

# SIG7293: 9.6kSPS, 24-bit Sigma-Delta ADC with PGA

## FEATURES

- Programmable Gain: 1/2/4/8/16/32/64/128**
- Data Rates: 9.4SPS to 9.6kSPS**
- RMS Noise: 12nV at 10SPS (Gain=128)**
- 22.9 noise-free bits at 10SPS (Gain=1)**
- Offset Drift: 3nV/°C (Gain=128)**
- Gain Drift: 0.5ppm/°C**
- Integral Non-Linearity: 3ppm**
- Internal or External Clock**
- Simultaneous 50Hz/60Hz Rejection**
- 4 Differential/8 Pseudo Differential Inputs**
- Automatic Channel Sequencer**
- Burnout Current Sources**
- 4 General Purpose Digital Outputs**
- Parity Check**
- Power Supply**
  - AVDD: 2.7V to 5.25V or ±2.5V**
  - DVDD: 2.7V to 5.25V**
- Current: 4.8mA**
- Package: 28-lead TSSOP**

## APPLICATIONS

- Weigh Scales**
- Strain Gauges**
- Temperature Measurement**
- Industrial Process Control**
- Pressure Sensors**

## DESCRIPTION

The SIG7293 is a low noise, low drift, and high-resolution 24-bit analog-to-digital converter (ADC) with integrated programmable gain amplifier (PGA) that offers high-accuracy measurement solutions for bridge sensors, thermocouples, and resistance temperature devices (RTD).

The device contains a low noise PGA with gains selected from 1, 2, 4, 8, 16, 32, 64, and 128, a delta-sigma ( $\Delta\Sigma$ ) modulator, and a programmable digital SINC4/SINC3/fast settling filter. 50Hz/60Hz simultaneous rejection option is also provided. The output data rate from the device can be configured from 9.4SPS up to 4800SPS. This device provides channel sequencer feature to measure four differential inputs or eight pseudo differential inputs automatically. Burnout current sources are provided at the analog inputs for sensor connection diagnosis.

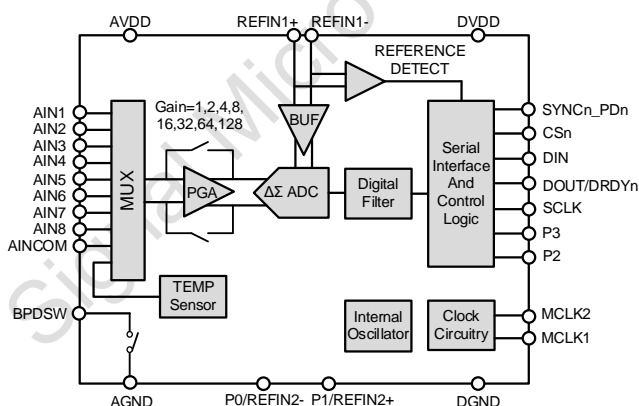
Offset and gain calibration registers are provided with calibration command or direct register write to calibrate the ADC errors or overall system errors. SPI-compatible interface is used for device configuration and parity check is provided for data integrity.

The on-chip oscillator, an external clock, or an external crystal can be used as the clock source to the device.

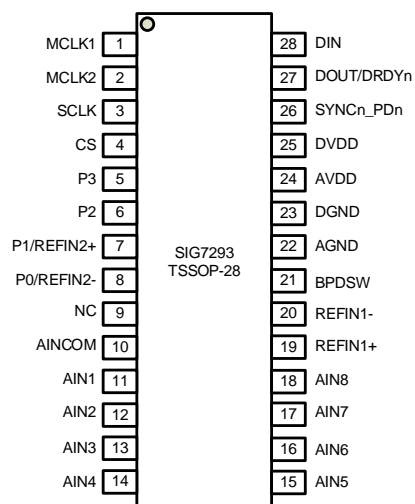
The device can operate with bipolar  $\pm 1.35V$  to  $\pm 2.625V$  analog power supplies, or with a single 2.7V to 5.25V analog power supply.

The SIG7293 is available in 28-lead TSSOP package and is fully specified over the  $-40^{\circ}C$  to  $+125^{\circ}C$  temperature range.

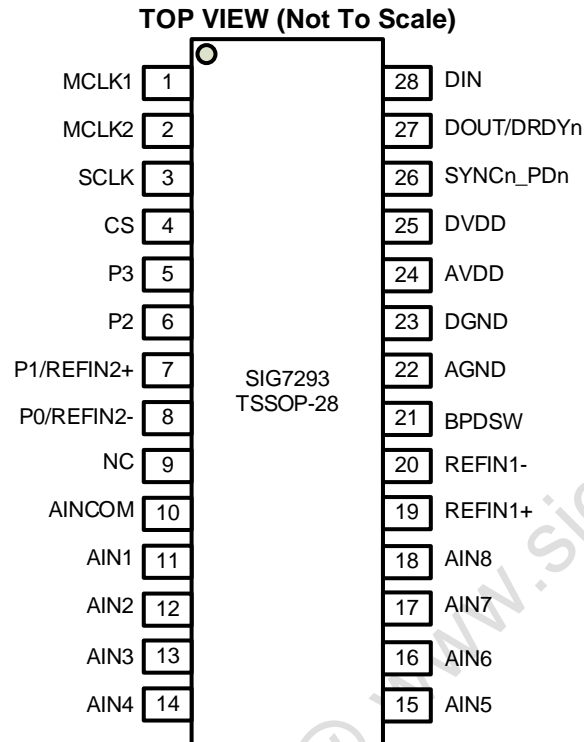
**Function Block Diagram**



**TSSOP-28**



## PIN CONFIGURATION and DESCRIPTIONS



PIN		FUNCTION	DESCRIPTION
NO.	NAME		
1	MCLK1	Digital Input	Crystal Connection.
2	MCLK2	Digital Input/Output	Master clock input or internal clock output depending on <a href="#">MODE Register</a> bits CLK[1:0].
3	SCLK	Digital Input	Serial data clock.
4	CSn	Digital Input	Serial chip select. Active low.
5	P3	Analog Output	General purpose output bit between AVDD and AGND.
6	P2	Analog Output	General purpose output bit between AVDD and AGND.
7	P1/REFIN2+	Analog Input/Output	General purpose output bit between AVDD and AGND or second positive reference input.
8	P0/REFIN2-	Analog Input/Output	General purpose output bit between AVDD and AGND or second negative reference input.
9	NC	Analog	No connection (float) or connect to AVDD/AGND.
10	AINCOM	Analog Input	Negative analog input for pseudo differential operation.
11	AIN1	Analog Input	Analog input channel 1.
12	AIN2	Analog Input	Analog input channel 2.
13	AIN3	Analog Input	Analog input channel 3.
14	AIN4	Analog Input	Analog input channel 4.
15	AIN5	Analog Input	Analog input channel 5.
16	AIN6	Analog Input	Analog input channel 6.
17	AIN7	Analog Input	Analog input channel 7.
18	AIN8	Analog Input	Analog input channel 8.
19	REFIN1+	Analog Input	Positive reference input.
20	REFIN1-	Analog Input	Negative reference input.
21	BPDSW	Analog Input	Bridge Power-down switch to AGND.

