain diagnosis S+	
11		0x0	AuxMeasEnable0Aux12	Bit 19 : AFE gain diagnosis S-	
10		0x0	AuxMeasEnable0Aux11	Bit 22 : AFE offset diagnosis	
9		0x1	AuxMeasEnable0Aux10	Bit 27 : Bridge Sensor connection check, INP or INN open	
8		0x1	AuxMeasEnable0Aux9	Bit 28 : Bridge Sensor connection check, INP and INN shorted	
7		0x0	AuxMeasEnable0Aux8	All other bits reserved	
6		0x0	AuxMeasEnable0Aux7	Bit Value Meaning	
5		0x0	AuxMeasEnable0Aux6	0 : Aux measurement Skipped	
4		0x0	AuxMeasEnable0Aux5	1 : Aux measurement Executed	
3		0x0	AuxMeasEnable0Aux4		
2		0x0	AuxMeasEnable0Aux3		
1		0x0	AuxMeasEnable0Aux2		
0		0x0	AuxMeasEnable0Aux1		

## 12.6.8 0x29 – Afe2MeasCfg4

Wrong setting of this parameter can corrupt firmware execution. Leave the computation of necessary setup for this register to the GUI.

Address : 0x29		Register Name : Afe2MeasCfg4		Default: 0x00400000
Bits	Access	Default	Field Name	Description
31:25	Reserved	0x0		Reserved
24		0x0	SensBufDepth	Bridge Sensor data buffer depth in SRAM 0x0 : data buffer depth 1 0x1 : data buffer depth 8
23		0x0	IrqEnableEoauxaz	End of AZ Measurement 0x0 : IRQ disabled 0x1 : IRQ enabled
22		0x1	IrqEnableEoauxseq	End of Aux Sequence 0x0 : IRQ disabled 0x1 : IRQ enabled
21		0x0	IrqEnableEoauxins	End of Inserted AUX Measurement 0x0 : IRQ disabled 0x1 : IRQ enabled
20:5		0x0	IdleTime	In continuous cyclic measurement mode idle times up to 10ms can be asserted between two sequences. IdleTime represents a number of AFE clocks – 4MHz by default
4	Reserved	0x0	AuxMeasEnable1Aux37	Enable CVC diagnosis leak_2 S+
3	Reserved	0x0	AuxMeasEnable1Aux36	Enable CVC diagnosis leak_2 S-
2	Reserved	0x0	AuxMeasEnable1Aux35	Enable CVC diagnosis leak_1 S+
1	Reserved	0x0	AuxMeasEnable1Aux34	Enable CVC diagnosis leak_1 S-
0	Reserved	0x0	AuxMeasEnable1Aux33	Enable sensor leakage check P

## 12.7 Diagnosis

### 12.7.1 0x2A – DiagSen.DiagCfg

Address : 0x2A		Register Name : DiagSen.DiagCfg		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:17	Reserved	0x0		Reserved
16:15		0x0	Extt3Range	Reference for Temp Sensor open check on T3 0x0 : 2MΩ 0x1 : 0.5MΩ 0x3 : 0.1MΩ
14		0x0	Extt3Pt100	Reference for temperature sensor short measurement on T3 0x0 : RT_SHORT < 500Ω 0x1 : RT_SHORT < 10Ω
13	Reserved	0x0		Reserved
12:11		0x0	Extt2Range	Reference for Temp Sensor open check on T2 0x0 : 2MΩ 0x1 : 0.5MΩ 0x3 : 0.1MΩ
10		0x0	Extt2Pt100	Reference for temperature sensor short measurement on T2 0x0 : RT_SHORT < 500Ω 0x1 : RT_SHORT < 10Ω
9	Reserved	0x0		Reserved
8:7		0x0	Extt1Range	Reference for Temp Sensor open check on T1 0x0 : 2MΩ 0x1 : 0.5MΩ 0x3 : 0.1MΩ
6		0x0	Extt1Pt100	Reference for temperature sensor short measurement on T1 0x0 : RT_SHORT < 500Ω 0x1 : RT_SHORT < 10Ω
5:4		0x0	Afe2GainChkResDacVal	Resistive Diagnosis DAC value at AFE2 0x0 : 2mV 0x1 : 10mV 0x2 : 100mV 0x3 : 200mV
3		0x0	Afe2GainChkResDacEn	Resistive Diagnosis DAC activation at AFE2 0x0 : Disabled 0x1 : Enabled
2:1		0x0	Afe1GainChkResDacVal	Resistive Diagnosis DAC value at AFE1 0x0 : 2mV 0x1 : 10mV 0x2 : 100mV 0x3 : 200mV
0		0x0	Afe1GainChkResDacEn	Resistive Diagnosis DAC activation at AFE1 0x0 : Disabled 0x1 : Enabled

### 12.7.2 0x2B – DiagSen.Range[0].Inp

Address : 0x2B		Register Name : DiagSen.Range[0].Inp		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:16		0x0	Max	
15:0		0x0	Min	

### 12.7.3 0x2C – DiagSen.Range[0].Inn

Address : 0x2C		Register Name : DiagSen.Range[0].Inn		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:16		0x0	Max	
15:0		0x0	Min	



## 12.7.4 0x2D – DiagSen.Range[1].Inp

Address : 0x2D		Register Name : DiagSen.Range[1].Inp		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:16		0x0	Max	
15:0		0x0	Min	

## 12.7.5 0x2E – DiagSen.Range[1].Inn

Address : 0x2E		Register Name : DiagSen.Range[1].Inn		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:16		0x0	Max	
15:0		0x0	Min	

## 12.7.6 0x2F – DiagSen.GainChk[0]

Address : 0x2F		Register Name : DiagSen.GainChk[0]		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:16		0x0	TolVal	Gain Tolerance Value for Gain Drift Diagnosis A tolerance value in ADC counts for acceptable gain drift over lifetime shall be stored in this register A gain failure is signaled after the Gain Drift Check if the determined AFE Gain Value is either < (RefVal - TolVal) or > (RefVal + TolVal)
15:0		0x0	RefVal	Gain Reference Value for Gain Drift Diagnosis During sensor calibration an initial AFE Gain Check measurement with a properly defined AFExGainCheckResDacVal setting must be done and the obtained RAW output value shall be stored in this register for later reference.

