DATASHEET

AS23C-01BA-00

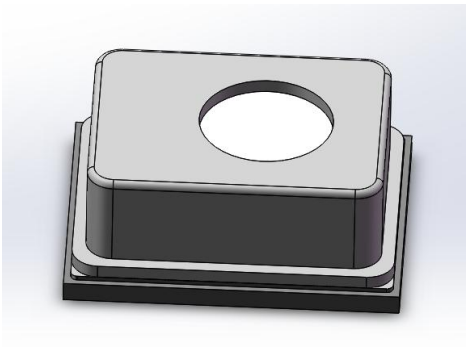
AIoTSensing Inc.
Website: http://www.aiotsensing.com

History of Revision

Datasheet Rev.	Date	Note
00	Oct/12/2019	Draft
01	Feb/22/2021	Released

CONTENTS

1. OVERVIEW



1.1 Features

- Pressure temperature sensitivity: < 0.5Pa/K
- Average current consumption Standby: <1μA
- Supply voltage: VDDIO: 1.2 – 3.6 V, VDD: 1.7 – 3.6 V.
- Operating modes: Command (manual), Background (automatic), and Standby.
- FIFO: Stores up to 32 pressure or temperature measurements. Streaming or stop-on full mode. Optional interrupt on full or watermark interrupt.
- Interface: I2C with optional interrupt, 4-wire SPI, 3-wire SPI with optional interrupt.
- Waterproof and anti-corrosion
- Size: 2.5 x 2.0 x 1.0 mm

1.2 Applications

- Local weather station and Thermostat
- Air flow control
- Health and sports
- Outdoor navigation
- Indoor navigation
- Smart Home

1.3 Descriptions

The AS23C-01BA-00 is a monolithic digital barometric air pressure sensor die, comprising the full MEMS and ASIC system. The AS23C-01BA-00 is capable of measuring both air pressure and temperature, with high accuracy and low current consumption. Pressure sensing is carried out using a capacitive sensor element, guaranteeing high accuracy over temperature. The small chip dimensions and low current consumption make the AS23C-01BA-00 a perfect fit for mobile and consumer applications.

The pressure and temperature sensor elements are measured by a 24-bit ΣΔ ADC. Measurement results can be accessed over I2C or SPI, with an optional configurable interrupt and a result FIFO capable of holding 32 pressure and/or temperature measurements.

Each AS23C-01BA-00 contains dedicated fuse locations to allow for individual calibration of each unit and storing of calibration coefficients. These coefficients are used in the application to convert the measurement results to high accuracy pressure and temperature values.

The AS23C-01BA-00 contains a FIFO which can store up to 32 measurements. By using the FIFO, the host processor can remain in a sleep mode for a longer period of time between readouts, reducing the overall system power consumption. Sensor measurements and calibration coefficients are available through the serial I2C or SPI interface. The measurement status is indicated by status bits or interrupts on the SDO pin.

Parameter	Symbol	Min	Typ.	Max	Unit	Note / Test Condition
Pressure	Pa	300		1200	hPa	
Temperature	Ta	-40		85	℃	
Supply voltage	V_{DD}	1.7		3.6	V	
Supply voltage IO	V_{DDIO}	1.2		3.6	V	
Supply voltage ramp -up time	t_{vddup}	0.001		5	ms	Time for supply voltage to reach 90% of final value.
Solder drift			0.5		hPa	Drift measured 72 hours after reflow. Minimum solder height 50um.
Long term stability			±1		hPa	12 months

1.4 Block Diagram

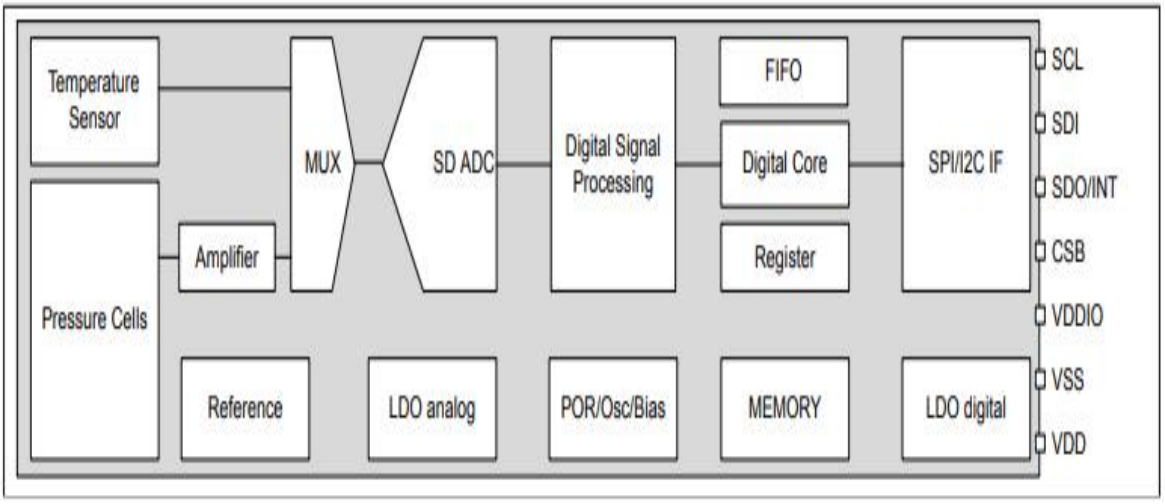


Figure 1: Functional Block Diagram

2. Electrical Specifications

2.1 Pressure and Temperature Characteristics

The following operating conditions must not be exceeded in order to ensure correct operation of the device. All parameters specified in the following sections refer to these operating conditions, unless noted otherwise

Table1: Pressure Output Characteristics @VDD=3.0V, T=25°C unless otherwise noted

Sensor Performances (VDD = 3.0 V)	Min	Typ	Max	Unit
Pressure Range	300		1200	hPa
Temperature Range	-40		85	°C
ADC		24		bit
Pressure sensor precision: (high precision mode).		± 0.005		hPa
Absolute Accuracy		± 1		hPa
Relative Accuracy		± 0.06		hPa
Temperature accuracy		± 0.4		°C
Measurement time for standard mode (16x).		27.6		ms
Measurement time for low precision mode.	3.6			ms
Average current consumption for pressure measurement[1)]		1.7		µA
Average current consumption for temperature measurement[1)]		2		µA

1) @1Hz sampling rate

2.2 Absolute Maximum Rating

Maximum ratings are absolute ratings. Exceeding any one of these values may cause irreversible damage to the integrated circuit.

Table2: Absolute Maximum Rating

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min	Typ	Max		
VDD and VDDIO	V_{DDxx_max}			4	V	
Voltage on any pin	Vmax			4	V	
Storage temperature	Ts	-40		125	℃	
Pressure	Pmax			10000	hPa	
ESD	V_{ESD_HBM}	-2		+2	kV	HBM (JS-001)
Attention: Stresses above the values listed as "Absolute Maximum Ratings" may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.						

2.3 Current consumption

Test conditions (unless otherwise specified in the table): VDD= 1.8V and VDDIO=1.8V.

Table 3Current consumption

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min	Typ	Max		
Peak Current Consumption	I_{peak}		345		μA	during Pressure measurement
			280		μA	during Temperature measurement
Standby Current Consumption	I_{stb}		1		μA	
Current Consumption. (1 measurement per second.)	I_{1Hz}		3.2		μA	Low precision
			17			Standard precision
			44			High precision
Note: The current consumption depends on both pressure measurement precision and rate. Please refer to the register description for an overview of the current consumption in different combinations of measurement precision and rate.						

2.4 Pressure transfer function

Test conditions (unless otherwise specified):
VDD= 1.8V, VDDIO=1.8V. Typ. values (PA=1000hPa and TA=25° C).
Note:
Pressure accuracy and precision values are after individual unit calibration in package.
For application-specific requirements, advice on calibration and packaging is available.
Table 6 Pressure sensor transfer function

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min	Typ	Max		
Absolute pressure accuracy	Ap_abs		±100		Pa	PA=300-1200hPa TA=25...+65° C, excluding solder effects
			±300		Pa	PA=300-1200hPa TA=-10...+25° C, excluding solder effects
Relative pressure accuracy	Ap_rel		±6		Pa	Any △25 hPa in the range PA=800-1200hPa Any constant temperature in the range TA=20...+60° C
Pressure precision	Ap_prc		5.0		P_{aRMS}	Low Power
			1.2			Standard
			0.5			High Precision
Note: Pressure precision is measured as the average standard deviation. Please refer to the PSR_CFG register description for all precision mode options.						
Power supply rejection	Ap_psr			TBD	P_{aRMS}	50mVppsine wave, sweep from 100Hz to 5MHz
Pressure temperature sensitivity of calibrated measurements	Ap_tmp		0.5		Pa/K	1000hPa, 25...+40° C.
Pressure data resolution	Ap_res			0.06	P_{aRMS}	
Pressure measurement rate	f	1		128	Hz	
Pressure measurement time (including 1x decimation temperature measurement)	t		8.8		ms	Low Power (1x decimation)
			32.8			Standard (16x decimation)
			119.2			High Precision (64x decimation)
Note: The pressure measurement time (and thus the maximum rate) depends on the pressure measurement precision. Please refer to the PSR_CFG register description for an overview of the possible combinations of measurement precision and rate.						

3. Function Descriptions

The AS23C-01BA-00 is a versatile sensor, capable of providing fast, accurate pressure and temperature measurements at low current. In order to best support a wide range of applications there are a small number of configurable features which can be easily and quickly set on device start up.