22	AGND	Analog	Negative analog power supply. AGND can be taken below DVSS to provide bipolar power supplies. For example, AGND can be tied to -2.5V and AVDD can be tied to +2.5V, providing a $\pm 2.5V$ dual supplies to the ADC.
23	DGND	Digital	Digital ground reference point.
24	AVDD	Analog	Positive analog power supply. 2.7V to 5.25V relative to AGND. AVDD is independent of DVDD.
25	DVDD	Digital	Digital power supply, 2.7V to 5.25V. DVDD is independent of AVDD.
26	SYNCn_PDN	Digital Input	Synchronization control signal, hold low for 0.83ms to enter power-down.
27	DOUT/DRDYn	Digital Output	Serial data output and data ready indicator.
28	DIN	Digital Input	Serial data input.

## PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKING OPTION
SIG7293	TSSOP-28	-40°C to +125°C	SIG7293-ITSP28-RL	Reel, 3000

## SPECIFICATIONS

### Absolute Maximum Ratings

Over operating free-air temperature range, unless otherwise noted.<sup>(1)</sup>

		MIN	MAX	UNIT
Voltage	AVDD to AGND	-0.3	6.5	V
	AGND to DGND	-3	0.3	V
	DVDD to DGND	-0.3	6.5	V
	Analog input	$V_{AGND} - 0.3$	$V_{AVDD} + 0.3$	V
	Digital input	$V_{DGND} - 0.3$	$V_{DVDD} + 0.3$	V
Current	Input current	-10	10	mA
Temperature	Junction ( $T_J$ )	-50	150	°C
	Storage ( $T_{stg}$ )	-60	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### ESD Ratings

SYMBOL	PARAMTER	CONDITION	VALUE	UNIT
HBM	Human-body model	ANSI/ESDA/JEDEC JS-001	±8000	V
CDM	Charged-device model	JEDEC EIA/JESD22-C101F	±2000	V
MM	Machine model	JEDEC EIA/JESD22-A115C	±600	V



This integrated circuit can be damaged by ESD. Signal Micro recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## Electrical Characteristics

Minimum/Maximum specifications apply from -40°C to +125°C. Typical specifications are at +25°C. All specifications are at  $V_{AVDD}=5V$ ,  $V_{AGND}=0V$ ,  $V_{DVDD}=3.3V$ ,  $V_{REF}=2.5V$ ,  $f_{CLK}=4.9152MHz$ , data rate=10SPS, and PGA Gain=1, unless otherwise noted.

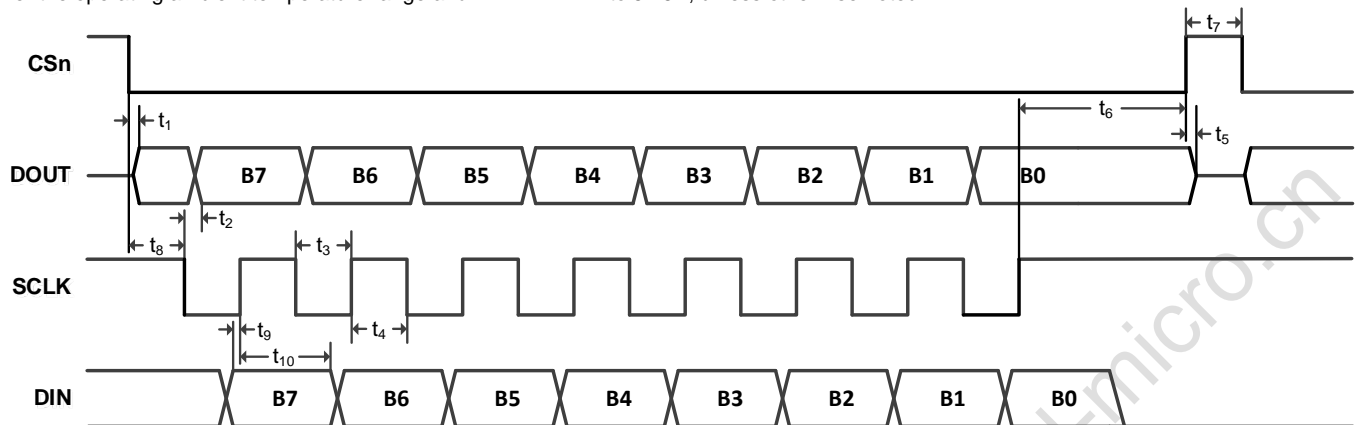
PARAMETER	TEST CONDITION OR NOTES	MIN <sup>(1)</sup>	TYP	MAX <sup>(1)</sup>	UNITS
<b>ANALOG INPUTS</b>					
Differential Input Voltage	$V_{IN} = V_{INP} - V_{INN}$	$-V_{REF}/Gain$		$+V_{REF}/Gain$	V
Absolute Input Voltage	Buffer Off, Gain = 1	$V_{AGND} - 0.05$		$V_{AVDD} + 0.05$	V
	Buffer On	$V_{AGND} + 0.5$		$V_{AVDD} - 0.5$	V
Common Mode Input Range	Buffer On	$V_{AGND} + 0.5 +  V_{INMAX}  \cdot Gain/2$		$V_{AVDD} - 0.5 -  V_{INMAX}  \cdot Gain/2$	V
Absolute Input Current	Buffer off, Gain = 1		$\pm 100$		nA
	Buffer On		$\pm 2$		nA
<b>SYSTEM PERFORMANCE</b>					
PGA Gain			1/2/4/8/16/32/64/128		V/V
Resolution			24		Bits
Data Rate		9.4		9600	SPS
Noise			See Noise Table		
Integral Nonlinearity (INL)	Buffer Off, Gain=1		$\pm 10$		ppm
	Buffer On		$\pm 2$		ppm
Offset Error	All PGA gains		$\pm 150/Gain$		$\mu V$
	After calibration		In order of noise		
Offset Drift vs. Temperature	All PGA gains		$\pm 150/Gain \pm 2$		nV/°C
Gain Error <sup>(2)</sup>	Gain = 1, 2, and 4	-200	$\pm 60$	-200	ppm
	Gain = 8, 16, and 32	-250	$\pm 100$	-250	
	Gain = 64 and 128	-350	$\pm 200$	-350	
Gain Mismatch <sup>(2)</sup>	All PGA gains		150	350	ppm
Gain Drift vs. Temperature	All PGA gains	-3	$\pm 0.5$	+3	ppm/°C
Normal Mode Rejection (NMRR)	$f_{IN} = 50/60Hz, \pm 2\%$ , data rate=10SPS		See Table 21		dB
Common Mode Rejection (CMRR)	$f_{IN} = 50Hz$ , data rate = 1200SPS	100	120		dB
Power Supply Rejection (PSRR)	AVDD, AGND	85	105		dB
	DVDD	90	110		dB
<b>REFERENCE INPUT</b>					
Differential Reference Voltage ( $V_{REF}$ )	$V_{REF} = V_{REFP} - V_{REFN}$	0.5		$V_{AVDD} - V_{AGND} + 0.1$	V
Absolute Negative Reference Voltage ( $V_{REFN}$ )		$V_{AGND} - 0.05$		$V_{REFP} - 0.5$	V
Absolute Positive Reference Voltage ( $V_{REFP}$ )		$V_{REFN} + 0.5$		$V_{AVDD} + 0.05$	V
Average Voltage Input Current			$\pm 1$		$\mu A$
<b>Burnout Current Sources</b>					
Current Setting			1		$\mu A$
<b>ADC CLOCK</b>					
External Clock	Frequency Range	1	4.9152	5.0	MHz
	Duty Cycle	40%		60%	
Internal Oscillator	Nominal Frequency		4.9152		MHz
	Accuracy	-3%	$\pm 0.5\%$	3%	
Crystal Oscillation	Frequency Range	1	4.9152	2.5	MHz
	Start-up Time		20		ms
<b>DIGITAL INPUT/OUTPUT</b>					
High-level Output Voltage ( $V_{OH}$ )	$I_{OH} = 4mA$	$0.8 \cdot V_{DVDD}$			V
Low-level Output Voltage ( $V_{OL}$ )	$I_{OL} = -4mA$			$0.2 \cdot V_{DVDD}$	V