## 12.7.7 0x30 – DiagSen.GainChk[1]

Address : 0x30		Register Name : DiagSen.GainChk[1]		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:16		0x0	TolVal	
15:0		0x0	RefVal	

## 12.7.8 0x31 – DiagSen.OfstChk[0]

Address : 0x31		Register Name : DiagSen.OfstChk[0]		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:16		0x0	TolVal	
15:0		0x0	RefVal	

## 12.7.9 0x32 – DiagSen.OfstChk[1]

Address : 0x32		Register Name : DiagSen.OfstChk[1]		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:16		0x0	TolVal	
15:0		0x0	RefVal	

## 12.8 Temperature Channel Mapping

### 12.8.1 0x33 – TempMapChId

Address : 0x33		Register Name : TempMapChId		Default: 0x0000001A
Bits	Access	Default	Field Name	Description
31:9	Reserved	0x0		Reserved
8:6		0x0	Tch3	Temperature Sensor Source for Temperature Channels 1, 2, 3 0x0 : None 0x1 : PTAT 0x2 : T1 0x3 : T2 0x4 : T3
5:3		0x3	Tch2	
2:0		0x2	Tch1	

## 12.9 SSC Algorithm Selection

### 12.9.1 0x34 – MathSbrAlgoSel

Address : 0x34		Register Name : MathSbrAlgoSel		Default: 0x00000011
Bits	Access	Default	Field Name	Description
31:12	Reserved	0x0		Reserved
11		0x0	TlcChOrder	Third Logic Channel Operand Order 0x0 : CH1 op CH2 0x1 : CH2 op CH1
10:8		0x0	TlcOp	Third Logic Channel Operation 0x0 : Subtraction 0x1 : Division 0x2 : Ratio
7:4		0x1	Sensor2	SSC Algorithm for Bridge Sensors 1 & 2 0x0 : None 0x1 : SOT Parabolic 0x2 : SOT S-Shaped
3:0		0x1	Sensor1	

## 12.10 EOC / Alarm

### 12.10.1 0x35 – EocAlarmPin[0].Reg1

Address : 0x35		Register Name : EocAlarmPin[0].Reg1		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:29	Reserved	0x0		Reserved
28		0x0	Range	Alarm Range 0x0 : Above / Outside 0x1 : Below / Inside
27:26		0x0	NrThresh	Number of Alarm Thresholds 0x0 : None (EOC Mode) 0x1 : Enabled 0x2 : Window (2 Thresholds)
25		0x0	Pol	Output Polarity 0x0 : Active High 0x1 : Active Low
24		0x0	En	EOC / Alarm Activation 0x0 : Disabled 0x1 : Enabled
23:0		0x0	Thresh1	Alarm Threshold 1 24 bit value, matches SSC output number format

### 12.10.2 0x36 – EocAlarmPin[0].Reg2

Address : 0x36		Register Name : EocAlarmPin[0].Reg2		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	Thresh2	Alarm Threshold 2 24 bit value, matches SSC output number format

## 12.10.3 0x37 – EocAlarmPin[0].Reg3

Address : 0x37		Register Name : EocAlarmPin[0].Reg3		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24		0x0	Persist	
23:0		0x0	Hyst	Alarm Hysteresis 24bit value, matches SSC output number format

## 12.10.4 0x38 – EocAlarmPin[1].Reg1

Address : 0x38		Register Name : EocAlarmPin[1].Reg1		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:29	Reserved	0x0		Reserved
28		0x0	Range	Alarm Range 0x0 : Above / Outside 0x1 : Below / Inside
27:26		0x0	NrThresh	Number of Alarm Thresholds 0x0 : None (EOC Mode) 0x1 : Enabled 0x2 : Window (2 Thresholds)
25		0x0	Pol	Output Polarity 0x0 : Active High 0x1 : Active Low
24		0x0	En	EOC / Alarm Activation 0x0 : Disabled 0x1 : Enabled
23:0		0x0	Thresh1	Alarm Threshold 1 24 bit value, matches SSC output number format

## 12.10.5 0x39 – EocAlarmPin[1].Reg2

Address : 0x39		Register Name : EocAlarmPin[1].Reg2		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	Thresh2	Alarm Threshold 2 24 bit value, matches SSC output number format

## 12.10.6 0x3A – EocAlarmPin[1].Reg3

Address : 0x3A		Register Name : EocAlarmPin[1].Reg3		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24		0x0	Persist	Alarm Condition Persistence before Alarm State is changed 8bit value (0 ... 255)
23:0		0x0	Hyst	

## 12.11 Analog Output (AOUT)

### 12.11.1 0x3B – AoutSelParam

Address : 0x3B		Register Name : AoutSelParam		Default: 0x00000001
Bits	Access	Default	Field Name	Description
31:7	Reserved	0x0		Reserved
6:3		0x0	AoutModSel	Analog Output Driver Mode 0x0 : Disabled 0x1 : Absolute Voltage Output 0-10V 0x2 : Absolute Voltage Output 0-5V 0x3 : Absolute V 0-1V 0x4 : Ratiometric Voltage Output 0x5 : 2-Wire Current Loop 0x6 : 3-Wire Current Loop 0x7 : Auto-Detect Current Loop
2:0		0x1	SelAfeForDac	Source Signal for Analog Output 0x0 : None 0x1 : Bridge Sensor Channel 1 0x2 : Bridge Sensor Channel 2 0x3 : Third Logic Channel 0x4 : Temperature Channel 1 0x5 : Temperature Channel 2 0x6 : Temperature Channel 3

### 12.11.2 0x3C – AoutRegCtrl

Address : 0x3C		Register Name : AoutRegCtrl		Default: 0x0000001A
Bits	Access	Default	Field Name	Description
31:13	Reserved	0x0		Reserved
12:11		0x0	Aout5vRdacRefSel	
10:9		0x0	AoutVddnLoad	VDDN Charge Pump Load Current 0x0 : 0.5mA    0x2 : 3mA 0x1 : 1mA     0x3 : 5mA
8		0x0	AoutVddnEn	VDDN Charge Pump for Negative Supply 0x0 : Disabled 0x1 : Enabled
7		0x0	AoutOffsetCompOff	Analog Output Offset Compensation 0x0 : Disabled 0x1 : Enabled
6:5		0x0	AoutCurrLim	Analog Driver Output Current Limitation 0x0 : 6mA     0x2 : 18mA 0x1 : 12mA    0x3 : 25mA
4		0x1	AoutFeedBackEn	Analog Driver Feedback 0x0 : External 0x1 : Internal
3		0x1	AoutHighPowEn	Analog Driver Output Power 0x0 : Low Power 0x1 : High Power
2:1		0x1	AoutMode	Analog Output Mode 0x0 : Current Loop 5V-RDAC 0x1 : VOUT 5V 0x2 : VOUT 1V 0x3 : Current Loop 1V-RDAC
0		0x0	AoutEn	Analog Output Activation 0x0 : Disabled 0x1 : Enabled