The AS23C-01BA-00configurable features are:

- Operating mode:
  - Command Mode (single-shot)
  - Background Mode (periodic)
  - Standby Mode
- Pressure measurement precision and rate
- Temperature measurement precision and rate
- FIFO settings:
  - FIFO on/off
  - FIFO behavior: stop-on-full/ streaming
  - FIFO depth
  - FIFO watermark level
- Interrupt behavior:
  - New measurement results available
  - FIFO full to watermark level
  - FIFO full
  - No interrupt

The precision and measurement rate of the pressure and temperature measurements can be set independently by writing to the PSR_CFG and TEMP_CFG registers. The precision and measurement rates used are dictated by the requirements of the application, and a balance must be found between high precision and low power consumption.

3.1 Operating modes

The AS23C-01BA-00 supports 3 different modes of operation:

- Standby Mode:
  - Default mode after power on or reset. No measurements are performed.
  - All registers and compensation coefficients are accessible.
- Command Mode:
  - One pressure and/or temperature measurement is performed according to the selected precision.
  - The sensor will return to Standby Mode when the measurement is finished, and the measurement result will be available in the dedicated result registers or FIFO output registers.
  - The FIFO can be used when the AS23C-01BA-00 is in Command mode. Several measurements can be requested before reading data back from the FIFO.
- Background Mode:
  - Pressure and/or temperature measurements are performed continuously according to the selected measurement precision and rate. If enabled, the temperature measurement is performed immediately after the pressure measurement.
  - After each measurement is completed, the result will be available in the dedicated result registers if the FIFO is disabled. If the FIFO is enabled it will be added to the FIFO.
  - The FIFO can be used to store up to 32 measurement results and minimize the number of times the sensor must be accessed to read out the results. Using background mode and FIFO streaming mode, the AS23C-01BA-00 measures continuously and the most recent 32 measurements can be read at any time.
  - The FIFO behavior can be configured to either stop-on-full mode, which stops recording data once the FIFO is full, or to streaming mode, which will continue recording data once the FIFO is full, deleting the oldest data each time a new measurement is recorded.

Attention:
Switching power mode from Background Mode to Standby Mode is initiated by setting the measurement control bits [2:0] in MEAS_CFG to 0. If a measurement is taking place when these bits are set, the AS23C-01BA-00 will complete the measurement before switching power modes. The value of the Continuous Mode Flag, bit [6] in MEAS_CFG, will update to 0 once this measurement has been completed and the AS23C-01BA-00 has returned to Standby Mode. This bit can be monitored after initiating a power mode change if confirmation of the mode change is required.

3.2 Mode transition diagram

The mode transition diagram is shown below.

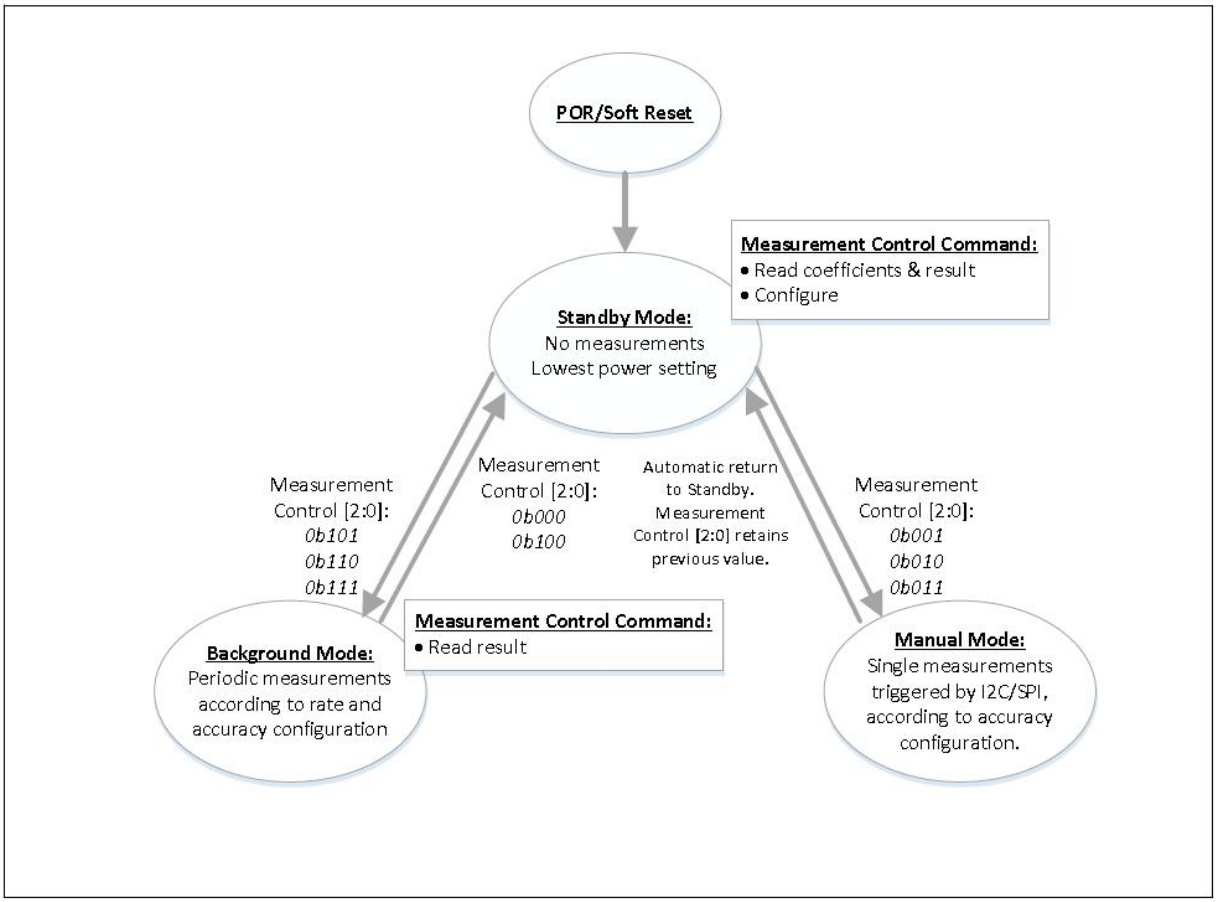


Figure 2 AS23C-01BA-00 mode transition diagram.

3.3 Measurement precision and rate

When the AS23C-01BA-00 is in Background mode, the measurement precision and rate can be configured to match the requirements of the application. This reduces current consumption of the sensor and the system.
In order to achieve a higher precision, the AS23C-01BA-00 will read the sensor multiple times (oversampling), and combine the readings into one result. This increases the current consumption and also the measurement time, reducing the maximum possible measurement rate. It is necessary to balance the accuracy and data rate required for each application with the allowable current consumption.
The measurement precision, rate and time are set in the PSR_CFG and TEMP_CFG. The register descriptions contain information about the current consumption and the possible combinations of measurement precision, time, and rate.

Temperature measurements must be enabled for the AS23C-01BA-00 to compensate for temperature drift in the pressure measurement. The rates of these measurements can be set independently, but temperature compensation is more accurate when temperature and pressure measurements are taken together. This reduces the maximum pressure measurement rate:

$Rate_{temperature}*Time_{temperature} + Rate_{pressure}*Time_{pressure} < 1$ second.

Measurement settings and use case examples contains a table with examples of combinations of pressure and temperature precision and rates for different use cases.

The figure below show the temperature and pressure measurement sequence in Background mode.

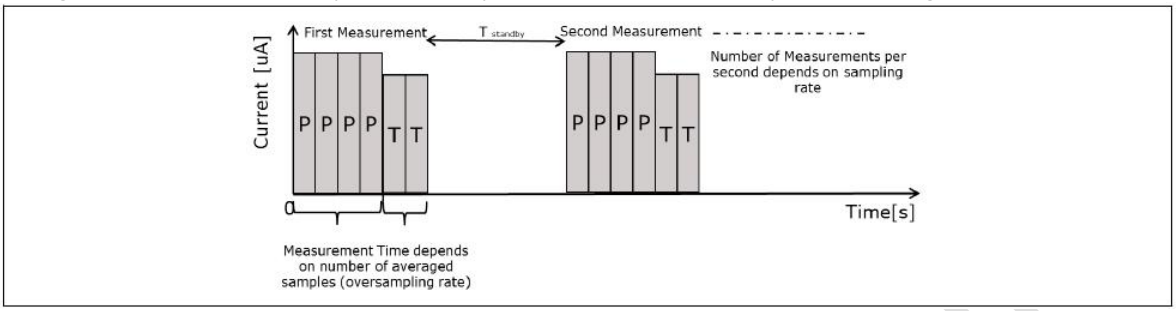


Figure 3 Background mode temperature and pressure measurements sequence

3.3.1 Oversampling rate, kP

Increasing the pressure or temperature oversampling rate increases the number of times the $\Sigma\Delta$ ADC will sample and average the input before generating an output value.

Increasing the oversampling rate improves the measurement accuracy by reducing noise, but it also extends the length of time required to carry out a measurement. Increasing the measurement time increases average current consumption, as the AS23C-01BA-00 will spend longer in full power mode, and less time in standby mode. A balance must be found between current consumption and measurement accuracy, depending on the application requirements.

Increasing the OSR is a good way to remove high frequency noise, but if the measurement time is too long, there will also be a filtering effect on transient pressure events such as spikes caused by doors or windows opening. If the application requires the AS23C-01BA-00 to detect these events, the oversampling rate should not be set too long. The oversampling rate will also have no effect on low frequency fluctuations caused by unstable ambient pressure.

When calculating the pressure measurement from the output register value, it is necessary to include a calculation factor called kP. The value of kP changes depending on the oversampling rate selected for the measurement. The table below lists the oversampling rates and the respective kP values.