High-level Input Voltage ( $V_{IH}$ )		$0.7 \cdot V_{DVDD}$		$V_{DVDD}$	V
Low-level Input Voltage ( $V_{IL}$ )		$V_{DGND}$		$0.3 \cdot V_{DVDD}$	V
Input Hysteresis			0.5		V
Input Leakage				$\pm 10$	$\mu A$
<b>POWER SUPPLY</b>					
AGND Voltage ( $V_{AGND}$ )		-2.625		0	V
AVDD Voltage ( $V_{AVDD}$ )		$V_{AGND} + 2.7$		$V_{AGND} + 5.25$	V
DVDD Voltage ( $V_{DVDD}$ )		2.7		5.25	V
AVDD, AGND Current ( $I_{AVDD}$ )	Buffer Off		1.8	2.5	mA
	Buffer On		4.5	5.6	mA
	Sleep Mode		1		$\mu A$
	Power-down Mode		1		$\mu A$
DVDD Current ( $I_{DVDD}$ )	Active Mode		330	450	$\mu A$
	Sleep Mode		50		$\mu A$
	Power-down Mode		5		$\mu A$
Total Power Dissipation	Buffer Off		10		mW
	Buffer On		23.6		mW
	Sleep Mode		0.16		mW
	Power-down Mode		0.02		mW
<b>TEMPERATURE RANGE</b>					
Specified temperature range		-40		125	$^{\circ}C$
Operating temperature range		-50		125	$^{\circ}C$
Storage temperature range		-60		150	$^{\circ}C$

- (1) Compliance to datasheet limits is assured by one or more methods: production test, characterization and/or design.  
(2) MIN and MAX values listed for gain error are for +25 $^{\circ}C$  room temperature only.

## Timing Requirements: Serial Interface

Over the operating ambient temperature range and DVDD = 2.7V to 5.25V, unless otherwise noted.



**Figure 1. Serial Interface Timing Requirements**

SYMBOL	DESCRIPTION	MIN	MAX	UNIT
t <sub>1</sub>	CSn falling edge to DOUT/DRDYn driven: propagation delay <sup>(1)</sup>		50	ns
t <sub>2</sub>	SCLK falling edge to valid DOUT/DRDYn: propagation delay <sup>(1)</sup>		50	ns
t <sub>3</sub>	SCLK low pulse width	100		ns
t <sub>4</sub>	SCLK high pulse width	100		ns
	SCLK period	200	10 <sup>6</sup>	ns
t <sub>5</sub>	CSn rising edge to DOUT high impedance: propagation delay		40	ns
t <sub>6</sub>	Last SCLK rising edge to CSn rising edge: delay time	50		ns
t <sub>7</sub>	CSn high pulse width	50		ns
t <sub>8</sub>	CSn falling edge to first SCLK falling edge: setup time <sup>(2)</sup>	50		ns
t <sub>9</sub>	Valid DIN to SCLK rising edge: setup time	50		ns
t <sub>10</sub>	Valid DIN to SCLK rising edge: hold time	25		ns

(1) DOUT load = 20pF || 100kΩ to DGND.

(2) CSn can be tied low.

## NOISE PERFORMANCE

The noise performance of the ADC is affected by PGA gain, data rate, and digital filter setting. The following tables show the rms noise and peak-to-peak noise for SINC4 and SINC3 filters and fast settling mode with chop disabled. The effective number of bits (ENOB) and noise-free bits are also listed according to Equation (1) and Equation (2):

$$\text{ENOB} = \log_2(2 \times V_{\text{REF}} / \text{Gain} / V_{\text{RMS}}) \quad (1)$$

$$\text{Noise Free Bits} = \log_2(2 \times V_{\text{REF}} / \text{Gain} / V_{\text{p-p}}) \quad (2)$$

The noise data listed in the table are typical and are generated from continuous ADC readings with differential input voltage of 0 V. With chop enabled, the resolution improves by 0.5 bits.

### SINC4 and Chop Disabled

**Table 1. ADC Noise in  $\mu\text{VRMS}$  ( $\mu\text{VPP}$ ) at  $T_A = 25^\circ\text{C}$ ,  $V_{\text{AVDD}} = 5\text{ V}$ ,  $V_{\text{REF}} = 5\text{ V}$ , SINC4 Filter, Chop Disabled**

Filter Word	Data Rate (SPS)	PGA GAIN							
		1	2	4	8	16	32	64	128
960	10	0.195(1.04)	0.141(0.848)	0.074(0.424)	0.045(0.259)	0.029(0.159)	0.021(0.121)	0.015(0.090)	0.012(0.064)
192	50	0.435(2.32)	0.314(1.90)	0.166(0.948)	0.101(0.579)	0.066(0.356)	0.046(0.270)	0.035(0.201)	0.028(0.143)
160	60	0.477(2.54)	0.344(2.08)	0.182(1.04)	0.110(0.635)	0.072(0.390)	0.051(0.296)	0.038(0.220)	0.031(0.157)
64	150	0.754(4.02)	0.544(3.28)	0.287(1.64)	0.175(1.00)	0.114(0.616)	0.080(0.468)	0.060(0.348)	0.048(0.248)
32	300	1.07(5.68)	0.770(4.65)	0.406(2.32)	0.247(1.42)	0.161(0.871)	0.113(0.662)	0.085(0.492)	0.068(0.351)
24	400	1.23(6.56)	0.889(5.36)	0.469(2.68)	0.285(1.64)	0.186(1.01)	0.131(0.764)	0.098(0.568)	0.079(0.405)
20	480	1.47(8.94)	1.01(5.36)	0.580(3.87)	0.307(1.79)	0.216(1.38)	0.143(0.857)	0.109(0.633)	0.085(0.508)
12	800	1.93(12.5)	1.20(8.35)	0.701(4.17)	0.403(2.46)	0.263(1.45)	0.182(1.16)	0.135(0.903)	0.106(0.652)
10	960	1.98(11.9)	1.40(9.54)	0.778(4.77)	0.450(3.28)	0.308(2.01)	0.198(1.19)	0.151(0.969)	0.120(0.773)
5	1920	2.99(19.1)	1.87(11.6)	1.08(7.15)	0.636(4.40)	0.407(2.46)	0.278(1.83)	0.205(1.38)	0.172(1.11)
4	2400	3.16(21.5)	2.12(14.6)	1.20(8.79)	0.717(4.92)	0.461(3.13)	0.309(2.18)	0.230(1.59)	0.189(1.19)
2	4800	6.87(48.9)	3.92(26.5)	2.18(15.6)	1.19(9.24)	0.723(6.71)	0.458(3.84)	0.339(2.38)	0.269(2.09)
1	9600	57.6(550)	28.8(268)	14.7(119)	7.50(135)	3.89(45.8)	1.92(14.6)	1.00(6.58)	0.585(4.13)