## 12.11.3 0x3D – AoutRegDiag

Address : 0x3D		Register Name : AoutRegDiag		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:4	Reserved	0x0		Reserved
3		0x0	AoutDiagVddaEn	VDDA Diagnosis if VDDA regulator for AOUT is turned on 0x0 : Disabled 0x1 : Enabled
2:1		0x0	AoutDiagOutValue	Analog Output Mode 0x0 : $V_{AOUT} = V_{SS}$ 0x2 : $V_{AOUT} = 96\%V_{DD}$ 0x1 : $V_{AOUT} = 5\% V_{DD}$ 0x3 : $V_{AOUT} = V_{DD}$
0		0x0	AoutDiagOutEn	Diagnosis Level Output at AOUT 0x0 : Normal Operation Mode 0x1 : Diagnosis Output Mode

## 12.11.4 0x3E – AoutCI2Coeff

Address : 0x3E		Register Name : AoutCI2Coeff		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:16		0x0	CIDelta	2-Wire Current Loop Calibration Coefficient CL2_Delta 16-bit Value
15:0		0x0	CIOffset	2-Wire Current Loop Calibration Coefficient CL2_Offset 16-bit Value

## 12.11.5 0x3F – AoutCI3Coeff

Address : 0x3F		Register Name : AoutCI3Coeff		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:16		0x0	CIDelta	3-Wire Current Loop Calibration Coefficient CL3_Delta 16-bit Value
15:0		0x0	CIOffset	3-Wire Current Loop Calibration Coefficient CL3_Offset 16-bit Value

## 12.12 System Startup

## 12.12.1 0x40 – StartupParamCfg

Address : 0x40		Register Name : StartupParamCfg		Default: 0x00000001
Bits	Access	Default	Field Name	Description
31:9	Reserved	0x0		Reserved
8		0x0	EobEn	End of Busy Enable 0x0 : Disabled 0x1 : Enabled
7:2	Reserved	0x0		Reserved
1:0		0x1	StartupMode	System Startup Mode 0x0 : Cyclic Mode 0x1 : Command Mode

## 12.13 IIR Filter

### 12.13.1 0x41 – IIRFiltCoeffReg

Address : 0x41		Register Name : IIRFiltCoeffReg		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:30	Reserved	0x0		Reserved
29:27		0x0	FiltTemp3Diff	IIR Diff Value Temperature Channel 3
26:24		0x0	FiltTemp3Avg	IIR Avg Value Temperature Channel 3
23:21		0x0	FiltTemp2Diff	IIR Diff Value Temperature Channel 2
20:18		0x0	FiltTemp2Avg	IIR Avg Value Temperature Channel 2
17:15		0x0	FiltTemp1Diff	IIR Diff Value Temperature Channel 1
14:12		0x0	FiltTemp1Avg	IIR Avg Value Temperature Channel 1
11:9		0x0	FiltSbr2Diff	IIR Diff Value Sensor Bridge 2
8:6		0x0	FiltSbr2Avg	IIR Avg Value Sensor Bridge 2
5:3		0x0	FiltSbr1Diff	IIR Diff Value Sensor Bridge 1
2:0		0x0	FiltSbr1Avg	IIR Avg Value Sensor Bridge 1

## 12.14 General AFE Configuration

### 12.14.1 0x42 – AfeConfig

Address : 0x42		Register Name : AfeConfig		Default: 0x20000000	
Bits	Access	Default	Field Name	Description	
31		0x0	CLMode	AFE Operation Mode for 2-Wire Current Loop application 0x0 : Disabled 0x1 : Enabled	
30:26	Reserved	0x8	AfeMisc	Reserved	
25		0x0	Afe2LowSpeed	AFE2 clock speed with respect to AFE1 0x0 : Normal (equal) Speed 0x1 : Quarter Speed	
24	Reserved	0x0	CM2En	Reserved	
23	Reserved	0x0	CM1En	Reserved	
22		0x0	Vdda3Brownout	AOUT Vdda Brownout Diagnosis 0x0 : Disabled 0x1 : Enabled	
21		0x0	Vdda2Brownout	AFE2 Vdda Brownout Diagnosis 0x0 : Disabled 0x1 : Enabled	
20		0x0	Vdda1Brownout	AFE1 Vdda Brownout Diagnosis 0x0 : Disabled 0x1 : Enabled	
19	Reserved	0x0	CMDitheringEnable	Reserved	
18	Reserved	0x0	CMNoiseInt1	Reserved	
17		0x0	TNoiseInt1	ADC 10 $\mu$ V Noise Reduction 0x0 : Disabled 0x1 : Enabled	
16		0x0	ExtTemp3NoiseInt1		
15		0x0	ExtTemp2NoiseInt1		
14		0x0	ExtTemp1NoiseInt1		
13		0x0	BM2NoiseInt1		
12		0x0	BM1NoiseInt1		
11:10		0x0	TChpMode	PGA Chopper Mode PTAT Temperature Sensor 0x0 : 100kHz    0x2 : 50kHz 0x1 : 200kHz    0x3 : Chopper Off	
9:8		0x0	ExtTemp3ChpMode	PGA Chopper Mode External Temperature Sensor T3 0x0 : 100kHz    0x2 : 50kHz 0x1 : 200kHz    0x3 : Chopper Off	
7:6		0x0	ExtTemp2ChpMode	PGA Chopper Mode External Temperature Sensor T2 0x0 : 100kHz    0x2 : 50kHz 0x1 : 200kHz    0x3 : Chopper Off	
5:4		0x0	ExtTemp1ChpMode	PGA Chopper Mode External Temperature Sensor T1 0x0 : 100kHz    0x2 : 50kHz 0x1 : 200kHz    0x3 : Chopper Off	
3:2		0x0	BM2ChpMode	PGA Chopper Mode Bridge Sensor 2 0x0 : 100kHz    0x2 : 50kHz 0x1 : 200kHz    0x3 : Chopper Off	
1:0		0x0	BM1ChpMode	PGA Chopper Mode Bridge Sensor 1 0x0 : 100kHz    0x2 : 50kHz 0x1 : 200kHz    0x3 : Chopper Off	

