SD5020

Single Wire Communication Digital Temperature Sensor

Features

- 12 bits temperature reading with 0.0625℃ resolution
- ±0.8℃ maximum error at -10℃~ +85℃ range
- ±1.5℃ maximum error at -55℃~+125℃ range
- Single wire communication with CRC function
- programmable 40 bits slave address
- Programmable over-temperature alarm threshold and hysteresis
- 2.7V ~ 5.5V power supply range
- Pin compatible with DS18B20

Description

SD5020 is a highly accurate temperature measurement IC. It supports single wire bus communication and outputs 12 bits temperature readings. The typical error is ±0.5℃ for the -10℃ ~ +85℃ range, and ±0.8℃ for the -55℃ ~ +125℃ range. Over-temperature alarm thresholds and hysteresis can be set through internal register.

Each chip has a unique 40 bits address useful for multi-slave communication system.

Applications

Temperature control systems, industrial process control, power system thermal protection, ambient temperature measurement

Ordering Information

Package	Part Number
TO-92	SD5020A
SOP8	SD5020B

Pin Diagram and Descriptions

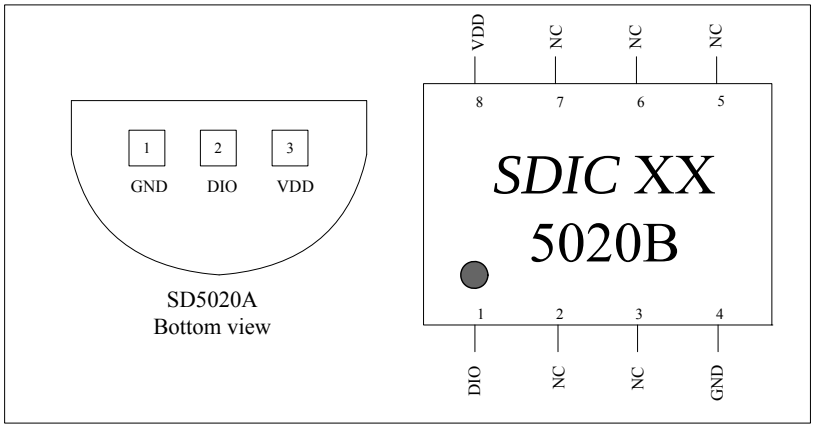


Figure 1. TO-92 and SOP8 pin out diagram

Table 1. Pin Descriptions

Pin Number		Pin Name	Attribute	Description
SD5020A (TO-92)	SD5020B (SOP8)			
2	1	DIO	I/O	Open drain Single wire data communication port
--	2--3, 5--7	NC	--	No Connect
1	4	GND	Ground	
3	8	VDD	Power	

Functional Description

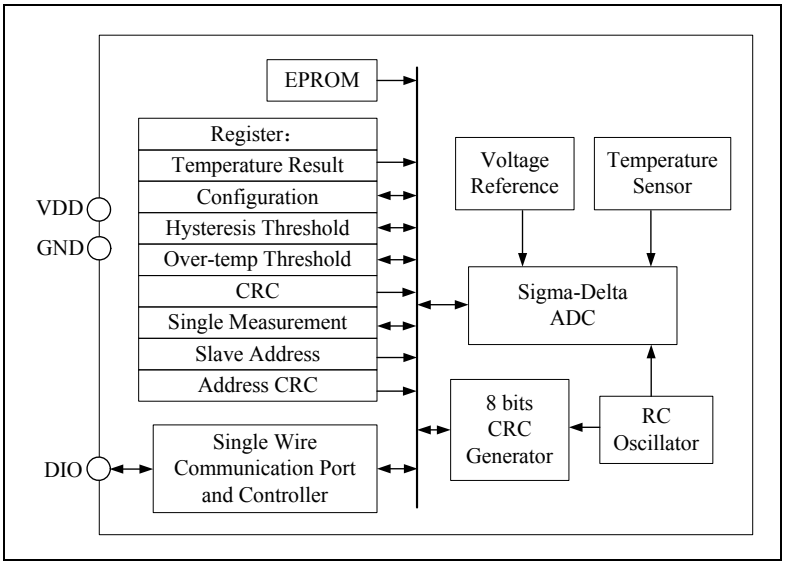


Figure 2. Functional block diagram

Figure 2 is the functional block diagram of SD5020. It is a digital temperature sensor with single wire communication capability. The DIO pin requires an external pull-up resistor. The slave address is 40 bits wide, which is very suitable for multi-slave communication system.

