1. Description

MXH1321 is a digital temperature sensor with small size and high accuracy. The device offers ±0.5°C accuracy without extra calibration or additional signal conditioning. The device features two-wire I2C interface for digital output and on-chip 12-bit ADC for 0.0625°C/LSB resolutions. The device operates on supply voltages from 1.4 to 3.6 V with low quiescent current of 10μA over the full operating range. It is ideal for high accuracy temperature measurement in computer, consumer, environmental, industrial, and instrumentation applications.

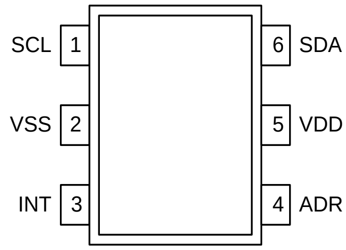
2. Features

- Supply range
  - 1.4V to 3.6V
- Temperature range
  - -40°C to +125°C
- I²C SMBUS interface
- 4 slave addresses
- Thermostat mode
- Temperature reading accuracy
  - Typical ±0.25°C from -40°C to +50°C
  - Typical ±0.5°C from +50°C to +125°C
- Low quiescent current
  - Max. 10uA in active, max. 1uA in shutdown
- Small size package
  - 1.6mm x 1.6mm SOT563

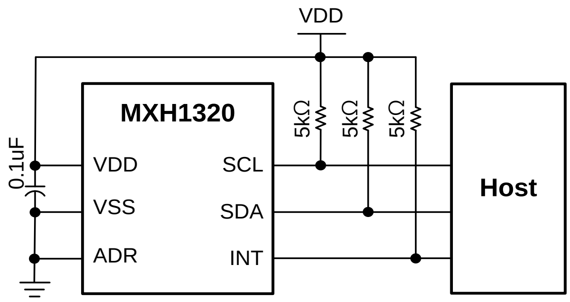
3. Applications

- Battery-powered applications
- Power-supply temperature monitoring
- Display panel thermal protection
- Notebook computers
- Battery management system
- Thermostat controls

4. Pin Assignment



5. Application Circuits



6. Block Diagram

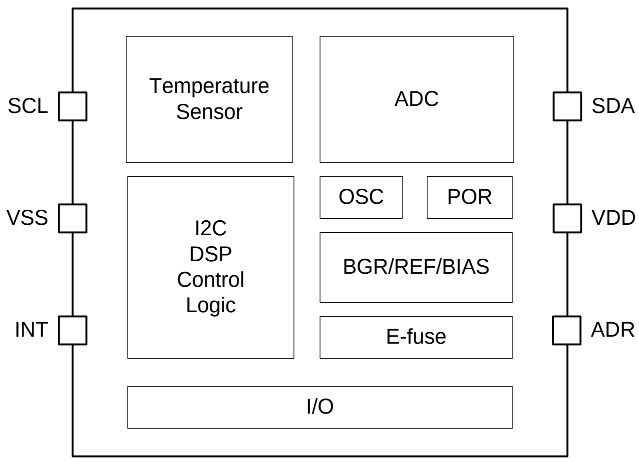


Table of Contents

7. Ordering Information

Part No	PACKAGE	DESCRIPTION
MXH1321AST	SOT563	Low power digital temperature sensor

8. Pin Description

Name	Pin#	Type	Description
SCL	1	I	Serial clock signal
VSS	2	-	Ground
INT	3	O	Interrupt output signal (open drain output)
ADR	4	I	Slave address select. Connect to VDD or VSS or SCL or SDA
VDD	5	I	Supply voltage, 1.4V to 3.6V
SDA	6	I/O	Serial data signal (open drain output)

9. Specifications

9.1. Absolute Maximum Ratings

Symbol	Parameter	Min	Max	Unit
V_{DD}	Power supply	-0.3	4	V
V_{LOGIC}	Digital I/O pins (SDA, SCL, INT, ADR)	-0.3	V_{DD} + 0.3	V
T_{STG}	Storage temperature	-55	150	°C
T_{OP}	Operation temperature	-40	125	°C

9.2. Electrical Characteristics

Test conditions are V_{DD} = 3.3V, T = 25°C, unless otherwise noted.

- Power Supply Specifications

Parameter	Test Condition	Min	Typ	Max	Unit
Operating Supply Range		1.4		3.6	V
Average Current	I_{AVG}, CR1=1, CR0=0 (default)		7	10	μA
Shutdown Current	I_{SD} (serial bus active)		0.5	1	μA

- Temperature Input Specifications

Parameter	Test Condition	Min	Typ	Max	Unit
Accuracy	-40°C to +50°C		±0.25	±0.5	°C
(Temperature Error)	50°C to +125°C		±0.5	±1.0	°C
V_{DD} Supply Sensitivity			0.0625	0.25	°C/V
Resolution			0.0625		°C/LSB