**Table 2. ADC ENOB (Noise Free Bits) at  $T_A = 25^\circ\text{C}$ ,  $V_{\text{AVDD}} = 5\text{ V}$ ,  $V_{\text{REF}} = 5\text{ V}$ , SINC4 Filter, Chop Disabled**

Filter Word	Data Rate (SPS)	PGA GAIN							
		1	2	4	8	16	32	64	128
960	10	25.6(23.2)	25.1(22.5)	25.0(22.5)	24.7(22.2)	24.3(21.9)	23.8(21.3)	23.3(20.7)	22.6(20.2)
192	50	24.5(22.0)	23.9(21.3)	23.8(21.3)	23.6(21.0)	23.2(20.7)	22.7(20.1)	22.1(19.6)	21.4(19.1)
160	60	24.3(21.9)	23.8(21.2)	23.7(21.2)	23.4(20.9)	23.0(20.6)	22.6(20.0)	22.0(19.4)	21.3(18.9)
64	150	23.7(21.2)	23.1(20.5)	23.1(20.5)	22.8(20.2)	22.4(20.0)	21.9(19.3)	21.3(18.8)	20.6(18.3)
32	300	23.2(20.7)	22.6(20.0)	22.6(20.0)	22.3(19.7)	21.9(19.5)	21.4(18.8)	20.8(18.3)	20.1(17.8)
24	400	23.0(20.5)	22.4(19.8)	22.3(19.8)	22.1(19.5)	21.7(19.2)	21.2(18.6)	20.6(18.1)	19.9(17.6)
20	480	22.7(20.1)	22.2(19.8)	22.0(19.3)	22.0(19.4)	21.5(18.8)	21.1(18.5)	20.5(17.9)	19.8(17.2)
12	800	22.3(19.6)	22.0(19.2)	21.8(19.2)	21.6(19.0)	21.2(18.7)	20.7(18.0)	20.1(17.4)	19.5(16.9)
10	960	22.3(19.7)	21.8(19.0)	21.6(19.0)	21.4(18.5)	21.0(18.2)	20.6(18.0)	20.0(17.3)	19.3(16.6)
5	1920	21.7(19.0)	21.3(18.7)	21.1(18.4)	20.9(18.1)	20.6(18.0)	20.1(17.4)	19.5(16.8)	18.8(16.1)
4	2400	21.6(18.8)	21.2(18.4)	21.0(18.1)	20.7(18.0)	20.4(17.6)	19.9(17.1)	19.4(16.6)	18.7(16.0)
2	4800	20.5(17.6)	20.3(17.5)	20.1(17.3)	20.0(17.0)	19.7(16.5)	19.4(16.3)	18.8(16.0)	18.1(15.2)
1	9600	17.4(14.1)	17.4(14.2)	17.4(14.4)	17.3(13.2)	17.3(13.7)	17.3(14.4)	17.2(14.5)	17.0(14.2)



**SINC3 and Chop Disabled**
**Table 3. ADC Noise in  $\mu\text{VRMS}$  ( $\mu\text{VPP}$ ) at  $T_A = 25^\circ\text{C}$ ,  $V_{\text{AVDD}} = 5\text{ V}$ ,  $V_{\text{REF}} = 5\text{ V}$ , SINC3 Filter, Chop Disabled**

Filter Word	Data Rate (SPS)	PGA GAIN							
		1	2	4	8	16	32	64	128
960	10	0.233(1.32)	0.145(0.801)	0.090(0.518)	0.049(0.295)	0.034(0.212)	0.022(0.112)	0.016(0.094)	0.014(0.077)
192	50	0.521(2.95)	0.324(1.79)	0.201(1.16)	0.111(0.659)	0.076(0.474)	0.049(0.250)	0.036(0.211)	0.030(0.171)
160	60	0.571(3.23)	0.355(1.96)	0.220(1.27)	0.121(0.722)	0.084(0.519)	0.054(0.274)	0.040(0.231)	0.033(0.187)
64	150	0.903(5.11)	0.561(3.10)	0.348(2.01)	0.192(1.14)	0.132(0.821)	0.086(0.434)	0.063(0.365)	0.053(0.296)
32	300	1.28(7.23)	0.793(4.39)	0.493(2.84)	0.271(1.61)	0.187(1.16)	0.121(0.613)	0.089(0.516)	0.074(0.419)
24	400	1.47(8.35)	0.916(5.07)	0.569(3.28)	0.313(1.86)	0.216(1.34)	0.140(0.708)	0.103(0.596)	0.086(0.484)
20	480	1.59(9.54)	0.978(5.07)	0.575(3.73)	0.354(2.09)	0.232(1.19)	0.136(0.838)	0.113(0.754)	0.091(0.545)
12	800	1.95(11.9)	1.34(9.24)	0.798(4.62)	0.448(2.83)	0.291(2.09)	0.191(1.34)	0.144(0.941)	0.124(0.894)
10	960	2.32(13.7)	1.49(9.54)	0.841(4.92)	0.472(2.53)	0.317(1.94)	0.215(1.17)	0.163(0.959)	0.127(0.806)
5	1920	5.51(31.6)	2.96(20.9)	1.60(9.39)	0.883(5.59)	0.528(3.61)	0.329(1.97)	0.228(1.78)	0.183(1.32)
4	2400	9.25(53.6)	4.85(31.3)	2.49(17.1)	1.31(8.87)	0.732(4.77)	0.426(3.06)	0.276(1.84)	0.212(1.63)
2	4800	69.1(399)	35.0(196)	17.3(95.2)	8.48(46.1)	4.35(25.7)	2.19(12.3)	1.13(6.79)	0.603(3.63)
1	9600	568(3000)	283(1600)	135(763)	69.8(387)	34.4(188)	17.2(90.9)	8.64(47.7)	4.38(26.1)

**Table 4. ADC ENOB (Noise Free Bits) at  $T_A = 25^\circ\text{C}$ ,  $V_{\text{AVDD}} = 5\text{ V}$ ,  $V_{\text{REF}} = 5\text{ V}$ , SINC3 Filter, Chop Disabled**