The internal sensor generates a voltage signal that is proportional to temperature. The signal is digitized by an ADC which carries its own voltage reference. The result is a 12 bits word in two's complement format. The highest bit is the sign bit where "0" indicates positive temperature and "1" indicates negative temperature. This result is compared with the values in the over temperature threshold register and the hysteresis threshold register to decide whether to set the over-temperature alarm signal.

The system clock comes from the RC oscillator. Each temperature measurement takes about 85ms, during which the ADC, voltage reference, clock circuits are all active. The power consumption then is at the maximum.

Temperature value read out and register setting are done via a single wire communication interface. One can perform CRC check on register addresses 0000H-0007H to ensure that the register data is read correctly, and thus enhance the communication reliability.

SD5020 works in single measurement mode. It enters the standby state after each measurement. User sends commands to start the next measurement through the single wire interface.

The chip goes into a very low power shutdown mode after setting bit 0 of the Configuration Register to "1". The IC halts operation and consumes less than 1uA. Set the bit back to "0" in order to leave the Shutdown Mode.

Temperature Format

Measurement result is stored in the upper 12 bits of the 16 bits Temperature Result Register in two's complement format.

Upper byte (0001H) of the Temperature Result Register contains the measurement result's integer part. Upper 4 bits of the lower byte (0000H) contains the decimal part. Therefore the resolution is 2^{-4}=0.0625℃. If the temperature goes beyond the -55℃ to +125℃ range, the result's inaccuracy may exceed the maximum limit. Use the upper byte only if one degree Celsius resolution is sufficient.

Table 2. Temperature Measurement Results

Temperature	Binary Measurement Result
-55℃	1100 1001 0000 XXXX
-40℃	1101 1000 0000 XXXX
-25℃	1110 0111 0000 XXXX
-0.0625℃	1111 1111 1111 XXXX
0	0000 0000 0000 XXXX
0.0625℃	0000 0000 0001 XXXX
25℃	0001 1001 0000 XXXX
75℃	0100 1011 0000 XXXX
80℃	0101 0000 0000 XXXX
85℃	0101 0101 0000 XXXX
125℃	0111 1101 0000 XXXX

The temperature measurement result conversion formula is as follows:

For 8 bits results:

+ve temperature = meas. result

-ve temperature = meas. result-256

For 10 bits results:

+ve temperature = meas. result/4

-ve temperature = (meas. result-1024)/4

For 12 bits results:

+ve temperature = meas. result/16

-ve temperature = (meas. result-4086)/16

Single Measurement Mode

The IC operates in single measurement mode. It is in standby state when not measuring temperature.

Writing any value to the Single Measurement Command Register (0008H) will initiate a temperature measurement, which takes 85ms typically to complete. Afterwards the IC immediately returns to standby. The new temperature value is stored in the Temperature Result Register. Its upper 8 bits is also stored in the Single Measurement Command Register.

The new temperature value will be compared with the value in the Over-Temperature Threshold Register (0005H~0006H). If the new value is greater than or equal to the threshold, Configuration Register bit7 will become "1" indicating an over-temperature condition.

The chip consumes less than 1uA during standby.

In order for the IC to operate properly, Configuration Register bit5 must be set to "1" after power on and before the first temperature measurement.

Registers Description

Table 3 is a list of SD5020 registers. Detail descriptions are in the following paragraphs.

