



# SGM51610C

## Ultra-Small, Low-Power, 16-Bit

### Analog-to-Digital Converter with Internal Reference

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## GENERAL DESCRIPTION

The SGM51610C is a low-power, 16-bit, precision, sigma-delta ( $\Sigma\Delta$ ) analog-to-digital converter (ADC). It operates from a 2V to 5.5V supply.

The SGM51610C contains a very low-drift on-chip reference and oscillator. It has an I<sup>2</sup>C-compatible interface, and it can select four I<sup>2</sup>C slave addresses. The data rate of the filter is up to 960SPS. The SGM51610C has an on-chip PGA, which can provide input ranges to as low as  $\pm 256\text{mV}$  from the power supply.

The input multiplexer supports 4 single-ended inputs or 2 differential inputs configuration.

The SGM51610C is available in Green MSOP-10 and TDFN-3 $\times$ 3-10L packages. It operates over an ambient temperature range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

## FEATURES

- **Single-Supply Voltage Range: 2V to 5.5V**
  - ◆ I<sup>2</sup>C Bus Voltage Range: 2V to 5.5V
- **Low Quiescent Current:**
  - ◆ Continuous Mode: 310 $\mu\text{A}$  (TYP)
  - ◆ Power-Down Mode: 0.65 $\mu\text{A}$  (TYP)
- **Selectable Data Rates: 5SPS to 960SPS**
- **Single-Cycle Settling**
- **50/60Hz Line Rejection**
- **Input Multiplexer**
  - ◆ 4 Single-Ended Inputs or 2 Differential Inputs
- **Internal Programmable Gain Amplifier (PGA)**
- **Internal Voltage Reference and Oscillator**
- **Selectable Digital Comparator**
- **I<sup>2</sup>C-Compatible Serial Interface**
- **Available in Green MSOP-10 and TDFN-3 $\times$ 3-10L Packages**

## APPLICATIONS

Portable Devices  
Process Control  
Battery Monitoring System  
Temperature Measurement

# SGM51610C Ultra-Small, Low-Power, 16-Bit

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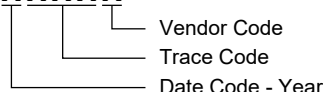
### PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM51610C	MSOP-10	-40°C to +125°C	SGM51610CXMS10G/TR	SGM0KS XMS10 XXXXX	Tape and Reel, 4000
			SGM51610CXMS10SG/TR	SGM0KS XMS10 XXXXX	Tape and Reel, 500
	TDFN-3×3-10L	-40°C to +125°C	SGM51610CXTD10G/TR	SGM 0KRD XXXXX	Tape and Reel, 4000
			SGM51610CXTD10SG/TR	SGM 0KRD XXXXX	Tape and Reel, 500

### MARKING INFORMATION

NOTE: XXXXX = Date Code, Trace Code and Vendor Code.

**XXXXX**



Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

### ABSOLUTE MAXIMUM RATINGS

Voltage Range (with Respect to GND)

$V_{DD}$ .....	-0.3V to 5.5V
Analog Input Voltage.....	-0.3V to 5.5V
SDA, SCL, ADDR, ALERT/RDY Voltage .....	-0.3V to 5.5V
Input Current (Momentary).....	100mA
Input Current (Continuous) .....	10mA
Package Thermal Resistance	
MSOP-10, $\theta_{JA}$ .....	139.4°C/W
MSOP-10, $\theta_{JB}$ .....	90.6°C/W
MSOP-10, $\theta_{JC}$ .....	47.7°C/W
TDFN-3×3-10L, $\theta_{JA}$ .....	39.5°C/W
TDFN-3×3-10L, $\theta_{JB}$ .....	16.8°C/W
TDFN-3×3-10L, $\theta_{JC (TOP)}$ .....	46.2°C/W
TDFN-3×3-10L, $\theta_{JC (BOT)}$ .....	4.7°C/W
Junction Temperature .....	+150°C
Storage Temperature Range .....	-65°C to +150°C
Lead Temperature (Soldering, 10s) .....	+260°C
ESD Susceptibility <sup>(1) (2)</sup>	
HBM .....	±4000V
CDM .....	±1000V

NOTES:

1. For human body model (HBM), all pins comply with ANSI/ESDA/JEDEC JS-001 specifications.
2. For charged device model (CDM), all pins comply with ANSI/ESDA/JEDEC JS-002 specifications.

### RECOMMENDED OPERATING CONDITIONS

Operating Temperature Range..... -40°C to +125°C

### OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

### ESD SENSITIVITY CAUTION

This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO 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 even small parametric changes could cause the device not to meet the published specifications.

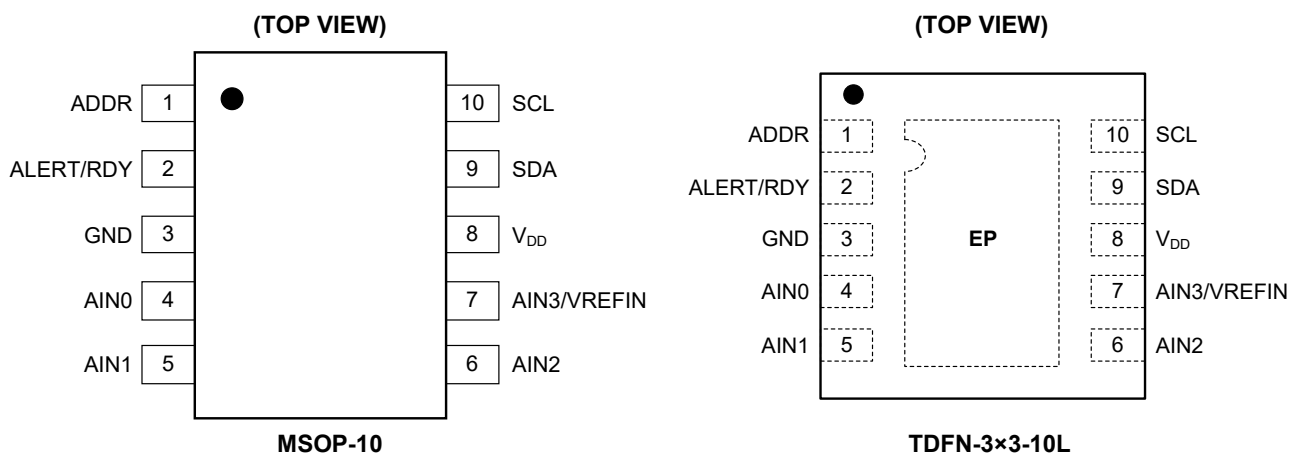
### DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, or specifications without prior notice.

# SGM51610C

## Ultra-Small, Low-Power, 16-Bit Analog-to-Digital Converter with Internal Reference

### PIN CONFIGURATIONS



### PIN DESCRIPTION

PIN		NAME	TYPE	FUNCTION
MSOP-10	TDFN-3x3-10L			
1	1	ADDR	DI	I <sup>2</sup> C Address Selection Pin.
2	2	ALERT/RDY	DO	Digital Comparator Output/Conversion Ready Pin.
3	3	GND	G	Ground.
4	4	AIN0	AI	Positive Input of Differential Channel 1 or Input of Single-Ended Channel 1.
5	5	AIN1	AI	Negative Input of Differential Channel 1 or Input of Single-Ended Channel 2.
6	6	AIN2	AI	Positive Input of Differential Channel 2 or Input of Single-Ended Channel 3.
7	7	AIN3/VREFIN	AI	Negative Input of Differential Channel 2 or Input of Single-Ended Channel 4, or External Reference Input.
8	8	V <sub>DD</sub>	P	Power Supply Pin. It can be operated from 2V to 5.5V.
9	9	SDA	DIO	Serial Data Pin.
10	10	SCL	DI	Serial Clock Input Pin.
—	Exposed Pad	EP	—	Exposed pad should be soldered to PCB board and connected to GND.

NOTE: AI = analog input, DI = digital input, DO = digital output, DIO = digital input and output, P = power, G = ground.

# SGM51610C

## Ultra-Small, Low-Power, 16-Bit Analog-to-Digital Converter with Internal Reference

### ELECTRICAL CHARACTERISTICS

( $V_{DD} = 3.3V$ ,  $DR = 5SPS$ , full-scale input voltage range (FSR) =  $\pm 2.048V$ , internal reference, maximum and minimum specifications apply from  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ , typical values are measured at  $T_A = +25^{\circ}C$ , unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Analog Input							
Full-Scale Input Voltage <sup>(1)</sup>		V <sub>IN</sub> = AIN <sub>P</sub> - AIN <sub>N</sub>			±4.096/PGA		V
Analog Input Voltage		AIN <sub>P</sub> or AIN <sub>N</sub> to GND		-0.1		V <sub>DD</sub>	V
Differential Input Impedance					See Table 1		
System Performance							
Resolution		No missing codes		16			Bits
Data Rate	DR				See Table 5		SPS
Data Rate Variation		All data rates		-3.5		3.5	%
Output Noise				See Table 6 and Table 7			
Integral Nonlinearity	INL	DR = 5SPS, FSR = ±2.048V <sup>(2)</sup>			1	4	LSB
Offset Error	E <sub>O</sub>	FSR = ±2.048V	Differential inputs	-6	-1	6	LSB
			Single-ended inputs	-7	-1	7	
Offset Drift		FSR = ±2.048V			0.005	0.025	LSB/°C
Offset Power Supply Rejection		FSR = ±2.048V			0.6		LSB/V
Gain Error <sup>(3)</sup>	E <sub>G</sub>	FSR = ±2.048V at +25°C			0.01	0.15	%
Gain Drift <sup>(3) (4)</sup>		FSR = ±0.256V			6		ppm/°C
		FSR = ±2.048V			6	15	
		FSR = ±6.144V <sup>(1)</sup>			6		
Gain Power Supply Rejection					80		ppm/V
PGA Gain Match <sup>(3)</sup>		Match between any two PGA gains			0.01	0.1	%
Gain Match		Match between any two inputs			0.01	0.08	%
Offset Match		Match between any two gains			2	9	LSB
50/60Hz Rejection		FSR = ±2.048V			100		dB
Channel-to-Channel Crosstalk		At DC and FSR = ±2.048V, differential or single-ended inputs adjacent channels			110		dB
Common Mode Rejection Ratio	CMRR	At DC and FSR = ±0.256V			105		dB
		At DC and FSR = ±2.048V			100		
		At DC and FSR = ±6.144V <sup>(1)</sup>			90		

#### NOTES:

1. The full-scale range of the ADC scaling. In any event, it should not exceed  $V_{DD} + 0.3V$  applied to this device.
2. Best fit (99% of full-scale).
3. It includes all errors from on-chip PGA and reference.
4. Gain temperature drift is defined as the maximum change of gain error measured over the specified temperature range. The gain error drift is calculated using the box method, as described by Equation:  $\text{Gain Error Drift} = (GE_{MAX} - GE_{MIN}) / (T_{MAX} - T_{MIN})$ .