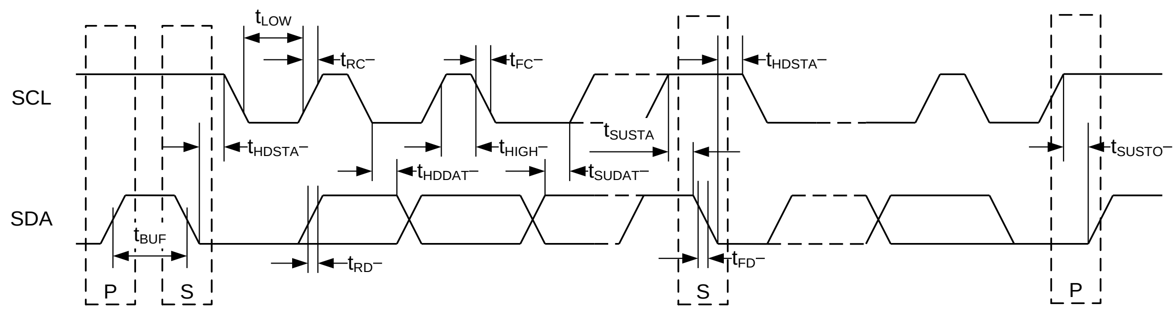
- Digital Input/Output Pin DC Specifications

Parameter	Test Condition	Min	Typ	Max	Unit
V_{IH} Input logic high		0.7xV_{DD}	-	V_{DD}	V
V_{IL} Input logic low		-	-	0.3xV_{DD}	V
I_{IN} Input current	0 < V_{IN} < 3.6V			1	μA
V_{OL} Output logic	V_{DD}>2V, I_{OL} =3mA	0		0.4	V
(SDA, INT)	V_{DD}<2V, I_{OL} =3mA	0		0.2xV_{DD}	
Conversion time			18	24	ms
Conversion mode	CR1 = 0, CR0 = 0		0.25		conv/s
	CR1 = 0, CR0 = 1		1		(Hz)

	CR1 = 1, CR0 = 0 (default)		4		
	CR1 = 1, CR0 = 1		8		
Timeout time			30	40	ms

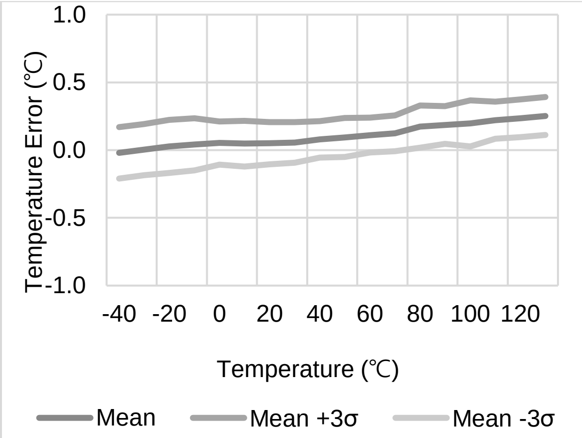
- Serial Interface Timing Specifications

Parameter	Symbol	Fast Mode			High-Speed Mode			Unit
		Min	Typ	Max	Min	Typ	Max	
SCL frequency	f_{SCL}	0.001		0.4	0.001		2.85	MHz
Bus free time between stop and start condition	t_{BUF}	600			160			ns
Hold time after start condition. After this period, the first clock is generated.	t_{HDSTA}	600			160			ns
Repeated start condition setup time	t_{SUSTA}	600			160			ns
Stop condition setup time	t_{SUSTO}	600			160			ns
SDA hold time	t_{HDDAT}	100		900	25		105	
SDA setup time	t_{SUDAT}	100			25			
SCL low period	t_{LOW}	1300			210			ns
SCL high period	t_{HIGH}	600			60			ns
SDA fall time	t_{FD}			300			80	ns
SDA rise time	t_{RD}			300				ns
SCL fall time	t_{FC}			300			40	
SCL rise time	t_{RC}			300			40	