Table 3. SD5020 Registers

Address	Description	R/W	Default Value
0000H	Temperature Result Register, lower 4 bits at bit7-bit4, fractional part	R	0X00
0001H	Temperature Result Register, upper 8 bits, integral part	R	0X00
0002H	Configuration Register	R/W	0X40
0003H	Hysteresis Threshold Register, lower 4 bits at bit7-bit4	R/W	0X00(75℃)
0004H	Hysteresis Threshold Register, upper 8 bits	R/W	0X4B
0005H	Over-temperature Threshold Register, lower 4 bits at bit7-bit4	R/W	0X00(80℃)
0006H	Over-temperature Threshold Register, upper 8 bits	R/W	0X50
0007H	CRC Code for Registers 0000H~0006H	R	0X2B
0008H	Single Measurement Command Register	R/W	00
000BH	SD5020 Slave Address Register[39:32]	R	*
000CH	SD5020 Slave Address Register[31:24]	R	*
000DH	SD5020 Slave Address Register[23:16]	R	*
000EH	SD5020 Slave Address Register[15:8]	R	*
000FH	SD5020 Slave Address Register[7:0]	R	*
0010H	CRC Code for Slave Address Registers 000BH~000FH	R	*

***** Each SD5020 is assigned a unique slave address during production. Please consult factory if specific address is desired.

Temperature Result (0000H-0001H):

The latest temperature measurement result is stored in this register. It is 12 bits wide in two's complement format. The upper 8 bits is in 0001H and the lower 4 bits is in bit7-bit4 of 0000H. Bit3-bit0 of 0000H are invalid bits.

Configuration (0002H):

The register is 8 bits wide and is readable/writable. Table 4 lists the function of each bit.

Table 4. Configuration Register Bit Function

Bit	Function
7	Alarm, read only
6	Reserved
5	Reserved, must set to "1"
4	Over-temperature occurrence
3	
2	Reserved
1	Reserved
0	Shutdown mode

Bit7: Alarm bit. Read only. It is set to "1" when the latest temperature result is equal or higher than the value in the Over-temperature Threshold Register. If the result is lower then this bit is set to "0".

Bit6: Reserved.

Bit5: Reserved. Must be set to "1" after power on and before first temperature measurement.

Bits4-3: Number of over-temperature occurrence (N). To avoid false alarm, the alarm bit is set only after N contiguous occurrence. Table 5 shows the relation between bit4-bit3 and number of occurrence.

Table 5. Number of over-temp occurrence

Bits4-3	Number of Over-temp Occurrence
00	1
01	2
10	4
11	6

Bit2: Reserved.

Bit1: Reserved.

Bit0: Shutdown mode. The IC enters the shutdown mode when this bit is set to "1". All internal circuits is halted. Total IC current is less than 1uA.

Hysteresis Threshold (0003H-0004H):

The threshold value is 12 bits wide in two's complement format. The over-temperature alarm is cleared when the newly measured temperature is below this value. The default value is 75℃.

The register is readable and writable. Threshold's upper 8 bits is in 0004H and lower 4 bits in bit7-bit4 of 0003H. Bit3-bit0 of 0003H are invalid bits.

Over-Temperature Threshold (0005H-0006H):

The threshold value is 12 bits wide in two's complement format. When the newly measured temperature is above this value, it counts as one over-temperature occurrence. The default value is 80℃.

The register is readable and writable. Threshold's upper 8 bits is in 0006H and lower 4 bits in bit7-bit4 of 0005H. Bit3-bit0 of 0003H are invalid bits.

CRC (0007H):

CRC (Cyclic redundancy check) is the most common error checking code in data communications. To ensure correct reading of temperature result and chip settings, an 8 bits CRC checksum is calculated on registers 00H-06H and placed in 07H. The generator polynomial is:

$$CRC = X^8 + X^5 + X^4 + 1$$

The host reads data in 00H-07H and calculates the checksum. Read data is accurate if the checksum is 0, otherwise the host should re-read.

Single Measurement Command (0008H):

Refer to **Single Measurement Mode** description.

SD5020 Slave Address (000BH-000FH):

Stored 40 bits slave address. 000BH is the highest byte and 000FH is the lowest byte. Each IC has its own unique address.

Address CRC (0010H):

8 bits CRC code for address 000BH-000FH.

Single Wire Communication Port

SD5020 uses single wire to communicate. Figure 3 shows a typical single slave application. The communication port DIO is open drain and needs a pull-up resistor.