Where:

- $GE_{MAX}$  and  $GE_{MIN}$  are the maximum and minimum gain errors, respectively.
- $T_{MAX}$  and  $T_{MIN}$  are the maximum and minimum temperatures, respectively, over the temperature range  $-40^{\circ}C$  to  $+125^{\circ}C$ .

# Ultra-Small, Low-Power, 16-Bit

## Analog-to-Digital Converter with Internal Reference

### SGM51610C

### ELECTRICAL CHARACTERISTICS (continued)

( $V_{DD} = 3.3V$ , DR = 5SPS, full-scale input voltage range (FSR) =  $\pm 2.048V$ , internal reference, maximum and minimum specifications apply from  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ , typical values are measured at  $T_A = +25^{\circ}C$ , unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>Reference</b>						
External Reference			0.5		2.5	V
External Reference Input Current		$V_{REFIN} = 2.5V$ , continuous mode		2.35		$\mu A$
<b>Digital Input/Output</b>						
High Input Voltage <sup>(5)</sup>	$V_{IH}$		$0.7 \times V_{DD}$			V
Low Input Voltage <sup>(5)</sup>	$V_{IL}$				$0.3 \times V_{DD}$	V
Low Output Voltage	$V_{OL}$	$I_{OL} = 3mA$		0.13	0.4	V
High Input Leakage Current <sup>(6)</sup>	$I_{IH}$	$V_{IH} = 5.5V$		0.1	1	$\mu A$
Low Input Leakage Current <sup>(6)</sup>	$I_{IL}$	$V_{IL} = GND$		0.1	1	$\mu A$
<b>Power Supply Requirements</b>						
Power Supply Voltage	$V_{DD}$		2		5.5	V
Supply Current	$I_{DD}$	$V_{DD} = 5.5V$	Power-down current at $+25^{\circ}C$	0.65	1.2	$\mu A$
			Power-down current up to $+125^{\circ}C$		3.5	
			Operating current at $+25^{\circ}C$	310	380	
			Operating current up to $+125^{\circ}C$		400	
Power Dissipation	$P_D$	$V_{DD} = 5V$		1.5		mW
		$V_{DD} = 3.3V$		0.8		

#### NOTES:

5. There are two scenarios:  $V_{DD} = 5V$ ,  $V_{BUS}$  can be 2V to 5V.  $V_{DD} = 3.3V$ ,  $V_{BUS}$  should be 3.3V. Note that  $V_{BUS} = 2V$  may cause leakage in some extreme conditions, and it is better to make it higher than 3.1V. For  $V_{BUS} = V_{DD}$ ,  $V_{IL}/V_{IH} = 30\%/70\%$  of  $V_{BUS}$ . For  $V_{BUS} = 3.3V$  and  $V_{DD} = 5V$ ,  $V_{IL}/V_{IH} = 20\%/80\%$  of  $V_{BUS}$ .

6. Meet the "loss of  $V_{DD}$ " requirement of  $I^2C$  fast mode. When  $V_{DD}$  is lost, the leakage drawn from the pin is controlled.

# SGM51610C

## Ultra-Small, Low-Power, 16-Bit Analog-to-Digital Converter with Internal Reference

### TIMING CHARACTERISTICS

PARAMETER	SYMBOL	CONDITIONS	FAST MODE		HIGH-SPEED MODE		UNITS
			MIN	MAX	MIN	MAX	
SCL Operating Frequency	$f_{SCL}$		0.01	0.4	0.01	3.4	MHz
Bus Free Time between START and STOP Conditions	$t_1$		1300		160		ns
Hold Time after Repeated START Condition. After This Period, the First Clock is Generated	$t_2$		600		160		ns
SCL Clock Low Time	$t_3$		1300		160		ns
SCL Clock High Time	$t_7$		600		60		ns
Repeated START Condition Setup Time	$t_9$		600		160		ns
STOP Condition Setup Time	$t_{10}$		600		160		ns
Data Hold Time	$t_5$		0		0		ns
Data Setup Time	$t_8$		100		10		ns
Clock/Data Fall Time <sup>(1)</sup>	$t_6$			300		40	ns
Clock/Data Rise Time	$t_4$			300		80	ns

NOTE:

1.  $t_6$  (MIN) for SDA output is 20ns for normal/fast mode and 10ns for high-speed mode. Glitch filter capability is 50ns for normal/fast mode and 10ns for high-speed mode.

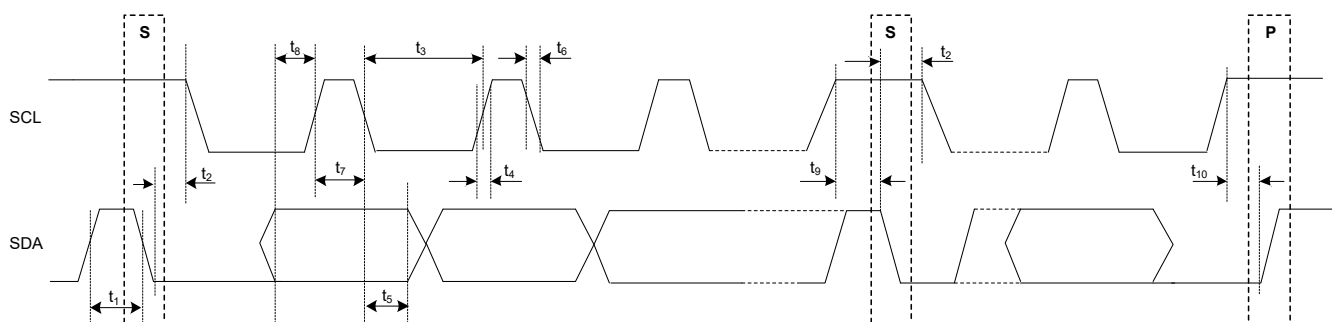


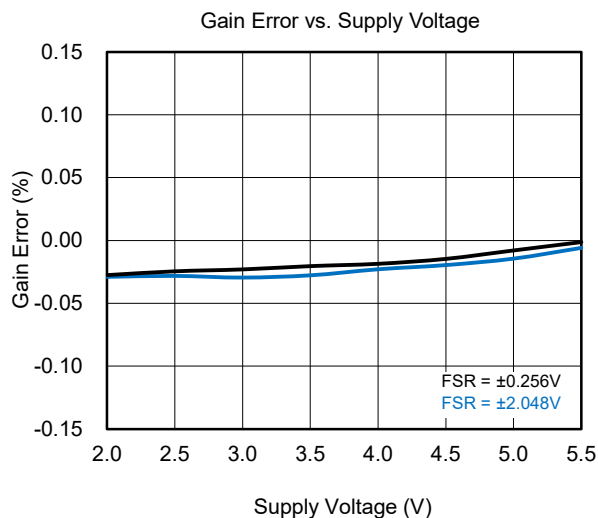
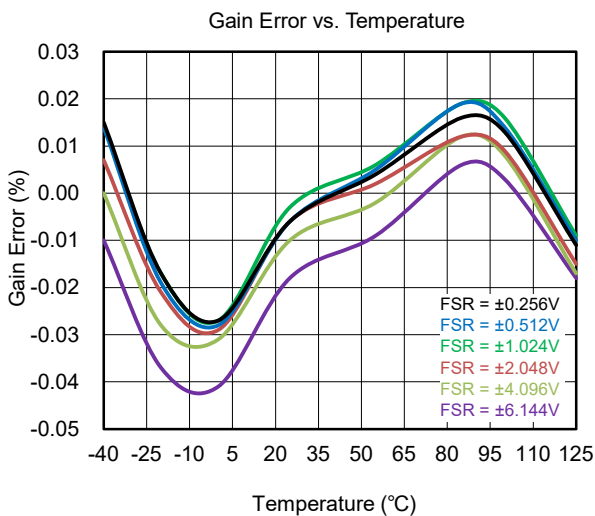
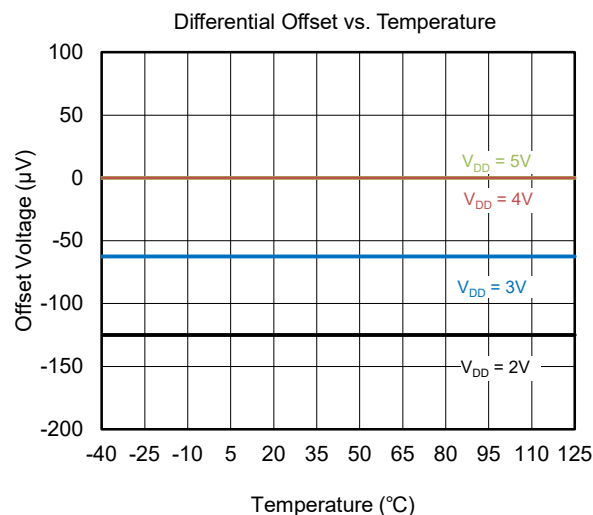
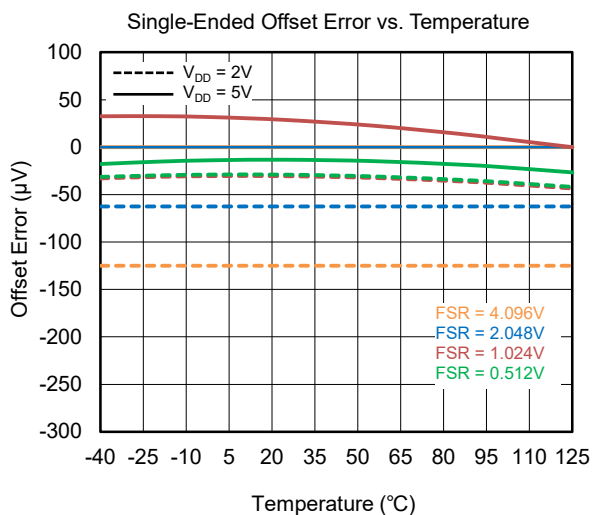
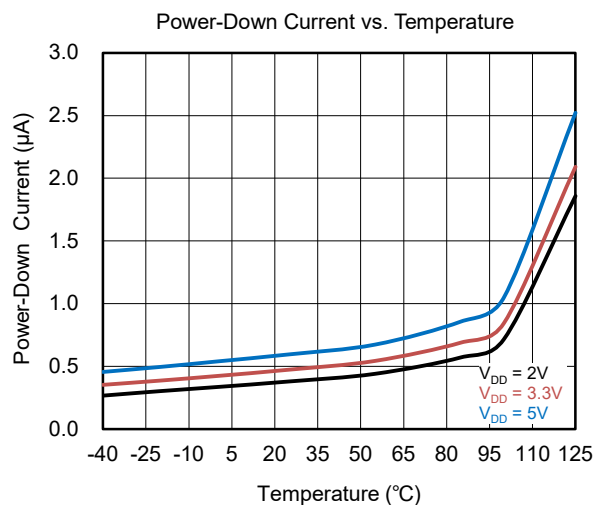
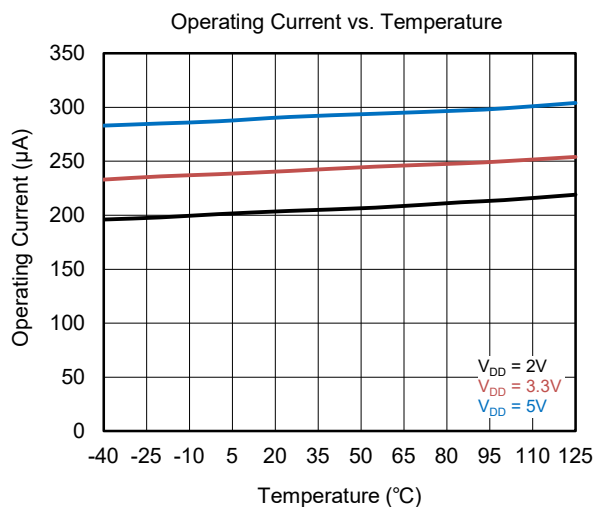
Figure 1. I²C Timing Diagram