Table 9 kP values associated with each oversampling rate

Bit Field Value	No. Samples	kP
000	256	524288
001	512	1572864
010	1024	3670016
011	2048	7864320
100	4096	253952
101	8192	516096
110	16384	1040384
111	32768	2088960

The kP values are used in the pressure calculation in the sections:

- Calculating pressure reading

3.4 FIFO operation

The AS23C-01BA-00 FIFO can store up to the last 32 measurements of pressure and/or temperature. This reduces the overall system power consumption as the host processor does not need to continuously poll data from the sensor but can go into standby mode for longer periods of time.

The FIFO can store any combination of pressure and temperature results, according to the background mode measurement rate settings.

The least significant bit of the FIFO measurement result register PSR_B0 is used to indicate whether the measurement is a pressure or temperature result. The least significant bit is set to:

- '1' if the result is a pressure measurement.
- '0' if it is a temperature measurement.

Note: The sensor uses 24 bits to store the measurement result, which is more than is necessary to cover the full dynamic range of the pressure sensor. Using the least significant bit to label the measurement type does not affect the precision of the result.

The FIFO can be enabled in the CFG_REG. The data from the FIFO is read out from PSR_B2, PSR_B1 and PSR_B0 regardless of whether the result in the FIFO is a temperature or a pressure measurement.

When a measurement has been read, the FIFO will automatically increment and place the next result in the data register. The FIFO empty bit is set in FIFO_STS when the FIFO is empty, in this case all FIFO reads return 0x800000.

If the FIFO is full, the FIFO interrupt Full/WM bit in the FIFO_STS register is set. If the Interrupt select [3:0] bits in the CFG_REG register is set to 0x08, an interrupt will also be generated when the FIFO is full.

If the FIFO watermark interrupt is configured by setting the Interrupt select [3:0] bits in the CFG_REG register to 0x04, the FIFO will generate an interrupt when the number of pressure and temperature results stored in the FIFO equals the configured watermark level.

The FIFO can be configured to one of two behaviors' when full:

- FIFO stops recording new measurement results when full.
- FIFO continues recording new measurement results when full, overwriting the oldest measurement.

This behavior can be configured by setting the FIFO Stop on full bit in the CFG_REG register. Setting this bit to 0 will enable streaming mode, setting to 1 will enable stop-on-full mode.

Attention:

It is recommended not to poll the FIFO full flag bit in register INT STS faster once every 375 μs, as it is not updated immediately. Similarly, the FIFO full status bit in register FIFO_STS should only be polled once every 250 μs.

3.5 Interrupt

The AS23C-01BA-00 has a user configurable interrupt, which is generated on the SDO output.

The AS23C-01BA-00 can be configured to generate an interrupt on the following events:

- New measurement result available
- FIFO full to configured watermark level
- FIFO full

The sensor uses the SDO output for the interrupt signal. The interrupt is not supported if the interface is 4-wire SPI. The interrupt is enabled and configured in the CFG_REG register. In I2C mode SDO serves as both interrupt and as the least significant bit in the device address. SDO has an internal pull up resistor, which defaults the address selection functionality to 0x77.

The SDO output has a push-pull output stage so there is no need to use an external pull-down resistor if the default I2C address is suitable for the application. Active high or active low interrupt operation can be selected using the Interrupt polarity bit, bit [3] in the CFG_REG register.

Note:

An external pull up resistor is never required on SDO and should not be used.

The interrupt status can be read from the INT STS register.

3.6 Start-up sequence

The AS23C-01BA-00 start-up sequence is shown below. This diagram shows when the registers are accessible for read/ write operations and also when the pressure/temperature measurements can start.

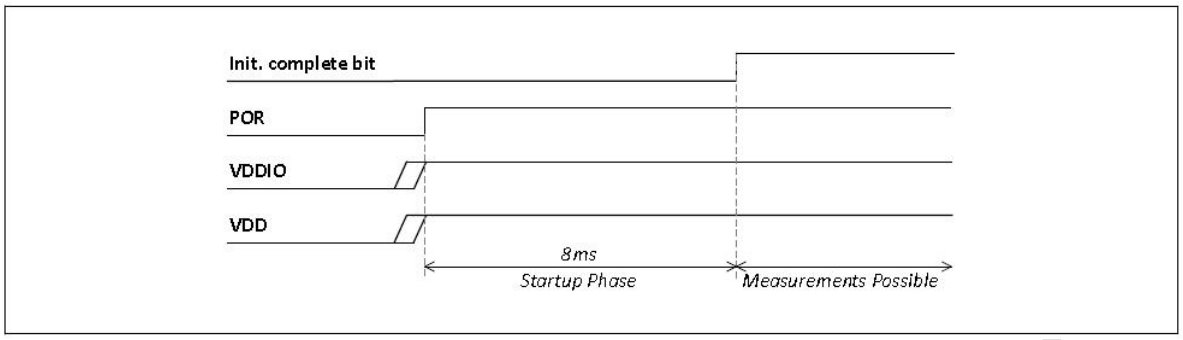


Figure 5 AS23C-01BA-00 start-up sequence.

3.7 Sensor interface

The AS23C-01BA-00 can be accessed as a slave device through mode '11' SPI 3-wire, SPI 4-wire, or I2C serial interface.

- I2C interface
  - The sensor's default interface.
  - The sensor's address is 0x77 (default) or 0x76 (if the SDO pin is pulled-down to GND).
- SPI interface
  - The sensor will switch to SPI configuration if it detects an active low on the CSB pin. SPI 4-wire is the default SPI interface.
  - To enable SPI 3-wire configuration, a bit must be set in the CFG_REG register after start up.

  More details about digital interfaces are available in the Digital interfaces section.

4 Pressure measurement

Attention:

The AS23C-01BA-00 contains a number of one-time programmable (OTP) calibration coefficient fuse registers. These registers are intended to store a set of calibration coefficients, which are determined on an individual unit-by-unit basis. Details of these registers can be found in the section Calibration coefficients.

The application note "Monolithic Pressure Sensor Calibration Procedure" contains instructions for the calibration procedure and fusing. The following instructions for calculating temperature measurement assume that the AS23C-01BA-00 has been correctly calibrated and fused according to these instructions, and refers to the calibration coefficients as defined in the section Calibration coefficients.

The AS23C-01BA-00 is a monolithic MEMS pressure sensor die which makes use of a capacitive measurement principle.

The AS23C-01BA-00 sensor element consists of a number of sealed vacuum cells. Each cell consists of a hollow, evacuated cavity with a flexible membrane sealing the top. The top membrane and the bottom of the cell are electrodes, which form a capacitor. Due to the pressure difference between the interior of the cell and the ambient environment, the top membrane is deflected towards the bottom of the cell.

The vacuum cells are combined in a parallel measurement configuration, to increase the sensitivity and noise performance of the AS23C-01BA-00.

Increasing ambient pressure causes greater deflection towards the bottom of the cell and hence and increase in the capacitance between the membrane and the bottom of the cell. Decreasing ambient pressure reduces the deflection of the membrane and reduces the capacitance between the membrane and the bottom of the cell.

Pressure measurement is carried out by measuring the capacitance between the top and bottom of the cells and applying a calculation to the capacitance result to determine the pressure in Pa. It is also required to include a temperature correction in this calculation to eliminate temperature drift from the output.

4.1 Pressure measurement results

After starting the measurements, the latest pressure and temperature raw data will be available as 24-bit 2's complement numbers in their respective result registers if the FIFO is disabled: PSR_B2 to PSR_B0, and TMP_B2 to TMP_B0.

If the FIFO is enabled, all measurement results will be stored in registers PSR_B2 to PSR_B0. In this case, the register value will update to the next result stored in the FIFO after each read. The least significant bit of PSR_B0 will read "1" if the measurement is a pressure reading, or "0" if the measurement is a temperature reading. When all of the FIFO values have been read, the result register will be set to 0x800000.

When the FIFO is disabled, reading the result register will not affect the register value, it will only be updated when a new measurement is completed.

All measurement data can be read in a single command using auto-increment read.

4.1.1 Calculating pressure reading

To calculate the AS23C-01BA-00 pressure reading, it is necessary to first read and parse the calibration coefficient registers from addresses 0x26 to 0x39. These values only need to be read and parsed once for each device, they are fused in memory and will not change during operation. The method to generate the Calibration Coefficient values is described in the Calibration coefficients section of this document.

The pressure values stored in the result registers must be scaled according to the oversampling rate. The numbers in the registers must be divided by kP before they are used in the pressure reading calculation formula. The kP values for each oversampling option can be found in Table 9.

$$Pres_{SCALED} = Pres_{RAW} / kP$$

$$Temp_X = Temp_{RAW} / 1048576$$

$$Temp_{SCALED} = (8.5 \times Temp_X) / (1 + 8.8 \times Temp_X)$$

Where:

- $Pres_{RAW}$ is the 24 bit, 2's complement number read from the pressure output registers or FIFO
- $Temp_{RAW}$ is the 24 bit, 2's complement number read from the pressure output registers or FIFO

Equation 1 Deriving the scaled pressure and temperature values

Once the calibration coefficients have been read, and pressure and temperature register values have been read and scaled, the pressure reading can be calculated using the following formula:

$$Pres_{CALIBRATED} = C00 + [C10 \times Pres_{SCALED}] + [C01 \times Temp_{SCALED}] + [C20 \times Pres_{SCALED}^2] + [C02 \times Temp_{SCALED}^2] + [C30 \times Pres_{SCALED}^3] + [C11 \times Pres_{SCALED} \times Temp_{SCALED}] + [C12 \times Pres_{SCALED} \times Temp_{SCALED}^2] + [C21 \times Pres_{SCALED}^2 \times Temp_{SCALED}]$$

Where:

- C00, C10, C01, C20, C02, C30, C11, C12 and C21 are the calibration coefficients read from registers 0x26 to 0x39.