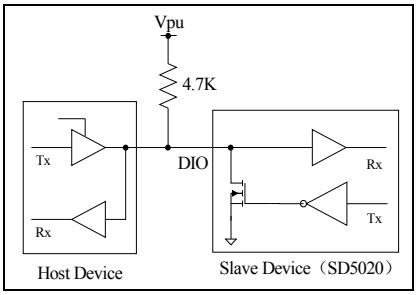


Figure 3. Single wire communication schematic

Single Wire Communication Protocol

Figure 4 shows the single wire communication data format where the sequence is: lead code + 8 bits data byte + stop code. The data byte's lowest bit is always sent first.

When the host is sending data, the timing range of each section is:

- Lead code: low level, 820us ~ 1000us.
- Data "0" and "1" are both high level first and then low level.
- Data "0" and "1" low level both are 200us ~ 420us.
- Data "0" high level is 160us ~ 210us.
- Data "1" high level is 700us ~ 800us.
- Stop code: high level, 250us ~ 500us.

When sending data from the slave device, the timing ranges are always more lenient. The ranges are listed in Table 8.

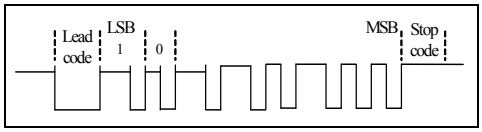


Figure 4. Data transmission format

Figure 5 shows the single wire communication protocol including handshaking, reading from and writing to registers, and reading the slave address. Table 6 is the command list.

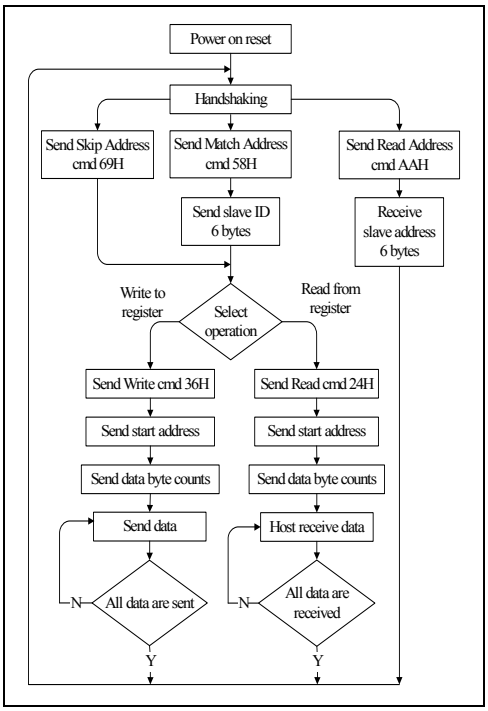


Figure 5. Single wire communication protocol

Table 6. Command List

Command	Command Word
Read Address	AAH
Match Address	58H
Skip Address	69H
Write	36H
Read	24H

Handshaking

Handshaking between host and slave must be carried out before communication to ensure their readiness. The handshake process (Figure 6) is:

Host set the bus low for 5 ~ 8ms. Slave detects the valid handshake signal and wait 180us ~ 500us, then set the bus low for 100us ~ 250us. Host detects the response signal. The handshake between both sides is then successful.

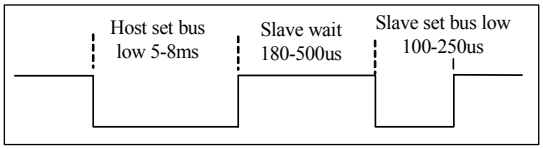


Figure 6. Handshaking before reading/writing the registers

Steps before Reading / Writing Register

The host sends a command to the slave device after a successful handshaking. Depending on the command, the slave device will perform the following:

- If it is the Read Address command AAH, refer to the **Read Slave Address** description.
- If it is the Match Address command 58H, the host will send over 6 bytes of data looking for a particular slave device (5 address bytes with the highest byte first + their CRC byte). The host can then read or write registers of the slave device with matched address.
- If it is the Skip Address command 69H, the host can read/write the slave device register directly. This is suitable when there is only one slave device.