# SGM51610C

## Ultra-Small, Low-Power, 16-Bit Analog-to-Digital Converter with Internal Reference

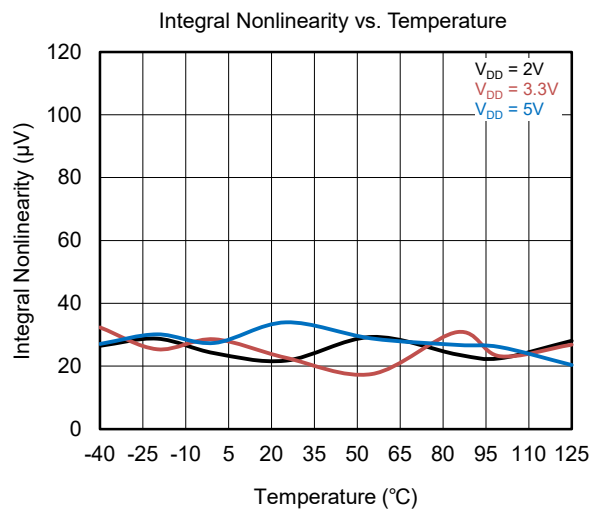
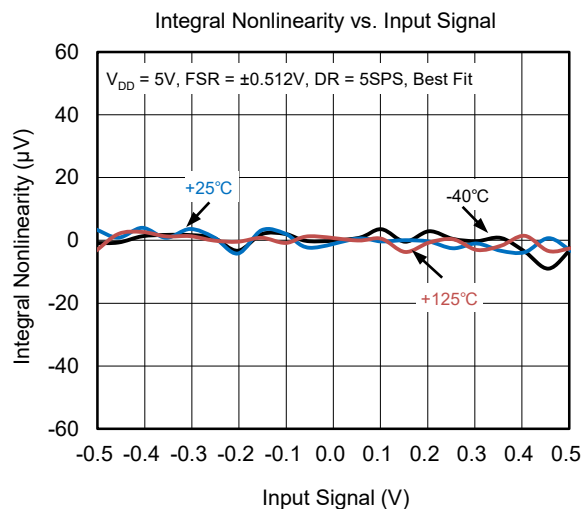
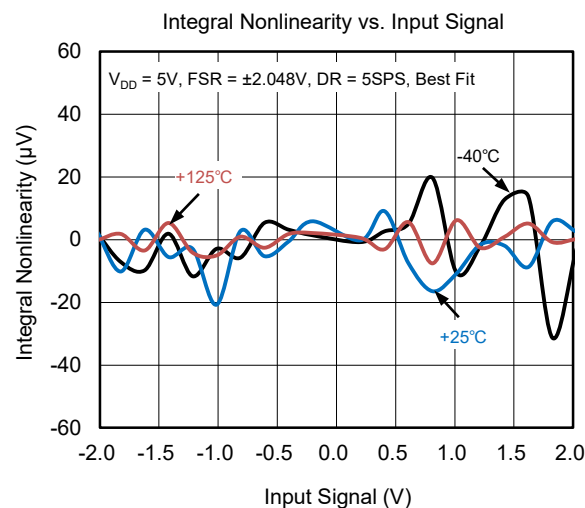
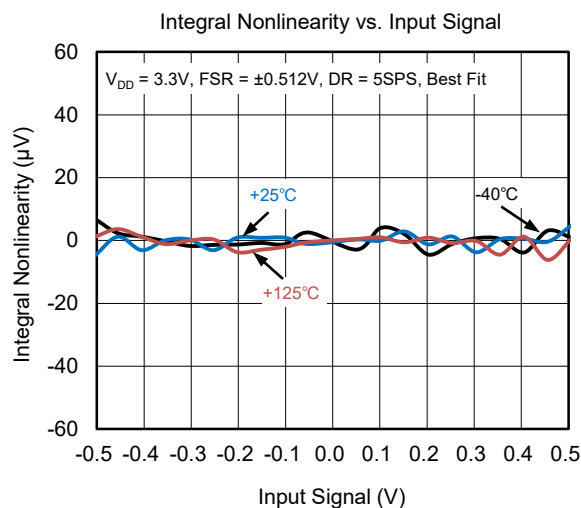
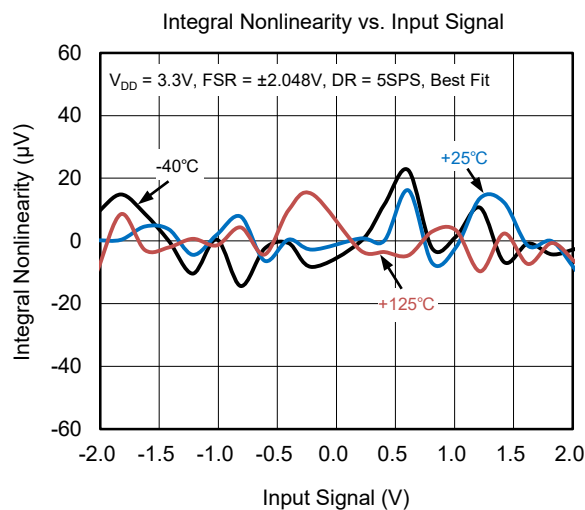
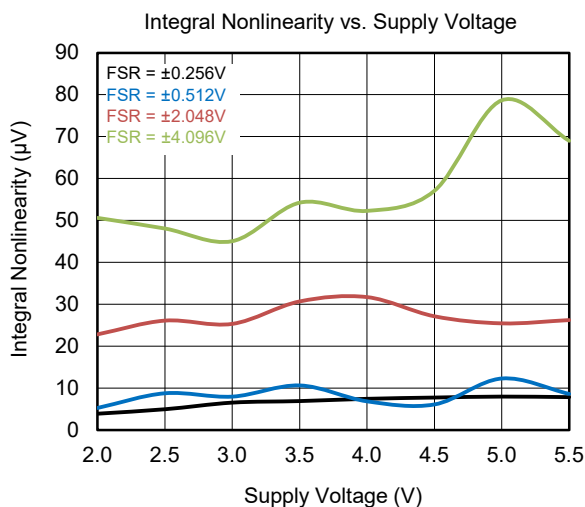
### TYPICAL PERFORMANCE CHARACTERISTICS

$T_A = +25^\circ\text{C}$ ,  $V_{DD} = 3.3\text{V}$ ,  $\text{FSR} = \pm 2.048\text{V}$ ,  $\text{DR} = 5\text{SPS}$ , unless otherwise noted.



**TYPICAL PERFORMANCE CHARACTERISTICS (continued)**

$T_A = +25^\circ\text{C}$ ,  $V_{DD} = 3.3\text{V}$ ,  $\text{FSR} = \pm 2.048\text{V}$ ,  $\text{DR} = 5\text{SPS}$ , unless otherwise noted.