Filter Word	Data Rate (SPS)	PGA GAIN							
		1	2	4	8	16	32	64	128
960	10	25.4(22.9)	25.0(22.6)	24.7(22.2)	24.6(22.0)	24.1(21.5)	23.8(21.4)	23.2(20.7)	22.5(20.0)
192	50	24.2(21.7)	23.9(21.4)	23.6(21.0)	23.4(20.9)	23.0(20.3)	22.6(20.3)	22.0(19.5)	21.3(18.8)
160	60	24.1(21.6)	23.7(21.3)	23.4(20.9)	23.3(20.7)	22.8(20.2)	22.5(20.1)	21.9(19.4)	21.2(18.7)
64	150	23.4(20.9)	23.1(20.6)	22.8(20.2)	22.6(20.1)	22.2(19.5)	21.8(19.5)	21.2(18.7)	20.5(18.0)
32	300	22.9(20.4)	22.6(20.1)	22.3(19.7)	22.1(19.6)	21.7(19.0)	21.3(19.0)	20.7(18.2)	20.0(17.5)
24	400	22.7(20.2)	22.4(19.9)	22.1(19.5)	21.9(19.4)	21.5(18.8)	21.1(18.8)	20.5(18.0)	19.8(17.3)
20	480	22.6(20.0)	22.3(19.9)	22.1(19.4)	21.8(19.2)	21.4(19.0)	21.1(18.5)	20.4(17.7)	19.7(17.1)
12	800	22.3(19.7)	21.8(19.0)	21.6(19.0)	21.4(18.8)	21.0(18.2)	20.6(17.8)	20.0(17.3)	19.3(16.4)
10	960	22.0(19.5)	21.7(19.0)	21.5(19.0)	21.3(18.9)	20.9(18.3)	20.5(18.0)	19.9(17.3)	19.2(16.6)
5	1920	20.8(18.3)	20.7(17.9)	20.6(18.0)	20.4(17.8)	20.2(17.4)	19.9(17.3)	19.4(16.4)	18.7(15.9)
4	2400	20.0(17.5)	20.0(17.3)	19.9(17.2)	19.9(17.1)	19.7(17.0)	19.5(16.6)	19.1(16.4)	18.5(15.5)
2	4800	17.1(14.6)	17.1(14.6)	17.1(14.7)	17.2(14.7)	17.1(14.6)	17.1(14.6)	17.1(14.5)	17.0(14.4)
1	9600	14.1(11.7)	14.1(11.6)	14.2(11.7)	14.1(11.7)	14.2(11.7)	14.2(11.7)	14.1(11.7)	14.1(11.5)

**Fast Settling, Average=16, SINC4 and Chop Disabled**
**Table 5. ADC Noise in  $\mu\text{VRMS}$  ( $\mu\text{VPP}$ ) at  $T_A = 25^\circ\text{C}$ ,  $V_{\text{AVDD}} = 5\text{ V}$ ,  $V_{\text{REF}} = 5\text{ V}$ , SINC4 Filter, Chop Disabled**

Filter Word	Data Rate (SPS)	PGA GAIN							
		1	2	4	8	16	32	64	128
192	3.125	0.202(0.800)	0.116(0.533)	0.069(0.333)	0.040(0.200)	0.023(0.108)	0.015(0.071)	0.011(0.044)	0.010(0.042)
60	10	0.369(1.46)	0.211(0.973)	0.127(0.608)	0.074(0.365)	0.042(0.198)	0.027(0.129)	0.020(0.080)	0.018(0.076)
12	50	0.826(3.26)	0.473(2.18)	0.283(1.36)	0.165(0.816)	0.094(0.442)	0.061(0.289)	0.046(0.179)	0.040(0.170)
10	60	0.905(3.58)	0.518(2.38)	0.310(1.49)	0.181(0.894)	0.103(0.484)	0.067(0.317)	0.050(0.196)	0.044(0.186)
4	150	1.17(7.15)	0.789(3.58)	0.446(2.68)	0.228(1.19)	0.158(0.931)	0.101(0.503)	0.075(0.410)	0.072(0.438)
2	300	1.55(8.94)	1.07(6.56)	0.639(3.43)	0.359(2.24)	0.233(1.30)	0.157(0.857)	0.112(0.577)	0.096(0.522)

**Table 6. ADC ENOB (Noise Free Bits) at  $T_A = 25^\circ\text{C}$ ,  $V_{\text{AVDD}} = 5\text{ V}$ ,  $V_{\text{REF}} = 5\text{ V}$ , SINC4 Filter, Chop Disabled**

Filter Word	Data Rate (SPS)	PGA GAIN							
		1	2	4	8	16	32	64	128
192	3.125	25.6(23.6)	25.4(23.2)	25.1(22.8)	24.9(22.6)	24.7(22.5)	24.3(22.1)	23.7(21.8)	22.9(20.8)
60	10	24.7(22.7)	24.5(22.3)	24.2(22.0)	24.0(21.7)	23.8(21.6)	23.4(21.2)	22.9(20.9)	22.1(20.0)
12	50	23.5(21.5)	23.3(21.1)	23.1(20.8)	22.9(20.5)	22.7(20.4)	22.3(20.0)	21.7(19.7)	20.9(18.8)
10	60	23.4(21.4)	23.2(21.0)	22.9(20.7)	22.7(20.4)	22.5(20.3)	22.2(19.9)	21.6(19.6)	20.8(18.7)
4	150	23.0(20.4)	22.6(20.4)	22.4(19.8)	22.4(20.0)	21.9(19.4)	21.6(19.2)	21.0(18.5)	20.0(17.4)
2	300	22.6(20.1)	22.2(19.5)	21.9(19.5)	21.7(19.1)	21.4(18.9)	20.9(18.5)	20.4(18.0)	19.6(17.2)

## ON-CHIP REGISTER MAPS

There are total eight registers inside the device which is 8-bit or 24-bit wide. These registers are used to configure and control the ADC to the desired mode of operation. These registers can be accessed through the SPI-compatible serial interface by using register read and write commands. At power-on or reset, the registers default to their initial settings, as shown in the *Reset Value* column of [Table 7](#).