Write Register

The host sends sequentially the Write command 36H, high byte of the starting register address, the low byte, high byte of the number of bytes to write, the low byte, and then the data. The data can be transmitted continuously until it is all sent.

Read Register

The host sends sequentially the Read command 24H, high byte of the starting register address, the low byte, high byte of the number of bytes to read, and the low byte. It then starts to receive data from the slave device. The data can be transmitted continuously until it is all sent.

Read Slave Address

The host sends the Read Address command AAH, and then receive 6 bytes of data from the slave device (5 address bytes with the highest byte first + their CRC byte).

Self Heating Effect

SD5020 temperature measurement accuracy will be affected by its own power consumption and chip package thermal resistance. The IC's own power consumption is very small (typically 0.51mW at 3V supply voltage), but will still cause some temperature rise.

The SD5020A temperature rise is:

$$\Delta T \approx 0.51mW \times 162°C/W = 0.08°C$$

The SD5020B temperature rise is:

$$\Delta T = 0.51mW \times 240°C/W = 0.123°C$$

Temperature Calibration

SD5020 has been accurately calibrated in the factory. No further calibration by the user is needed.

DIO Pin Description

SD5020's DIO pin is an open drain port. An external pull-up resistor as shown in Figure 7 is needed to provide convenient interface to other circuits with different power supplies.

IC Placement

SD5020 measures the IC's internal temperature. When it is used to monitor a heat source temperature, one should place the IC close to the heat source, and minimize the thermal resistance between them.

Typical Application

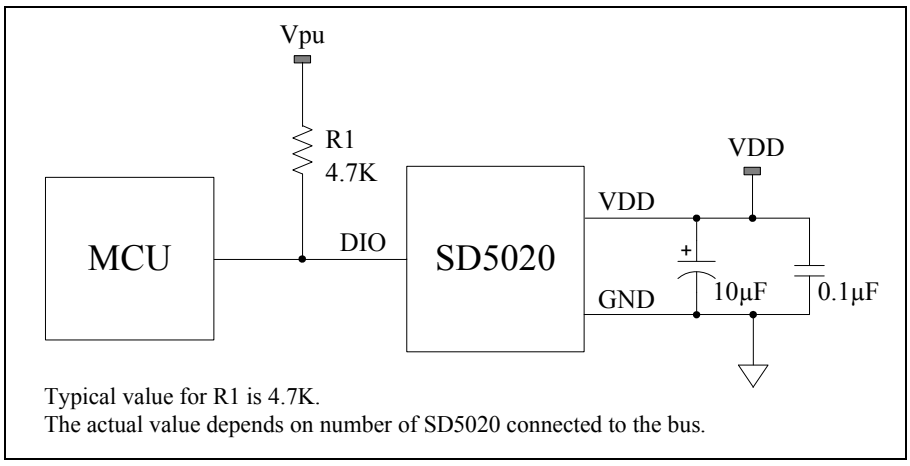


Figure 7. Typical application diagram

Electrical Specifications

Table 7. Absolute Maximum Ratings

Symbol	Parameter	Minimum	Maximum	Unit
T_A	Operating temperature	−55	+125	℃
T_S	Storage temperature	−65	+150	℃
V_{DD}	Supply voltage	−0. 3	+7. 0	V
V_{IN}, V_{OUT}	Digital input/output voltage	−0. 3	VDD+0. 3	V
T_L	Reflow temperature profile	Per IPC/JEDECJ-STD-020C		
$Iout_{max}$	Maximum output current		10	mA
ESD	HBM	2000		V

Remarks:
1. CMOS device can easily be damaged by electrostatics. It must be stored in conductive foam, and with care taken to not exceed the operating voltage range.
2. Turn off power before inserting or removing the device.