## 12.15 Output Modulation

### 12.15.1 0x43 – OutModConf

Address : 0x43		Register Name : OutModConf		Default: 0x27106400
Bits	Access	Default	Field Name	Description
31:16		0x2710	FmMaxFreqPwmBaseFreq	Frequency Modulation - Maximum Frequency in Hz 16bit value in range 1,000 to 10,000  Pulse Width Modulation - PWM Mapping Selects if the conditioned result is inverted. 0x0 : 200 Hz 0x1 : 500 Hz 0x2 : 500Hz + 1 * 500Hz = 1kHz 0x3 : 500Hz + 2 * 500Hz = 1kHz 0x4...31 : 500Hz + (FmMinFreqPwmMap-1) * 500Hz 0x32 : 500Hz + 31 * 500Hz = 15kHz
15:8		0x64	FmMinFreqPwmMap	Frequency Modulation - Minimum Frequency in Hz 8bit value in range 100 to 255  Pulse Width Modulation - PWM Mapping Selects if the conditioned result is inverted. 0x0 : SSCMax = 100% and SSCMin = 0% 0x1 : SSCMax = 0% and SSCMin = 100%
7:5		0x0	ChGpio7	Source Signal for FOUT/PWM_2 0x0 : Not Used 0x1 : Bridge Sensor 1 0x2 : Bridge Sensor 2 0x3 : Third Logic Channel 0x4 : Temperature Channel 1 0x5 : Temperature Channel 2 0x6 : Temperature Channel 3
4:2		0x0	ChGpio1	Source Signal for FOUT/PWM_1 0x0 : Not Used 0x1 : Bridge Sensor 1 0x2 : Bridge Sensor 2 0x3 : Third Logic Channel 0x4 : Temperature Channel 1 0x5 : Temperature Channel 2 0x6 : Temperature Channel 3
1:0		0x0	Sel	Output Modulation Type 0x0 : No Output Modulation 0x1 : Frequency Modulation 0x2 : Pulse Width Modulation



## 12.16 Output Clipping, Diagnostic Range Assignment and Watchdog

### 12.16.1 0x44 – DiagClipOutCfg.SysDiagCfg

Address : 0x44		Register Name : DiagClipOutCfg.SysDiagCfg		Default: 0x0DA50000			
Bits	Access	Default	Field Name	Description			
31:28	Reserved	0x0		Reserved			
27:24		0xD	WatchdogTimeout	Watchdog Timeout 0x0 : 8ms    0x4 : 40ms    0x8 : 100ms    0xC : 1s 0x1 : 10ms    0x5 : 50ms    0x9 : 150ms    0xD : 2s 0x2 : 20ms    0x6 : 60ms    0xA : 200ms    0xE : 4s 0x3 : 30ms    0x7 : 80ms    0xB : 500ms    0xF : 8s			
23:16		0xA5	WatchdogDisableKey	Watchdog Disable Key 0xA5 : Watchdog disabled    All other codes enable watchdog			
15:2	Reserved	0x0		Reserved			
1		0x0	ClipOutEn	Two-Sided Clipping to Upper and Lower Diagnostic Limit 0x0 : Disabled 0x1 : Enabled <b>Note:</b> Enabling this feature requires enabling ClipOutEn. <b>Note:</b> DiagOutEn sets the AOUT to either 0% (LDR) or 100% (UDR) <b>Note:</b> UDR will have higher priority than LDR if configuration mixes both failure output signalization states.)  Failure signalization of saturation requires enabling of any additional AFE or sensor diagnosis functions.			
0		0x0	DiagOutEn	Output Signalization of Diagnostic State at AOUT 0x0 : Disabled 0x1 : Enabled <b>Note:</b> Clipping limits are defined in DiagClipOutCfg.ClipOutLvl register.			

### 12.16.2 0x45 – DiagClipOutCfg.DiagOutLvl[0]

Address : 0x45		Register Name : DiagClipOutCfg.DiagOutLvl[0]		Default: 0x00007FFE			
Bits	Access	Default	Field Name	Description			
31:0		0x7FFE	DiagOutLvl[0]	Select register for UDR / LDR assignment of diagnostic checks			

### 12.16.3 0x46 – DiagClipOutCfg.DiagOutLvl[1]

Address : 0x46		Register Name : DiagClipOutCfg.DiagOutLvl[1]		Default: 0x00000000			
Bits	Access	Default	Field Name	Description			
31:0		0x0	DiagOutLvl[1]	Select register for UDR / LDR assignment of diagnostic checks			

### 12.16.4 0x47 – DiagClipOutCfg.DiagOutLvl[2]

Address : 0x47		Register Name : DiagClipOutCfg.DiagOutLvl[2]		Default: 0x0000003F			
Bits	Access	Default	Field Name	Description			
31:0		0x3F	DiagOutLvl[2]				

### 12.16.5 0x48 – DiagClipOutCfg.ClipOutLvl

Address : 0x48		Register Name : DiagClipOutCfg.ClipOutLvl		Default: 0xF3330CCC			
Bits	Access	Default	Field Name	Description			
31:24	Reserved	0xF3		Reserved			
23:16		0x33	ClipOutHigh	Upper Clipping Limit 0xF333 : 95% Full Scale			
15:0		0xCCC	ClipOutLow	Lower Clipping Limit 0x0CCC : 5% Full Scale			

## 12.17 SSC Coefficients

### 12.17.1 0x4D – Bs1Coeff.SOffset

Address : 0x4D		Register Name : Bs1Coeff.SOffset		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	SOffset	Sensor offset term <i>Offset_S</i>

### 12.17.2 0x4E – Bs1Coeff.SGain

Address : 0x4E		Register Name : Bs1Coeff.SGain		Default: 0x00200000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x200000	SGain	Sensor gain term <i>Gain_S</i>

### 12.17.3 0x4F – Bs1Coeff.SSot

Address : 0x4F		Register Name : Bs1Coeff.SSot		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	SSot	Second-order term for sensor non-linearity <i>SOT_sens</i>

### 12.17.4 0x50 – Bs1Coeff.SShift

Address : 0x50		Register Name : Bs1Coeff.SShift		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	SShift	Post-calibration term <i>SENS_shift</i>

### 12.17.5 0x51 – Bs1Coeff.STco

Address : 0x51		Register Name : Bs1Coeff.STco		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	STco	Temperature coefficient offset term <i>Tco</i>

### 12.17.6 0x52 – Bs1Coeff.SSotTco

Address : 0x52		Register Name : Bs1Coeff.SSotTco		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	SSotTco	Second-order term for Tco nonlinearity <i>SOT_tco</i>

### 12.17.7 0x53 – Bs1Coeff.STcg

Address : 0x53		Register Name : Bs1Coeff.STcg		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	STcg	Temperature coefficient gain term <i>Tcg</i>

### 12.17.8 0x54 – Bs1Coeff.SSotTcg

Address : 0x54		Register Name : Bs1Coeff.SSotTcg		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	SSotTcg	Second-order term for Tcg non-linearity <i>SOT_tcg</i>

## 12.17.9 0x55 – Bs1Coeff.OutScaleGain

Address : 0x55		Register Name : Bs1Coeff.OutScaleGain		Default: 0x00100000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x100000	OutScaleGain	Post SSC Output Scaling Gain