Equation 2 AS23C-01BA-00 Pressure output calculation

5 Temperature measurement

The AS23C-01BA-00 temperature measurement uses a silicon bandgap temperature sensor, measuring the base-emitter voltage (Vibe) of two BJT transistors, biased at different currents (IC1 and IC2). This measurement is used at a system level in the pressure output calculation to correct any temperature related measurement drift. The temperature of the transistors can be accurately determined by measuring the difference in voltage between both and applying the formula:

$$\Delta VBE = ((K*T)/ q) * (\ln(IC1 / IC2)$$

Where T is the temperature in Kelvin, K is Boltzmann's constant and q is the charge of a single electron. The measurement rate and precision (oversampling) can be modified by writing to the TEMP_CFG register, as described in the Measurement precision and rate section.

Note: For ambient temperature sensing, full system modeling should be carried out across temperature. This will account for internal heating effects of the system when calculating the ambient temperature value.

5.1 One time calculation of A' and B' coefficients

In order to calculate temperature output values in ° C, it is first necessary to calculate two coefficients, A' and B'. These coefficients are calculated from values stored in the AS23C-01BA-00 calibration coefficients registers, and do not change. These two coefficients can be calculated once on device start up and then stored in memory to be used in all future high accuracy temperature measurements.

The steps required to calculate A' and B' are below, calculation constants can be found in Table 10.

1. Read $T_{\_Vbe}$, $T_{\_dVbe}$ and $T_{\_gain}$:

These parameters are read directly from the calibration coefficient registers 0x20 to 0x22. These three values are in 2's complement.

2. Calculate V_{BE}, ΔV_{BE} and A_{ADC}:

These values are calculated directly from the calibration coefficient values:

- $V_{BE} = T_{\_Vbe} \times 1.05031E\text{-}4 + 0.463232422$
- $\Delta V_{BE} = T_{\_dVbe} \times 1.25885E\text{-}5 + 0.04027621$
- $A_{ADC} = T_{\_gain} \times 8.4375E\text{-}5 + 0.675$

3. Calculate V_{BE_CAL} and ΔV_{BE_CAL}:

- $V_{BE\_CAL} = V_{BE} / A_{ADC}$
- $\Delta V_{BE\_CAL} = \Delta V_{BE} / A_{ADC}$

4. Calculate calibration Temperature T_{CALIB}:

- $T_{CALIB} = A_0 \times \Delta V_{BE\_CAL} - 273.15$

5. Calculate $V_{BE\_CAL(TREF)}$, the V_{BE} value at reference temperature T_{REF}:

- $V_{BE\_CAL(TREF)} = V_{BE\_CAL} - (T_{CALIB} - T_{REF}) \times (T_{C\_VBE})$

6. Calculate P_{TAT} correction coefficient:

- $k_{PTAT} = [V_{BE\_TARGET}(T_{REF}) - V_{BE\_CAL}(T_{REF})] \times k_{PTAT\_CORNER} + k_{PTAT\_CURVATURE}$

7. Calculate A' and B' coefficients:

- $A' = A_0 \times (V_{BE\_CAL} + \alpha \times \Delta V_{BE\_CAL}) \times (1 + k_{PTAT})$
- $B' = -273.15 \times (1 + k_{PTAT}) - k_{PTAT} \times T_{CALIB}$

5.2 Calculating temperature output using A' and B'

Once the A' and B' coefficients have been calculated once, they can be stored in the host system and used for all future high accuracy temperature calculations for that AS23C-01BA-00 unit.

The calculation of high accuracy temperature readings using A' and B' is a four-step process, shown below.

1. Read out temperature result TRAW from registers TMP_B2 to TMP_B0 or FIFO, if enabled.
2. Scale the temperature measurement:

• $T_{CAL} = T_{RAW} / 1048576$

3. Calculate μ coefficient:

• $\mu = T_{CAL} / (1 + \alpha \times T_{CAL})$

4. Calculate T_{OUT}:

• $T_{OUT} = (A' \times \mu) + B'$

5.3 A' and B' calculation constants

The following table lists all of the coefficients required to calculate the A' and B' coefficients, as described in the Onetime calculation of A' and B' coefficients section.

Table 10 A' and B' calculation constants

Name	Unit	Value
T_{REF}	°C	27
$V_{BE\_TARGET}(T_{REF})$	V	0.687027
α	-	9.45
T_{C_VBE}	V	-1.735E-3
k_{PTAT_CORNER}	-	-0.8
$k_{PTAT\_CURVATURE}$	-	0.039
A_0	K	5030

6 Applications

6.1 Measurement settings and use case examples

The AS23C-01BA-00 provides versatile pressure measurements for a wide range of applications. The requirements of these applications can be very different, and so the AS23C-01BA-00 can be quickly configured with a couple of register writes to ensure the speed, accuracy and current consumption are in line with the application priorities.

Table 11 Measurement settings and use case examples

Use Case	Performance	Pressure Register Configuration Address: 0x06	Temperature Register Configuration Address: 0x07	FIFO Enabled? Address: 0x09	Other
Weather Station (Low power)	5 Pa precision. 1 pr sec. 3 µA FIFO disabled	0x01	0x00	Bit 1 = 0	Start background measurements (addr 0x08)
Indoor navigation (Standard precision, background mode)	10 cm precision. 2 pr sec. 35 µA FIFO enabled	0x14	0x93	Bit 1 = 1	Start background measurements (addr 0x08)
Sports (High precision, high rate, background mode)	5 cm precision 4 pr sec. 175 µA FIFO enabled	0x26	0xA3	Bit 1 = 1	Start background measurements (addr 0x08)

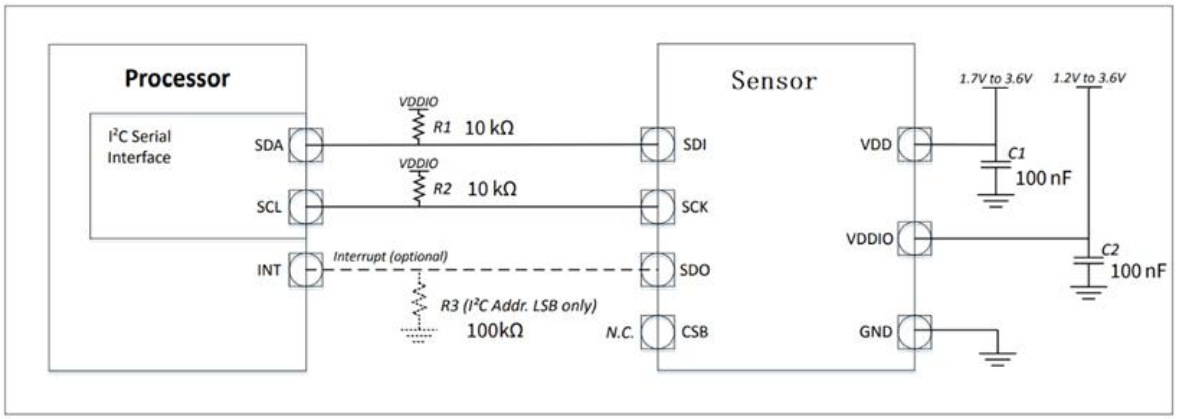
6.2 Application circuit examples

The example application circuits below demonstrate the connection of the I2C and SPI serial interfaces.

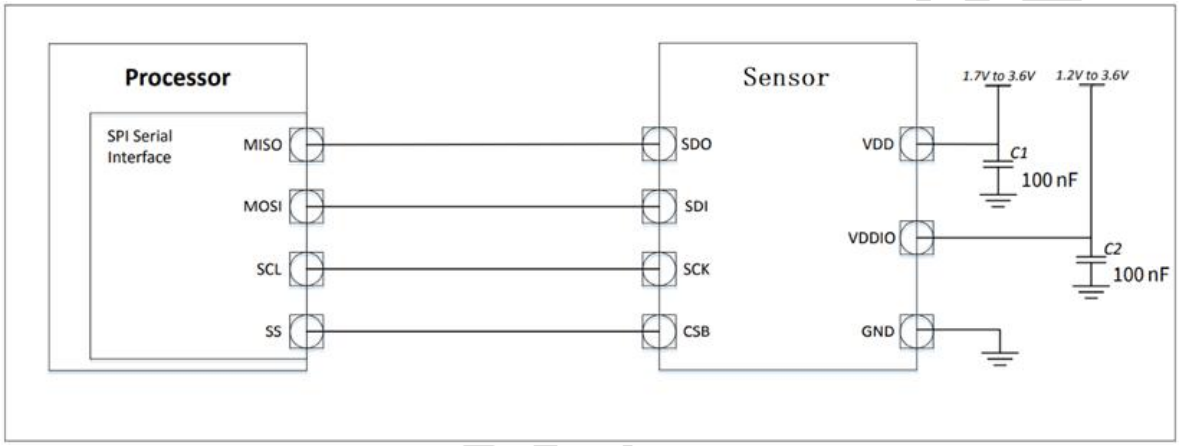
- In I2C mode, the SDO pin can be used for interrupt output and/or to set the least significant bit of the device address.
- In 3-wire SPI mode, the SDO pin can be used for interrupt output.
- In 4-wire SPI mode, the SDO pin can only be used as the serial data output.

The AS23C-01BA-00 analog core supply voltage is internally regulated, guaranteeing robustness to external VDD supply variations within the specified range. The simplest voltage supply solution is to connect VDD and VDDIO to 1.8V supply and add a suitable decoupling capacitor to reduce VDD ripple below 50mVpp.