Table 8. Electrical Specifications
(VDD=3.0V ~ 5.0V, T_A=25℃. **Bold items applicable for T_A=-55℃ ~ +125℃。**)

Symbol	Parameter	Minimum	Typical	Maximum	Unit	Conditions/Remarks
VDD	Supply voltage	2. 7	3. 0	5. 5	V	
T_A	Operating temperature	−55		+125	℃	
LSB	Resolution	--	0. 0625	--	℃	12 bits digital output
Terr	Accuracy	--	±0. 5	**±0.8**	℃	-10℃ ~ +85℃,VDD=2. 7V~ 5. 5V
		--	±0. 8	**±1.5**		-55℃ ~ 125℃, VDD=2. 7V~ 4. 0V
Ivdd1	Supply current	--	170		uA	Measuring temperature No communication
Ivdd2		--	--	**2**		Standby or shutdown mode
Tconv	Measurement cycle	65	85	110	ms	
PSRR	Power supply rejection ratio	--	0. 1	--	℃/V	VDD=2. 7V ~ 5. 5V[1]
DIO open drain output drive strength						
Isink	Low current sink	4	--	--	mA	VOL=0. 3V
Ileak	High leakage source	--	--	1	uA	VOH=VDD
Single wire communication timing range（Slave SD5020 sending to host）						
Lead code		750	940	**1200**	us	
Data at low level		250	312	**400**	us	
Data “0” high level		150	188	**240**	us	
Data “1” high level		600	750	**960**	us	
Stop code		250	312	--	us	
Slave waiting time after host sent handshake signal		250	--	**500**	ms	
Slave response low time		125	--	**200**	us	

Single wire communication timing range（host sending to slave SD5020）					
Lead code	820	940	**1000**	us	
Data at low level	200	312	**420**	us	
Data “0” high level	160	188	**210**	us	
Data “1” high level	700	750	**800**	us	
Stop code	250	375	--	us	
Host initialize handshake low time	5	6.5	**8**	ms	