## 12.17.10 0x56 – Bs1Coeff.OutScaleOfst

Address : 0x56		Register Name : Bs1Coeff.OutScaleOfst		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	OutScaleOfst	Post SSC Output Scaling Offset

## 12.17.11 0x57 – Bs2Coeff.SOffset

Address : 0x57		Register Name : Bs2Coeff.SOffset		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	SOffset	Sensor offset term <i>Offset_S</i>

## 12.17.12 0x58 – Bs2Coeff.SGain

Address : 0x58		Register Name : Bs2Coeff.SGain		Default: 0x00200000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x200000	SGain	Sensor gain term <i>Gain_S</i>

## 12.17.13 0x59 – Bs2Coeff.SSot

Address : 0x59		Register Name : Bs2Coeff.SSot		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	SSot	Second-order term for sensor non-linearity <i>SOT_sens</i>

## 12.17.14 0x5A – Bs2Coeff.SShift

Address : 0x5A		Register Name : Bs2Coeff.SShift		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	SShift	Post-calibration term <i>SENS_shift</i>

## 12.17.15 0x5B – Bs2Coeff.STco

Address : 0x5B		Register Name : Bs2Coeff.STco		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	STco	Temperature coefficient offset term <i>Tco</i>

## 12.17.16 0x5C – Bs2Coeff.SSotTco

Address : 0x5C		Register Name : Bs2Coeff.SSotTco		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	SSotTco	Second-order term for Tco nonlinearity <i>SOT_tco</i>

## 12.17.17 0x5D – Bs2Coeff.STcg

Address : 0x5D		Register Name : Bs2Coeff.STcg		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	STcg	Temperature coefficient gain term <i>Tcg</i>

## 12.17.18 0x5E – Bs2Coeff.SSotTcg

Address : 0x5E		Register Name : Bs2Coeff.SSotTcg		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	SSotTcg	Second-order term for Tcg non-linearity <i>SOT_tcg</i>

## 12.17.19 0x5F – Bs2Coeff.OutScaleGain

Address : 0x5F		Register Name : Bs2Coeff.OutScaleGain		Default: 0x00100000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x100000	OutScaleGain	Post SSC Output Scaling Gain

## 12.17.20 0x60 – Bs2Coeff.OutScaleOfst

Address : 0x60		Register Name : Bs2Coeff.OutScaleOfst		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	OutScaleOfst	Post SSC Output Scaling Offset

## 12.17.21 0x61 – Tch1Coeff.TOffset

Address : 0x61		Register Name : Tch1Coeff.TOffset		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	TOffset	Offset coefficient for temperature <i>Offset_T</i>

## 12.17.22 0x62 – Tch1Coeff.TGain

Address : 0x62		Register Name : Tch1Coeff.TGain		Default: 0x00200000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x200000	TGain	Gain coefficient for temperature <i>Gain_T</i>

## 12.17.23 0x63 – Tch1Coeff.TSot

Address : 0x63		Register Name : Tch1Coeff.TSot		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	TSot	Second-order term for temperature source <i>SOT_T</i>

## 12.17.24 0x64 – Tch1Coeff.TShift

Address : 0x64		Register Name : Tch1Coeff.TShift		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	TShift	Shift for post-calibration/post-assembly offset compensation <i>T_Shift</i>

## 12.17.25 0x65 – Tch2Coeff.TOffset

Address : 0x65		Register Name : Tch2Coeff.TOffset		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	TOffset	Offset coefficient for temperature <i>Offset_T</i>

## 12.17.26 0x66 – Tch2Coeff.TGain

Address : 0x66		Register Name : Tch2Coeff.TGain		Default: 0x00200000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x200000	TGain	Gain coefficient for temperature <i>Gain_T</i>

## 12.17.27 0x67 – Tch2Coeff.TSot

Address : 0x67		Register Name : Tch2Coeff.TSot		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	TSot	Second-order term for temperature source <i>SOT_T</i>

## 12.17.28 0x68 – Tch2Coeff.TShift

Address : 0x68		Register Name : Tch2Coeff.TShift		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	TShift	Shift for post-calibration/post-assembly offset compensation <i>T_Shift</i>

## 12.17.29 0x69 – Tch3Coeff.TOffset

Address : 0x69		Register Name : Tch3Coeff.TOffset		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x0	TOffset	Offset coefficient for temperature <i>Offset_T</i>

## 12.17.30 0x6A – Tch3Coeff.TGain

Address : 0x6A		Register Name : Tch3Coeff.TGain		Default: 0x00200000
Bits	Access	Default	Field Name	Description
31:24	Reserved	0x0		Reserved
23:0		0x200000	TGain	Gain coefficient for temperature <i>Gain_T</i>

## 12.17.31 0x6B – Tch3Coeff.TSot

Address : 0x6B		Register Name : Tch3Coeff.TSot		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:0		0x0	TSot	Second-order term for temperature source <i>SOT_T</i>

## 12.17.32 0x6C – Tch3Coeff.TShift

Address : 0x6C		Register Name : Tch3Coeff.TShift		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:0		0x0	TShift	Shift for post-calibration/post-assembly offset compensation <i>T_Shift</i>

**12.17.33 0x80 – SscCoeffFmSot.Offset**

Address : 0x80		Register Name : SscCoeffFmSot.Offset		Default: 0x40000000
Bits	Access	Default	Field Name	Description
31:0		0x40000000	Offset	

**12.17.34 0x81 – SscCoeffFmSot.Gain**

Address : 0x81		Register Name : SscCoeffFmSot.Gain		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:0		0x0	Gain	

**12.17.35 0x82 – SscCoeffFmSot.Sot**

Address : 0x82		Register Name : SscCoeffFmSot.Sot		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:0		0x0	Sot	

**12.18 Customer ID****12.18.1 0xFD – Customer ID 0**

Address : 0xFD		Register Name : Customer_ID_0		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:0		0x0	Customer_ID_0	

**12.18.2 0xFE – Customer ID 1**

Address : 0xFE		Register Name : Customer_ID_1		Default: 0x00000000
Bits	Access	Default	Field Name	Description
31:0		0x0	Customer_ID_1	

**12.19 CCP Version****12.19.1 0xFF – CcpVersion**

Address : 0xFF		Register Name : CcpVersion		Default: 0x81010501
Bits	Access	Default	Field Name	Description
31:24		0x81	Pid	
23:16		0x1	PatchVer	CCP Patch Version
15:8		0x5	MinorVer	CCP Minor Version
7:0		0x1	MajorVer	CCP Major Version