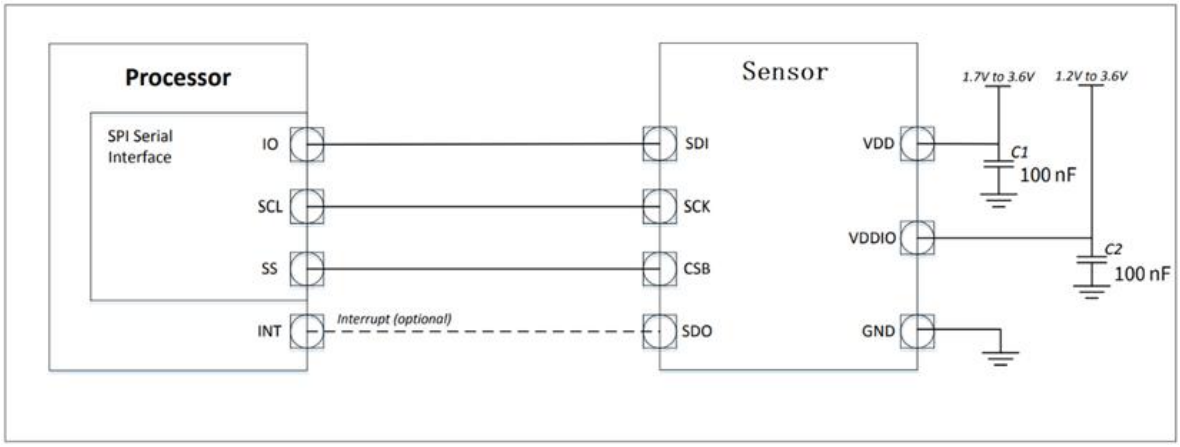
6.3 Application Circuit



Application circuit example using the I2C serial interface



Application circuit example using the SPI 4-wires serial interface



Application circuit example using the SPI 3-wire serial interface

7 Digital interfaces

The AS23C-01BA-00 measurement data, calibration coefficients, Product ID and configuration registers can be accessed through both the I2C and SPI serial interfaces.
The SPI interface can be configured to operate in 3-wire or 4-wire mode.
In I2C and SPI 3-wire, an interrupt output can be implemented on the SDO pin.
The SPI interface only supports mode '11' (CPOL=CPHA='1') in 4-wire and 3-wire configuration.
The following commands are supported by the I2C interface:

- Single byte read
- Single byte write
- Multi-byte read, with automatic register increment
- Multi-byte write, with automatic register increment

The following commands are supported by the SPI interface:

- Single byte read
- Single byte write
- Multi-byte read, with automatic register increment

Note: Multi-byte write is not supported by the SPI interface.
The communication interface is selected using the CSB pin:

- If CSB is connected to VDDIO, the I2C interface is active.
- If CSB is connected to ground, the SPI interface is active.

Once CSB has been pulled down, the I2C interface is disabled until the next power-on-reset.
If CSB is high, the I2C interface is selected by addressing the AS23C-01BA-00 over the I2C bus. After this, the I2C interface is locked, and pulling down CSB will not activate the SPI interface. The SPI interface can only be selected by pulling CSB low after the next power-on-reset, before the AS23C-01BA-00 is addressed over I2C.

7.1 I2C interface

The I2C slave interface is compatible with Philips I2C Specification version 2.1. The I2C interface supports standard, fast and high-speed mode.
The sensor's address is 0x77 if the SDO pin is left floating or pulled-up to VDDIO, or 0x76 if the SDO pin is pulled down to GND. The I2C interface uses the pads described in the Pad configuration section. Refer to Application circuit examples for connection instructions.

The basic timing is shown in the diagram below:

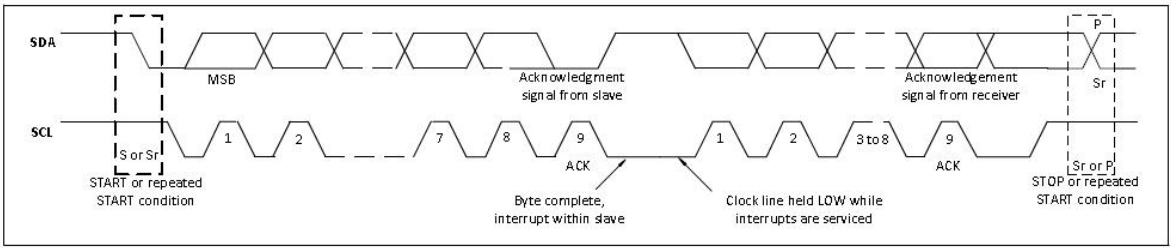


Figure 10 I2C timing diagram

In one access, without a stop command, incremental read (address is auto increment) and auto-incremental write are supported. The read and write access is shown below:

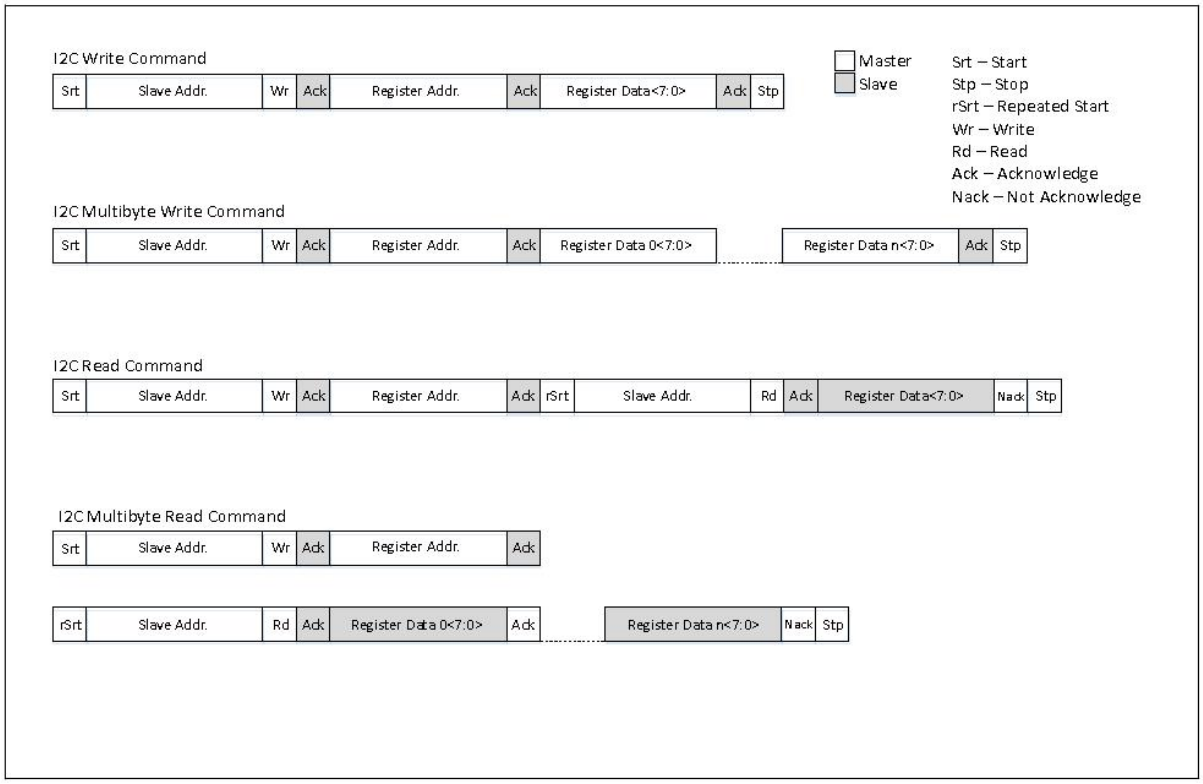


Figure 11 I2C write and read commands

7.2 SPI interface

The SPI interface is compatible with SPI mode '11' (CPOL = CPHA = '1'. The SPI interface has two modes: 4-wire and 3-wire.

The protocol for 3-wire and 4-wire SPI is similar. The 3-wire SPI protocol uses a single shared data line, the 4 -wire SPI protocol uses separate Serial Data Out (SDO) and Serial Data In (SDI) data lines. The naming of these data lines refers to the direction of data respective to the slave device.

3-wire SPI mode is selected by setting bit [0] in the CFG_REG register to '1'.