Note 1: PSRR parameter uses the temperature value at VDD=3.0V as reference。

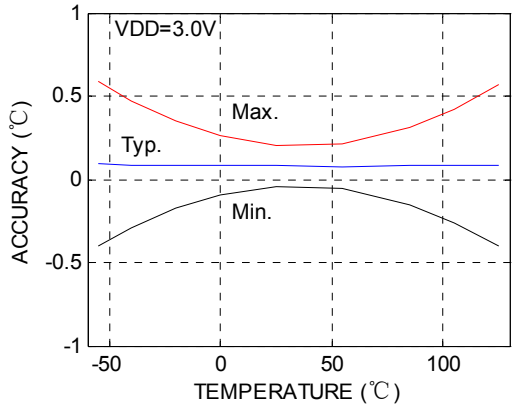


Figure 8. Temperature accuracy at 3V

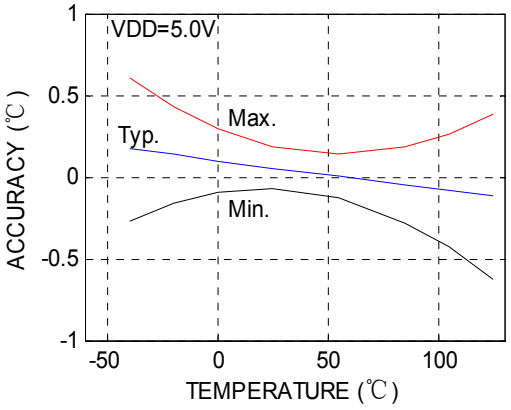


Figure 9. Temperature accuracy at 5V

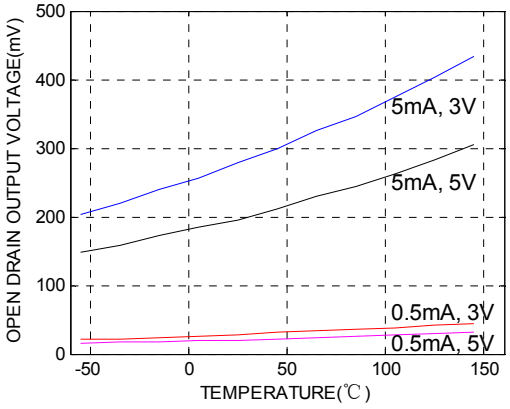


Figure 10. Open drain output voltage

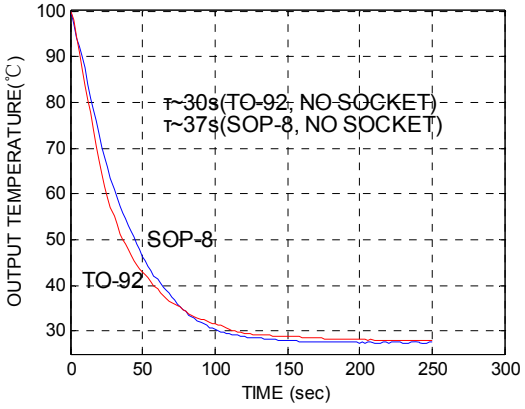


Figure 11. Thermal response time

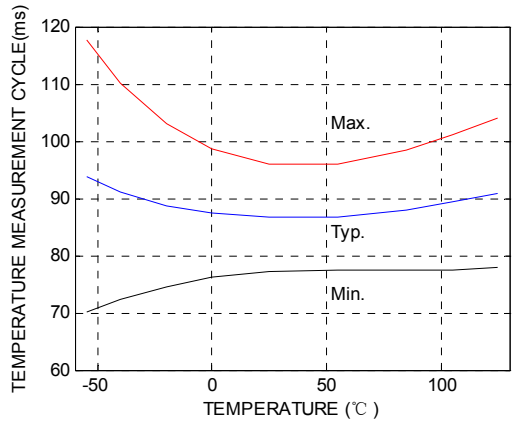


Figure 12. Temperature measurement cycle

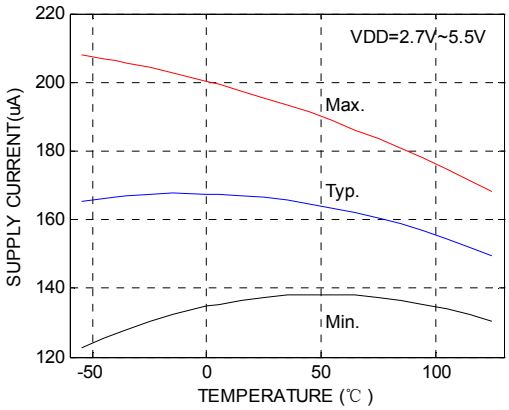


Figure 13. Supply current

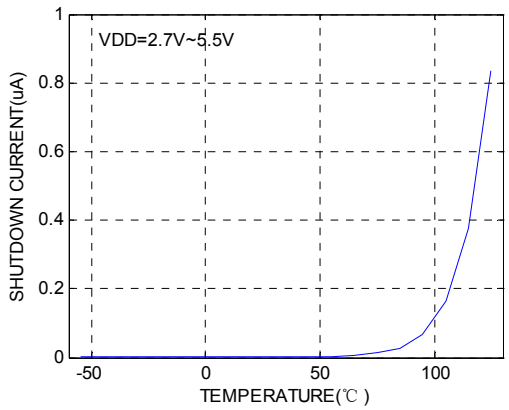
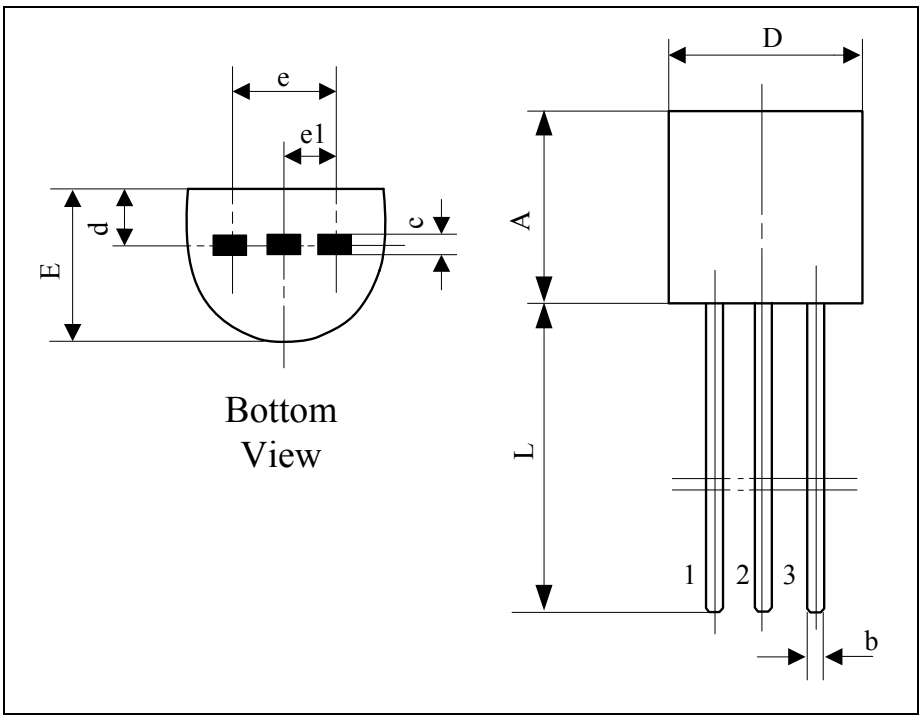