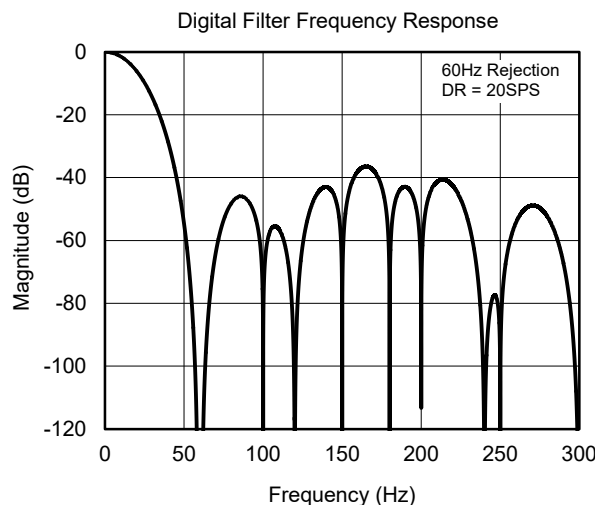
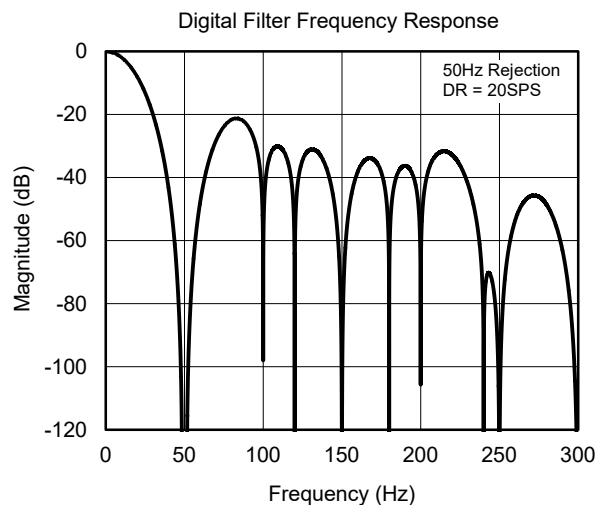
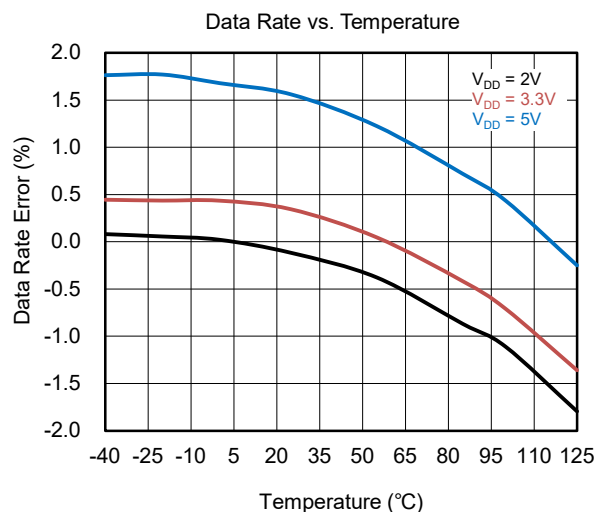
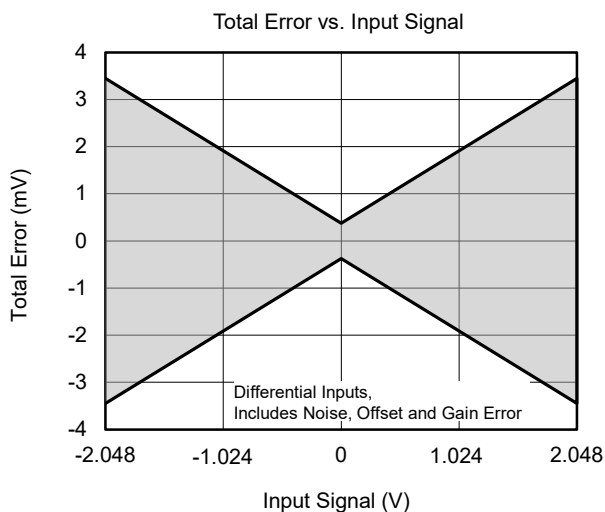
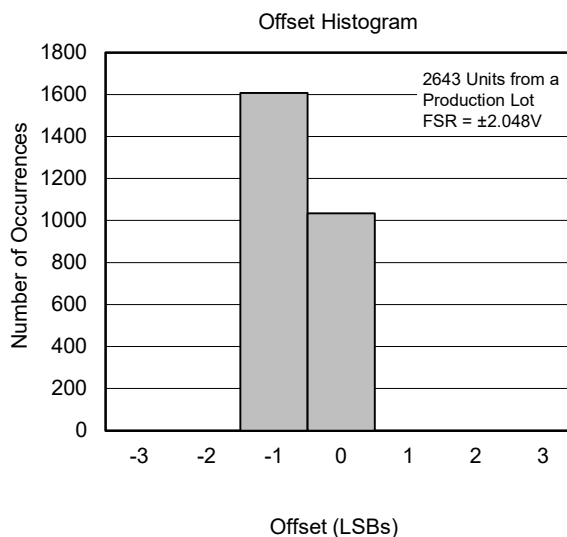
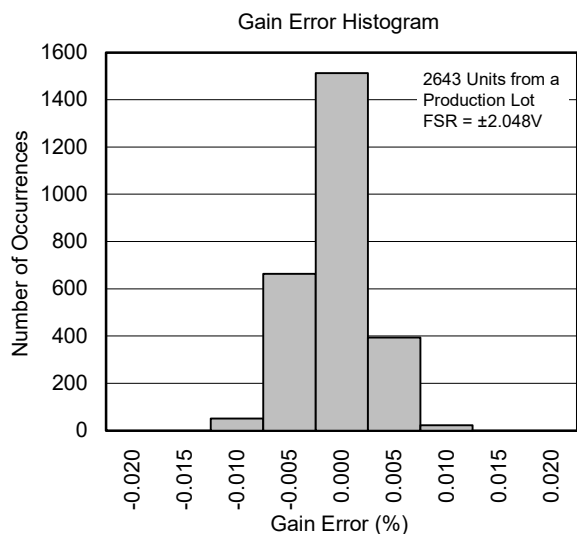


# SGM51610C Ultra-Small, Low-Power, 16-Bit

## Analog-to-Digital Converter with Internal Reference

### TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$T_A = +25^\circ\text{C}$ ,  $V_{DD} = 3.3\text{V}$ ,  $\text{FSR} = \pm 2.048\text{V}$ ,  $\text{DR} = 5\text{SPS}$ , unless otherwise noted.



## FUNCTIONAL BLOCK DIAGRAM

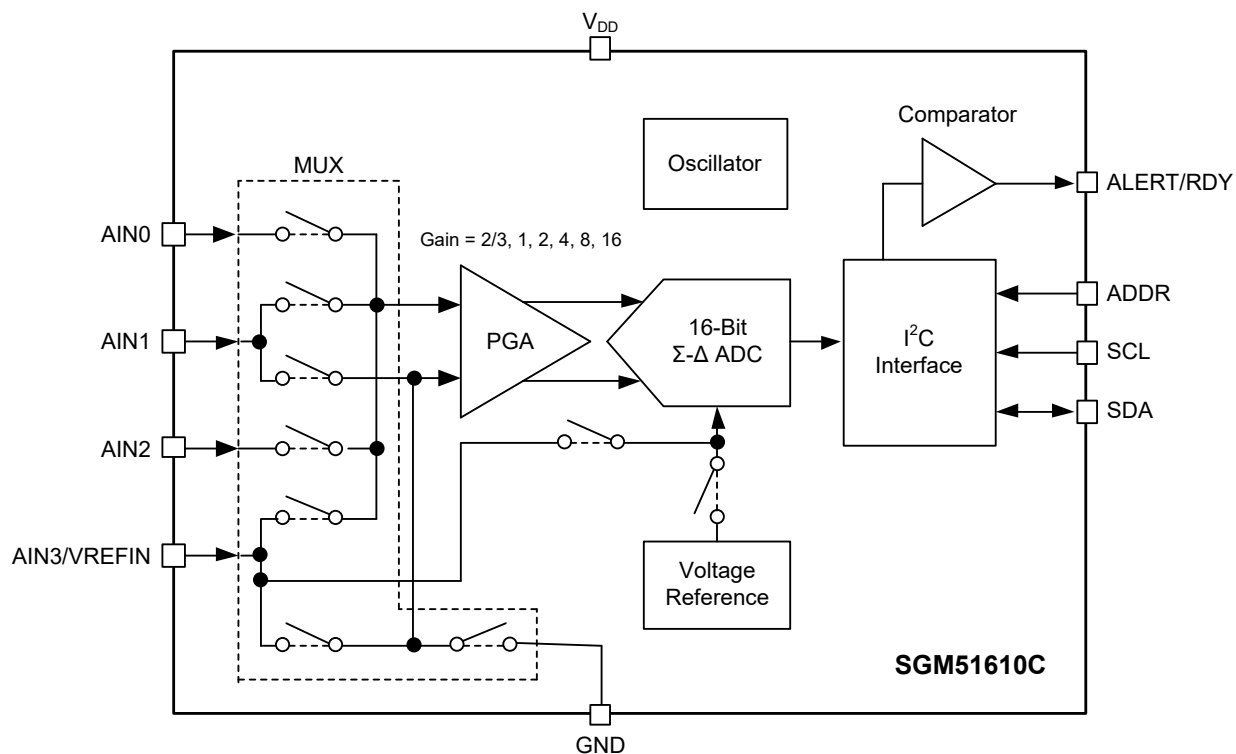


Figure 2. Functional Block Diagram

## DETAILED DESCRIPTION

## Overview

The SGM51610C is a low-power, 16-bit, sigma-delta ( $\Sigma$ - $\Delta$ ) analog-to-digital converter (ADC).

The SGM51610C supports both differential inputs and single-ended inputs.

The SGM51610C has two working modes: single-shot mode and continuous conversion mode.

In single-shot mode, the ADC performs one conversion and gives full settled data, no data needs to be discarded. Once ADC completes the conversion, it then goes to low-power shutdown mode.

In continuous mode, the ADC will achieve the first fully settled data without discarding any data, similar in single-shot mode. And the ADC begins a new conversion automatically after a previous conversion is completed. Every conversion result is given out. The data rate is equal to the configured data rate.

## Quickstart Guide

The basic connection of ADC is shown in Figure 3. The communication interface is I<sup>2</sup>C compatible. The SGM51610C works in slave mode. The I<sup>2</sup>C address is configured as 0b1001000 (ADDR is connected to GND).

Figure 4 and Figure 5 show the demo read and write operation sequences.