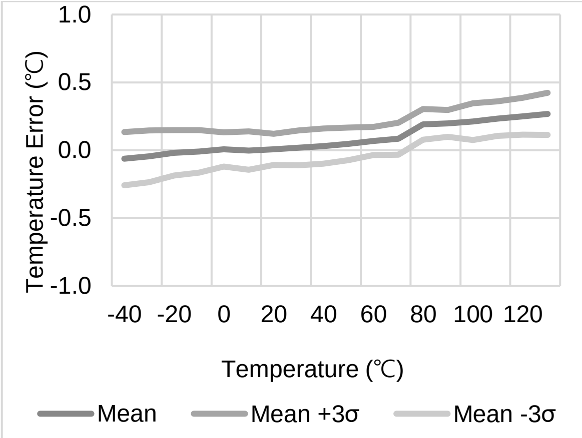


<Two-wire Timing Diagram >

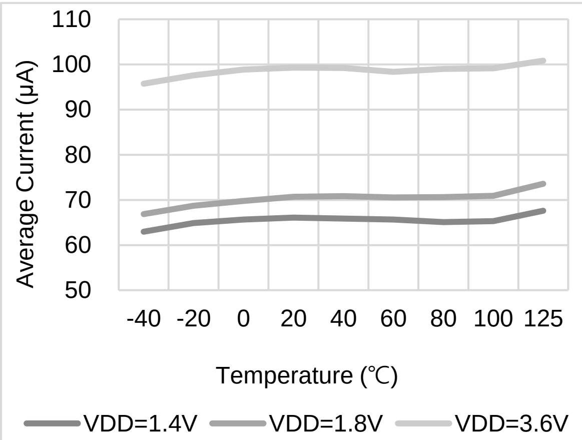
9.3. Typical Operating Characteristics



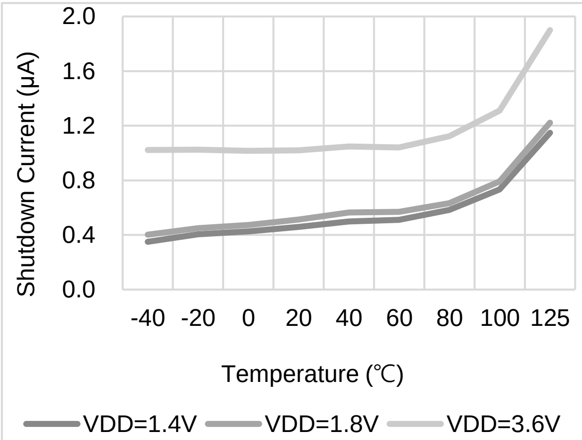
<Temperature Error vs Temperature in V_{DD}=1.8V>



<Temperature Error vs Temperature in V_{DD}=3.3V>



<Average Current vs Temperature>



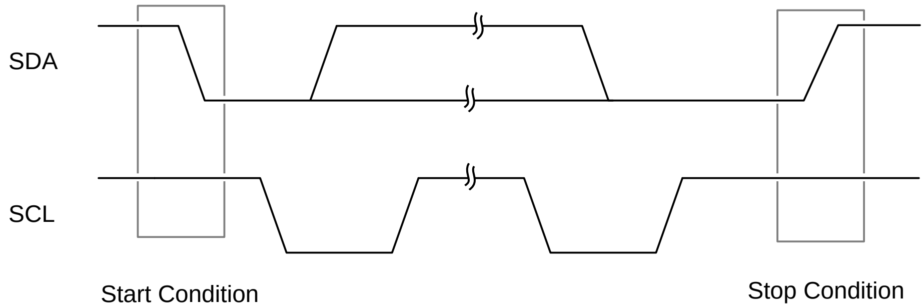
<Shutdown Current vs Temperature>

Note) All characteristics were measured at T_A = 25°C and V_{DD} = 1.8V unless otherwise noted

10. Communication by I²C protocol

10.1. Start/Stop Sequence of I2C

I2C communication can be initiated by sending a START condition from the master, a high-to-low transition on the SDA line while the SCL is high. A Stop condition, a low-to-high transition on the SDA line while the SCL input is high, is sent by the master.



<Definition of I2C Start and Stop Conditions>

10.2. Slave Address

ADR are selectable address pin for the LSB of the I2C interface address.

Slave Address							ADR pin connection
A6	A5	A4	A3	A2	A1	A0	
1	0	0	1	0	0	0	VSS
1	0	0	1	0	0	1	VDD
1	0	0	1	0	1	0	SDA
1	0	0	1	0	1	1	SCL

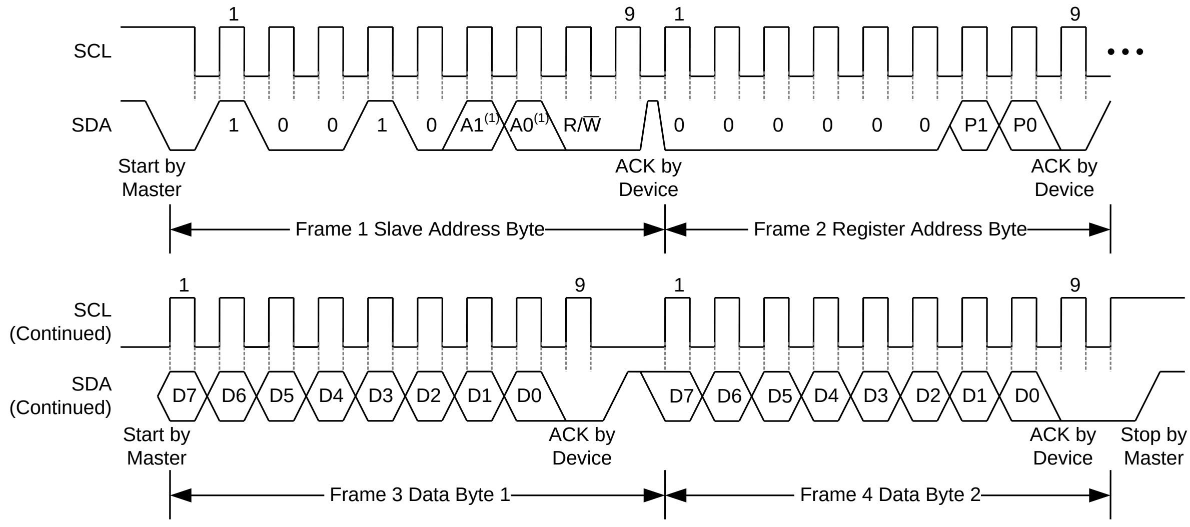
10.3. High-Speed (HS) Mode

In order to the two-wire bus to operate at frequencies above 400kHz, the master device must issue an HS-Mode master code (0000 1xxx) as the first byte after a start condition to switch the bus to high-speed operation. After the HS-Mode master code has been issued, the master transmits a two-wire slave address to initiate a data transfer operation.
The bus continues to operate in HS-Mode until a stop condition occurs on the bus. Upon receiving the stop condition, the MXH1321 device switches back to fast-mode operation.