## 13 Application Information

### 13.1 2-Bridge Application 1.8V to 5.5V Supply

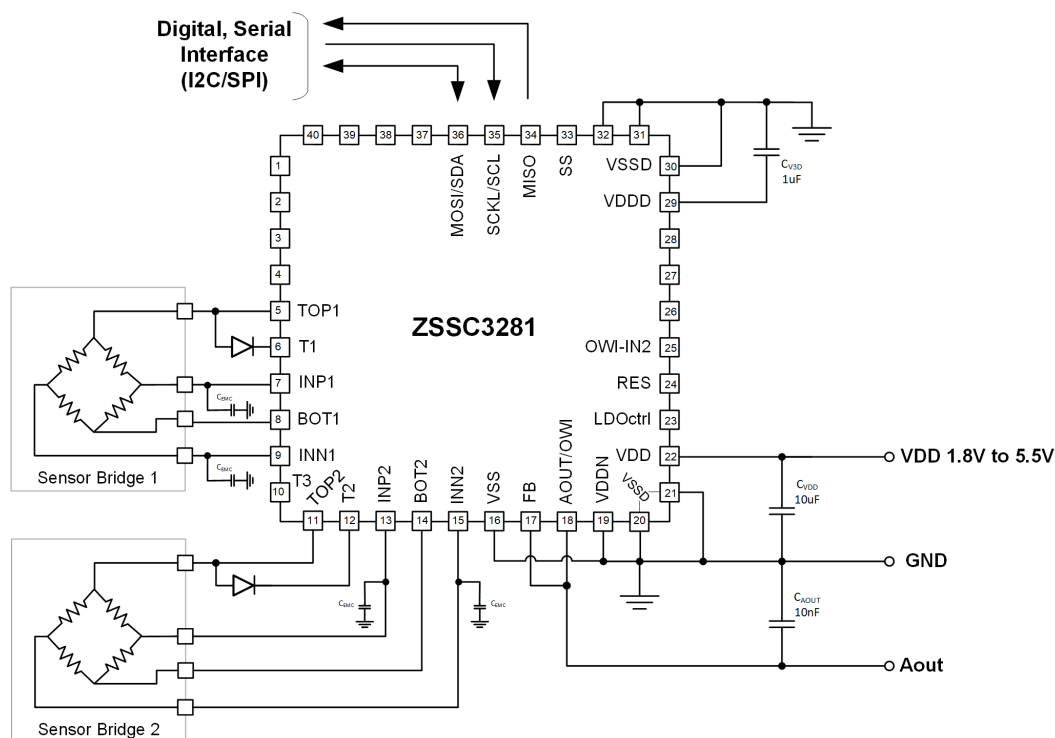


Figure 61: 2-Bridge Application 1.8V to 5.5V Supply

### 13.2 2-Bridge Application 7V to 48V Supply

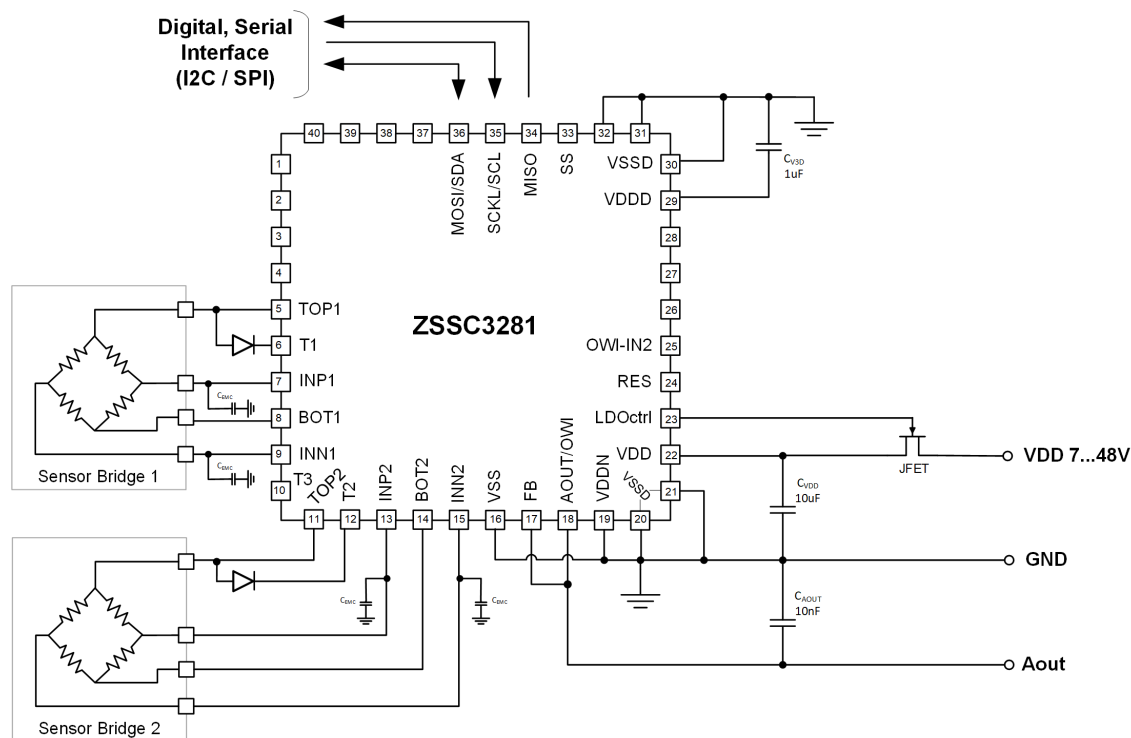


Figure 62: 2-Bridge Application 7V to 48V Supply

### 13.3 2-Wire Current Loop Application

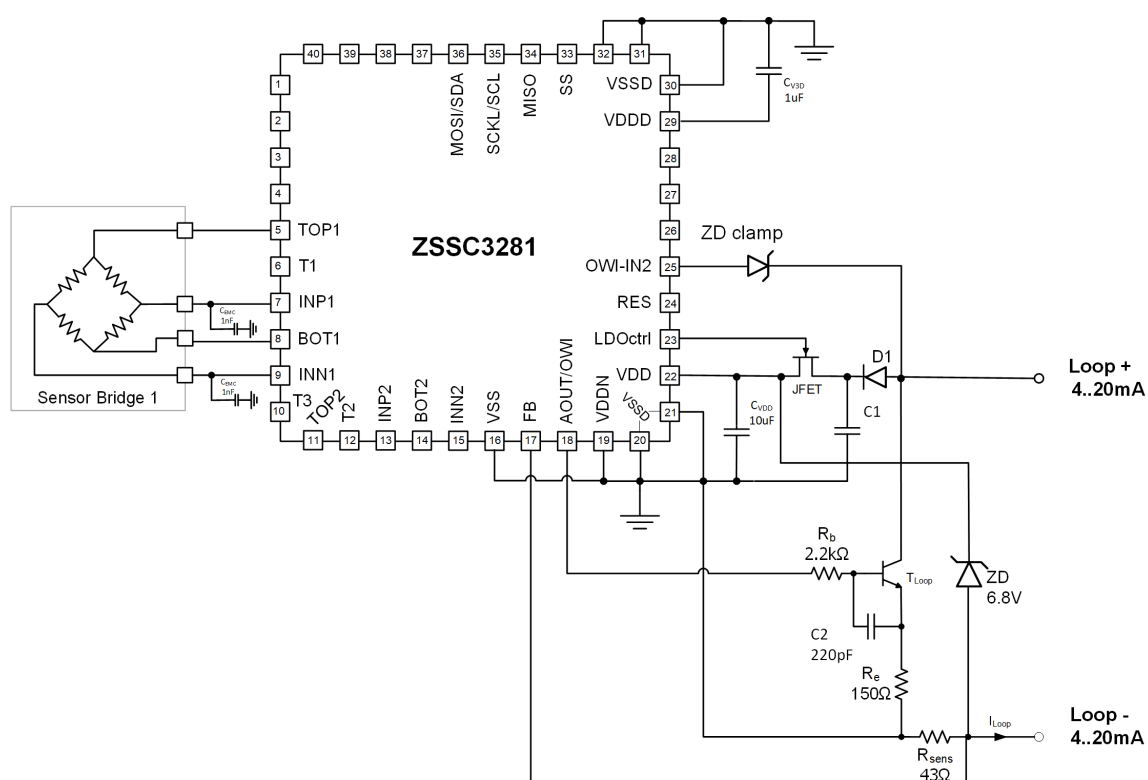


Figure 63: 2-Wire Current Loop Application

### 13.4 3-Wire Current Loop Application

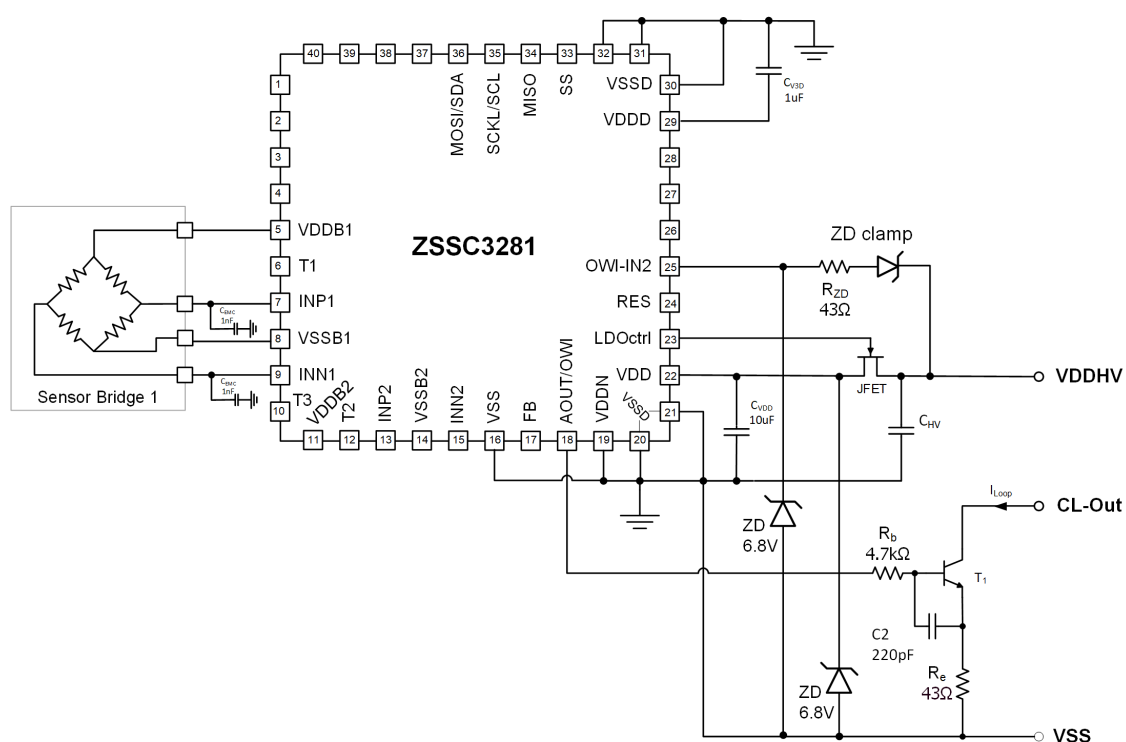


Figure 64: 3-Wire Current Loop Application



## 13.5 Power Supply

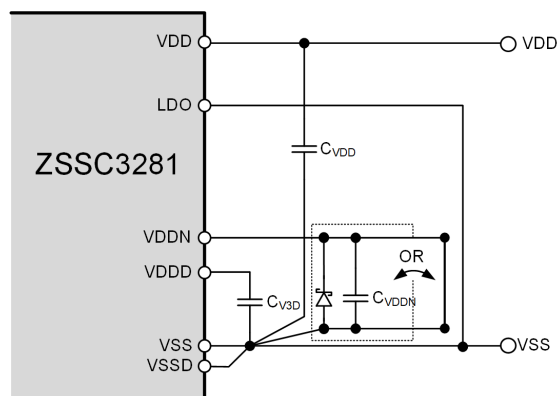
### 13.5.1 Power Supply Modes

ZSSC3281 supports two different main supply modes (Direct VDD Supply and Pre-Regulated High Voltage Supply) and an optional negative voltage supply for the Analog Output Driver. Respective application schematics are shown in 13.5.2 and 13.5.3.