The SPI interface uses the pads described in the Pad configuration section. Refer to Application circuit examples for connection instructions. The SPI protocol is shown in the diagram below:

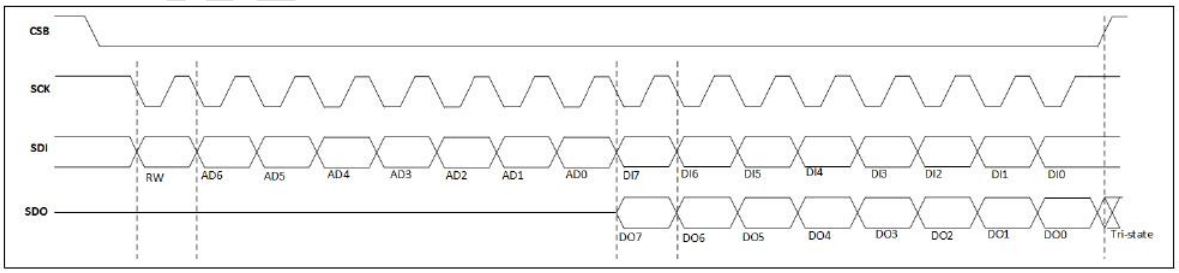


Figure 12 SPI protocol, 4-wire without interrupt

7.3 Interface parameter specification

7.3.1 General interface parameters

The general interface parameters are given in the table below:

Table 13 Interface parameters

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Input voltage for low logic level at input pins	Vlow_in			0.3 * V_{DDIO}	V	V_{DDIO}=1.2V to 3.6V
Input voltage for high logic level at input pins	Vhigh_in	0.7 * V_{DDIO}			V	V_{DDIO}=1.2V to 3.6V
Output - low level for I2C	Vlow_SDI			0.1 * V_{DDIO}	V	V_{DDIO}=1.8V, iol=2mA
Output voltage for low level at pin SDI for I2C	Vlow_SDI_1.2			0.2* V_{DDIO}	V	V_{DDIO}=1.20V, iol=1.3mA
Output voltage for high level at pins SDO, SDI	Vhigh_out	0.8 * V_{DDIO}			V	V_{DDIO}=1.8V, iol=1mA (SDO, SDI)
Output voltage for high level at pins SDO, SDI	Vhigh_out_1.2	0.6 * V_{DDIO}			V	V_{DDIO}=1.2V, iol=1mA (SDO, SDI)
Pull-up resistor	Rpull	60	120	180	kohm	Internal pull-up resistance to V_{DDIO}
I^2C bus load capacitor	Cb			400	pF	On SDI and SCK

7.3.2 I2C timing parameters

The I2C timing is shown in the diagram below and corresponding values are given in the table below. The naming refers to I2C Specification version 2.1, the abbreviations used "S&F mode" = standard and fast mode, "HS mode" = high speed mode, Cb = bus capacitance on SDA line.

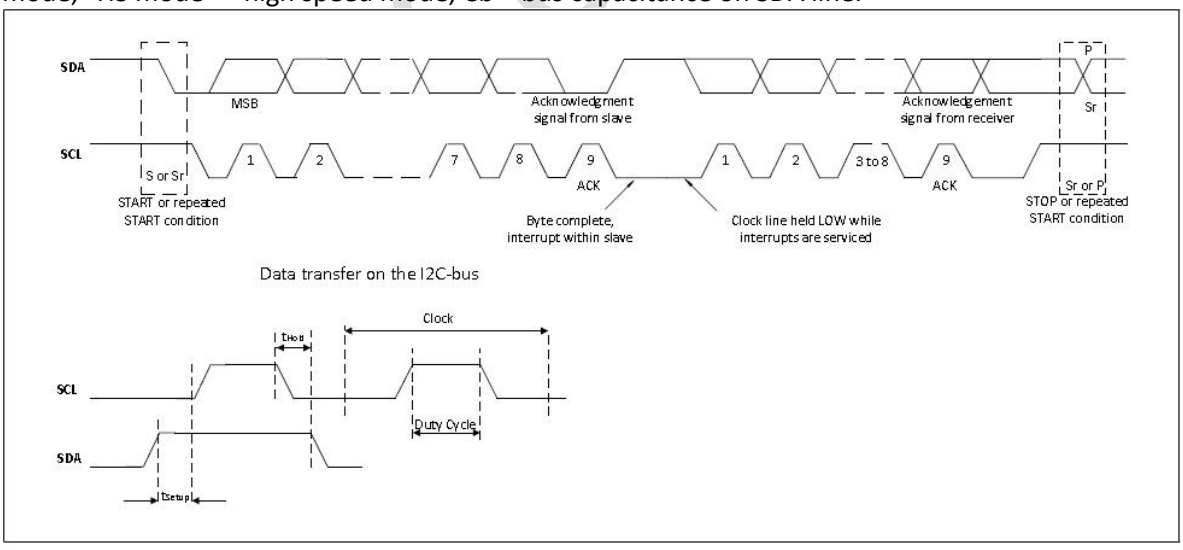


Figure 14 I2C timing diagram

Table 14 I2C timings

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Data setup time on SDI pin	t_{Setup}	20			ns	S&F mode
		5			ns	HS mode
Data hold time on SDI pin	t_{Hold}	0			ns	S&F&HSmode,
Duty Cycle	DC			70	%	S&F mode,
				55	%	HS mode,

7.3.3 SPI timing parameters

The SPI timing diagram is shown in the figure below and the corresponding values are given in the table below. All timings apply both to 4-wire and 3-wire SPI.

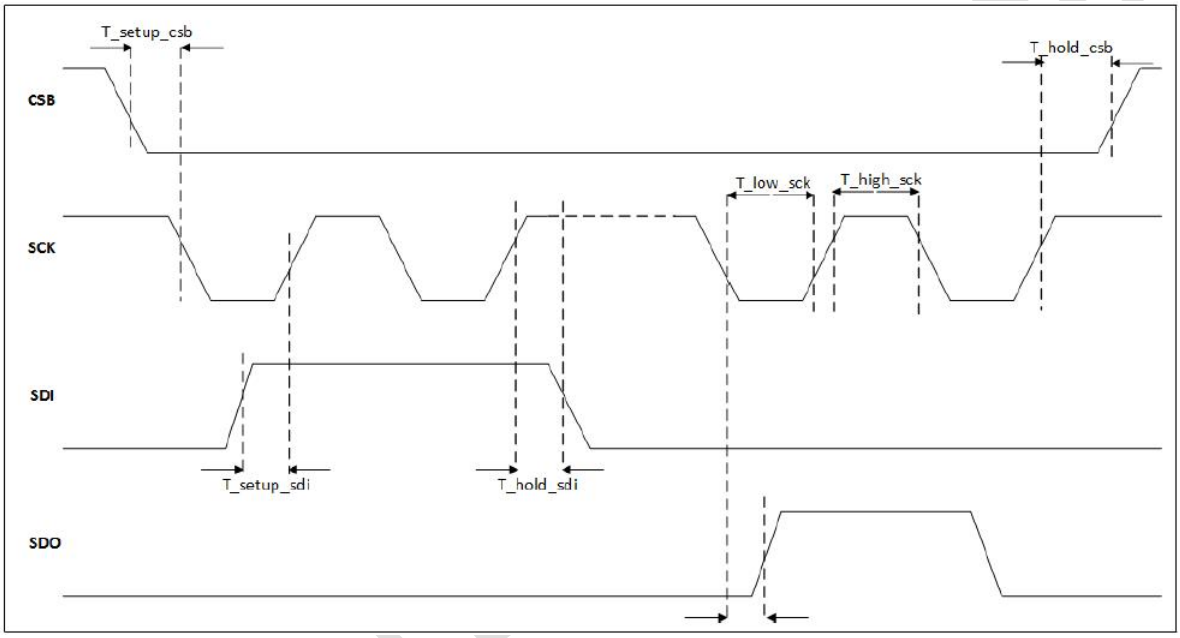


Figure 15 SPI timing diagram

Table 15 SPI timings

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Duty Cycle (Thigh%)	SPI_DC	30			%	V_{DDIO} = 1.2V
		20			%	V_{DDIO} = 1.8V/3.6V
SDI setup time	T_setup_sdi	2			ns	
SDI hold time	T_hold_sdi	2			ns	
Clock	SPI_CLK			10	MHz	
CSB setup time	T_setup_csb	15			ns	
CSB hold time		15			ns	

8 AS23C-01BA-00 Register map

The AS23C-01BA-00 user registers are listed and described below. The calibration coefficient registers can be found in the Calibration coefficients section.

Table 16 AS23C-01BA-00 Register Map

Register Name	Addr.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Reset Value
PSR_B2	0x00	Pressure measurement MSB <23:16>								0x80
PSR_B1	0x01	Pressure measurement LSB <15:8>								0x00
PSR_B0	0x02	Pressure measurement XLSB <7:0>								0x00
TMP_B2	0x03	Temperature measurement MSB <23:16>								0x80
TMP_B1	0x04	Temperature measurement LSB <15:8>								0x00
TMP_B0	0x05	Temperature measurement XLSB <7:0>								0x00
PSR_CFG	0x06	-	Pressure measurement rate [2:0]			-	Pressure measurement resolution [3:0]			0x00
TEMP_CFG	0x07	Must be set to 1	Temperature measurement rate [2:0]			-	Temperature measurement resolution [3:0]			0x80
MEAS_CFG	0x08	Init. complete	Cont. mode flag	Temp. data ready	Press. data ready	-	Measurement control [2:0]			0x00
CFG_REG	0x09	Interrupt select [3:0]				Interrupt polarity	FIFO Stop on full	FIFO enable	SPI mode	0x00
INT STS	0x0A	-	-	-	-	-	FIFO interrupt Full / WM	Temp. interrupt	Press. interrupt	0x00
WM_CFG	0x0B	-	-	-	Watermark level[4:0]					0x1F
FIFO_STS	0x0C	FIFO fill level[5:0]						FIFO Full / WM	FIFO empty	0x00
RESET	0x0D	FIFO flush	-	-	-	Soft reset[3:0]				0x00
PROD_ID	0x1D	Revision ID[3:0]				Product ID[3:0]				0x1A

Attention: To ensure correct functionality, registers not listed in this register map must not be accessed.

Table 17 PSR_B2 bit fields

Bit Name	Bits	Type	Description
Pressure measurement MSB <23:16>	<7:0>	R	Pressure measurement result bits 23 to 16.

Table 18 PSR_B1 bit fields

Bit Name	Bits	Type	Description
Pressure measurement LSB <15:8>	<7:0>	R	Pressure measurement result bits 15 to 8.

Table 19 PSR_B0 bit fields

Bit Name	Bits	Type	Description
Pressure measurement XLSB <7:0>	<7:0>	R	Pressure measurement result bits 7 to 0.

Table 20 TMP_B2 bit fields

Bit Name	Bits	Type	Description
Temperature measurement MSB <23:16>	<7:0>	R	Temperature measurement result bits 23 to 16.