**Table 7. Register map**

ADDR.	NAME	DIR.	RESET VALUE	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0			
3'b000	STATUS	R	80	DRDYn	ERR	NOREF	PARITY	CHD[3:0]						
3'b001	MODE	R/W	080060	MD[2:0]			DATUS	CLK[1:0]		AVG[1:0]				
				SINC3	0	ENPAR	0	SINGLE	REJ60	FS[9:8]				
3'b010	CONFIG	R/W	000117	CHOP	0	0	REFSEL	0	PSEUDO	SHORT	TEMP			
				CH[7:0]										
				BCS	REFDET	0	BUF	FORMAT	PGA[2:0]					
3'b011	DATA	R	000000	DATA[23:16]										
				DATA[15:8]										
				DATA[7:0]										
3'b100	ID	R	X3	x	x	x	x	0	0	1	1			
3'b101	GPOCON	R/W	00	0	BPDSW	GP32EN	GP10EN	P3DAT	P2DAT	P1DAT	P0DAT			
3'b110	OFFSET	R/W	800000	OFFSET[23:16]										
				OFFSET[15:8]										
				OFFSET[7:0]										
3'b111	GAIN	R/W	555555	GAIN[23:16]										
				GAIN[15:8]										
				GAIN[7:0]										

## STATUS Register

**Table 8. STATUS Register (Address = 3'b000)**

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DRDYn	ERR	NOREF	PARITY	CHD[3:0]			

Power-On/Reset Value = 0x80

Bits	Bit Name	Access	Reset	Description
7	DRDYn	R	1'b1	<b>ADC Ready Bit:</b> This bit is cleared when new data is written to the ADC data register. It is set automatically after the ADC data register is read. In addition to this bit, DOUT/DRDYn pin can also be used as an alternative to monitor the update of new ADC data.
6	ERR	R	1'b0	<b>ADC Error Bit.</b> This bit is written at the same time as new data update. Error sources include input overrange, input underrange, or lower than expected reference voltage.
5	NOREF	R	1'b0	<b>No External Reference Bit:</b> The function of this bit is only enabled by setting the REFDET bit in the <a href="#">CONFIG Register</a> to 1. While the REFDET bit is 1 and the selected reference voltage is below a specified threshold, which is about 0.4V, this bit is set and conversion results are clamped to all 1s.
4	PARITY	R	1'b0	<b>Parity Check Bit:</b> The function of this bit is only enabled by setting the ENPAR bit in <a href="#">MODE Register</a> to 1. While the ENPAR bit is 1 and there is odd number of 1s in the data register, this bit is set. Otherwise it is always 0.
3:0	CHD[3:0]	R	4'b0000	<b>Data Channel Number:</b> These bits indicate the corresponding channel to the ADC data in data register (see <a href="#">Table 11</a> ).

**MODE Register**
**Table 9. MODE Register (Address = 3'b001)**

BIT 23	BIT 22	BIT 21	BIT 20	BIT 19	BIT18	BIT 17	BIT 16
BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT10	BIT 9	BIT 8
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
MD[2:0]			DATUS	CLK[1:0]		AVG[1:0]	
SINC3	0	ENPAR	0	SINGLE	REJ60	FS[9:8]	
FS[7:0]							

Power-On/Reset Value = 0x080060

Bits	Bit Name	Access	Reset	Description
23:21	MD[2:0]	R/W	3'b000	<b>Mode Select Bits:</b> These bits select the operating mode of the device. 000: Continuous conversion mode. (default) 001: Single conversion mode. ADC first wakeup if in idle or sleep mode; resets the filter to perform one conversion; and enters sleep mode. The conversion result remains in the data register with DOUT/DRDYn as low. 010: Idle mode. The digital filter is in reset state with ADC free running. 011: Sleep mode. Most of circuitry is turned off to save the power. BPDSW remains active in sleep mode. 100: Internal zero-scale calibration. 101: Internal full-scale calibration. 110: System zero-scale calibration. 111: System full-scale calibration. For each above calibration mode, DOUT/DRDYn goes high when the calibration is initiated and returns low when the calibration is complete. The ADC is automatically placed in idle mode after the calibration. The measured offset/full-scale coefficient is placed in the offset/full-scale register of the selected channel.
20	DATUS	R/W	1'b0	<b>Status Enable Bit:</b> When DATUS is set, the contents of the status register are transmitted along with each data register read.
19:18	CLK[1:0]	R/W	2'b10	<b>Clock Select Bits:</b> These bits select the clock source for SYSCLK. 00: External crystal applied between MCLK1 and MCLK2. 01: External clock applied to the MCLK2 pin. 10: Internal 4.9152MHz clock with MCLK2 tristated. (default) 11: Internal 4.9152MHz clock with its output on MCLK2 pin.
17:16	AVG[1:0]	R/W	2'b00	<b>Fast Settling Filter Setting:</b> In fast settling mode, a first-order average is added after the SINC filter to further improve the rms noise. It can work for any data rate select bits FS[9:0]. 00: Not averaging (default) 01: Average by 2 10: Average by 8 11: Average by 16
15	SINC3	R/W	1'b0	<b>SINC3 Enable Bit:</b> 0: SINC4 filter (default) 1: SINC3 filter
14	RESERVED	R/W	1'b0	<b>Reserved</b> Always write 1'b0
13	ENPAR	R/W	1'b0	<b>Enable Parity Bit:</b> This bit enables the parity check on the data register.
12	RESERVED	R/W	1'b0	<b>Reserved</b> Always write 1'b0

11	SINGLE	R/W	1'b0	<p><b>Single Cycle Conversion Bit:</b> When this bit is set, the ADC settles in one conversion cycle so that it functions as a zero latency ADC. When chop is disabled, fast settling mode is disabled, continuous conversion mode is selected, and SINGLE bit is set, the output data rate is</p> $\text{Output Data Rate} = \text{SYSCLK} / 512 / \text{FS}[9:0] / N$ <p>Where N is 3 for SINC3 filter and 4 for SINC4 filter. With a nominal SYSCLK of 4.9152MHz, default Data Rate bits 0x060=96, and SINC3 bit set to 0, output data rate is <math>4915200 / 512 / 96 / 4 = 25\text{SPS}</math>.</p>
10	REJ60	R/W	1'b0	<p><b>50/60Hz Notch Bit:</b> This bit can only be effective while FS[9:0]=0x0C0. A filter notch is placed at 60Hz to allow simultaneous 50Hz/60Hz rejection.</p>
9:0	FS[9:0]	R/W	0x060	<p><b>Data Rate Select Bits:</b> The 10 bits are used to configure the ADC data rate. When chop is disabled, fast settling mode is disabled, and continuous conversion mode is selected, the output data rate is</p> $\text{Output Data Rate} = \text{SYSCLK} / 512 / \text{FS}[9:0]$ <p>With a nominal SYSCLK of 4.9152MHz and default Data Rate bits 0x060=96, output data rate is <math>4915200 / 512 / 96 = 100\text{SPS}</math>.</p>

## CONFIG Register

**Table 10. CONFIG Register (Address = 3'b010)**

BIT 23	BIT 22	BIT 21	BIT 20	BIT 19	BIT 18	BIT 17	BIT 16
BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT 10	BIT 9	BIT 8
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
CHOP	0	0	REFSEL	0	PSEUDO	SHORT	TEMP
CH7	CH6	CH5	CH4	CH3	CH2	CH1	CH0
BURN	REFDET	0	BUF	FORMAT	PGA[2:0]		