For example, writing to the configuration register 0x1 sets the SGM51610C to continuous conversion mode, the following order can be followed:

1. The first byte, 0b1001000 (first 7-bit is I<sup>2</sup>C address), the 8<sup>th</sup> bit is read/write bit which is low writing now
2. The second byte, 0b00000001 (points to Config register 0x1)
3. The third byte, 0b10000100 (MSB of the Config register to be written, Bit[8] = '0' means the continuous mode)
4. The fourth byte, 0b10000011 (LSB of the Config register to be written, Bit[7:5] = '100' means data rate 100Hz)

For example, to read the conversion result from SGM51610C, the following order can be followed:

1. The first byte, 0b1001000 (first 7-bit is I<sup>2</sup>C address), the 8<sup>th</sup> bit is read/write bit which is low writing now
2. The second byte, 0b00000000 (points to Conversion register 0x0)
3. The third byte, 0b10010001 (first 7-bit is I<sup>2</sup>C address), the 8<sup>th</sup> bit is read/write bit which is high reading now
4. The fourth byte, the SGM51610C answers with the MSB of the Conversion register
5. The fifth byte, the SGM51610C answers with the LSB of the Conversion register

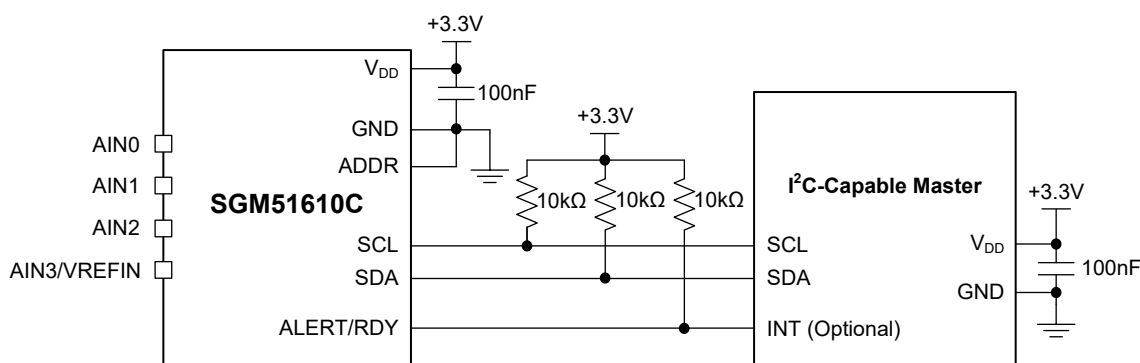
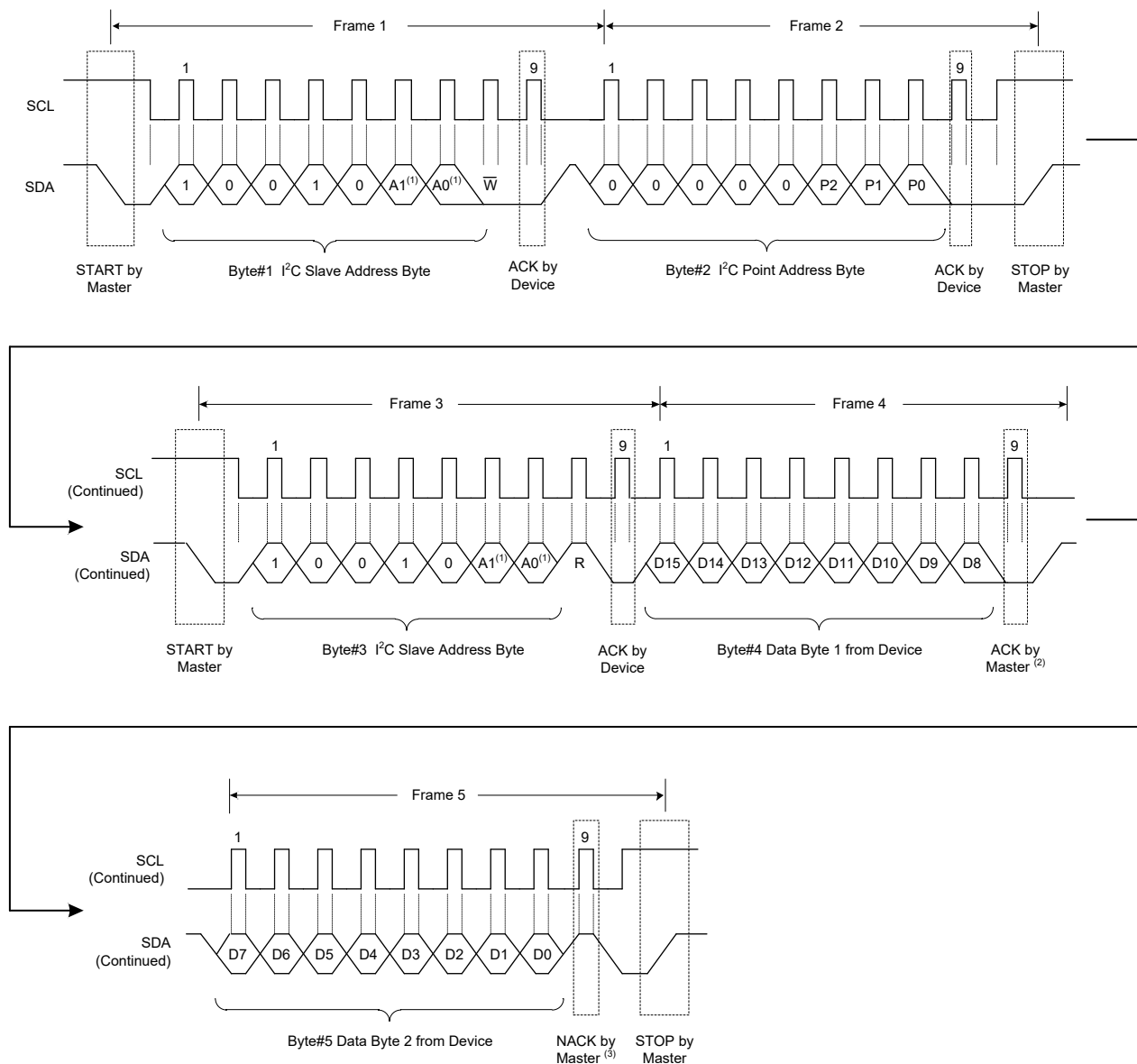


Figure 3. Basic Hardware Configuration

## DETAILED DESCRIPTION (continued)

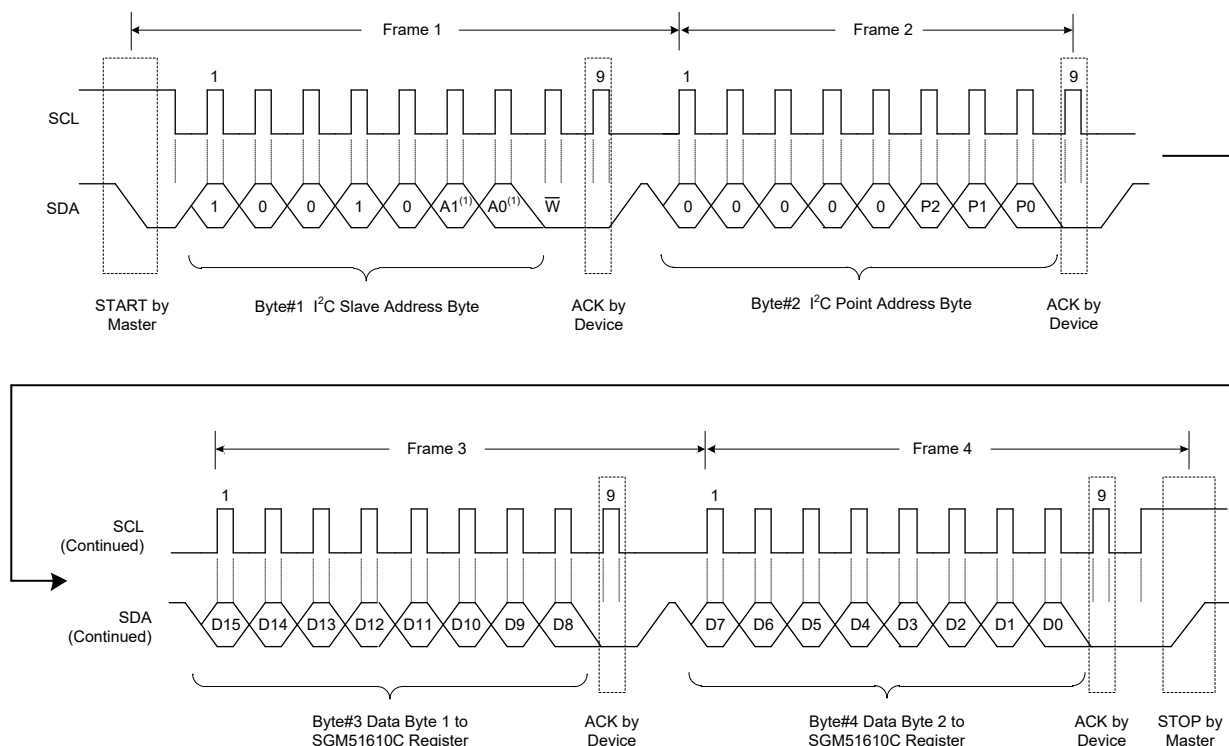


### NOTES:

1. The A0 and A1 values depend on the ADDR pin.
2. SDA can be set high by master to terminate a single-byte read operation.
3. SDA can be set high by master to terminate a two-byte read operation.

**Figure 4. Timing Diagram for Read Word Register**

### DETAILED DESCRIPTION (continued)



NOTE:

1. The A0 and A1 values depend on the ADDR pin.

Figure 5. Timing Diagram for Write Word Register

### Multiplexer

The SGM51610C has a flexible input multiplexer. It can be configured as 2 differential inputs or 4 single-ended inputs.

Whether the input is configured as differential inputs or single-ended inputs, the absolute voltage on any inputs pin must be in the range from GND to  $V_{DD}$ .

### Analog Inputs

The SGM51610C has a switched capacitor input stage. There are charge and discharge current when ADC is working. The equal effective input impedance can be estimated by  $R_{EFF} = V_{IN}/I_{AVERAGE}$ .

The differential input impedance is  $Z_{DIFF}$  in Figure 6. Table 1 shows the typical differential input impedance.

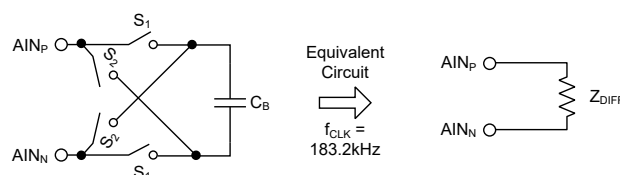


Figure 6. Simplified Analog Input Circuit

Table 1. Differential Input Impedance

FSR (V)	Differential Input Impedance (MΩ)
$\pm 6.144$ <sup>(1)</sup>	2.3
$\pm 4.096$ <sup>(1)</sup>	2.1
$\pm 2.048$	1.4
$\pm 1.024$	1.2
$\pm 0.512$	0.752
$\pm 0.256$	0.452

NOTE:

1. FSR = Full-scale range of the ADC scaling. In any event, it should not exceed  $V_{DD} + 0.3V$  applied to this device.

## DETAILED DESCRIPTION (continued)

## Full-Scale Input

The SGM51610C has an internal PGA. The PGA can be set to gains of 2/3, 1, 2, 4, 8 or 16. Table 2 and Table 3 show the corresponding full-scale ranges (FSR).

Analog input voltages can never exceed the analog input voltage limits.