10.4. Timeout Function

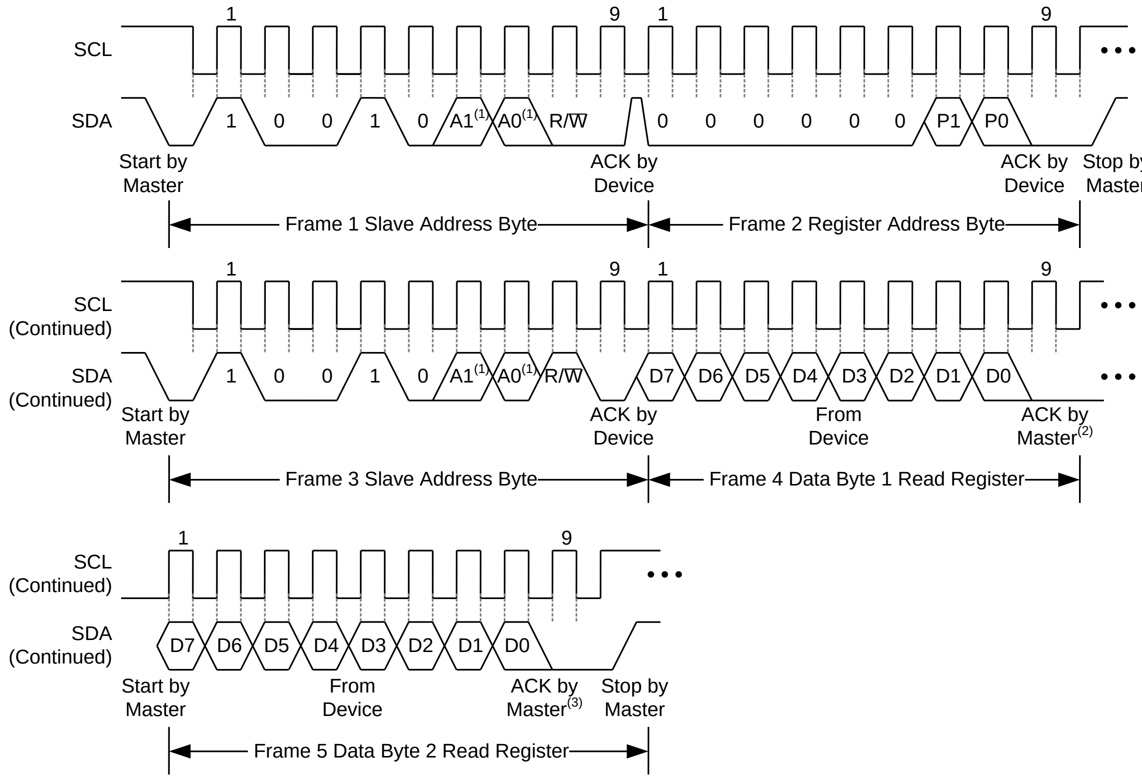
The MXH1321 device resets the serial interface if SCL is held low for 30ms (typ) between a start and stop condition. The MXH1321 device releases the SDA line if the SCL pin is pulled low and waits for a start condition from the host controller. To avoid activating the time-out function, maintaining a communication speed of at least 1kHz for SCL operating frequency is necessary.

10.5. Timing Diagrams



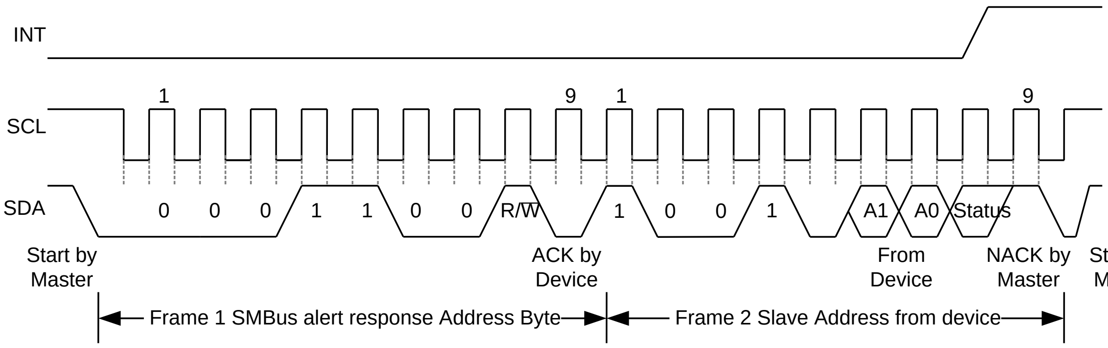
NOTE (1) The value of A0 and A1 are determined by the ADR pin

<Two-Wire Timing Diagram for Write Format>



NOTE (1) The value of A0 and A1 are determined by the ADR pin
(2) Master should leave SDA high to terminate a single-byte read operation
(3) Master should leave SDA high to terminate a two-byte read operation