Table 21 TMP_B1 bit fields

Bit Name	Bits	Type	Description
Temperature measurement LSB <15:8>	<7:0>	R	Temperature measurement result bits 15 to 8.

Table 22 TMP_B0 bit fields

Bit Name	Bits	Type	Description
Temperature measurement XLSB <7:0>	<7:0>	R	Temperature measurement result bits 7 to 0.

Table 23 PSR_CFG bit fields

Bit Name	Bits	Type	Description
Pressure measurement rate[2:0]	<6:4>	RW	Pressure measurement rate: • 000 - 1 sample/sec • 001 - 2 samples/sec • 010 - 4 samples/sec • 011 - 8 samples/sec • 100 - 16 samples/sec • 101 - 32 samples/sec • 110 - 64 samples/sec • 111 - 128 samples/sec
Pressure measurement resolution[2:0]	<2:0>	RW	Pressure measurement resolution: • 000 - 256 samples - 1x decimation • 001 - 512 samples - 2x decimation • 010 - 1024 samples - 4x decimation • 011 - 2048 samples - 8x decimation • 100 - 4096 samples - 16x decimation • 101 - 8192 samples - 32x decimation • 110 - 16384 samples - 64x decimation • 111 - 32768 samples - 128x decimation

Table 24 TEMP_CFG bit fields

Bit Name	Bits	Type	Description
Must be set to 1	<7>	RW	*Warning:* *This bit **must** be set to '1' to configur the temperature measurement correctly. If this bit is not set, the temperature and pressure measurements will not function correctly.*
Temperature measurement rate [2:0]	<6:4>	RW	Temperature measurement rate: • 000 - 1 sample/sec • 001 - 2 samples/sec • 010 - 4 samples/sec • 011 - 8 samples/sec • 100 - 16 samples/sec • 101 - 32 samples/sec • 110 - 64 samples/sec
Temperature measurement resolution [2:0]	<2:0>	RW	Temperature measurement resolution: • 000 - 256 samples - 1x decimation • 001 - 512 samples - 2x decimation • 010 - 1024 samples - 4x decimation • 011 - 2048 samples - 8x decimation • 100 - 4096 samples - 16x decimation • 101 - 8192 samples - 32x decimation • 110 - 16384 samples - 64x decimation • 111 - 32768 samples - 128x decimation

Table 25 MEAS_CFG bit fields

Bit Name	Bits	Type	Description
Init. complete	<7>	R	Status bit set when initialisation procedure is complete.
Cont. mode flag	<6>	R	Status bit set when ICPRE100 is in continuous measurement mode.
Temp. data ready	<5>	R	Status bit set when new temperature measurement data is available. Cleared when register 0x05 is read.
Press. data ready	<4>	R	Status bit set when new pressure measurement data is available. Cleared when register 0x02 is read.
Measurement control [2:0]	<2:0>	RW	Configuration register controlling measurement mode: • 000 - Idle / Stop Background • 001 - Pressure Measurement • 010 - Temperature Measurement • 011 - Pressure and Temperature Measurement one shot • 100 - Idle / Stop Background • 101 - Continuous Pressure Measurement • 110 - Continuous Temperature Measurement • 111 - Continuous Pressure and Temperature Measurement

Table 26 CFG_REG bit fields

Bit Name	Bits	Type	Description
Interrupt select[3:0]	<7:4>	RW	Select interrupt source: • 0000 - no interrupt enabled • 0001 - Pressure Interrupt enabled • 0010 - Temperature Interrupt enabled • 0011 - Pressure & Temperature Interrupt enabled • 0100- FIFO Watermark Interrupt enabled • 1000- FIFO FULL Interrupt enabled All other settings are invalid. Interrupt pin(*SDO* pin) is cleared when the Interrupt Status Register (0x0A) is read.
Interrupt polarity	<3>	RW	Interrupt active polarity: • 0 - Active low • 1 - Active high *Note: Interrupt can only be output when the ICPRE100 is in I^2C or 3-wire SPI modes.*
FIFO Stop on full	<2>	RW	Configures FIFO behaviour when full: • 0 - FIFO in streaming mode. When full, oldest data is overwritten as new data is available. • 1 - FIFO in stop on full mode. When full, old data is retained, new data is not stored.
FIFO enable	<1>	RW	Enables pressure and temperature result FIFO: • 0 - FIFO is disabled. Old results are not stored. Pressure and temperature results stored in respective results registers. • 1 - FIFO is enabled. Results are read from result registers 0x00 - 0x02. Up to 32 results can be stored.
SPI mode	<0>	RW	Configures the SPI protocol used: • 0 - 4-wire SPI interface. • 1 - 3-wire SPI interface

Table 27 INT STS bit fields

Bit Name	Bits	Type	Description
FIFO interrupt Full / WM	<3>	R	This bit is set when FIFO is full or when FIFO reaches watermark level. Source depends on setting inCFG_REG register. *Note: This bit should not be polled faster than once per 375 µs.*
Temp. interrupt	<2>	R	This bit is set when new temperature data is available.
Press. interrupt	<1>	R	This bit is set when new pressure data is available.

Table 28 WM_CFG bit fields

Bit Name	Bits	Type	Description
Watermark level[4:0]	<4:0>	RW	Configures number of measurement results which must be in the FIFO to trigger the FIFO watermark interrupt. • 0x00 - Interrupt generated when FIFO contains 1 unread measurement result. • 0x1F - Interrupt generated when FIFO contains 32 unread measurement results.

Table 29 FIFO_STS bit fields

Bit Name	Bits	Type	Description
FIFO fill level[5:0]	<7:2>	R	This bit field contains the number of pressure and/or temperature measurements currently stored in the measurement results FIFO.
FIFO Full / WM	<1>	R	This bit is set when FIFO is full or when FIFO reaches watermark level. Source depends on setting in WM_CFG register. *Note: This bit is updated every 250 µs*
FIFO empty	<0>	R	This bit is set when the FIFO is empty. • 0 - FIFO currently contains data • 1 - FIFO does not currently contain data *Note: This bit is updated every 250 µs*

Table 30 RESET bit fields

Bit Name	Bits	Type	Description
FIFO flush	<7>	W	Setting this bit to 1 clears all data in the measurement results FIFO.
Soft reset[3:0]	<3:0>	W	Two soft reset options are available, depending on the value sent to this bit field. • 0b1000: Reset configuration registers without eFuse refresh. Duration ~0.7ms. • 0b1001: Full reset. Similar to power-on-reset, all registers are reset and eFuses refresh is carried out. Duration ~3ms. *Note: Only the listed values should be written to the soft reset bit field. Writing incorrect values may result in unexpected behaviour.*

8.1 Calibration coefficients

The AS23C-01BA-00 register map contains a number of one-time programmable fuse registers which are intended to be used to store calibration coefficients, which are individually calculated and are used in the calculation of pressure and temperature measurements.

The three temperature measurement coefficients should be stored across three registers at addresses 0x20 to 0x22. These coefficients must be used to accurately convert the temperature measurement value stored in the results registers TMP_B0 to TMP_B2 into a temperature value in ° C.

Pressure calibration coefficients should be stored in register addresses 0x26 to 0x39. These coefficients must be used in the calculation of pressure measurement results to eliminate any measurement non-linearities caused by temperature changes.

The following tables shows the recommended register layout of the calibration coefficients. It is recommended to block read these coefficient registers and then parse according to the bit label lings in the table.

Table31AS23C-01BA-00 Temperature Calculation Coefficients

Register Name	Addr.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
T_GAIN_COEFF	0x20	T_gain <7:0>							
T_dVBE_COEFF	0x21	T_dVbe<6:0>							T_Vbe<0>
T_VBE_COEFF	0x22	T_Vbe<8:1>							

Table32 AS23C-01BA-00 Pressure Measurement Calibration Coefficients

Register Name	Addr.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
COEFF_REG_1	0x26	C00 <19:12>							
COEFF_REG_2	0x27	C00 <11:4>							
COEFF_REG_3	0x28	C00 <3:0>				C10 <19:16>			
COEFF_REG_4	0x29	C10 <15:8>							
COEFF_REG_5	0x2A	C10 <7:0>							
COEFF_REG_6	0x2B	C01 <19:12							
COEFF_REG_7	0x2C	C01 <11:4							
COEFF_REG_8	0x2D	C01 <3:0>				C02 <19:6>			
COEFF_REG_9	0x2E	C02 <15:8>							
COEFF_REG_10	0x2F	C02 <7:0>							
COEFF_REG_11	0x30	-	C20 <14:8>						
COEFF_REG_12	0x31	C20 <7:0>							
COEFF_REG_13	0x32	-				C30 <11:8>			
COEFF_REG_14	0x33	C30 <7:0>							
COEFF_REG_15	0x34	C11 <16:9>							
COEFF_REG_16	0x35	C11 <8:1>							
COEFF_REG_17	0x36	C11 <0>	C12 <16:10>						
COEFF_REG_18	0x37	C12 <9:2>							
COEFF_REG_19	0x38	C12 <1:0>		C21 <13:8>					
COEFF_REG_20	0x39	C21 <7:0>							

8.2 Coefficient number formats

8.2.1 The six temperature calculation coefficients use the following number formats:

Table33 AS23C-01BA-00 Temperature Calculation Coefficients formats

Coefficient	Format
T_gain	8 bits, 2's complement
T_dVbe	7 bits, 2's complement
T_Vbe	9 bits, 2's complement