Table 2. PGA Gain Full-Scale Range with Internal Reference

PGA Setting	FSR (V)
2/3	$\pm 6.144^{(1)}$
1	$\pm 4.096^{(1)}$
2	$\pm 2.048$
4	$\pm 1.024$
8	$\pm 0.512$
16	$\pm 0.256$

NOTE:

1. FSR = Full-scale range of the ADC scaling. In any event, it should not exceed  $V_{DD} + 0.3V$  applied to this device.

Table 3. PGA Gain Full-Scale Range with External Reference

PGA Setting	FSR (V)
2/3	$\pm 6.144 \times V_{REF}/1.2$
1	$\pm 4.096 \times V_{REF}/1.2$
2	$\pm 2.048 \times V_{REF}/1.2$
4	$\pm 1.024 \times V_{REF}/1.2$
8	$\pm 0.512 \times V_{REF}/1.2$
16	$\pm 0.256 \times V_{REF}/1.2$

## Data Format

The SGM51610C conversion result data is in binary two's complement format.

Table 4 shows the ideal output codes for different input signals.

Table 4. Ideal Output Code for Different Input Signals

Input Signal $V_{IN}$ ( $A_{INP} - A_{INN}$ )	Ideal Output Code <sup>(1)</sup>
$\geq FS (2^{15} - 1)/2^{15}$	7FFFh
$+FS/2^{15}$	0001h
0	0
$-FS/2^{15}$	FFFFh
$\leq -FS$	8000h

NOTE:

1. Except for effects of INL, noise, offset, and gain errors.

## Aliasing

For some applications, an RC external filtering is recommended.

## Operating Modes

The SGM51610C has two working modes, continuous mode and single-shot mode.

In continuous mode, the ADC begins a new conversion automatically after a previous conversion is completed. Every conversion result is given out.

In single-shot mode, if OS bit is written to '1', a single-shot conversion is started, during the conversion process, the OS bit is kept '0', and the chip doesn't response to OS bit operation. If conversion data is ready, the OS bit is set to '1' and the chip goes power-down automatically, and user can write '1' to OS bit to call a single-shot conversion again.

## Power-Up and Reset

When the SGM51610C is powered up, all registers are reset to default values.

The SGM51610C supports I<sup>2</sup>C general call reset command. See I<sup>2</sup>C General Call section for details.

## Duty Cycling for Low-Power

In some power sensitive application, the SGM51610C can work in sampling and power-down mode periodically. The duty cycle of working time and power-down time can be controlled by microcontroller flexibly.

For example, if the SGM51610C is configured as sample data rate at 960Hz, it can be operated with 125ms duty cycle. It means that if the chip is called to do single-shot conversion every 125ms, it will take the chip 1.2ms for sampling and then stay in power-down mode for 123.8ms. Under this working mode, it will reduce 103/104 power consumption compare with 960Hz operation in continuous mode.

## Data Rate

Table 5. ADC Output Data Rate (SPS)

DR[2:0] Bits in Config Register	ODR
000	5Hz
001	10Hz
010	20Hz
011	50Hz
100	100Hz
101	200Hz
110	480Hz
111	960Hz

## DETAILED DESCRIPTION (continued)

## Comparator

The SGM51610C has an inside comparator that can be used to check ADC conversion results with high threshold and low threshold. When the result exceeds the limited setting, the chip can give an alert on the ALERT/RDY pin.

The comparator has two working modes: traditional mode and window comparator mode. These modes are configurable. Under both working modes, the comparator can be configured as latch output or no-latch output (COMP\_LAT bit in Config register). In latch output mode, the latched

comparator output can be cleared by issuing an SMBus alert response or by reading the Conversion register. The ALERT/RDY pin output active polarity (low or high) can be configured by COMP\_POL bit in Config register. Demos are shown in Figure 7 and Figure 8.

The comparator output trigger waiting times can be set by COMP\_QUE[1:0] bits in Config register. It means comparator output can wait until the ADC results beyond the threshold configured times (which can be one, two, or four times). See Config Register section for details.

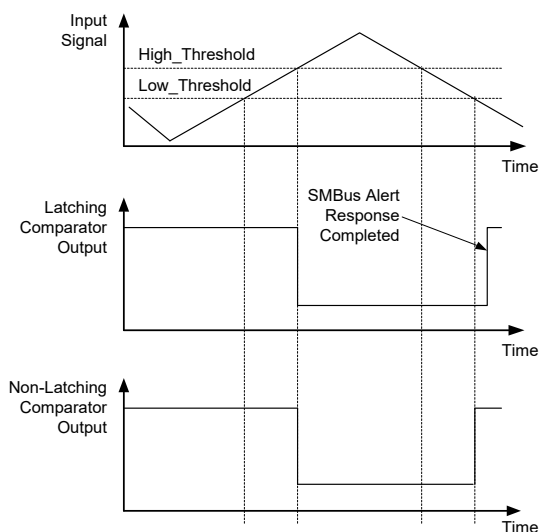


Figure 7. Alert Pin Timing Diagram when Configured as a Traditional Comparator

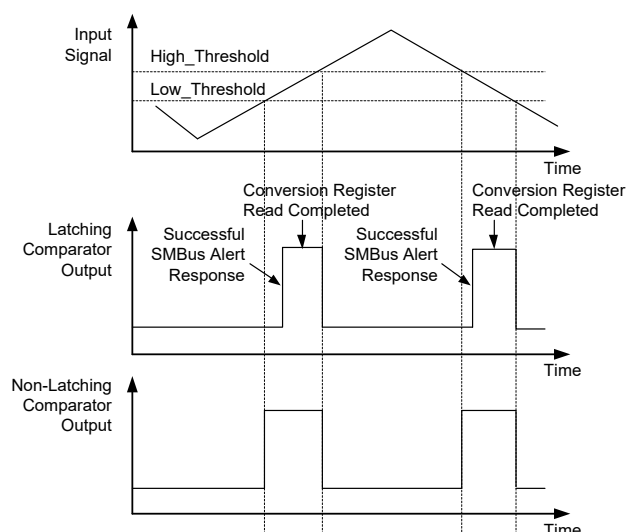


Figure 8. Alert Pin Timing Diagram when Configured as a Window Comparator

## ADC Noise

Table 6. ADC Noise with Internal Reference (RMS in  $\mu\text{V}$ )

DR FSR	960	480	200	100	50	20	10	5
6.144	187.5	187.5	187.5	187.5	187.5	187.5	187.5	187.5
4.096	125	125	125	125	125	125	125	125
2.048	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5
1.024	31.25	31.25	31.25	31.25	31.25	31.25	31.25	31.25
0.512	15.62	15.62	15.62	15.62	15.62	15.62	15.62	15.62
0.256	7.81	7.81	7.81	7.81	7.81	7.81	7.81	7.81

Table 7. ADC ENOB (ENOB =  $\ln(\text{FSR}/V_{\text{RMS-Noise}})/\ln(2)$ )

DR FSR	960	480	200	100	50	20	10	5
6.144	16	16	16	16	16	16	16	16
4.096	16	16	16	16	16	16	16	16
2.048	16	16	16	16	16	16	16	16
1.024	16	16	16	16	16	16	16	16
0.512	16	16	16	16	16	16	16	16
0.256	16	16	16	16	16	16	16	16

**DETAILED DESCRIPTION (continued)****Digital Filter**

The SGM51610C features a finite impulse response (FIR) digital filter with linear-phase characteristics. This filter serves a dual purpose, filtering and decimating the incoming digital data stream from the modulator. Notably, the digital filter automatically adapts to different data rates, ensuring a settling process within a single cycle. Operating at data rates of 5SPS, 10SPS and 20SPS, the filter configuration provides flexibility to reject either 50Hz or 60Hz line frequencies. One bit (DR\_SEL) in the configuration register enables easy customization of the filter's behavior.

**Conversion Ready Pin**

If ALERT/RDY pin is used as a conversion ready pin, the following operations need to be followed, firstly set the MSB (Most Significant Bit) of the high threshold register to '1', secondly set the MSB of the low threshold register to '0', and select COMP\_QUE[1:0] bits in '00'/'01'/'10' modes. It should be noted that COMP\_QUE[1:0] bits can disable this pin function. The COMP\_MODE and COMP\_LAT bits have no affection on this function.

The ALERT/RDY pin is an open-drain output, it needs a pull-up resistor outside.

When the SGM51610C works in continuous mode, the ALERT/RDY pin gives a pulse (~8 $\mu$ s) at the end of every conversion completion.

When the SGM51610C works in single-shot mode, the ALERT/RDY pin goes low (COMP\_POL bit is set to '0') when the conversion data is ready, and keeps low until the next conversion starts. Please see demos in Figure 9 and Figure 10.

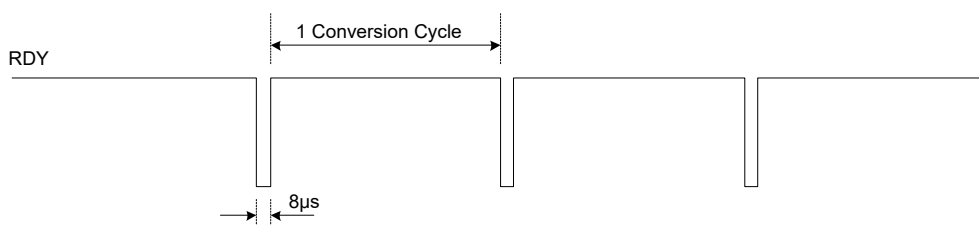
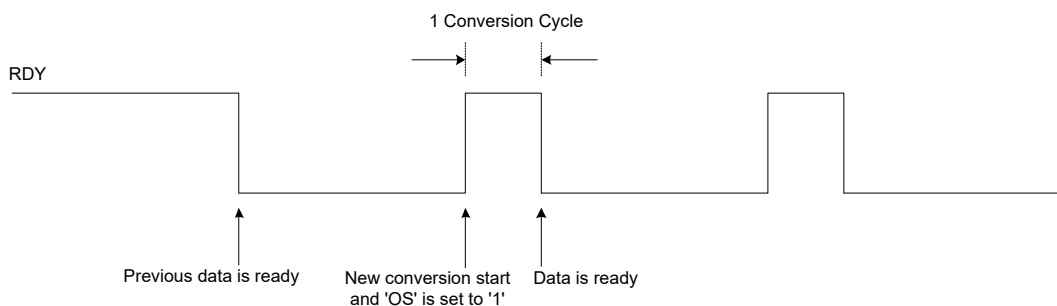
**SMBus Alert Response**

The ALERT/RDY pin can output as an SMBus alert. When it is in latch mode, the COMP\_LAT bit is set to '1'. And the pin output is latched, it can be cleared by reading ADC conversion data, or by issuing an SMBus alert response (reading the alerting device I<sup>2</sup>C address).