Figure 14. VDD current at shutdown mode

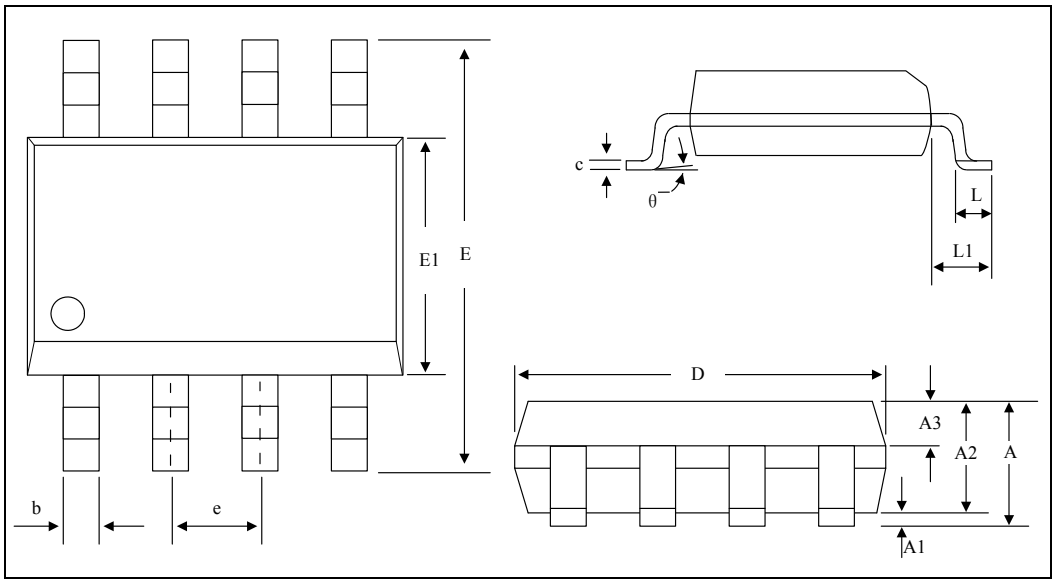
Packaging Information



Dimensions: mm

Symbol	Min.	Nom.	Max.
A	4. 3	——	5. 3
b	0. 3	——	——
c	0. 3	——	——
φD D	4. 3	——	5. 2
d	1. 0	——	1. 7
E	3. 2	——	4. 2
e	——	2. 54	——
e1	——	1. 27	——
L	12. 7	——	——

Figure 15. TO-92 mechanical specification



Dimensions: mm

Symbol	Min.	Nom.	Max.
A	1.35	——	1.80
A1	0.10	——	0.25
A2	1.25	1.40	1.55
A3	0.60	0.65	0.70
D	4.78	4.90	5.00
E	5.80	6.00	6.30
E1	3.80	3.90	4.00
L	0.40	——	1.27
L1	1.05BSC		
b	0.33	——	0.51
c	0.19	——	0.25
e	1.27BSC		
θ	0°	——	8°

Figure 16. SOP8 mechanical specification