Power-On/Reset Value = 0x000117

Bits	Bit Name	Access	Reset	Description
23	CHOP	R/W	1'b0	<p><b>Chop Enable Bit:</b> When this bit is enabled, the offset and offset drift of the ADC are dramatically improved with longer conversion time and settling time. For default data rate settling of 50SPS with SINC4 filter, the conversion time is 20ms and the settling time is 80ms with chop disabled. If chop is enabled, the conversion time is 80ms and the settling time is 160ms.</p>
22, 21	RESERVED	R/W	2'b00	<p><b>Reserved</b> Always write 2'b00</p>
20	REFSEL	R/W	1'b0	<p><b>Reference Select Bit:</b> Select the reference source for the ADC. 0: REFIN1+, REFIN1- (default) 1: REFIN2+, REFIN2-</p>
19	RESERVED	R/W	1'b0	<p><b>Reserved</b> Always write 1'b0</p>
18	PSEUDO	R/W	1'b0	<p><b>Pseudo Enable bit:</b> When the pseudo bit is set to 1, the device is configured to have eight pseudo differential analog inputs. When pseudo bit is set to 0, the device is configured to have four differential analog inputs.</p>
17:8	SHORT, TEMP, CH7 to CH0	R/W	0x01	<p><b>Channel Select Bits:</b> These bits select which channels are enabled for ADC conversion (see <a href="#">Table 11</a> and <a href="#">Table 12</a>). When more than one channel are enabled, ADC automatically sequences them and places the data into data register with corresponding channel information in STATUS register and append them during data register read if DATUS bit in <a href="#">MODE Register</a> is enabled. For calibrations, only one channel can be selected and the lowest bit channel is selected if more than one channels are enabled.</p>
7	BURN	R/W	1'b0	<p><b>Burnout Enable Bit:</b> When this bit is enabled, a pair of 1µA current</p>

sources are applied to analog inputs to source positive input and sink negative input.

6	REFDET	R/W	1'b0	<b>Reference Detection Enable Bit:</b> When this bit is enabled, the NOREF bit in the <a href="#">STATUS register</a> indicates when the reference input voltage is less than specified threshold, which is about 0.4V.
5	RESERVED	R/W	1'b0	<b>Reserved</b> Always write 1'b0
4	BUF	R/W	1'b0	<b>Buffer Enable Bit:</b> When this bit is set, analog input is buffered. Otherwise the input buffer is bypassed.
3	FORMAT	R/W	1'b0	<b>Data Format Bit:</b> This bit sets the ADC data format. 0: Bipolar mode (default) 1: Unipolar mode
2:0	PGA[2:0]	R/W	3'b111	<b>PGA Gain Configuration:</b> Selects the PGA gain. If PGA gain is set to other than 1, the BUF bit setting is ignored with buffer always enabled. 000: Gain=1 001: Gain=2 010: Gain=4 011: Gain=8 100: Gain=16 101: Gain=32 110: Gain=64 111: Gain=128 (default)

**Table 11. Channel Selection (Pseudo Bit =0)**

Channel	Channel Enabled		Status Register Bits CHD[3:0]	Calibration Register Pair
	Positive Input AIN+	Negative Input AIN-		
CH0=1	AIN1	AIN2	0000	0
CH1=1	AIN3	AIN4	0001	1
CH2=1	AIN5	AIN6	0010	2
CH3=1	AIN7	AIN8	0011	3
CH4=1	AIN1	AIN2	0100	0
CH5=1	AIN3	AIN4	0101	1
CH6=1	AIN5	AIN6	0110	2
CH7=1	AIN7	AIN8	0111	3
TEMP=1	Temperature Sensor		1000	
SHORT=1	AIN2	AIN2	1001	0

**Table 12. Channel Selection (Pseudo Bit =1)**

Channel	Channel Enabled		Status Register Bits CHD[3:0]	Calibration Register Pair
	Positive Input AIN+	Negative Input AIN-		
CH0=1	AIN1	AINCOM	0000	0
CH1=1	AIN2	AINCOM	0001	1
CH2=1	AIN3	AINCOM	0010	2
CH3=1	AIN4	AINCOM	0011	3
CH4=1	AIN5	AINCOM	0100	4
CH5=1	AIN6	AINCOM	0101	4
CH6=1	AIN7	AINCOM	0110	4

CH7=1	AIN8	AINCOM	0111	4
TEMP=1	Temperature Sensor		1000	
SHORT=1	AIN2	AIN2	1001	0

## DATA Register

**Table 13. DATA Register (Address = 3'b011)**

BIT 23	BIT 22	BIT 21	BIT 20	BIT 19	BIT 18	BIT 17	BIT 16
BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT 10	BIT 9	BIT 8
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DATA[23]	DATA[22]	DATA[21]	DATA[20]	DATA[19]	DATA[18]	DATA[17]	DATA[16]
DATA[15]	DATA[14]	DATA[13]	DATA[12]	DATA[11]	DATA[10]	DATA[9]	DATA[8]
DATA[7]	DATA[6]	DATA[5]	DATA[4]	DATA[3]	DATA[2]	DATA[1]	DATA[0]

Power-On/Reset Value = 0x000000

Bits	Bit Name	Access	Reset	Description
23:0	DATA[23:0]	R	0x000000	<b>Data Bits:</b> The 24-bit word is signed number in 2's complement format. See <a href="#">Data Format</a> section for more information.

## ID Register

**Table 14. ID Register (Address = 3'b100)**

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
x	x	x	x	0	0	1	1

Power-On/Reset Value = 0xX3

Bits	Bit Name	Access	Reset	Description
7:0	ID	R	8'bxxxx0011	<b>ID Bits:</b> Read only.

## GPOCON Register

**Table 15. GPOCON Register (Address = 3'b101)**

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
0	BPDSW	GP32EN	GP10EN	P3DAT	P2DAT	P1DAT	P1DAT

Power-On/Reset Value = 0x00

Bits	Bit Name	Access	Reset	Description
7	RESERVED	R/W	1'b0	<b>Reserved</b> Always write 1'b0
6	BPDSW	R/W	1'b0	<b>Bridge Power-down Switch Control Bit:</b> When this bit is set to 1, the switch is closed to short BPDSW to AGND with low on-resistor of typical 3 Ohms. The switch is open if the bit is cleared. The switch remains active in idle and sleep modes.
5	GP32EN	R/W	1'b0	<b>P3 and P2 Output Enable Bit:</b> When this bit is set to 1, the P3 and P2 pins are configured as outputs. When this bit is set to 0, the P3 and P2 pins are tri-state.
4	GP10EN	R/W	1'b0	<b>P1 and P0 Output Enable Bit:</b> When this bit is set to 1, the P1 and P0 pins are configured as outputs. When this bit is set to 0, the P1 and P0 pins are tri-state.
3	P3DAT	R/W	1'b0	<b>Data Output P3 Bit:</b> This bit sets the value of the P3 output pin if GP32EN bit is set to 1. During GPO register read, the P3DAT reflects the status of the P3 pin if GP32EN bit is set to 1.

2	P2DAT	R/W	1'b0	<b>Data Output P2 Bit:</b> This bit sets the value of the P2 output pin if GP32EN bit is set to 1. During GPO register read, the P2DAT reflects the status of the P2 pin if GP32EN bit is set to 1.
1	P1DAT	R/W	1'b0	<b>Data Output P1 Bit:</b> This bit sets the value of the P1 output pin if GP10EN bit is set to 1. During GPO register read, the P1DAT reflects the status of the P1 pin if GP10EN bit is set to 1.
0	P0DAT	R/W	1'b0	<b>Data Output P0 Bit:</b> This bit sets the value of the P0 output pin if GP10EN bit is set to 1. During GPO register read, the P0DAT reflects the status of the P0 pin if GP10EN bit is set to 1.