**Table 55: Power Supply Specifications**

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
VDDHV	High voltage supply	Requires external pre-regulator JFET	VDD+0.5		48	V
VDDN	Negative voltage supply for analog output (AOUT)	Internally generated, requires activation of VDDN Charge Pump		$V_{ExtShottky}$		V
		Externally supplied	0	-0.3	-0.5	V
VSS	Analog ground reference			0		V
VSSD	Digital ground reference			0		V
C <sub>HV</sub>	External high voltage buffer cap	All applications except 2-wire Current Loop		10		μF

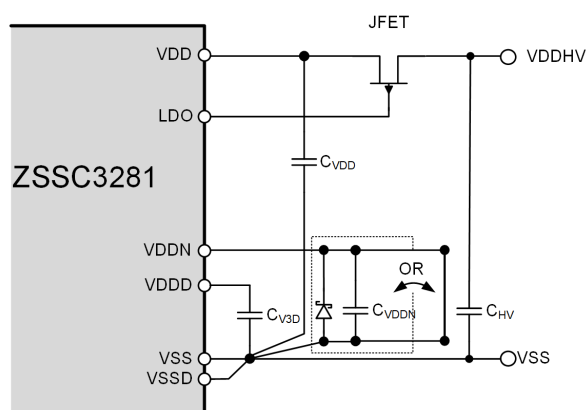
### 13.5.2 Direct VDD Supply



**Figure 65: Application with Direct IC Supply**

The Direct VDD Supply configuration requires the LDO pin to be connected to VSS on PCB level. To minimize power consumption in all operation modes, the LDO driver circuit is turned off as soon as the user selects 'Direct VDD Supply' mode during device configuration (see GUI Tab: Configure\Power Supply And Oscillator\Supply Mode).