<Two-Wire Timing Diagram for Read Format>



<Two-Wire Timing Diagram for INT>

11. Registers

11.1. Register Map

ADDR	R/W	Name	Function	Default
N/A	W	Address Pointer	Address storage for subsequent operations	00h
00	R	Temperature	Two bytes read temperature	-
01	R/W	Configuration	Control the operational mode of the temperature sensor	60A0h
02	R/W	T_{LOW}	Temperature low limit register	4B00h
03	R/W	T_{HIGH}	Temperature high limit register	5000h

11.2. Temperature Register

The temperature register is configured as a 12bit read-only register (setting the EM bit to 0 in configuration register) or as a 13-bit read-only register (setting the EM bit to 1 in the configuration register) that stores the output of the most recent conversion. Two bytes must be read to obtain data and are listed in Table 10.1 table. Byte 1 is the most significant byte (MSB), followed by byte 2, the least significant byte (LSB). The first 12 bits are used to indicate temperature. The least significant byte does not have to be read if that information is not needed. The data format for temperature is listed in Table 10.2 and Table 10.3. One LSB equals 0.0625°C. Negative numbers are represented in binary two's complement format. Following power up or reset, the temperature register reads 0°C until the first conversion is complete. Bit D0 of byte 2 indicates normal mode (EM bit = 0) or extended mode (EM bit = 1) and can be used to distinguish between the two temperature register data formats. Th unused bits in the temperature register always read 0.

ADDR	R/W	Byte	D7	D6	D5	D4	D3	D2	D1	D0	Default
00	R	1	T11 (T12)	T10 (T11)	T9 (T10)	T8 (T9)	T7 (T8)	T6 (T7)	T5 (T6)	T4 (T5)	00h
		2	T3 (T4)	T2 (T3)	T1 (T2)	T0 (T1)	0 (T0)	0 (0)	0 (0)	0 (1)	00h

Extended mode 13-bit configuration shown in parentheses.

<Table 10.1 Byte1 & 2 Temperature Register>

Temperature (°C)	Digital Output	Hex
128	0111 1111 1111	7FF
127.9375	0111 1111 1111	7FF
100	0110 0100 0000	640
80	0101 0000 0000	500
75	0100 1011 0000	4B0

50	0011 0010 0000	320
25	0001 1001 0000	190
0.25	0000 0000 0100	004
0	0000 0000 0000	000
-0.25	1111 1111 1100	FFC
-25	1110 0111 0000	E70
-55	1100 1001 0000	C90

<Table 10.2 12-bit Temperature Data Format>

- To convert positive temperature to a digital data format:
  1. Divide the temperature by the resolution
  2. Convert the result to binary code with a 12-bit, left-justified format, and MSB = 0 to denote a positive sign.

Example: (50°C) / (0.0625°C / LSB) = 800 = 320h = 0011 0010 0000

- To convert a positive digital data format to temperature:
  1. Convert the 12-bit, left-justified binary temperature result, with the MSB = 0 to denote a positive sign, to a decimal number.
  2. Multiply the decimal number by the resolution to obtain the positive temperature.
- Example
  - 0011 0010 0000 = 320h = 800 × (0.0625°C / LSB) = 50°C

- To convert negative temperatures to a digital data format:
  1. Divide the absolute value of the temperature by the resolution and convert the result to binary code with a 12-bit, left-justified format.
  2. Generate the twos complement of the result by complementing the binary number and adding one. Denote a negative number with MSB = 1.
- Example
  - (|-25°C|) / (0.0625°C / LSB) = 400 = 190h = 0001 1001 0000
  - Two's complement format: 1110 0110 1111 + 1 = 1110 0111 0000

- To convert a negative digital data format to temperature:
  1. Generate the twos compliment of the 12-bit, left-justified binary number of the temperature result (with MSB = 1, denoting negative temperature result) by complementing the binary number and adding one. This represents the binary number of the absolute value of the temperature.
  2. Convert to decimal number and multiply by the resolution to get the absolute temperature, then multiply by -1 for the negative sign.
- Example
  - 1110 0111 0000 has twos compliment of 0001 1001 0000 = 0001 1000 1111 + 1
  - Convert to temperature: 0001 1001 0000 = 190h = 400; 400 × (0.0625°C / LSB) = 25°C = (|-25°C|); (|-25°C|) × (-1) = -25°C

Temperature (°C)	Digital Output	Hex
150	0 1001 0110 0000	0960
128	0 1000 0000 0000	0800
127.9375	0 0111 1111 1111	07FF
100	0 0110 0100 0000	0640
80	0 0101 0000 0000	0500
75	0 0100 1011 0000	04B0
50	0 0011 0010 0000	0320
25	0 0001 1001 0000	0190
0.25	0 0000 0000 0100	0004
0	0 0000 0000 0000	0000
-0.25	1 1111 1111 1100	1FFC
-25	1 1110 0111 0000	1E70
-55	1 1100 1001 0000	1C90

<Table 10.3 13-bit Temperature Data Format>

11.3. Configuration Register

ADDR	R/W	Byte	D7	D6	D5	D4	D3	D2	D1	D0	Default
01	R/W	1	OS	R1	R0	F1	F0	POL	TM	SD	60h
		2	CR1	CR0	AL	EM	0	0	0	0	A0h

<Table 10.4 Configuration and Power-up/reset formats>

Byte1 D0: Shutdown Mode (SD)
The shutdown mode bit saves maximum power by shutting down all device circuitry other than the serial interface, reducing current consumption to typically less than 0.5uA. Shutdown mode is enabled when the SD bit = 1, the device shuts down when current conversion is completed. When SD = 0, the device maintains a continuous conversion state.