If an alert is output at the ALERT/RDY pin and latched, the master controller accepts the alert, it sent an SMBus alert command (0b00011001) to I<sup>2</sup>C bus. Any SGM51610C on the bus will response with their own address, the lowest I<sup>2</sup>C address chip will occupy the bus and it will clear itself ALERT/RDY pin, the chip which loses I<sup>2</sup>C bus will keep alert on ALERT/RDY pin. The master will repeat SMBus alert command until all slave chips clear their alert.

When ALERT/RDY pin is configured as window comparator mode, if ADC result is higher than upper threshold or ADC result is below the lower threshold, the pin is set (active low or active high).

Timing diagram for SMBus alert response is shown in Figure 11.

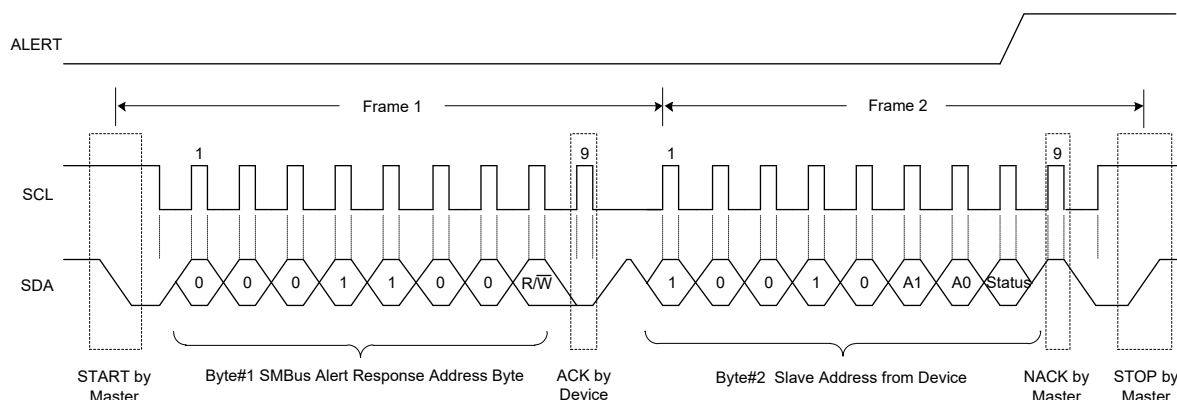
**Figure 9. RDY in Continuous Mode****Figure 10. RDY in Single-Shot Mode**



# SGM51610C

## Ultra-Small, Low-Power, 16-Bit Analog-to-Digital Converter with Internal Reference

### DETAILED DESCRIPTION (continued)



NOTE:

1. The A0 and A1 values depend on the ADDR pin.

**Figure 11. Timing Diagram for SMBus Alert Response**

### I<sup>2</sup>C Interface

The SGM51610C communication interface is an I<sup>2</sup>C interface. The SGM51610C can only act as slave devices. An I<sup>2</sup>C timing diagram is shown in Figure 1.

### I<sup>2</sup>C Address Selection

The SGM51610C has a separate address setting pin ADDR, which can be connected to GND, V<sub>DD</sub>, SDA and SCL. Table 8 shows the four available addresses.

**Table 8. ADDR Pin Connection and Corresponding Slave Address**

ADDR Pin	Slave Address
GND	1001000
V <sub>DD</sub>	1001001
SDA	1001010
SCL	1001011

### I<sup>2</sup>C General Call

The SGM51610C supports I<sup>2</sup>C general call address (0000000) and the eighth bit must be '0'. The device acknowledges the

general call address. And if the second byte is 00000110 (06h), the SGM51610C resets all registers and goes to power-down.

### I<sup>2</sup>C Speed Modes

The I<sup>2</sup>C bus operation supports three speed modes: standard mode, fast mode, and high-speed mode. See Timing Characteristics section for more details.

To enter standard and fast mode, it needs no special operation.

To enter high-speed mode, send a special address byte of 00001XXX following the I<sup>2</sup>C start condition. The SGM51610C doesn't give an ACK (acknowledge) to this byte, the SGM51610C switches to high-speed mode after receiving this byte. The SGM51610C quits high-speed mode with the next STOP condition.

### Slave Mode Operations

The SGM51610C works in slave mode and doesn't drive the SCL line.

## REGISTER MAPS

### Register Address

The SGM51610C has seven pointer registers. Table 9 and Table 10 show these register maps. Figure 4 shows how to access this pointer registers.

**Table 9. Register Address**

Address	Register
0x0	Conversion Register
0x1	Config Register
0x2	Low_Thresh Register
0x3	High_Thresh Register
0x4	Config1 Register
0x5	Chip_ID Register
0x6	GN_Trim1 Register for EXT_REF bit

### Pointer Register

**Table 10. Pointer Register Byte (Write-Only)**

MSB						LSB	
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	Register Address		

### REG0x0: Conversion Register [Reset = 0x0000]

The ADC conversion result is 16-bit two's complement format. Table 11 shows the data format. Its reset default value is '0'.

**Table 11. 16-Bit Conversion Register (Read-Only)**

MSB														LSB	
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
D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

## REGISTER MAPS (continued)

### REG0x1: Config Register [Reset = 0x8583]

The configuration register (Config Register) is shown in Table 12.

**Table 12. Config Register Details**

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[15]	OS	1	R/W	Working Status/Single-Shot Conversion Start For a write status: 0 = No effect 1 = Start a single conversion (when in single-shot mode)  For a read status: 0 = The chip is doing a conversion 1 = The chip is not doing a conversion  This bit reports the status of the chip. It can only be written when the chip is in power-down.
D[14:12]	MUX[2:0]	000	R/W	Input Multiplexer (MUX) Configuration 000 = AIN <sub>P</sub> = AIN0 and AIN <sub>N</sub> = AIN1 (default) 001 = AIN <sub>P</sub> = AIN0 and AIN <sub>N</sub> = AIN3 010 = AIN <sub>P</sub> = AIN1 and AIN <sub>N</sub> = AIN3 011 = AIN <sub>P</sub> = AIN2 and AIN <sub>N</sub> = AIN3 100 = AIN <sub>P</sub> = AIN0 and AIN <sub>N</sub> = GND 101 = AIN <sub>P</sub> = AIN1 and AIN <sub>N</sub> = GND 110 = AIN <sub>P</sub> = AIN2 and AIN <sub>N</sub> = GND 111 = AIN <sub>P</sub> = AIN3 and AIN <sub>N</sub> = GND
D[11:9]	PGA[2:0]	010	R/W	Programmable Gain Amplifier (PGA) Configuration 000 = FSR = $\pm 6.144V$ <sup>(1)</sup> 001 = FSR = $\pm 4.096V$ <sup>(1)</sup> 010 = FSR = $\pm 2.048V$ (default) 011 = FSR = $\pm 1.024V$ 100 = FSR = $\pm 0.512V$ 101 = FSR = $\pm 0.256V$ 110 = FSR = $\pm 0.256V$ 111 = FSR = $\pm 0.256V$
D[8]	MODE	1	R/W	Device Operating Mode 0 = Continuous conversion mode 1 = Power-down or single-shot mode (default)
D[7:5]	DR[2:0]	100	R/W	Data Rate These bits control the data rate setting. See Table 5.
D[4]	COMP_MODE	0	R/W	Comparator Mode 0 = A traditional comparator with hysteresis (default) 1 = A window comparator
D[3]	COMP_POL	0	R/W	Comparator Polarity 0 = Active low (default) 1 = Active high This bit sets the active polarity of the ALERT/RDY pin.
D[2]	COMP_LAT	0	R/W	Latching Comparator 0 = Non-latching comparator (default) 1 = Latching comparator This bit sets whether the ALERT/RDY pin latches once its outputs sets or resets when ADC conversion result is within the upper and lower threshold limitations.
D[1:0]	COMP_QUE[1:0]	11	R/W	Comparator Queue and Disable Function 00 = Assert after one conversion 01 = Assert after two conversions 10 = Assert after four conversions 11 = Disable comparator (default) These bits can disable the comparator. They can set the required times of successive ADC conversion beyond the threshold before an alert output on ALERT/RDY pin.

NOTE:

1. This is a theoretical full-scale range of the ADC scaling. The real input must be within the electrical limitation (0V to V<sub>DD</sub> + 0.3V).

## REGISTER MAPS (continued)

### REG0x2 ~ REG0x3: Low\_Thresh [Reset = 0x8000] and High\_Thresh [Reset = 0x7FFF]

#### Registers

The lower (Low\_Thresh) and upper (High\_Thresh) threshold registers are in 16-bit two's complement format. Table 13 shows these two register format.

**Table 13. Low\_Thresh and High\_Thresh Registers Format (Read/Write)**

Low_Thresh Register							
Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8
Low_Thresh[15:8]							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Low_Thresh[7:0]							
High_Thresh Register							
Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8
High_Thresh[15:8]							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High_Thresh[7:0]							

### REG0x4: Config1 Register [Reset = 0x0000]

**Table 14. 16-Bit Config1 Register Details**

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[15:9]	Reserved	000 0000	R/W	
D[8]	PD	0	R/W	Writing '1' to PD powers down this part, and this PD bit is automatically cleared internally by any of the following continuous or single-shot conversion operations.
D[7]	DR_SEL	0	R/W	FIR Filter Configuration This specific bit is designated for the customization of filter coefficients dedicated to the internal finite impulse response (FIR) filter. Kindly employ these bits in conjunction with the 5SPS, 10SPS and 20SPS configuration.  0 = 50Hz rejection only (default) 1 = 60Hz rejection only
D[6:4]	Reserved	000	R/W	
D[3]	EXT_REF	0	R/W	0 = None (default) 1 = Use AIN3 as external reference for ADC
D[2:0]	Reserved	000	R/W	

### REG0x5: Chip\_ID Register [Reset = 0x0280]

**Table 15. 16-Bit Chip\_ID Register for Identifying Chip ID and Its Subversions (Read-Only)**

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[15:13]	Reserved	000	R	Reserved.
D[12:8]	ID[4:0]	0 0010	R	
D[7:5]	VER[2:0]	100	R	
D[4:0]	Reserved	0 0000	R	Reserved.

## REGISTER MAPS (continued)

### REG0x6: GN\_Trim1 Register (When Using EXT\_REF Bit) [Reset = 0x999A]

The ADC gain coefficient for user selecting Config1 register EXT\_REF bit as reference. A default value is provided and the user is responsible for writing proper value to the register if they want to compensate external reference error. This register does not take effect when EXT\_REF = 0 and the internal reference is selected.