## OFFSET Register

The device has five OFFSET registers, each channel has a dedicated OFFSET register (see [Table 11](#) and [Table 12](#)). OFFSET register read is allowed anytime, but writing to OFFSET register is only allowed while the device is in idle or sleep mode.

**Table 16. OFFSET Register (Address = 3'b110)**

BIT 23	BIT 22	BIT 21	BIT 20	BIT 19	BIT18	BIT 17	BIT 16
BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT10	BIT 9	BIT 8
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
OFFSET[23]	OFFSET[22]	OFFSET[21]	OFFSET[20]	OFFSET[19]	OFFSET[18]	OFFSET[17]	OFFSET[16]
OFFSET[15]	OFFSET[14]	OFFSET[13]	OFFSET[12]	OFFSET[11]	OFFSET[10]	OFFSET[9]	OFFSET[8]
OFFSET[7]	OFFSET[6]	OFFSET[5]	OFFSET[4]	OFFSET[3]	OFFSET[2]	OFFSET[1]	OFFSET[0]

Power-On/Reset Value = 0x800000

Bits	Bit Name	Access	Reset	Description
23:0	OFFSET[23:0]	R/W	0x800000	<b>Offset Calibration Bits:</b> The 24-bit word is signed number in offset binary format. See <a href="#">Calibration</a> section for more information.

## GAIN Register

The device has five GAIN registers, each channel has a dedicated GAIN register (see [Table 11](#) and [Table 12](#)). GAIN register read is allowed anytime, but writing to GAIN register is only allowed while the device is in idle or sleep mode.

**Table 17. GAIN Register (Address = 3'b111)**

BIT 23	BIT 22	BIT 21	BIT 20	BIT 19	BIT18	BIT 17	BIT 16
BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT10	BIT 9	BIT 8
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
GAIN[23]	GAIN[22]	GAIN[21]	GAIN[20]	GAIN[19]	GAIN[18]	GAIN[17]	GAIN[16]
GAIN[15]	GAIN[14]	GAIN[13]	GAIN[12]	GAIN[11]	GAIN[10]	GAIN[9]	GAIN[8]
GAIN[7]	GAIN[6]	GAIN[5]	GAIN[4]	GAIN[3]	GAIN[2]	GAIN[1]	GAIN[0]

Power-On/Reset Value = 0x555555

Bits	Bit Name	Access	Reset	Description
23:0	GAIN[23:0]	R/W	0x555555	<b>Gain Calibration Bits:</b> The 24-bit word is unsigned positive number in binary format. See <a href="#">Calibration</a> section for more information.

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## REVISION HISTORY

The revision history provided is for informational purposes only and is believed to be accurate, but not warranted. Please contact to make sure you have the latest revision.

DATE	REVISION	CHANGE
Jul. 20, 2020		Initial release.

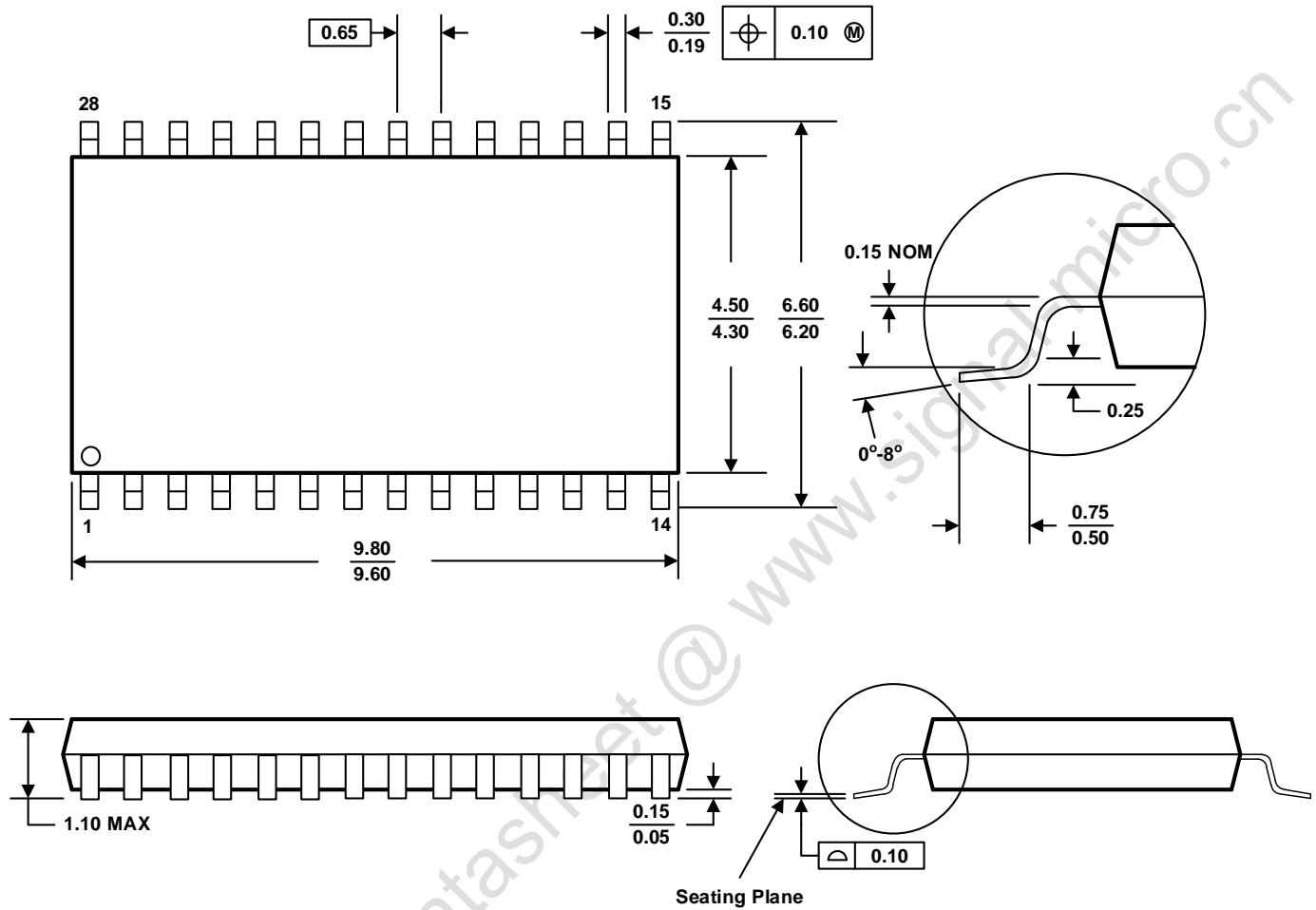
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**PACKAGE OUTLINE DIMENSIONS**



- A. Compliant to JEDEC STANDARDS MO-153-AD.
- B. All linear dimensions are in millimeters.
- C. This drawing is subject to change without notice.