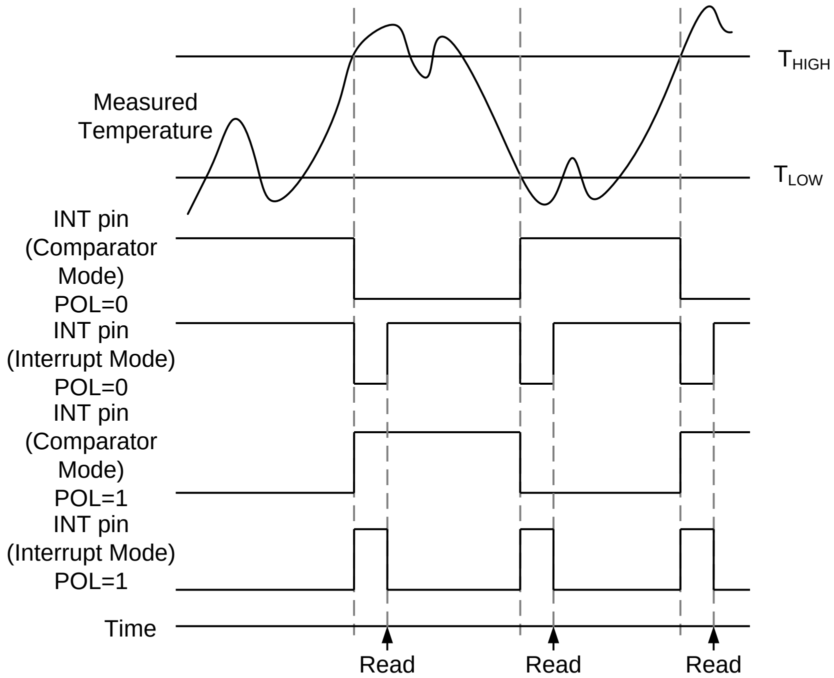
Byte1 D1: Thermostat Mode (TM)
The Thermostat mode bit indicates to the device whether to operate in Comparator mode (TM = 0) or Interrupt mode (TM = 1).

In comparator mode (TM=0), the INT pin becomes active when the temperature equals or exceeds the value in the T_{HIGH} register and generates a consecutive number of faults according to fault bits F1 and F0. The INT pin remains active until the temperature falls below the indicated T_{LOW} value for the same number of faults.

In interrupt mode (TM=1), the INT pin becomes active when the temperature equals or exceeds the value in T_{HIGH} for a consecutive number of fault conditions (as shown in Table 10.5). The INT pin remains active until a read operation of any register occurs.

Both operating modes are represented in Figure 10.1. Table 10.7 and Table 10.8 list the format for the T_{HIGH} and T_{LOW} register. The most significant byte is sent first, followed by the least significant byte.

Byte1 D2: Polarity (POL)
The polarity bit allows the user to adjust the polarity of the INT pin output. If the POL bit is set to 0 (default), the INT pin becomes active low. When the POL bit is set to 1, the INT pin becomes active high and the state of the INT pin is inverted. The operation of the INT pin in various mode is illustrated in Figure 10.1.



<Figure 10.1 Output Transfer Function Diagrams>

Byte 1 D4/D3: Fault Queue (F1/F0)
A fault condition exists when the measured temperature exceeds the user-defined limit set in the T_{HIGH} and T_{LOW} registers. Additionally, the number of fault conditions required to generate an alert may be programmed using the fault queue. The fault queue is provided to prevent a false alert as a result of environmental noise. The fault queue requires consecutive fault measurements in order to trigger the alert function. Table 10.5 lists the number of measured faults that may be programmed to trigger the alert condition in the device. For T_{HIGH} and T_{LOW} register format and byte order, see the High and Low limit register.

F1	F0	Consecutive Faults
0	0	1
0	1	2
1	0	4
1	1	6

<Table 10.5 Fault Settings>

Byte 1 D6/D5: Converter Resolution (R1/R0)
The converter resolution bits R1 and R0 are read-only bits. The converter resolution is set at device start up to 11 which set the 12bit resolution.

Byte 1 D7: One-Shot (OS)
When the device is in shutdown mode, writing a 1 to the OS bit begins a single temperature conversion. During the conversion, the OS bit reads 0. The device returns to the shutdown state at the completion of the single conversion. After the conversion, the OS bit reads 1. This feature reduces power consumption in the MXH1321 device when continuous temperature monitoring is not required.

Byte 2 D4: Extended Mode (EM)
The extended mode bit configures the device for normal mode operation (EM=0) or extended mode operation (EM=1). In normal mode, the temperature register and the high and low limit register use a

12-bit data format. Extended mode (EM=1) allows measurement of temperatures above 128°C by configuring the temperature register, and high and low limit register for 13-bit data format.