**Table 16. GN\_Trim1 Register Format**

Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8
GN15	GN14	GN13	GN12	GN11	GN10	GN9	GN8
1	0	0	1	1	0	0	1
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GN7	GN6	GN5	GN4	GN3	GN2	GN1	GN0
1	0	0	1	1	0	1	0

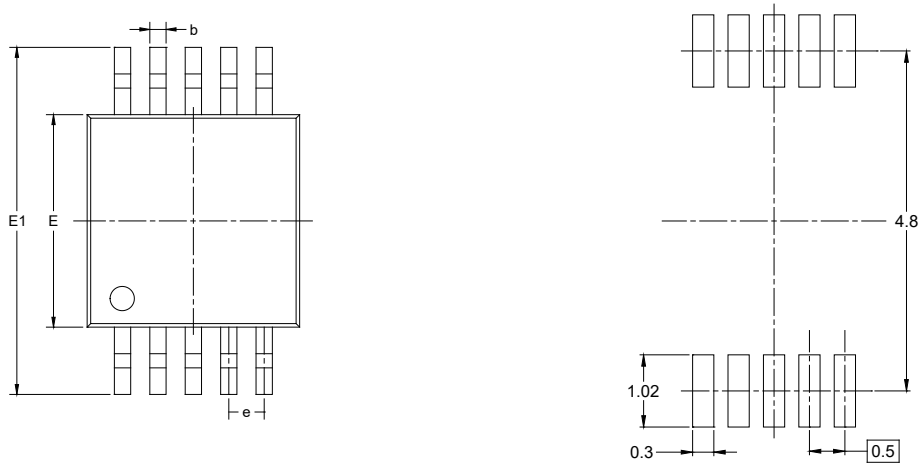
## REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

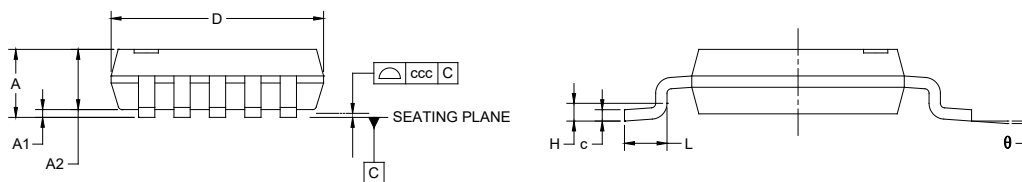
FEBRUARY 2025 – REV.A to REV.A.1	Page
Updated Detailed Description section .....	12, 15, 16
Updated Register Maps section .....	19, 20
Changes from Original (DECEMBER 2024) to REV.A	Page
Changed from product preview to production data .....	All

## PACKAGE OUTLINE DIMENSIONS

### MSOP-10



RECOMMENDED LAND PATTERN (Unit: mm)



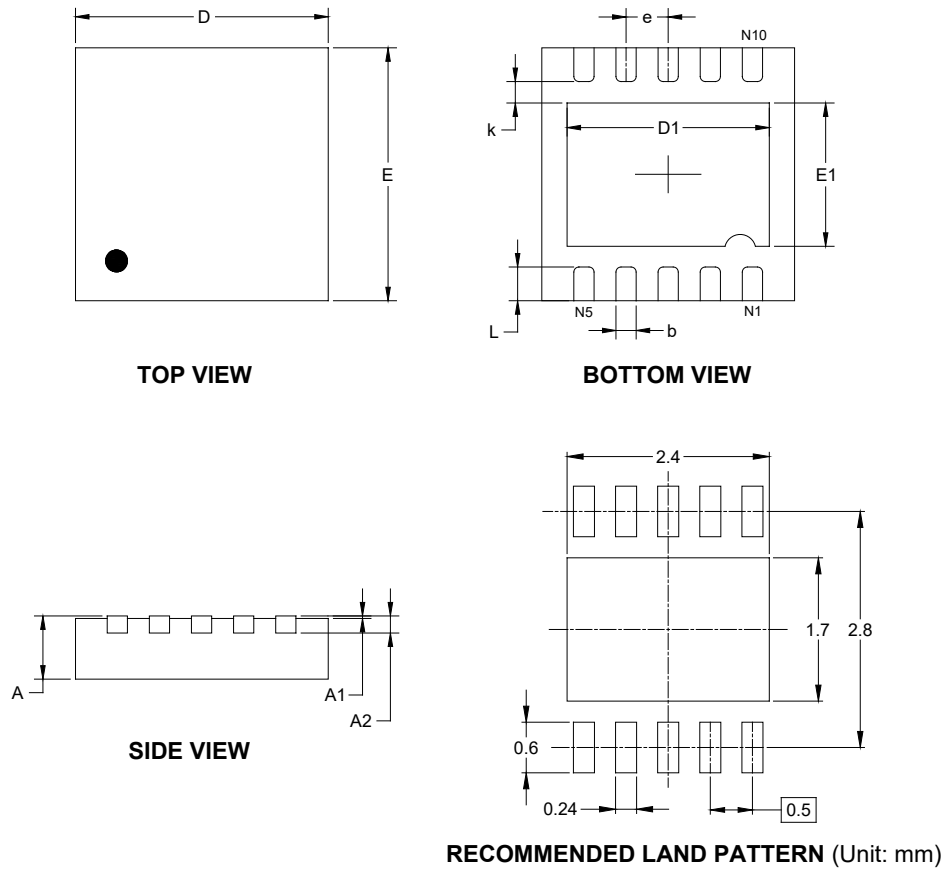
Symbol	Dimensions In Millimeters		
	MIN	NOM	MAX
A	-	-	1.100
A1	0.000	-	0.150
A2	0.750	-	0.950
b	0.170	-	0.330
c	0.080	-	0.230
D	2.900	-	3.100
E	2.900	-	3.100
E1	4.750	-	5.050
e	0.500 BSC		
H	0.250 TYP		
L	0.400	-	0.800
θ	0°	-	8°
ccc	0.100		

NOTES:

1. This drawing is subject to change without notice.
2. The dimensions do not include mold flashes, protrusions or gate burrs.
3. Reference JEDEC MO-187.

## PACKAGE OUTLINE DIMENSIONS

### TDFN-3×3-10L



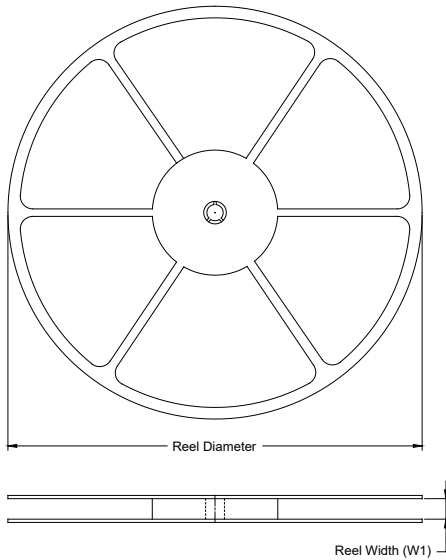
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	2.900	3.100	0.114	0.122
D1	2.300	2.600	0.091	0.103
E	2.900	3.100	0.114	0.122
E1	1.500	1.800	0.059	0.071
k	0.200 MIN		0.008 MIN	
b	0.180	0.300	0.007	0.012
e	0.500 TYP		0.020 TYP	
L	0.300	0.500	0.012	0.020

NOTE: This drawing is subject to change without notice.

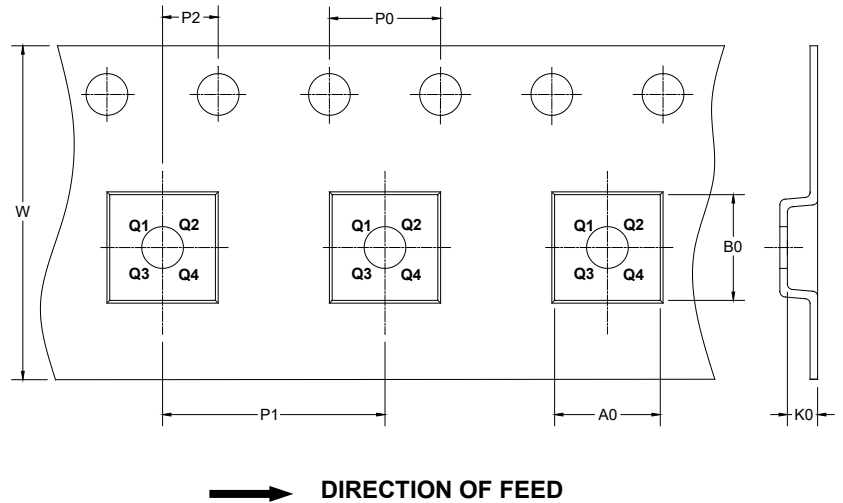
# PACKAGE INFORMATION

## TAPE AND REEL INFORMATION

### REEL DIMENSIONS



### TAPE DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

### KEY PARAMETER LIST OF TAPE AND REEL

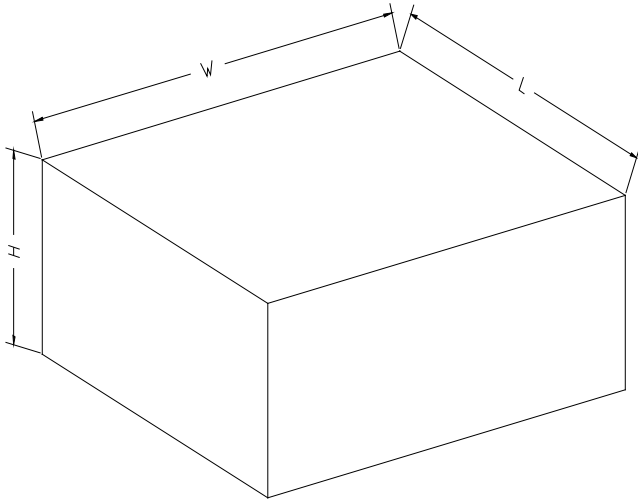
Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
MSOP-10	13"	12.4	5.20	3.30	1.50	4.0	8.0	2.0	12.0	Q1
TDFN-3×3-10L	13"	12.4	3.35	3.35	1.13	4.0	8.0	2.0	12.0	Q1

DD0001



## PACKAGE INFORMATION

### CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

### KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
13"	386	280	370	5

DD0002