### 13.5.3 Pre-Regulated High Voltage Supply



**Figure 66: Application with External Regulator**

Higher than 5.25V supply voltages require an external JFET as pre-regulation device. The LDO output pin of ZSSC3281 is able to drive the JFET devices listed in Table 56 in a circuit configuration as shown in Figure 66.

**Table 56: Supported JFET Devices**

Manufacturer	Type	Typical $V_{GS(TH)}$	Typical ID/A at 25°C
Supertex inc.	DN3545	-3.5V to -1.5V	0.2
Infineon	BSP149	-1.8V to -1V	0.66
Infineon	BSS169	-2.9V to -1.8V	0.17

The output voltage of the JFET assisted pre-regulator is configurable as shown in Table 57. In the GUI it can be configured through the field Configure\Power Supply And Oscillator\Regulated VDD.

**Table 57: Configurable Pre-Regulator**

Output Voltage (VDD)	VDDHV Min	VDDHV Max <sup>1</sup>	Unit
3	3.5	48	V
4	4.5	48	V
5	5.5	48	V
5.25	5.75	48	V

<sup>1</sup> VDDHV depends on selected external JFET parameters.

Besides the VDD buffer capacitor  $C_{VDD}$  another buffer capacitor  $C_{HV}$  is recommended on the high voltage supply VDDHV for stability reasons.

### 13.5.4 Negative Voltage Supply for AOUT

To support True-0V signals on the Analog Output (AOUT), ZSSC3281 provides an option to externally supply a negative voltage rail for the AOUT buffer at VDDN. VDDN supply specifications are shown in 55.

The negative VDDN voltage can also be generated by an internal charge pump circuit. The internal charge pump can be activated through GUI field: Configure\AOUT\VDDN Charge Pump.

The charge pump function is only available for all AOUT Operation Modes with Voltage Output. The charge pump circuit requires an external buffer capacitor  $C_{VDDN}$  and a Schottky Diode to work properly.

If no True-0V signals are required at AOUT, the user must directly connect VDDN with VSS on PCB level.

## 14 Package Information

### 14.1 Package Outline Drawings

The package outline drawings are accessible from the link below. The package information is the most current data available.

QFN40: [Package Outline Drawing Code: NDG40S1 40-VFQFPN 5.0 x 5.0 x 0.9 mm Body, 0.4 mm Pitch \(renesas.com\)](#)

WLCSP: [Package Outline Drawing Code: AWG48D1 48-DSBGA 3.61 x 3.24 x 0.6 mm Body, 0.4 mm Pitch \(renesas.com\)](#)

### 14.2 QFN40 Marking Diagram



Figure 67: QFN40 Marking Diagram

1. "ZSSC3281" C is the truncated part number.
2. "YyywwGR" where "Y" and "GR" are fixed and "yyww" represents the last digits of the year and week that the part was assembled.
3. "LOT" is the complete lot number of the part.

### 14.3 WLCSP Marking Diagram

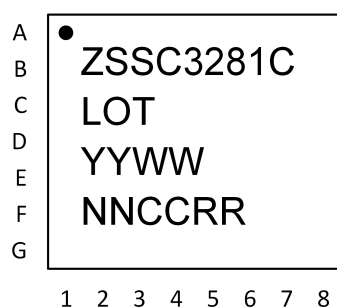


Figure 68: WLCSP Marking Diagram

1. "ZSSC3281C" is the truncated part number.
2. "LOT" is the complete lot number of the part.
3. "YYWW" represents the last digits of the year and week that the part was assembled.
4. "NNCCRR" contains the wafer position information:
  - "NN": Scribe Number
  - "CC": Column of die location
  - "RR": Row of die location

## 15 Glossary, References and History

### 15.1 Glossary

Term	Description
ADC	Analog to Digital Converter
AFE	Analog Front End
ARM	Provider of microcontroller core
AUX	Auxiliary measurement, in addition to main sensor bridge measurement
AZ	Auto-zero
BLOB	Binary Large Object
BOT	Bottom
CCP	Configuration and Calibration Page
DAC	Digital to Analog Converter
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FB	Feedback input for analog output buffer
FS	Full Scale
FW	Firmware
GPIO	General Purpose Input Output
GUI	Graphical User Interface
HF	High Frequency
HW	Hardware
I2C	Inter Integrated Circuit communication protocol
ID	Identification
IIR	Infinite Impulse Response
ISDU	Indexed Service Data Unit
LDR	Lower Diagnostic Range
LF	Low Frequency
LSB	Least Significant Bit
MISO	Master-In Slave-Out
MOSI	Master-Out Slave-In
MSB	Most Significant Bit
OWI	One Wire Interface
PGA	Programmable Gain Amplifier
PHY	Physical Layer
POR	Power-On-Reset
PTAT	Proportional to absolute temperature current source
R	Read
RAM	Random Access Memory
RCA	Renesas Code Area
RDAC	Resistive Digital to Analog Converter
RTD	Temperature dependent resistor
RW	Read/Write
SM-	Main Sensor Measurement, inverted signal polarity
SM+	Main Sensor Measurement, standard (non-inverted) signal polarity
SOT	Second Order Term
SPI	Serial Peripheral Interface
SS	Slave Select
SSC	Sensor Signal Conditioner
SSP	Smart Sensor Profile

Continued on next page

Term	Description
TFW	Technology Firmware
TLC	Third Logic Channel
UART	Universal Asynchronous Receiver / Transmitter
UDR	Upper Diagnostic Range
W	Write
WURQ	Wake-Up Request

## 15.2 Firmware Revision History

Revision	Date	Description
1.5.0	January 31, 2025	Initial release revision C
1.4.0	November, 2023	Latest release for revision B

## 15.3 Document Revision History

Revision	Date	Description
2.0	July 7, 2025	Initial release revision C
1.3	March 13, 2023	Latest release for revision B