Byte 2 D5: Alert (AL)
The AL bit is a read-only function. Reading the AL bit provides information about the comparator mode status. The state of the POL bit inverts the polarity of data returned from the AL bit. When the POL bit equals 0, the AL bit reads as 1 until the temperature equals or exceeds T_{HIGH} for the programmed number of consecutive faults, causing the AL bit to read as 0. The AL bit continues to read as 0 until the temperature falls below T_{LOW} for the programmed number of consecutive faults, when it again reads as 1. The status of the TM bit does not affect the status of the AL bit.

Byte 2 D7/D6 : Conversion Rate (CR1/CR0)

CR1	CR0	Converter Rate
0	0	0.25Hz
0	1	1Hz
1	0	4Hz (default)
1	1	8Hz

<Table 10.6 Converter Rate Settings>

11.4. High and Low Limit Register

The temperature limits are stored in the T_{LOW} and T_{HIGH} registers in the same format as the temperature result, and their values are compared to the temperature result on every conversion. The outcome of the comparison drives the behavior of the INT pin, which operates as a comparator output or an interrupt, and is set by the TM bit in the configuration register.

ADDR	R/W	Byte	D7	D6	D5	D4	D3	D2	D1	D0	Default
02	R/W	1	L11 (L12)	L10 (L11)	L9 (L10)	L8 (L9)	L7 (L8)	L6 (L7)	L5 (L6)	L4 (L5)	4Bh
		2	L3 (L4)	L2 (L3)	L1 (L2)	L0 (L1)	0 (L0)	0 (0)	0 (0)	0 (0)	00h

Extended mode 13-bit configuration shown in parentheses.

<Table 10.7 Byte1 & 2 of T_{LOW} Register>

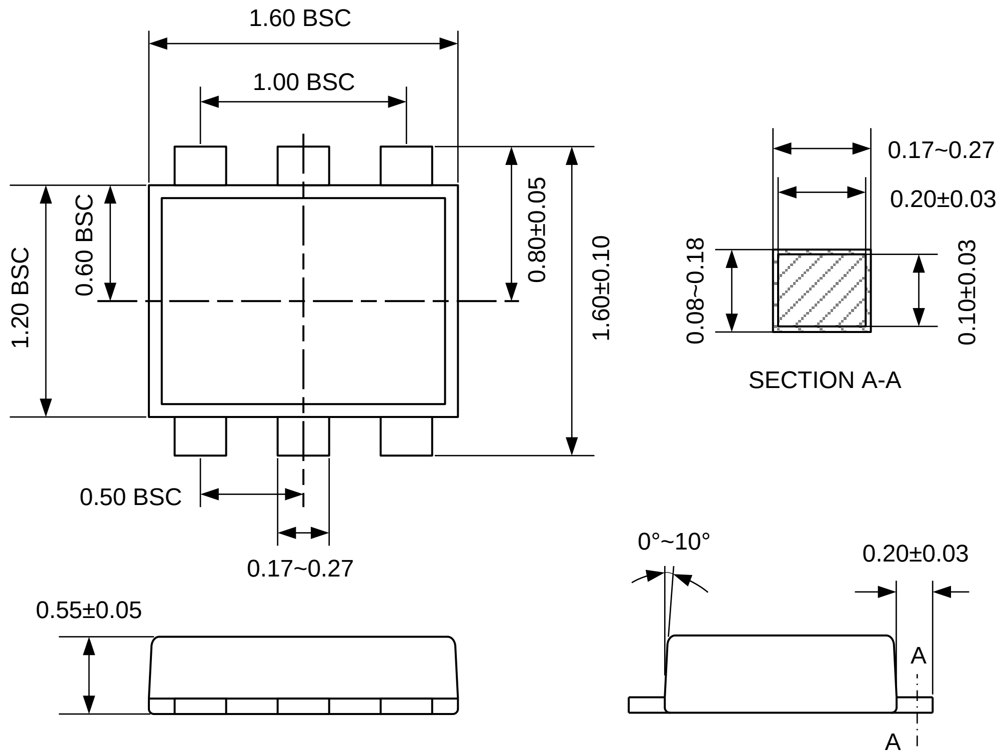
ADDR	R/W	Byte	D7	D6	D5	D4	D3	D2	D1	D0	Default
03	R/W	1	H11 (H12)	H10 (H11)	H9 (H10)	H8 (H9)	H7 (H8)	H6 (H7)	H5 (H6)	H4 (H5)	50h
		2	H3 (H4)	H2 (H3)	H1 (H2)	H0 (H1)	0 (H0)	0 (0)	0 (0)	0 (0)	00h

Extended mode 13-bit configuration shown in parentheses.