8.2.2 The pressure measurement calibration coefficients use the following number formats:

Table34 AS23C-01BA-00 Pressure Measurement Calibration Coefficients formats

Coefficient	Format
C00	20 bit, 2's complement
C01	20 bit, 2's complement
C02	20 bit, 2's complement
C10	20 bit, 2's complement
C11	17 bit, 2's complement
C12	17 bit, 2's complement
C20	15 bit, 2's complement
C21	14 bit, 2's complement
C30	12 bit, 2's complement

9. Package Outlines and Pin Configuration (GENERAL TOLERANCE ± 0.10mm)

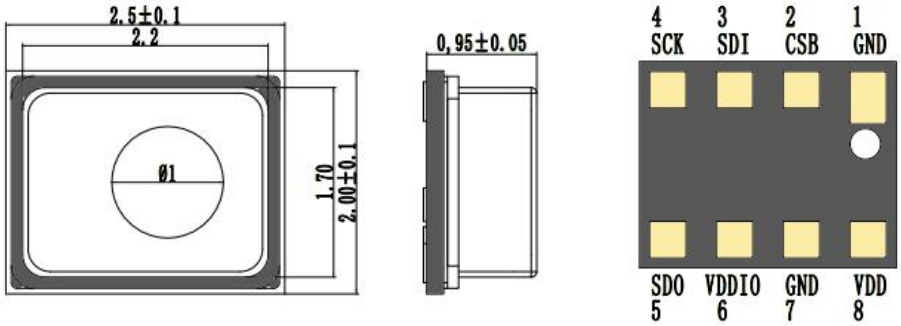


Figure5: Package Outlines

Pin	Name	Type	Function
1	GND	G	Power ground
2	CSB	I	Chip select - active low /SPI Mode Not used - open (internal pull-up) or tie to VDDIO / I 2C Mode
3	SDI	I/O	Serial data in / out / SPI 3-wire Serial data in / out / SPI 3-wire with interrupt Serial data in / SPI 4-wire Serial data in / out / I 2C Serial data in / out / I 2C with interrupt
4	SCK	I	Serial data clock
5	SDO	I/O	Not used/ SPI 3-wire Interrupt/ SPI 3-wire with interrupt Serial data out/ SPI 4-wire Least significant bit in the I2C address/ I 2C Interrupt pin and LSB of I2C address[1)]/ I 2C with interrupt
6	VDDIO	P	Digital supply voltage for digital blocks and I/O interface
7	GND	G	Power ground
8	VDD	P	Supply voltage for analog blocks

Figure 6: Pin Configuration and Description

1) Address pin state detected on start-up only. Internal pull up resistor maintains a high logic level on start-up if pin is not connected. Internal pull up resistor is disabled - her start-up if a logic low state is detected (due to external pull down), or if the interrupt output is enabled

10. Recommended Pad Layout

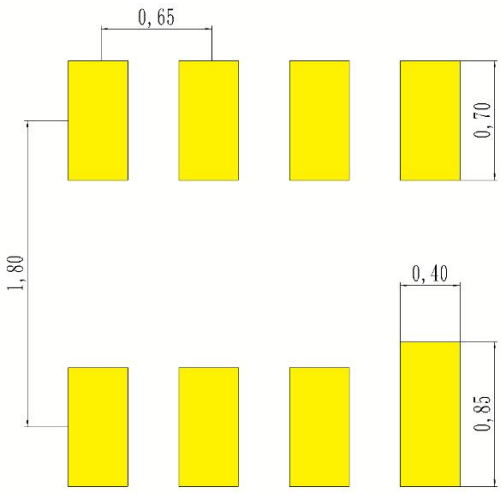
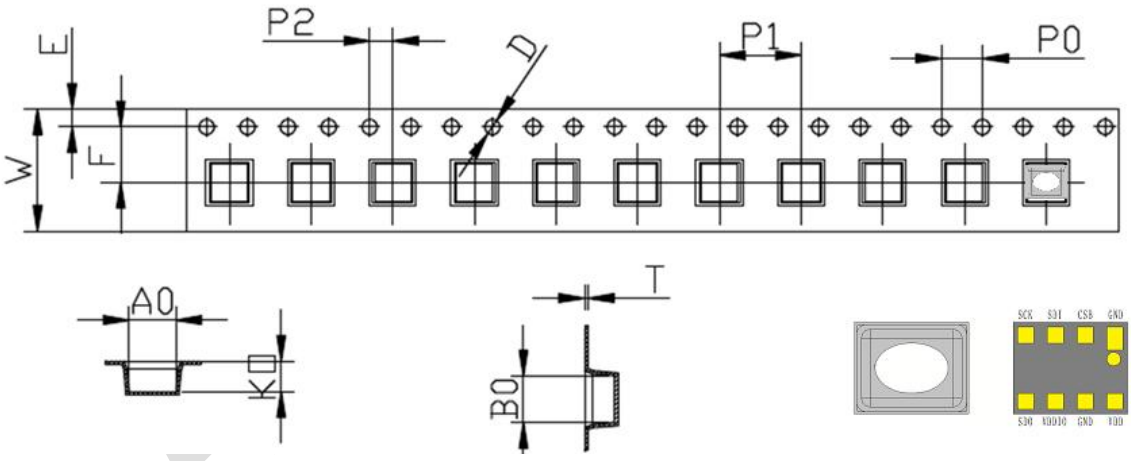


Figure7: Pad layout

11. Shipping Package

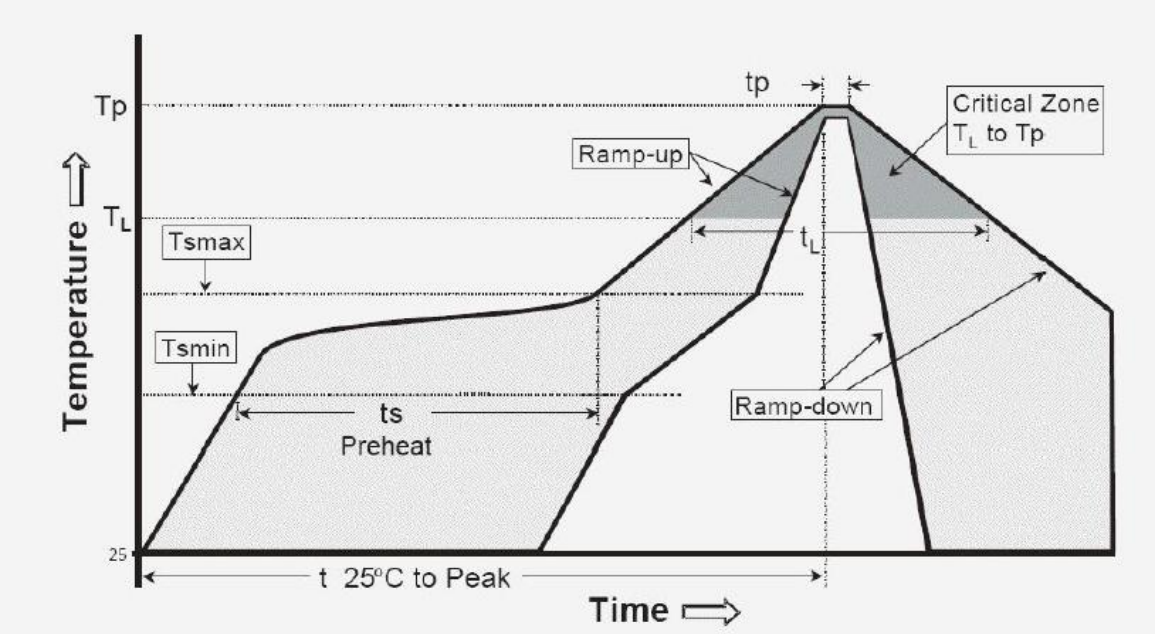
a) Tube

b) Tape & Reel



ITEM	W	A0	B0	K0	K1	P1	F	E	D	D1	P0	P2	T
DIM	12.0	3.60	3.60	3.0	0.00	8.0	5.5	1.75	1.5	0	4.0	2.0	0.35
TOLE	±0.3	±0.1	±0.1	±0.1	±0.1	±0.1	±0.05	±0.1	+0.1 -0.0	min	±0.1	±0.1	±0.05

12.Soldering Recommendation（IPC/JEDEC J-STD-020B (July 2002)）



IPC/JEDEC J-STD-020B (July 2002)	Pb-Free Assembly
Average Ramp-up rate（TL-Tp）	3℃/s（Max.）
Preheat –Temperature Min. (Tsmin) –Temperature Max. (Tsmax) –Time (Min. to Max.) (ts)	 150℃ 200℃ 60-150 seconds
Tsmax to TL –Tp	3℃/s（Max.）
Time maintained above: –Temperature (TL) –Time (tL)	 217℃ above 50-90 seconds
Peak temperature (Tp)	240 +0/-5℃
Time of Real peak temperature within 5℃ (tp)	40 seconds
Average Ramp-down rate（Tp-TL）	4℃/s（Max.）
Time 25℃ to peak temperature	8min.（Max.）

13. LEGAL DISCLAIMER

1) For the export of products which are controlled items subject to foreign and domestic export laws and regulations, you must obtain approval and/or follow the formalities of such laws and regulations.

2) Products must not be used for military and/or antisocial purposes such as terrorism, and shall not be supplied to any party intending to use the products for such purposes.

3) Unless provided otherwise, the products have been designed and manufactured for application to equipment and devices which are sold to end-users in the market.

4) Before using products, which were not specifically designed for use in automotive applications, please contact an AIOT sales representative.

5) This specification is subject to change without notice.

AIoTSensing Inc.

TEL：+86 0551-65336537

Email：sales@aiotsensing.com

Website：http://www.aiotsensing.com

Address: 2nd Floor, Building 4, Ming Zhu Industrial Park, No. 106, Chuang Xin Avenue, High-tech Zone, Hefei City, 230088 China