<Table 10.8 Byte1 & 2 T_{HIGH} Register>

12. Package Outline Dimensions

12.1. Package Type: SOT563



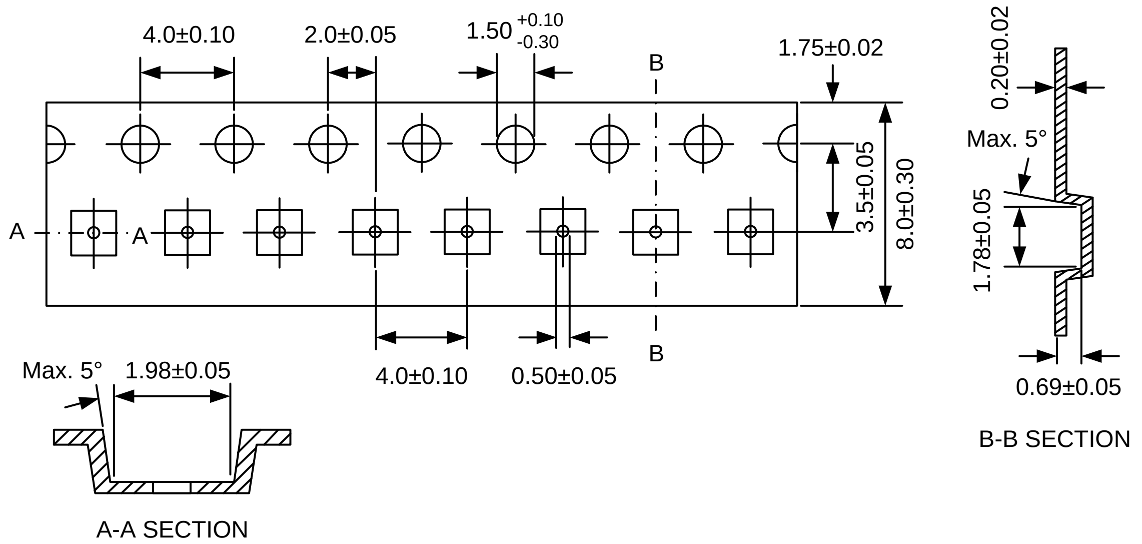
<Unit: mm>

<Package Dimension>

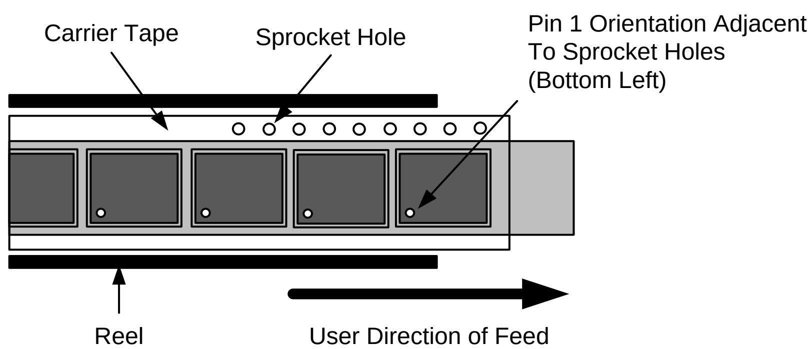
13. Shipping Package

13.1. Package Type: SOT563

MXH1321 is provided in tape & reel shipment packaging. Standard packaging sizes is 4,000 units per reel.



Unit: mm



Note: The reel diameter and width(W1) is 178 mm (7 Inch) and 8 mm.

<Technical Drawing of Packaging Tape>

14. NOTICE

The followings should be noted when this LSI specification is used.

1. The information in this document is subject to change without notice for the purpose of product improvement and technical progress.
2. The descriptions of circuits, software and other related information in this document are provided for illustrative purpose in semiconductor product operation and application examples. When you use this product, please design circuits and mount with consideration for external conditions.
3. The incorporation of these circuits, software and information in the design of customer's equipment shall be done under the full responsibility of customer. HAECHITECH assumes no responsibility for any losses incurred by customers or third parties arising from the use of these circuits, software and information.
4. HAECHITECH does not assume any liability for infringement of patents, copyrights or other intellectual property rights of third parties by or arising from the use of HAECHITECH semiconductor products listed in this document or any other liability arising from the use of such products. No license expressed, implied or otherwise, is granted under any patents, copyrights or other intellectual property rights of HAECHITECH and/or others.
5. Even though this product has an ESD protection circuit at every pin, please take any necessary countermeasures against any destruction from ESD with use of earth bands, conductive floors and etc.
6. If semiconductor is exposed to strong light, temporal error operation may happen. According to the environment, shield the semiconductor to avoid any error operation.
7. While HAECHITECH endeavors to enhance the quality, reliability and safety of HAECHITECH semiconductor products, our customers agree and acknowledge that the possibility of defects thereof cannot be eliminated entirely. To minimize risks of damage to property and/or injuries (including death) to persons arising from defects in HAECHITECH semiconductor products, customers shall incorporate sufficient safety measures in their design, such as redundancy, fire-contaminate, and anti-features.
8. The product listed in this document is intended for usage in general electronics applications (Computers, personal equipment, office equipment, measuring equipment, industrial robotics, domestic appliances, etc.). This application is neither intended nor warranted for usage in equipment that requires extraordinarily high quality and /or reliability or malfunction or failure of which may cause loss of human life or bodily injury ("Unintended Usage"). Unintended Usage includes atomic energy control instruments, airplane or spaceship instruments, transportation instruments, traffic signal instruments, combustion control instruments, medical instruments, all types of safety devices, etc. Unintended Usage of HAECHITECH products listed in this document shall be made at the customer's risk. No part of this document may be copied or reproduced in any forms or by any means without prior written consent of HAECHITECH. HAECHITECH assumes no responsibility for any errors that may appear in this document.